[Waterways and] Water Transport

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NEWTON CUTTING ON THE BIRMINGHAM CANAL (TAME VALLEY).

WATERWAYS

AND

WATER TRANSPORT

IN DIFFERENT COUNTRIES:

WITH A DESCRIPTION OF THE PANAMA, SUEZ, MANCHESTER, NICARAGUAN, AND OTHER CANALS.

BY

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INTRODUCTION AND OUTLINE.

It would probably be difficult to name any subject that is of more importance to the material interests of a country than adequate means of transport. Without such means, nations possessed of the most abundant natural resources in many other respects would be likely to decay. With ample facilities of transport, however, the most limited natural resources may be made to go a long way, and nations that are not possessed of great natural endowments may even rise to a high place in the economy of human industry.

Transportation facilities naturally divide themselves into the two categories of facilities by land and facilities by water. The former category embraces highways and railroads; the latter includes the navigation of seas, lakes, rivers, and canals.

It is the purpose of this volume to deal with water transport only, and more particularly that part of water transport which is carried on by means of artificial waterways. Railway transport, therefore, will only be incidentally referred to. Nor do we propose to expatiate to any extent upon the navigation of seas and lakes, which is a matter quite apart from canal and river navigation, and is usually carried on under very different conditions.

Canals are usually ranged under one or other of three great categories, namely :—

1. For purposes of navigation.
2. For irrigation, and
3. For domestic water supply.

Under the first heading there are many different descriptions of waterways, the more important being—

a. Canals intended for the purpose of connecting oceans or seas, such as those of Suez, Panama, the North Sea, and Nicaragua.

b. Canals for the purpose of bringing the sea to an inland town, such as those of Manchester and St. Petersburg.

c. Canals designed to connect and complete communication between different rivers or lakes, like the Grand Canal of China, the Erie Canal, and the Welland Canal.

d. Canals constructed for the purpose of enabling the obstructions caused by falls or cataracts on natural waterways to be overcome by artificial means.

As water transport by the most efficient and most economical means practicable is the *raison d'être* of the present work, we shall speak for the most part of navigation canals only.

The chapters that follow will show, that canal navigation has not only an interesting, but a very ancient history. It is, indeed, so long since canals were first projected and constructed that it is extremely difficult to trace their beginnings.

The Bœotian Canal, which is said to have drained the Lake Mœris by several channels carried in tunnels through high mountainous barriers, is of such fabulous age as to have led fiction to usurp the place of history, and even of tradition, when describing the work at a period of time so far back as prior to the conquest of Greece by Rome.

The celebrated canals of China have been assigned an unknown antiquity, but trustworthy representations have led authorities to conclude that they are scarcely older than the works in the Deccan. At all events, they date from less than 900 years ago, a century subsequent to the first irrigation of Valentia. In Spain, the Moors constructed canals to connect inland places with rivers, particularly the Guadalquiver, and connecting Granada with Cadiz. They also introduced, when they conquered that country, their own system of irrigation, with the customs and laws relating thereto, which are followed at the present hour without material change.

Cresy has pointed out that Pliny's correspondence with the Emperor Trajan proves the importance attached to the subject of waterways. "The consul in a letter points out such designs as were worthy the glorious and immortal name of Trajan, 'they being no less useful than magnificent.' He describes an extensive lake near the city of Nicomedia, upon which the commodities of the country were easily and cheaply transported to the high road, and thence were conveyed on carriages to the sea coast at great charge and labour. To remedy this inconvenience, he recommends that a canal should be, if possible, cut from the lake to the sea, observing that one had already been attempted by one of the kings of the country, but whether for the purpose of draining the adjacent lands, or making a communication between the lake and the river, was uncertain. These useful works, in common with all others, fell into decay with the decline of the Roman empire. During the disastrous period which succeeded, until the time of Charlemagne, Europe is deficient in any examples of similar undertakings: this sovereign commenced the projects of uniting the Rhine to the Danube, and of opening a new communication between the German Ocean and the Black Sea."

The Romans were great canal-makers. They were, indeed, as their extant works in Italy, Spain, and other countries show to this day, very capable hydraulic engineers. But in Roman times, canals were constructed for irrigation and water-supply purposes, rather than for purposes of navigation. It was not until some centuries after the decline of the Roman power that navigation canals began to attract attention. Previous to the time when locks, sluices, and other works of engineering art became general, canals could only be carried through comparatively level territories. Hence we not unnaturally find that some of the earliest canals for navigable purposes were constructed in Holland, where the configuration of the ground is specially adapted to their construction.

Mr. Vignoles, in his address to the Institution of Civil Engineers in 1870, remarked that, when the success of canals in the Low Countries attracted the attention of Europe, a sort of mania arose in France for inland navigation. Most of these were rendered abortive, and became abandoned, "from uncertainty in the supply of water on account of irregular rainfall, and from the pre-existing monopolies of the millers, who appear at all times and places to have been, as they still are, the natural enemies and thorns in the sides of the hydraulic engineer." Navigation on the upper branches of rivers rapidly ceased, but concessions for canals in France were then given, the Canal de Briare being the earliest, and next the Languedoc Canal, though neither was finished until about forty years after their first imperfect commencement. So early as the twelfth century, large canals had been cut in Flanders, though the great canal from Brussels to the Scheldt was not completed until 1560. This, however, was about a century before Louis XIV. had finished the earliest canal in France.

Probably the first canal constructed in England was the Exeter Canal, a comparatively short waterway, completed in 1572. But the regulation and canalisation of rivers had been attempted long before that time. The improvement of the navigation of the Thames was undertaken in 1423; of the Lea, in 1425; of the Ouse (Yorkshire), in 1462; of the Severn in 1503; of the Stour (Essex), 1504; of the Humber, in 1531; and of the Welland, in 1571.

During the seventeenth century, again, many similar works were undertaken. The Colne, the Itchin, the Wye, the Avon, the Medway, the Wey, the Bure, the Foss Dyke, the Witham, the Fal and Vale, the Aire and Calder, and the Trent were all more or less canalised during the period between 1623 and 1699.

In the next century, projects for river improvement and canal navigation proceeded apace. In 1700, the rivers Avon and Frome were regulated. In the following twenty years improvements were carried out on the Dee, the Lark, the Derwent, the Frant, the Stour, the Nene, the Kennett, the Wear, the Weaver, the Mersey and the Irwell. The Leeds and Liverpool Canal was commenced in 1720, the Stroudwater Canal in 1730, and the Bridgwater Canal in 1737.

From this date, until 1794, canal navigation was extended rapidly, while Acts of Parliament were obtained for the improvement of the Ley, the Avon, the Cart, the Blyth, the Hebble, the Stort, and the Clyde. Between 1763 and 1800 upwards of eighty different canal projects were put forward, and most of them were completed. The Trent and Mersey, the Staffordshire and Worcestershire, the Droitwich, the Coventry, the Birmingham, the Forth and Clyde, the Oxford, the Monkland, the Leeds and Liverpool, the Chesterfield, the Bradford, the Ellesmere, the Market Weighton, the Bude, Sir John Ramsden's, the Gresley, the Dudley, the Stourbridge, the Basingstoke, the Bedford, the Thames and Severn, the Shropshire Union, the Andover, and the Cromford Canals were all undertaken between 1767 and 1790. The following ten years, however, may be regarded as the heyday of canal-making in England. In 1791 the Hereford and Gloucester, the Leicester, the Manchester, Bolton and Bury, the Leominster, the Melton Mowbray, the Neath, and the Worcester and Birmingham Canals were commenced. Eighteen more canals were undertaken in 1793, and twelve others in 1794.

The same year that witnessed the opening of the Stockton and Darlington Railway, saw also the construction of the English and Bristol Channels Canal, otherwise the Liskeard and Looe; but the number of canals constructed since 1825 has been very limited. Eight different canals were opened between 1826 and 1830, including the Macclesfield, the Birmingham and Liverpool, the Avon and Gloucestershire, and the Nene and Wisbech; but since 1830 the only canals for which Parliamentary sanction was obtained, until the Act was passed for the Manchester Ship Canal in 1886, were the Ellesmere and Chester Canal, and the Droitwich Junction Canal.

Since 1830 the canals of Great Britain have been under a great ban. The superior speed and the greater punctuality provided by railway transport have caused them to be neglected, and, with only a few exceptions, more or less disused. The railway system has been extended so rapidly, and has secured the carrying trade of the country so completely, that canals have until lately been regarded as practically obsolete and useless. Many miles of canal navigation have passed into the hands of the railway companies, while a considerable mileage has become derelict.

Although the railways have secured possession of some 1700 miles of canals in Great Britain, they do not appear to have profited much thereby. The Great Western Railway Company owns no less than seven canals, on which they have expended a million sterling. In 1887 one of these canals earned 2700*l.* profit, while the other six lost 1300*l.*, besides the whole of the interest upon their capital cost.

The experience of the other railway companies has been more or less similar to that of the Great Western. The railways have been nursed and developed; the canals have been neglected and allowed to perish. The railway companies have been accused of acquiring canal property in order that they might destroy it, and thereby get rid of a dangerous rival. This is probably not the case. The railway companies are fully aware of the fact that water transport under suitable conditions is more economical than railway transport. It would therefore have suited them, at the same rates, to carry by water heavy traffic, in the delivery of which time was not of much importance. But the canals, as they came into their possession, were really not adapted for such traffic without being more or less remodelled, and this the railway companies have not attempted.

When we consider the enormous disadvantages under which the majority of the canals of this country now labour, the great matter for wonder is, not that they do not secure the lion's share of the traffic, but that they get any traffic at all. A railway is usually carried from point to point by the most direct route possible, and the cases in which there is any considerable diversion from the most direct route are comparatively rare. But in laying out the canals the designers and promoters appear to have endeavoured to take the longest instead of the shortest route available. Thus, for example, the distance between Liverpool and Wigan is thirty-four miles by canal while it is only nineteen miles by railway. Again, the railway route from Liverpool to Leeds is eighty miles, whereas by canal the distance is not less than 128 miles. If the canal rates were very much lower than the railway rates, these differences would still be very much against them. But there is not really much difference between them at present, the Leeds and Liverpool Canal, which is a fairly representative one, charging a halfpenny to twopence per ton per mile, according to the nature of the traffic. Then again, the speed on British canals can seldom be carried above 2½ miles per hour, not to speak of the delay in getting through the locks, of which there are ninety-three between Leeds and Liverpool.

It would be the idlest of idle dreams to expect that the canal system of this or any other country, as originally constructed, can be resuscitated, or even temporarily galvanised into activity, in competition with railways. Canals as they were built a century ago have no longer any function to fulfil that is worthy of serious consideration. Their mission is ended; their use is an anachronism. They do not provide the means of cheaper transport, and they have no other advantage to offer to the trader that would be a sufficient equivalent for the tedium of their transport. The canals of the future must be adapted to the new conditions of commerce. What we now require is that our great centres of population and industry shall be made seaports—that Birmingham, Leeds, Sheffield, and other places, shall not suffer hurt because they are inland towns. The existing canals may serve as a valuable nucleus for the new departure. Their importance as a means to this end has already been practically recognised. The Manchester Ship Canal Company has acquired the Bridgwater Navigation. For the purposes of the projected Sheffield and Goole Ship Canal it is proposed to acquire several of the old navigations, including the Dearne and Dove Canal, the Stainforth and Keadby Canal, and other waterways. Other improved canals have been suggested, and Mr. Samuel Lloyd has advocated the construction of a great national canal which would connect all the principal industrial centres of the kingdom with each other and with the sea. There appears to be no insuperable difficulty in the way of realising such a project. Capital alone is wanted. Whether that essential will be forthcoming is, however, very doubtful. Much is likely to depend on the extent to which the Manchester Ship Canal is successful. It would be a mistake to go too quickly. If ship canal transport is likely to be a means of salvation to British trade and commerce, we shall not be much the worse if we wait for it a little longer. It is not well to do anything that would tend to destroy or discount the value of the vast railway property of this country. The traders have long been trying to "agree with their adversary," in so far as they have differences with the railway companies; and if the latter are duly reasonable, the future may still be theirs.

It has been objected that a canal could not provide large manufacturers, mine owners, or others who now enjoy the advantages of sidings, giving direct connection with the railway system upon which their works or mines are situated, with the same facilities as they are now possessed of. This, however, is a mistake. The fact is that a wharf may be provided almost as easily and as cheaply as a railway siding. On some canals, as for example on the Birmingham system, the different works along the route of the canal have been supplied in almost every case with wharves, until they are now counted by hundreds.

Broadly stated, the problem that now presses for solution amounts to this—In what way can we best take advantage of the well-ascertained fact that under ordinary conditions a ton of goods can be transported about 2000 miles by water for the same cost that it can be sent 100 miles on land? It is no unusual thing to find that a ton of goods can be transported 40 miles by steamer for one penny, making allowance for every charge.* It is not, of course, pretended that goods can be carried by inland navigation for anything like this rate. But it has been well established that even on canals, with all the disadvantages of slow speed, limited depth, small boats, frequent locks, and other drawbacks, the transport of heavy traffic can be effected for less than one-sixth of a penny per ton per mile, which is not one-half of the lowest rates at which the railways of Great Britain carry mineral traffic at the present time. It is necessary to add that canal companies do not, in Great Britain at least, carry for anything like the low rate stated, except perhaps on the Weaver Navigation, which is quite exceptional.

An important question that naturally occurs to any one who has studied the history of canal navigation in foreign countries is that of how far it is the duty of the State to take such waterways under its

* Mr. Bailey, in his interesting address to the Manchester Association of Foremen Engineers, in 1886, stated that he had found this to be the cost of transport with a vessel of 2360 tons, including interest, depreciation, and insurance.

control. This is really a political problem, which scarcely belongs to that part of the subject which we have undertaken to consider. It may, however, be observed that in the United States, in France, and in one or two other countries, canals have been acquired by the State, and made as free of tolls as the rivers. This, of course, affords to canal transport in those countries a striking advantage over the system in Great Britain. It has been calculated by a high authority * that an expenditure of 12,000*l.* per mile would be required to put the inland navigations of England into good order, and to adapt them generally for larger traffic, with steam-tugs and barges or boats of sufficient size. This would mean for the 3000 miles of canal already constructed an expenditure of 24,000,000*l.* It is calculated that about 20,000,000*l.* have already been expended upon our waterways,† so that the total outlay, after the expenditure suggested by Sir John Hawkshaw, would be about 44,000,000*l.* If the State were to borrow this sum, it could procure it, no doubt, at 3 per cent., which would mean that the total annual burden entailed upon the country by the freeing of the canals would be 920,000*l.*, or only a $\frac{1}{125}$ part of our total national expenditure. This is certainly a small price to pay for so desirable an object. But upon the proposal as just stated there are two important remarks to be made—the first, that the suggested expenditure of 12,000*l.* per mile would only give us canals adapted for the navigation of large barges or vessels of not more than 150 to 200 tons, whereas what is chiefly required is internal water communication that would enable an ordinary merchant steamer to sail right up to Birmingham, Leeds, Bradford, and other large towns; the second, that no such maritime ship canal has hitherto been constructed for less than 120,000*l.* per mile, including all contingencies.‡ The raising of this sum is a very different item from the raising of 12,000*l.* per mile. The most serious objection, however, would be the outcry on the part of the railway interest that the Government

* Sir John Hawkshaw, in his evidence before the Select Committee on Canals, 1883.

† The total expenditure has been variously stated. Smiles, in his 'Lives of the Engineers,' puts it at one figure, while it was stated before the Select Committee on Canals at another.

‡ The actual cost of construction of the Suez Canal was about this amount, but the additional expenses incurred, and in the majority of cases necessary to such an enterprise, brought the cost up to 200,000*l.*, which was also the average cost of the Amsterdam Ship Canal. The Manchester Ship Canal is estimated to cost some 250,000*l.* a mile.

was entering into competition with private enterprise. This, of course, would be no new thing. The New York State canals compete with the railways, which are private property, and so do the canals of France. The duty of the State stops at providing the waterway. It does not, of course, undertake transportation. That business is left, like the same business on the railways, to private enterprise. The canals might, therefore, if acquired by the State, be regarded as so many additional miles of navigable rivers possessed by the country, or so many more miles of seaboard provided for the benefit of towns that have hitherto been shut out from direct maritime advantages. Canals are, indeed, entitled to be regarded in the same light as a common turnpike road. The State would hardly be likely to permit private ownership in turnpikes. The community at large are taxed for their maintenance, and there has never been any serious contention that it should be otherwise. The time has come when it behoves us to consider whether canals should not be similarly controlled and administered, since they are, without doubt, as necessary for the transport of goods as turnpike roads are for the passage of vehicles and pedestrians.

As to the reasons that have led the author to undertake the publication of the present volume, a remark or two may be permitted. In 1875 he undertook the preparation of a work* on the growth of the railway system up to that time for the Directors of the North-Eastern Railway, on the occasion of their celebration at Darlington of the Jubilee of the Stockton and Darlington line—the first passenger railway constructed in this country on which locomotives were employed. In inquiring into the history of that railway, he was struck with the importance that was attached half a century before to the possession of canal navigation, and with the great facilities that it afforded to the districts through which it was carried. Since then he has from time to time had occasion to look into the same subject, and especially so in 1882, when he was required to give evidence before the Select Committee on Railway Rates and Fares,† as to the differences that exist on English and Continental railways in the charges made for the transport of heavy traffic. He found also that, notwithstanding the lower rates of transport on Continental railways, very great importance was attached to the maintenance, in a high state of efficiency, of the waterways of all other countries in Europe

* 'Jubilee Memorial of the Railway System,' Longmans.

† Report of Select Committee.

except our own, and that in most other countries the State specially charged itself with the duty of seeing that this was effectually done. It was but a short step from the acquisition of this knowledge to the natural endeavour to ascertain why English canals were not deemed equally important to the trade and commerce of the greatest of commercial nations. The results of that inquiry are set forth in the following pages; but the author has not been content to examine the economic side of the case alone. Finding not only that the canals of the world had a most interesting history, which has never hitherto been set forth in the form of a continuous narrative, but that one of the most remarkable movements of the present time was a demand for artificial waterways, in order to reduce both the time and the distance now required for the intercourse of different important centres of our planet, and give inland towns a more direct connection with the sea, he has devoted much research to the investigation of the origin and growth of these enterprises, and has set down the results in as interesting and useful a form as he could.

A good deal of attention has been given in this work to the subject of isthmian canals. It has been suggested that a "ship and barge" railway would be an improvement upon both railways and canals in the joint advantages of economy and speed of transport. This is an "American notion," which has not yet, so far as we are aware, been put in practice, although it was put forward by the late Captain Eads, in the form of a project for a ship railway across the isthmus of Techuantepec, as the true solution of isthmian transit. It has been claimed that such a railway "can be operated and maintained at less cost than the canal, employ a rate of speed five times as great as is possible in the canal, can be operated for the whole twelve months of the year instead of six—or during the lake navigation, like the ship canal—will require no breaking bulk, and through freight can be hauled over it at 2½ cents. per bushel of wheat," i.e. for a distance of about 340 miles.* On the other hand, however, no one appears to have seriously prosecuted this enterprise since the decease of its gifted author, while two ship canals have been promoted across the American isthmus.

In the appendix will be found a large mass of information as to the extent of the British canal system, and the dates at which the principal canal and river navigations were executed. Some data as to the extent and character of the principal river systems have also

* 'Transactions of the American Institute of Civil Engineers,' vol. xiv. p. 48.

been introduced in tabular form. It is not pretended that this latter information is by any means complete. The merest epitome of the rivers and river systems of all the countries of the world would itself fill a volume; but it is hoped that the most essential data have been supplied with sufficient fullness and accuracy.

In the best interests of British commerce and industry, we cannot do better than attempt to follow the excellent counsel given by Ald. Bailey, of Manchester, when he urged * that we should "make England to the world what London is to England: make every part of the verge, fringe, shore, creek, bay, river, and inlet of our map as equal as possible in relation to distance from the shores of foreign countries; increase the value of the silver streak, double the coast line, resuscitate the ancient ports, extend some more inland, make Britain narrower, shorten the distance from coast to coast, from sea to sea, and increase the setting of Shakespeare's

'Fortress built by nature for herself,
This little world—
This precious stone set in a silver sea.'"

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* Address to the Manchester Association of Engineers.

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CHAPTER I.

THE TRANSPORTATION PROBLEM.

"Of all inventions, the alphabet and the printing press alone excepted, those inventions which abridge distance have done most for civilisation."—*Macaulay*.

The history of transportation is largely, and of necessity, the history of material progress. It is hardly possible to conceive of the prosperity of a people to whom the most precious possessions that the arts and sciences have bestowed upon mankind for the purposes of commerce were unknown. Such a people could, no doubt, exist, and perhaps maintain a considerable amount of rude health. But, like the aborigines of an unsettled and uncultivated territory, they would find themselves shut out from participation in the advantages which civilisation confers upon mankind. They would be exclusive, uncultivated, ignorant, incapable of great effort, limited in their capacity for enjoyment, subject to the constant danger of famine, and without the command of those amenities which have created such a gulf between the "rude forefathers of the hamlet" and the happy possessors of all that civilisation can bestow.

Only a very perfunctory acquaintance with the physical configuration of our planet is required, in order to show that the natural arrangement of land and water is not the most convenient that could be devised for the purposes of commerce and travel. The oceans and seas do not afford in all cases the most direct and desirable routes between one part of the world and another. Rivers of otherwise gigantic dimensions are now and again found to be possessed of rocky and shallow beds that are unsuited to navigation except by the tiniest craft. Promontories are projected into "the waste of waters," compelling the navigator to sail for hundreds or thousands of miles further than "the crow flies" in order to reach his destination. Every here and there an isthmus is found to divide waters that appear as if they were intended by Nature to be joined together.

The same remarkable absence of facilities for promoting the requirements of commerce is apparent on land as on water. The surface of the earth, and the divisions of land and water, appear to have been left by Nature in such a condition as to tax the highest powers and capacities of man. The knowledge of roads, of bridges, of canals, has been laboriously acquired and slowly applied. The aboriginal inhabitants of a country usually care for none of these things. Beasts of burden are seldom used in the most primitive conditions of existence, and, without these, roads are not so much of a necessity. Man, however, found out, in course of time, that it suited his interests and his convenience to establish a system of interchange of commodities. The simple and self-contained habits of the trapper and the hunter gave place to a more composite order of being. Then it was that the primeval forest, the jungle, the morass, and the prairie became rectangulated with roadways over which traffic could be rudely transported on the backs of mules, horses, or other beasts of burden. As exchange and barter extended, the pack-horse was found inefficient. He could only perform a very limited day's work, whether measured by quantity or by distance. For transport over great distances he was virtually useless. In the absence of any other system of transport, districts near the sea, or placed on navigable rivers with easy access to the ocean, became developed at the expense of other districts that had equal, and perhaps greater, facilities otherwise except those of transport. A notable case in point is that of the coal trade. For many years the export coal trade of this country was limited to an area within 12 miles of convenient ports, because coal could not be transported beyond that distance except at a virtually prohibitory cost.

A hundred and thirty years ago, England was in a very different position to that which she occupies to-day. So, also, was the rest of the world. The woollen trade was the greatest of our national industries. The cotton industry was just beginning to take a firm root. The quantity of coal produced in Great Britain was estimated at five or six millions of tons per annum. The quantity of iron produced was believed to be about 100,000 tons. The only coalfield that had been developed to any extent was that of Durham and Northumberland. The working of coal far from the seaboard was impossible on a large scale, because there were no means of transportation that would allow of anything being carried more thar a few miles, unless it were of the highest value. The cotton, woollen, silk, and other textiles were made by hand-looms, and for the most part in the private dwellings of the workers. The modern factory system had not come into being.

The condition of the roads, even so late as the middle of the eighteenth century, was in a very large number of cases a matter for just and serious complaint. Lord Hervey wrote from Kensington in 1736 that the road between that village (at that time) and London had become so bad that "we live here in the same solitude as we would do if cast on a rock in the middle of the ocean, and all the Londoners tell us that there is between them and us an impassable gulf of mud." In London itself the pedestrians who made use of the public thoroughfares had to walk on the ordinary round paving-stones which are still employed in some towns for the centre of the road, pavements being unknown. The streets were lit with oil-lamps sufficiently to make darkness visible, gas not having been introduced. The common highway was also the common sewer. The ruts in the thoroughfares, even in the streets of London, made it dangerous to employ vehicles, which, indeed, except in the form of sedan-chairs, had not yet come to be largely employed.

But these dangers and troubles, manifest and inconvenient though they were, by no means exhausted the list. In the absence of a proper system of police, and with streets enveloped in darkness, there was serious danger incurred in stirring abroad after nightfall, The public thoroughfares were infested by bands of footpads and robbers. The main streets of London were the worst off, and so serious was the danger of going out at night that it was the rarest thing to find any one stirring after dark. So far was this system carried that robberies took place in broad daylight. Even such public places as Piccadilly and Oxford Street were not exempted from the common danger. Horace Walpole relates that he was robbed in this way, with Lord Eglinton, Lady Albemarle, and others. Those who had to travel to the adjacent villages of Paddington and Kensington were afraid to proceed alone. It was therefore customary to wait until a sufficiently numerous band had been collected to enable the pedestrians to resist any possible attack of footpads. The

Vauxhall and Ranelagh Gardens, then the chief places of amusement in the vicinage of the metropolis, had to employ patrols to keep the way clear to London.

As in the metropolis, so in the provinces. The roads, both in the towns and outside them, were in many cases as bad as bad could be. Their not unusual condition was that of "a narrow hollow way, little wider than a ditch, barely allowing of the passage of a vehicle drawn by horses in a single line." This deep, narrow road was flanked by an elevated causeway, covered with flags or boulder stones, along which the traffic of the locality was carried on the backs of single horses, so that "it is difficult to imagine the delay, the toil, and the perils by which the conduct of the traffic was attended." Under these circumstances, "there were towns, even in the same county, more widely separated for all practical purposes than London and Glasgow in the present day."* Business was done slowly, and involved so great an expenditure of time and trouble that prices were necessarily high. News travelled more slowly still, and it was sometimes months before the people who lived at the extremities of the island knew what had happened in the metropolis.

The reader who desires to obtain a graphic and eloquent account of the circumstances of England previous to the canal era could not do better than consult Macaulay, who, in the famous third chapter of his 'History,' has devoted a considerable amount of space to the consideration of the social and economic changes that had come over the country since 1685. The description given of the condition of the people in that year might almost be literally applied to their condition in the middle of the eighteenth century. The population had increased, it is true, and commerce had been developed in the interval. But the facilities for rapid and economical transportation had not been materially altered for the better. The great mass of the people were as ignorant, as superstitious, as shiftless as in the seventeenth century. Their sanitary surroundings were as unwholesome, their industrial pursuits as improvident, their habits as deplorable, their hardships as irksome, their discomforts and inconveniences as tiresome. From this remarkable record of the days of our forefathers we quote the following passages as being specially germane to the subject under consideration:—

* Smiles's 'Lives of the Engineers,' vol. i. p. 180.

† Ibid., p. 184.

"It was by the highways that both travellers and goods generally passed from place to place; and those highways appear to have been far worse than might have been expected from the degree of wealth and civilisation which the nation had even then attained. On the best lines of communication the ruts were deep, the descents precipitous, and the way often such as it was hardly possible to distinguish, in the dusk, from the unenclosed heath and fen which lay on both sides. Ralph Thoresby, the antiquary, was in danger of losing his way on the great North Road between Barnsley Moor and Tuxford, and actually lost his way between Doncaster and York. Pepys and his wife, travelling in their own coach, lost their way between Newbury and Reading. In the course of the same tour they lost their way near Salisbury, and were in danger of having to pass the night on the Plain. It was only in fine weather that the whole breadth of the road was available for wheeled vehicles. Often the mud lay deep on the right and the left, and only a narrow track of firm ground rose above the quagmire. At such times obstructions and quarrels were frequent, and the path was sometimes blocked up during a long time by carriers, neither of whom would break the way. It happened, almost every day, that coaches stuck fast, until a team of cattle could be procured from some neighbouring farm to tug them out of the slough. But in bad seasons the traveller had to encounter inconveniences still more serious. Thoresby, who was in the habit of travelling between Leeds and the capital, has recorded in his Diary such a series of perils and disasters as might suffice for a journey to the Frozen Ocean or to the Desert of Sahara.*

* Judging from the diary of Mr. Justice Rokeby, which has been recently printed by Sir Henry Peek, in the time of William and Mary going circuit was arduous work, and the arrangements for reaching the scene of his labours occupied almost as much of a Judge's attention as the execution of the Royal commission when he arrived. Mr. Justice Rokeby, according to this record (as abridged in the *Times*), usually travelled in a four-horse coach with his chamber clerk, while his groom or valet attended him on a saddle-horse, which also carried the Judge's "portmantle." Generally both coach and horses were hired for the occasion, the rate appearing to be about 22*s*. for each travelling day, and 12*s*. for each resting day. Sometimes the learned Judge economised by "putting a pair of his own horses to the wheel," and had his own coachman to drive. But more than once it was necessary to take six horses in the coach, and occasionally a couple of servants on saddle-horses were in attendance. In the spring of 1692–93, "after the circuits were all settled and the term ended—viz. February 25—there fell a very great snow, which occasioned the King to issue out a proclamation, March 2, 1692–3, to alter all the circuits to later days but only the Norfolk and Oxford circuits, which continued upon their first appointment." Mr. Justice Rokeby,

"The markets were often inaccessible during several months. It is said that the fruits of the earth were allowed to rot in one place, while in another place, distant only a few miles, the supply fell far short of the demand. The wheeled carriages were in this district generally pulled by oxen. When Prince George of Denmark visited the stately mansion of Petworth, in wet weather, he was six hours in going nine miles, and it was necessary that a body of sturdy hinds should be on each side of his coach in order to prop it. Of the carriages which contained his retinue several were upset and injured. A letter from one of the party has been preserved, in which the unfortunate courtier complains that, during fourteen hours, he never once alighted, except when his coach was overturned and stuck fast in the mud."

A story is told of an old stage-coach driver who, finding that his occupation had been seriously interfered with by the modern innovation of railways, thought he would strike a blow for the old system by attacking the railway in a vulnerable part. "Consider," he argued, "what happens in case of a collision. If two stage coaches come into collision, and thee is an upset, why, there you are. But

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being unlucky enough to be going on the Norfolk circuit, derived no benefit from the postponement, but "by reason of the badness of the ways was forced to take six horses," so that he was "out of purse" on the circuit above 52*l.* The previous summer the waters were out, and travelling in the valley of the Thames was no easy matter. "I began my journey into this circuit (the Oxford) from London," says the Judge, "on Monday, June 27, and baited at Maidenhead, but the waters were so great upon the road that at Colebrook they came just into the body of the coach, and we were forced to boat twice at Maidenhead, and we boated the coach, and at the second time we boated ourselves, but the coach came through the water, and it came very deep into the body of it, and that night we lay at Henley-upon-Thames, where we were forced to boat the coach again." For years afterwards we read that the way from Oxford to Gloucester was so bad that it took 14 hours to accomplish the distance, though it was not more than 33 miles, while there was a "very bad and shaking way" from Monmouth to Hereford; and at an earlier stage of the circuit the Judge chronicles his safe arrival at High Wycombe from London with the pious but significant ejaculation, "Thanks be to God!" Sometimes the Judges, apparently, hired a coach between them, but Mr. Justice Rokeby had a little difference with his brother Judge, Mr. Justice Eyre, on his second circuit, concerning the division of expenses, and this probably led to his making independent carriage arrangements subsequently. On this occasion Mr. Justice Rokeby was called back to town at an early point of the circuit, and Mr. Justice Eyre declined to take on the coach, but finished the circuit on horseback, and it was his demand to be paid a share of the expenses of his saddle-horse which led to the difference of opinion.

in a railway collision, where are you?" In those days stage coaches did not enjoy the immunity from disaster that they do in these, when macadamised roads enable them to roll along almost as if they were on a billiard table.* When the canal system was being fairly started in England, only one stage coach ran between London and Edinburgh, starting once a month from each city, and taking ten days for the journey in summer, and twelve days in winter. It took fourteen days to travel between London and Glasgow. In 1760 it took three days to travel from Sheffield to London, and in 1774 Burke travelled from London to Bath with what was described as "incredible speed" in twenty-four hours.

Much of the discomfort, the high range of prices, the general existence of poverty, the limited extent of commercial operations, in the early part of the eighteenth century was no doubt due to the imperfect development of the modern processes of manufacture and distribution—to the production of textiles by the old hand-loom, of iron by the old-fashioned type of blast-furnace, of steel by the costly cementation process, of clothing without the aid of the sewing-machine, and of agricultural crops without any of the mechanical aids to husbandry that are now so general and so conducive to economical working. But the high cost of transport had also much to answer for. Before the period of Macadam, it cost 2*s.* 6*d.* per mile to transport coal by the old pack-horse on an ordinary road. At this rate, it would have cost from 10*l.* to 15*l.* to transport a ton of coals from the Midland coalfield to London, a service which is now performed for 6*s.* to 7*s.* per ton. With only the old pack-horse facilities it would have cost an almost incredible sum to have performed the same service which the railways now render to the people of the United Kingdom in the transport of minerals and merchandise.

While the knowledge of the arts, and especially of the arts that relate to transportation, were in so backward a state, it was inevitable that the prices of commodities should be high, and their interchange limited. Having to pay so much for the articles that they did not grow or produce themselves, the people of England, in the middle of the eighteenth century, were extremely poor, as a rule, and had very

* The difference between macadamised and ordinary roads, in the cost of conveyance, not to speak of comfort, is extraordinary. Nicholas Wood estimated that the transport of coal by the old pack horse was reduced from about 2*s.* 6*d.* to 8*d.* per ton on a good road of this description.

little chance to increase their wealth. The wages of the working classes were very low. A shilling a day was deemed to be excellent earnings. In Scotland the wages of a day labourer were only 5*d.* per day in summer and 6*d.* in winter. The price of bread was ordinarily much higher than it is at the present time.* The prices of clothing and of the usual requisites for domestic comfort and convenience were very much more than at the present day. The rates of wages were hardly enough to enable the great mass of the people to keep body and soul together. Butchers' meat was all but unknown, even among those who were tolerably well off.† Plain homespun was almost the only description of clothing that was worn. Shops were hardly known in the smaller towns or villages, and the country people were mainly supplied with such requirements as they were able to indulge in, outside of their own productions, by hawkers, who carried packs everywhere, as they sometimes do in remote country places in our own day. In localities where coal was not produced, it was not to be purchased for love or money, unless at seaport towns, and the fuel ordinarily used was either turf or wood.

From this condition of things England was largely rescued in the latter part of the eighteenth century by the introduction and development of internal waterways. This movement gave a remarkable stimulus to commercial and industrial progress. It enabled raw materials to be transported at about one-tenth of what they had formerly cost, and facilitated the interchange of commodities between the different parts of the kingdom to an extent previously undreamt of.

It is remarkable what a large crop of important discoveries and inventions were made about the time that canals began to be generally used as waterways. Robinson's project for working steam locomotives on common roads was put forward the year after Brindley commenced the Bridgwater Canal. In the same year the manufacture of thread and gauze was commenced at Paisley, and Jedediah Strutt made his first improvement on the stocking loom. Two years later Arkwright obtained his first patent for the spinning-frame, and Watt made his first experiments on the power of steam

* According to the tables in Adam Smith's 'Wealth of Nations' (Book i. chap. xi.) the average price of wheat between 1637 and 1700 was 2*l.* 11*s.* 0$\frac{1}{3}$*d.* per quarter; from 1700 till 1764 it was 2*l.* 0*s.* 6$\frac{9}{32}$*d.* per quarter.

† Even so late as 1794, Hepburn, in his 'General view of the Agriculture and Economy of East Lothian,' stated that, not long before, not a single bullock was slaughtered in the butcher market at Haddington except at a special time.

with Papin's digester. . It was in 1762 that the production of Wedgwood ware was first begun, and the same year witnessed a notable development of the linen manufacture of Ireland, while in 1763 Hargreaves the weaver produced his spinning-jenny in his house adjoining the print works of the first Sir Robert Peel. These are but a few of the concurrent and collateral movements of the period. Of the measure in which they were aided by internal transport we shall have more to say by and by.

An examination of the geography of European countries will disclose the fact that the United Kingdom is almost unique in regard to its possession of a magnificent coast-line, studded with harbours and docks, and approached by a large number of navigable rivers, which afford easy communication with the sea. If we compare our facilities with those of Germany, Austria, Belgium, Holland, Italy, or indeed any other European country, we cannot fail to be struck with their enormous superiority. Scarcely any part of the United Kingdom is more than a hundred miles distant from a good harbour. In many European countries there are important towns that are very much further, while some countries, like Switzerland, have no seaboard at all, and others, like Austria, besides having very few ports worthy of the name, are landlocked on more sides than one.

Again, let us look at the recent history of European politics. Do we not find that a more extensive seaboard is the ruling passion of such nations as Germany and Russia, whose outlets are few and inconvenient? The half-suspected designs of Germany upon Holland, and of Russia upon Turkish and Chinese territory, have been mainly ascribed to this ambition. To obtain such an outlet for the Asiatic part of her dominions, Russia is at the present moment laying down a railway across Siberia, which will give her a closer connection with China than the Chinese seem to care for, and is likely, in the opinion of some shrewd politicians, to eventuate in her obtaining possession of a large slice of the Celestial Empire. The neutralisation of certain prominent waterways is, moreover, regarded as a matter of so much importance, that costly and protracted wars have been undertaken with a view to that end, nor would it be difficult to trace a connection between the passion for more ports and the costly armaments which have now for many years threatened the peace and impoverished the resources of Europe.

Nevertheless, with a command of the sea that makes us at once the envy and the despair of rival nations, and has placed our shipping supremacy on such a pinnacle of power and prosperity as the world has never before been acquainted with,* we still require to pay more for reaching our ports, relatively to the distance traversed, than any other nation in Europe, and very much more than either the United States of North America, or our own possessions of India and Canada. It is not too much to say that if we possessed the same transportation rates as some of these countries, our trade with the rest of the world would be much greater than it is; while if we had the same distances to traverse as in these countries, at the existing railway rates of our own, competition in neutral markets with the low-rate countries of the Continent would be impossible.

In making these statements we impute no blame and make no reflections. We are only concerned to state the simple truth. It may be that the railway companies in this country cannot afford to carry goods at cheaper rates. That is their look-out. They have undoubtedly incurred vast expense in providing the most ample and the most admirable facilities of transport, short of the all-important item of its cost. In no other country do we find such a splendid service. No other country has better roads nor more capable administration, nor quicker and more reliable dispatch, nor greater conveniences for traffic of all kinds. Unfortunately, also, in no other country have the railways been so costly; so that for the same volume of traffic English railways require to have higher rates, in order that the charges on capital may be met.† But why should trade suffer, and freighters find themselves *in extremis*, because British railways have made cheap rates all but impossible? There is sure to arrive, sooner or later, a point—which in England is seldom far distant—when railway rates become prohibitive. That point has almost been reached when traffic can be delivered in England from the heart of Belgium at 5*s*. per ton, as compared with 10*s*. and 12*s*. per ton for railway transport between the Midlands and the metropolis. The real question now is—Can nothing be done to remedy this state of things, not in a spirit of hostility to the railways, which may have done their best, but with a

* The writer has shown, in articles published in the *Times* on January 5th, 1887, and again on January 2nd, 1888, what are the extent and the distinguishing features of this supremacy.

† The average cost per mile of the railways in England and Wales is about 50,000*l*., as against 12,700*l*. in the United States, 21,000*l*. in Germany, 25,300*l*. in Belgium, 27,500*l*. in France, and 20,000*l*. in Holland.

view to the preservation and increased development of British trade and industry? The nation is either hopelessly at the mercy of railway boards, or it is not. Our trade and manufactures are either compelled to pay every year an undue proportion of their hard earned receipts to railway shareholders, or they are not. If they are not—if there is a way of escape from this bondage—it is well that the nation should know what it is, and how best to take advantage of it. This is mainly the purpose of some of the chapters which follow.

Up to the period of the first Canal Acts, English waterways were under the control of the State, or of authorities appointed by the State for the conservancy of navigation; and that such an arrangement was, on the whole, not without its advantages, is proved by the fact already referred to, viz.: that in the middle of the eighteenth century the advantages with regard to water carriage enjoyed by England enabled her to outstrip other countries in the development of her manufactures. With the construction of the first canal began the era of private enterprise in respect of inland navigation, which owes its existence, as it is hardly necessary to remark here, to the genius of Brindley, and to the unflagging determination of the Duke of Bridgwater—whose efforts in the cause of progress were, like those of Stephenson, and the pioneers of railway enterprise after them, at first strenuously opposed by the public, and almost entirely neglected by the State.

The turning point of public opinion, as regards both canals and railways, was the discovery that money might be made out of them. Brindley's grand project of uniting the four great ports of Liverpool, Hull, Bristol, and London by a system of main waterways from which subsidiary branches might be carried to the contiguous towns, had been, to a large extent, successfully accomplished at the end of the first quarter of the present century, and when canals began to pay dividends, the nation began to admit their public utility. In a very few years after Brindley's death in 1772, an immense number of navigation Acts received the sanction of Parliament, canals began to be freely quoted "on 'Change," and, in 1790, "the canal mania" began.* The *Gazette* of August, 1792, contained notices of eighteen new canals, and the premiums of single shares in companies had reached such figures as 155*l.* (Leicester), 350*l.* (Grand Trunk and Coventry), and 1170*l.* (Birmingham). Canals began to be used for passenger traffic; and we read in the *Times* of 19th December, 1806,

* See a paper read before the British Association at Birmingham, 1887.

of troops being despatched from London to Liverpool by the Paddington Canal, *en route* for Ireland, a mode of transport which the writer pointed out would enable them to reach Liverpool "in only seven days!" In the four years ending 1794, some 81 canal and navigation Acts were obtained, of which 45 were passed in the latter two years, authorising an expenditure of over 5,000,000*l.* No less than 1,200,000*l.* was spent upon the construction of the 130 miles of waterway connecting Liverpool, by way of Skipton, with the Aire and Calder at Leeds (a work begun in 1770, but not completed till 41 years afterwards); and when the last canals in England were completed, in 1830, the total amount that had been expended upon our waterways was about 14,000,000*l.* Out of some 210 rivers in England and Wales, 44 in England have hitherto been made navigable.* The Thames, the Severn, and the Mersey are connected by 648 miles of river and canal, the Thames and Humber by 537 miles, the Severn and Mersey by 832 miles, and the Mersey and Humber by 680 miles; the Fen waters have an extent of 431 miles, and the remaining canals of England and Wales amount to 1204 miles.† This fine system of waterways, with a total length of 4332 miles, furnishes no less than 21 through routes for traffic between London and the manufacturing districts, but, as it is scarcely necessary to observe, a very large portion of it has ceased to be of any practical value, while the utility of that which is still available to the public is constantly diminishing, through the neglect due to the impoverished condition of many of the canal companies and other causes.

In the eyes of engineers, the defects of natural geography were made to be corrected by their skill, experience, and ingenuity. Peninsulas and isthmuses, whether large or small, appear to be designed only for the purpose of being pierced with artificial waterways. Hydraulic engineers are the high priests of science, whose mission it is to publish the banns of marriage between seas and oceans, and complete the nuptials in a way that no man may put asunder. By their sacerdotal functions, the Mediterranean has been married to the Red Sea, the Caspian to the Black Sea, the North Sea to the Atlantic, the Adriatic to the Archipelago, and the Atlantic almost to the Pacific, while we have seen many unions of less distinguished members of the great maritime family. The importance of these alliances to the trade, the wealth, the intercourse, the facility

* Report of House of Lords Committee on Conservancy Boards, 1877.

† Report of Select Committee on Canals, 1883.

of intercommunication, and the general convenience of the world, not to speak of strategical and political considerations, affecting individual nations, can hardly be over-estimated. But much still remains to be done. The high contracting parties are in some cases coy and bashful, requiring more effective wooing before they can be won. The prospective matchmakers must not forget that

> "It's not so much the lover who woos
> As the gallant's way of wooing."

There is a personal history belonging to the development of canal navigation of a much more engrossing interest than can usually be claimed for so unromantic a type of institutions. The annals of that history extend over many centuries. They reach back even to the times of ancient Egypt, the cradle of the sciences, and were contemporaneous with the building of the Pyramids. Menes, who lived 2320 years before the Christian era, constructed water courses, which were simply canals, for carrying off the superfluous waters that reduced the greater part of Egypt in his time to the condition of an extensive marsh.* Sesostris, 1659 B.C., undertook the cutting and embanking of canals on a more extensive scale, carrying them at right angles with the Nile, as far as from Memphis to the sea, for the quick conveyance of corn and merchandise.† Ptolemy II. (Philadelphus) completed a canal, which had been commenced and continued by several previous sovereigns, and which is said ‡ to have afforded a connection with the sea; § while even at this early date, gates or sluices were constructed, which opened to afford a passage through the Egyptian canal to the sea.||

In Roman times, again, Julius Cæsar, Caligula, and Nero were canal-makers, having each in his day attempted to unite the Ionian Sea with the Archipelago, through the isthmus of Corinth—an undertaking which is only in our own day being consummated. The emperor Trajan was also greatly interested in canals, as his correspondence with Pliny proves, while all the principal Roman consuls and generals appear to have possessed some knowledge of hydraulics, and applied that knowledge to useful purpose.

Charlemagne attempted to unite the Rhine with the Danube, and to establish water communication between the German Ocean and the Black Sea. Leonardo da Vinci was equally great as a canal-

* Herodotus, lib. ii. c. lxlix.

† Diodorus Siculus, lib. i. c. iv.

‡ Strabo, lib. xvii.

§ Diodorus Siculus, lib. i. c. i.

|| Cresy's 'Encyclopædia of Civil Engineering,' c. iv.

maker and a painter, having constructed some of the earliest canals in Italy. The Doges of Venice, "the City in the Sea," naturally paid much attention to the same subject, which was, indeed, essential to their convenience, security, and prosperity.

It is to the credit of many of the sovereigns of France that they have sought to promote the security and welfare of their country by similar means. Henry II. employed Adam de Crapone, about 1555, to cut the Canal of Charolais; and Henry IV. continued the work. Louis XIV. engaged an Italian to construct one of the greatest of the French canals—that of Languedoc, which is elsewhere referred to. In more recent times Napoleon Buonaparte and Napoleon III. have interested themselves actively on behalf of canal navigation; and it appears to have been by a mere chance that the latter did not become a canal administrator in Central America, where he took a keen interest in the proposed ship canal across the isthmus of Nicaragua.

If we cast our eyes over the rest of the European Continent we shall find that wherever artificial waterways have been provided, Royal or Imperial encouragement has assisted in the operation. Peter the Great and Catherine attached the utmost importance to the development of Russia by this means. In Sweden, Gustavus Vasa and his successors were equally solicitous, in a country full of natural waterways, that these should be utilised and connected by artificial means.

A system that has been instrumental in giving to Europe such towns as Amsterdam, Rotterdam, and Venice, which has facilitated the progress of commerce in a hundred different directions, which was practically the only means of transport for nearly a century in all the chief countries of the world, and which still makes provision for the interchange of commodities at a cheaper rate than any other; which has involved the expenditure of hundreds of millions, and has found employment for vast numbers of well-remunerated *employés*; which abridges distance and time, and brings into closer contact different districts and countries, seas and oceans; which has engaged the attention of the greatest potentates and princes of recorded history, and has in all times been deemed a fit subject for the exercise of kingcraft; which, in our more prosaic age, brings us cheap food, cheap coal, and cheap commodities generally—such a system is one that can hardly be lightly esteemed, even now, notwithstanding that its waning light has been eclipsed by the brilliance of that other system which has been so marked a development of our nineteenth century civilisation.

Canal engineering, besides, has a very remarkable record, and has achieved many notable triumphs. These have hardly received the attention to which their importance entitles them. It is true that no canal has been carried, like the Callao, Lima, and Oroya railroad, in Peru, to the height of nearly sixteen thousand feet above the level of the sea.* It has, however, on the Languedoc and other canals been found easily feasible to carry a canal to a height of 600 to 1000 ft. above the sea. Canal engineers have not, perhaps, pierced the Alps with a tunnel ten miles in length, as on the Saint-Gothard Railway; but they have carried a tide-water canal from the Mediterranean to the Red Sea, and they have essayed to perform the same feat through the Cordillera. Hydraulic engineering has, next to railway engineering, been the most remarkable manifestation of the applied science of modern times, and in canal construction it has attained some of its most successful results.

Sufficient credit, moreover, has hardly been given to the canal system for the important part which it has taken in opening up the resources of different countries, and thereby bringing about the remarkable development of commerce and industry which has been so marked a feature of our own times. The Act for the construction of the Bridgwater Canal was obtained in 1759, previous to which time the internal commerce of the country, as we have seen, was carried on by pack-horses or waggons, on common turnpike-roads. Mr. Wood has calculated † that the average cost of conveying heavy goods on macadamised turnpike-roads by this system was 8*d.* per mile, while light goods cost 1*s.* per ton per mile. As that calculation applies to a time when wages, fodder, and other items involved in the expense of such transport, were lower than now, it is a fair assumption that it will be at least as much to-day, and for facility of reckoning we may take the average at the convenient and fairly likely figure of 10*d.* per ton per mile over all. Now, the total quantity of merchandise carried on the railways of the United Kingdom in 1887 was about 269 millions of tons. No evidence exists as to the total mileage over which this vast tonnage was carried, or, as it

* The railway starts from Callao at a height of 448 ft. above sea level, and at 104½ miles distance it passes through the summit tunnel at a height of 15,645 ft. above that level.

† 'Practical Treatise on Railroads,' third edition, p. 684.

is expressed in railway phraseology, of the ton-mile traffic. But if we assume that the average charge for traffic carried by railway in 1887 was 1*d.* per ton per mile, the total movement would be represented by the enormous figure of 8962 millions of ton-miles. To have carried the same traffic under the system of transport that preceded the canals would have been impossible, but it would have cost the country, if it had been practicable, no less a sum than 373½ millions sterling, which is about one-third of the estimated amount of our national income from all sources. But this, after all, is not the most curious part of the calculation. In order to understand how impossible our present transport system would have been under the old *régime*, we must assume that a horse is capable, under ordinary circumstances, of carrying one ton about ten miles a day. Working for 300 days a year, therefore, he would be able to carry a total weight of about 3000 tons one mile in the course of twelve months. To undertake the same work as that performed by our railways would therefore require close on three million horses, or, practically, the whole of the horses that exist in the United Kingdom at the present time, for every purpose, including agriculture.

It was while we were depending exclusively upon this expensive and tedious system of conveyance, when the internal development of the country was rendered all but impossible by the heavy expense of bringing produce to the sea, and when our export trade was consequently of the most restricted dimensions, that canals came to the rescue. They worked a marvellous change in the trade of the country —a change which can, perhaps, be best illustrated by the ordinarily dry, but in this case almost thrilling, returns of our exports and imports. Burke, in one of his greatest speeches,* spoke of a total exportation of the value of 14½ millions, and a total importation of 9½ millions sterling, as an index of extraordinary prosperity. In another equally great oration † he said, speaking of the fact that we were then exporting rather over six millions a year to our colonies, that "when we speak of the commerce with our colonies, fiction lags after truth; invention is unfruitful, and imagination cold and barren." What would he have said had he lived to see, as we have done, our exports reach the vast total of 250 millions a year, with nearly 90 millions of exports to our colonies? Canals certainly did not complete this

* Observations on a late publication 'The Present State of the Nation,' Bohn's series, vol. i. p. 198.

† Speech on conciliation with America, ibid., pp. 461–62.

revolution, but they had a very important share in giving it a start. Between the time when the canal system was commenced, about 1760, and the end of the first canal period, which may be put at 1838, the export trade of the country advanced from 14 millions to about 50 millions per annum. This is poor progress, compared with what has since been attained, through the development of the steamship, the railway, the telegraph, and other modern adjuncts of commerce, but it was deemed as remarkable for that day as we consider our subsequent progress to be in ours.

It is practically impossible to arrive at a correct estimation of the tonnage of goods of different kinds that goes to make up the inland and the external trade of this country. We know that the railways of the United Kingdom annually carry about 280 millions of tons of minerals and merchandise (according to the Board of Trade returns), but a considerable part of this tonnage is duplicated, in consequence of passing over more than one railway. Of the total tonnage carried by railway, the greater part probably goes no farther. It is consumed on the spot, like the coal traffic of London and the minerals supplied to our great ironmaking centres. But a very much larger quantity is carried from inland centres to seaports, and thence shipped for places of consumption at home and abroad. The coastwise carrying trade of the United Kingdom is now represented by 60 million tons a year. The foreign shipping trade amounts to over 70 million tons a year. Only a comparatively small proportion of these quantities is consumed at the ports of shipment. The greater part is carried farther by railway, thus breaking bulk twice—once in moving it from the ship to the railway wagon, and again in removing it from the railway wagon. Much of it has to be carried from the ship in barges, and thence transferred to the railway. All this means loss of time, loss of money, and deterioration of quality, which adequate water facilities should do much to obviate.

There is no class of property that has undergone a more remarkable range of vicissitudes than canal ownership. In the early years of the present century, the value of canal companies' shares was much higher than that of any railway property has been since that time. The price of some canal shares rose to a hundred times their nominal or par value. Enormous dividends were often paid. In other cases, where the navigation had been neglected, the properties were very lightly esteemed, and yielded unsatisfactory results. The Fossdyke

Navigation in Lincolnshire was leased about 1840, by the Corporation of Lincoln, to a Mr. Elison for nine hundred and ninety-nine years, at 75*l.* a year! Six years later the executors of the lessee leased it to the Great Northern Railway Company for 9575*l.** The Loughborough Canal shares, which were once worth 4500*l.*, are now scarcely worth 100*l.*; and a still more notable decline is that of the Erewash Canal, whose shares, now quoted at about 50*l.*, were once worth fully 3000*l.*

There are three great epochs in the modern history of canal navigation, each marked by characteristics peculiar to itself, and sufficiently unlike those of either of the others to enable it to be readily differentiated. They may be thus described :—

1. The era of waterways, designed at once to facilitate the transport of heavy traffic from inland centres to the seaboard, and to supersede the then existing systems of locomotion—the wagon and the pack-horse. This era commenced with the construction of the Bridgwater Canal between 1766 and 1770, and terminated with the installation of the railway system in 1830.

2. The era of interoceanic canals, which was inaugurated by the completion of the Suez Canal in 1869, and is still in progress.

3. The era of ship-canals intended to afford to cities and towns remote from the sea, all the advantages of a seaboard, and especially that of removing and despatching merchandise without the necessity of breaking bulk.

The second great stage in the development of canal transport is of comparatively recent origin. It may, in fact, be said to date only from the time when the construction of a canal across the Isthmus of Suez was proved to be not only practicable as an engineering project, but likewise highly successful as a commercial enterprise. Not that this was by any means the first canal of its kind. On the contrary, as we have shown elsewhere, the ancients had many schemes of a similar kind in view across the same isthmus. The canal of Languedoc, constructed in the reign of Louis XIV., was for that day as considerable an undertaking. It was designed for the purpose of affording a safe and speedy means of communication between the Mediterranean and the Atlantic Ocean; it has a total length of 148 miles, is in its highest part 600 ft. above the level of

* The navigation had, however, been deepened in the interval for drainage purposes, largely at the expense of the Land Drainage Commissioners, which caused a considerable increase of traffic.

the sea, and has in all 114 locks and sluices. In Russia, canals had been constructed in the time of Peter the Great, for the purpose of affording a means of communication between the different inland seas that are characteristic of that country. The junction of the North and Caspian Seas, of the Baltic and the Caspian, and the union of the Black and the Caspian Seas, had all been assisted by the construction of a series of canals which were perhaps without parallel for their completeness a century ago. In Prussia a vast system of inland navigation had been completed during the last century, whereby Hamburg was connected with Dantzic, and the products of the country could be exported either by the Black Sea or by the Baltic. In Scotland the Forth and Clyde Canal, and the Caledonian Canal, were notable examples of artificial navigation designed to connect two seas, or two firths that had all the characteristics of independent oceans; and the Erie Canal, in the United States, completed a chain of communication between inland seas of much the same order.

But, although a great deal had been done in the direction of facilitating navigation between different waters by getting rid of the "hyphen" by which they were separated anterior to the date of the Suez Canal, this grand enterprise undoubtedly marked a notable advance in the progress of the world from this point of view. The work was at once more original and more gigantic than any that had preceded it—so much so that in this country, as we have elsewhere shown, it was generally discredited. Probably no other canal previously constructed had cost anything like the same large sum that was set aside for that of Suez. The canal of Languedoc, constructed in the seventeenth century, is stated to have cost fourteen millions of livres. The Erie Canal had cost fivemillion seven hundred thousand dollars (1,140,000*l.*). The Caledonian Canal cost 1,035,460*l.* The Amsterdam Canal cost about the same amount. The Suez Canal, however, was estimated to cost 8,000,000*l.* to 10,000,000*l.*, or nearly ten times as much as the largest canals constructed up to that time. Nowadays this would not be regarded as a large sum for such a purpose. We have got accustomed to big figures. A hundred millions sterling is not an uncommon capital for a railway company. The Manchester Canal, only some thirty miles long, is estimated to cost about eight millions sterling, and more than sixty millions have been sunk at Panama. But so little faith was felt in the success of the Suez Canal, with such a large expenditure, that it was seriously maintained in the "Edinburgh Review" that, "were it to become the great highway of nations between the West and the East—even the Gates of the East, as it has been the fashion to call it—and were all the local advantages predicted for Egypt to be derived from it, still, on account of the enormous expense of construction and maintenance, it would not pay."

While these views were entertained about a waterway that promised to become the general and almost exclusive means of communication between the West and the East, between Great Britain and her Australasian and Indian possessions, it is not much a matter for surprise that other projects of a similar character remained in abeyance. But the Suez Canal once completed and successful, other ship canal schemes came "thick as autumnal leaves in Vallombrosa." Several of these were eminently practical, as well as practicable. The Hellenic Parliament determined on cutting through the tongue of land which is situated between the Gulfs of Athens and Lepantus, known as the Isthmus of Corinth. This isthmus divides the Adriatic and the Archipelago, and compels all vessels passing from the one sea to the other to round Cape Matapan, thus materially lengthening the voyages of vessels bound from the western parts of Europe to the Levant, Asia Minor and Smyrna. The canal is now an accomplished fact. Another proposal was that of cutting a canal from Bordeaux to Marseilles, across the South of France, a distance of some 120 miles, whereby these two great ports would be brought 1678 miles nearer to each other, and a further reduction, estimated at 800 miles, effected in the distance between England and India. The Panama Canal (projected in 1871, and actually commenced in 1880) is, however, the greatest enterprise of all, and in many respects the most gigantic and difficult undertaking of which there is any record. The proposed national canal from sea to sea, proposed by Mr. Samuel Lloyd and others for Great Britain, the proposed Sheffield Ship Canal, the proposed Irish Sea and Birkenhead Ship Canal, and the proposed ship canal to connect the Forth and the Clyde, are but a few of many notable examples of the restlessness of our times in this direction. All these canals are intended to economise time and space, which has become the greatest desideratum of our age. By fulfilling this mission they facilitate commerce, cheapen the cost of commodities, bring nations into closer touch, and materially lengthen the sum of work and knowledge that can be crowded into the average span of human life.

We are now in the very throes of the revolution that appears to be destined, before it closes, to secure for most of the great inland centres of population a large share of the advantages that result from being on the seaboard. The location of many of our large towns is difficult to understand. Their prosperity, in spite of their location, is still more unintelligible, on the first blush. Very few of our great cities are on the seaboard. London is over 60 miles from the Nore. Paris is 227½ miles from the sea at Havre, and Berlin, Vienna, and Madrid are each over or nearly 200 miles. In England we have such towns as Leeds, Sheffield, Bradford, and Birmingham, situated at long distances from shipping facilities, and flourishing in spite of that disadvantage. But the fact has been recognised as a disadvantage, none the less. Manchester, less unfavourably situated than some of the towns we have named, has resolved to "burst its birth's invidious bar" by the construction of the ship canal that is now being proceeded with. Sheffield has initiated a project with the same end in view. The people of Birmingham and the Midlands generally appear to have made up their minds to have direct communication with the Bristol Channel. In regard to all of these towns canal facilities of an inferior kind already exist. These, however, are now held to be quite unequal to the demands of modern commerce. They do not give to any town the position of a seaport, and that is the main requirement. The time has gone past when barges of forty or fifty tons, plying on a canal 60 to 80 feet wide, could be seriously put forward as contributing essentially to this end. The canal system of a hundred years ago has been put to the trial, and has been found wanting. We now carry millions where we then carried hundreds and thousands of tons.

The great commercial characteristics of our time are to have things done on a large scale, with the utmost practicable facility, and at the lowest possible cost. The existing canal system is quite out of touch with these desiderata. It "cumbereth the ground," and must be got rid of. But the waterways that still survive may in many cases be made the nucleus of a new and better system, under which the great inland towns of Lancashire, Staffordshire, and Yorkshire may find their lines cast in more satisfactory maritime places.

There are not a few people who regard the canal system almost as they might regard the Dodo and the Megatherium. It is to them an effete relic of a time when civilisation was as yet but imperfectly developed. It is placed on the shelf of their memories and sympathies much as the old handloom, or the earliest forms of metallurgical processes, might be ; and if by accident an old canal happens to cross their path, it is regarded with the same sort of curiosity as would be bestowed upon the Great Wall of China or the Pyramids of Egypt.

Canals do, indeed, belong to the past. In this respect they are entitled to be regarded with interest, and even with veneration. The Cnidians, according to Herodotus, the Boetians, according to Strabo, the Babylonians, according to Ptolemy, and the Romans, according to Pliny, were all skilled in the art of canal-making, and employed their skill to good purpose. From those times until these the waterways of art have supplemented those of nature as handmaidens of trade and commerce, as fertilisers of the soil, and as military and strategical highways. That canals also belong to the present, Egypt, the American isthmus, Manchester, Corinth, and other places, fully prove; and, unless we greatly err, they are no less the heritage of the future.

CHAPTER II.

ENGLISH RIVERS.

"Rivers, arise; whether thou be the son
Of utmost Tweed, or Ouse, or gulphy Don,
Or Trent, who, like some earth-born giant, spreads
His thirty arms along the indented meads;
Or sullen Mole, that runneth underneath;
Or Severn swift, guilty of maiden's death;
Or rocky Avon, or of sedgy Lee;
Or coaly Tine, or ancient hallowed Dee;
Or Humber loud, that keeps the Cythian's name;
Or Medway smooth, or royal-towered Thame."—*Milton.*

One of the earliest pioneers of inland navigation was Wm. Sandys, of Ombersley Court, in Worcestershire, who, in 1636, applied for Parliamentary powers to make the river Avon navigable for boats and barges, from the Severn at Tewkesbury to the city of Coventry. Part of the work which was executed in pursuance of the powers so obtained exists to the present time. In 1661 Sandys sought for Parliamentary authority to make the Salwarp navigable from the Severn to his own town of Droitwich, and to make navigable the rivers Wye and Lug, and the brooks running into the same in the counties of Hereford, Gloucester, and Monmouth.

Our great rivers, the Thames, Severn, Trent, Ouse, &c., were the recognised means of transit long before the time of the Romans, who were so far advanced in inland navigation as to cut canals of forty miles in length, as instanced in the Caerdyke, between Peterborough and Lincoln (though now filled up), as also to build docks. as shown in the old dock walls, &c., still standing at the outfall of the Trym into the Avon below Bristol.

The Fossdyke navigation from Lincoln to the Trent is also of Roman origin, and probably an extension of the Caerdyke, on their route to York. Torksey, at the junction with the Trent, was a Roman town and fort, and continued possessed of many privileges, down to the Norman period, on condition that the knights who held it should carry the King's Ambassadors, as often as they came that way, down the Trent in their own barges, and conduct them to York. This is recorded in 'Domesday Book.' Itchin Dyke to Winchester was also cut by the Romans.

It is usual to date the first beginning of canal navigation in England from the time when Brindley constructed the famous canal between Worsley and Salford for the Duke of Bridgwater. This, no doubt, was the first important artificial navigation throughout. But Sandys had practically undertaken canal construction about a hundred years before. The Act of Parliament which sanctioned the various enterprises that he had projected, authorised him to construct new channels, and to set up, in convenient places, "locks, wears, turnpikes, penns for water, cranes, and wharfs, to lay timber, coals, and all other materials that shall be brought down;" to have and use "a certain path, not exceeding four feet in breadth, on either side of the said rivers and passages," for the "towing, pulling, or drawing-up of their barges, boots, leighters, and other vessels passing and repassing them, or any part of them, by strength of men, horses, lines, ropes, winches, engines, or other means convenient;" and "to dig, carry, trench, or cut, or make any trench, river, or new channel, or wharf," &c., after having arranged with the "respective Lords, owners, or occupiers of the said lands." *

Sandys, however, did not succeed in carrying out the intended navigation between the cities of Hereford and Bristol as he proposed. He attempted to make the Wye navigable by locks and weirs on the pound-lock system, which did not suit its rapid current. The enterprise was accordingly abandoned, after a trial of several years.

In 1688 the project of making the Wye navigable was revived. It was now proposed to abandon the pound-lock system, to purchase and remove all the mill-weirs and fishing-weirs between Hay, in Herefordshire, and the sea, and to deepen the channels of the shallow streams. The weir-owners rose in opposition to these proposals, and for several years the subject was the occasion of a bitter controversy. When the Bill was applied for in 1695, the city of Hereford, and thirty-two parishes in the county, petitioned in its favour; while the towns of Ross and Monmouth, and thirteen parishes, petitioned against it. The Bill, however, ultimately became law,† and although, owing to the uncertainty of its depth and current, the Wye was never adapted for regular navigation, it was so far improved

* A.D. 1661, Anno. 14 Car. Reg. ii.

† 7 and 8 Gul. III.

that throughout the eighteenth century it was of great service to the county of Hereford.*

One of the earliest to advocate river improvements in Britain was Andrew Yarranton, an original genius, who had ideas and plans quite a hundred years in advance of his times.† He occupied himself with many different projects designed to effect improvements in means of communication, and in developing the resources of the country generally. At one time serving as a soldier, at another engaged in the manufacture of iron; now planning how to provide employment for the poor, and again studying how to bring about more economical processes of husbandry, Yarranton made a special hobby of the improvement of navigation, undertaking surveys of the principal rivers in the West of England at his own cost, and urging upon the people the importance of opening up the facilities of communication thereby available to them.

In 1665 Yarranton proposed to the burgesses of Droitwich to deepen the small river Salwarp, so as to connect that town, now an important centre of the salt industry, with the river Severn. He was offered terms to carry out his plans, but the offer does not appear to have been good enough.‡

In 1666 Yarranton proposed to make the river Stour navigable between Stourport and Kidderminster, and to connect it with the river Trent by a navigable canal. He carried out this work so far as to make the river navigable from Stourbridge to Kidderminster; but his scheme was not completely adopted for lack of means. He says that he "laid out near 1000*l*.," and "carried down many hundred tons of coal," § although, on account of the novelty of his enterprise, it was greatly ridiculed. At a later date Yarranton proposed to connect the Thames and the Severn by means of an artificial cut, "at

* Papers relating to the History and Navigation of the Rivers Wye and Lug. By John Lloyd, junr.

† Andrew Yarranton was born in the parish of Astley, Worcestershire, in the year 1616. He wrote a work which is well known to economists, entitled 'England's Improvement by Land and Sea, or How to beat the Dutch without Fighting,' describing observations that he had made during his travels in Holland, Saxony, and other countries.

‡ Smiles states that Yarranton was offered 250*l*. and eight salt vats at Upwich, valued at 80*l*. per annum, with three quarters of a vat in Northwich for 21 years, in payment for the work. It is interesting to compare these terms with those on which some of our modern streams have been deepened and improved.

§ Yarranton's 'Improvement by Land and Sea.'

the very place where, more than a century after his death, it was actually carried out by modern engineers." *

Although the proprietors in what was called the "Old Quay Company" had obtained an Act of Parliament in 1733 for improving by weirs and cuts the rivers Mersey and Irwell, between Runcorn and Manchester, the first association incorporated for making a regular navigable canal in England was not till more than twenty years later, six centuries after the first canals in Italy and Flanders, and a hundred years subsequent to some of the chief canals of France being in operation. It is but fair to add that England carried the movement further than most other countries.

It is unnecessary to enter into the history of the development of the navigable resources of the rivers of the United Kingdom during the last two centuries, even if it were possible, which, of course, it is not in a work of this description. The dates when the several principal navigation works were undertaken will be found set out in Appendix I. But we may, nevertheless, bestow some consideration upon the principal steps that have brought about the remarkable facilities that England, Scotland, and, to a less extent, Ireland, respectively enjoy at the present time in the matter of internal transport. The Clyde, the Tyne, the Tees, the Wear, and other prominent English rivers have been transformed from shallow brawling streams, some of them easily fordable at all states of the tide, into magnificent waterways, capable of bearing on their bosoms the largest vessels afloat. This work has necessarily involved great engineering capacity, a large expenditure, and a judicious administration of their powers and resources by the public bodies through whom it has been carried to completion.

The Mersey.

On the Liverpool side of the Mersey there are sixty docks and basins of the ordinary type, having a total water area of 368 acres and 25 miles of quay berthing. On the Birkenhead side, there are 164½ acres of docks, with 9½ miles of quayage, three graving docks, having a total length of 2430 feet, and every facility for loading and unloading ships.

The total expenditure incurred on this enormous provision for

* 'Industrial Biography,' by S. Smiles, p. 65.

shipping has been upwards of twenty millions, and the total annual revenue of the Mersey dock estate is about a million and a half sterling.

The entire length of the Mersey is 56 miles. For the first 37 miles of this distance, the river has a tortuous course, ill-adapted for navigation, and passes through an almost exclusively agricultural country. From Runcorn to the sea, the form of the river is that of a bottle, of which the wide expanse between Runcorn and Liverpool forms the body, and the narrow part opposite Liverpool the neck. Through this neck there annually passes nearly twenty million tons of shipping, including entrances and clearances.

The unassisted efforts of nature have hitherto maintained the navigable channels of the Mersey, so that the conditions of navigation remain practically uniform. The bar, however, is gradually moving in a seaward direction, while maintaining its general form and characteristics. In Liverpool Bay there is a great range of tide, which insures a depth of at least 30 feet over the bar once in every twelve hours, even on the lowest neaps. Some two or three million cubic yards of upland water every twelve hours are discharged into the estuary, chiefly by the Mersey and the Weaver, which, with 710 million cubic yards on a high spring tide, maintains the normal capacity of the estuary, and counteracts the process of silting. Some 17,300 acres of a deposit of sand in the estuary are above the low-water mark. Through this the upland water forms and maintains a channel in its course to the sea, and any serious exclusion of this tidal water would be likely to so far injure the sea channels as to interfere with the trade and shipping of the port.

The Mersey is the outlet for several important canal navigations, including the Weaver Navigation Canal, near Weston Point, the Bridgwater Canal at Runcorn, the Sankey Canal at Widnes, the Shropshire Union Canal at Ellesmere, the Leeds and Liverpool Canal at the Docks, and the Manchester Ship Canal, now under construction, at Eastham. The position of these several canals in relation to the river may be traced in a map accompanying a paper read by Mr. Lyster, the engineer, before the Institution of Naval Architects. These canals are important factors in assisting the growth of the trade of the Mersey. The Leeds and Liverpool is, however, the only canal that has a direct connection with the Liverpool Docks.

By this canal Liverpool has water communication with the important town of Leeds, and thence, by the Aire and Calder Canal, with Hull and the other ports on the Humber. By the Shropshire

Union Canals the Mersey is connected with the network of canals in the Midland Counties and with the River Severn.

In Camden's time Liverpool must have been a very obscure place. The author of 'Britannia' dismisses it almost in a sentence, observing that "from Warrington, the River Mersey, spreading abroad, and straightwaies drawing in himselfe again, with a wide and open outlet, very commodious for merchandise, entereth into the Irish Sea, where Litherpoole, called in the elder ages Lipen-poole, common Lirpoole, is seated, so named, as it is thought, of the water spreading itself in manner of a poole."

With the exception of the Thames—which it rivals, and with which for a number of years past it has run a neck-to-neck race—the Mersey is, so far as its volume of business is concerned, the most important river in the world. This, however, is an attainment of comparative modern origin. The first wet dock was constructed at Liverpool, in 1708–9, on the site now occupied by the Custom House. In the latter part of the same century several other docks were constructed. The dock estate has now an area of 1078 acres, the whole of which is appropriated to basins, docks, quays, and premises worked in connection therewith.

The Weaver.

The history of the navigation of the river Weaver, which adjoins the Mersey in Cheshire, supplies a notable example of what may be made of an originally insignificant and tortuous stream in order to adapt it for the requirements of commerce. The river has been canalised between Northwich and Chester, twenty miles of the navigation being artificial navigation, and the other thirty miles being river proper.

In 1721 three Cheshire gentlemen obtained the first Act of Parliament for making the river Weaver navigable. The depth then provided for was only 4 feet 6 inches, and boats of more than 40 to 50 tons could not enter.

About the year 1760, the navigation was carried down so as to enable vessels to enter at nearly all tides, and in 1810 the river was further improved by the Weston Canal, which is four miles long, enabling vessels of much deeper draught to enter without navigating a dangerous part of the old river. This canal forms a junction with the Bridgwater Docks at Weston Point, and a dock was formed in connection with it so as to enable vessels to wait for the tide.

In 1830 the depth was increased to 7 feet 6 inches, with locks 88 feet long and 18 feet wide, capable of taking cargoes of 100 to 150 tons. There were at this time eleven single locks on the river, not including the entrances to the Mersey. About 1860, a second set of locks, having 10 feet of water on the sills, and 100 feet long by 22 feet wide, was placed by the side of the existing locks, and the number was reduced to nine pairs. The larger size, owing to the vessels being built almost to the shape of the lock, were capable of passing vessels with nearly 320 tons on board.

This continued until about seventeen years ago, when it was decided to replace these locks by some of very much larger dimensions, and also to greatly reduce the number. With this object, locks were built at Dutton and Saltersford near the site of existing locks, and of sufficient height of walls to enable the two ponds above to be thrown into one, thus doing away with the four smaller locks. The same has been done at Hunts, and, more recently, at Valeroyal, above Northwich. The locks at Dutton and Saltersford are entirely built of masonry, having limestone sills and rubbling courses, with the intermediate part sandstone. All the work on the river is of this description, with the exception of the Hunts and Valeroyal large locks, which are built of concrete.

When these improvements are completed there will be only four locks on the twenty miles of navigation, the larger of each pair of locks being 220 feet long, by 42 feet 6 inches wide, and having 15 feet of water on the sills. Most of the river is now dredged to 12 feet, there only being 10-feet bars at certain points. The ordinary width is about 95 to 100 feet at water level, and 45 feet at the bottom. More than a million tons of salt annually pass down the Weaver to the Mersey.

The Tyne.

This noble river, from Newcastle to the sea, is one of the greatest triumphs of modern engineering. Good old Camden quaintly remarks, that "where the wall (Roman) and the Tine almost met together Newcastle sheweth itself gloriously, the very eye of all the townes in these parts, ennobled by a notable haven, which Tine maketh, being of that depth that it beareth very tall ships, and also defendeth them, that they can neither easily be tossed with tempests nor driven upon shallows and shelves." *

* 'Britannia,' Holland's Translation, 1637.

No better example of what has been done within recent years in the way of providing additional facilities for the wants of British shipping, could be quoted than the case of the Tyne. That river is the natural outlet of the great northern coalfield. It is also the outlet for a very great trade in chemicals, engineering, iron and steel, and other industrial products. But in order to adapt it for the purposes of its large and rapidly-growing commerce, it was necessary not only to provide several docks—the more important of which, the Northumberland and the Coble Dene, cost 352,000*l.* and 528,000*l.* respectively—but it was also requisite to expend over 1,300,000*l.* in dredging the bed of the river, so as to provide access for the largest size of vessels, to expend nearly three-quarters of a million on other river works, to construct North and South Piers at a cost of over 820,000*l.*; and to incur a total outlay considerably exceeding 4,000,000*l.* The effect of these improvements and structural works has been that the Tyne has been transformed from "a series of shoals, with a narrow and generally serpentine channel between and past them, through which vessels of about 15-ft. draught could get up at high-water spring tides, whilst at low-water it was a not uncommon occurrence for small river steamers, drawing from 3 to 4 ft. of water, to be aground on their passage between Shields and Newcastle for three or four hours," to a magnificent navigable highway, that admits vessels of 3000 tons and upwards at all states of the tide with perfect safety. At the time that the great work was commenced, and for many years afterwards, the revenue from shipping dues was quite insufficient to enable any substantial progress to be made, and the trade grew so rapidly that it became imperative to either borrow money in order to carry out the required works, or allow the shipping to seek other ports, where better facilities were provided. The works to the end of 1882 had, therefore, to be chiefly carried out by the aid of borrowed money. As a matter of fact, only 426,000*l.* was expended out of income, while 3,673,000*l.* was borrowed. The results, however, appear to have justified the course. The annual income from dues and tolls has grown, within twenty years, from 91,000*l.* to over 251,000*l.*

The Tyne Improvement Commission, chiefly under the presidency of Sir Joseph Cowen, have deepened the river to a uniform depth of nearly 30 feet, built training walls, dredged the bar, built new channels, and otherwise revolutionised the old order of things. The results have been extremely striking. In 1888 14,668 vessels, having a total tonnage of 6,734,000 tons, cleared from the Tyne ports; while 6093 ships, having 1,662,000 tons register, entered the same ports. The people of Tyneside are proud of their river, as well they may be.

The Ribble.

Preston is a busy town and port in the county of Lancashire, situated on the river Ribble, about seventeen miles from the sea. The navigation of the port has hitherto been confined to coasting vessels drawing about 14 feet of water. The amount of shipping entering the port has been under 30,000 tons a year. The Ribble rises in the West Riding of Yorkshire, at the east foot of Whernside, and arrives at Preston after a course of fifty-seven miles With its tributaries it drains about 800 square miles of land, a great part of which is moorland. The annual rainfall over this district averages about 37 inches. Below Preston, the channel of the river opens out into a broad sandy estuary, four or five miles in width, the whole of which is covered at high water of spring-tides, and the greater part of which is dry at low water. The course of the river, after it leaves the trained portion, is along the northern shore of this estuary to Lytham, whence the main navigable channel, called "The Gut," bends in a south-westerly direction between the Salt-house and the Horse-shoe banks to the Irish Sea. The width of the estuary between the two forelands on the coast, Stanner Point on the north, and Southport on the south, is five miles. The sands extend four miles seaward beyond this line, and are uncovered at low water. The depth at low water spring tides on the bar, or the portion of the navigable channel with deep water, is four feet. Beyond this the depth seawards rapidly increases, from 20 feet immediately beyond, till, at the Nelson buoy—which is two miles beyond the bar, and the first buoy belonging to the Ribble navigation—the depth is six fathoms. The depth above the bar along the Gut channel, which is rather tortuous and narrow, being shown on the Admiralty chart as less than a quarter of a mile wide, varies from 4 to 24 feet. This channel is buoyed out with eight buoys, which are shifted as the channel varies. There are three other channels between Lytham and the sea, called, respectively, the South Channel, the Penfold, and the North Channel. These are more or less navigable; but the Gut is the main sea-fairway. From Lytham a shallow channel runs near the shore for about a mile to "The Dock," where ships can lie at anchor. Thence it winds towards the Wage through the sands. This channel is continually shifting its course, owing to gales and freshets. From this point the river has been trained by rubble-stone training walls, put in about thirty-four years ago, which continue for seven miles up to Preston. These walls rise seven feet above low water, and are 300 feet apart at the top. Spring-tides rise 24 feet at the bar, and neaps 17 feet, and at Preston the rise is 10 feet and 4 feet 6 inches. The project of constructing a dock at Preston has been agitated for some years, and has been strongly advocated by Mr. Garlick, M.I.C.E., who was the engineer to the Navigation Commissioners. It was considered that by providing deep-water accommodation to the town, its trade and prospects would be greatly increased, having regard to the large manufactories by which it is surrounded, the immense population in the immediate neighbourhood, and the nearness of the Wigan coalfield. This work is now in progress, including the division of the river; the estimated cost being about 440,000*l.*

The Severn.

This famous river is navigable up to Welshpool, a distance of 155 miles by water, from the mouth of the Bath Avon river. The extreme branch of this river may be traced for about 45 miles above Welshpool, to Plinlimmon Hill, and numerous other branches extend for great distances into the country on both sides. The whole of this great length of navigation was, till lately, unimproved by art, the river having no locks, weirs, or other erections throughout its whole length, for surmounting the numerous shallows and irregularities which the current over variable strata had formed in its bed. The first or lowest 42 miles of this river, extending to the city of Gloucester, are very wide for a great part of the way, and have a most rapid tide; but the last 28 miles are so crooked, that ships are said to be often several days in passing it; on which account, a ship canal, calculated for vessels of 300 tons burthen, was in the year 1793 projected and begun between Gloucester and Berkeley, of 18¼ miles in length, for avoiding these 28 miles of the river. From Gloucester to Worcester the distance is 30 miles by the course of the stream, the rise in this length being 10 feet, or at the rate of 4 inches a mile; from Worcester to Stourport the distance by water is 13 miles, and the rise 23 feet, or at the rate of 1 foot 9 inches per mile; from Stourport to Bridgnorth it is 18 miles, and the rise $41\frac{3}{4}$ feet, or 2 feet 4 inches per mile on the average; and from Bridgnorth to the new town at the junction of the Shropshire canal, called Coalport, the distance is about 7 miles, and the rise about 19 feet, being a rate of about 2 feet 8 inches per mile. William Reynolds, the founder of Coalport, caused an account to be daily registered of the depth of the stream in the bed of the Severn at that place, between the 7th of October, 1789, and the 23rd of December, 1800, of which Mr. Telford has given the particulars, except on twelve occasions when the river had overflown its bounds and covered the usual marks (on Sundays during some part of the time), the intervals of frost in which the river was frozen over, and for three short intervals, when, unfortunately, the experiment was by some accident suspended. During all the months of January, in the above period of eleven years, ending the 6th of October, 1800, the river does not appear to have exceeded the depth of 16 feet, that being the greatest depth at any time recorded; and several times, when no depths are inserted to the great floods, it is stated in the table that the water was above all the marks. Besides these, there were thirty-two smaller floods, or times when the water had risen, and was falling again for some days after; the highest of these had a depth of 13 feet (5th January, 1790), the lowest 4 feet, and the mean of the whole of these floods is $7\frac{1}{2}$ feet. In the months of February there were two of these overflowings, one of which (11th February, 1795) followed a frost and continued for five successive days: nineteen floods, the two highest of which were equal (17th and 20th February, 1799) to 12 feet.

The Witham.

On the Witham, for a distance of thirty miles, between Boston and Lincoln, the river is practically a canal. The tide is stopped by a sluice at Boston, and a weir and locks had to be constructed at Bardney and Lincoln. The inland water is held up to a constant height on the sill of this sluice by penstocks, for the purposes of the navigation. The navigation having been taken over by the Great Northern Railway Company, the works are maintained in efficient condition; but the obligation imposed by the original Act of holding up the water seriously affects the drainage. The river Slea, from Sleaford to the Witham, was made into a canal in 1792. The navigation on this river having almost entirely ceased, the company was dissolved by an Act of Parliament. The Bane, another affluent of the Witham, was also canalised, forming a navigation from the Witham to the town of Horncastle; but the dues obtained are insufficient to maintain the works in proper order.

The Nene and Ouse.

On the Nene, which is canalised from Peterborough to Northampton, the navigation is reduced to a few barges. The constant floods on this river are ascribed in a great measure to the defective condition of the works. The proprietors of the navigation, on whom was cast the duty of maintaining the river, no longer have the funds, and there is nobody to take their place. The same thing has occurred on the Ouse between Earith and Bedford.

On some of the affluents of these rivers, which, under legislative powers granted last century, had been converted into "navigations," the proprietors have obtained Acts of Parliament relieving them of their rights and liabilities, and there is now no jurisdiction over these rivers, or anybody responsible for removing shoals or cutting weeds. The beds of these streams have consequently become shallow, and they are no longer capable of acting as efficient arterial drains. Thus, on the Ivel, an affluent of the Ouse, the navigation trust, created in the reign of George II., was abolished in 1876. The river is said to have since diminished one-half in width, and one-half in depth, and the bottom is being gradually raised to the level of the land. In like manner, the Lark, another canalised affluent, has almost entirely silted up since the navigation of the river ceased. The Ouse itself, above Earith, is obstructed by numerous shoals, and an enormous growth of weeds. These were originally kept down by the constant passage of the vessels, and the shoals were removed by the trustees of the navigation.

The Tees.

The improvements that have been carried out for the purpose of opening up the navigation of the river Tees, although less considerable than those carried out for some of the larger rivers of Great Britain, are yet entitled to take rank as among the most notable river engineering achievements of the century. They are also among the most recent. It was not until 1852 that the Act was passed creating the Tees Navigation Commission. At that time there were three or four channels in the estuary, all of them very shallow. The shifting sandbanks caused great trouble and not a little danger to navigation, and the depth of water near to

Middlesbro' did not admit of the passage of vessels of large size. Since then, about twenty miles of low water training walls have been erected for the purpose of confining the navigable channel. The volume of water and its scour have thereby been much increased. The river has been continuously dredged in order to secure a depth of water that would allow of the passage of vessels of large tonnage into the Middlesbro' Docks. About 23 million tons of material have been dredged from the bed of the river, and the channel has been generally straightened and widened. Breakwaters have been constructed on both sides, one of them, called the North Gare, being about two miles and a half long. A remarkable feature of the work is that these breakwaters have been constructed of slag, obtained from the blast-furnaces in the neighbourhood. Some millions of tons of slag have been employed in this way, the ironmasters having paid to the Conservancy Commissioners a small sum for removing the slag, the disposal of which had been a great source of difficulty previous to this application.

As a result of the works that have been carried out for the improvement of the navigation of the Tees, the shipping trade of the river, and especially of the port of Middlesbro', has greatly increased. The main element in this development has been the growth of the iron industry; but the second element has undoubtedly been the increased facilities for navigation. The popular impression about Middlesboro' is that only a single house stood in 1830, where there is now a busy town of more than 70,000 inhabitants. This may or may not be a legend, but there is no doubt about the fact that in 1850 there were only from two to three feet of depth on the bar of the Tees, where it was possible to wade across at low water; whereas now there is about 20 feet of water, and a harbour of refuge has been provided in which ships can ride in safety whatever the condition of the usually stormy seas outside.

The Irwell.

This river has been partly canalised, in order to afford a means of communication between Warrington, Manchester, and other large towns, and Liverpool, but it was only adapted for light craft and has consequently fallen largely into disuse. The Mersey and Irwell Navigation was acquired by the Bridgwater Company, and has now, with the rest of the Bridgwater property, passed under the control of the Manchester Ship Canal Company.

The Wear.

This river, which has its rise in the district that unites Durham and Westmoreland, falls into the North Sea at Sunderland after a course of thirty miles. The river is under the jurisdiction of the Wear Commissioners from about nine miles from the bar to the sea. Over this distance very considerable improvements have been carried out during the last half century. These improvements have resulted in making the Wear one of the foremost shipbuilding rivers in the United Kingdom, and have given it the second place in the coal-shipping trade. The revenue of the Wear Trust, which only averaged about 14,000*l.* a year between 1840 and 1850, has within recent years amounted to about 130,000*l.* a year. One of the most extensive works undertaken on the river, besides graving docks, wharves, &c., and the deepening of the bed, was the construction of a lock at the sea outlet, designed to obviate the detention of screw-colliers when waiting for the tide. This lock is 481 feet in length by 90 feet in breadth, and has a depth of 29½ feet at ordinary spring tides. The present docks can accommodate 200 ships of large size, drawing up to 24 feet of water. The area of the docks is over 78 acres, and they are fitted with nineteen coal spouts, at which 15,000 tons of coal can be shipped daily.

In this chapter we have dealt with a few only of the more notable examples of river improvement in modern times. The list might be almost indefinitely extended. There is hardly a brawling mountain torrent between Land's End and John o' Groat's that has not been reclaimed, deepened, widened, or otherwise improved upon by the art and the genius of the engineer. Nor has the work been confined to modern times. The Romans are known to have constructed embankments for the control of British rivers during the period of their occupation, although for something like 1000 years afterwards their example was not followed. The engineers and the local authorities of the nineteenth century have done much to redeem this reproach. The improvement and conservancy of rivers have now been reduced to a science, founded mainly upon the following general principles * :—

1. That the freer the admission of the tidal water, the better is the river adapted for all purposes, whether of navigation, drainage, or fisheries.

* Address of the President of Section G, British Association Meeting at Dublin, 1878.

2. That its sectional area and inclination should be made to suit the required carrying power of the river throughout its entire length, both for the ordinary flow of the water and for floods.

3. That the downward flow of the upland water should be equalised as much as possible throughout the entire year; and

4. That all abnormal contaminations should be removed from the streams.

Our tidal rivers are undoubtedly one of the chief sources of our maritime supremacy. For this reason it is of the utmost importance that they should be kept in good repair, free from unnecessary obstructions, and well adapted to the purposes of navigation. As it is, however, this is not always the case. The chief reason for existing maladministration, where it exists, is the absence of a uniform system of control. The Thames, for example, has been hitherto controlled partly by the Thames Conservancy and partly by the Metropolitan Board of Works. The Great Sluice, at Boston, in Lincolnshire, was constructed in 1764 by Smeaton, for the purpose of stopping the flow of the tide in the river Witham, and converting the upper part of the river into a fresh-water canal as far as Lincoln. As, however, the control of the river is divided—one body dealing with the tidal part from the Grand Sluice to the sea, and the other with the canal and drainage of the land above—each opposes the schemes of the other, and the navigation has been ruined.*

There is one course whereby this condition of things, where it exists, may be prevented. It has been suggested that a new Government Department should be created, with entire charge of and control over all estuaries and navigable channels, and presided over by a member of the Cabinet. The interests at stake are sufficiently large to justify this.† They are as vital to our commerce and

* Paper on "River Control and Management," by J. C. Hawkshaw, 'British Association Report for 1878.'

† The following figures give the tonnage of the entrances and clearances in the foreign trade (including British possessions) of the principal rivers in 1888:—

River.	Entrances.	Clearances.	Total.
	tons	tons	tons
The Thames	7,471,000	5,471,000	12,942,000
,, Mersey	5,368,000	4,941,000	10,309,000
,, Clyde (Glasgow only)	994,000	1,154,000	2,148,000
,, Tyne	2,818,000	4,392,000	7,210,000
,, Tees (Middlesbro' only)	681,000	555,000	1,236,000
,, Humber	1,897,000	1,503,000	3,400,000

industry as any matter now dealt with by the State, affecting our material well-being, and they are every year increasing in extent and importance. As regards the principal rivers—the Mersey, the Tyne, the Tees, the Clyde, and the Wear especially—they are now controlled in accordance with the recommendation made by the Duke of Richmond's Select Committee, that "each catchment area should be placed under a single body of conservators, who should be responsible for maintaining the river, from its source to its outfall, in an efficient state." There are other rivers, however, that are administered rather in the interest of the landed proprietors than in that of navigation, and where these two come into conflict the State should have powers that would enable the public interest, which is both national and international, to be effectually protected.

The following table gives the area and length of some of the chief rivers of England :—

North-East of England.

	Area. Miles.	Length. Miles.
Coquet	240	40
Wansbeck	126	22
Blyth	131	16
Tyne	1,130	34
Wear	456	45
Tees	708	79
Esk	147	21
Humber	10,500	..
Hull	364	20
Foulness	133	14
Derwent	794	64
Ouse	1,842	40
Aire and Calder	815	78
Don	682	57
Trent	4,052	147
Ancholme	244	25
Ludd	139	7
Withern Eau	189	13

East Anglian Rivers.

	Area. Miles.	Length. Miles.
Bure	348	45
Yare	880	48
Blyth	79	17
Alde	109	24

	Area. Miles.	Length. Miles.
Deben	153	27
Orwell	171	16
Stour	407	45
Colne	192	24
Crouch	181	15
Roding	317	33

OTHER RIVERS.

	Area. Miles.	Length. Miles.
Witham	1,079	40
Welland	760	42
Nene	1,077	100
Great Ouse	2,667	143
Wissey, or Stoke	243	28
Nar, or Setchy	131	25

Many of the above rivers are not navigable for vessels of any size, and are therefore not of much value to the transportation resources of the country. In the majority of cases, also, the character of the waterways, as regards locality, water-supply, &c., would not justify any large expenditure in adapting them for purposes of transport.

CHAPTER III.

THE ENGLISH CANAL SYSTEM.

"Of famous cities we the founders know,
But rivers, old as seas to which they go,
Are nature's bounty; 'tis of more renown,
To make a river than to build a town."—*Waller.*

THE general circumstances under which artificial navigation came to be adopted in our own and other countries have already been set forth to a limited extent. We have now to consider the special circumstances that have led to the adoption of particular routes and particular means of transport, as well as to make some attempt to indicate the conditions under which canals may be used with advantage.

The routes that are provided by canal navigations are usually either local or national—local, when they only connect two inland centres; national, when they afford access from manufacturing or agricultural centres to the sea. In the earlier history of the canal system both of these ends were kept in view. It was just as important to bring raw materials from their place of production to the centres of consumption as to connect the centres of manufacture with the outer world.

About the middle of the last century, the cost of goods by road, between Manchester and Liverpool, was 40*s.* per ton; whilst, by the Mersey and Irwell route, the water rate was 12*s.* per ton. After the opening of the Bridgwater Canal the cost was reduced to 6*s.* per ton, and a better service was given than either of the previous routes had afforded.

Again, the cost of carriage on coal by pack-horse from Worsley to Manchester, which had been 6*s.* to 8*s.* per ton, was reduced to 2*s.* 6*d.* per ton on the same canal. In fact, the Duke bound himself not to exceed that freight, although the old Mersey and Irwell Company still held to their toll of 3*s.* 4*d.* for all the coal the Duke sent by their route.

The costs of transports throughout the country were on a similar scale, except where held in check by the river traders, who, whilst competing, had still an interest in high freights. From Manchester to Nottingham the charge was over 6*l.* per ton; to Leicester, over 8*l.*, and so on. These rates were reduced to 2*l.* and 2*l.* 6*s.* 8*d.*, respectively, after the opening of the Trent and Mersey Canal, which also reduced the cost of transport between Manchester and Hull to less than 2*l.* per ton, owing to the back-carriage secured from that port, together with the tide service of 80 miles up the Humber and the Trent.

The real commercial prosperity of England dates from this period of canal development and enterprise. Raw materials, manufactures, and produce, were easily transported at a reasonable cost between Liverpool, Manchester, Staffordshire, Nottingham, and places on the route to Hull and Northern Europe. These advantages were extended to the Severn route by the Staffordshire and Worcestershire Canal Act, which was obtained during the year 1766, and by the navigation of the Soar to Leicester.*

In 1761 it was estimated that the quantity of traffic carried between the two great cities of Lancashire—Manchester and Liverpool—was about 40 tons per week, or about 2000 tons a year. The cost of transport, as we have just seen, was upwards of 1*s.* per mile. It is calculated that the traffic now carried on between the two towns is not less than ten million tons, and the cost of transport is stated at from 3*s.* to 8*s.* per ton. But the present conditions of transport are nevertheless regarded as unsatisfactory, and hence the movement for the construction of the Ship Canal, which is expected to carry traffic for less than one-half of the amount charged by the railway companies.

When the public mind became fully alive to the importance of providing internal means of transport by water, there were not wanting those who were able to provide the ability and the experience necessary to execute the plans proposed. The history of the Bridgwater Navigation has been so fully related by Smiles,† that nothing which we could say here would materially enhance the interest of the story. For all practical purposes, this was the first great artificial waterway in England. It was, indeed, so remarkable a work for the time that we shall briefly recapitulate its history.

In 1758 the Duke of Bridgwater got his first Act of Parliament, which awakened a general ardour for similar improvements among the landowners, farmers, merchants, and manufacturers of the kingdom,

* 'Journal of the Society of Arts,' 1888.

† 'Lives of the Engineers.'

and although there was not a Louis XIV. nor a Colbert to encourage them, engineers were found fully equal to Riquet, so that England, though late, began to make good use of the resources she possessed in her inland provinces.

The history of the Bridgwater canal may fairly be said to occupy, in relation to the annals of internal navigation, much the same place that the Liverpool and Manchester Railway does in relation to the development of the railway system. It is necessary to review some of the circumstances connected with this enterprise in order that the actual position of transport at that time may be understood.

Although an Act of Parliament had been obtained many years previously for the purpose of making the Mersey and the Irwell navigable from Liverpool to Manchester, the facilities thereby provided were defective and unsatisfactory in the extreme. The freight charged for water transport between the two towns was 12*s.* per ton, when the navigation was available, but this was not always at command. Boats could not pass between the lowest lock and Liverpool without the assistance of a spring tide. There were many fords or shallows in the Irwell, over which boats could not pass at all "except in great freshes, or by drawing extraordinary quantities of water from the locks above." The consequence was that most of the traffic between the two towns was carried on by road, at a much higher cost for rather over thirty miles. The new navigation, although it promised to reduce this charge to 6*s.* per ton, to abridge the distance by nine miles, to provide wharfage that was not already available, and to give transportation facilities at all times, was strongly denounced and opposed. It was argued that the canal would cut through and separate the land in the possession of several gentlemen along the proposed line of route, that a great number of acres would be covered with water and for ever lost to the public, that the canal could confer no advantage not already secured by the Irwell and the Mersey, that the taking from those streams of the water required for the canal would greatly prejudice, if it did not totally obstruct, the old navigation in dry seasons, and that the property of the old navigation should not be prejudiced without full compensation being made to the proprietors.*

* An excellent summary of these and other matteıs connected with the early history of this enterprise is given in a little work published in 1766, entitled 'The History of Inland Navigation."

A letter written in 1767,* at Burslem, states that "gentlemen come to see our eighth wonder of the world—the subterraneous navigation, which is cutting by the great Mr. Brindley, who handles rocks as easily as you would plum-pies, and makes the four elements subservient to his will. He is as plain a looking man as one of the boors of the Peake, or one of his own carters, but when he speaks all ears listen, and every mind is filled with wonder at the things he pronounces to be practicable. He has cut a mile through bogs, which he binds up, embanking them with stones which he gets out of other parts of the navigation, besides about a quarter of a mile into the hill Yelden; on the side of which he has a pump, which is worked by water, and a stove, the fire of which sucks through a pipe the damps that would annoy the men who are cutting towards the centre of the hill."

The Bridgwater Canal has had a very remarkable career. It was sold by Lord Ellesmere to the Bridgwater Navigation Company for 989,612*l.*, including plant valued at 150,000*l.* In 1886, the Bridgwater Navigation Company sold the canal to the Manchester Ship Canal Company for 1,710,000*l.* The Bridgwater Canal was followed, after a few years, by a number of similar undertakings.

We cannot pretend in this chapter to write the history of the canal movement; but we may, nevertheless, rapidly pass in review some of the prominent features of that movement, the better to illustrate the development of canal navigation, and to show how it came to be such as it is.

About the year 1769 we find that the counties of Lancashire, Staffordshire, Cheshire, Leicestershire, and Warwickshire, were greatly exercised concerning the proposal to cut a canal between the Mersey and the Humber by way of Harecastle, Stoke, Burton, and Wilden, near which latter place it was intended to effect a junction with the Trent. Branches were proposed to Birmingham, Lichfield, Tamworth, and Newcastle-under-Lyme. The canal, it was expected, would develop the trade in white flint ware, "which is as strong and sweet as Indian porcelain;" in the noted quarries of Swithland slate, in Leicestershire, "a beautiful and durable covering for houses;" in limestone, "on which the village of Breden, in Leicestershire, is situated;" and "in that sort of iron-ore, commonly called ironstone, proper for making cold-short iron, and which, when mixed with the red ore from Cumberland, makes the best kind of tough or merchant

* 'History of Inland Navigations.'

iron."* It is somewhat curious, at this time of day, to find that the facilities which it would offer for the exportation of corn were put forward as one of the principal arguments in favour of the new navigation.†

The Hull and Liverpool Canal.

In the year 1755, the Liverpool Corporation authorised a survey to be made with a view to the construction of a line of navigation between Liverpool and Hull. Brindley made a survey of the same route three years later, and he, in turn, was followed by Smeaton. Brindley's plans were ultimately adopted. He proposed to complete the canal "as far north as Harecastle, purchase the land, erect locks, make towing paths, build bridges, and defray every expense, except that of obtaining the Act of Parliament, for 700*l.* per mile," but beyond Harecastle it was estimated that the works would cost 1000*l.* a mile.‡ Brindley proposed to make the canal 12 feet wide at the bottom, and three feet deep on an average, with a depth of 30 inches at the fords. The boats designed to be worked on the canal were 70 feet long, 6 feet wide, drawing 30 inches of water, and carrying 20 tons. Their cost was stated at 30*l.* each.§

It is interesting to record that when the proposal to construct a canal from Liverpool to Hull was under consideration, about the middle of the last century, one of the arguments used in its favour was that it would enable American iron to be brought cheaper to the manufacturing towns from the ports of Liverpool and Hull, and so contribute to lessen the consumption of foreign European iron, "to the great profit of this nation in general, and our own ironworks in particular"; while it was even suggested that, in order to develop this branch of business between our then American colonies and the mother country, a bounty should be offered on the import of American pig-iron, thereby contributing to "clear the lands in America," and "to preserve the woods in England."

* This refers to the South Staffordshire mine, which is hardly worked now. The iron trade of that period was chiefly carried on in Staffordshire, and nothing except a little charcoal iron was made in the Cumberland district, where the annual production, including Furness, is now over a million and a half tons per annum.

† It was thought a great thing that over five million quarters of corn were exported from Great Britain in the five years ending 1750.

‡ 'The History of Inland Navigations,' &c., London, 1769.

§ Ibid., p. 58.

The project to construct a new waterway through the manufacturing districts between Liverpool and Hull was strenuously opposed by a number of Cheshire gentlemen, who were the owners of the Weaver or Northwich Navigation, and who proposed to carry that waterway to Macclesfield, Stockport, and Manchester. In 1765, a plan was submitted for extending the navigation of the Weaver from Winsford Bridge, in Cheshire, to the river Trent, in the county of Stafford, there joining the Trent and the Severn by canals, and thereby "opening an inland communication between the great ports of Liverpool, Bristol, and Hull."

In view of the attention that has recently been given to the salt industry, it may be stated that the transport of that commodity was one of the principal reasons offered for the construction, in 1769, of a canal between Liverpool and Hull, *viâ* Cheshire. At that time manufactured salt was carried on horseback "to almost all parts of Staffordshire, Derbyshire, Leicestershire, Nottinghamshire, Yorkshire, and Lincolnshire," and it was stated that "so great is the home consumption of this article, that from the saltworks of Northwich alone, a duty of 6,7000*l.* was last year paid into the Exchequer. At Northwich and Wisford are annually made about 24,000 tons." *

The Leeds and Liverpool Canal.

The Leeds and Liverpool Canal, which was commenced in 1770 and completed in 1816, is one of the most important lines of navigation in the United Kingdom, connecting, as it does, the Irish Sea at Liverpool with the German Ocean at Hull. The works were extended over a period of about forty-one years, and cost altogether 1,200,000*l.* The course of the canal from Leeds is *viâ* the Abbey of Kirkstall, Calverley, Woodhouse, Apperley Bridge, Shipley, Bingley, Skipton, Burnley, Blackburn, Wigan, and so on to Liverpool. It is the longest canal in Great Britain, and in some respects, the most remarkable. It has many important works of art on its course, the summit level of which is reached at an elevation of 411 feet above the Aire at Leeds, 41 miles from that town. At Foulridge there is a tunnel 1640 yards in length, 18 feet high, and 17 feet wide. Near to this tunnel are two reservoirs for the supply

* In the same district over a million tons are now annually sent down the river Weaver.

of the canal. They cover an area of 104 acres, and store up 12,000 cubic yards of water. The canal is carried on aqueducts across the Aire, the Colne Water, the Brown, the Calder, the Henbarn, the Derwent Water, and the Roddlesworth Water. The total length of the navigation is 127 miles, and the total lockage 844 feet 7½ inches, while the canal basin at Liverpool is 56 feet above low-water mark on the river Mersey. The canal has several important feeders or branches.*

Kennet and Avon Canal.

The Kennet and Avon Canal starts from the port of Bristol and runs to Bath, Dundas (for the Somersetshire Coal Canal), Bradford-on-Avon, Semington (for the Wilts and Berks Canal), Devizes, Honeystreet, Pewsey, Burbage, Hungerford, Newbury, Reading, where it joins the Thames for Henley, Marlow, Maidenhead, Windsor, Staines, and London. The distance from Bristol to Bath is 15 miles, from Bath to Newbury 57 miles, from Newbury to Reading 18½ miles, and from Reading to London 74 miles.

The river Avon, from Bristol to Bath, will admit of barges being worked carrying 90 tons when the water is high, but in low water this weight would be reduced to 50 or 60 tons, in consequence of the want of cleansing and dredging. This part of the navigation is under an Act of Parliament, 10 Queen Anne, 1711, and is to be free and open for ever upon payment of toll.

The canal from Bath to Newbury (under an Act of Parliament of George III.) has been constructed for vessels drawing five feet of water, measuring 14 feet wide, and according to the present soundings on the lock-sills, vessels of that draught ought now to navigate the canal, but they are not able to do so from the great accumulation of mud, which is seldom less than one foot in thickness, and generally two feet or more. This not only prevents the barges from using the canal for carrying full cargoes, but necessitates the employment of extra towing power. One horse would tow a barge 2 to 2½ miles an hour, if the canal were kept in proper working order. At the present time two or more horses are required to do what ought to be only the work of one. Many of the lay byes throughout the canal were originally made to enable vessels to turn; nearly all of these are now of no use, owing to their being full of mud and weeds, consequently

* A detailed description of this Navigation is given in Priestley's 'Historical Account of the Navigable Rivers, Canals, and Railways of Great Britain,' p. 385.

barges have often to go long distances beyond their proper destination in order to turn. Owing to the accumulation of mud on the sides of the canal, barges can only pass one another with great difficulty, causing much loss of time. The gearing of the paddles of most of the locks is very insufficient and out of repair. On all properly managed navigations, dredgers are kept almost constantly at work cleansing out the mud, which rapidly accumulates, but on this canal there are none. The only men employed on the canal are a few labourers to clean out the weeds with rakes, which are deposited on the towing-paths, and allowed to remain for months, thus obstructing the use of the paths. The pounds between the locks at Devizes are nearly all full of mud and weeds.

The construction of the new port of Sharpness, opened in 1874, is due to the Gloucester and Berkeley Canal Company, which constructed at the small promontory of that name, about midway between Avonmouth and Gloucester, a large tidal basin, 350 feet by 300 feet, a lock 320 feet long, with three pairs of gates of large size, and a discharging dock 2200 feet long, and occupying an area of 13½ acres. The entrance to the docks from the Severn is 60 feet wide, and the depth at high water averages 26 feet.

The canal company, by this provision, has been able to retain for Gloucester a great deal of the shipping which formerly, although chartered for that city, has, owing to the old canal entrance being too small, been obliged to discharge at one of the South Wales ports. Almost simultaneously with this step, the Gloucester and Berkeley Canal Company purchased the Worcester and Birmingham Canal, thereby enabling water communication to be opened up with the heart of the Midlands.

The Ellesmere Canal.

The Ellesmere Canal, in North Wales, consists of a series of navigations proceeding from the river Dee in the vale of Llangollen. One branch passes northward, near the towns of Ellesmere, Whitchurch, Nantwich, and the city of Chester, to Ellesmere Port on the Mersey; another in a south-easterly direction, through the middle of Shropshire towards Shrewsbury on the Severn, and a third in a south-westerly direction, by the town of Oswestry, to the Montgomeryshire Canal, near Llanymynech; its whole extent, including the Chester Canal, incorporated with it, being about 112 miles. The heaviest and most important part of the works occurred in carrying the canal through the rugged hill country, between the rivers Dee and Ceriog, in the vale of Llangollen. From Nantwich to Whitchurch the distance is 16 miles, and the rise 132 feet, involving nineteen locks; and thence to Ellesmere, Chirk, Pont Cysylltan, and the river Dee, 1¾ mile above Llangollen, the distance is 38¼ miles, and the rise 13 feet, involving only two locks. The latter part of the undertaking presented the greatest difficulties, as, in order to avoid the expense of constructing numerous locks, which would involve serious delay and heavy expense in working the navigation, it became necessary to contrive means for carrying the canal on the same level from one side of the respective valleys of the Dee and the Ceriog to the other, and hence the magnificent aqueducts of Chirk and Pont Cysylltan, characterised by Phillips as "among the boldest efforts of human invention in modern times."

The Chirk Aqueduct carries the canal across the valley of the Ceriog, between Chirk Castle and the village of that name. At this point the valley is above 700 feet wide; the banks are steep, with a flat alluvial meadow between them, through which the river flows. The country is finely wooded. Chirk Castle stands on an eminence on its western side, with the Welsh mountains and Glen Ceriog as a background; the whole composing a landscape of great beauty, in the centre of which Telford's aqueduct forms a highly picturesque object.

The aqueduct consists of ten arches of 4 feet span each. The level of the water in the canal is 65 feet above the meadow, and 70 feet above the level of the river Ceriog.

The proportions of this work far exceeded anything of the kind that had up to that time been attempted in England. It was a very costly structure; but Telford, like Brindley, thought it better to incur a considerable capital outlay in maintaining the uniform level of the canal than to raise and lower it up and down the sides of the valley by locks at a heavy expense in works, and a still greater cost in time and water. The aqueduct is an admirable specimen of the finest class of masonry, and Telford showed himself a master of his profession by the manner in which he carried out the whole details of the undertaking. The piers were carried up solid to a certain height, above which they were built hollow with cross walls. The spandrels also, above the springing of the arches, were constructed with longitudinal walls, and left hollow. The first stone was laid on the 17th of June, 1796, and the work was completed in the year 1801.

Aire and Calder Canal.

The Aire and Calder Canal, in Yorkshire, which is connected with the Leeds and Liverpool Canal at Leeds Bridge, and thence communicates with the Mersey at Liverpool, was originally constructed with locks 60 feet long by 15 feet wide, and with a depth of 3 feet 6 inches. It has been subsequently twice reconstructed in all its main features. In 1820, the diversion between Knottingley and Goole was constructed, with locks 72 feet long, 18 feet wide, and with 7 feet depth of water; but this being found inefficient, the whole of the works between Goole and Leeds, on the Aire branch of the navigation, and Wakefield on the Calder, have been again reconstructed, with locks of 215 feet long, 22 feet wide, and 9 feet on the sills. In addition to this, the undertakers have purchased and improved the Barnsley Canal, and also, to some extent, as lessees, they have extended their improvements to the Calder and Hebble Navigation. From time to time, the port of Goole, which forms a part of the Aire and Calder Navigation, has been improved, and its capacity enlarged, new docks and entrance-locks have been built, and the channel has been generally improved.

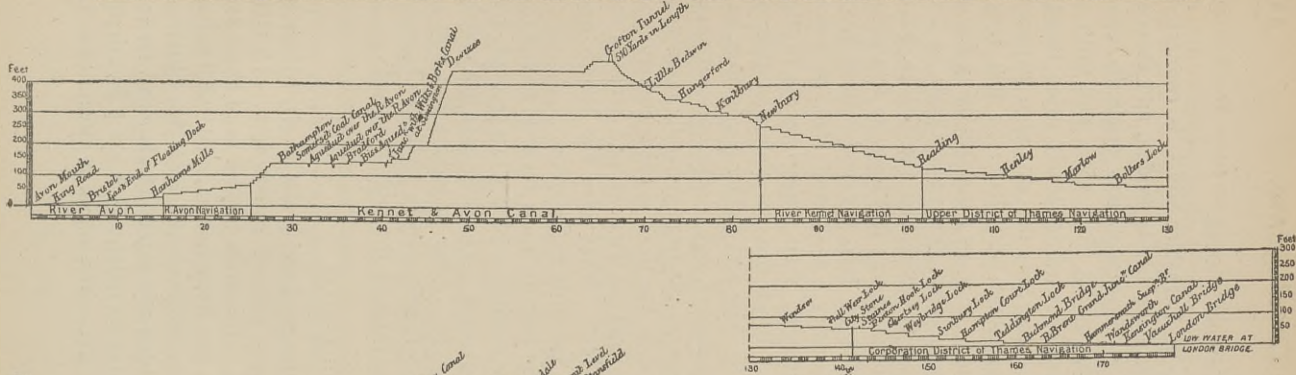
The accompanying diagrams show the lines of canal communication between the Severn at Bristol and the Thames, and between the ports of Liverpool, Goole, and Hull. They give the length and profile of each canal, and require but little explanation.

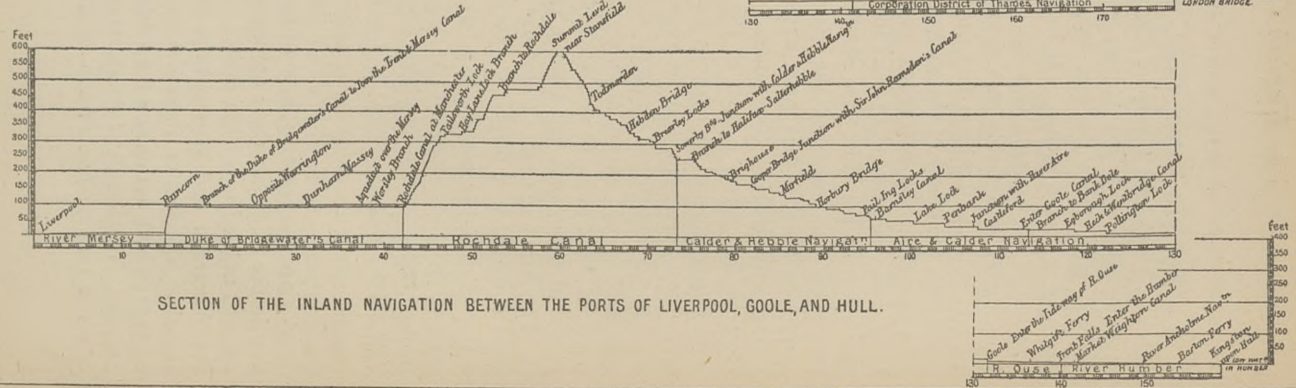
The Aire and Calder Canal has been in many respects one of the most remarkable in England. Its original capital was 150,000*l.*, but it is now stated to amount to 1,697,000*l.* The difference has mainly resulted from accumulations of profit. After deducting the cost of maintenance, the sum available for distribution in 1888 was 85,000*l.* The gross yearly income is now as large as the original capital.

Midland Canals.

A glance at the canal map of England and Wales (p. 57) will show that in the Midlands there are many existing canals, some of which are still utilised to a large extent. The more important of these are the Worcester and Birmingham, the Birmingham, and the Dudley Canals. The first of these was constructed under an Act obtained in 1791, which authorised the raising of a capital of 180,000*l.* for the purpose. The length of the canal is 29 miles, and it has 6 feet depth of water and 42 feet of top width. The canal is exceptional in

SECTION OF THE LINE OF NAVIGATION FROM THE RIVER SEVERN AT BRISTOL BY WAY OF DEVIZES TO THE RIVER THAMES AT LONDON BRIDGE.





SECTION OF THE INLAND NAVIGATION BETWEEN THE PORTS OF LIVERPOOL, GOOLE, AND HULL.

passing through no less than five tunnels in its course—the first at West Heath, the second at Tardebigg, the third at Shortwood, the fourth at Oddingley, and the fifth at Edgbaston. There is also a fall of 428 feet in 15 miles by 71 locks, which are 15 feet wide and 18 feet long, to the level of the Severn. Priestley wrote of the canal that it was "the channel for supplying Worcester and the borders of the Severn down to Tewkesbury and Gloucester with coal, and, in return, conveys the hops and cider of that part of the country northwards, and more particularly affords a ready means for the export of the Birmingham manufactures, through the port of Bristol, to any part of the world."

The general direction of the Dudley Canal is nearly north-west by a crooked course of 30 miles in Worcestershire, a detached part of Shropshire, and Staffordshire; it is situate very high; its two ends are on the eastern side of the grand ridge, while its middle, by means of two very long tunnels, is on the western side of the same. The communication of this canal with the Stourbridge Canal, by the Black Delph branch, and the terminating canals, occasions a considerable carrying trade thereon. This canal commences in the Worcester and Birmingham Canal at Selly Oak, and terminates in the old Birmingham at Tipton Green. From near Dudley there is a branch of two miles to the Stourbridge Canal at Black Delph in Kingswinford; there is another branch of 1¼ mile to near Dudley town, and a branch from this last of three-quarters of a mile to the Dudley collieries. From the Worcester and Birmingham Canal to the Black Delph branch 10½ miles are level, thence to near the entrance of the Dudley Tunnel, about three-quarters of a mile, there is a rise of 31 feet by five locks, thence through the tunnel it is level, and thence again in the last one-eighth of a mile a fall of 13 feet is overcome by two locks to the old Birmingham Canal. The Black Delph branch has a fall of 85 feet by nine locks to the Stourbridge Canal; the Dudley branch has a rise of 64 feet in the first three-quarters of a mile, the remainder being level. The depth of water in this canal is 5 to 6 feet; the width of the locks on the Black Delph branch is 7 feet. To near Lapal, or Laplat, the canal passes through a tunnel 3776 yards long; at Gorsty Hill it passes through another of 623 yards, under a collateral branch of the Grand Ridge; and at Dudley there is another tunnel of 2926 yards in length, near the summit-level of the canal. The arch of this last tunnel has a height of 13½ feet. At Cradley Pool a large reservoir exists for supplying the lockage of the Black Delph branch. It is provided, that level cuts may be made from this canal towards any coal-mine to the extent of 2000 yards. A stop-lock is erected at the junction with the Worcester and Birmingham Canal, by which either company has a power of preventing the other from drawing off their head of water. The Black Delph branch was first executed, and this was then united with the Dudley part of the canal, which had been constructed by Lord Dudley and Ward; these were completed and in use before the extension or main length to Selly Oak was designed. The company was authorised to raise a capital of 229,100*l.*, the amount of the shares being originally 100*l.* each. Owing to the different Acts under which the parts of the canal were progressively undertaken, the rates of tonnage differ considerably.

Canals in Wales.

The principal artificial waterways in Wales are the Swansea Canal, about 19 miles in length, which was opened in 1798, and which connects the harbour of Swansea with the various copper and other works between that point and Pen Tawe; the Neath Canal, which is about 14 miles in length, and which, commencing near Abernant, and terminating at Neath river harbour, with a branch to a short canal called the Briton Canal, near Giant's Grave, Pill; the Aberdare Canal, which, about 6½ miles in length, connects the Glamorganshire Canal with Aberdare, and runs through a district of great mineral and manufacturing resources; and the Glamorganshire Canal, which in a total length of 25 miles has a rise of about 611 feet, and which, commencing on the east side of the Taff river, and near its entrance into Penarth harbour, terminates in the town of Merthyr Tydfil. The canal was opened between Merthyr and Cardiff in 1794, and at the end of the canal, which terminates in the Taff river, there is a sea-lock, with a floating dock, capable of admitting vessels of considerable tonnage.

In May 1885 the Glamorganshire and Aberdare Canals, in South Wales, were transferred to the Bute Dock Company, who formally commenced working them in September 1887. The old system of conducting the traffic on these canals was to charge toll rates, but the Marquis of Bute has adopted the system of charging through rates from any place on the Bristol Channel to Cardiff.

There are many continuous lines of water communication between different commercial points of importance in England, as, for example, between London and Liverpool, Liverpool and Hull, Birmingham and London, Leeds and Liverpool, &c.; but it often happens upon such through routes that there are great differences in the sizes of the locks, which are shorter or narrower at one point than at another. Thus, for example, between the Derbyshire district and London, the canal communication is in the hands of seven different companies, with four different gauges at least, the effect of which is to limit the carrying capacity of the boats to the very low maximum of 24 tons. A considerable number of canal boats continue to navigate these through routes in spite of all these drawbacks, but they have very little encouragement to do so, inasmuch as the different canal companies impose different rates of toll, the aggregate of which comes to almost, if not quite, as much as would be paid to the railway companies for the service. It is hopeless to expect to see this condition of affairs quite remedied until all these through routes pass into the hands of the same companies. It has been computed by capable engineers that an average expenditure of 10,000*l.* or 12,000*l.* would enable the canal system of England to become efficient, and it is probable that before long this expenditure will be found worth while.

According to the most recent returns available, the canal mileage owned by the principal railway companies in England and Wales, and the number of employés thereon, were as under:—

	Miles of Canal Owned.	No. of Employés thereon.
Great Western	258	270
London and North-Western	488	214
Midland	50	..
Manchester, Sheffield, and Lincolnshire	180½	538
North Staffordshire	121	263
Caledonian	60	340

The total number of employés on the canals of England and Wales in 1884 was 1479 for 1333 miles owned, being an average of little more than one employé to the mile. On the railways of England and Wales for the same year the number of employés was 310,568 for 18,000 miles worked, being an average of 17·2 employés per mile. As, however, there are no returns of canal traffic available, we cannot say how the two sets of figures compare in the matter of results.

While several new canal projects are in process of incubation the existing canal property of the United Kingdom, which has cost not less than sixty millions sterling, has been allowed to go to rack and ruin by reason of defects and neglect that are quite inexcusable, and which seriously prejudice not only the canals themselves, but the trade and commerce of the country as a whole.

The unsatisfactory condition of the waterways of the United Kingdom is sufficiently proved by a few returns that were presented to the Select Committee on canals * (1883). At that date there were fifty-seven canals in England and Wales belonging to independent companies, twenty-seven canals and navigations under public trusts, forty-five owned or controlled by railway companies, and fourteen that were either derelict, or had been converted into railways.

Of the canals under the control of independent companies, a considerable number were in anything but a flourishing condition, and most of them, apparently, because they entirely failed to meet the requirements of commerce.

So far as mere mileage is concerned, the waterways of England, including canals and canalised rivers, are really of very considerable, if not sufficient extent, as the following figures show :—

	Miles.
Owned by public trusts	927¼
Independent canals	1445¼
Guaranteed and owned by railways	1333
Derelict	118½
Ownership not known	36¾

Besides these, there have been about 120 miles of canals converted into railways. But these canals are of very limited use, because of the haphazard and unsystematic way in which they have been laid out. Scarcely any two canals have a common gauge, and upon the same canal several gauges of locks may often be found.

The four great industrial rivers of England, and the four most important maritime outlets, are connected with each other by 650 miles of inland waterway. The Thames and the Humber, the Severn and the Mersey, and the Severn, Mersey and the Humber, ought to

* Appendix to Report, p. 206.

be placed in communication with each other by as perfect a system of waterways as it is possible to provide. But this desirable end has been frustrated by railway action. In the first group, 175 miles of canal have been acquired by railway companies; in the second group, 490 miles; and in the third group, 360 miles. It has been computed that the average cost of the canals in the first group was 5000*l.*, and in the second group 9000*l.* per mile. The railways that connect the same four maritime points have a total mileage of about 9500 miles, and an aggregate capital of about 360 millions.

The history of British canals, with all the most interesting information bearing upon their extent, capacity, and traffic, has been written by Priestley in a work that is to this day the standard authority on the subject. The same subject has been dealt with very extensively in Rees's 'Cyclopædia,' under the heading of "Canals." With these sources of information open to all the world, it would be quite supererogatory to go into much detail relative to these waterways of Great Britain, except in so far as they are of cardinal importance, or are likely to exercise an influence in the future development of canal navigations. It will be understood, therefore, that in these notes no attempt is made to afford minute details of the different canals dealt with; while many of the canals that have either been abandoned, or have become the property of railway companies, or have otherwise ceased to be of public importance, have been entirely disregarded.

It is an axiom in water transport that the larger the vessel employed, within certain limits, the more inexpensive is the cost of the service performed. It has been calculated* that at the present time, the cost of transporting fifty tons of material between London and Liverpool, a distance of 180 miles, is 25*l.*, or 10*s.* per ton exclusive of tolls. But then the boats employed are only 25-ton craft, which take eight days on the journey, with one day to load, and one day to unload, making, with two spare days, twelve days in all. If, however, large craft were substituted, capable of carrying 120 tons each, and towed by a steam barge carrying 90 tons—making a total load of 450 tons—the cost would be reduced to about 2*s.* 6½*d.* per ton, or about one-fourth of the existing cost, and the time occupied by the journey would be lessened by two days. In both cases profit is included, at the rate of 25 per cent.

In order, however, to have this substitution generally effected, a

* Report of Canal Committee of 1882, Appendix No. 9, p. 230.

large number of the existing canals would require to be deepened and widened. The size of the craft suggested for the more economical trip would be 84 feet by 12 feet by 6 feet 3 inches draft. A smaller vessel would not answer the purpose. Now, there are comparatively few canals that would at the present time admit of the passage of such craft, and in some cases waterways that are nominally adapted for even larger boats, are in such an imperfect condition of repair that they are not suited for use. The canals of the independent companies that profess to be adapted for vessels of this size, and the size of craft which they severally admit, are—

Canal.	Length of Navigation.	Size of Craft.				
	miles.	ft.	in.		ft.	in.
Aire and Calder	80	212	0	by	22	0
Bridgwater	97	84	0	,,	15	0
Bude *	35½	104	0	,,	29	6
Gloucester	16	163	0	,,	29	6
Leicester and Northampton	24	88	0	,,	15	6
Louth	11¾	87	6	,,	15	6
Medway Navigation	7¾	86	0	,,	23	0
Regent's and Hertford Union	10¼	90	0	,,	15	0
Stort	13½	100	0	,,	13	6
Thames and Medway	9	94	8	,,	22	8
Trent, River	72	90	0	,,	15	0
Total †	306¾	..				

Here then we have only 306¾ miles of canal suited to the passage of craft 84 feet by 12 feet, including the river Trent, which, of itself, contributes 72 miles to the total. In other words, only about twenty per cent. of the total independent waterways of the country can admit craft that would enable them to realise the full value of economical

* This, however, is not a canal of uniform size, and part of it will only admit vessels 63 ft. by 14 ft. 7 in.

† This total does not include the Thames and Severn, the Wey, and the Wisbech canals, because each of these has two dimensions, the smaller of which is too limited to admit the passage of large craft, and they are therefore unsuited, without trans-shipment of traffic, for the purpose in view.

transport. Of the remainder, a great part of the navigations vary from 60 to 75 feet in width, so that presumably they could be adapted for the larger sizes of craft without very material expense.

The canals and navigations managed by public trusts are in a decidedly better position. Commencing with the noble Severn, which, for a great part of its canalised course of forty-four miles, admits

Map showing the Canals and Navigations in England and Wales.

craft 270 feet by 35 feet, there are the Thames (from London Bridge), the Lea, the Weaver, and the Wye, which are suited to craft of considerable dimensions, but these for the most part can hardly be described as canals proper.

The canals that have passed into the possession of the railway companies are not, as a rule, so well adapted for navigation as those controlled by independent companies. On the face of it, indeed, there is a presumption that the railways could not have acquired the property if it had been as it should have been. The only railway canals that are capable of admitting craft exceeding 84 feet in length are the Kennet and Avon, 85 miles long; the Grantham Canal, 33½ miles long; and the Nottingham Canal, 15 miles in length—about 133 miles in all. Out of a total of 1333 miles of the derelict and converted canals, only the Melton Mowbray, 14¾ miles in length, was adapted for the larger size of vessels.

The preceding map shows the canals in England and Wales that are in the hands of independent owners or public trusts, and in the possession of railway companies, respectively.

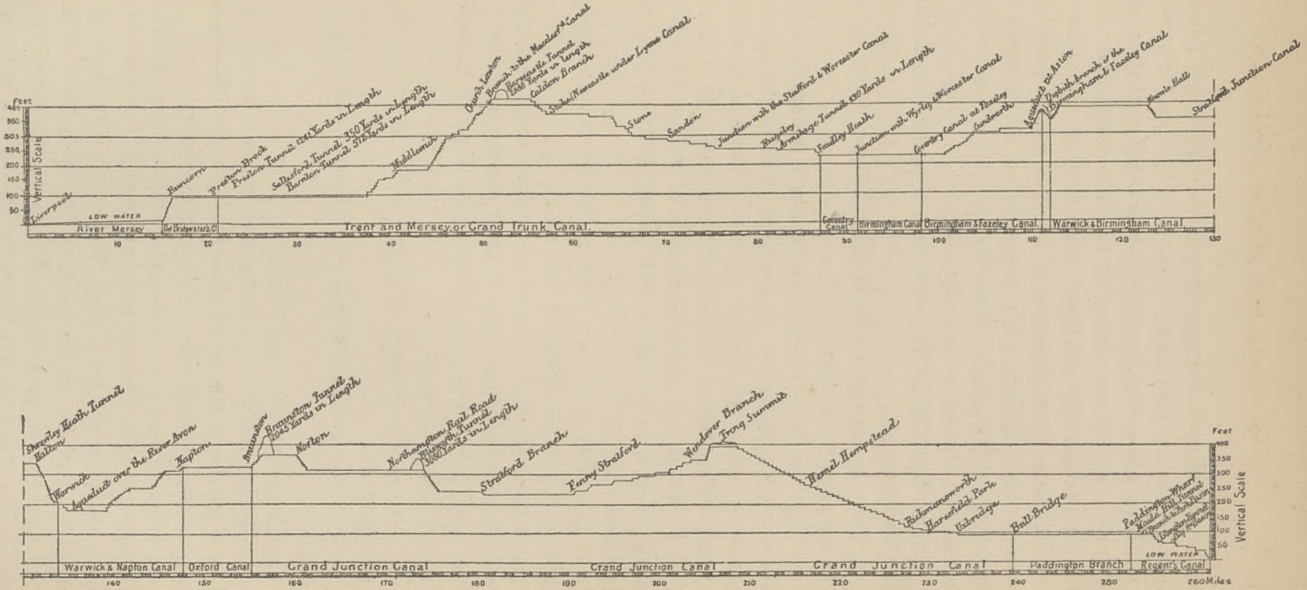
Under the circumstances stated, it is perfectly evident that the canals of England and Wales have not had a fair chance. Out of a total of over 4000 miles of canal and river navigations, the proportion that is suited to craft of 200 tons burden is almost fractional. With such a size of vessel, cheap transport is difficult.

Between London and Birmingham the following canals form a system of communication :—

Canal.	Length of Navigation.	Size of Locks.
	miles.	ft. ft. in. ft. in.
Grand Junction, between Brentford and Braunston	92	80 by 14 6 by 4 6
Oxford, between Braunston and Napton ..	5½	no lock.
Warwick and Napton, between those places	13½	72 by 7 by 4 0
Warwick and Birmingham	21½	72 by 7 by 4 0
	132½	
Paddington Arm of the Grand Junction ..	13½	
	146	

The diagram on the next page shows the section of the line of canal navigation between the Mersey and the Thames by way of Birmingham, the total distance being 260 miles. It will be observed that the system is an extensive one, embracing no fewer than twelve different waterways, the more important of which are the Trent and Mersey, and the Grand Junction canals.

SECTION OF THE LINE OF NAVIGATION FROM THE RIVER MERSEY AT LIVERPOOL BY WAY OF BIRMINGHAM TO THE RIVER THAMES AT LIMEHOUSE, LONDON.



The principal advantages afforded by canals are thus concisely stated by General Rundall:—

1. They admit of any class of goods being carried in the manner and at the speed which proves to be most economical and suitable for it, without the slightest interference with any other class.

2. The landing or shipment of cargo is not necessarily confined to certain fixed stations, as is obligatory on railways, but boats can stop at any point on their journey to load and unload, and discharge their cargoes direct over the ship's side.

3. The dead weight to be moved in proportion to the load is much less.

4. The capacity for traffic is practically unlimited, provided the locks are properly designed.

5. There is no obligation to maintain enormous or expensive plant or establishments, as all those can, and would be, provided by separate agencies and distinct capital. Thus a large outlay in first cost and subsequent maintenance of rolling stock is avoided.

6. There is an almost total absence of risk, and the reduction of damage to cargo in transit, and consequently of insurance, to a minimum.

On the other hand, the defects, besides those of original construction, in existing British canals, are:—

1. A total absence of unity of management. For example, on one of the routes from London to Liverpool there are seven different canals and navigations; on another also there are nine, and on a third ten different companies.

2. A want of uniformity of gauge in the locks, as well as in the canals themselves.

3. With few exceptions they are not capable of being worked by steam.

4. An unequal system of tolls.

5. The many links in the communications in the hands of the railways paralyses any unity of action, and renders any scheme of amalgamation between the several lines impossible.

If a restoration, or an extension of its ancient water lines, is to be undertaken in Great Britain, it is essential that it should be devised on the most improved principles. The chief points requiring attention are the dimensions to be given to the main lines, with the best relative proportion of width to depth; uniformity of gauge in the locks or lifts, which should be so designed as to ensure changes of level being overcome in the quickest time; the remodelling of the cargo boats; the use of the electric light for night navigation; a readjustment of the rates of toll; and suitable provision for loading and discharging cargo.

The works of the canal and river engineer are of the most varied, difficult, and onerous character. He has to deepen the beds of rivers, so as to secure uniform depths and absolute immunity from dangers of projecting rocks, reefs, or sandbanks. He has to divert the beds of torrential streams, and construct new channels, as has been done with the Thames, the Danube, the Tees, and many other rivers. He has to overcome the obstacles to navigation presented by cataracts like Niagara, St. Anthony's, and other falls, by laying down a new waterway, where locks or lifts will overcome the differences of level or gradient represented by the cataracts. He has to feed artificial waterways in such a fashion that they are never short of water. He has to carry canals under mountains by tunnels, and through valleys by aqueducts. He has to raise the level of his waterways for navigation or for irrigation by barrage works, like those that are now being carried out on the Nile at Damietta and Rosetta. He has to overcome the differences of level in inland seas, as has been done by the St. Mary's Falls and Welland Canals on the American continent. He has to join together seas that have been sundered by Nature, as in the case of the Suez, Corinth, Panama, Nicaragua, and other canals. He has to build training-walls, close passes, direct and confine currents, throw dams across minor channels, concentrate low-water flows, rectify shifting sandbars, equalise and distribute water-power, cleave through mountains (as in the case of the Culebra Col, on the line of the Panama Canal), raise rivers to the level of lakes, and lower lakes to sea-level (as in the case of the proposed Nicaraguan Canal), and to deal with many other phenomena that appear to the ordinary mind to be so many impossibilities. The engineering history of some rivers is an epitome of engineering achievements. The case of the Mississippi river, in the United States, is a notable case in point. That splendid highway, with its navigation of some 15,000 miles, and its infinite number of tributaries, each of them a noble river in itself, has been regulated, canalised, and otherwise improved at a hundred different points along its course, with results that are notable in the annals of engineering precedents. Most of our rivers, lakes, and canals have gone through the same process. It has been the work of the engineer, and that alone, which has conferred upon them the advantages possessed by our great maritime highways at the present day. The extent of that work, and the means whereby it has been accomplished, are the noblest memorial of nineteenth century science.

One of the most important applications of canal navigation has been in enabling the navigation of important rivers to be continued, where Nature had interposed a barrier in the form of impassable cataracts or otherwise. Examples of this sort are the Welland Canal between Lake Erie and Ontario, which provides a navigation parallel to the Niagara river, rendered impassable by the Falls of that name; the Des Moines Canal, which overcomes the barrier interposed by the Des Moines Rapids, on the Mississippi; the canal that overcomes, in the same way, the difference of level in the Mississippi caused by the St. Anthony's Falls * near Minneapolis; and the Gotha Canal, which overcomes the difficulties of Trölhatta Falls on the Gotha river in Sweden.

These achievements and responsibilities have not been carried so far in Great Britain as in some other countries. The existing canal system of that country is more primitive than that of any other leading European State, and it is very much more imperfectly developed than those of Canada and the United States. The Manchester Canal project, described at a later stage of this work, will do something to wipe away this reproach.

* At these falls 790,000 cubic feet of water drops from a height of 75 feet every minute, giving some 112,000 horse-power, which is utilised in manufactures of different kinds.

CHAPTER IV.

THE WATERWAYS OF SCOTLAND.

"Former things
Are set aside, like abdicated kings."—*Ovid.*

SCOTLAND has a number of rivers of the first importance, especially the Clyde, the Tay, the Dee, and the Tweed. It has a large number of smaller streams, most of them, however, having too tortuous a course, too impetuous a flow, or too shallow a bed, to be used to any extent for purposes of navigation. This remark does not, of course, apply to the numerous lakes or lochs of Scotland, but these are, for the most part, either situated in inaccessible regions, or in localities where there is not trade enough to provide any considerable amount of traffic.

The Clyde is pre-eminently distinguished for the extent of its traffic, and for the improvements that have made it what it is.

Camden does not say much as to the condition of the Clyde in his time, and he is almost equally reticent about Glasgow. "The river Glotta or Clwyd," he says, "runneth from Hamilton, by Bothwell . . . and so straight forward, with a readie stream, through Glasgow, in ancient times past a Bishop's seat . . . now the most famous town of merchandise in this tract." In Camden's time the other qualifications of Glasgow appear to have been that it had "a pleasant site, and apple-trees, and other like fruit trees, much commended, having also a very fine bridge supported with eight arches."

It is upwards of 300 years since the Magistrates and Town Council of Glasgow made the first attempts to improve the Clyde, then a shallow, brawling stream, which could easily be crossed on foot even opposite Glasgow, and was only suitable for the navigation of herring boats, and similarly small craft. In 1768 an engineer, named Golborne, contracted the river by the construction of rubble jetties, and the removal of sand and gravel shoal by dredging, &c.

From 1781 till 1836, the works carried on for the further improvement of the river under the direction, consecutively, of Golborne, Rennie, and Telford, consisted chiefly in the shortening of some, and the lengthening of other of Golborne's jetties, the construction of additional jetties, the connecting of the outer ends of these jetties by half-tide training walls on both sides of the river, so as to confine the water and increase the ebb scour, and the removal of hard shoals by dredging.

It was not till 1836 that the river from Glasgow to Port Glasgow was treated as a whole, and a true appreciation shown of its future by the Clyde Trustees' then Engineer Logan, in the laying down of river lines, which, with some slight modifications and expansions, have up till now formed the limits of the river's improvements.

Parliamentary plans on these lines approved of by James Walker, Consulting Engineer to the Trustees, were submitted to and sanctioned by Parliament in 1840; but so inadequate was the appreciation of the depth required, that 20 ft. at high water neap tides was recommended by Logan as the extreme depth of the river and harbour, and a clause in the Act empowering the deepening to proceed until every part thereof shall have attained at least a depth of 17 ft. at high water neap tides.

The depth in the harbour of Glasgow at the present time is from 25 ft. to 29 ft., and in the river from 27 ft. to 29 ft. at high water neaps, high water springs being about 2 ft. higher. The average tidal range of spring tides at Glasgow is 11 ft. 2 in., and at Port Glasgow 10 ft.; and of neaps at Glasgow 9 ft. 2 in., and at Port Glasgow 8 ft. 3 in.

While jetties and training walls, or parallel dykes, performed a useful part in the early improvement of the river, it is to persistent dredging that the enormous increase in the magnitude of the river since 1840 is due.

The early dredging was performed by large rakes, or porcupine ploughs, as they were called, because they were provided with strong iron teeth, wrought by hand capstans, which drew the material from the bed of the river on to the banks.

Hand-wrought, and subsequently horse-wrought, dredges, with small buckets on a ladder, succeeded the plough, and in 1824 the first steam dredger was started on the river. It dredged, however, only to 10 ft. 6 in. Now several of the dredges employed can work in 35 ft. depth of water.

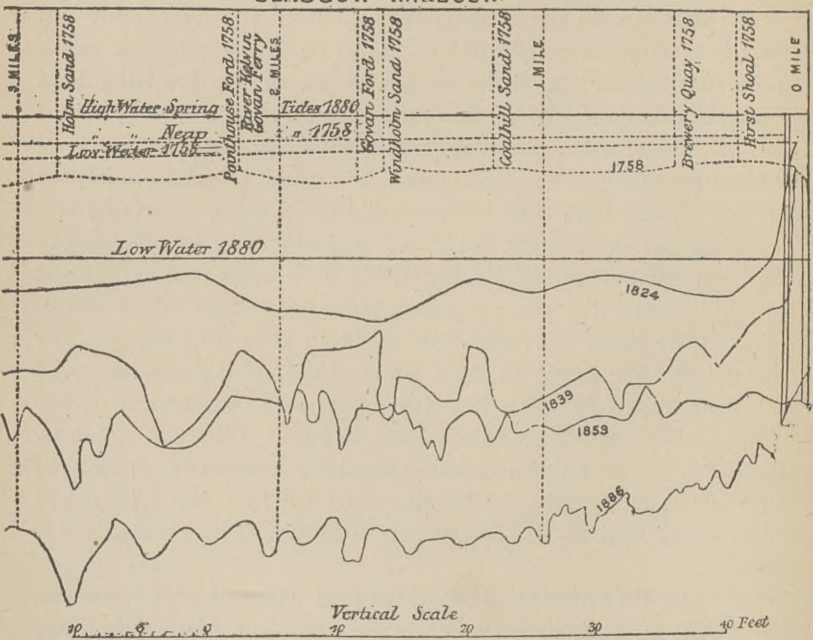
Mr. Deas, the engineer to the Clyde Trust, has stated * that it is due to the application of steam power to dredges, and the subsequent adoption of steam hopper barges for carrying the dredged material to

* Paper read in 1888 before the Institution of Naval Architects.

the sea, that the rapid enlargement not only of the Clyde and the Harbour of Glasgow, but of the Tyne, the Tees, and several other similar rivers in recent years are due. But for the introduction of the latter, it would have been physically, financially, and otherwise impossible to have disposed, within so limited a time, of the enormous quantities of material which have been dredged from these various rivers and harbours.

Up till 1862, all the material dredged from the river Clyde and harbour of Glasgow was loaded on punts holding eight cubic yards, and deposited on the alveus or foreshores, or the low-lying land adjoining the river. Many acres were thus reclaimed, to the great gain of the riparian proprietors, to whom the Trustees required to hand over the ground free of cost. The adoption of steam hopper barges, holding from 240 to 320 cubic yards each, removed these obstacles, and enabled the deepening, widening, and straightening of the river and harbour to be proceeded with more rapidly, without seriously obstructing the navigation with steam tugs and trains of punts. The result has been that while in 1861 the total quantity dredged and deposited on land was 593,176 cubic yards, the total quantity dredged in 1887 was 1,319,344 cubic yards, only 64,000 cubic yards of which was deposited on land. The total quantity dredged during the forty-two years ending 1888 amounted to 32,027,834 cubic yards, the quantity in the first twenty-one years being 9,091,544 cubic yards, and in the last twenty-one years, 22,936,290 cubic yards.

In 1755, the Clyde at Glasgow was only 15 in. deep at low water, and 3 ft. 8 in. at high water, while the depth at Marlinford, three miles below the harbour, was 18 in., and at Erskine, or Kilpatrick Sands, about eight miles below, and at Dumbuck Ford, ten miles below, only 2 ft. at low water. In 1781, the depth at Dumbuck Ford was 14 ft. at low water; it is now 20 ft. In 1806, Telford reports that on February 14th of that year the *Harmony*, of Liverpool, came up with ordinary spring tide, drawing 8 ft. 6 in. of water; but up till 1812, the river from the harbour downwards to Bowling was so shallow, that the *Comet* required to leave Glasgow and Greenock, respectively, at or near high water to prevent it grounding in the river. Now, vessels drawing 23 and 24 ft. of water pass up the river almost daily. The Clyde Trust, who are charged with the control of the river, had expended thereon, up to the middle of 1887, upwards of eleven and a half millions sterling, and had, besides, contracted a debt of over four and a half millions. The accompanying diagram will show the depths of the channel in Glasgow harbour at different dates, but the whole of the river has been dredged constantly from that city down to Port Glasgow, a distance of nearly twenty miles, and the bed of the river between these points is now virtually level throughout.



Depth of the Clyde at Different Periods.

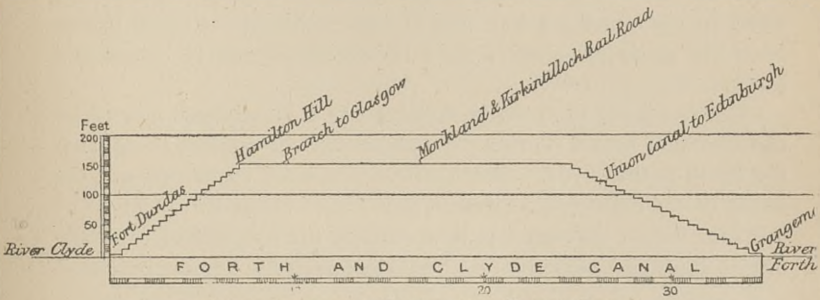
The shipping industry has, in consequence, enormously increased. In 1888, 8428 vessels, of 1,891,000 tons, entered, and 8053 vessels, of 1,444,000 tons, cleared from Glasgow in the coasting trade; while the total number of all vessels that entered in the same year was 8217, with 2,416,000 tons register, the clearances being 8738 vessels, with 2,787,000 tons.

The Forth and Clyde Canal.

This, the most important Canal in Scotland, commences in Grangemouth harbour, in the small river Carron, about two miles, by the low-water channel, above its mouth in the estuary of the Eorth.

The general direction of the canal is that of west by south. It at first runs a considerable way on one level along the south side of the Carron, with which it again communicates by a cut from it at Bainsford, to that river at the Carron Iron Works.

The main line then passes to the north-west of Falkirk, and thence to Bonny Bridge, proceeding by the south side of Kilsyth, and along the south bank of the river Kelvin, and over the Logie Water by a stone aqueduct at Kirkintilloch. It then reaches Hamilton Hill about two miles from the north-west quarter of the city of Glasgow, to which there is a branch of two miles, and three quarters, communicating with a branch from the Monkland Canal at Port-Dundas Basin. The main line now proceeds Westerly, crossing the Kelvin by an aqueduct, and then runs along the side of the Clyde,



SECTION OF THE FORTH AND CLYDE CANAL.

till it at length locks down to that river at Bowling Bay. The main line is 35 miles long, 56 feet wide at top, 27 feet at bottom, and 10 feet deep. In $10\frac{3}{4}$ miles from Grangemouth to the summit, it rises 156 feet by 20 locks. The summit-level continues about 16 miles. and from it to the Clyde there is a descent of 156 feet by 19 locks. Each lock is 74 feet long by 20 feet wide.

At lock No. 16 from Grangemouth, this canal connects with the Edinburgh, and Glasgow Union Canal.

Instead of having the eastern extremity of this canal in the Carron, it was originally intended to have had it considerably farther east, or lower down the Forth, in the deeper water at Borrowstounness. This would have been an improvement, but probably one not so easily executed. The work was once really begun, and afterwards abandoned, chiefly, it is presumed, from the difficulty of passing over the river Avon, without raising the canal a good deal for several miles

F 2

along the low carse lands. The remains of a bungled aqueduct bridge for this purpose were lately to be seen on the banks of that river.

The present canal joining the Forth and the Clyde was begun in 1768, but it was suspended in 1777, and not resumed until after the close of the American war. It was completed in 1790. It was built on a larger scale than any of the English Canals up to that time. Originally the canal was about 8 ft. 6 in. deep, but its banks were afterwards raised, and the depth of water was increased to 10 feet. In completing this canal many serious difficulties were encountered. These, however, were successfully overcome; and though unprofitable for a while, it afterwards, for many years, yielded a handsome return to its proprietors, the dividend having been at one time about 28 per cent. on the original stock. Swift boats were established on this canal in 1832, and the waterway is historically interesting as having been the scene of some of the earliest experiments in steam propulsion.

Reference has been made elsewhere to the proposals now under consideration with a view to the construction of another canal from the Forth to the Clyde. Should these proposals be carried out, the future of the existing Forth and Clyde Canal could hardly fail to be overcast, but as the canal is now virtually the property of the Caledonian Railway Company, that would not probably be greatly felt.

The Union and Monkland Canals.

There are two canals that are in the same locality as the Forth and Clyde, already alluded to, but of greatly subordinate importance. The Monkland serves the important iron and coal mining and manufacturing districts in the West, of which Airdrie and Coatbridge are the principal centres, and gives access therefrom to the Clyde. The Union Canal is really a feeder to, and branch of, the Forth and Clyde Canal, some distance further east.

The Union Canal joins the Forth and Clyde Canal near Falkirk, and stretches thence to Edinburgh, being 31½ miles in length. It is 40 feet wide at the top, 20 at the bottom, and 5 deep, It was completed in 1822, but has been, in all respects, a most unprofitable undertaking. For many years the proprietors have not received any dividend, and their prospects, we understand, are not improving.

A canal intended to form a communication between Glasgow, Paisley, and Ardrossan was commenced in 1807, but only that portion connecting Glasgow with Paisley and the village of Johnston has hitherto been finished. This part is about 12 miles long, the canal being 30 feet broad at top, 18 at bottom, and 4½ deep. It was here that the important experiments were originally made on quick travelling by canals, which demonstrated that it was practicable to impel a properly constructed boat, carrying passengers and goods, along a canal at the rate of 9 or 10 miles an hour, without injury to the banks.

The Caledonian Canal.

A valley remarkable for its uniformity, straightness, and depth, and extending from sea to sea, between two parallel ranges of steep mountains, divides the Highlands of Scotland into two nearly equal parts. The general direction of this chasm is from north-east to south-west, making an angle of about 35 degrees with the meridian; and, besides being entered at each extremity by an arm of the sea, viz., by the Moray Firth on the north, and Loch Linnhe on the south, the rest of its bottom is for the most part occupied by a series of rivers and lakes. The remarkably elongated form and contiguity of these lakes had long ago suggested the facility of forming an inland communication between the Atlantic Ocean and the German Sea. In order to accomplish this important object, it seemed sufficient to connect these lakes and the friths by several short canals amounting together to 23 miles, and thereby obtain a navigable line to an extent of more than 100 miles; and this was farther recommended by the summit-level only rising 94½ feet above the sea.

So far back as the year 1773, this line had been surveyed by James Watt, who reported favourably of it, and proposed that the lakes should be connected by a canal of a very moderate size. Nothing further, however, was done till early in the present century, when the subject was taken up by Government, and new surveys were made by Messrs. Jessop and Telford, who recommended a canal of such dimensions as should admit frigates of thirty-two guns, and the greater part of merchant ships, particularly that class which trade between the Baltic and the ports of Ireland and the west coast of Britain; thus avoiding, it was hoped, a tedious, and often dangerous navigation by the Orkneys. The dimensions proposed by Telford, and mainly adhered to, were a width of 50 feet at bottom, 120 feet at top, and 20 feet deep; the locks from 170 to 180 feet long, and 40 wide, with a depth of 20 feet of water besides the lift, or rise. The canal has, however, only been excavated to the depth of 15 feet in the summit-level, though the width has been increased to 122 feet at the top, with such a break in the slope that there is on each side a horizontal shelf 6 feet broad at the depth of 2 feet under the surface of the water. The design in this break in the slope of the sides is to keep large vessels from approaching too close to the edge of the canal, and destroying the upper part of the banks, either by contact or by the eddy produced between the vessel and the sides of the canal. On the north, the Caledonian Canal commences with a sea lock at Clach-na-Carry, in a sheltered bay of Loch Beauly, which is the more inland part of the Moray Firth. The sea-lock here is about two miles north-west of Inverness, and three-quarters of a mile west of the Ferry of Kessock, which is near the mouth of the river Ness. In order to have sufficient depth of water at ordinary neap-tides, it was necessary, on account of the flatness of the shore, to place this lock 400 yards within sea-water mark, an operation attended with difficulty on account of the softness of the bottom. This lock is 170 feet long, 40 wide, with a lift of 8½ feet; and proceeding from it, the canal is formed by embankments till it passes the sea-mark, where another lock of the same size, with a lift of 6 feet, is built on firm ground. On the south of this is the Muirton basin, 967 yards long and 162 yards broad, with a wharf for the trade in that quarter, being about a mile from Inverness. At the southern extremity of this basin is a swivel or swing bridge for the public road between Beauly and Inverness; and then four locks, which, however, from their being connected, have only five double gates in the whole. These raise the canal 32 feet, which puts it on the ordinary summer level of Loch Ness. Each lock is 180 feet between the gates, and 40 feet wide. The canal thence proceeds until it meets, and runs along the north-west bank of the river Ness to the small lake Doughfour, which is about 2100 yards long, and from 5 to 9 fathoms deep, and is 6½ miles from Clach-na-Carry. It communicates with Loch Ness by the pass of Bona Ferry. The intended line of canal being on the west side of the river Ness, which in three different places approached close to the steep sides of the hills on the west, it was necessary to alter the course of that river, so as to obtain room for the canal without cutting into the hills. At the entrance to Loch

Doughfour is a regulating, or guard-lock, without any lift, to prevent any overflow from the lake. It is 170 feet long, and 40 wide. It was necessary to deepen this small lock in several places by dredging, and to raise it 6 feet to the level of Loch Ness by a weir, and embankment. The next part of this navigation, and by far the most extensive lake in it, is Loch Ness, a fine sheet of water about 24 miles long, and from 1 to 1½ miles broad. Its depth is so great that it never freezes, being from 5 to 129 fathoms, and along the middle it averages 100. It affords good anchorage at each end, and also in a few bays, although the sides of this lake are generally straight. It was proposed to introduce buoys for more convenient moorings. There are nowhere in it either rocks or banks detached from the shore.

Loch Ness receives the river Oich in its western shore not far from its southern extremity, and a little south of this the canal leaves the lake, whilst almost quite at the southern end stand the fort and village of Fort Augustus. From this the canal ascends 40 feet by five locks, and at Callachie, about 2½ miles further on, it rises 8 feet by another lock. Three miles more bring it to Loch Oich, where a regulating lock raises it 30 inches, so as to be even with that lake, which is on the summit level.

To obtain a proper line for the canal upon the south-east side of the river Oich, the channel of that river has been somewhat altered. Loch Oich, which forms the summit-level of this navigation, is about 3¾ miles long, and on an average a quarter of a mile broad. In one place in the middle, and at both ends, it had to be deepened by dredging. The water which falls into this lake, particularly from the river Garry, affords at all times an ample supply for the canal. Between Loch Oich and the next lake in the line, Loch Lochy, there is no natural communication. The interval is about 1¾ miles, and rises 20 feet above the Loch Oich, which, with the depth of the canal, required a cutting of 35 feet. Loch Lochy, which was 21 feet 9 inches lower than Loch Oich, has been raised about 12 feet by an embankment to avoid rock-cutting, and the canal descends to it 9 feet 9 inches by two locks, one of which is also a regulating, or guard lock. Loch Lochy is 10 miles long, and averages one in breadth. In some places it is 76 fathoms in depth. About half a mile of the course of the river Lochy had to be shifted into a new bed to make room for the canal, which, now in its last stage, proceeds from the lake for 8 miles along the north-west bank of that river over a rugged surface to the shore of Loch Eil, which is the more inland part of the Frith, called Loch Linnhe. A little south of Loch Lochy there is a regulating lock; and about a mile from Loch Eil there are eight connected locks, called Neptune's Stairs, by which the canal descends 64 feet. At Corpach shore it falls 15 feet by two locks, and, after expanding into a basin 250 yards long and 100 broad, it finally descends 7 feet 9 inches by the sea-lock into Loch Eil near Fort William.

The entire length of this navigation is 60½ miles, and that of the artificial part, including Loch Doughfour, is 23 miles. There are in all twenty-eight locks. This canal has, as yet, been a most unprofitable speculation, not even paying the expense of its maintenance.

Before leaving the waterways of Scotland, it may be interesting to remark that inland navigation occupied a good deal of attention from James Watt,* although the great mechanician did not accomplish so much in this direction as his contemporary, Brindley. Watt was employed in 1767 to make a survey for a canal of junction between the rivers Forth and Clyde, by what was called the Lomond passage, and attended Parliament on the part of the subscribers, where the Bill was lost. An offer was then made to him of undertaking the survey and estimate of an intended canal for the Monkland Collieries to Glasgow, and these proving satisfactory the superintendence of the execution was confided to him. This was quickly followed by his being employed by the Trustees for Fisheries and Manufactures in Scotland to make a survey for a canal from Perth to Forfar, through Strathmore; and soon afterwards by the Commissioners of the Annexed Estates, to furnish a report and estimate of the relative advantages of opening a communication between the Forth of Clyde and the western ocean, by means of a navigable canal across the isthmus of Crinan,† or that of Tarbert. Business of this description crowded upon him; and surveys, plans, and estimates, were successively undertaken by him for the deepening of the river Clyde, the rendering navigable of the rivers Forth and Devon, and the

* James Watt was born at Greenock on the 19th January, 1736, and died at Heathfield on the 25th August, 1819. His great invention was the steam engine; but he was an almost universal genius, having been almost equally at home in many branches of antiquity, metaphysics, medicine, and etymology, architecture, music, and law, the modern languages, and German logic and poetry.

† This canal has since been carried out, and now forms an important link in the chain of communication between the west of Scotland and Inverness, viâ the "Royal," or West Coast route.

water of Leven; the making of a canal from Machrihanish Bay to Campbeltown, and of another between the Grand Canal and the Harbour of Borrowstounness. But the last and greatest work of the kind upon which Watt was employed was the survey and estimate of the line of the canal between Fort William and Inverness, since executed, as we have seen, by Telford, upon a larger scale than was at that time proposed.

Estuaries hardly come within the scope of the present work, otherwise the Forth Bridge, recently opened by the Prince of Wales, would demand and deserve an extended notice. That remarkable engineering achievement, due to the genius of Sir John Fowler and Sir Benjamin Baker, is likely for a long time to remain a unique *tour de force* as a means of communication between the opposite shores of an arm of the sea, and opens up a vista of possibilities in regard to transport that were undreamt of until recently.

CHAPTER V.

THE WATERWAYS OF IRELAND.

"Such was the Boyne, a poor inglorious stream,
That in Hibernian vales obscurely strayed,
And, unobserved, in wild meanders played."—*Addison.*

If there is one country more than another that ought to be possessed of ample and complete water communication, that country is surely Ireland. Surrounded on all sides by the sea, with a population greatly inured to the conditions of living upon or by the water, it should have at once the cheapest and the most comprehensive system of water transport in the world. This, however, is far from being the case. Neither in point of rivers, nor in point of canals, does Ireland compare favourably with Scotland, not to speak of the much more abundant resources of England. The actual waterways that are of real importance besides the Liffey, are the Earne and Shannon rivers, and the Grand Canal. About these we shall say as much as may be necessary to indicate their general characteristics.

It has been said that the unfortunate Earl of Strafford, from from having seen the utility of inland navigation in the Low Countries, first suggested the improvement of river navigation in Ireland. In 1703 the first Act of Parliament was passed for rendering the Shannon navigable, and many improvements were projected. Nothing, however, was effected, although a useless expenditure of 140,000*l.* was made on the Shannon and Boyne in the year 1758. Various other large sums were afterwards granted, and frittered away in partial improvements of the Shannon, Boyne, Barrow, and Newry rivers, besides the Grand, Royal, Kildare, Naas, and Lough Earne navigations.

The Shannon.

The Shannon river forms the most important feature in the inland navigation of Ireland. For the first 144 miles of this waterway, from the head of Lough Allen to the sea below Limerick, the

Shannon is like a series of rivers and lakes. Issuing from Lough Allen, it passes Leitrim, Carrick, Tarmonbury, &c., and then enters, at Lanesborough, a very irregularly-shaped and extensive sheet of water, called Lough Ree, about 17 miles in length. Leaving it, the river, now greatly augmented, passses Athlone, and then winds by Shannon Bridge and Banagher to Portumna, near which it expands into Lough Derg, another narrow lake, 23 miles long, with deep bays and inlets. From the southern extremity of this lake it flows on to Limerick. In this extent of navigation we have first Lough Allen, 10 miles; thence to Lough Ree, 43; Lough Ree itself, 17; thence to Lough Derg, 36; Lough Derg, 23; thence to Limerick, 15; making together 144 miles. The mean height of Lough Allen above the sea at Limerick is about 143½ feet, being on an average about a foot of declivity per mile. Instead of the natural fall, however, the water has been reduced by means of locks to a series of level pools. The estuary or frith of the Shannon extends south-west about 70 miles beyond Limerick to its mouth, which is finally about 8 miles wide between Loop Head and Kerry Head, at the Atlantic.

The direction of the Shannon from Lough Allen to Limerick, though generally south by south-west, is very circuitous, and broken by many streams, islands, and rocks. The soundings are as various, and both banks are liable to be overflowed by the river to a great extent; and the large expanse of the lakes would require a different sort of vessel from those which navigate the river. The works which have been constructed to overcome the natural difficulties of the navigation are either insufficient or in a state of decay; and it seems to be generally admitted that very little real good can be effected until the natural obstructions are removed, the number of lakes reduced, and the channel deepened and improved in various parts; though it is still doubted if the navigation would even then be suitable for anything but steam-vessels. The Shannon connects with the Royal Canal at Tarmonbury, and with the Grand Canal at Shannon harbour, near Banagher. At Shannon Bridge it receives on the west its principal tributary, the Suck; on the east, the Inny, the Upper and Lower Brosna, Mulkerna, Maig, Fergus, &c.

The Shannon river connects the tide water of the Atlantic in Limerick with Dublin by two canals, the Grand and the Royal. It passes by the towns of Limerick, Killaloe, Portumna, Banagher, Shannon Bridge, Athlone, Lanesboro', Yarmon, Roosky, Drumsna, Carrick, Leitrim, and Drumshambo.

The expenditure on the river up to 1878 was 800,738*l.* The average cost of maintenance was 3300*l.*, and the total receipts from tolls during the previous five years was 9510*l.*, being an average yearly receipt of 1902*l.* This sum, deducted from the average expenditure of 3300*l.*, left a net yearly loss of 1398*l.* At this average rate for the previous thirty years the money loss by the Shannon navigation amounts to 41,940*l.*

The depth of water for this navigation, over 7 feet to 10 feet, is maintained by eight wholly immovable weir-mounds. These weir-mounds cause inundations, damaging 24,000 acres of land. This damage during the last thirty years amounts to more than 100,000*l.* In the section between Limerick and Athlone, 68 miles, the average receipts of tolls for the five years ending 1878 was 1274*l.* Out of that sum an engineer and eighteen lock-keepers had to be paid 686*l.*, together with repairs, which left from 300*l.* to 400*l.* a year profit.

In the section above Athlone, about 80 miles, the average receipt of tolls in the same five years was 197*l.*, against the annual expenses of repairs and the salaries of an engineer and ten lock-keepers, amounting to 385*l.*

The interests of the Shannon drainage do not, in Mr. Lynam's view,* require to diminish the minimum depth of water under 5½ feet on the lock sills. These interests require merely that the surface of the river and lakes shall be kept within a range of 5½ feet to 8½ feet on the sills of all locks from Athlone to Limerick. The bye-laws made by the Board of Works for the Shannon limit the draught of boats to 4 feet 10½ inches. The river and locks are maintained by the weir-mounds at levels that rarely are less than 7½ feet on the lock sills, and rise in floods to 9 feet.

The Earne and Shannon rivers have three features which render them, in Mr. Lynam's opinion, peculiarly easy to regulate their floods, and prevent inundations. They have large superficial areas of lakes. Their channels between the lakes are wide and deep, so capacious as to carry their floods with an inclination of less than an inch a mile. Their floods rise slowly, 4 inches to 8 inches in twenty-four hours, very rarely rising 1 foot in twenty-four hours. On the Shannon, all the mill-weirs and fish-weirs have been purchased and removed, and all the shoals have been deepened at a cost of 529,716*l.* The lakes in the Lough Earne basin have an area of about 50,000 acres. The shoals and straits, which obstruct the

* 'The Engineer,' Oct. 11, 1878.

river and cause the inundations, have an aggregate length of merely 6 miles. Only one mill-weir (which is the only fish-weir) exists, and it is at the outlet, where there is a fall of 12 feet. The Shannon basin has lakes of the superficial area of 87,000 acres. In the length, from the Battle Bridge above Carrick-on-Shannon to Killaloe Bridge, of 128 miles, the lakes occupy 50½ miles; the broad, deep channel extends for 73½ miles; the confined portions of the channel occupy merely 4 miles; the portions of the channel confined so as to be visible obstructions are but 2 miles long. Neither mill-weir nor fish-weir stands in the way of the current. The floods scarcely ever rise 1 foot in twenty-four hours. The great floods are but 4 feet where deepest on the lands, and generally but 2 feet deep, and merely 18 inches deep over large areas. Many damaging floods are not more than 6 inches deep on the land.

From Lough Allen to the tide of the Atlantic Ocean at Limerick, a length of 149 miles by the sinuosities of the river, the Shannon has been made navigable for steamers with a depth of 6 feet of water. The river lies naturally in eight separate levels, but the lowest, at Limerick, is very small, and detached from the others by a length of 5 miles and a fall of 90 feet. The upper level, at the outlet from Lough Allen, has a fall of 20 feet in 6 miles. The lowest level, between Castleconnell and Killaloe, contains only 641 acres of lowland, rarely flooded in summer or autumn, and rarely covered by more than 1½ foot of water. To preserve the land from summer and autumn floods the surface of the floods must be lowered 2 feet nearly. A permanently solid embankment, used during many years for a navigation horse tow-path, extends along one side of the river, the only openings being four culverts for side drainage.

On the other side of the river there exists a natural ridge, which is a little higher than the highest floods. It is not continuous, but interrupted in five places. These circumstances are held by Mr. Lynam to "render it very easy to protect the lowlands from all floods." Very favourable sites exist for back-drains to carry off rain-water and springs. The 641 acres of lowlands may be thus protected from summer and autumn floods at a cost of 6000*l.*, being 10*l.* per acre. This would allow of winter irrigation also, which the occupiers of the lands particularly require. The system of river embankments is much objected to as dangerous, and properly so, when it is proposed to make high embankments. In this case the required embankments are in existence for seven-eighths of the required length, so permanently solid as to be absolutely safe, and the small portions to be built need not be more than 3 feet to 5 feet high. The obstructions are a rock-shoal near the middle of the length, an old bridge with narrow arches and thick piers, and a shoal of solid limestone rock at the outlet.

Minor Irish Rivers.

The Barrow River has been rendered navigable from the tideway below St. Mallins up to where it is joined by the Grand Canal at Athy Bridge, a distance of 43 miles, falling 172 feet. But from Athy to the mouth of the Barrow, in the estuary of Waterford Harbour, and through that to St. George's Channel, the distance exceeds 60 miles.

The Blackwater River, county Cork, is navigable from its mouth at Youghall up as far as the tide reaches, or at most to Cappoquin.

There is another, and smaller Blackwater, connected with the Tyrone Canal, and flowing into Lough Neagh.

The Boyne River is navigable from the Bay of Drogheda for 22 miles, up to Trim, in the last 7 miles of which it ascends from Navan 189 feet by means of locks, which are from 80 to 100 feet long and 15 feet wide.

The Corrib River and Lough, or Lake, form a navigable line, commencing at the mouth of that river, in Galway Bay, and extending from Galway town in a north-westerly direction for about 24 miles.

The Earne River and Lough, or Lake, are navigable through the lake from the upper part, where the river enters it, below Belturbet, till it leaves it again at Enniskillen, where it is obstructed by weirs; but below the isle on which that town is built the river again expands into the lower part of the lake, through which it is also navigable. Thus far the entire distance is about 30 miles, and the navigation is terminated by a fall, from which the river has a rapid course of 9 miles to Donegal Bay.

It has been proposed to construct a canal from Lough Earne, beginning near Belturbet, and to follow along the valleys of the Finn and Blackwater to Lough Neagh.

The Fergus River, county Clare, is navigable from its mouth, in the Shannon, up to Ennis, the county town.

The Foyle River is navigable for 10 miles from its mouth, in the estuary of Lough Foyle, below Londonderry, up to Strabane.

The Lagan Navigation commences in the tideway at Belfast, and proceeds mostly by the course of the rivers as far as Lisburn, from which it is continued by a canal by Hillsborough and Moira to Lough Neagh. The total length is 28 miles.

The Lee River is navigable in the tideway up to the city of Cork, and for small craft somewhat farther. Below Cork, however, the navigation is principally an arm of the sea called Cork Harbour.

The Liffey River is navigable from its mouth in Dublin Bay for about 3 miles up to Carlisle Bridge, at the farther end of the city of Dublin. From the south side of this navigable part proceeds the Grand Canal, and from the north side the Royal Canal, of which we shall presently speak.

The Limerick Navigation commences at that city, and proceeds in a north-easterly direction, partly in the Shannon and partly by canals, for 15 miles, to Killaloe, at the south end of Lough Derg.

The Moig River, county Limerick, is navigable from its mouth in the Shannon to near Adare.

The Moy River, county Mayo, is navigable for about 5 miles, from Killala Bay up to Ballina.

The Neagh Lough, or Lake, being about 20 miles long and 10 broad, is generally of sufficient depth to be navigable to a considerable extent in every direction. It communicates with Belfast by the Lagan Navigation, with the Tyrone Collieries by the Blackwater, with Antrim by the Antrim river, and southward with the sea by the Newry Navigation.

The Newry Navigation commences in the tideway of Lough Fathom, 3 miles below Newry, which it passes, and proceeds 16 miles by a canal to the Upper Bann River, in which it continues to Lough Neagh. The entire length is about 30 miles, generally in a northerly direction. This, which has always been a very imperfect navigation, was the first executed in Ireland.

The Slane, or Slaney River, is navigable from its mouth in Wexford Haven, for 14 miles, to Enniscorthy.

The Suir, or Sure River, unites with the Barrow in the estuary called Waterford Harbour, about 5 miles below the town, and is navigable from that up to Carrick for sloops, and to Clonmel for barges. At the town of Waterford the largest ships lie afloat in 40 feet water.

The Tyrone Colliery Canal commences at the south-west extremity of Lough Neagh, proceeding by a short cut across the isthmus of

Maghery to the Blackwater River, and, following it a short way, passes by another cut of 3 miles to the Colliery Basin, from which a railway extends to the mines.

The Grand Canal.

The Grand Canal was begun in 1765 by a body of subscribers; but they could not have completed the work without very large advances from Government. The canal commences at Dublin and stretches in a westerly direction, inclining a little to the south, to the Shannon, with which it unites near Banagher, a distance of 85 statute miles, and thence on the west side of the river to Ballinasloe, 4 miles distant. But, exclusive of the main trunk, there is a branch to Athy, where it joins the Barrow, a distance of about 27 miles, and there are branches to Portarlington, Mount Mellich, and some other places. There is also a westerly branch, more recently constructed, from the Shannon to Ballinasloe, about 14 miles in length. The total length of the canal, with its various branches, is about 164 English miles. Its summit elevation is 230 feet above the level of the sea at Dublin. It is 40 feet wide at the surface, from 24 to 20 feet at the bottom, has 6 feet depth of water, and cost, in all, about 2,000,000*l.* The tonnage on this canal for the eight years ending with 1837 varied from 215,000 to 237,000 tons, while the tolls varied from 33,000*l.* to 38,000*l.* The highest part of the canal rises 298 feet above sea level.

Two errors are said to have been committed in the formation of the Grand Canal; it was framed on too large a scale for that time, and it was carried too far north. Had it been 4 or 4½ feet, instead of 6 feet deep, its utility would have been but little impaired, while its expense would have been very materially diminished.

But the greatest error was in the direction of the canal. Instead of joining the Shannon about 15 miles above Lough Derg, it should have joined it below Limerick, and conversely would have avoided the difficult and dangerous navigation of the upper Shannon. The canal would then have passed through a comparatively fertile country, and it would not have been necessary to carry it across the bog of Allen, in which, says Mr. Wakefield, "the company have buried more money than would cut a spacious canal from Dublin to Limerick." The main line of the Grand Canal is 89 miles long, but there are branches to Naas, Mount Mellick, Portarlington, and other places. On the main line there are six locks, each 70 feet by 14½ feet.

The Royal Canal.

The Royal Canal was undertaken in 1789. It stretches westwards from Dublin to the Shannon, which it joins near Tormanbury. Its entire length is about 92 miles, exclusive of a branch of 5 miles, from Kilashee to Longford; its highest elevation is 307 feet above the level of the sea. At the bottom it is 24 feet wide, and it has 6 feet depth of water. It had cost, exclusive of interest on stock, loans, &c., advanced by Government, in February 1823, 1,421,954*l.* The tolls produced in 1826 25,148*l.*, the expenses of the canal for the same year being 11,912*l.*, leaving only 13,236*l.* net. The canal has paid dividends over a number of years, although not on a high scale.

This canal seems to have been wrongly planned, for throughout its whole course it is nearly parallel to, and not very distant from, the Grand Canal. There are consequently two large canals where there ought not to be more than one. It is probable that one canal of comparatively small dimensions would have been quite enough for all the business of the district, though it were much greater than it is, or is likely to become.

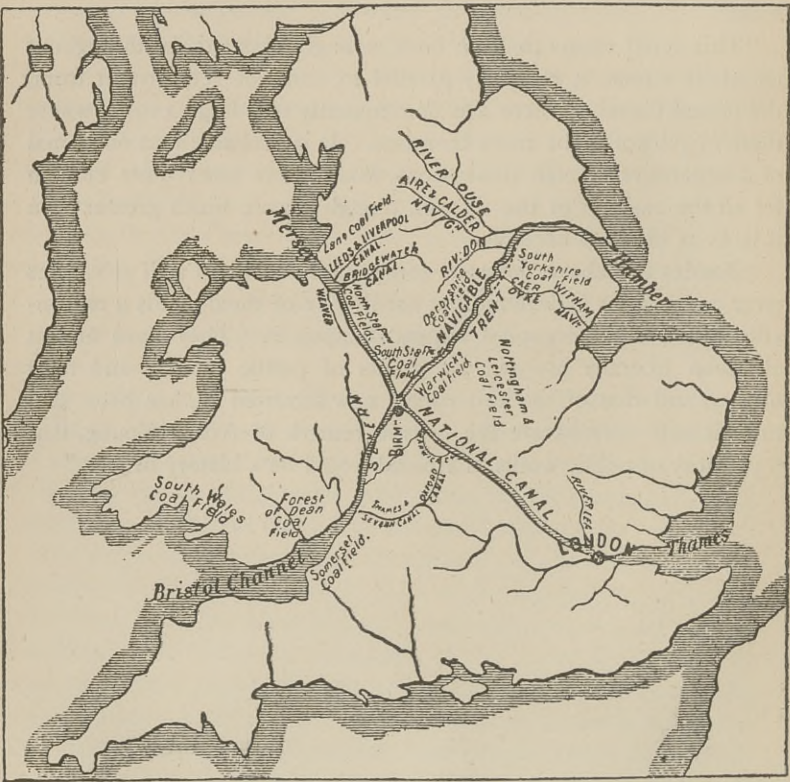
Besides the above there are some other canals, as well as various river excavations in Ireland, but hardly one of them yields a reasonable return for the capital expended upon it. They have almost all been liberally assisted by grants of public money, and their history, and that of the two canals now adverted to, has been said to strikingly corroborate the caustic remark of Arthur Young, that "a history of public works in Ireland would be a history of jobs."

CHAPTER VI.

PROJECTED CANALS IN THE UNITED KINGDOM.

"Where of late the kids had cropt the grass,
The monsters of the deep now take their place."—*Ovid.*

One of the most notable features of the engineering and commercial development of to-day is the movement, elsewhere alluded to, for



Sketch of the Proposed National Canal.

making ship canals with the view of converting inland towns into seaports. The Manchester Ship Canal, now well advanced towards completion, undoubtedly gave the first impulse and has since supplied the impetus to this movement. Whether the movement will proceed much farther than plans and prospectuses remains to be seen. But at the present moment the principal proposals affecting the United Kingdom are—

1. The construction of a National canal, passing right through from the Bristol Channel to the Humber on the one side, and from the Thames to the Mersey on the other.

2. The conversion of the existing waterways into a ship canal, between Sheffield and Goole.

3. The construction of a ship canal between the Forth and the Clyde.

4. The construction of a canal from the Irish Sea to Birkenhead through Wallesey Pool and the Wirral Peninsula.

5. The construction of a ship canal between the Mersey and the city of Birmingham, connecting with the Manchester Ship Canal and the Mersey, by way of the Weaver Navigation.

6. A canal to connect the city and district of Birmingham, with the river Trent, and thereby with the North Sea.

7. An improved waterway between the Midlands and the Thames.

8. The improvement of the Wiltshire and Berkshire canal, so as to give better inland water transport between Bristol and London.

The Forth and Clyde Canal.

The most probable, and at the same time one of the most important of the foregoing proposals, is that designed to connect the Forth with the Clyde, thereby enabling vessels of considerable tonnage to pass from the one sea to the other, without passing round the further extremity of the island. There is already a canal between the two seas, but this waterway is too contracted to be of much use for vessels of any size, and it is not, therefore, proposed to utilise the existing canal in the new scheme.

The greatest height of the present canal is 141 feet. It is crossed by about 30 drawbridges, and passes over 10 considerable aqueducts, and 30 small ones, the largest being that over the Kelvin, at Maryhill, near Glasgow. The canal is supplied with water from eight reservoirs, which cover 721 acres. The original cost of the canal was about 300,000*l.*, and 50 years after its opening the annual revenue amounted to about 100,000*l.*, and the expenditure to about

40,000*l.* In 1869, the canal passed into the possession of the Caledonian Railway Company, when, with the adjoining Monkland Canal, it was valued at 1,141,000*l.* The Caledonian Company undertook to pay an annuity of 91,333*l.*, being a guaranteed dividend of six and a quarter per cent. It was, however, like many other similar arrangements made by railway companies in Great Britain, a very bad bargain for the new proprietors, since the profits from the working of the canal are now much less than they were.

Messrs. Stevenson, of Edinburgh, who have been consulted as to the most practicable route for the proposed canal, have recommended that the canal proper should begin at Alloa on the Forth, where vessels would be raised by a lock to the level of Loch Lomond, 13 feet above high water, which would be the summit level of the canal. The canal would proceed thence along the valley of the Forth to Loch Lomond, through that loch to Tarbet, and would afterwards be carried along the narrow neck of land to Loch Long, or, alter natively, across to the opposite shore of Loch Lomond, near Arden, and thence into the Forth of Clyde, near Helensburgh. The average depth of cutting is stated at 47 feet, but there would be a heavy cutting, some three miles long and 203 feet deep on an average, which the engineers propose to make a tunnel, with 150 feet of headway. The estimated cost of the work is about 8,000,000*l.*, or much the same as the cost of the Manchester Ship Canal. The traffic is calculated at 9,516,000 tons, and it is estimated that at 1*s.* 6*d.* per ton, this traffic would yield a gross annual income of 713,748*l.* which would be sufficient to yield 8 per cent. after deducting working expenses, &c. It is proposed to make the canal 30 feet deep, and 72 feet wide at the bottom.

And the route has been recommended for the proposed ship canal, which is termed the direct route, and which is 27 miles shorter from Greenock than the proposed Loch Lomond route *via* Tarbet. This route would start from the Clyde at a point near to Whiteinch, join the line of the present Forth and Clyde Canal near Maryhill, and thereafter proceed in the same direction to the junction of the canal with the Firth of Forth. The shorter route would, however, be the most difficult, inasmuch as there is a very steep hill immediately after leaving the Clyde, between Whiteinch and Maryhill. The height to be surmounted here is not less than 150 feet; and for a ship canal, which ought to be a tide-level waterway, in order to be satisfactory, this would be a serious drawback.

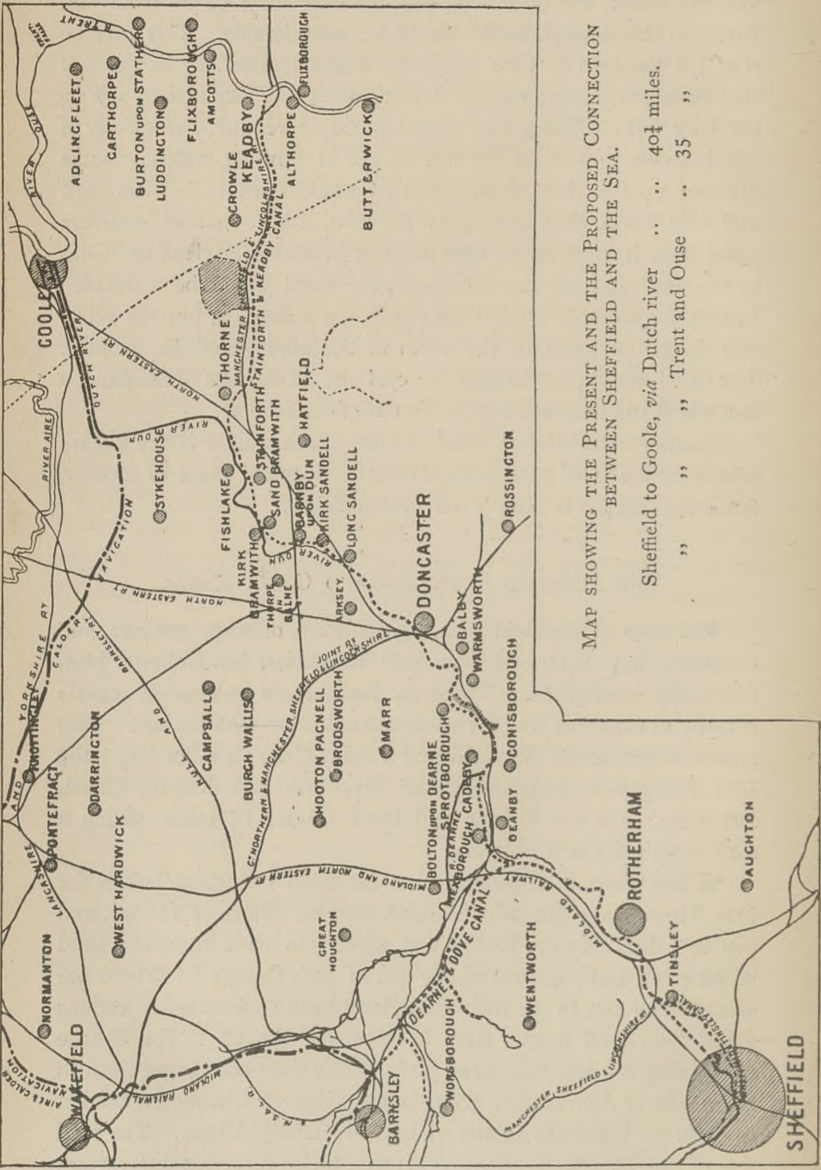
It is contended that, being the shortest route between America and the Baltic, the Continent, and the east coast of Scotland and England, the through traffic would be considerable. This may be true, but the gain in time would be reduced materially by the fact that vessels in coming off the Atlantic would be required to sail up the long forth (Clyde), and would probably require, particularly if deeply laden, to wait on the tide to get to Bowling, which is some distance up the river, or the channel would need to be deepened and broadened, thus adding to the cost. For channel steamers going from Ireland, or the west coast of Scotland, England or Wales to the east coast or the Continent, the canal would be a decided benefit, for not only would their voyage be shortened, but the rocky and dangerous coast of the north of Scotland would be avoided. The canal would pass through the coal and oil districts of Scotland, a fact which has been adduced in favour of the scheme.

Another consideration which carries much weight is the facility gained for the rapid passage of battleships from one shore to another, rendering defence in time of war more effective.

The Proposed Sheffield and Goole Canal.

The town of Sheffield, with a population of some 300,000, and extremely important and diversified industries, has hitherto been practically landlocked. There is, however, a system of canals actually in existence which gives communication with the sea. This system embraces the Sheffield and Tinsley Canal, 4 miles long; the Dun Navigation, 28¼ miles; the Stainforth and Keadby Canal, 12¾ miles; and the Dearne and Dove Canal, 14 miles, giving a total of 59 miles of navigation.

In this chain of communication the most important link is the Dun River Navigation, which begins near the village of Tinsley, and proceeds thence by the Tinsley Cut, which was made to avoid a bend in the river, under powers of the Act of 12th George I. There are several other cuts in the river which have been constructed at various times, their total length, from Mexborough Church to the Dearne river, being not less than 2220 yards. The river has passed through the hands of Vermueden, who, in the reign of Charles I., used it to drain the low lands in the vicinity of Hatfield Chase. The total rise of the Dun Navigation, by sixteen locks, from low-water mark in the river, is 92¼ feet. Writing in 1831, Priestley stated that "the



MAP SHOWING THE PRESENT AND THE PROPOSED CONNECTION BETWEEN SHEFFIELD AND THE SEA.

Sheffield to Goole, *via* Dutch river .. .. $40\frac{1}{4}$ miles.

,, ,, ,, Trent and Ouse .. 35 ,,

Dun Navigation is of the utmost importance for exporting the produce of the extensive coal and iron works which abound at its western extremity; also, the vast quantity of manufactured iron goods and cutlery which is annually produced in the populous town and neighbourhood of Sheffield." This, however, was before the present system of railways was completed, and before the waterways on this route fell into the hands of their great rivals. Not more than half a million tons now annually pass through the port of Keadby, which is the connecting point between the Dun Navigation and the Stainforth and Keadby Canal, the latter being a continuation thereof, and the river Trent.

It is not proposed to do more than improve the existing navigations to the extent of enabling them to take barges with a carrying capacity of 700 tons, and sea-going steamers capable of carrying 300 to 400 tons, whereas at present they cannot carry boats of more than 80 tons. Such vessels could carry coal cargoes from the South Yorkshire collieries situated upon this waterway, and London or any other large consuming centre on the British shores. The existing waterways are, however, in the hands of the Manchester, Sheffield, and Lincolnshire Railway Company, which, of course, will have to be consulted as to their acquisition. The accompanying diagram shows the route of the proposed improved navigation.

The Proposed Irish Sea and Birkenhead Ship Canal.

A company was established in 1888 for the purpose of cutting a canal, through the Wallasey Pool, from the Irish Sea to Birkenhead, The object of this undertaking is to improve the approach to the port of Liverpool, which is at present greatly prejudiced by the shifty channel, the numerous sandbanks on either side of the bar, and the risks and delays that are thereby entailed. The scheme is not a new one entirely. On the contrary, Telford, Nimmo, and Robert Stephenson, in 1838, reported upon a kindred project, and estimated its cost at 1,400,000*l.* The sum named, however, was too much for the promoters to raise, and a modified plan was submitted, calculated to cost about half the money. The Corporation of Liverpool, however, opposed the scheme, and privately bought up the land on either side of the Wallasey Pool, with a view to frustrate its accomplishment. Telford's plans have, however, quite recently been revived, and it is now proposed to make a cut from an arm of the Wallasey

Pool—which, running for about half a mile inland, has, notwithstanding the enormous extension of dock accommodation all around, been left in its natural condition—to the west end of the Leasowe embankment, near Dove Point, whence a tidal channel would be formed through the foreshore to the Rock Channel, the ancient entrance to the port of Liverpool. This tidal channel would be protected by a breakwater running from the Leasowe embankment to a point in the Rock Channel west of the Dove Spit. An outer breakwater would also run in an easterly and south-easterly direction for a distance of 5000 feet, sheltering the greater part of the Rock Channel, which is to be dredged for upwards of a mile to a depth of 30 feet below low-water mark. The scheme does not appear to be either difficult or costly, but as it is objected to by the Corporation of Liverpool and by the Mersey Harbour Board, it may not come to maturity. That it would, if carried out, be a great convenience to the many thousands who annually arrive at or depart from Liverpool for the United States and other countries, is sufficiently manifest.

The Canal Connection between London and Bristol.

The Wiltshire and Berkshire Canal was acquired by some capitalists towards the close of 1889, with a view to working it in competition with the Great Western Railway between London and Bristol. The canal in question leaves the Kennett and Avon Canal at Semington, a few miles on the Bristol side of Devizes, and proceeds thence through Melksham, Wootton Bassett, Swindon, and Challow to the Thames at Abingdon. Although the Kennett and Avon Canal, which joins the Thames at Reading, is 23 miles shorter between London and Avonmouth, it labours under the disadvantage of rising to a much greater height, and therefore requiring twenty-eight additional locks. It is also proposed to develop the Thames and Severn Canal, which is connected by a short branch from Swindon, through Cricklade, with the Wiltshire and Berkshire.

During the year 1888 attention was called to a project for the union of the Bristol and English Channels by a ship canal, running from Stolford, near Bridgwater, which has the advantage of being opposite Cardiff, *viâ* Bridgwater, Taunton, and Exeter, to Langstone Point, on the west side of Exmouth Bight, where the southern harbour would be formed.

This route is described as offering every facility for the work, the chief elevation, White Ball Hill, which is 536 feet high, being turned by following the course of the old Great Western Canal. A part of the existing canals, or their remains, and the floating basin at Exeter, with its 5½ miles of canal to the Exe, are intended to be acquired, and the deepest cutting on the whole system will not exceed 200 feet. The canal would be on the level of the sea, taking its supply chiefly from that source, with sea-locks only at each end. The dimensions proposed are: length, 62 miles; width at surface, 125 feet, at bottom, 36 feet; and depth 21 feet, the figures being much the same as those of the ship canal from Amsterdam to the Helder, which admits loaded vessels of 1000 to 1500 tons, drawing 18 feet. Coal from South Wales and adjoining fields would be likely to provide a large revenue for a short cut to the English Channel, and thence to London, say 355 miles, in order to better compete with the North of England. The cost of the scheme has been set down at 3,080,000*l.*

Proposed Waterways from Birmingham to the Sea.

Of all the towns in the United Kingdom that labour under the disadvantage of being remote from the sea, none are so entirely excluded from sea competition as the capital of the Midlands. Birmingham is unlike most of the other cities and towns of the country in this respect, that it is neither built upon a navigable river, nor upon any other waterway that would be likely to secure for traders some relief from their almost abject dependence upon railway transport. And yet the town and district of Birmingham are not altogether without the means of water transport. The locality is, in point of fact, the centre of a network of canals, which, if they were properly adapted to its requirements, would place it in direct communication by water with all the principal ports and markets in the kingdom. By the Birmingham, Warwick and Birmingham, Warwick and Napton, Oxford, Grand Junction, and Regent's Canals it is placed in communication with the metropolis, although the distance is 163½ miles, as against only 100 miles by the shortest railway route. It has two similar routes to the great port of Liverpool—the first by the Birmingham, Staffordshire and Worcestershire, North Staffordshire, and Bridgwater Canals, and the river Mersey; the second route by the same route as regards the Birmingham Canal, and thence *viâ* the Staffordshire and Worcestershire Canal for a mile and a quarter, until the Shropshire Canal is broached, when the route is continued over this waterway for a distance of 68 miles, until the Mersey is reached. The distance by the first of these routes is 106½, and by the second only 89¼ miles, against 90 miles by railway. Hull is in water communication with Birmingham by way of the Birmingham, the Coventry, and the North Staffordshire Canals, and thence by the open navigation of the Trent and the Humber for a distance of 120½ miles. Finally, Birmingham has three separate water routes to the Severn ports, all of them terminating in the Gloucester and Berkeley section, after traversing the Severn for 30 to 44 miles—the entire distance being 86 miles in two cases, and 95 miles in another. The nearest means of getting at the sea available at present to the people of Birmingham is, therefore, 86 miles. But neither this nor any of the other routes indicated are of any real value to the Midlands, owing to the limited size of the canals, and the difficulty of working them as an unbroken chain of communication. Thus, taking the water route to London, the three first canals—the Birmingham, the Warwick and Birmingham, and the Warwick and Napton—have locks only 72 feet long by 7 feet broad and 4 feet draft. On the section of the Oxford Canal to be passed over, only 5 miles in length, there is no lock, but on the Grand Junction Canal, which has to be traversed for a distance of 101 miles, the locks are 14 feet by 6 feet by 4 feet 6 inches, and on the Regent's Canal, where the transport terminates, the locks are 90 feet by 15 feet by 5 feet. The same condition of things applies to the physical characteristics of the waterways between Birmingham and Liverpool. Hull might be more readily reached if only the Trent were a little deeper, but as the average draft of the locks on that waterway does not exceed 3 feet 6 inches, it is clear that no vessel of large size could navigate it, and to dredge it to a reasonable depth for the whole distance of 102 miles would be a most serious undertaking. The most promising means of reaching the sea are therefore those provided by the Severn route. The river itself is available for the greater part of the distance on this route in one case, after traversing 26 miles of canal on the Birmingham, Stourbridge, and Staffordshire and Worcestershire systems. The average depths of the locks on the Severn over the 44 miles that it has to be navigated by this route is about 6 feet, while they are 99 feet long and 20 feet wide. These dimensions would allow of the passage of really good-sized boats, but as it is, with the broken gauge of the other canals, no boat can pass through to the Severn loaded beyond 33 tons. Another matter that seriously militates against the water facilities of Birmingham is that the different canals are, of course, under different administrations, and each authority levies tolls capriciously and disproportionately to the distance traversed and facilities afforded. Thus, it was given in evidence before the Canal Committee of 1883 * that the Birmingham Canal Company charged in respect of bricks $11\frac{1}{4}d.$ per ton for $6\frac{3}{4}$ or 7 miles, whereas the adjoining Warwick Canal Company charged $6\frac{1}{2}d.$ for $37\frac{1}{4}$ miles, and the Grand Junction Canal Company only charged 1*s.* $4\frac{1}{2}d.$ for 101 miles.

At different times during the last two or three years proposals have been put forward, having for their object to place Birmingham in direct connection with the sea, either—

1. By a ship canal, that would enable vessels of 200 tons at least to proceed to the Bristol Channel.

2. By a canal that would enable canal boats to navigate the lower Trent to the North Sea; and

3. By the construction of an improved canal, between the Midlands and London.

Each of these routes has been canvassed and considered over the last few years; and it is probable that some really effectual steps will be taken before long, in order to realise the long cherished and most desirable end of giving Birmingham a satisfactory outlet to the sea. The people of the Midlands have really been more active in this direction than those of any other locality. But they have apparently sought too much from the State and trusted too little to themselves. The Birmingham Town Council, in 1888, appointed a committee, with instructions either to get clauses introduced into the Railway Rates Bill, then under consideration, or to introduce a separate measure with a view to the formation of Canal Trusts, &c. In May of 1889, again, the Midlands sent a deputation to the Board of Trade, in order to urge upon that department, the desirability of improving the canal communication, between the Midlands and the sea. Besides this, the traders and manufacturers of Birmingham, have met and passed resolutions, calling upon the Government to inquire into the canal system without delay, with a view to its acquisition by the State. More real good would be done if the money were subscribed, to open up a first class waterway to the sea, as has been done, with so much spirit, by the people of Lancashire. Whether this waterway

* Report, Q. 251.

should connect with London, with Bristol, or with the Mersey, or whether it would be worth while to incur the expenditure required to connect all three, is a matter that would have to be very carefully considered.

As regards the proposal to provide an improved canal, between London and Birmingham, it is suggested that it should have a minimum top width of 45 feet, and a depth of 8 feet. The number of locks proposed is 90 instead of 154, but by adopting a partially new route, so as to avoid the depression in crossing the valley of the Avon, at Warwick, the number may be reduced to 75. The time of transit between Birmingham and London would thereby be shortened by 12 hours, and it is estimated that the additional facilities afforded for the passage of steam-tugged trains of boats, would enable the cost of haulage to be reduced nearly one-half. The carrying capacity of the improved canal has been put at two millions of tons annually, and the cost of the improvements at a million and a quarter. A committee of traders in the Midlands has recently had this project under consideration.

CHAPTER VII.

THE WATERWAYS OF FRANCE.

WITHIN recent years, the advocates of water transport in Great Britain and other countries, have been accustomed to point to France as a notable example of the advantages of improving and extending the internal navigations of a country. It is true that no nation has done more with this end in view. From first to last, France has expended a larger sum on canal navigation than any other nation. Her system of water transport is also in some respects more complete than that of any other country, having been designed and carried out upon a systematic plan, which permits of the ways of water communication being connected with each other, and with the chief centres of population and industry. The waterways of France, are, moreover, mainly owned by, or under the control of the State, which has instituted elaborate inquiries from time to time into the subject of their development and utilisation. It cannot, nevertheless, be claimed for the canals of France, as a rule, that they present any unusual economic or engineering features, although they provide for a low cost of transport, of which we shall have more to say when we come to deal especially with that branch of our subject.

A glance at a canal and river map of France, is sufficient to show that in the more important parts of the country, there is a very excellent system of communication by water. Between Dunkerque, Gravelines, and Paris, there is a large traffic carried to the latter city, through an elaborate system of main and lateral canals. The river Seine connects Paris with the ports of Havre and Rouen. From the Belgian frontier, quite a network of canals connect with Paris; and on the German frontier, near Nancy, the Canal de la Marne au de Rhin gives access to the capital, both by the Marne river to the Seine, and by the Oise, through the Aisne canal.

On the Mediterranean seaboard, the Canal du Midi connects with the Canal des Etangs and the Canal de Beaucaire, and thence by the Rhône and Saône, the Canal du Centre, the Canal de Briare, the Canal de Loing, and the Seine to Paris, taking Lyons, Chalons, Dijon, Nivers, and other important towns *en route.* In the south of France, the only important canal is that of the Midi, which connects Bordeaux with Cette; and on the west, the ports of Brest and St. Nazaire are connected with the main line of communication already described—the former by the Canal de Nantes à Brest, and the latter by the Loire river, the Canal Noyers du Berry, and the Canal d'Orleans. It is, however, on the north that the canal system has its greatest development, and especially on the Belgian frontier. The system has been contrived to meet the requirements of all the populous places on the line of route, so that it is very far from having been arranged to save time and distance. This, however, is no disadvantage in cases where density of traffic was the point to be kept in view. Some of the canals have at one end no outlet or through communication. The Canal du Berry, for example, terminates abruptly at Montluçon, the Canal de Roanne à Dijon at Roanne, and the Canal de l'Ourcq at Port-aux-Perches, but this is very exceptional. The system is generally designed to enable one waterway to give immediate access to another, so that through routes are the most characteristic and valuable feature which it presents.

The very elaborate statistics which the French people make it their business to collect relative to all their mundane affairs enable us to obtain information as to the character of the traffic on French waterways, and the conditions of its movement, that are not accessible for most other countries. In order that some light may be thrown upon the problem of "how they manage these things in France," we have been at some pains to get together the most important *data* bearing on the subject:

Imprimis, then, it appears that the total tonnage carried on the canals of France in 1887—there are no returns yet issued for a later year—was 21,050,180 tons. As this traffic was carried for a total distance of 1762 millions of miles, it follows that the average distance over which each ton was carried was 84 miles.

It is interesting to compare these returns with the corresponding returns for the French railways, which carried 80,360,000 tons for a total distance of 6801 millions of miles, giving an average transport or lead of 84½ miles per ton.

There are no detailed returns at command of the amount of expenditure at which the traffic on the waterways of France has been carried on. In the nature of the case, indeed, there could hardly be such information, seeing that the rivers, and to a large extent the canals as well, are free of tolls, and the expenses of haulage will vary in every case, according to the means employed, and other determining circumstances. On the French railway system, however, the average rate charged for the transport of goods per ton per mile amounted in 1887 to less than 0·9*d.*, taking the eight great companies as a whole.*

Roughly, therefore, the average distance over which each ton was transported on the waterways and railways of France was almost exactly the same, but the railways carried almost four times as much traffic as the waterways. This difference applied almost as much to heavy as to light traffic. The total quantity of coal and coke carried on the waterways was 5,964,000 tons, while on the railways it amounted to 22,395,000 tons, being again nearly four times as much.

The total length of the canals of France in 1887 was 4759 kilometres, or 2998 miles. The average number of tons carried for each mile of canal constructed was, therefore, 4005. The railways of France had, at the same time, a length of 28,922 kilometres, or 18,095 miles, and the average number of tons carried per mile was about 4400. The French waterways, therefore, had a somewhat less density of traffic than the railways.

Many of the canals of France, however, have almost ceased to be used, and their traffic has become so small that it is hardly worth reckoning.

In the case of Paris, the second largest city in Europe, the total quantity of traffic brought within the municipal bounds for the use of the inhabitants amounted, in 1886, to 9,412,589 tons, of which 60 per cent. was received by railway and 40 per cent. by waterways. Of the traffic sent out from Paris, amounting to 2,989,000 tons, 80 per cent. was despatched by rail, and 20 per cent. by water.† In reference to the traffic entering Paris, it would seem as if the waterways competed with some measure of success with the railways, but

* This does not include the six small companies, whose united lines only make up 217 kilometres, nor the *reseau de l'Etat*, which has 2164 kilometres more. Over the latter system the number of tons carried one mile was 133 millions, and the receipts therefrom amounted to about 12 millions of francs, which corresponds to an average of 0·91*d.* per ton per mile, showing that the independent companies carry traffic cheaper than the State lines.

† 'Bulletin du Ministère des Travaux Publics,' Tome xviii. p. 329.

as regards the traffic sent out from Paris, the railway is by no means so successful.

The waterways that give access to Paris are mainly the High Seine, the Low Seine, and the Canal de l'Ourcq. The Seine carried 1,979.000 tons to Paris in 1886, as compared with 1,791,000 tons carried on the canals as a whole.

These are the broad general facts of the situation in which Paris is placed as regards her supplies of food, fuel, and other requirements. The details of the movement of this traffic are equally interesting, but we have no space to devote to them here. We may, however, remark that from every part of the empire, from Belgium and the Ardennes, from the north and the east, from Marseilles on the one hand and from Rouen and Havre on the other, the traffic on which Paris is dependent from day to day is carried as well by waterways as by railways. From the coal basins of the Nord and of the Pas-de-Calais the waterways carry almost as much fuel to Paris as the railways; from the basins of the Loire and of the Centre they carry much more. Belgium, again, sends a large proportion of the total quantity of coal that she supplies to Paris by water, but German and English coal is received mainly by rail.*

It would be interesting to compare the quantities of merchandise and food supplies of all kinds received by water and by rail in different large centres of population, but the materials do not exist for a very exact comparison over a wide area. In no English city can such materials be obtained, inasmuch as no record is available of the different quantities that constitute the transit trade; but in several German cities there are more accurate materials at command, and the

* The proportions of the total coal supply of 3,065,800 tons received by Paris in 1886 were contributed thus :—

	By Water.	By Rail.
	tons.	tons.
French coal	839,200	889,700
Belgian ,, ...	402,300	557,200
English ,, ...	26,700	191,100
German ,, ...	26,400	133,200
Totals	1,294,600	1,771,200

following figures show how the import traffic of Paris compares with that of some German towns for the year 1887 :—

Tonnage brought into	By Rail.	By Water.
	tons.	tons.
Paris	5,647,000	3,765,000
Berlin	3,504,000	3,348,002
Hamburg	1,191,000	3,221,000
Cologne	1,132,000	314,000
Magdeburg..	1,650,000	1,118,000
Total	13,124,000	11,766,000

During the year 1886 the traffic of the port of Paris amounted to a total of 5,455,000 tons, which was transported in 35,291 boats. The boats thus carried an average of about 155 tons.* This, however, was composed of a considerable range of variations, the boats from the Sambre, on the canal of that name, carrying an average of 216 tons, while those on the canals of the Aisne and the Ardennes only carried about 55 tons. On the Seine, from Oise to Paris, the average size of the boats was 166 tons.

More than a fourth of the water-traffic entering Paris belongs to the Ourcq Canal, which is connected with the Marne and with the Seine, both above and below Paris, by means of the St. Martin and the St. Denis Canals. These and the Ourcq Canals belong to the Municipality of Paris, which has recently increased the width of the swing bridge across the canal from 25½ to 50 feet, and has provided an uniform depth of 10½ feet.

According to an interesting statement issued by the French Minister of Public Works in 1880,† the length of the canals then constructed in France was 2882 miles, of which 2248 miles were described as principal lines, and cost about 10,300*l.* per mile, while 634 miles were secondary lines, and cost 7200*l.* per mile. The total amount expended on canals of both categories was about thirty-three millions sterling.

* It is interesting to compare, or rather contrast, this with the traffic of the port of London, where, in 1888, the entrances of shipping amounted to close on 12½ millions of tons, carried in 49,213 vessels, the average tonnage being over 700 tons.

† 'Album de Statistique Graphique.'

There were besides, 4598 miles of rivers which had been adapted, by canalisation or otherwise, for purposes of navigation, at a total cost of about 11½ millions sterling. About 1398 miles of river routes were classed as principal lines, and upon these an expenditure of 7,918,000*l.* had been undertaken, or about 5700*l.* per mile. About 3200 miles more were classed as secondary lines, and had been improved for navigation at a total cost of 3,561,000*l.*, or 1113*l.* per mile. On both canals and rivers the total amount expended had been over 44 millions sterling. Besides this, however, 190 miles of additional waterways had, up to 1880, been constructed and improved, at an additional cost of 3,400,000*l.*, and were described as new waterways; and it may be added that, up to the same date, about 19¾ millions sterling had been expended on the ports of France, especially those of Havre (3,300,000*l.*), Marseilles (2,800,000*l.*), St. Nazaire (1,100,000*l.*), and Bordeaux (960,000*l.*).

These figures appear large, but while it may very well be that the amount expended upon canals *pur et simple* has been greater in France than in our own and other countries, the expenditure upon the rivers of France and upon the improvement of ports and harbours is very greatly below that incurred in our own country. At Liverpool alone the sums expended in this direction from first to last will probably exceed the total amount expended upon the harbours of France up to the present time. France is, however, so fully aware of the importance of providing good shipping facilities, that she has quite recently undertaken a large expenditure in improving the harbours of Havre and Calais, canalising the Seine, and other similar works.

At the end of 1886, there were thirty-one chief canals in operation in France having a total length of 3267 kilometres, and 1446 kilometres of smaller canals, making a total of 4713 kilometres. The canals varied in their volume of annual traffic from over 3½ millions of tons each on the Deûle (Haute) canal, 63 kilometres in length, and on the St. Quentin canal, 93 kilometres in length, to 243,700 tons on the *Latéral à la Garonne*, 204 kilometres in length. The total traffic carried on the canals from year to year has been remarkably constant.* The canals have, moreover, carried a considerably larger quantity of traffic than the rivers of France, notwithstanding that the latter have a total length of 7825 kilometres, or

* Traffic on French canals :—1883, 11,975,000 tons ; 1884, 11,936,000 tons ; 1885, 11,102,000 tons ; 1886, 12,027,000 tons.

66 per cent. more, and that one or two of them, especially the Aisne and the Oise have been specially canalised.*

The waterways of France are classified by basins, and according to the statistics published for 1886, the number of waterways in each basin with the number of vessels of all kinds making use of them, and the number of tons transported were as under :—

French Rivers and Streams only (Canals not included).

Basin of the	Number of Lines.	Total Length in Kilometres.	Number of Vessels employed in 1886.	Tons of Traffic carried.
Aa	1	29	12,778	1,308,564
Adour	9	257	19,903	423,666
Charcute	8	301	20,169	239,069
Escaut	8	219	42,242	8,184,233
Garonne	25	1752	30,952	1,096,482
Loire	22	1660	17,669	1,084,542
Moselle	6	231	1,601	200,980
Rance	1	16	1,832	66,498
Rhone	22	1731	25,799	2,358,675
Sambre	1	54	2,589	580,761
Seine	18	1191	102,117	18,843,313
Vilaine	4	151	4,450	216,601
Vire and Taute	3	113	6,494	111,207

We may now appropriately follow up the more general information already afforded by some details as to the history and topography of the chief canals and river works in France.

Some French Canals.

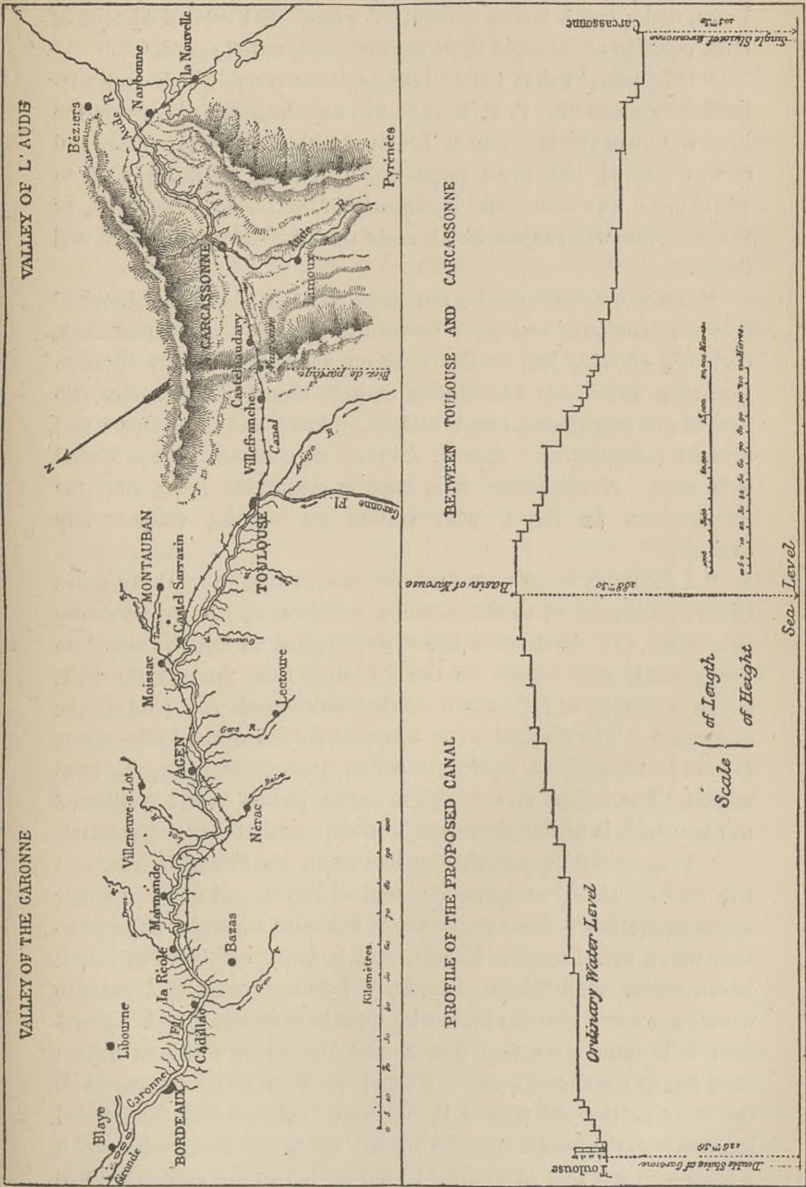
Briare, &c.—The canal of Briare was begun in the time of Henry IV. and the Duke of Sully, and was completed under Louis XIII. and Cardinal Richelieu. Its length is eleven French leagues, and it forms a communication between the Loire and the Loing, which is one of the tributaries of the Seine. Under Louis XIV. another canal was drawn from the Loire, near Orleans, which flowed to

* Traffic on French rivers:—1883, 8,873,000 tons; 1884, 8,936,000 tons; 1885, 8,353,000 tons; 1886, 8,950,000.

meet the first canal of Briare, near Montargis; and as in summer there was an insufficiency of water in the Loing to supply a considerable navigation, under the minority of Louis XV. they determined to run another canal along the banks of the river to the vicinity of the Seine, which is, properly speaking, the continuation of the old canal of Briare. In this canal there are, in all, forty-two sluices; and in that of Orleans, twenty. In the reign of Louis XV., and under the inspection of the celebrated Belidor, the canal of Picardie was carried out, forming a junction between the Somme and the Oise, which afterwards enters the Seine about five leagues from Paris.

Languedoc.—The famous canal of Languedoc, better known as the Canal du Midi, which forms a communication from the Mediterranean Sea to the Garonne and the Ocean is one of the best known in France. By this canal, for many years, boats have passed in a few days from the one sea to the other, traversing valleys and hills, and ascending to the height of 600 feet above the level of the two seas. The harbours of Bordeaux and Marseilles formerly avoided, by this means, a circuitous route of communication of several hundred miles. This great undertaking, projected under three other kings, was at last perfected in the reign of Louis XIV., after a labour of fourteen years, at an expense of eleven millions of livres, without reckoning the additional expense of two millions more, incurred in re-establishing the harbour of Cette. Andressi first suggested the plan, and Riquet directed almost the whole of its execution. He began the work in 1666. The canal begins at a lake nearly four miles in circumference, which, collecting the waters of Mont Noir, conveys them at Naurose into a reservoir, of very considerable extent, whence the waters are distributed to the right until they meet the Garonne near Toulouse, and to the left as far as the Lake of Tau, which is near the port of Cette. The breadth of the canal is 30 feet, its length is rather over 125 miles, which equals 50½ French leagues. Nearly a sixth part of the canal is carried over mountains deeply excavated; and, at a spot called the Mal Pas, it crosses a rock cut into the form of an arch, eighty toises in length, four toises in width, and four and a half in height. It has one hundred sluices, and a great number of aqueducts and bridges.

Admiral Lord Clarence Paget undertook, in 1881, a canal voyage through this Canal, of which he has supplied some interesting


VALLEY OF THE GARONNE
VALLEY OF L' AUDE
Béziers
Narbonne
La Nouvelle
Aude R.
Pyrénées
CARCASSONNE
Limoux
Castelnaudary
Villefranche
Canal
Ariège R.
Garonne Fl.
TOULOUSE
MONTAUBAN
Castel Sarrazin
Moissac
Lectoure
Gers R.
AGEN
Villeneuve-s-Lot
Nérac
Marmande
Bazas
La Réole
Libourne
Cadillac
Caronne
Blaye
Gironde
BORDEAUX
Kilomètres
PROFILE OF THE PROPOSED CANAL BETWEEN TOULOUSE AND CARCASSONNE
Carcassonne
Basin of Naurouse
Sea Level
Ordinary Water Level
Scale { of Length / of Height
Toulouse

particulars. The yacht, the *Miranda*, was 85 feet over all, 11 feet beam, and 4 feet 8 inches draught of water. She carried 6½ tons of coal, equal to about eight days' consumption, at full speed.

"Originally," writes Lord Clarence, "the canal, which immortalised its constructor, P. P. Riquet, was only intended to connect the head waters of the Garonne at Toulouse with the Mediterranean, and it was opened with great pomp and ceremony by Louis XIV. in 1681, but it was soon found inadequate to the purposes required, as the Garonne was subject to all sorts of vicissitudes of drought and floods.

"It was not, however, till our own times that the 'Canal Lateral,' between Toulouse and near Bordeaux, has been completed, and, curiously enough, just at the moment when the railway between Bordeaux and Cette has almost entirely absorbed the traffic. So here is this magnificent canal, with its 99 locks and its viaducts and bridges comparatively unused, save by an occasional barge loaded with wine. Nevertheless, it is kept in admirable order, and the passage can be made, with certain precautions, without any difficulty.

"A pleasant, though not very picturesque voyage of thirty miles of river, brought us to the entrance of the canal. It was necessary to put on our canal screw before entering, so we laid the vessel on the ground, and entered on the following tide, through the lock, which is double, or rather twin, so that two vessels can pass at the same time. The dimensions of this, and indeed all the locks, are as follows:—Length, 28 metres; breadth, 5·80 metres; depth, 1·60 metres The height of the bridges varies, but no vessel is allowed to pass which is higher above the level of the canal than 2·72 metres.

"Thus, it will be seen that we had about six feet of length, and five feet of width, to spare, one foot of height, and one foot under our bottom; nor is this by any means too large a margin, since, however well a vessel may be steered, and however quickly stopped, it is impossible at all times, particularly if there be a strong breeze, to ensure her entry into the locks with exactly sufficient speed. Moreover it is quite necessary that a boat should be afloat, to make a rope fast to the shore, where the canal has very sharp curves, as is the case in the old part of it, between Toulouse and Cette; and inasmuch as the boat cannot be hoisted up to davits or inboards, it will be manifest that room must be left for her in the lock. We had just room under the stern for one 13 feet boat athwart. The safe passage through the first lock and under the first bridge caused us pleasant anticipations.

"We were satisfied to have accomplished our first lock, and made fast opposite the house of the 'Chef du Section,' of which there are seven on the canal. He and his lady paid us a visit, as did the curé and principal inhabitants of La Reole. Next morning, the 28th, we fairly tackled the business, and accomplished that day eleven locks, stopping at Buzet. It would be tedious to describe our daily routine, and I need only remark that we took advantage of all the daylight—at this season only about 8½ hours—and accomplished some 35 to 40 miles per day, always ascending, till we arrived at Toulouse on the sixth day. This 'Canal Lateral' follows much the course of the Garonne. It is a splendid work, and is kept in beautiful order. The grand features are the bridges which carry the canal across the Garonne and other rivers. There are three, but by far the grandest and most interesting is that at Agen, where we found ourselves in mid-air, with the river, the railway, the high road, and part of the town far beneath us. The centre arch is a hundred feet high. After leaving Agen, the scenery became picturesque, and sometimes grand; but to really enjoy this trip it should be taken before the fall of the leaf. The whole length of the canal is lined on either side by poplar, plane, and other trees, many of them of great height, so as almost to shade the vessels passing. The locks are admirably managed, and it is surprising how little delay they cause—always supposing that there is no vessel to take precedence; but whether by chance, or that orders had been sent on to keep the road clear, we were rarely detained, and the average time in passing through was about five minutes. As we approached Toulouse, the air became keen and the nights frosty. Our 'Chef du Section,' who always accompanied us, informed me that some years since the canal was frozen up in the middle of December, and we consequently delayed as little as possible, and only spent a couple of days at Toulouse, which I regretted, as, besides being a pretty town, it is especially interesting as being the grand central depot of the canal, and the junction with the old 'Canal du Midi,' a name which has outlived the original title of Louis XIV., who christened it 'Canal de Languedoc.' Here, or rather a few miles to the eastward, are the numerous reservoirs and alimentary canals which bring the waters from the 'Montagnes Noires.' We could not stop to see them in detail, but could trace their outline far away in the distance.

"When the celebrated engineer, Vauban, came to inspect these works, he was astonished, and exclaimed that one thing was wanting only, namely, a monument and statue to the founder. This has since been rectified, and a grand obelisk is visible at the source of the canal. The story of Pierre Paul Riquet is that of many, nay, of most, great patriots. He met with scant assistance from the Government, and strenuous opposition from his countrymen; he was treated as a madman, and died of a broken heart before the great work was finished. His career seems to have been very similar to that of an illustrious man of our own day—Lesseps—save and except that the latter, happily, has been spared to see the final achievement of his splendid work.* He had, however, one attribute which is not common among inventors—he knew how to strike a bargain; and his contract still enriches several families, his descendants, especially the Caramans.

"On December 5th, we arrived at the summit of the canal, and it was interesting to observe the alimentation going both ways. Here the whole character and structure of the works change; instead of many miles of straight reaches of uniform width of about 100 feet, the canal becomes tortuous to a degree which is almost absurd, but which is accounted for by the fact that, in Riquet's day there was no law 'd'expropriation,' and he had to make a bargain with every little landowner for permission to pass through his grounds, and being in many cases refused, he had to cut away in another, and often opposite direction. The locks here are also peculiar, being oval-shaped, to admit of two abreast; the effect of this is, that although on the map, Toulouse is at least two-thirds of the distance from Bordeaux to Cette, it is, by the canal, not quite half-way.

"These sharp curves are inconvenient, as it is necessary to turn the corners very slowly, for fear of running into vessels coming in the opposite direction, and often they are so very acute as to necessitate stopping the engines and using poles, and sometimes ropes, to get round the corners.

"Another peculiar feature of this part of the canal is the constant recurrence of multiple locks. On the first approach to double, treble, quadruple, and even quintuple locks, one feels somewhat like going

* Lord Clarence Paget here refers, of course, to the Suez Canal, since the Panama Canal, which is dealt with elsewhere in this volume, is in quite a different category.

over a precipice, but this soon wears off, and in reality, the ground is got over quicker than with single locks.

"The famous octuple lock at Beziers only required half-an-hour to accomplish, and it is one of the most wonderful features of this canal, it is like going down a steep ladder from the top of a cliff to the valley below. Our passage must have been a source of amusement to the natives, judging by the crowds which met us at each stopping place. I never could quite understand the exact cause of this. I asked M. Moffre, to whom I have already alluded as the obliging and amiable chief, but he did not satisfy me by saying, 'It is the first steam yacht we have had, except one which belongs to the Emperor of Austria, and which passed through five years ago.' . . .

"From Carcassone we descended rapidly by multiple locks to the plain of Agde, having always as a grand back-ground to the south the range of the Pyrenees, but this plain is anything but picturesque, being rocky and barren. Here we pass what the ignorant and misguided people of Riquet's days thought would be a barrier to his great work. A sharp spur of the 'Montagnes Noires' here juts out into the plain, which looks like 'thus far, no farther,' but he was equal to the task, and set to work to tunnel an imitation of the only tunnel existing in those days, the grotto of Pausillipo at Naples, which he visited on purpose, and it is exactly similar and about the same length. Who does not remember the odd mysterious passage, high enough to pass a line-of-battle ship through? A part, unfortunately, has given way, and necessitated arching the roof, which has somewhat marred the effect, but it is still interesting and imposing. From here, a sharp descent through several multiple locks, brings us to the level of the Mediterranean, whose blue waters are seen in the distance; and on Saturday, the 10th of December, being our fourteenth day since leaving Bordeaux, we emerged from the canal into the Etang du Thau, at the mouth of which is Cette, giving access to the Mediterranean."

The Crapponne Canal.—The authority to construct this canal was conceded to Adam de Crapponne, an eminent engineer in the year 1554. It takes its water through sluices, from the river Durance, near St. Estève-Ianson, at an altitude of 492 feet above sea level. There the river varies from 600 to 6500 feet in width, and the bed consists of a succession of sand and gravel banks, and alluvial deposits, intersected by numerous branches, which shift at every flood.

Such a state of things cannot be considered as constituting the bed of the river, in the ordinary acceptation of the term, and to have constructed a permanent and fixed barrage across the river, to lead the water through the sluices, would not only have been a costly work at that time, but also one of considerable difficulty. Crapponne constructed, therefore, what are termed "barrages volants" across the river. These are formed where the depth of the water is about two feet, by stakes with fascines, and filled in with stones. In the deeper parts of the river, which may be sometimes 12 to 15 feet, "chevalets" are driven in place of stakes. These consist generally of trunks of trees cut near the point of the bifurcation of the principal branches, and which are placed closer together in proportion to the depth. The "chevalets" are bound by cross-pieces and supported by fascines. These "barrages volants" are always placed obliquely to the current of the river, for the purpose of causing the fascines to press against the stones or the "chevalets." Such "barrages volants" need continual repair, but their cost is comparatively trifling. It is mostly a question of labour, as the material employed is cheap.

The average cost of maintenance of the barrage for the Crapponne canal is about 500*l.* per annum. This system, adopted by Crapponne more than 300 years ago, has never been changed, and has been found by experience to answer its purpose of diverting the Durance waters through the sluices into the canal in all seasons, and the same system is adopted for some other irrigation canals. The Crapponne Canal, is the main canal from the river Durance to Lamanon, and is 14¼ miles in length. At Lamanon the canal has two main branches, one flowing south towards Salon and St. Chanas, and the other to the west towards Arles. The total length of the canal is about 77 miles, not comprising the whole development of the branch to Arles, which is a special property, independent of the original canal.

The quantity of water supplied by the canal, is as follows:—The main canal is 26 feet wide, and 6·5 feet deep; the mean velocity is 5 feet per second. The branch to Salon is 10 feet wide, and 6·5 feet deep; the mean velocity is 6·5 feet per second. The branch to Arles is 16·5 feet wide, and 3·28 feet deep; the mean velocity is 5·3 feet per second. The branch to Istres is 6·6 feet wide, and 3·3 feet deep; the mean velocity is 6·6 feet per second.

The Alpines Canal.—This canal, which was commenced in 1773, takes its water, for the main channel, from the Durance at Mallemort, and for the west branches, near Chateaurenard. The main canal is considered one of the best in Europe as regards its utility. The system consists of more than 194 miles of canal, disposing of 770 cubic feet of water per second, which, with the west branches of the canal, irrigates more than 20,000 acres. The branches to Carascon and Barbentane, have generally an inclination of 1 in 2000. In some portions of the former branch, the inclination is 1 in 4500; in other portions 1 in 1250, while over some of the aqueducts it is as much as 1 in 154. The widths at the bottom of the west branch canal vary from 7·8 to 9·2 feet, and for a branch to Barbentane, between 5·2 and 6·2 feet. The inclinations of the slopes varies from 1 to 1, to 1½ to 1, in ordinary cuttings and embankments. The west branches of the canal have passed through considerable financial difficulties, and are now managed by an independent company.

In order to develop irrigation, numerous syndicates have been formed, as some of the land was held in small parcels by proprietors and farmers who had neither the funds nor the power, in opposition to intervening landowners, to obtain branches to conduct the water from the main irrigating canal to their properties. The price charged for the water is regulated by the price charged for corn on the basis of 1·66 bushel per acre irrigated. The quantity of water given at the above rate, is fixed about 0·57 gallon per acre per second, supposed to flow continuously during the irrigation season, commencing on the 1st of April and terminating on the 1st October of each year, which is equal to covering the ground for the total number of irrigations to a depth of 66½ inches, and with 22,130 cubic yards of water. In 1874, the cost of irrigation was equivalent to about 11*s.* 6*d.* per acre, being the price of 1·66 bushel of corn. The price has recently been reduced to about 8*s.* per acre, for three irrigations required during the season for such crops as corn and olive orchards. The same reduced price per acre is also charged for inundating vineyards during the autumn, as a preventive to the phylloxera.

Lens la Deule Canal.—Lens, a town of 11,800 inhabitants, and the capital of the coalfields of the Pas-de-Calais, has recently been connected with the existing system of navigable waterways by a canal, which passes near a great number of pits belonging to the companies of Lens and of Courriéres, the most important of the district, and serves the Liévin mines, which previously possessed no water communication. The probable traffic on this canal has been estimated at 290,000 tons, with a prospect of future increase. The canal starts a little beyond Lens, and passes close to the town; and after a course of 4 miles 7 furlongs it joins the Souchez Canal at Harnes. This canal, about 2 miles 1 furlong in length, was constructed about 1862, and connects the Lens Canal with the Deûle Canal a little beyond Courrières. The total fall of the Lens Canal is 31 feet 10 inches, which is effected by three locks, the first by a fall of $8\frac{1}{4}$ feet and the other two of 11 feet $9\frac{1}{2}$ inches. It has a bottom width of $17\frac{3}{4}$ feet in the straight portions, and in the curved portions the width at the bottom is regulated according to the formula $\left(17\frac{3}{4}\ \frac{1246}{R}\right)$ feet; and its depth is $7\frac{1}{4}$ feet for an available draught of $6\frac{1}{2}$ feet. Crossing places, 31 feet wide at the bottom and 360 feet long, have been formed about every 5 furlongs; and places for barges to wait in have been constructed of the same width, at the commencement and end of the canal, 2300 and 1800 feet long respectively. Above the third lock the canal traverses fissured chalk for a distance of 1640 feet, and has accordingly been lined with concrete up to 1 foot above the water level at a cost of 2*l.* per yard; and where the canal passes over a marsh, filled up with stones from the pits, for about 330 feet, it has been cut off from the marsh by a puddle-trench carried down into a substratum of clay $13\frac{3}{4}$ feet below the water-level. The locks are of the ordinary type, 17 feet wide, $126\frac{1}{3}$ feet available length, and $8\frac{1}{4}$ feet in depth, with sluices in the gates; and the gates have iron ribs and a wooden skin, and cost on the average 4*l.* per square yard. The canal is fed by the river Souchez only 620 feet from its commencement. The discharge of the river during the long drought of the summer of 1886 did not fall below 4·6 cubic feet per second, whilst the traffic on the canal only required $2\frac{1}{2}$ cubic feet per second, allowing for losses from evaporation and leakage. There is, therefore, an ample supply for other purposes, and for increased demands for traffic. The canal was begun on the 1st of February, 1885, and was opened for traffic on the 30th of October, 1886. The works, including land, cost 74,000*l.*, or 15,206*l.* per mile.

The Marne Canal.—The original canal was constructed between the years 1838 and 1853. It commences by a junction with the Upper Marne Canal at Vitry le Français, and terminates by a junction with the river Ill and the Rhine Canal, near Strasburg, thus connecting the valleys of the Seine and the Rhine, and also the intervening rivers, which include the Maas, Moselle, Soar, &c. Its length between Vitry and Strasburg is 193½ miles, and it crosses the four watersheds dividing the catchment basins of the Marne, Maas, Moselle, Soar, and Rhine; there are, however, only two summit reaches, as the divides between the Maas and Moselle, and the Soar and the Rhine, are tunnelled through at Fory and Arzweiler, respectively. There are altogether five tunnels, with a total length of 5½ miles.

The level of the water above the sea is, at Vitry, 332·62 feet; at the Mauvages summit tunnel, through the Marne-Maas divide, 922·75 feet; at Nancy, 648·10 feet; at the Vosges summit level, 873·93 feet; and at Strasburg, 444·18 feet. There are 177 locks on the canal, and the mean rise of each is 8·69 feet.

Some years since it was contemplated to increase the water supply, but the improvements were delayed by the Franco-German war, which resulted in a transfer to Germany of the Alsatian portion of the canal, and also of one of the most important sources of supply, viz. the river Soar. To render the system independent of this latter portion, in 1874 the construction of the East Canal was authorised. This commences at Givet, on the Belgian frontier, joins the Rhine-Marne Canal at Troussey, and again leaving the latter canal at Toul, follows the course of the Upper Moselle to Epinal, where it branches off in a south-westerly direction to its termination at Port-sur-Saône. The depth of water in this canal was fixed at 6 feet 6 inches.

The Rhine-Marne Canal had originally a depth of 5 feet 3 inches, a bottom breadth of 32 feet 10 inches, and sides sloped at 1½ to 1. This depth has been increased to 6 feet 6 inches, the canal bed has been cleaned and lined with concrete 6½ inches to 8½ inches thick, where necessary, and the headways of the bridges and tunnels has been raised to 12 feet 2 inches above the new water-level. Through the Mauvages tunnel a chain has been laid, and all the traffic is worked by two chain steam-tugs with fireless boilers (Francq's patent).

The most important of the new works are those for the additional supply of water. They comprise pumping-stations at Pierre-la-Treiche and Valcourt, near Toul, at both of which the pumps are actuated by turbines, and a steam-pumping station at Vacon, as well as ducts for conveying the water from the pumping-stations to the canal, and an impounding reservoir at Paroy.

	Gallons.
The total amount of water required annually for the Rhine-Marne canal is	1,364,620,000
The total amount of water required annually for the East canal is	748,340,000
Total	2,112,960,000
In addition to which there is the Meurthe branch, requiring	462,210,000
Making a grand total of	2,575,170,000

Besides the above artificial sources, the canals are fed by springs at Vacon, and by the Moselle, &c.

The arrangements at Pierre-la-Treiche and at Valcourt are nearly similar. There are two turbines, actuating force pumps, capable of raising from 143 to 198 gallons per second to a height of 131 feet 3 inches, through a line of cast-iron pipes of 2 feet 7½ inches diameter, delivering into an open duct connecting with the east end of the Pagny Reach of the canal. This duct commences at Pierre-la-Treiche, and is 8¼ miles long, and feeds both canals.

	£
The cost of these works was	51,920
Of which the pumping station at Pierre-la-Treiche cost	15,616
And the pumping station at Valcourt	26,908

The steam pumping-station at Vacon is near the west end of the Pagny Reach. The pumps are 250 H.P., and capable of lifting 8,804,000 gallons per twenty-four hours to a height of 121 feet 4 inches, or 110 gallons per second. The water is conveyed into a duct, which also carries the water from the Vacon springs, and empties into the Pagny Reach. The reservoir at Paroy has an area of 180 acres, and contains 376,371,000 gallons. The dam is 1378 feet long, and 18 feet 3 inches high; the cost of construction was 20,800*l.* The canal traffic in 1884 amounted to 634,936 tons.*

The Canalisation of the Moselle.—The French Government, in the period from 1836 to 1860, undertook the regulation of this river from Frouard to the Prussian frontier by means of works parallel to the

* These details are abstracted from the 'Minutes of Proceedings of the Institution of Civil Engineers,' vol. 86, p. 419, *et seq.*

existing river-bed, and by embankments; but sandbanks and shoals were nevertheless deposited which impeded the navigation, and led to the proposal, in 1860, to erect a series of sluices and movable weirs extending from Frouard to Thionville, which would, if constructed, entail an estimated outlay of 11½ millions of francs, the total distance being 92 kilometres, and the minimum depth of water to be maintained being set down as 1·6 metre. Owing to the opposition of some of the Communes, who dreaded the injury to their land by the alterations in the water-level, the plans were modified, and only certain reaches of the river, where the riparian conditions were favourable, were kept up by weirs and locks, side-channels fed from the main stream being constructed to connect these deepened sections.

The Proposed Mediterranean and Biscay Canal.—The project for connecting the Mediterranean and the Bay of Biscay by a ship canal has often been under discussion, and would, no doubt, if carried out, prove of considerable utility. Not only would such a canal shorten by several days the distance between the principal ports on the North Sea and the eastern basin of the Mediterranean—thereby bringing England into closer contact with the far Orient—but there would be a greater security to shipping, as a result of avoiding the stormy coasts of Spain and Portugal during the winter months. The proposed canal has been variously named the "*Canal de deux Mers*," the "*Canal du Midi*," &c., but it would practically be identical with the Languedoc Canal already described, and by means of which boats of small size are even now passed between the two seas.*

The route proposed for the Mediterranean and Bay of Biscay Ship Canal is from Bordeaux to Cette by Agen, Montauban, Toulouse, Carcassonne, and Béziers. The canal, after following largely the course of the Garonne, from Bordeaux, would tap the Dorpt, the Lot, the Aveyron, and the Tarn, whence it would draw its water supply. From Toulouse, the canal would follow the course of the South Canal, and would thence proceed by Béziers, to the Lake of Thau, which would be transformed into an inland port. The financial and other difficulties in the way of the project have, however, proved insurmountable up to the present time. Both the City of Bordeaux, which is the port chiefly interested, and the Government of France have declined to aid in the realisation of the project; and the State

* Lord Alfred Paget's paper, originally published in the 'Journal of the Society of Arts,' giving an account of a yacht voyage which he made over this canal, has already been referred to.

has even refused to grant the necessary concession for its construction, on the ground that its cost would be quite out of proportion to its utility, that it would isolate a large portion of French territory, and that costly works would have, in any case, to be provided by the Government at both ends of the canal.

It is pointed out,* on the other hand, and with some force, that in the case of a maritime war between France and England, the proposed Atlantic and Mediterranean Canal would allow of vessels reaching the former sea without passing Gibraltar. Brest and Toulon could also be brought into more rapid activity, and the concentration of troops could be more readily effected. A plan and profile of the proposed route appears at p. 101.

The Rhone Canals.—At the mouth of the Rhone artificial waterways of considerable importance have been provided for navigation purposes, the chief of which, the St. Louis Canal, has a draught of water of $19\frac{2}{3}$ feet at low sea-level; its width is 100 feet at the bottom, and 207 feet at the surface of the water.

The channel into the sea is 200 feet wide, at the bottom, from the shore out to the 4-metre (13 feet) line, and 656 feet wide from the 4-metre (13 feet) line to the 6-metre (20 feet) line. The canal is separated from the Rhone by a lock having a depth of water of $24\frac{1}{2}$ feet, a depth of 72 feet, and an available length of 525 feet. Below the lock, at the commencement of the canal, a basin has been excavated, 30 acres in area, and with 20 feet depth of water. The works were begun in 1863, and finished in 1873.

The St. Louis Canal is a work of far greater importance, as regards navigation, than the results anticipated from the improvement of the mouth of the Rhone, to vessels finding a sufficient depth to get up to Arles. This depth was restricted to $6\frac{1}{2}$ feet at low-water level. The St. Louis Canal Works afford access to the Rhone for vessels up to 20 feet draught, and provide these vessels with a harbour, opening into a sheltered bay, in which they are able with ease to load and discharge their cargoes.

The project of the St. Louis Canal was from the first assailed by the partisans of the embankment works, as well as by those who considered that the proper expedient was to enlarge the canal from Arles to Bouc. It was urged that the canal would soon be silted up by deposits from the Rhone, both at the sea end and also at the lock. The canal from Arles to Bouc was constructed in 1802, but as it has

† M. E. Couillard in 'Annales Industrielles,' June, 1887.

only a depth of 6½ feet and a width of 26¼ feet on the locks, it has not been available for the craft usually navigating the Rhone since steam navigation was established.

General Features of French Canals.—The general characteristics of the principal canals of France will be understood from the following table, which gives the number of locks, the length of the locks, and their average width and depth on fifteen of the principal canals in the country, as recorded in the Government Reports on the French Waterways :—

STATEMENT showing the number of Locks, with their length, width, and average depth, on the chief Canals in France.

Canals.	Number of Locks.	Length of Locks.	Width of Locks.	Average Depth of Locks.
		metres.	metres.	metres
De la Deûle	1	38·70	..	..
Meuse	26	45	5·70	2·42
De la Sambre	38	37·60	5·20	2·34
De l'Est	33	38 to 45	5·20 to 5·70	2·60
De l'Aisne de la Marne ..	24	35	5·20	2·68
St. Quentin	35	34	5·2 to 6·40	2·29
De l'Ourcq	10	38·80 to 63	5·20 to 6·20	..
De Briare	43	33	5·20	2·87
Du Muernais	116	33	5·10	2·07
Du Rhone au Rhin	73	30	5·13 to 5·30	2·23
De Neufosse	6	34·80 to 36·53	5·20	2·67
De l'Aire	1	37·95	5·20	2·00
De la Somne	23	45	6·30	2·49
De l'Oise et à l'Aisne ..	35	34	52 to 8·40	2·29
De la Haute Marne	34	25 to 38·50	5·20	3·10

The French Assembly adopted, in August 1879, a law which decreed that the principal lines of canal communication ought to have a depth of 2 metres, and locks not less tnan 38 metres 50 long, by 5 metres 20 wide. In the South of France the only canals that conform to these requirements are those of the Midi and the Aulize; in Central France, the Canal du Centre, the Canal Roanne à Dijon, the Canal du Berry, and the Canal du Rhone au Rhin. The Canal de Bourgogne, the Canal de Briare, and the Canal d'Orleans, are also up to these requirements. In the north of France, and on the Belgian frontier, it may be said that all the waterways are of the required minimum dimensions.

Paris is the natural centre of the French canals. Barges find their way there from the ports of Dunkirk, Gravelines, Calais, and Havre, large quantities of coal, iron, and wheat being carried, and in the fall of the year the cargoes of numerous timber vessels are made into rafts and floated to their destination. Of late years, however, the increasing quantities of planks and deals sawn in the north, are loaded into the barges. The important coal and iron districts of Belgium, at Mons and Charleroi, provide a good deal of freight for Paris, which goes *viâ* Condé from the former, and *viâ* Landrecies from the latter, the two routes uniting at La Fere, whence the Seine, at Conflans, is reached by descending the river l'Oise. The river Rhine is communicated with at Saarbruck and Strasburg; Switzerland at Bâle, and the important ports of Marseilles and Cette by the Yonne, the Burgundy Canal, and the rivers Saône and Rhone. The western ports of Nantes, Brest, and Bordeaux have also canal communication with Paris.

The large *péniches* of 270 tons, which are about 116 feet long, 16 feet beam, bluff at bow and stern, and almost flat bottomed, draw 1·80 metres when loaded. They are usually worked by two men and the wife of the captain. The value of these craft, with their equipments, is from 10,000 to 15,000 francs, and they are always insured against damage or loss. In all rivers and places with the slightest risk, the use of pilots is compulsory.

During the latter part of 1888, the French Chambers had under consideration a proposal to reimpose the tolls that were formerly levied on canals and navigable rivers, but which, within recent years, have been removed. It was contended that the waterways, exempt from tolls, were likely to be dangerous rivals to the railways. The railway interest clamoured accordingly for what they called fair play. The Budget Commission, however, refused to entertain the idea of resuming the canal tolls, holding, as expressed by their spokesman, that "by developing the waterways, and thereby serving industry in the cheap transport of raw materials which were incapable of bearing a high charge for carriage, production would be increased, and the traffic of the railways in manufactured goods would be proportionately augmented."

A considerable amount of light has been thrown upon the circumstances of the internal navigation of France by a census that was recently taken of the boats employed upon the navigable rivers and canals. This census showed that, at the end of 1887, there were employed on the national waterways no fewer than 15,730 vessels, having a total tonnage capacity of 2,724,000 metrical tons, or an average of 173 metrical tons per vessel. Of these boats, 933, with a total tonnage of 342,933, or an average of 370 tons per vessel, had a length of 38 metres 50 and over; 4863 boats, having a total tonnage of 1,415,904 metrical tons, or an average of rather under 300 tons each, had a length of 33 metres to 38 metres 50; while 9934, with a total tonnage of 965,000 tons, or an average of 96 tons, were less than 33 metres in length. Of the 15,730 vessels employed in the inland navigation of France, 14,252 were found to have been constructed in the country, 1017 in Belgium, 339 in Germany, and 122 in other countries. It would thus appear that France retains in her own hands the shipbuilding involved in the navigation of her own waterways. Finally, it appears that 8537 boats, with a total tonnage of 1,632,000 tons, were employed on the canals, and 7203 boats, with a tonnage of 1,092,000 tons, on the rivers.

It would take up far too much of our time and space if we were to attempt to speak of the resources of the principal rivers of France, and of the means that have been taken by the State to maintain and improve them. Much has been done in this direction within recent years, and more is proposed in the near future. Until quite recently, if not actually up to the present time, the cost of transporting a ton of coal from Cardiff or Newcastle to Paris has been about 16 francs, being 9 francs to Rouen, and 6 francs from Rouen to Paris, with 1 or 1½ francs for unloading into river boats at Rouen. The consumption of coal in Paris is from 2½ to 3 million tons a year, and it has been argued that the cost of this coal could be reduced to the consumers by some 6 francs if Paris were converted into a seaport by improving the Seine. One objection offered to this proposal is that it would interfere with the French collieries in the Nord and the Pas-de-Calais, if so obvious an advantage were given to English coal; and to meet this difficulty it has been proposed to have another special canal from those districts, which would start from St. Denis or Creil, and would communicate by two branches with Antin and Lens. It is argued that the cost of conveying coal from the north to Paris by this means would not exceed 2 to 2½ francs, or 4 francs less than at the present time.

CHAPTER VIII.

THE WATERWAYS OF GERMANY.

> "How many spacious countries does the Rhine,
> In winding banks and mazes serpentine,
> Traverse, before he splits on Belgia's plain,
> And, lost in sand, creeps to the German main."
>
> *Sir R. Blackmore.*

THERE is perhaps no country that enjoys greater facilities of transport than Germany, relatively to its area, its population, and its commerce. This happy condition of things is due, partly to the fostering care of a paternal government, which has taken transportation under its special care, and controls by far the larger part of the ways of communication both by land and water; partly to the competition, at low rates of freight, between railways, rivers, and canals; and partly to the close attention which has been given by traders, economists, and engineers to the problems that determine the ultimate economy of transport under different conditions. With a railway system that has now been completed to the extent of 25,000 miles, with 17,000 miles of rivers, and with 1250 miles of canal navigation that is soon likely to be considerably increased, the German Empire offers facilities for the study of the transportation problem that entitle it to the serious attention of all who are interested in the matter. This is all the more obvious that Germany, although possessed of very moderate natural resources otherwise, has attained a front rank among commercial nations.

River Systems.—The chief river systems of Germany are those of the Rhine, draining an area of 76,000 square miles, and having a course of 850 miles; the Elbe, which drains an area of 55,000 square miles, and is, next to the Rhine, the most important of the German rivers; the Oder, which has a drainage basin of 50,000 square miles, and a course of 550 miles; the Vistula, which rises in the Carpathian mountains, 2000 feet above sea level, has a drainage area of 74,000 square miles, and a length of 600 miles; the Niemen, which has a drainage area conterminous with that of the Duna, and of about the same extent, i.e., 35,000 square miles; the Weser, which has a drainage area of 18,000 square miles, and a course of 355 miles; with the Ems and one or two smaller streams. The flow of the chief streams is as follows:—

River.	Sea.
The Danube	The Black Sea.
Rhine, Elbe, and Weser	The North Sea.
Vistula, Oder, Memel, and Pregel ..	The Baltic.

Of the Danube we shall speak at some length when we come to deal with the waterways of Austria, to which that river mainly belongs. But most of the other rivers of Germany have been more or less canalised, and we shall therefore refer to some of the changes thereby effected in river transport.

The Rhine.—The lowest velocity of the Rhine is 2·62 feet per second; the highest 11·15 feet per second, and, at Düsseldorf, 5·24 to 6·56 feet, with 9·84 feet mean-water on the Cologne gauge. The width of the river at St. Goar is 180 yards, and the depth 98 feet; at Düsseldorf it is 275 yards wide, and 72 feet deep. These are the two greatest depths of the river. In the Rheingau and the Lower Rhine, the width increases to about 770 yards. At Wesel the proportion of volume of low and high water is 1·14.

The steamers now employed to navigate the Rhine are constructed for cargoes of about 800 tons. The first improvement-works were carried out from 1847 to 1850; in 1868, with low water equal to 4·92 on the Cologne gauge, the channel from Bingen to Coblenz was clear to an equal minimum depth of 6·56 feet; from Coblenz to Cologne 8·2 feet; and from Cologne to Rotterdam, 9·84 feet.

In 1874, the 8·2 feet channel was extended from Cologne to St. Goar. With the improvement works, the width of the river channel is now from 100 to 160 yards; below Cologne it expands to 330 yards. The cost of the works has been as under:—

	£
Previous to 1851	650,000
1881–1861	225,000
1861–1879	475,000
The remaining works are to be completed within eighteen years at an estimated cost of	1,100,000
Making the total expenditure	£2,450,000

Down to Cologne the banks rise above water level. Further seawards the ground is low-lying, and dykes have to be employed. These commence near Düsseldorf.

The traffic carried on the Rhine is very considerable, especially between the Dutch ports and the Westphalian manufacturing districts. It embraces large quantities of coal, iron ore, iron and steel manufactures, &c., and the cost of its transport compares favourably with railway rates.

The navigable length of the Rhine is 435 miles, and on this length it has a yearly traffic of about 5500 vessels, averaging some 200 tons each. The Rhine has a greater density of traffic than the Danube, on which only some 800 vessels are employed, also averaging some 200 tons; but the Danube, which is navigable to Regensburg, 281 miles from Vienna, has a much longer navigation. It is believed that chain traction could be carried as far as Ulm, which is 131 miles farther.

The Ems.—This river has a limited interior communication, the tide flowing for not more than 15 to 20 miles. The Ems takes its rise only in the territory of Munster, receiving the river Hase, a little above Meppin, and the Söste at Leer, and it is navigable at no great distance in its current. It then runs by the Dollart, a sort of bay betwixt Embden and the Dutch coast, into the North Sea, in two branches; one called the eastern, the other the western Ems, forming betwixt them the island of Borcum. Formerly the river passed close by Embden, from a cut being made to force the current of the river that way, but, being neglected, it has taken its course by the coast of Groningen. A narrow channel from Embden is, however, kept clear, in consequence of four sluices in the town, which are opened whilst the ebb tide continues.

The Ems has enjoyed a considerable degree of celebrity, not so much from its extent as from its local advantages, and from the political situation of Holland. It enjoys a free navigation by its neutrality, it is under the protection of Prussia, and it is contiguous to Delfzyl, an excellent entrance into Holland, by a canal which runs through the northern provinces, by the city of Groningen, into the Zuyder Zee. It thus communicates with all Holland and Flanders, the trade of which countries, and some parts of Germany and France, were formerly largely carried on by it.

The Mosel.—The canalisation of the Mosel from Frouard to Diedenhofen, nearly 57 miles, is a portion of an intended navigable communication from Louisenthal, on the Rhine-Marne canal system, to Saar-Kohbenbecken, on the Saar. From Frouard to Arnaville, about 25 miles, it was carried out by the French Government between 1867 and 1870; and from Arnaville to Metz by the Prussian Government, under Herr J. Schlichting, between 1872 and the present time. The canalisation from Metz to Diedenhofen, and the proposed connection between the Nied canals of the Mosel, the Saar, and the Maas, remain to be completed As the main object of this canalisation was to provide a navigable passage for craft having a draught of 5·9 feet, the minimum depth of water was fixed at 6·56 feet. The bottom width of the canal is 39·4 feet.

Of the 25·15 miles of river dealt with by the French, only 3·14 miles were rendered navigable. The remainder of the main course adapted for navigation consisted of four portions of canal, in all 17 miles in length. In addition there were 1·25 mile of short canals, connecting the main course with the Mosel. Corresponding to the canals there are four movable weirs in the Mosel at Custines, Marbache, Dieulouard, and Pont-à-Mousson, which maintain the necessary water-level in dry seasons. The fall from the Rhine-Marne Canal at Frouard to the Mosel system is 26·25 feet, and the fall from Frouard to Arnaville is 48·6 feet, overcome by six locks. The cost of these 20 miles of navigable channel is stated by the French engineers to have been 208,000*l.* The German works recently executed include a continuation of the main canal from Arnaville to Novéant, where it debouches into the Mosel for a length of 1·05 mile; the canalisation of the Mosel itself thence to Jouy-aux-Arches, 3·38 miles long, where a movable weir maintains the water-level in this reach; and a main canal thence to Metz on the right bank of the river, 5·55 miles long. The branch canals are comparatively independent of the above. One of them is situated on the left bank at Ars, and consists of a rectification of a side channel of the river, 2·54 miles long, intended solely for the use of the iron foundries of that town; a feeder of this, being on low-lying ground, requires special protective embankments. The other, 1258 yards long, connects the main canal with a basin at the railway terminus at Metz. The portion of the Mosel from the embouchure of the Ars branch canal down to the island of Vaux is made into a navigable basin for the use of the foundries, a movable weir at the latter place giving the necessary increased depth of water.

The Rhine and Danube Canal.—In 1834 an elaborate report was made by C. T. Kleinschrod, of Munich, relative to the feasibility of constructing a canal to connect the Rhine and the Danube.* The proposal was to proceed from the Rhine by way of the Main as far as Bamberg, and there commence a canal which should proceed by Nüremberg to Keeheim, where it would effect a junction with the Danube. The total length of the artificial waterway between these two points, Bamberg and Keeheim, was stated at $23\frac{1}{3}$ German miles. The writer of the pamphlet made an elaborate estimate of the probable cost of the undertaking, which had the support of the King of Bavaria, and it was demonstrated that at that time, when there were hardly any railways in Germany, it would be attended with a great economy of transport. Owing, however, to the competition of railways, and the extent to which they soon afterwards met the requirements of the country, the project was not entirely successful. The canal was completed in 1844. It is 110 miles long and 7 feet deep.

The Danube, which is practically navigable from the town of Regensburg, 281 miles westward of Vienna, and the Black Sea, is the chief important waterway of Austria. Communication is obtained with Prussia by the Danube-Oder canal, and it is now proposed to establish a communication between this canal and the Elbe, in which case, traffic could be carried from Vienna to Hamburg by water all the way. It has been suggested to have communication made between the Danube and the Rhine either by Dilligen, 31 miles below Ulm, *viâ* Konigsbronn, 1640 feet above sea-level, to the Neckar, and from Cannstadt to Mannheim, and alternatively by Kehlheim, Nuremburg, and Bamberg, an ascent of 1375 feet to the Main, whence Mayence would be reached *viâ* Frankfort.

The Oder and the Elbe Canal.—At an early period in the history of European trade, the desirability of having the Oder and the Elbe connected by an artificial waterway was discussed. This was even more of a desideratum about a century and a half ago than it is to-day. At that time, Stettin, which is built on the west side of the Oder, about 46 miles from its mouth, was perhaps the leading commercial city in Germany, having a large trade with England, France, and other countries on the west, with Scandinavia, and with the Baltic countries. The importance of joining such a port with Berlin,

* Those who are interested in perusing this Report will find it contained in a volume of pamphlets in the Library of the Royal Statistical Society.

Hamburg, Dresden, and with other cities either upon or near to the Elbe, was manifest.

The first canal built for this purpose was that of Plaven, completed in 1745. This canal joined the Havel with the Elbe at Parcy. It is about twenty English miles in length, 40 to 50 feet in width, and has three sluices. It reduces by more than one half the length of the navigation between the Oder and the Elbe. About the same time the canal of Finow was constructed to connect the same rivers by the Finow and the Havel. There are thirteen sluices on this canal. Another canal, called the Frederick William, joins the Oder and the Spree above Frankfort, and, uniting with the Havel near Brandenburg, connects the latter with the Elbe. It is fifteen English miles long, and has ten sluices.

The Holstein Canal was begun in 1777, and was completed on the 4th of May, 1785, but was opened in 1784. The cost of the undertaking was 2,512,432 rix dollars. There are six sluices, which cost 70,000 rix dollars each. This canal, on the side of the Baltic, commences about three English miles north of Kiel, at a place called Holtenau, where there is a sluice, another at Knoop, and a third at Rathmansdorf, till it comes to the Flemhude Lake, which is the highest point; and from this lake, on the side of Rendsburg, there are three other sluices—one at Königsford, another at Kluvensiek, and the last at Rendsburg. These are on what is called the Upper Eyder, and the Lower Eyder is from Rendsburg to its mouth, running by Tonningen, below which place it falls into the sea between Eyderstadt and Dithmarschen. The distance is about 100 English miles, and vessels must either sail or tide it, or both; whilst from Rendsburg to Holtenau, nearly at the mouth of Kiel Bay, upon the Baltic, it is only about 25 English miles, which can be navigated in all weathers, except during a strong frost, as horses can be had, if required, at fixed rates. The vessels are let through a sluice in little more than eight or ten minutes each. For each sluice they pay only 4 schillings Danish, or about so many pence English. The surface breadth of this canal is 100 feet, and at the bottom 54 feet Danish measure, and the depth is at least 10 feet throughout. Vessels can pass through the sluices 100 feet in length, 26 feet in breadth, and 9 feet 4 inches draught of water, Danish measure, and which, for the regulation of the British merchant and shipowner, as well as the master, it may be observed, corresponds in English measure to vessels of 95 feet 4 inches length; 24 feet 9 inches breadth; and 9 feet depth.

An increase and improvement of the waterways of Germany is looked upon as a pressing present necessity by many, and provision has been made for the commencement of three great canals—the connection of the Baltic with the North Sea, of the Spree with the Oder, and of the Ems with the Rhine. The first mentioned is to be built chiefly from military considerations, so that the German iron-clads can get from Kiel to the Atlantic. The two others are to be constructed for commercial purposes. In connection with these there will also be canals built from the Rhine to the Elbe, and from the Oder to the Silesian Mountains. The agricultural interest very strongly opposed the Spree-Oder and Ems-Rhine Canal, because they feared the foreign grain would be more plentifully brought into the empire thereby, but their opposition was not successful.

Besides these works the river Weser is being deepened, and a new channel has been constructed between Bremen and the sea—a distance of about 50 miles.

The North Sea and Baltic Ship Canal.—This new ship canal is to be international as well as national in its character. It will reduce the sea passage, as compared to the Sound route, by 237 sea miles, shorten the journey of sailing vessels by at least three days, and that of steamers by about twenty-two hours in normal weather, and these advantages are to cost the shipowners 9*d.* per registered ton when the canal is navigable. About 35,000 vessels pass through the Sound annually. It is, moreover, intended to strengthen the offensive and defensive power of Germany. It may, however, be remarked that Count Moltke never from the first gave the plan his cordial support from a strategical point of view, maintaining then, as now, that the money which the canal is to cost would have been more judiciously spent if employed to strengthen the national navy.

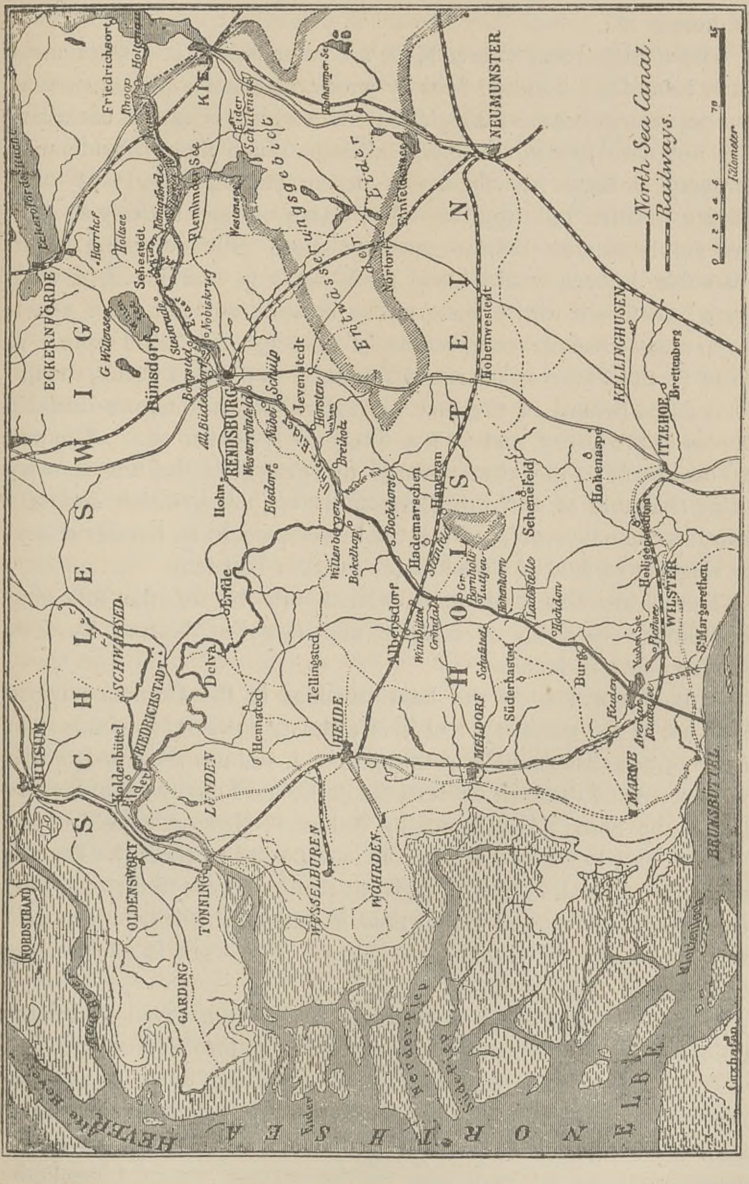
The Baltic Ship Canal begins at Holtenau, a small village just north of the royal dockyard of Kiel, on the Baltic, and enters the Elbe 15 miles above the North Sea, near Brunsbûttel. It will have a total length of 75 to 80 kilometres, as seen on the sketch-map at page 125. Its width is to be, on the water surface, 60 metres; on the bottom, 26 metres; its depth is to be 8½ metres, and its total cost 156 million marks, as estimated. The canal may be looked upon as a mere cutting, in which the water-level is to be that of the Baltic Sea, and there will only be floodgates or sluices where it enters the river Eider and at its termination in the Elbe; these will be, as a matter of fact, open all the year round. For the convenience of the Royal Marine, rather extensive works will be carried out at the Elbe embouchure, consisting of large and small locks, and eventually a floating basin for at least four large armour-clads, besides coaling stations at either end of the canal. The four railways crossing the canal, as well as the two main post roads, will be carried over it by means of iron swing-bridges; and steam and manual pontoons will serve for the other various crossing-points of the canal. There are no engineering difficulties to contend with, excepting perhaps a boggy portion not very remote from the Elbe. The highest point of cutting is about 24 kilometres distant from the Elbe, and here it will be 30 metres distant from the bottom level of the canal, otherwise the ground to be removed is mostly sand or sandy loam.

This canal will unite the Gulf of Kiel with the mouth of the Elbe, and will run by way of Rendsburg to a point midway between Brunsbüttel and St. Margarethen, a few miles below Hamburg. It will, when completed, be 61 miles long, 196 feet broad at the water level, 85 feet broad at the bottom, and 28 feet deep, and it will have but two locks—one at each end. The canal will take in the largest warship that has been or will be constructed in Germany, and will, moreover, take her at all states of the tide and in less than eight hours it will be possible for her to proceed by it from Kiel to the Elbe, or *vice versâ*. The canal, therefore, will enable Germany to regard with some degree of indifference the possession of the mouths of the Baltic. She will always have her own entrance into that sea, and will be in a position at very short notice either to reinforce her squadrons there with ships from the North Sea, or to draw ships thence to reinforce Kiel and the Elbe. It is proposed to supplement this strategical waterway by means of a further canal, which shall traverse Hanover from Neuhaus, on the Elbe, opposite Brunsbüttel, to Bremerhaven, at the mouth of the Weser. It will then be possible for the whole voyage between Kiel and Wilhelmshaven to be performed in what are practically inland waters. This last section of canal is, indeed, necessary for the thorough completion of the scheme of coast defence; for the position of Great Britain at Heligoland renders a blockade by her of the mouths of the Elbe and Weser comparatively easy, unless provision be made for the safe concentration at will, either at Brunsbüttel or at Wilhelmshaven, of a fairly formidable fleet.

The Eyder, which divides Schleswig from Holstein, flows through territory to be regarded as permanently German into the North Sea at Tönning, From Rendsburg, to which place the Eyder is navigable, the Eyder or Schleswig-Holstein canal was dug towards the close of the last century to Kiel Bay, on the Baltic. It is from 10 to 11 feet deep, and has locks. Vessels, though of no great burden, can thus at present pass from the one sea to the other. As soon as Prussia occupied the Danish Duchies, proposals were entertained by it for an increase of the depth and width of this canal. Its maintenance, as it is necessitates a large expenditure on dykes, and the contemplated improvements, of which the charge would fall wholly or mainly on Prussia, must inevitably be exceedingly costly. When they were fully carried out, they might not answer the commercial needs of the chief centres of German trade, and might even divert custom from them. Hamburg wants a canal nearer to its end of the peninsula. It will be likely to attain its wish by the measure which has now been sanctioned by the Imperial Parliament. By this scheme the two German seas will be united at points most convenient for the accommodation of the entire Empire.

In addition to the Eyder Canal, a second but more indirect water communication between the Baltic and North Seas has existed for five hundred years in the Steckenitz Canal, by which the Hanse city of Lübeck connected the Steckenitz and Delvenau with the Elbe. But this is not the route which wins engineering or political favour. The line most strongly supported is from Kiel, south-westwards to Brunsbüttel, at the mouth of the Elbe, opposite Cuxhaven. It would satisfy the demands of Hamburg, which, though it seems to be jealous of Altona, practically embraces within the limits of its port the whole Elbe estuary. Kiel has a rising commerce which is likely to be greatly expanded by the undertaking. In the eyes of German statesmen, the plan has commended itself as giving the principal war harbour of the Empire an independent outlet to the North Sea. The Northern Powers might, as things now are, if hostile, seal up the German Navy in the Baltic. They hold the keys, and could convert the sea into a lake. Whatever the German naval strength at Bremerhaven, on the Elbe, and at Kiel, it could be cut in half, and prevented from co-operating at the discretion of Scandinavia.

This is, as we have seen, a reason of the highest State for undertaking the new waterway. German ships, unprovided with a waterway between the German Ocean and the Baltic, have been exposed to extraordinary risks. This fact alone is, in the eyes of Germany,



Map showing the Route of the North Sea and Baltic Canal.

a sufficient reason for such an enterprise. But there are also the equally cogent reasons of trade, and the preservation of shipping and human life.

The Kattegat and Skager Rack are computed to cost Germany a yearly loss of five hundred lives by wreck, and half a million sterling. The pecuniary damage through the trade which is turned back, and does not dare to defy the peril, must be much more considerable. Germany at large has finally to defray the major part of these charges, positive and negative. The saving of them is likely to yield very ample interest on the seven or eight millions to be spent. Venerable Lübeck would alone have cause to murmur at a work which threatens it with more grievous competition than even now it has to meet from the competition of Kiel for the Baltic trade. A writer in the *Times* has, however, pointed out that Lübeck, though it has fallen behind in the race with Hamburg, has its own intrinsic sources of prosperity, and is not likely to let them slip. The one real drawback to the attractions of the project is the unaccommodating character of a North German winter. Ice, which seriously obstructs the navigation of the tidal rivers, would be harsher still to the sluggish surface of a fresh-water canal in Holstein.

The North Sea and Baltic Canal will be of the following dimensions:—Breadth at surface 200 feet; at bottom 85 feet. Depth 27 feet 10 inches.

This size will allow the heaviest ships in the German navy to make use of the waterway, and it is estimated that 18,000 ships out of the 35,000 that annually pass the Sound, will use the canal, which will shorten the distance between the Baltic and London by 22 hours; Hull by 15 hours; Hartlepool by 8 hours; Newcastle-on-Tyne by 6 hours; and Leith by 4 hours. It is expected to affect the English coal trade with Baltic ports, by giving readier access to German coal ports, and in addition to saving time in transit, it will relieve vessels from the danger of doubling the Skaw. The work is likely to be completed in 1893 or 1894.

The cost of the canal is estimated at between seven and eight millions sterling, of which 2½ millions are to be provided by Prussia.

It is the inevitable result of every new addition to the transportation facilities of a country to benefit more or less some places at the expense of others. The North Sea Canal is likely to prove disadvantageous, as we have seen, to the ancient city of Lübeck, in consequence of a diversion of its traffic. To meet this drawback, it has been proposed to construct a new canal through Holstein, connecting the Trave with the Elbe. Negotiations have been carried on between Lübeck and Prussia, with this end in view. The canal would be 72 kilometres in length, and is estimated to cost 18 millions of marks (900,000*l.*). With this canal, Lübeck is expected to retain its considerable trade with North-eastern Europe.

The Rhine-Ems Canal.—The proposed Rhine-Ems Canal is expected, by bringing the Rhine and the Ems into more direct connection with the Westphalian coalfield, to bring German into very close competition with English coal at the North Sea and Baltic ports. The plan is a very old one, and was resuscitated some thirty years ago, but nothing came of the project till three sessions ago, when the Chambers voted a large sum to carry it out under Government, provided the interested country districts through which the canal was to pass, beginning at Dortmund, would acquire the requisite land through which the canal was to be cut, and hand it over for the common good. The money has been coming in since by driblets, slowly and reluctantly, from one township and the other, but at last it seems probable that it will ultimately be subscribed, and for this eventuality English coalowners must be prepared. A glance at a map will show that from Dortmund to Emden, and thence through the North Sea and Baltic Canal, a direct route to the East seaports will be opened up; and as the Westphalian coal can then be placed at Emden at the same price as the English at one of the east coast shipping ports, and the distance from Emden to the Baltic by the new ship canal is twenty-three hours less than from Hull, twenty-seven from Hartlepool, thirty from Newcastle, and thirty-six from Leith, it is evident that a sharper rivalry may be established. If the ship canal be not used, the difference in time between Emden and the Baltic will be less by thirty-eight hours from Hull, thirty-six from Newcastle, thirty-five from Hartlepool, and forty from Leith. No steps have yet been taken with regard to the continuation of the canal from Dortmund to the Rhine, which would then open up a new and shorter waterway from South Germany and Switzerland to the Baltic.

The Dortmund and Emden Canal is designed to develop the communication between the Westphalian coalfield and the harbour at the mouth of the Ems, and comprises (1) the completion of the canal direct from the collieries, and joining the Ems at Papenburg, and (2) the improvement of the navigation at Emden harbour. The canal follows, at the outset, the Emscher valley to Henrichenburg, whence it is intended to construct a branch of about 5 miles to the Rhine; the length of this section being about 9¼ miles, with a fall of about 45·3 feet. The section of 38 miles past Münster, is unbroken by locks, but falls of 50 feet to Bevergern, whence the previously existing Haulken Canal is followed as far as Meppen. The fall from Bevergern to Papenburg is 130·9 feet: and the distance 68 miles; the total fall from Dortmund to Emden being 226·2 feet, with twenty-six locks.

From Papenburg the Ems is navigable for the largest barges; but at Oldersum, about 6 miles from the mouth of the river, the channel becomes exposed to northerly storms, and from this point, therefore, a new cut, closed from the river by a lock, joins the new harbour, which, however, is yet unfinished, and is capable of considerable extension. The dimensions of the work are:—

Canal.	ft.	in.	*Locks.*	ft.	in.
Width of bed	52	0	Length	220	0
,, at water level	78	0	Clear width of gates	28	3
Depth	6	6	Depth on sill	8	3

The aqueducts, by which the canal is carried over the Lippe and Stever valleys, having also a depth of 8 feet 3 inches, the canal can

SECTIONS AND DETAILS OF COST OF THE DORTMUND AND EMDEN CANAL.

Section.	Length in Miles.	Cost of Works.		Total Cost (including land).	
		Per Mile.	Total.	Per Mile.	Total.
		£	£	£	£
Dortmund to Henrichenburg	9¼	26,082	243,000	34,373	320,500
Branch to Herne (5 miles) ..	..	17,468	84,500	21,574	104,500
Henrichenburg to Bevergern	59½	{18,354 {..	1,092,500 37,500	20,608 ..	1,228,500 37,500
Bevergern to Papenburg ..	68	14,973	1,019,500	15,939	1,093,000
River (Ems) from Papenburg to Oldersum	} 19½				
Eldersum to Emden	5¾	25,760	147,000	28,738	164,000
Emden Harbour	¾	..	295,000	..	295,000
Total distance, Dortmund to Emden Harbour	}162¾	..	2,919,000	..	3,233,000

at any time be dredged to this depth throughout. The navagation can be worked by steam-power, and when the harbour is completed, so that the coal can be brought direct from the collieries, the freight charges will probably be reduced to *2s. 3d.* or *2s. 6d.* per ton, as against *3s. 6d.*, the lowest now charged. The preceding table is a statement of the details of this undertaking.

Scheldt and Rhine Canal.—For a considerable time past, a canal has been in course of construction between the Scheldt and the Rhine. The undertaking has been jointly promoted by Holland, Belgium, and Germany. The two former countries are said to have completed their part of the new waterway, but the German section of the work has been allowed to stagnate for lack of support, and in 1887 the Frankfort Chamber of Commerce applied to the German Government for assistance, with a view to its completion. At the present time, the Rhine is one of the most important waterways in Europe in reference to the extent of its traffic. The port of Rotterdam is, however, the only one open by this route, while the new canal would give access to the magnificent port of Antwerp, whence cheaper freights are obtained to North America than from any other European port.

Oder and Upper Spree Navigation.—The old Friedrich-Wilhelm Canal, constructed over two hundred years since, was till recently the only means of water communication through this district; but the dimensions of the channel, as well as the locks, were too small for present requirements, and in preference to reconstructing the whole work, it was decided to cut another channel, joining the Oder a few miles further from Frankfurt. The country traversed is easier than in the case of the Ems, and as the Oder does not take such large vessels as the Ems, the dimensions of the canal are smaller; the limit being for 400 ton barges:—

Canal.	ft.	in.	*Locks.*	ft.	in.
Width of bed	46	0	Length	180	0
,, at water level	76	0	Clear width of gates	28	3
Depth	6	6	Depth of sill	8	3

The total length of this navigation is stated at $54\frac{1}{2}$ miles, and the cost is estimated at 11,592*l.* per mile.

It is now proposed to connect the North Sea at Hamburg with Vienna, and thence, by the Danube, with the Black Sea and the Orient generally, by a canal from Kosel to the Danube. The

Prussian canal system now allows of water transport all the way from Hamburg to Breig, whence the canalisation of the Oder to Kosel, now being carried out, will be completed in 1894. Prussia would continue the canal thence to the Austrian frontier if it was completed to the Danube, 273 kilometres further, by others, and efforts have recently been made to bring this about.

This navigation improvement will bring the coalfields of Eastern Silesia into direct communication with Berlin.

In 1885, a project was brought forward in Prussia for the construction of a canal that would join the Rhine, the Ems, the Weser, and the Elbe. The length of this waterway was estimated at 181¼ miles, the depth at 6 feet, 8 inches, and the width at 53 feet, 4 inches at the bottom, and 80 feet on the water-line. The canal is intended to accommodate vessels not exceeding 500 tons burden. The outlay proposed for this and collateral canals was estimated at 4,050,000*l.*

Traffic on German Waterways.

The quantity of traffic carried on the waterways of Germany has been calculated at 11,797,000 tons, of which North Germany furnished 11,249,000 tons, and Southern Germany 548,000 tons.*

This, however, does not include the Rhine and the Main, which would raise the figures for North Germany to about 16½ millions of tons, while other waterways in Southern Germany bring up the traffic in that division of the empire to about three millions of tons, being a total for both divisions of about twenty millions of tons in round figures, or approximately the same traffic as the waterways of France in the same year.

Dealing only with those waterways of Germany, in which the transportation of traffic is regularly carried on, and disregarding the streams or canals that are practically unused for this purpose, it

* The different river basins contributed the following proportions :—

Basins.	Tons.
The Elbe	7,767,000
The Vistula, Niemen, &c.	2,227,000
The Oder	861,000
The Weser and Ems	394,000
Lake of Constance	338,000
The Danube	210,000
Total	11,797,000

appears that the total length of internal navigation in Germany is about 3384 miles,* but it is important to remark that about 18 millions of the 20 millions of tons of traffic carried annually on these waterways make use of only 2360 miles, or 69 per cent. of the whole, leaving a million and a half to two millions of tons for the remaining 31 per cent.

The latest returns at command appear to show that the waterways of Germany were used by 17,885 sailing ships, of a total tonnage of 1,625,000 tons, or an average of 90 tons each; and by 830 steam ships, of a total tonnage of about 33,000, being an average of 53 tons per vessel.

The total number of vessels employed in carrying merchandise, on the waterways of Germany, in the form of tugs, kedges, and steamers, in addition to the above, is given as 483, having an indicated horse-power per boat varying from an average of 280 on the Rhine to one of only 53 on the Oder.

It is clear from these returns that the waterways of Germany employ a large number of very small craft. It is equally clear that under these circumstances, the cost of transport cannot be so cheap as it otherwise would be. If the average tonnage of all the vessels employed under steam is only 53 tons, there must be a number of very small craft indeed employed on the other waterways, in order to make up for the considerably larger average of the vessels employed on the Rhine.

In Germany, as in France and Belgium, it is chiefly traffic of the heavy kind that makes use of the waterways. About 28 per cent. of the total traffic carried on the canals and rivers of the Empire takes the form of coal and coke. On the Rhine, almost one-half of the total traffic carried is mineral, but on the Elbe, mineral traffic only constitutes 18 per cent. of the whole. But on this, and the other water-

* The distribution of this navigation is as follows, according to basins:—

Basin.	Miles of Navigation.
The Rhine	931
The Elbe	870
The Oder	497
The Weser	280
The Danube	248
The Ems	196
Other waterways	372
Total	3384

ways as well, timber, stone, clay, and lime, are carried in considerable quantities, as well as vegetables and leguminous plants.* It is estimated that eight millions of tons of traffic in Germany use both waterways and railways, and on the Rhine alone over five millions of tons are carried in this way.

The average traffic carried per mile on the Rhine is not less than 7400 tons. On the 2484 miles of waterways that are regularly navigated in Germany, the density of traffic is about 7200 tons per mile. On the railways of Germany, however, the density of goods traffic only amounts to about 4864 tons per mile. The French waterways have a density of 7246 tons per mile, as against a density of 4500 tons on their railways. It is impossible to speak of the density of the traffic on English waterways, inasmuch as no regular returns are collected of the canal business of Great Britain; but as the canals have for the most part been allowed to get very much out of repair, it is safe to assume that the existing water transport will not compare favourably with the traffic carried by railway.

An interesting statement has recently been compiled, showing the quantities of traffic carried on the railways and waterways of Germany, to and from the principal centres of population. It appears from this return that the total quantity of traffic carried by water to and from Berlin, Hamburg, Magdeburg, Mannheim, and one or two other cities of importance, compares not unfavourably with rail transport. The particulars are given in the table on the following page.

It is the practice in Germany for the Government to maintain the inland navigations, charging only 6*s*. for lockage. This allows of very cheap transport—so much so, indeed, that it is stated that between Hamburg and Berlin, notwithstanding that the railway rates are extremely low, all heavy traffic is carried by barges or steamers.

On the fourteen principal waterways in Germany, including the Oder, the Spree, the Elbe, the Rhine, and the chief canals, the 17½ million tons of traffic carried in 1887 was transported in 132,863 boats that were full and 35,989 boats that were not full. The average tonnage carried on the same waterways between 1881 and 1885 was 14,318,000 tons. As compared with the vessels employed, and the tonnage carried, in preceding years, there was an

* On the railways of Germany in 1886 coal traffic was 48·5 per cent. of the whole; timber, 5·8 per cent.; stone, 7·5 per cent.; and grain 6·2 per cent. About 84·7 per cent. of the whole was heavy traffic. The total railway traffic was about 5½ times that of the total water traffic of the empire.

TRAFFIC ON THE RAILWAYS AND WATERWAYS OF GERMANY.

Cities.	Number of Inhabitants.	Tons of Goods Carried			Number of Tons per Head of Population.
		By Rail.	By Water.	Total.	
Berlin	1,200,000	3,504,000	3,348,000	6,852,000	5·71
Breslau	270,000	1,237,000	350,000	1,587,000	5·88
Hamburg	410,000	1,191,000	3,221,000*	4,442,000	10·7
Magdeburg (including Buckau and Neustadt)	165,000	1,650,000	1,118,000	2,768,000	16·7
Dresden	220,000	1,411,000†	534,000	1,945,000	8·8
Bremen	112,000	776,000	184,000*	960,000	8·5
Ports of Rhine—Rhurort, Duisburg, and Hochfeld)	70,000	5,427,000	4,107,000	9,554,000	136·0
Cologne (including Deutz)	160,000	1,132,000	314,000	1,634,000	10·0
Mannheim and Ludwigshafen	75,000	1,776,000	2,041,000	3,817,000	50·0

advance of 15·4 per cent. in the number of the boats, and of 22·7 per cent in the amount of traffic carried.

In the year 1878 it was announced that over 1045 miles of new canal navigation had been ordered throughout Germany, in addition to the 1289 miles then open, and the 4925 miles of navigable rivers available.‡ This fact sufficiently indicates the great importance that is attached in Germany to adequate water communication, and it is all the more notable that very few countries are possessed of equally cheap railway transport.

* Not including sea tonnage.

† Exclusive of arrivals and departures by rail from Dresden and Breslau.

‡ Report of Messrs. Meyer and Werneigh.

CHAPTER IX.

THE WATERWAYS OF BELGIUM.

THE little kingdom of Belgium enjoys the advantage of having both a complete railway system and an excellent system of canal transport. There is, indeed, no country in Europe where the conditions of economical transportation have been more closely and more effectually studied. To this fact is largely to be attributed the unique position which Belgium holds among the industrial nations of the world. With limited coal resources, which are much behind those of some other European countries, alike as regards their quality and the economical conditions under which they can be mined; with iron ore supplies that are almost exhausted, and which only meet her own consumption to a very limited extent; with hardly any other mineral resources worth speaking of, excepting only certain deposits of zinc ores, Belgium has relatively a larger industrial population than any other country in Europe, and enjoys a degree of prosperity that is rare even in countries more liberally endowed with Nature's gifts.

Belgium possesses twenty-nine different canals or canalised waterways, of which three—the Escaut, the Lys, and the Meuse—are each over 100 kilometres in length. The total length of the waterways of Belgium in 1885 was 1634 kilometres, or 1013 miles. The total number of tons of traffic carried on the Belgian waterways was 31,362,000, and the total number of tons transported one kilometre was 726,359,000, so that the average length of transport per ton was 23·2 kilometres.* There are, however, cases in which the average length of lead is much under this figure, as for example that of the "Raccordement à Gand," where it is only 1·8 kilometre. For a number of years past the canal traffic has been tolerably steady,

* The chief elements of this traffic were:—

	Tons transported one kilometre.
Coal and coke	147,402,000
Other minerals and metals	200,606,000
Agricultural products, wood, &c. ..	130,571,000
Industrial products, and others	247,780,000

but between 1879 and 1884 there was a decrease of absolute quantity, although not of the kilometric tonnage.

The Belgian Ship Canals.—Belgium has two excellent ship canals —one from Terneuzen to Ghent, and the other from Ostend to Bruges. The improvement of the ship canal from Ghent to Terneuzen was begun in 1874, and concluded in 1879. Originally the canal had many bends, which rendered navigation difficult, and it was also of too limited dimensions to admit the large size of craft that was desired. The depth of the canal up to 1873 was 14 feet 4 inches, and its width was 98 feet 6 inches at the water-level. The improvement works then undertaken were designed to increase the depth to 21 feet 3 inches, and the width to 103 feet 9 inches on the water-level.

There is much traffic in the Upper Scheldt from Antwerp to Ghent, the water being tidal to the latter town, with a depth of 6 to 8 feet, working the river with the tide. The Terneuzen Canal is 35 kilometres in length, and is used by some twenty steamers from England weekly, taking coals, pig iron, and other articles, and loading manufactured iron and other goods from all parts of Belgium. The inland harbour at Ghent has been much enlarged of late, and the lock has been removed, thus rendering access more easy. It is now a waterway of ample depth and great width, with locks at Terneuzen on the Scheldt, and at Sas van Gent, near the Belgian frontier. There is a pilot station at Terneuzen, the men taking their turns to and from Ghent. English coal may be bought for 15 to 18 francs a ton at Ghent, being carried at a very low freight for want of cargo on the outward voyage. Vessels of the following dimensions can use this canal:—Length, 110 metres; breadth, 11·50 metres; and draught, 5·85 metres. Their speed *en route* when exceeding 2·75 metres draught, is 145 metres a minute; when under 1·50 metres draught, 250 metres a minute.

The enormous difference that results to the prosperity of a city from the possession of facilities for the navigation of vessels is well illustrated in the case of the old town of Bruges in Belgium, as compared with that of her rival Antwerp. Nay, the point is forcibly brought home by the history of Bruges herself.

This "Venice of the North" lay formerly near the sea, on a gulf of large extent and considerable depth; she was easily accessible, not only to the ordinary run of vessels, but even to the largest of ships. That her port of Damme was large is evident from the fact that in

1213 Philip Augustus, at the head of 1700 sail, closed in it with the allied English and Flemish fleets. This fact alone will give an idea of the importance of Bruges harbour, then one of the largest in Europe. As long as these means of communication with the sea remained open, Bruges maintained her commercial power. The successive accumulations of clay in the Zwyn and in the havens of Damme and Sluys, the outer ports of Bruges, were the causes of the lamentable state of things which followed.

About the beginning of the 13th century, vessels sailed into Damme, the port of Bruges, from all quarters of the world, and poured into her markets the trade and wealth of the South and East. Less than a century later the inhabitants of Bruges were compelled to lengthen their maritime channel to Sluys, a small town situated on the Zwyn, about eight miles beyond Damme. The new canal was so constructed as to give access to vessels of from 400 to 500 tons, the largest then built; it passed by Dudzeele and Westcapelle. Hardly had it been opened when the commercial movement of Bruges took a fresh start; from 1420 to 1470 Bruges was the mart of the world, and her fortune had reached its climax. By the Sluys Harbour, into which entered in 1468 with one tide as many as 250 vessels, Bruges was in communication with the North and South of Europe; she was also the only market city for the Netherlands and the Hanseatic League. But from 1470 onwards, i. e. twenty-two years before the discovery of America, the accumulation of clay in the Zwyn again made its disastrous effects felt. Caracks, galleys, and other large vessels could no longer enter the channel. Charles the Bold, in order to deepen it, had the *polder* * of the Zwartegat opened, but without avail. Twelve years later, in 1482, matters stood in a much worse condition, and vessels of large draught had completely ceased to appear. No work such as cleansing was carried out, no artificial sluices for such a purpose constructed; and the Sluys Canal, that bold work which during one whole century had maintained the marvellous prosperity of Bruges, now wellnigh useless, became entirely choked up, and like the harbour of Sluys itself, disappeared in the depths of the vast gulf, under the clayey mud and deposits of its alluvia-bearing waves. Bruges was thenceforth condemned to a long decline.

In 1622, during the reign of Albert and Isabella, the opening of

* This was an extensive plain in the Netherlands, protected by dykes, which was formerly covered by the sea.

a canal from Bruges to Ostend, *viâ* Plasschendacle was for the first time determined upon. Twenty years later was dug the canal from Bruges to Nieuport and from Nieuport to Dunkerque. In 1646 Dunkerque was given up to France, and consequently the Flemings were obliged, in 1664, to direct their attention towards Ostend. The dimensions of this canal were now largely increased, and the sluices of Plasschendacle replaced by those of Slykens, much nearer the sea. In 1717, a powerful society, known as the *Compagnie des Indes*, was organised at Ostend. The undertaking met with wonderful success at its very beginning, and would probably have given back to Bruges some of its former movement and life, had not the Treaty of Paris of 1727, inspired by the jealousy of Holland and England, suspended for seven years the grant of the company, and later on forbidden all commercial intercourse between the Austrian Netherlands and the Indies. Four years later the Treaty of Vienna of 1731, stipulated expressly—Sec. 4 of the Act, dated from the Hague, 20th February, 1732—"That all commerce and navigation from the Austrian Netherlands to the East Indies, as also that all commerce and navigation from the East Indies to the Austrian Netherlands, shall cease for ever."

In 1783, Joseph II., wishing to end the state of subjection that his provinces were labouring under, conceived the idea of linking the waters of Flanders with those of the sea, by means of canals to be dug exclusively in Flemish ground. He failed in the attempt, and it was only after the Netherlands had been joined to the French Empire that the work which the inhabitants of Bruges had been in vain seeking for centuries was again attempted. At their urgent request, Napoleon ordered a canal to be dug from Bruges to Sluys *viâ* Damme; this it was intended to lengthen later on, as far as the Scheldt, somewhere near Breskens. The works unfortunately were carried on with extreme slowness, and the fall of the empire prevented their completion. In 1818 the canal was opened.

In 1829, King William found out the inefficiency of the issues of the Zwyn; he resumed the scheme of Napoleon I., and decided to push the new canal on to Breskens. The works were on the point of being ordered, when, in 1830, the Revolution broke out, and Bruges saw the realisation of her hopes again deferred.

Since 1470, then, three principal efforts have been made to bring Bruges into communication with the sea; first, in 1622, *viâ* Ostend; second, in 1640, *viâ* Dunkerque; third, in 1810, *viâ* Breskens. The two last failed through political events, which took away from Belgium the two principal points: Dunkerque scarcely five years after the canal was completed; Breskens before the works were even begun. One disadvantage to be noticed with regard to these two towns is the considerable distances at which they lie from Bruges—Dunkerque at over forty, Breskens at more than twenty miles. Moreover the works, comparatively speaking, were on a very small scale. As for the Ostend scheme, the canal necessarily encountered the same fate as the harbour itself—one continual struggle against alluvia. The case seemed hopeless, and Bruges in despair had resigned herself to her melancholy fate, when in 1877 M. A. de Maere Limnander started and publicly advocated a scheme which was intended to open for Bruges, once more a seaport town, a fresh era of prosperity. The work which he published on the subject, the result of long inquiry, has met with general approbation.

In the construction of the ship canal from Ostend to Bruges, the spot chosen for the outer port lay in the neighbourhood of Heijst, to the south-west of the mouth of the Sebzate and Schipdonek canals, at about 1250 metres (4114 feet) from the Heijst sluices. The motives for selecting this place are twofold—Firstly, the minimum of clearing to be executed in opening the downs, the depth of which is here of not more than from 50 to 60 metres (164 feet to 197 feet); secondly, the minimum of length to be given to the piers, the depth of seven metres (23 feet) at ebb tide being here very near the shore. This part of the coast, moreover, is also one which has stood in constant danger of irruption on the part of the sea, and has only recently needed strengthening. To maintain the depth at the entrance to the harbour the westerly pier is made the longer of the two, and slightly bent in towards the end; its length is fixed at 1100 metres (3620 feet), viz., 840 metres (2769 feet) from the base to the bend, and 260 metres (855 feet) from the bend to the end; that of the easterly one at 800 metres (2633 feet); the width at the entrance to the port at 300 metres (987 feet), and that at the base of the same at 1000 metres (3291 feet); the surface of the harbour thus amounts to 60 hectares (6000 acres, or 29,040,000 square yards). The masonry consists of artificial blocks of the largest possible dimensions, never weighing less than from 40,000 to 90,000 kilogs.—from about 85,000 lb. to about 180,000 lb. M. De Maere also advocates the construction along the outer side of the westerly pier of a breakwater, made of a single row of stakes. One or two lighthouses are to light the entrance to the harbour. The cost of this section of the works was estimated at 9,000,000 f. = 360,000*l.*

The canal runs in a straight line from the sea to the docks at Bruges. Its length is 12 kilos.—about 7½ miles; its floor width is 20 metres—65 feet; its width, measuring at the water-line, of 62 metres—204 feet; its depth from the water-line of 7 metres—23 feet. The slopes have a slant of 1 metre—3 feet 3½ inches—for every 3 metres—9 feet, 10½ inches. This lessens the expense of keeping in repair, and, where the necessity is felt, makes the widening of the bottom possible. The canal is exclusively fed with sea-water, and is so constructed as to allow of the Ghent-Heijst Canal being easily joined to it later on below the future sluice. The amount of earth dug out of the canal was about 8,887,000 cubic feet, and the cost of clearing it some 2,500,000 f.—100,000*l.* 2,700,000 cubic metres of earth were employed in the construction of banks or dykes along the canal. This necessitated the expropriation of 170 hectares—17,000 acres, or 82,280,000 square yards—of land, at the rate of 10,000 f.—400*l.*—per hectare, or 1,700,000 f.—68,000*l.*—for the 170 hectares.

Other features of the canal include a sea-sluice, constructed below the downs, with a double bridge, one-half of which will be devoted to the Blankenberghe-Heijst Railway; the other half to general use. The bridge is 8 metres—about 26 feet—wide, and the opening at the sluice, as also at the bridge, is 20 metres (about 65 feet), thus enabling several ships to enter at a time. Another sluice-gate is fixed some 200 metres (about 7900 feet) lower, and the part of the canal between will be made quite secure by means of a flood-gate. The cost of these works amounted to about 2,000,000 f. (80,000*l.*). The plans also provided for two bridges, one on the Lisseweghe-Dudgeele, the other on the Lisseweghe-Heijst high roads, and four syphons for the draining of the low waters of the country, to run under the canal at a depth of eight metres (about 26 feet) below the water-line.*

The river Rupel, which is about 12 miles above Antwerp, leads from the Scheldt to Willebrock, opposite the town of Boom. From here a canal with five large locks leads to Brussels. This canal, which had its origin in the year 1415, but which was only completed in 1561, is of considerable importance. The traffic on it is heavy, and it is worked by the Corporation of Brussels, the result usually

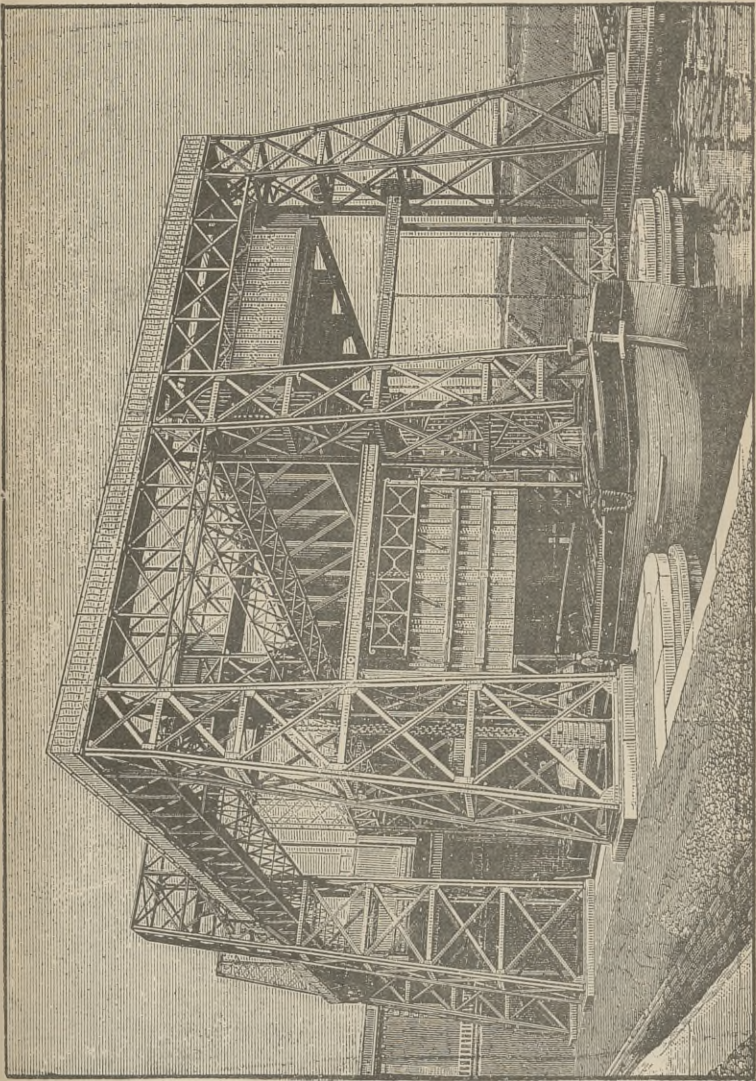
* These particulars are mainly abstracted from the *Engineer*, January 3rd, 1879.

leaving a profit. The tolls on this canal are—First class, ·06 franc; second class, ·04½ francs; third class, ·02 franc per ton. In all cases a cubic metre is reckoned as 1000 kilogrammes, or one metrical ton. In the first class is reckoned merchandise, &c.; in the second class, bricks, firewood, stone (wrought or unwrought), salt, &c.; and the third class, unladen vessels.

There is a depth of from somewhat over 10 feet of water, but this is limited to an effective depth of 3·10 metres where it passes over a small stream by a brick aqueduct. A line of steamers belonging to Messrs. Thomas & Co., of London, runs to Brussels regularly, and several Dutch lines of steam barges use this route. Sailing vessels and lighters are worked on the canal by means of the chain system, with *remorqueurs*, twenty to thirty being thus easily towed. The locks are large, and as many vessels pass at the same time, the trains are made up accordingly. When two meet, the ascending tug drops the chain, the train keeps on its right side, and the chain is again picked up by a grapple when the descending train has passed. With this system the vessels are easily steered by the men at the helm. When approaching a lock, the chain is thrown off in proper time, and the vessels' way being checked, they gradually settle side by side in the lock. Great skill and care is used by the men, damage by collision rarely occurring. One great advantage attending this system of towage is that the tugs make no wash, which so much destroys the banks of canals. The tolls are light, and the rates for towage very low. Empty vessels only pay 20 c. for a *laissez passer vide;* this ticket, as in France, can be taken from any *bureau de navigation* to any other place in the kingdom or in the Republic.

Belgium has made a substantial contribution to the more important engineering features of canals by the construction of the La Louviére Canal lift on the Terneuzen Canal, which is illustrated on the opposite page.

This canal lift was constructed for the Belgian Government by the Société Cockerill, of Seraing, from the designs and under the superintendence of Messrs. Clark, Stanfield, and Clark, of Westminster, consulting engineers to the Government, and the patentees of the system. The difference between the levels of the upper and lower canals—that is, the height the boats are raised—is 50 feet 6¼ inches. The lift consists of two pontoons, or troughs, each 141 feet long by 19 feet broad, with 8 feet draught of water, and are capable of



La Louvière Canal Lift.

holding the largest size of barge that navigates on the Belgian broad-gauge canal system. Such barges are capable of taking 400 tons of coal or other cargo, so that the total weight of the trough, water, and barge is not much under 1000 tons. This immense weight is supported on the top of a single colossal hydraulic ram of 6 feet 6¾ inches diameter and 63 feet 9½ inches long, working in a press of cast iron, hooped continuously, for greater security, with weldless steel coils. The working pressure in this press is about 470 lbs. to the square inch. The time actually occupied in lifting or lowering is only two and a half minutes. The La Louviére lift is said to be the largest in the world.

The Scheldt Navigation.—In the recent history of the shipping industry, the city of Antwerp has played a prominent part, thanks partly to the facilities afforded by the river Scheldt, partly to the easy means of access to other parts of Belgium and Holland by sea and canal, and partly to the very low rates charged for transport by both systems of navigation.

Up to the year 1863, the Dutch Government levied a tax upon all vessels using the Scheldt. This tax was found to be so onerous, that treaties were entered into in that year by which, in consideration of certain specific payments made by the various countries concerned in the navigation of the river, the King of Holland renounced his right to levy such duties.* Since then the trade of Antwerp has advanced by "leaps and bounds." Between 1862, the year previous to the abolition of the taxes on shipping, and 1887, the importations into Antwerp had increased by 335 per cent., and the exportations from Antwerp had increased by more than 500 per cent. In the general transit trade the increase was equally striking, amounting to about 400 per cent. The tonnage of vessels entering the port of Antwerp within the same period advanced by about 600 per cent.†

* The sum total of these amounts was 17,141,640 francs, or 685,666*l.*, of which more than one-half was paid by Great Britain, and fully one-sixth by the United States.

† The figures are so remarkable that it will probably be interesting to put them on record in a tabulated form:—

Year.	Importations by Sea.	Exportations by Sea.	Tonnage of Ships entering Antwerp.
	tons	tons	tons
1862	568,871	177,702	599,899
1886	2,438,178	821,753	3,658,900

Economical Conditions of Water Transport in Belgium.—The abolition of the taxes levied previous to 1863 has had the effect, coupled with a judicious development of the shipping facilities of the port, of placing Antwerp at the head of the maritime ports of Continental Europe, as regards both the volume of its trade and the low rate of freights that may be obtained thence for nearly all the other ports of the world.

There is no country that enjoys the advantages of such cheap railroad transportation, excepting some instances in the United States, as Belgium, and yet, as we have seen, there is no country that makes a more extensive use of its canal communications. The cost of transport on the canals from the Belgian coalfields to Paris amounted to 0·29*d.* in the spring, and 0·34*d.* in the autumn of 1883, not including interest.* The lowest rate of transport on English railways for the same description of traffic is ·49*d.* per ton per mile. The canal transport of Belgium, therefore, averaging the summer and winter rates, is ·18*d.*, or 58 per cent. cheaper † than that of the London coal traffic, which is pointed to in this country as a remarkable example of economical transport, and which certain authorities declare to be carried at a loss to the companies. ‡

Extent and Income of Belgian Canals.—We have seen that the total length of the canals of Belgium is over 1634 kilometres, of which the principal were the Communal Canal from Brussels to Rufel (28 kilometres), the canal from Brussels to Charleroi (24 kilometres), the Haut-Escaut Canal (115 kilometres), the Bas Escaut Canal, from Gand to the Dutch frontier (118 kilometres), the Ghent and Ostend Canal (70 kilometres), the Ghent and Terneuzen Canal (17 kilometres), the Meuse and Escaut Canal (86½ kilometres), the Lys Canal (113 kilometres), the canalised Meuse from Givet to Liege (113½ kilometres), the Mons and Condé Canal (20 kilometres). Altogether there are forty-five canals in Belgium, which in 1886 carried 763,108,000 kilometric tons—equal to about 480 million ton miles. The total tonnage carried on the canals, as a whole, is returned at about 33½ millions, including the Meuse, and the average distance over which each ton was carried was 22·8 kilometres. The principal

* Minutes of Proc. Inst. C. E., vol. 68, p. 484.

† Subject, of course, to the charge for interest, which, however, will be very trifling.

‡ Mr. F. R. Conder maintains that the London coal traffic is carried at a loss to the railways of 822,000*l.* per annum, or 40 per cent. on the traffic.

elements of the canal traffic are shown in the appended statement of tons carried one kilometre :—

	Kilometric Tons.
Coal and coke	167,221,000
Iron, iron ore, building materials, &c.	210,600,000
Agricultural produce	117,217,000
Industrial products, &c.	268,400,000

The annual income of the Belgian canals, notwithstanding that the facilities for canal navigation have been considerably extended and improved, has not increased during recent years. On the contrary, while the annual income between 1841 and 1850 was 2,885,000 francs, and from 1851 to 1860, 2,974,000 francs, the average of 1871 to 1880 had fallen to 1,676,000 francs, and in 1887 it was only 1,266,000 francs. The latter fall, however, must be due to a decrease in rates, as the amount of traffic carried between 1881 and 1886 increased from 30,562,000 tons to 33,419,000 tons. The ordinary expenses of maintaining the canals of Belgium have been reduced from 2,600,000 francs in 1881 to 2,100,000 francs in 1886. For a number of years past there has been a considerable extraordinary expenditure on the canals, the special credits for this purpose having been as much as 12½ million francs in 1883.

CHAPTER X.

THE WATERWAYS OF HOLLAND.

"Jupiter, surveying earth from high
Beheld it in a lake of water lie."—*Ovid.*

Holland, the land of dykes and ditches, is completely cut up into small islands by its extensive system of canals, which cross and interlace each other like the threads of some large fishing net. Owing to the level condition of the country, the construction of a canal involves but comparatively little labour and expense, and many of them are used as substitutes for public highways, while in the winter, their frozen surfaces offer convenient roads for skaters. The North Holland canal was, until recently, the finest work of its kind in Europe, and was built during the years 1819–23, at a cost of 950,000*l.* Since not only the surface, but the beds of many of these canals are above the level of the land, drainage is a matter of great importance, and is effected by means of windmills working pumps.

Phillips* speaks of Holland as being intersected by innumerable canals. "They may," he says, "be compared in number and in size to our public roads and highways, and as the latter with us are continually full of coaches, chaises, waggons, carts, and horsemen, going to and from the different cities, towns, and villages, so on the former, the Hollanders, in their boats and pleasure barges, their *breckshuyts* and vessels of burden, are continually journeying and conveying commodities for consumption or exportation, from the interior of the country to the great cities and rivers. An inhabitant of Rotterdam may, by means of these canals, breakfast at Delft or the Hague, dine at Leyden, and sup at Amsterdam, or return home again before night. By them, also, a most prodigious trade is carried on between Holland and every part of France, Flanders, and Germany." The same author declares that the 400 miles of inland navigation open in Holland in his time, yielded an average income of about 625*l.* per mile, which he declares to be, "almost beyond belief." What would

* 'History of Inland Navigation.'

he have thought had he lived in our time, and seen canals producing an income of 30,000*l.* to 40,000*l.* per mile? *

The Haarlem Canal was constructed about fifty years ago, for the purpose of draining the *Meer* or lake of that name. This lake had been formed by an inundation in the end of the sixteenth century, and in the beginning of the eighteenth century it had covered an area of 45,000 acres. Seeing that the lake was gaining upon the land, it was resolved to take effectual means for draining it. This course was precipitated by two furious hurricanes, one in November 1836, which drove the waters of the lake upon the city of Amsterdam, and another in December of the same year, which submerged the lower parts of the city of Leyden. The first step incidental to draining the lake—a work which was undertaken by the Government in 1839—was to dig a canal round about it for the reception of the water, and to accommodate the great traffic which had hitherto been carried on by its means. This canal was made 38 miles in length, 130 feet wide on the west side, and 115 feet on the east side of the lake, and 9 feet deep. All the inlets into the lake, were then closed by large earthen dams; and various works were executed to facilitate the flow of water into the sea. These preliminary works occupied till 1845. To give some idea of the magnitude of the undertaking, it may be mentioned that the area of water enclosed by the canal was rather more than 70 square miles, and the average depth of the lake was 13 feet 1·44 inches. The water had no natural outfall, being below the lowest possible point of sluiceage, and, including rain water, springs, &c., during the time of drainage, it was calculated that probably 1000 million tons would have to be raised by mechanical means. After drainage, too, the site could only be kept dry by mechanical power, so that the annual drainage might amount to 54,000,000 tons, to be raised on an average 16 feet, and it might happen that as much as 35,000,000 tons of that amount would have to be raised in one month.

The North Sea Canal was constructed for the purpose of facilitating the navigation of the Zuyder Zee, which, by reason of its numerous shallows, was very intricate and difficult, and in order that vessels might avoid the Pampus—a bank that rises where the Y joins the Zuyder Zee, and formerly compelled large vessels to load and unload a part of their cargoes in the roads. These obstacles frequently detained vessels for as much as three weeks.†

* The Suez Canal gives this return.

† M'Cullough's 'Commercial Dictionary,' Art., Amsterdam.

M'Cullough spoke of this canal as "the greatest work of its kind in Holland, and probably in the world."* It was begun in 1819, and completed in 1825. The length of the canal is about 50½ miles; the breadth at the surface, 124½ English feet, and at the bottom 30 feet, while the depth is 20 feet 9 inches. It is a tide-level canal, and is provided with two tide-locks at each end. Intermediately, there are two sluices, with flood-gates. The locks and sluices are double. The canal is crossed by about eighteen drawbridges. The cost of the undertaking was about million sterling.

At the further end of the canal, at Niewdiep, a harbour was constructed, which has been very much frequented by the shipping of Amsterdam. About eighteen hours were formerly occupied in towing ships from Niewdiep to Amsterdam.

The Amsterdam Ship Canal.—The Amsterdam Ship Canal, designed by Mr. Hawkshaw, and Heer J. Dirks, of Holland, is a gigantic example of engineering compressed within a limited extent. The burgesses of Amsterdam had spent millions in improving the access to that great commercial port—first, on long previous operations in the Zuyder Zee, and, subsequently, on the North Holland Ship Canal, which stretches nearly due north from their city to the Helder, between which point and the Texel Island opposite is the entrance from the North Sea, which was then the only available channel for large vessels.

The exigiencies of their trade calling imperatively for further improvements, the engineers furnished them with the design for a new ship canal, which reduces the navigable distance to 15½ miles, on a course about west from Amsterdam to the North Sea, available for larger vessels than formerly entered the port—and has provided a new harbour on the coast, with an area of 250 acres, bounded by breakwaters formed of concrete blocks set in regular courses, with 853 feet of entrance between the pier heads, and 26¼ feet minimum depth of water. The width of the sea canal is 197 feet at the surface, and 88 feet at the bottom; minimum depth, 23 feet; the locks are 59 feet wide, and of proportionate length.

There are three locks or entrances at the north end of the canal from the new harbour. Eastward, and below the city and wharves of Amsterdam, there is an enormous dyke to shut out the Zuyder Zee, pierced with three locks, besides sluices. These are built upon such a lake of mud as to require nearly 10,000 piles in their foundation. Thus the canal is approached by locks at each end, not for the

* M'Cullough's 'Commercial Dictionary,' Art., Canals.

purpose of locking up, but for locking down, as the surface water of the canal has to be kept twenty inches under low-water mark. To accomplish this, in addition to the locks and sluices, that can only avail at low tides, pumping power was required at the dyke, which bars out the Zuyder Zee. The three large centrifugal pumps by Messrs. Eastons, Amos, and Anderson, were constructed to lift together 440,000 gallons of water per minute. The works on this canal took nearly ten years to complete. They included the construction of branch canals to the several towns and ports on the borders of the lakes, which, although of smaller sectional area, exceeded the sea canal in their total extent. Mr. Vignoles, in his Presidental Address to the Institution of Civil Engineers,* from which most of the above particulars are taken, has stated that the Amsterdam Ship Canal resembled the Suez Canal, in passing through large muddy lakes, similar to Lake Menzaleh. (See Suez Canal).

The ship canals communicating with Rotterdam are described by a recent writer † on the subject as follows:—

1. *The Voorne Canal* running from Helvoetsluis through the island of Voorne to the river Maas. The resolution of March 9th, 1880, resettled the police regulations for this route; the maximum dimensions of vessels using it being—length, 110; beam, 13·70; draught, 6 metres.

2. *The Niewe-waterweg*, or direct entrance from the North Sea to the Maas, which is without sluices, and is cut through the Hoek van Holland, thus forming a new outlet to the Maas.

Besides these approaches, there is another route to Rotterdam, to which great attention has been paid of late years, but the railway bridge across the river at Rotterdam causes a certain inconvenience to vessels using it. Vessels coming from the sea by the Hollandschdiep, enter the narrow passage of the Kil near the great Moerdyke railway bridge, and passing Dordrecht, the Maas is reached above the Rotterdam railway bridge. The Nieuwe-Haven, just above this bridge, is a most convenient port for small steam-yachts visiting Rotterdam.

There are two other important ship canals, giving access from the river Schelde to the inland waters of Holland:—

1. *The Walcheren Canal*, about seven miles long, from the new port of Flushing to Veere, which place, formerly known as Campvere,

* 'Proceedings,' vol. xxix., p. 289.

† Report of the Conference on Inland Navigation at the Society of Arts, 1888.

was a free port of the Scotch, who had a factory or trade station there for 300 years, from the year 1506. The maximum dimensions for vessels using this canal are:—Length, 120; breadth, 19·75; and draught, 7·10 metres.

2. *The South Beveland Canal*, from the West Schelde at Hansweert to the East Schelde at Wemeldinge, is five miles in length. The regulations of this canal, fixed by the resolution of May 28th, 1880, allow vessels of the following dimensions to use it, viz. length, 100; breadth, 15·75; draught, 7·10 metres.

The former of these two canals is not much used, but there is a great traffic of the large Rhine arks, and the inland steam barges and sailing vessels of Holland, going to and from Antwerp, Brussels, Ghent, and other towns of Belgium. The locks, like the others in the more important canals, take in thirty to forty of these vessels at once, all masters having to show their papers before passing. These ship canals are all State property, and are under the management of the Minister of the Waterstaat, Trade, and Industry. Many of the smaller inland navigations are under State control, but others belong to the communes through which they pass. The water-level, which is so all-important in the Netherlands, is regulated by the Amsterdam mark, called the A.P. (Amsterdamsche Peil).

The following navigations, with some others, are also regulated by police rules, fixed by resolutions of the State:—

1. *The Afwaterings Kanaal*, from the Noordervaart and the Neeritter, near Venlo, for vessels—length, 24; breadth, 3·70; draught, 1 metre. The use of steam is forbidden.

2. *The canalised river Ijssel*, from the river Lek, opposite to Ijsselmonde, to Gouda, whence there is canal communication with the river Amstel, to Amsterdam, and also by the old Rhine, *viâ* Leiden and Haarlem, to Spaandam, to the North Sea Canal. There is a great traffic in the former of these two routes, there being always a great collection of craft at the sluices at Gouda, waiting their turns to pass. Large and improved locks are said to be urgently required at this place. The depth of water on this route is at least six feet.

3. *The Keulsche Vaart*, from Vreeswijk, on the river Lek, *viâ* Utrecht, the Vecht, and Weesp, to the river Amstel and Amsterdam. Vessels of a breadth of 7·50 metres, and draught of 2·10 metres, can use the route. The sluices take in the very long Rhine craft. The pace allowed for steamers is 130 metres a minute for those of 1·50 draught, to 180 a minute for those of 1 metre draught.

4. *The Meppelerdiep*, Zwaartsluis to Meppel, for vessels of length, 60; breadth, 7·80; draught, 1·80 metres.

5. *The Drentsche, Hoofdvaart, and Kolonievaart*, from Meppel to Assen, for vessels drawing 1·60 metres, between Paradijssluis and Veenebrug; in other parts vessels of only 1·25 metres are allowed.

6. *The Willemsvaart*, from the town canal at Zwolle to the river Ijssel, by the Katerveer, for vessels of the following dimensions—length 100, breadth 11·80, and draught 3 metres.

7. *The Apeldoorn Canal*, from the Ijssel at the *sluis* near Dieren to the same river at Hattem, for vessels of the following dime n sions—length 30, breadth 5·90, and draught 1·56 metres.

8. *The Noordervaart*, between the Zuid Willemsvaart at *sluis* No. 15 and the provincial canal at Beringen, in the commune Helden, for vessels having a length of 51, a breadth of 6, and a draught of 1·50 to 1·65 metres.

9. *The Dokkum Canal*, from Dokkum (in Friesland) to Stroobos, and the Casper Roblesdiep or Kolonelsdiep, being the inland route from Friesland to Groningen.

A deep-water canal communicates between Groningen and Delfzijl, in the estuary of the river Ems, whereby the inland navigation of Germany may be entered, and, finally, the Baltic.

The Elbing Highland Canals.—This system of canals, constructed between the years 1844 and 1860, connects the group of lakes around Mohrungen and Preussische Holland, at a height of about 328 feet above the Baltic, with the Drausen Lake, whence flows the river Elbing, emptying itself into the Frische Haff, on the Gulf of Dantzic. The whole length of the canal navigation and branches is 123½ miles, of which 28 miles is artificial, and the remainder lake and stream.

The Puniau lakes are situated at a distance of 10 miles from, and its waters were originally at a level of 343 feet 9 inches (104·8 metres) above, the Drausen lakes. When the canal was first constructed, the water-level of the Puniau lake was lowered to the extent of 17 feet 5 inches, thereby reducing the difference in level between the two lakes to 326 feet 4 inches. Commencing from the Drausen Lake, the canal continues level for a length of 1¼ miles, and in the next 2·17 miles, rises a height of 45 feet 3 inches. This difference of level was surmounted in the first instance, by five locks, which have recently been abolished and replaced by an inclined plane. In the following 4·66 miles the remaining height of 281 feet is attained by four inclined planes.

The cost of original construction was 212,325*l.* (4,246,500 marks), and, assuming it to have been spent entirely upon the artificial portion of the canal navigation, which is 28 miles in length, would amount to 7,583*l.* per mile (94,376 marks per kilometre). Of this outlay 70,000*l.* was expended on the four inclined planes, exclusive of the earthwork, which latter cost 27,000*l.*, or an average of 24,250*l.* for each incline. The total height surmounted by these five locks and the four inclined planes being 326⅓ feet, the cost of each foot of rise for the whole length of the canal amounts to

$$\frac{212{,}325l.}{326 \cdot 33l.} = 650l.\ 12s.$$

The cost of maintenance of the whole system (including the lake portion) of the canal and works between the years 1861 and 1875 averaged annually 27*l.* 2*s.* per mile for the lake portion, and 120*l.* 4*s.* per mile for the artificial canal portion.

The Dutch canals, like those of Belgium and Germany, provide exceptionally low transport. The butter of Friesland is conveyed by canals in small boats to the home markets, whence it is carried twice a week to Harlingen and shipped to the London and other large places of consumption.

One of the most remarkable features in the landscape of Holland is the large number of windmills that are everywhere to be seen. In one province not more than 60 miles long, there are said to be more than 200 of these primitive appliances. The windmills are largely employed in spring time to drain the water from the low-lying lands and raise it into the canals, but they are "contrived the double debt to pay" of drainage and agricultural work.

The Dutch canals, which are for the most part elevated above the surrounding country, in order that they may the better carry off the water that inundates the land, are provided with strong dams or banks, which it is the care of the inhabitants to keep in good order. A system of militia was long maintained for the purpose of keeping the banks in repair. The ringing of a bell, or some other signal, brought the members of this force together, and, when the waters threatened danger, every man was found at his post, ready to repair any possible damage to the dykes. It is still the custom to assign to every family a certain length of embankment, which they are required to maintain.

It is, of course, essential that a system of water communication so complete and so important to the wellbeing of the country as that of Holland should be subject to very strict regulation. There are two principal sets of regulations—the first adopted on the 5th February, 1879, for the Government canals generally; and the second adopted on the 6th August, 1880, applying specially to the North Holland Canal. There is also a series of special regulations for the Walcheren Canal, which communicates between Flushing and Veere. These regulations have been translated into English, and may be easily acquired by any one who desires to possess them.*

* They are appended to a work which has recently been published, entitled 'On Dutch Waterways,' by G. C. Davies.

CHAPTER XI.

THE WATERWAYS OF ITALY.

" Though Tiber's streams immortal Rome behold,
Though foaming Hermus swells with tides of gold,
From Heaven itself, though sevenfold Nilus flows,
And harvests on a hundred realms bestows,
These now no more shall be the Muse's themes,
Lost in my fame as in the sea their streams."—*Pope.*

THERE is no characteristie of the ancient Roman Empire that is more striking at the present day, after the lapse of nearly twenty centuries, than the proficiency that the people had attained in the arts and sciences, and more especially in the arts of architecture and engineering. The aqueducts which they built for the supply of water for domestic purposes were vast structures that have hardly been equalled in any subsequent period, and the canals which they constructed for the drainage of morasses, or the transport of armies, were hardly less remarkable.

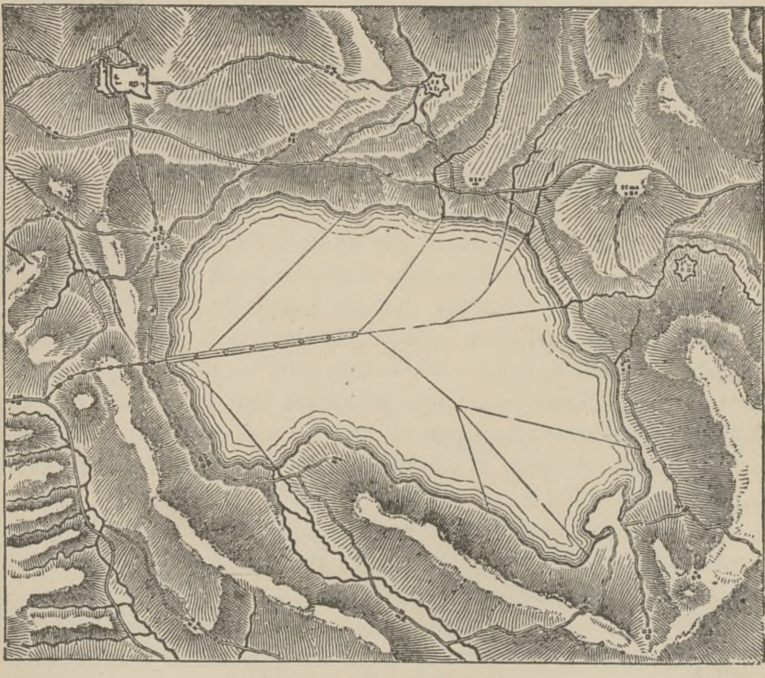
Early Canals.—Among the earlier navigation works, perhaps the most remarkable was the canal which the Romans constructed for the drainage of Lake Fucino, illustrated on p. 154.

This canal, which was commenced by order of the Emperor Claudius, is said by Pliny to have occupied 30,000 men for ten years. The lake is surrounded by a high ridge of mountains called Celano, which are stated to be nearly fifty miles in circuit. The passage of the waters from the lake into the canal was witnessed by a vast number of persons, when the undertaking was completed, but the canal was not sufficiently deep to allow the water from the lower part of the lake to drain off, and although it was sought to correct this defect in Nero's reign, the project was never really finished. As far as it went, the work is described by Tacitus,* while Virgil speaks of the lake—now no longer covered with water—as well known. †

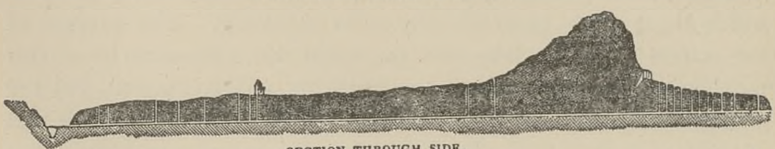
Hydraulic engineering formed so important a part of the business of the ancient Romans that the pro-consuls were charged to lay

* Ann., lib. xii. cap. 56. † Æn., t. v. 563.

before the emperors the best methods of changing the course of rivers, for the purpose of facilitating the approaches from the sea to the centres of the various provinces. Thus, we find that Lucius Verus, General of the Roman army in Gaul, undertook to unite the Saône and the Moselle by a canal. He is also said to have undertaken to connect the Mediterranean Sea and the German Ocean by means of



CANAL ON LAKE FUCINO.



SECTION THROUGH SIDE.

the Rhône, the Saône and the Moselle, but the project was never completed. Emilius Scaevius, more successful, united the waters of the Po, near Placentia, for the purpose of draining the marshes round about. Other rivers in Italy were straightened, deepened, widened, or otherwised improved, while Rome was still "the mistress of the world."

Some twelve centuries later the Italians were the canal makers of Europe. Alberto Pittentino, in 1188, converted the Mincio, from Mantua to the Po, into a canal, thus restoring it to the course from which the Romans had diverted it in the time of Quintus Curtius Hostilius.

The use of locks on canals may be said to date from this time. It is related that in the canalisation of the Mincio, Pittentino so regulated the rise and fall of the river that boats could ascend to Mantua and descend to Po, the depth being so equally maintained that the river was navigable for about twelve miles. This must have involved the employment of locks, however rude.*

The Lake Maggiore is the source of the Tesino, which in its course is divided into several streams, which, however, are reunited before it enters the Po, near Pavia. For the whole distance it is navigable, although at Pan Perduto, where the fall is considerable, it is sometimes hazardous. Immediately below this spot commences the canal to Milan, which at Abbiate divides into two channels. The entire length of the excavation is about 32 Italian miles, and its breadth 70 Milanese cubits.

The Canal della Martesana, by some supposed to have been executed by Leonardi da Vinci, was made in the year 1460, under the Duke Francis Sforza. Leonardi da Vinci joined the two canals some time during the reign of Francis I. The Canal della Martesana, which is drawn from the Adda, is 24 miles in length, and in width about 18 cubits; but when constructed at first, the water it

* "Before the introduction of locks, contrivances called conches were in use to moderate the too great declivity of the rivers, and which were opened to allow vessels to pass through. These openings were 16 or 18 feet in width; a balance lever, loaded at the end, was made to turn on a pivot, and with it three hanging posts, united by an iron bar, which crossed them immediately above the sill; besides these three perpendicular hanging posts were two others, let some inches into the side walls. These five posts were all on the same face, and the spaces between them were all equal. When the balance beam turned upon its pivot, the three middle posts alone opened, and allowed the boats to pass, after which the balance beam was turned back to its former position. At a little distance was placed another balance beam, having attached to it a wide plank, to allow the lock keeper to pass over, as well as to place in the grooves of the hanging posts the small planks which served to exclude the water, by closing up the intervals; these were on the side opposed to the current, and in number sufficient to keep the water at the required level. Such gates, or contrivances for damming up the waters of a river, were in use at a very early time in Italy, and two such were constructed at Governolo, in the twelfth century, to pen up the waters of the Mincio on the side of Mantua."—Cresy's 'Cyclopædia of Engineering.'

contained was barely sufficient for navigation for more than two days in the week, and this only when all the openings for the purposes of irrigation were closed.

One of the branches of this canal was carried for several miles by a stone dyke, and afterwards passed through a deep cutting. The other branch had its course through the rock, after which it was supported on one side by a lofty embankment, where it crossed the Molgara river by an aqueduct of three stone arches.

Early in the thirteenth century, Bassanallo had a canal 11 miles long, which was navigated by the vessels that brought building stones to Venice. One of the several canals in the lagunes, on which the latter city is built, is 36 miles long. Between Padua and Venice, again, there is a canal some twenty miles in length, which has a fall of 50 feet, to overcome which four locks are provided.

Milan, like Venice, is the centre of a network of canals. Here unite the great canal of Tesino and the branch from Pavia; the Muzza Canal, which commences at Cassano and ends at Castiglione, after traversing a distance of 40 miles; the canal of Abiato, made in the thirteenth century, which has a top breadth of 130 feet, and a bottom breadth of 46 feet; and the canal which connects Buffolaro, Biagrasso, and Arsago with Milan.

Nor is Piedmont less rich in monuments and resources of the same description, having more than half a dozen canals which communicate with the Po at different points. Most of these canal are, however, of limited extent, the longest, called the Naviglio d'Inea, being 38 miles in length.

The canals, large and small, in the Papal States, are so numerous that it would be wearisome to enumerate them. None are of great length, and most of them have been constructed rather with a view to drainage or irrigation than to navigation.

Pagnani has left us an account of the levels and other operations of art, undertaken by former engineers, to ascertain whether some navigable canals might not be projected in Lombardy; and, above all, to determine the practicability of joining the Lake of Como with the neighbouring lakes. In the first place they found that the surface of the lake of Como was 48 braces lower than the surface of the lake of Cevate, 62 braces lower than that of the lake of Pusiano, and about 100 braces below that of the lake of Lugano; further, that the lakes of Como and Lugano are, at the point of their nearest approximation, in the valley of Porlezza, about six miles distant from each other; and that they are separated by a very high ridge, which would render any attempt at a navigable canal very arduous, even independently of the very great difference in the levels. The general map of Lombardy will, on a slight inspection, show these several places.

The same engineers found that the scheme of running a canal from the lake of Lugano by the valley of the Olona to Milan was impracticable. It might, however, be possible to render the Olona navigable below Tredate, provided the waters were retained in the last trunk by means of some well-situated locks, and the upper mills were so placed as not to interrupt the bed of the river. In the project to render navigable the Tresa, which is the outlet by which the lake of Lugano discharges itself into the Lago Maggiore, these engineers found difficulties from the deficiency in the body of the water, and from the too great slope of the Tresa; to which it may be added that several torrents which enter it carry into it stones and gravel. It has been considered strange that these engineers never thought of another project, of which the execution would be easy, as well as convenient and useful—namely, to make navigable the Boza, which is the outlet of the little lake of Varese into the Lago Maggiore.

The scheme of conducting a navigable canal from Milan to Pavia is of a much older date, having been designed for the purpose of joining the two canals of Milan with the Tesino, the Po, and the sea. Galeazzo Visconte, the father of Azzon, began its excavation. In 1564, the completion of the work was made the subject of considerable discussion. It was imagined that the expense could not be very great; and that by giving the sluices the common height, a great number would not be required. The enterprise was abandoned afterwards, because the canal of Bereguardo, although it did not reach the Tesino, was found sufficient to keep up the commerce between the two cities of Milan and Pavia. Pagnani, in the Treatise already referred to, mentions some other projects of a similar nature.

The Tiber.—In Italy another great undertaking has been agitated, namely, to render the Tiber navigable from Ponte Nuovo, below Perugia, to the entrance of the Nera, from which the navigation begins to be free and without interruption, to the sea. MM. Boltari and Manfredi reported on an inspection which they made of the Tiber in 1732. In this report they laid it down as a first principle, derived from experience, that to navigate any river with facility, particularly against the stream, it is requisite that the slope should not exceed 3 Roman palms per mile (a Roman palm is about 8½ English inches).

Now, as the fall of the Tiber is 8 or 9 palms, they calculated that it would be very difficult to steer the boats down the river, and still more difficult to conduct them up against so rapid a stream, especially in some places where the fall was even greater, and where, consequently, the stream must, they held, remain impassable. They, moreover, pointed out the difficulties and the dangers which must be encountered in adopting the different expedients that had been proposed for reducing the excessive slope by weirs, for removing the detached stones by manual labour, for blowing up the obstructing rocks by mines, and for removing the bed, in certain places, by changing its course, or by contracting or enlarging its dimensions.

The schemes proposed for rendering the bed of the Tiber navigable having been thus discredited, the same engineers inquired whether a canal for boats of a moderate size and suitable burden might not be formed parallel with the river; observing the nature of the soil through which the canal must pass, the different crossings that would be required from one side to the other, the number of dykes and sluices that would be wanted, and the other works that would be necessary to secure the navigation against all accidents, and particularly those from floods. This undertaking they regarded as very difficult of execution, and they advised that it should not be attempted. They next examined the plan of making the Tiber navigable to Rome, proposed by the engineer Chiesa, in a report printed in 1745, but nothing came of these proposals.

Within the last two years, a new project has been brought forward with the view of rendering the Tiber navigable to the sea, and it is possible that this work will before long be attempted.

The Villoresi Canal.—The water for this canal is derived from the Ticino, at a place called "Rapida del Pamperduto," by means of a weir thrown across the river. This weir is 290 metres (951·2 feet) long, and 24 metres (78·72 feet) broad, and of sufficient height to raise the water in the Ticino 3·75 metres (12·30 feet) above the ordinary low-water level. Below the right abutment the river-bank is protected by a wall for a distance of 50 metres (164 feet), whilst up stream, on the same side, an embankment, partly in masonry and partly in earthwork faced with stone pitching, has been constructed for a distance of 600 metres (1968 feet), in order to confine the river to its present bed. At right angles to the weir is a lock, with a drop of 6 metres (19·68 feet), the largest in Italy, which serves for the passage of boats from a channel below, 10 metres (32·8 feet) wide, and about one kilometre (0·62 mile) long, from the canal to the Ticino. The channel is supplied with water from the basin below the measuring weir by means of four sluices 0·80 metre by 1·20 metre (2·62 feet by 3·93 feet) placed in the wall which separates the basin from the canal. On the side of the basin, opposite the weir, are two buildings, the first containing the sluices, which admit 8 cubic metres (282·52 cubic feet) per second of water into a canal belonging to the Visconti family; and the second, which forms the entrance to the Villoresi Canal, serves to regulate and maintain the level of the water in the basin constantly at 0·90 metre (2·95 feet) above the crest of the weir. It consists of a three-storied building, in the lower part of which are six sluices, 2·30 metres (7·45 feet) wide), and 3 metres (9·84 feet) deep, with iron gates, worked by suitable mechanism from the floor above. The headworks, which are on the left bank, consist of a building 67 metres (219·76 feet) long, 6 metres (19·68 feet) wide, and 12·80 metres high, provided with thirty sluices, each of 1·50 metre (4·92 feet) clear width, and 3·25 metres (10·66 feet) high, the cills of which are placed at 2·75 metres (9·02 feet) below the level of the crest of the weir. These sluices are capable of admitting 190 cubic metres (6710·13 cubic feet) per second into the canal from the river, of which 70 cubic metres (2472·15 cubic feet) per second is the amount granted by the concession to the Villoresi Canal. The remaining 120 cubic metres (4237·98 cubic feet) per second have to be returned to the Ticino by a specially constructed measuring weir established at 600 metres below the headworks, in order to respect the existing rights of others further down the stream. The passage of boats from the Ticino to the canal is provided for by means of a channel with a lock 8 metres (26·24 feet) wide.

The Canals of Venice.—In speaking of the canals of Italy, it would be unpardonable to omit due reference to those which give to Venice, the "mistress of the Adriatic," her peculiar and pre-eminent position. Founded in the year 452, soon after Attila invaded Italy, Venice is built upon a number of small islands, and is divided into two nearly equal parts by the "Grand Canal," 1200 yards in length, and 100 feet in breadth. Many smaller canals branch off from the Grand Canal.

These are crossed by some five hundred bridges, many of them of considerable architectural pretensions.

The construction of the canals of Venice was a work that would be naturally unlike that of laying out a canal in the ordinary course. The whole city, built on a number of small islands, is more or less constructed on piles; there is an almost dead level throughout; and the waterways would, no doubt, in the majority of cases, be naturally formed, at least to a partial extent. There is, however, very little information extant as to the circumstances under which the work of adapting the canals to the requirements of the population was carried out.

Irrigation Canals.—It would hardly be proper to pass from the canal system of Italy without making some remarks on the excellent system of irrigation canals that has been provided in Lombardy and Piedmont. Navigation canals take priority over irrigation canals in Lombardy in point of origin, but not to a great extent. The Vettabbia Canal, which is supposed to have been used for navigation previous to the eleventh century, is claimed as the oldest existing canal in Lombardy. In the latter part of the twelfth century, the Cistercian monks of Chiaravalle obtained possession of this canal, and applied its waters to irrigation purposes. Not very long afterwards the same order of monks constructed the Ticinello, a canal derived from the Ticino at Tornavento, and it was used exclusively for irrigation until 1177, when it was enlarged and partly opened for navigation. In 1257, the same canal was so far enlarged as to connect Milan with Lake Maggiore, and the waterway is now known as the Naviglio Grande.

One of the most important irrigation canals in Italy, which may be briefly described as illustrative of the system generally, is that of the Cavour Company, in Piedmont, which is derived from the left bank of the Po, near the town of Chivasso, and was constructed for the purpose of irrigating the provinces of the Vercellese, Novarese, and Lomellina. It was Francesco Rossi, a land surveyor of Vercelli, who, in 1844, first proposed to employ the waters of the Po for irrigation purposes. It was a good many years later, however, before the project was undertaken. The head works of the Canal Cavour are situated about 400 metres below the bridge over the river, on the road which connects Chivasso with the military road from Turin to Casale. The full discharge of this canal is 110 cubic metres per second, and its supply is obtained by means of a temporary dam of timber carried across the river. The sluice-house for regulating the supply of water to the canal is built across the canal, which is 40 metres in width, and consists of twenty-one openings separated by granite piers. Each opening is provided with three sluice-gates, which work in grooves cut in the granite piers, and can be easily raised or lowered by the sluice-keeper by means of a lever. The remainder of the building is constructed principally of dressed stone and bricks, and the contrast betwen the granite used for the quoins and the red brickwork has an excellent effect. Another sluice-house, placed at right angles to that of the main canal, communicates with that of the "Scaricatore," or discharge channel, by means of which the surplus waters in times of floods may be discharged into the Po, and any deposit of gravel and sand on the floors in front of the entrance to the main canal can be effectually swept away by the velocity of the water discharged into the "Scaricatore," which has a rapid fall, and enters the Po again, about 2 kilometres below the headworks.

The quantity of material used in the construction of this important work was :—

Excavation	695,000 cubic metres.
Bricks	2,000,000.
Dressed stone	3000 cubic metres.
Stone for *revetment*	3000 square metres.
Lime	3500 tons.
Oak piles	2200.
Oak sheet piles	8100 square metres.
Ironwork	39,780 kilos.

The width of the canal, which is 40 metres wide at the commencement, is gradually lessened until it reaches the aqueduct over the Dora Baltea near the 10th kilometre of its course, when its width becomes 20 metres. The sides, when not protected by retaining walls, have an inclination of 45°. Crossing the valley of the Dora, which is about 2 kilometres in width, on a high embankment, and the actual bed of the same river, by means of an aqueduct consisting of nine arches of 16 metres span each, the canal takes a north-easterly direction nearly parallel to the railway from Turin to Milan, which it crosses near the station of San Germano. At the 40th kilometre the canal passes in syphon under the torrent Elvo. This syphon is built in brickwork, and consists of five elliptical openings, 5 metres in width and 2·30 metres in height.

The next work of importance is the embankment and aqueduct over the torrent Cervo, and differs but little from that over the Dora. The most important work on the whole canal, with the exception of the headworks, is the syphon for passing underneath the torrent Sesia. It is similar in section to that previously described for the Elvo, but considerably longer, and is probably one of the largest works of this class in Italy.

The next works in importance are the aqueducts for crossing the torrents Roasenda and Marchiazza, and syphons under the torrents Agogna and Terdoppio, near Novara. The width of the canal up to the 62nd kilometre is 20 metres, and as, at this point, a considerable quantity of water is introduced from it into the Roggia, Busca and Rizzo-Biraga, the canal is reduced to 12·50 metres in width to the 74th kilometre, when its section is again reduced, and after passing under the Terdoppio—at which point the new branch canal "Quintino Sella" is derived—its width is only 7·50 metres The fall of the canal between the headworks at Chivasso and the Dora Baltea varies from 0·50 to 0·25 in 1000, and over the remainder—with the exception of aqueducts and syphons, when in some cases it is greater—the gradient is 0·25 per 1000. The total fall is 21·73. Besides the works just described, 480 of less importance, consisting of bridges for roads, aqueducts, syphons for the passage of existing watercourses and acnals of irrigation, watchhouses, &c., were constructed.

The River Po.—The Po, which takes its rise at Mont Viso, crosses the whole plain of Upper Piedmont, a plain formed of a deep alluvial soil, very fertile, and well cultivated. Passing through territory of Turin, it receives the drainage of the rich meadows, as also the sewage of that town, and before reaching Chivasso it receives the rivers Dora Riparia, Stura, Orco, and Malone. The waters of the Po in floods are dense with rich alluvial matter, of the fertilising properties of which evident proofs may be observed throughout the course of this river. After great floods, as if by magic, bare shoals of gravel become covered with a deep strata of alluvial soil, on which the seeds of trees and shrubs carried down by the waters soon take root, and in a very short time they are covered with a luxuriant vegetation. The waters of the Po on this account are highly valued for irrigation, as also from the fact of its temperature being higher than that of its tributaries. The fertilising properties of this water are now fully appreciated in Lomellina, where large tracts of land which were formerly bare and arid wastes, are now converted into rich meadows and rice fields, through the agency of the waters which have been brought to bear upon them by the Canal Cavour, already alluded to.

Even in the Vercellese, where the want of water is not so much felt, the waters of the Po, introduced into the existing canals, and mingling with those of the Dora, tend to modify the extreme coldness of the latter river, due to its origin in the glaciers of the Val d'Aosta and the siliceous-magnesian sands that its waters contain in suspension. It is, therefore, with just pride that Italians have named the Po the "Nile of Italy."

Although the Po is the only extensive river basin in Italy, there are many other rivers in that country that are more or less navigable, some of them inclined to the Tyrrhenian Sea, and some to the Ionian Sea, but most of them, including the Po, to the Adriatic.

Projected Canals.—Among the proposals recently put forward for extending, by artificial means, the commerce and navigation of Italy, one of the most important is designed to provide for the construction of a ship canal to connect the Tyrrhenian Sea, and the Adriatic, near Fano and Castro. The distance to be traversed by this canal would be 175 miles, and the cost has been estimated at about 20 millions sterling. It is claimed that the proposed canal would be of great advantage to the navigation between the east and the west coasts of the Peninsula.

In 1889 a company was formed in London for the purpose of establishing a system of canal, lake, and river navigation in the north of Italy. This company expects to carry a very large share of the traffic at lower rates than those quoted by the railways.

CHAPTER XII.

THE WATERWAYS OF SWEDEN.

> " From his side two rivers flowed,
> The one winding, the other straight, and left between
> Fair champaign, with less rivers intervened."—*Milton.*

ALTHOUGH Sweden is possessed of an admirable system of lakes, which facilitates transport over a wide area, and although the commerce of the country is limited, and the population sparse, the canal navigations are by no means unimportant. On the contrary, they have been carried out over a wide area, with great enterprise and skill, and at a very considerable expenditure. The two principal canal systems are those of Gotha and Dalsland—the former constructed for the purpose of connecting the two most important towns in the kingdom, Stockholm and Gothenburg; the latter intended to afford a means of communication between the province of Dalsland, with its productive forests and admirable command of water-power, and the rest of Sweden.

The Gotha Canal is one that has a very interesting history, and its ultimate completion may be said to make an epoch in the history of canal engineering, the obstacles to be surmounted being of a character that engineers had had but little experience of up to the commencement of the present century.

In Sweden, Gustavus Vasa fulfilled the same destiny in regard to artificial waterways, as Peter the Great did in Russia. The ambitious but generally utilitarian plans of the sovereign included that of connecting Gothenburg with Stockholm, by means of the Wenner, Hielmar, and Mælar. Eric XIV., the son of Gustavus Vasa, after his father's decease, caused a survey of the waters connecting with those lakes to be made, in order that they might be joined for purposes of navigation. Nothing further was done during his reign, but the design was revived by Gustavus Adolphus, who, however, could not find persons capable of carrying it out, and Charles XI. was advised by some Dutch engineers that the project was impracticable.

It was reserved for Charles XII. to commence the serious undertaking of rendering navigable the Gotha and the falls of Trolhätten, but the work was not completed in his lifetime. The projected work, as proposed by the engineer Polhem, was to connect the Mælar and the Hielmar, the Hielmar and the Wenner, and the Wenner with the German Ocean.

Difficulties occurred in the way of completing the connection between Lake Wenner, or Wenmon, and the Baltic; and in 1806 Thomas Telford was consulted, at the instance of the King of Sweden, as to the best means of carrying out the communication. Telford* made a complete survey, and prepared plans which were adopted. In 1810, he again visited Sweden for the purpose of inspecting the excavations then begun, and took with him a number of English navvies and lockmakers, in order that the Swedes might be instructed in the work. As designed by Telford, the Gotha canal was 120 miles in length, including the lakes, of which 55 miles were artificial navigation. The locks are 120 feet long, and 24 feet broad. The width of the canal at the bottom is 42 feet, and the depth of the water is 10 feet.

The completion of the Gotha canal was justly regarded at the time as one of the most important and able engineering works of the day. Previous to Telford's time, an artificial waterway, called the Carlsgraf Canal had been constructed in the time of Charles IX., and under his direction, to connect the Wenner with that part of the river Gotha where it is first navigable. From the end of this canal to the village of Trolhätta, a distance of five miles, the navigation of the river was uninterrupted, but when the cataracts of Trolhätten—locally spoken of as the "Gulf of Hell"—were approached, all farther navigation became impracticable through a space of about two miles. The river is here divided into four principal cataracts, separated by whirlpools and eddies, and descending through a perpendicular height of 100 feet. Several attempts having been made to construct a canal here, some of which ended in complete failure, while others, including that made in the time of Gustavus III., threatened

* Thomas Telford, born in Dumfries-shire, Scotland, in humble circumstances, was, next after Brindley, the greatest English canal engineer. He constructed the Caledonian, Ellesmere, Gloucester and Berkeley, Grand Trunk, Birmingham, Macclesfield, Birmingham and Liverpool Junction, and other canals. He also constructed a number of harbours, docks, roads, and bridges, including the Menai Bridge and St. Katherine's Docks. He died in 1834, and was buried in Westminster Abbey.

to involve so much expense, that that monarch, after visiting the works, ordered them to be suspended, a wooden road was constructed alongside the river, from the beginning to the end of the cataracts, in order to facilitate the conveyance of merchandise to Gothenburg.

The following data relative to the Gotha Canal are extracted from the large atlas of plates published along with the life of that engineer for the purpose of illustrating the principal works of Telford.

DETAILS OF THE GOTHA CANAL.

	Distance.				Lockage.	
	Canal.		Lake.		Fall.	Rise.
	miles	yards	miles	yards		ft. in.
Canal from Lake Wenern to the Wiken	22	1039	..	..	..	158 0
Lake Wiken	..	..	12	318	..	west end of summit.
Canal at Edet	..	534				
Lake	..	..	..	535		
Canal	..	581	..	..	East end of summit.	
Lake	..	..	..	117		
Canal near Forsvik	..	496			ft. in.	
Lake Boltensjön	..	..	4	803	9 9	
Canal at Rödesund	..	486				
Lake Wettern	..	..	19	1136		
Canal between Wettern and Lake Boren	2	841	..	..	49 9	
Lake Boren	..	..	6	1140		
Canal from thence to Roxen	14	63	..	..	130 9	
Lake Roxen	..	..	15	1423		
Canal from thence to Asplangen	4	446	..	..	19 6	
Lake Asplangen	..	..	3	208		
Canal from thence to the Baltic near Soderkoping	10	494	..	..	86 6	
Total length of canal	54	1460	..	..	296 3	
Total length of lake navigation	..	..	62	400		296 3
Total length of canal and lakes in English miles ..	..	miles 117	yards 100			454 3

About a mile below the cataracts, the course of the Gotha was again interrupted by a fall called Akerstræum; and at the end of last century a canal 182 feet long, and 36 feet broad, was constructed here, through a bed of rock, until, at the other end of the cataract, the river is clear to Gothenburg. Before the construction of the Gotha Canal, the traffic for Gothenburg was unloaded at the cataracts, carried over the wooden road to the end of the falls by horses, and again put on board vessels which carried it through the Akerstræum Canal to its ultimate destination.*

At Trolhätta, about 1¼ mile below the point where the river Göta-Elf leaves the Wenner Lake, there occurs a series of falls and rapids, the river descending 108 feet in a length of about 4590 feet. The works which were commenced at this place early in the last century, were well advanced in 1755, when an unusually heavy flood caused much destruction and loss of life, and the abandonment of the works, never since resumed. The intention was to surmount the difference of level, viz., 108 feet, at the falls above mentioned, by three locks only, with a rise of 36 feet each. In the canal, as constructed in 1800, there is a chain of eight locks (still in service), but these being insufficient for the traffic, a second set of eleven were constructed alongside the former in 1844. These are cut in the solid granite. There are sixteen locks in all, with a fall of 142 feet on this canal (Trolhätta), which is 22 miles long. The breadth of the canal-bottom is 39 feet in soil and 23 feet 5 inches in rock, with a depth at mean water-level of 12 feet 8 inches. The number of vessels passing annually is about 7000.

The West Gota Canal, connecting the Wenner and Wetter lakes, rises from the former by a series of nineteen locks, or a height of 154 feet 6 inches, to the summit level, which is 300 feet above the sea, and the descent from here to the Baltic, *viâ* the East Göta canal, is by thirty-nine locks. The breadth of the bottom of these canals is 46 feet 9 inches with a mean depth of 9 feet 9 inches. These two canals were completed in 1832 at a cost of 887,500*l*. The length of navigation is 116⅔ miles, of which 54⅓ miles are artificial canal, and 62⅓ miles lake channel. The traffic is from 4000 to 5000 vessels per annum.

The Dalsland Canal.—The eastern spurs of the high range dividing Norway from Sweden run in the south through the small province of Dalsland towards Lake Wenern, and from numerous

* Cox's 'Travels,' vol. iv.

valleys, which descend more or less abruptly to the shore, and serve as channels for many torrents from the mountain ridges. There are often considerable falls, which supply a vast motive power to works of various kinds, chiefly bar-iron forges and saw-mills. There was one serious drawback to this industry. Lake Wenern afforded the only means of communication between Dalsland and the outer world; and to reach that lake from the various works, a long and costly land transport was the sole resource. This became more and more an obstacle as increased facilities were developed in other parts of the world. Hence, some forty years ago, the question of utilising the Dalsland water-courses as a means of transport was broached, and this was accomplished in the year 1868. Along the Norwegian frontier, northward, in the province of Wermland, there is a lake, the Stora Lee, 20 miles long, with an extreme width of 3 miles, which joins Lake Wenern by a water-course, having eleven continually descending basins, together constituting a fall of 200 feet. At the northern extremity of the Stora Lee are the Toksfor works. At a distance of 12 miles southward, where there is a fall of 28 feet, are the iron works of Lennartsfors. At this point the Stora Lee is joined by Lake Leelângen; and lower down, at the junction with Las Lake, motive power is supplied by a fall to the Billingsfors works. Farther on, towards Lake Wenern, there are the Gustafsfors Ironworks and the Skapfors Sawmills, where several falls occur, the highest being a fall of about 30 feet at Upperud Ironworks.

The Dalsland Canal Company having been formed, with the governor of the province, Count Sparre, as president, the directors in 1864 succeeded in engaging the assistance of the late Baron Nils Ericson, Colonel of Engineers. His plan to some extent varied from former projects, and comprised the following main conditions:—The construction of a canal at Hofverud, near Upperud, instead of a railway, so as to avoid unloading and reloading; a route from Las Lake, past the Billingsfors works to Leelângen; the adoption of the same dimensions for the whole length of the canal from Upperud to Stora Lee, viz., a depth of 5½ feet, a width of 13 feet at the bottom, and a length of 100 feet between the lock gates; and an increase in the number of locks between Lake Wenern and Stora Lee to twenty-five instead of fifteen, as proposed. The contract for constructing the canal according to this plan, including excavations round the fall at Hofverud and an aqueduct over the stream at that place, was taken at about 76,000*l.* sterling, raised chiefly by shares and, to some extent, by state subventions. It was stipulated that the dimensions of the canal should be such that vessels of 75 feet in length, 13 feet beam, and drawing 5 feet of water should be able to navigate it. Consequently the locks were mainly of the following dimensions :—

	Ft.	In.
Minimum length between the gates	100	0
,, width in the flood gate	14	0
,, depth of water on the sill	5	2
,, height of the gate wall over the sill	6	7
,, width of the sill	6	0
,, length of the gate wall	7	0
Radius of the sill and of the left wall	16	0
Length of gate recess	17	0
Radius	50	0
Slope of the lock chamber sides 5 to 1.		
Versed sine of the exterior of the inner wall	2	0
,, ,, outer ,,	3	0

The gate-walls and recesses were all constructed with Wargo cement. The sides of the lock-chambers are of masonry in cement, supported by an earthen embankment. The gates are single, and have wooden bolts; the sills are formed of wooden beams 10 inches by 12 inches. Timber drawbridges are employed throughout, placed in front of a lock immediately before the recess or entrance.

The canal is of the following dimensions :—

	Ft.	in.
Minimum width at bottom	13	0
,, depth	5	6
Height of the bank above water level	2	0
Width of the bank at top	8	0
,, towing path	5	0

At the Waterfalls of Hofverud, the most interesting point of this canal, the rock on one side is almost perpendicular for 150 feet, while the other side of the stream is occupied by the ironworks of Hofverud. For this reason Ericson constructed an iron aqueduct over the fall of 110 feet span. This aqueduct has the form of an open box. The two sides for carrying the weight are wrought-iron bow girders, 10 feet deep at the middle and 6½ feet at the ends, of English iron plate ¼ inch. The bottom and top flanges are ½-inch and ⅛-inch thick respectively, formed of three layers of plates bolted together. The top flange serves as a pathway as well.

The Dalsland canal rises 192 feet 6 inches by twenty-five locks, the summit level being 338 feet above the sea. The length of the navigation is 155 miles; but the actual length of the works that were needed to complete the system is only 4·8 miles.

The locks on this canal are each about 98 feet 6 inches long, with a breadth of 13 feet 8 inches, and a depth over the sill of 5 feet 4 inches. The breadth of the bottom is 14 feet 6 inches and 15 feet 7 inches, in soil and rock, respectively. The canal is navigated by vessels of 70 tons, and steamers of 45 tons and 25 H.P. The traffic amounts to about 4000 vessels per annum. It was completed in 1868 at a cost of 81,500*l.*

The Kinda Canal rises 171 feet by fifteen locks to a level of 277 feet above the sea. The length of the navigation is 49½ miles, of which 22¾ is either artificial canal or trained river. The length of the locks is 90 feet 6 inches, breadth 18 feet 4 inches, and depth over sill 4 feet 10½ inches. The traffic is from 3000 to 4000 vessels per annum. It was completed in 1871 at a cost of 72,500*l.*

The Orebro Canal.—One of the most recent canal undertakings in Sweden is the Orebro Canal, which is designed to bring down to the town of that name the traffic from the Mälar and Hjelmar Lakes, instead of being compelled to cart it from the old harbour of Skebäck, two or three miles distant. There is no special engineering feature about the canal, which was commenced in June 1886, and opened in 1888. For some distance it follows the bed of the Svarta, and is subsequently divided into two branches, one of which, the main branch, to the south, has a length of 4600 feet, and the other, to the north, is 2600 feet long. The former is designed for passenger and lighter traffic, and the other is specially arranged for the transport of grain, coal, timber, &c. The main canal has a width of 80 to 90 feet at the water line, and has 8½ feet depth. The lock at the commencement of the canal is 125 feet long and 25 feet broad, and at the northern end of the canal, where there is a high granite quay, 1200 feet long, the canal is 150 feet wide. The water on the canal is enclosed by a dam of 200 feet long, and the total cost of the undertaking is about 40,000*l.* The enterprise is mainly interesting as an example of the local application of water power with a view to economy of local transport.

Projected Canals.—At the present time a canal is projected whereby it is intended to connect the Kattegat with the Lake of Wenern, thus bringing into direct water communication the towns of Uddevalla and Genersborg. The length of this canal will be about twelve miles, some four miles of that distance being through lakes. The level of the canal will be raised above that of Lake Wenern by three sluices. The depth of water in the Uddevalla harbour and in the Venersborgvik would limit the depth of the canal to about 21 feet, but this would be sufficient to admit vessels of about 3000 tons. The sluices proposed would be 350 feet long and about 45 feet in width. The canal would be a natural outlet for a large traffic in timber, iron, and wood pulp, now so largely employed in the manufacture of paper.

CHAPTER XIII.

THE WATERWAYS OF RUSSIA.

"The servitude of rivers is the noblest and most important victory which man has obtained over the licentiousness of Nature."—*Gibbon.*

THE Russian Empire is, in many respects, the most remarkable in the world. With an area of more than eight and a half million of square miles, and a population of 110 millions, it is larger than the whole of the British Empire, including India, Canada, and Australia, and is about seventy times the size of the British Islands alone. It is natural that the internal transport of such a vast territory should present problems of deep interest, and should tax the resources of the engineers that have been from time to time occupied with their determination. This has been more than ordinarily difficult because of the vast distances to be traversed, and the inclement character of the climate, which practically seals up navigation entirely over a great part of the Empire for about six months of the year. Happily, the Empire is provided with a very ample river system, having, indeed, longer and deeper rivers than any other country in Europe, which means, of course, that water transport is available over long distances, without making any special or costly provision for that purpose.

The enormous distances over which merchandise has been carried in pre-railway times, throughout the Russian Empire is justly regarded as one of the most remarkable chapters in the history of transportation. For many years previous to the commencement of the present century, large quantities of iron, salt, gold and silver, furs and skins, tallow, leather, marble and precious stones, in addition to the special products of China, were carried from the latter country to St. Petersburg, a distance of fully 2000 miles. The route adopted appears to have been by the Selenga to the Baikal Lake, and thence by the Angara to the Yenisey, where the merchandise was unloaded and carried overland as far as the river Ket. By this stream it was carried to the Obb, and thence up the Irtish and the Tobol, where it was again unloaded, and carried overland to the Tchussovaia, where it was put on vessels, and whence it was carried to the Kama and finally into the Volga. Such a system of transport is probably unequalled for extent and variety in any other part of the world, but the frequent removals and trans-shipments on this and on other principal routes rendered it a matter of urgent importance to connect the different waterways by canal navigation, whereby the leading maritime routes could be joined together.

When we consider the condition of the Russian Empire at the time of Peter the Great, the semi-barbarism of its inhabitants, and the comparatively limited resources at his disposal, the work planned and achieved by Peter the Great * in the construction of canals is little short of marvellous. It was he who planned the grand scheme for uniting the Caspian and the Baltic with the Black Sea, by the junction of the Volga and the Don. It was he, also, who began the Ladoga Canal in 1718, although it was not completed until the reign of the Empress Anne. This canal, as constructed, connected the Volkof with the Neva in a navigation of 67½ miles, with a uniform breadth of 70 feet, and a mean depth of 10 feet in spring and 7 feet in summer. Peter the Great connected Astracan and Petersburg by the canal of Vishni-Volotchok, although the canal was afterwards considerably improved by the Empress Catherine.† Peter the Great, who was the founder of Cronstadt, also constructed a canal giving access to the harbour of that place. It was not, however, completed in his lifetime. This canal, called after its founder, is lined with brick, as is also another canal, completed soon after the death of Catherine II., in order that vessels might be able to load and unload stores at the gates of the magazines built on both sides.‡

In the time of Peter, and under his direction or sanction, many other waterways were projected or improved in Russia. It was the aim of that monarch to render transport universal and economical throughout his wide dominions, and if his resources had been equal to his plans, Russia would have taken the foremost place in every-

* Peter the Great, as is well known, was a keen observer of everything that tended to open up the internal commerce of a country, and especially of all that tended to advance maritime progress, in which he took a deep interest. When Peter was residing in England canal navigation was hardly yet begun, but many rivers had been canalised, including the Aire and Calder, the Trent, the Witham, and the Medway.

† For additional information on this subject consult Tooke's 'View of the Russian Empire,' vol. i., and Cox's 'Travels in Poland and Russia,' vol. iii.

‡ Article "Canals," in 'Rees's 'Encyclopædia.'

thing relating to water communication. In 1718, finding that the mouth of the Vistula was so choked up with sand that even a small vessel had often difficulty in passing over it, he caused a canal to be constructed, about three-quarters of a mile in length, directly into the bay, having a breadth of 120 to 180 feet in some places, and a depth of 13 to 15 feet. From the end of this canal, next the sea, there were piers running out about 500 yards into the bay, whence ships could enter the canal with almost any wind, and be perfectly secure—as, indeed, the bay of Dantzic may usually be reckoned, having an excellent anchorage ground, and being safe against all storms, those from the north-east and east only creating any danger.

At the top of the canal just described, there were constructed flood gates, or a sluice, to prevent the waters of the Vistula running in, or choking it with sand. In the month of October, 1804, this sluice was finished. It will admit vessels of 36 feet beam, and drawing not more than 10 to 11 feet water. The ships thereby pass into the Vistula, and thence they may proceed up to the mouth of the Mottlau; or to the town, about four English miles; or they may lay in the Vistula close to the shore, in a good depth of water.

A canal for heavy goods was constructed from Lubeck to the Elbe, where it falls in at Lauenburg, passing through Möellon, being a distance of from 35 to 40 English miles. Oddy reported in 1820 that "there are about 100 boats constantly employed on this canal, and as many more may be procured, nearly of an equal size and the same construction, long and narrow, carrying about 90 shlb. of 280 lbs. each. These vessels are generally from ten to twelve days going from Lubeck to Hamburg, having only three men to navigate them, without the assistance of horses. The freight is generally reckoned for the whole of one of these vessels, 100 marks current, from Lubeck to Lauenburg on the Elbe, and generally from thence to Hamburg, one third more; for which the boatman are responsible against damage or robbery. This canal has the advantage of never suffering delay for want of water in summer, with which it is supplicd from the fine lake of Katzburg." *

An extraordinary access of enterprise appears to have occurred in Russia in or about the year 1796 in the construction of waterways designed to connect the different rivers and seas within or bordering upon the European dominions of that State. The Beresinski Canal was commenced in 1797; the Swir Canal in 1795; the Maria Canal

* Oddy's 'European Commerce,' p. 292.

in 1796; the Kamushuiski Canal was examined and ordered to be completed in the same year; while in 1797 the State undertook the construction of a canal from the Düna, below Riga, for the purpose of joining the Bay of Riga with the Bay of Finland. To the same period belong the project of a canal between Petersburg and Archangel; the Verroi Canal, designed to unite the Lake Waggola and the Black Rivulet; the Welikoluki Canal, designed to unite the rivers Neva and Dnieper with the Düna—a canal 81 miles in length; and the canals of Orel, designed to unite the rivers Bolwa and Shisdra; the Sna and Zon, and the Nerussa with the Kromü. This programme, comprehensive and liberal in its design, was only partially carried out, owing to the want of sufficient resources.

The Baltic and the Caspian Seas were united more than half a century ago by three different systems of canals—the first uniting the Neva with the Volga by Lake Ilmen and the canal of Vishni Volotchok; the second uniting the Neva with the Volga, by the Ladoga Canal, and by the canals of Tichwin and Sjâs; and the third joining the same rivers by Lake Onega and the Maria Canal, which unites the rivers Wytegra and Kowspaga.

The first of these three systems connects the Caspian and the Black Seas in a navigation of some 1434 miles. Ships or barges laden at Astracan ascend the river Volga to Twer, and thence proceed up the Twerza. After passing through the canal here, they descend the Msta to Novgorod, and proceed thence down the Volkhof to the Ladoga Canal, which connects with the Neva at Schlusselburg. Once on the Neva vessels can proceed direct to St. Petersburg without unloading cargoes.

In the second canal system referred to there are three different artificial waterways—those of the Tichwin, Sjâs, and Swir. The first of these was constructed for the purpose of connecting the Sominka with the Lid, which falls in the Tschagadosh, and thence into the Mologa, which is connected with the Volga. The Swir Canal is a continuation of that of the Ladoga, which unites the Volkhof with the Sjás river. The Swir Canal was completed in 1801, and in that year, according to Oddy,* 650 vessels of all sizes passed through it. The chief member of the third system is the Marian Canal, which was completed in 1801. The Onega Canal, designed to join the rivers Wytegra and Swir was built in 1808 to 1810. The Swir Canal, connecting the rivers Swir and Sjâs was completed in the year 1806.

* Oddy's 'European Commerce.'

The Baltic and the Black Sea, like the Baltic and the Caspian, were connected in the early part of the century by three different systems of canal communication, which are equally remarkable. The first of these, the Beresinski Canal, unites the Düna with the Dneiper, and thereby joins the Bay of Riga with the Black Sea. The second unites the Njemen with the Dneiper by the Ognisky Canal, and the Courland Canal. The third system unites the western Bug with the Dneiper by the King's Canal.

The Beresinski Canal was commenced in the year 1797. The principal part of the navigation was completed in 1801, but the canal was not entirely finished until 1809. It forms a junction with the Dneiper, first by the river Ulla, which falls into the Düna, then by the Sergatcha, which falls into the Beresina, and finally into the Dneiper. The lakes Beloje and Beresina, lying on the route, are utilised to facilitate the connection.

The Ognisky Canal, which was finally completed in 1803, was built largely at the expense of the Count of that name during the latter years of the Polish republic. It is thirty-four miles in length, and has ten sluices. For many years it afforded a passage for small craft between Konigsberg and the Black Sea. The canal joins the rivers Szzara and Jasiolda, the first of which falls into the Njemen, and the latter into the Pripecz, thereby opening a communication *viâ* the Dnieper with the Baltic and the Black Seas. The Governments of Lithuania, Volhinia, Little Russia, and Polish Ukraine, have long sent their produce by the Njemen to Konigsburg and Memel, near which latter place it falls into the Baltic. Nearly a hundred years ago it was proposed to unite the Njemen with the Bay of Riga by a canal of ten versts in length, which would unite the Nevesha with the Lavenna at the mouth of the great Ada.

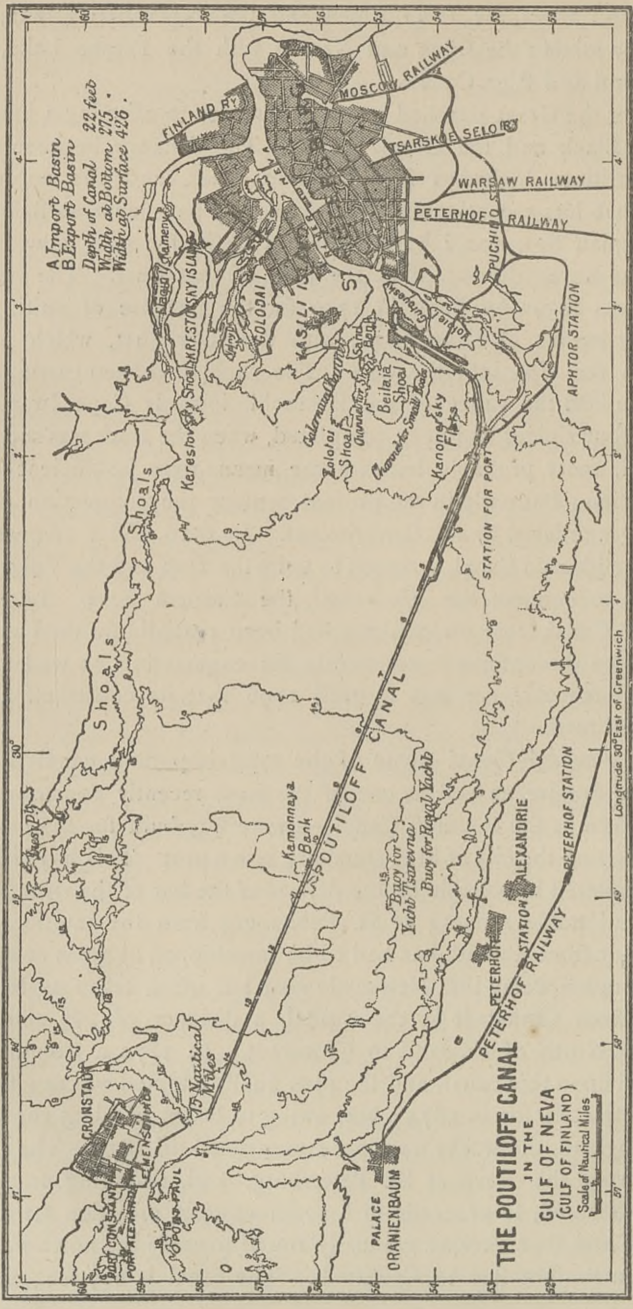
The last King of Poland began the canal which unites the western Bug with the Dneiper, and which for that reason was called the King's Canal. It unites the Prima and the Muckawetz, but it has not been very successful. As originally constructed, the canal had no sluices, and being short of water in the summer, and frozen in winter, it was only navigable in the spring months.

Another important maritime connection, to which great importance was attached in the early part of the century, was that of the Bay of Riga with the Bay of Finland. This connection was arranged for—first, by joining the rivers Pernau and Narova by means of the Lake Peipus and the canal of Fellin; second, by uniting the rivers

Düna and Neva, by Lake Ilmen and the Welikoluki Canal; and third, by joining the Düna and Narova with the Peipus Lake, and the Verroi and Riga Canals.

Peter the Great attached much importance to effecting a junction of the Black and the Caspian Seas. The distance between these two maritime highways is about 400 miles, and the enormous trade that has recently been developed in petroleum at Baku, on the Caspian Sea, would have created a traffic for such a waterway that was never dreamt of in the time of that Czar. The Iwanoff Canal was begun by Peter in 1700 for the purpose of uniting the Don by means of Lake Iwan, with the river Shat, which passes through the Upa into the Oka. The canal had been carried from the Don into the valley of the Bobrucki, towards Cape Iwan, and twenty-four sluices had been completed, when the work was suddenly stopped, most probably because the means were insufficient for its completion; but early in the present century the completion of the canal was ordered by the Government. In 1716, Peter commenced the Kamüshinski Canal, designed to unite the Don and the Volga, and thereby to connect the Black and the Caspian Seas. Like the Iwanoff Canal, this undertaking had been partially finished when it had to be discontinued, apparently for engineering as well as for financial reasons, nor was it until 1796 that its construction was again resumed.

The Poutiloff Canal.—One of the most important canals in the Russian Empire, as well as one of the most recently constructed is that known as the Poutiloff Canal—a waterway built for the purpose of converting the city of St. Petersburg into a port. This has hitherto been rendered impossible by the defects of the bar of the river Neva. Hence all traffic arriving at St. Petersburg from the interior, or at Cronstadt from abroad, has had to be transhipped at great cost, and with so much delay that Newcastle coal has often taken as long in transit from Cronstadt to the capital, a distance of 18½ miles, as from the North of England to Cronstadt. In 1872 a Commission reported upon this canal, and the plan finally adopted was sanctioned and contracted for in 1874; but, owing to losses of plant conveyed from England, the works were not commenced till 1877. The canal starts from the Neva at St. Petersburg, and, diverging from the estuary-channel, it proceeds in a south-westerly direction for about 2 miles, and then curving gradually round towards the north-west, it runs in a straight line to Cronstadt. The canal is 207 feet wide at



The Poutiloff Canal.

the bottom for the first part of its course, and has a continuous embankment on the side of the Gulf of Finland, and at places on the land side; at the termination of the curve it unites with a branch canal, which will eventually rejoin the Neva above St. Petersburg, and thence its navigable width is increased to 275 feet, its depth being 22 feet throughout. The first part of the straight portion is embanked on both sides, but for the last 10 miles a navigable channel, 275 feet wide, has been dredged through the Gulf, which has a depth there of only from 12 to 15 feet, while no banks have been made.

Three basins, formed by widening the canal at certain places, have been provided for the export and import trade, having a total area of 430 acres; but it is considered that these will not afford sufficient accommodation. Between 1877 and 1882, 5,304,000 cubic yards were excavated, out of a total of about 8,700,000 cubic yards. The working season, however, at St. Petersburg is short, and only one hundred and twenty-five days can be reckoned upon in the year, making an average of 8480 cubic yards per day. Water was admitted into the canal in the presence of the Emperor Alexander III. in November 1883; but the canal was not made available for the passage of vessels until 1884. The canal is reported to have greatly promoted the commercial prospects of the capital. This was much required, as, previous to the construction of the Poutiloff Canal, only vessels of very small size and light draught could ascend the Neva for the purpose of loading and unloading at St. Petersburg, while those of more than very limited draught were compelled to stop at Cronstadt, and discharge or load there. The cost of sending goods from Cronstadt to the capital was calculated at more than the freight from England,* without taking into account the loss of time, which often amounted to ten or fourteen days, and sometimes more.

The Poutiloff Canal was constructed by the Russian Government, at a cost of about a million and a quarter sterling, and has been thrown open free of tolls. The points A and B on the plan, where warehouse accommodation has been provided, are in communication by rail with all the railways going out of St. Petersburg, and can also be approached by lighters with cargo for transport. It is

* Report by Her Majesty's Ambassador at St. Petersburg, Commercial series, No. 2 1884.

expected that the canal will cause merchant-ships ultimately to abandon Cronstadt entirely.

At the St. Petersburg end of the canal, a Government Commission recommended some years ago, that two basins would be required, each 22 feet deep, and capable of holding 90 steamers and 70 sailing vessels, with a third basin, having a depth of $10\frac{1}{2}$ feet, in order to accommodate the barges arriving from the interior. The cost of these works has been estimated at over a million sterling. There has been a good deal of controversy as to the proper location for the port of St. Petersburg at the end of the canal. The original proposal was to erect the docks and basins at the head of the canal, close to the Poutiloff Ironworks, but the Ministry of Finance is reported to have favoured a project for constructing a port on the opposite side of the river—that is on the right bank—on the ground that it would be much less expensive. But the utility of the canal has already been so greatly proved, that the docks originally projected will be likely to be insufficient before long. About 2500 ships are stated to be annually employed in the foreign, and 700 in the local transport trade of the capital.*

The Perekop Canal is another recent undertaking of the Russian Government. According to 'Reports of the Consuls of the U.S.A.,' dated July 1888, Russia had then begun with the excavation of the Strait of Perekop, which connects the Crimea with the Russian continent. The canal is to go from Perekop to Goutschar, Sivash, and Genitschesk, and is to be 111 versts long. It will be 65 feet broad and 12 feet deep. At each end of the canal a port will be built. It is stated that the 85,000,000 roubles necessary for the undertaking have been found. The shortest road from Genitschesk to the northern ports of the Black Sea will be through the canal. The voyage from Odessa to Maripol is at present 434 sea miles long; through the canal it will be only 295 miles. The work will take five years to complete. When the canal is finished, it will be easy for Russia to send her ships through the Sea of Azof to Otschakow, to the mouth of the Dnieper, and to Odessa, because they will no longer have to sail round the Crimea, and they will thereby avoid the risk of being captured by foreign ships in case of war. The chief reason for building the Perekop Canal is stated to be the necessity for getting coal from the Don districts for the Russian fleet.†

* Paper read in 1886 before the Society for Promoting Russian Trade.

† London *Economist*, July 14, 1888.

The Baltic and White Sea Canal.—The latest project put forward with a view to extending and completing the canal system of Russia is that of an artificial connection between the Baltic and the White Seas. The principal port on the White Sea is Archangel, which is situated on the Dwina, about 30 English miles from its mouth. The building of St. Petersburg took away from Archangel a considerable part of its trade with European countries. The harbour of Archangel is, moreover, none of the best, and the bar at the entrance of the Dwina is said to have only about 14½ feet of water, so that ships which draw more water must be loaded out in the roads by lighters. Nevertheless, the shipping trade of Archangel is still considerable, and it is believed that it would be greatly promoted by a direct connection with the Baltic. The projected canal is estimated to cost 10 millions of roubles (1,000,000*l.*), and the length of the canal will be 210 versts. General Ignatieff is said to have declared in favour of the undertaking, and the Russian engineers who have reported upon it state that it is easily feasible.

Lake Onega Canal.—Another project that has for some time past found a great deal of favour in Russia is that of a waterway from the White Sea to the Baltic by way of Lake Onega. Communication already exists between the two seas, but it is by a roundabout water route, starting from Archangel, and running up the Dwina to a point near Vologda. A canal would reduce this distance of nearly 1500 miles to about one-third of that figure. The estimated cost of the canal is about 750,000*l.* The project is one that received the consideration of Peter the Great, who, as we have already seen, was the greatest canal-maker that Russia has produced.

The Volga and Don Canal.—The new canal between the Volga and the Don will be 53 versts in length, and is estimated to cost 2,780,000*l.* The canal will commence at the Volga, 7 feet below the level of the Black Sea, and will terminate at a point of the river Don which is 119 feet higher than that water. At its tenth verst from the river Don the canal will traverse the river Karpooka, and at the twenty-fourth verst it will pass the Krivomoozquiski Station of the Volga-Don Railway. Here a basin for shipping will be provided. The canal subsequently runs parallel with the railway until it reaches the river Tchervlenoi, a branch of the Karpooka. From this point the watershed of the Volga and the Don will be cut through, the deepest cutting being 140 feet. The soil, however, is sandy, and is easily dealt with. A rapid descent is made at the end of the canal, where there will be a fall of 270 feet in 6 miles, and where thirteen locks, each 6½ metres deep, will be constructed. The total amount of earth to be excavated is estimated at 2,780,000 Russian cubic fathoms. It is proposed to construct each lock large enough to contain at one time two vessels, severally 210 feet long, 42 feet broad, and 7 feet deep.

The Hyegra and Kovja Canal.—In July 1886, a new canal, which forms an important link in the chain of canals that connect the Caspian and the Baltic was opened. This canal is 15 miles in length, 70 feet wide, and 7 feet deep. It joins the rivers Hyegra and Kovja. Upwards of 20,000 labourers were employed in the undertaking, together with three dredging machines, but the greater part of the work was done by hand. The quantity of excavation required was upwards of 270,000 Russian cubic fathoms of earth. Some of the cuttings were 30 feet in depth. The undertaking did not, however, present any engineering difficulties of importance.

The traffic of the Caspian Sea is now very considerable, having been enormously increased within recent years by the development of the petroleum trade of Baku, and of the wealth of the minerals and other natural productions that are common to that region. The Baltic is a natural and the most convenient outlet for a great part of this trade, although pipes have been laid from the Caspian to the Black Sea, in order to discharge the petroleum into ships navigating that waterway.

The Proposed Black Sea and Azov Canal.—During the summer of 1888 the Russian Government complied with a demand for a concession, made by the Black Sea and Azov Canal Company, for the right to construct a canal intended to connect the Don basin and the Sea of Azov with the Dneiper basin and the Black Sea. The length of the proposed canal is stated to be a little over 26 English miles, and the cost is estimated at 3½ millions sterling. The mean depth proposed is about 14 feet. The work of construction is expected to occupy about four years.

It has been remarked as a singular phenomenon that whereas the canal traffic of England has relatively diminished, that of other countries has been maintained. This has been explained by the fact that in other countries the distances are generally greater, and the canals are more like rivers than the narrow waters usual in our own country. On Russian canals, for example, barges range in length from 100 to 300 feet, and, instead of being mere lighters, they are to all intents and purposes the counterparts of ocean-going steamships. Large-sized steamers can proceed from the Neva through the canal system to the Volga, and descend thence to the Caspian Sea. Again, it is no unusual thing for barges of 500 or 1000 tons burden to start from some stream in the Ural Mountains with the floods of spring, and reach the river Neva in the autumn—a journey of nearly 1000 miles.

The canals of Russia were for a long time, and are still to a considerable extent, largely navigated by flat-bottomed barques, of considerable length, but seldom more than 4 feet in depth, and drawing from 20 to 30 inches of water. "Their rudder," it is said, "is a long tree like an oar. In case of leakage, instead of a pump they put up a rough cross-bar, from which is slung, by means of a rope, a wooden scoop, with which they throw out the water. These vessels are rudely constructed, purposely for conveying only one cargo. They cost from 100 to 300 roubles each (20*l.* to 60*l.*), and when they arrive at Archangel, Petersburg, or Riga, and their cargoes are discharged, they are sold or broken up for firewood or other purposes, seldom fetching more than from 20 to 50 roubles." *

The Canals of Finland.—Finland has a considerable wealth of lake navigation, which has been connected by canals to the great gain of local commerce. One of these is the canal of the Samia, which connects a chain of lakes with the Gulf of Finland by a waterway 37 miles long, with a fall of 260 feet. The fifteen locks are all of substantial masonry, and are fitted with wooden gates, the use of iron in connection with the stone-work being dispensed with as much as possible, on account of its considerable changes of volume, due to the great range of temperature to which it is exposed. The masonry, though built in hydraulic cement, suffered considerably from the severe cold of winter; but in the year 1870 the plan was adopted of covering the lock chambers by means of 2-inch planks, and allowing the water to flow perpetually through the two gate sluices. Snow is allowed to accumulate over the temporary covers, and as the water running through has a mean temperature of 39° Fahrenheit, the lock chambers are readily kept at a temperature a little above the freezing-point. The levels between the locks are kept full all winter. The practice of running out the water is stated by a recent writer to be destructive to the banks.

* Oddy's 'European Commerce,' p. 69.

The canal of the Pielis connects two lakes; it is 40 miles long, and has a fall of 62 feet, surmounted by ten wooden locks. The crib-work of the walls is loaded with stone, and not clay or earth, as is commonly the case, in consequence of which the woodwork is not forced out of place by the expansion of the frozen filling, and does not rot so quickly.

From all that has already been put forward, it must be evident that Russia has long been fully alive to the importance of developing her maritime resources, and especially her system of inland water transport. The total canal mileage of Russia has been estimated by Sir Charles Hartley at about 200 miles (?), and he remarks that, "in most instances, they have been formed with but little difficulty across the gentle undulations of the great watershed, thus uniting the head waters of rivers which have their outlets at opposite extremities of the Continent." *

The River Systems of Russia.—No reference to the water transport of Russia would be complete unless it included the river-system of that interesting country, which is stated to be navigable to the extent of 19,000 miles. Rafts, however, can use such waterways to the extent of 38,000 miles. The chief rivers of Russia are the Volga, with a drainage area of 563,000 miles, and a course of over 2000 miles, making it the longest river in Europe; the Ural, with a drainage area of 95,000 square miles, and a course of 1446 miles; the Dwina, with a drainage area of nearly 100,000 miles, and a course of 650 miles; the Petchora, with a drainage area of 127,000 miles and a length of 915 miles; the Don, with a drainage area of 170,000 square miles, and a length of 980 miles; and the Dneiper, with a drainage area of 204,000 square miles, and a length of 1060 miles. In the summer these rivers, with their collateral canals, transport immense quantities of raw material to the south and west, and carry back manufactures of different kinds in exchange. In the winter, however, their navigation is generally closed, and traffic is carried either by railway or by road. There are, of course, many smaller streams, such as the Düna, 470 miles long; the Neva, 34 miles long; the Dneister, 640 miles in length; and the Bug, with a course of 430 miles.

* 'Inland Navigation in Europe,' March 1888.

CHAPTER XIV.

THE WATERWAYS OF AUSTRIA-HUNGARY.

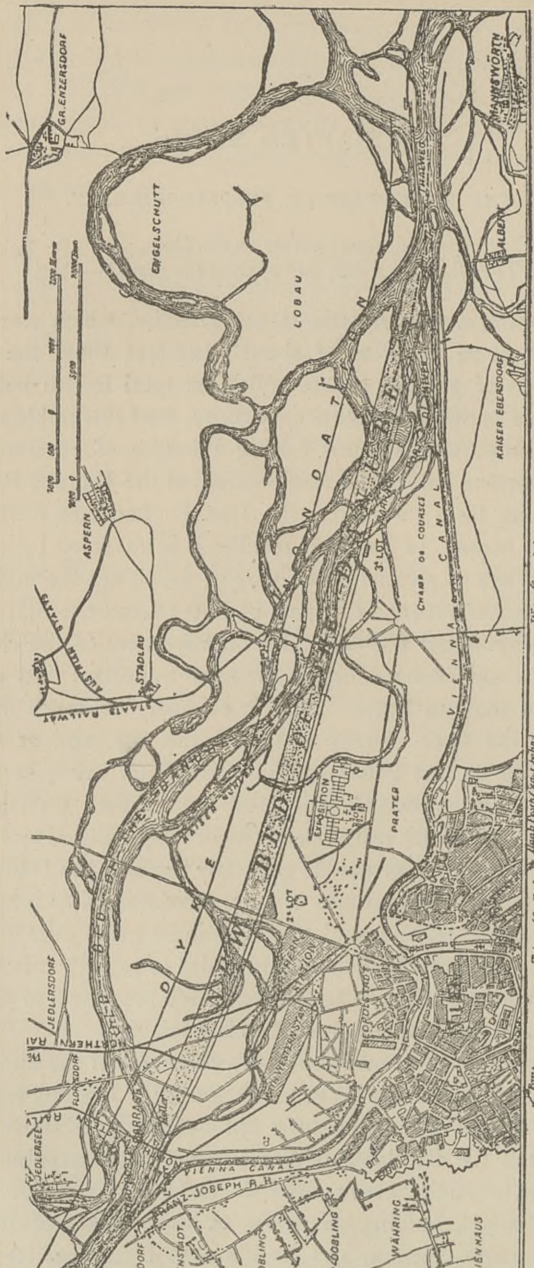
"Th' expanded waters gather on the plain,
They float the fields, and overtop the grain."—*Ovid.*

THE great waterway of Austria is the Danube, which rises in the Black Forest, at an elevation of about 3600 feet above the sea, and drains an area of 316,000 square miles, its total length being 1750 miles. Three hundred tributaries, or more, feed this noble river, the seven more important streams having a length of 2900 miles, and draining about one-half of the whole extent of the Danube Basin. At Ulm, 130 miles from its source, the Danube becomes navigable for flat-bottomed boats. In its lower reaches it is traversed by an almost innumerable fleet of steamers and barges, which are the main means of communication between this part of Europe and the Black Sea.

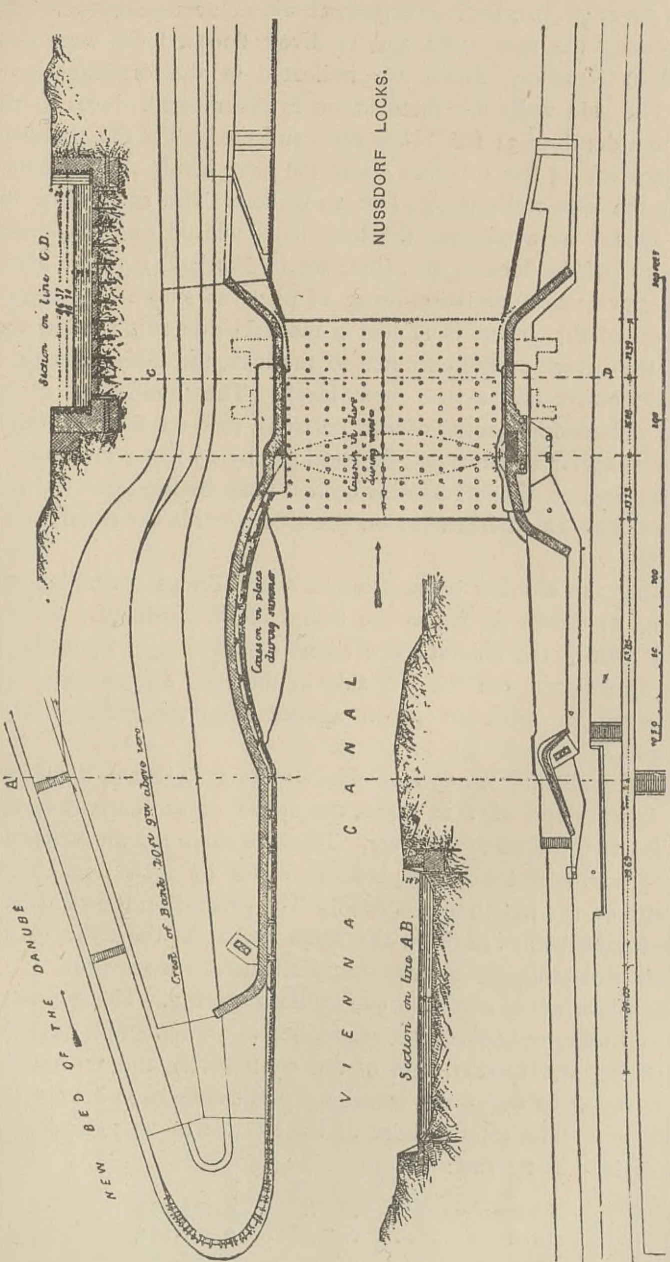
Danube Regulation Works.—The improvement of the channel of the Danube, near Vienna, is one of the most important river engineering works of modern times. A new channel, 10 miles in length, has brought the river $1\frac{1}{2}$ mile nearer to the city, and at a ground depth of 10 to 12 feet below ordinary low-water level, at a cost of 3,250,000*l.* The principal object of the scheme was to protect Vienna from floods, but it has also considerably assisted navigation.

Around Vienna the ground is generally flat, and the Danube, with various branches, was, in times of flood, accustomed to inundate the country for many miles round about, doing a great deal of damage both to the city and its suburbs. In order to remedy this condition of things, a commission was appointed which proposed to collect all the branches of the Danube into one channel.

The plan attached hereto shows the character of the undertaking. The new channel is nearly $9\frac{1}{2}$ miles in length. It starts from Nussdorf at the foot of the well-known hill called the Kahlenberg, and passes through the flat lands of the Prater, or great public park of Vienna, with a slight curve towards the city, in order that the navigable channel, holding generally to the outside of the curve, should be nearest Vienna, and as close to it as possible, thereby facilitating the shipping on the quays.



PLAN OF DANUBE IMPROVEMENT WORKS.



DANUBE IMPROVEMENT WORKS.

The Locks of Nussdorf.—To prevent winter accumulations of ice from entering the new canal, and to divert floods, locks were constructed at Nussdorf, which are indicated in the drawings herewith. The side walls are founded on cylinders sunk down to the gravel to a depth of 31 feet below zero, and the tops of the abutment of the lock are 15 feet 6 inches above the same level. The distance between the side walls is 155 feet 10 inches. The entrance to the lock is closed by a caisson, the lock being closed only in winter. The invert of the lock is of béton, set in Portland cement, 4 feet 1½ inch thick, the foundation being of piles, as shown on the plan. The level of this invert is 12 feet 9 inches below zero; below that part of the invert, at the entrance to the lock, the floor is made of heavy stonework laid at the same level. The foundations of the barrage at Nussdorf consist of iron caissons, that on the right bank being rectangular in form, and 81 feet long by 18 feet 7 inches wide, while the wall on the left bank is 99 feet long, by the same width as the other, with an enlargement on the side towards the canal for the lock gates.

Joining the old bed of the Danube at the Bridge of Stadlau, and following its course as far as the island of Wiedenhaufen, through which it passes, the channel line enters the river again opposite the village of Albern. On the left side of the river a protecting dyke was erected in order to guard against flood the great plains of Marchfeld.

The new channel is 933 feet wide, 8·3 to 11·4 feet in depth, and has a mean slope of 1 in 2272, the speed of the current varying according to the state of the river. The side slope has an inclination of 2 to 1, and is riveted throughout in stone 9¾ inch thick, with a banquette on the top 39 inches wide. The ground on the right bank has been raised so as to reach the same height as the dyke on the left, thus protecting the country round about from inundation.

The above works cost over two millions sterling. The quay walls locks, and other operations were described in a monograph published in 1878 by M. Hersent, one of the contractors, and reprinted in *Engineering*, from which the foregoing particulars have been mainly reproduced. The total amount of earthwork was 23,575,928 cubic yards, divided as follows:—

Excavators	4,775,334
Dredgers	9,491,254
Barrows	9,309,340

RÉSUMÉ OF WORKS EXECUTED FOR THE DANUBE REGULATIONS.

Nature of the Work.	First Section.	Second Section.	Third Section.	Total.
Earthwork	1,886,300 cub. yds.	6,204,900 cub. yds.	1,218,000 cub. yds.	9,309,200 cub yds.
Ordinary dredging	895,300 ,,	10,722,400 ,,	2,295,800 ,,	13,913,500 ,,
Destruction of old works, masonry, fascines, piling, &c.	247,600 ,,	30,900 ,,	74,600 ,,	353,100 ,,
Drawing piles	8267	1350	..	9617
Removing scaffolding	63,495 ft.	..	..	63,495 ft.
Revetments	166,100 cub. yds.	244,200 cub. yds.	130,500 cub. yds.	540,800 cub. yds.
Protection for slopes	44,100 sq. yds.	147,100 sq. yds.	131,000 sq. yds.	322,800 sq. yds.
Masonry of quays, &c.	284,000 cub. yds.	64,200 cub. yds.	..	92,600 cub. ,,
Foundations by compressed air	3600 ,,	..	..	3600 ,,
Piles driven 31 ft. long	3519	16,481	..	20,000
Sheet piling 21 ft 9 in.	1838	13,577	..	15,415
Fascine work	..	68,300 cub. yds.	26,600 cub. yds.	94,900 cub. yds.
Blasting cartridges	650 ft.	42,607 ft.	10,068 ft.	53,325 ft.

The average work done by each excavator was 1538 cubic yards per day over the five years ending 1874, the maximum being 1951 and the minimum 613 cubic yards. The excavators were of the same type as those employed on the Belgian Ship Canal works, illustrated elsewhere in this work, and are known by M. Condreux's name.

It is proposed to connect the Danube with the North Sea by a new canal, 273 kilometres in length, which is referred to at p. 130. This canal, if constructed, will, like the Prussian canal system generally, be 21 metres in width, 2 metres deep, and have locks 8·60 metres wide and 55 metres long. These will admit barges carrying 600 tons.

The other principal rivers of Austria-Hungary include the Pregel, the Elbing, the Vistula, and the Oder, inclined to the Baltic; the Elbe, the Saale, the Moldau, the Weser, the Ems, the Main, the Neckar, inclined to the North Sea; and the Pruth, the Theiss, the Temes, the Inn, and the Iser, inclined, like the Danube, to the Black Sea. About a dozen waterways, mostly small, are also inclined to the Adriatic.

In Hungary, there are two canals of importance—the first being the Bega, which joins Temesvar with the Theiss at Tetal, a little above its junction with the Danube, and has a total length of 75 miles; while the other is the Franz Josef Canal, extending for a distance of 69 miles, from the Danube at Battina by Zombor, to the Theiss near Foldvar. The great waterway of Hungary is, however, the Lower Danube, which is navigated by the Imperial and Royal Danube Steam Navigation Company. About 800 barges are employed for this purpose, the greater number having a carrying power of 250 tons. The improvements that have been made on this stream, under the Commission appointed for that purpose, between 1860 and 1883 have tended to increase the trade from 680,000 gross tons in 1859 to 1,530,000 tons in 1883, and to lower the charges on shipping from an average of 20*s.* per ton for lighterage before the deepening of the Sulina mouth to less than 2*s.* per ton register at the present time. Sir Charles Hartley claims that the Danube improvement works had, up to 1884, effected a saving of over 20 millions sterling.*

* 'Inland Navigations in Europe,' p. 155.

CHAPTER XV.

THE WATERWAYS OF THE UNITED STATES.

"The Erie Canal, conceived by the genius, and achieved by the energy of De Witt Clinton, was, during the second quarter of this century, the most potent influence of American progress and civilisation. It developed the north-west, by giving an outlet to the commerce of the great lakes, and it made New York the Empire State, and New York City the imperial mart of the New World."—*E. Sweet, in the Transactions of the American Society of Civil Engineers for* 1884.

A GLANCE at a map of the United States will suffice to show that it has unique natural facilities for water transport. Its great lakes, which are inland seas of no inconsiderable dimensions, now connected together by the Erie and St. Mary's Falls Canals, its magnificent rivers, such as the Mississippi and the Missouri, and the natural configuration of the country, create an *ensemble* for cheap transportation such as no other country can surpass. Besides these resources, however, the United States have now a railway system of over 160,000 miles.

The same favoured country has a large number of noble rivers, as well as a magnificent system of lakes. Of these, the most important is the Mississippi, which has a drainage area, estimated at 1,261,000 miles, and which, including its tributaries, has about 15,000 miles of navigable waters. A large portion is, however, closed at low water. From the source of its great tributary, the Missouri, to the Gulf of Mexico, its outlet, the Mississippi has a length of 4194 miles. It may, however, be maintained that the Mississippi is less a single river than the outlet of a number of rivers, each of considerable importance. The Missouri river has a drainage area of 518,000 square miles, and 3500 miles of navigable waters, while the Ohio river, which has the next most important basin, drains an area of 214,000 square miles, and has 5000 miles of navigation. The smaller tributaries include the Arkansas river, the Med river, the Yazoo, and the St. Francis. The navigation of the Mississippi river has for a number of years past been under the control of a special Government Commission, by whom the mouth of the river has been dredged, training walls have been built, shifting sand-bars have been regulated, and dams thrown across to concentrate the low-water flow in the main channel. On the Upper Mississippi, St. Anthony's Falls oppose a barrier which has been overcome by a canal and locks.

In no country has there been a longer or more severe struggle between canals and railroads than in the United States of North America. In no country have both systems of transportation had a more eventful, instructive, and interesting history. In no country have railroads and canals been afforded equally free scope for development, and in no country have transportation rates been cut so fine and reduced so low. We may, therefore, by a consideration of the conditions of transport in the United States, and especially by seeking to ascertain how far the two great systems of internal communication have competed with each other, learn something that will throw a good deal of light on this problem.

Washington, himself, was one of the first to appreciate the importance of canals. In his early life the father of his country was a land surveyor, in which capacity he became very familiar with the requirements of the region of the Potomac. Both in this employment, and subsequently, when in 1754 he commanded a military expedition to the Monongahela river, Washington was constantly seeking to improve transportation facilities. He was especially eager to have a waterway opened between the Chesapeake and the Ohio. The War of Independence for a time diverted his ideas from this purpose, but when the war was over he obtained a charter for a waterway between the great lakes and the Hudson, and became the first President of the company formed for its construction. Washington, therefore, stands, in relation to the waterways of the United States, in the same position as the Duke of Bridgwater does in regard to the canal system of our own country, Peter the Great in reference to the canal system of Russia, and Louis XIV. in relation to the canal system of France. It must be admitted that in every case the system has had a worthy sponsor.

In 1792, an Act was passed by the Legislature of the State of New York, incorporating two companies—one, the "Western Inland Lock Navigation Company," charged with the duty of constructing a canal, with locks, between the upper waters of the Mohawk and those flowing into Lake Ontario; the other, the "Northern Inland Lock Navigation Company," charged with the construction of a similar work from the Hudson to Lake Champlain—between which there is a remarkable depression in the general surface of the country. This Act, drawn up and mainly carried through the exertions of General Schuyler, was the first and most important step taken towards the construction of a general system of public works for the country. The objective point aimed at by the Western Company was Lake Ontario, at Oswego, by way of Wood's Creek, Oneida Lake, and the Oswego River. At that time, however, the great enterprise which was to follow—a canal from the Hudson to Lake Erie was not dreamt of. The purposes of the promoters were as distant from the ultimate result as those of Edward Pease and George Stephenson were when they planned the Stockton and Darlington Railway.

In 1796, the Western Inland Lock Navigation Company was formed in the United States for the purpose of opening up some of their projected inland waterways. This company constructed several small canals, but its operations were unsuccessful, and in 1808 it surrendered all its rights and property to the State for the sum of 140,000 dollars (28,000*l.*), which was only one quarter of their original cost.

During the existence of the company, freight designed for Lake Erie and the West took the route of Lake Ontario to the mouth of Niagara river. From that point to the head of the Falls was a portage of 28 miles. The charge for transporting a bushel of salt for this distance, according to the report made by Mr. Geddes in 1809, was 75 cents; and for a ton of general merchandise 10 dollars. All that can be said of the works of the Western Inland Navigation Company is, that they led the way to the construction of the Erie Canal. They never held the route of any considerable commerce. For a long time after their construction, the farmers of Central and Western New York, for want of other means, sent their produce to market down the Delaware and Susquehanna rivers in arks, which were broken up when the destined market was reached. In the meantime, the subject of a canal better adapted to the wants of commerce than that of the Western Inland Lock Navigation Company was by no means lost sight of. In 1807, in a series of articles published at Canandaigua in the Ontario *Messenger*, Jesse Hawley, their author, urged the construction of a canal from Lake Erie, 100 feet wide and 10 feet deep, "to be laid on an *inclined plane*," from Buffalo to Utica; thence down the channel of the Mohawk; thence across the portage to Albany—to be constructed at the expense of the National Government. This plan of an inclined plane, strange as it may seem, was, notwithstanding its gross absurdity, favourably received, and proved for a long time, from the great difficulties it involved, a serious obstacle to the early beginning of any work of the kind.

In February, 1808, Mr. Joshua Forman, a member of the Legislature from Onondaga, and subsequently one of the efficient promoters of the canal, proposed the appointment of a joint committee "to take into consideration the propriety of exploring and causing an accurate survey to be made of the most eligible and direct route for a canal to open a communication between the tide-waters of the Hudson river and Lake Erie." On the 21st of March, 1808, Mr. Gold, of the committee, made a report, enlarging upon the importance of the proposed work, "in drawing together and preserving in political concord the distant parts of a widely extended empire," and closed with a resolution that the Surveyor-General cause an accurate survey to be made of the rivers, streams, and waters in the usual route of communication between the Hudson river and the western waters, and such other contemplated routes as he may deem proper. For such survey the sum of 600 dollars was appropriated. The action under the resolution of Mr. Forman was the first step taken by the Legislature with a view to the construction of the Erie Canal. In 1810 commissioners were appointed to examine the route of the proposed canal. In 1811 the commission reported in favour of a canal, which, in order to produce the inclination of six inches to the mile to Schenectady was to cross the Genesee river by a viaduct 83 feet above the water, and the outlet of Cuyaga Lake at an elevation of 130 feet. In 1812 the commission made an estimate of the probable tonnage that would come upon the canal, and of the tolls that would accrue therefrom. They expressed their opinion that not improbably the canal, in twenty years from that time, would bring down 200,000 tons of traffic! *

In 1817, the Act for the construction of the Erie Canal was finally passed. The money was to be raised on the credit of the State. In 1825 the canal with its adjuncts was completed. The latter event was signalised by a holiday, and unusual rejoicings. It was regarded as a great thing that the news of the opening of the canal was conveyed to New York from Buffalo, by a discharge of cannon, whose

* In 1880, the Erie canal carried 4,608,651 tons of traffic and earned 1,120,691 dols. of income.

reverberations were repeated along a line of 513 miles in one hour and twenty minutes. The communication which the Erie Canal afforded between the vast inland seas of the United States and the Atlantic Ocean was, indeed, the greatest event in the history of transportation in that country up to the end of the first quarter of our century.

The opening of the Erie Canal was followed by the initiation of many other schemes of a similar kind. The real date of the era of canal building in the United States was 1825–30. Pennsylvania, following directly upon the heels of the Erie, constructed a work which was partly railway, and partly canal, and upon which the State expended no less a sum than 50 millions of dollars (10,000,000*l.*)* This line, however, was not successful. "The works, although of great local use and value, never became factors of any importance in the general commerce of the country."†

The State which, next to New York, achieved the greatest success in the construction of canals was Ohio. In 1832 two lines were opened through that State—one from Cleveland to Portsmouth, on the Ohio, the other from Toledo to Cincinnati. Their capacity did not allow the passage of boats carrying cargoes exceeding thirty tons. At its highest point, in 1857, their traffic reached 1,635,744 tons. The line which separated the tonnage going north to the lakes, and that going south to the river, passed east and west very near the centre of the State—the tendency of breadstuffs, on the whole, being toward the lakes, to seek their outlet through the Erie Canal; and of provisions of all kinds to the river, to seek their outlet through New Orleans. Of the exports of beef from Cincinnati in 1851, the year of the opening of the Erie railroad, and twenty-seven years after the opening of the Erie Canal, 97 per cent., went down the river to New Orleans, and only 2 per cent. northward to the lake. Of Indian corn, 96 per cent. went down the river, and only 3 per cent. to the lake. Of flour, 97 per cent. went down the river, only 1 per cent. to the lake. Of lard, 83 per cent. went down the river, and 9 per cent. to the lake. Of pork and bacon, 79 per cent. went down the river, and 5 per cent to the lake. A very small amount of these articles went up the river to Pittsburgh, the first great manufacturing city that grew up off the line of the sea-board. Taking the whole

* The main line of this canal was sold in 1857 to the Pennsylvania Railway Company for 7½ million dollars, and the branches were sold to various private companies for five million dollars more.

† Poor's 'Manual of the Railroads of the United States,' 1881.

State, two-thirds of its wheat went north, seeking an outlet by the way of the Erie Canal. Of corn and provisions, nineteen-twentieths went down the river to New Orleans. One reason, probably, for the excess of the southward movement of provisions was, that the animals were slaughtered in the autumn, too late to have their products forwarded by canal. Corn was grown chiefly in the southern part of the State. Live animals were never moved, either on the Ohio or on the New York canals. The provision trade, which now forms so enormous a traffic on the railroads running to tide-water, is wholly the creation of these works. The canals of Ohio maintained a considerable traffic until the construction of competing lines of railroads, when it declined so rapidly that, in 1856, the expense of their maintenance became greater than their revenues. They have long since been practically abandoned as routes of transportation.

The State of Indiana, following the lead of Ohio, constructed, with the aid of its creditors, a canal from the junction of the Miami Canal to the city of Evansville, completing it in 1855. Only the upper portion of this work came into considerable use. The whole system was abandoned upon the construction of railroads along its line.

The State of Illinois constructed a canal from Lake Michigan to Lasalle, at the head of navigation on the Illinois river, a distance of 100 miles from Chicago. It was originally intended to make the cut deep enough to feed the line from the lake. This project was abandoned from the cost of its execution, to be subsequently carried out by the city of Chicago for sanitary purposes. The canal had at the outset a considerable traffic, which, however, was lost upon the introduction of competing lines of railroads.

The preceding works include all the great water-lines constructed by the States for the purpose of giving direction to the general commerce of the country. Several considerable private works were executed, the most important of which was the Delaware and Raritan Canal, to connect the Delaware River with the harbour of New York, a work of large capacity, which still retains an extensive traffic. Several works of the kind were constructed, chiefly in Pennsylvania, for the transportation of coal—works which, upon the construction of railroads, lost all the importance they once enjoyed. The Chesapeake and Ohio, and the James River and Kanawha Canals, upon which large sums were expended, and for which great expectations were raised, were never completed, and do not require particular remark. The canal system of the country has now become so completely subordinate, that few are aware of its magnitude previous to the construction of railroads which caused a great part of it to be abandoned. At one time there were 5000 miles of canal lines in operation, built at a cost of 150,000,000 dollars, or 30,000,000*l.*

The growth of the traffic on the waterways of the United States was steady for a number of years. In 1837 it was nearly 1¼ million tons; in 1847 it was nearly three millions; and in 1857 it was 3,344,000 tons. In the latter year the traffic of the canals as a whole was 772,000 tons less than in the previous year. This decline, which occurred almost for the first time in the history of the system, created considerable alarm—all the more so that it fell coincidently with a large increase in the railway traffic. Up to 1851 the railways had not had a free hand. Laws were enacted imposing canal tolls upon railroad tonnage, and prohibiting any roads from carrying freight. The State authorities looked upon the canals as a trust confided to their keeping, and protected them against the railroads. But in 1851 these laws were repealed, and from that date the railroads entered upon a career of development such as they had not previously known.

From the first the struggle was vastly unequal. The railroads not only offered a much higher rate of speed, but very low rates as well. They entered into arrangements "with lines of propellers (steamers) on the lakes, and steam and tow boats on the Hudson, forming connected lines from the seaboard to Detroit, Cleveland, Sandusky, Toledo, and other western ports, to divert all the freight possible from the canals over their roads," and practically "contracted to carry freight on the propeller for nothing, for the sake of getting and securing the freight of it upon their roads." *

This is only a repetition of an experience that has been perfectly familiar in the transportation annals of England and other countries. But in no other country did the State take up an attitude of hostility to one interest in order that the other might be advanced. The proposal gravely made in the United States on behalf of the State was that railroad tonnage should be specially taxed, in order that it might be handicapped as against the canals. The Committee of Ways and Means did not seem to entertain any doubt that this species of tyranny was within their power. "The Legislature," they said, "has the power to move them (the railroads) in such form, and subject them to such charges and restrictions, as it may deem it the

* Report of the Committee of Ways and Means.

interest of the State to require." And then followed the astounding *non sequitur* that "the State has the power to prohibit them altogether from the carriage of freight!" The keen competition which had been going on between the canals and the railroads had no doubt seriously affected the trade and revenue of the canals, "and through them," added the State engineer, "the interest of every taxpayer in the State." This was greatly deplored, as the consequence of unnecessary rivalry. "The passenger travel belongs exclusively to the railroads, while the transport of cheap and heavy articles of freight belongs to the canals!"

It is not too much to say that if the report and recommendations of this Committee had been acted upon in the spirit in which they were made, there would have been a revolution in the United States compared with which the Boston tea riots were a mere fleabite. As it was, no such drastic remedies were adopted. The friends of the canals were shortly found "clothed and in their right mind." Instead of making *ad misericordiam* appeals for State intervention, they were soon afterwards setting their house in order. Attention was given to the increased use of steam as a propelling power, and the rates of toll were gradually reduced, until the canals were carrying much more cheaply than the railways, and in 1880 the canals were enfranchised and tolls were altogether abolished, since which time they have been able to compete with the railroads on still easier terms.

Judging by the ultimate quantities of traffic carried, there is only one opinion possible concerning the issue of this memorable struggle. The railroads have won all along the line. The total tonnage carried on the railroads of the United States in 1880 was 290,897,000 tons; the canals in the same year carried only 21,044,000 tons. The income of the railroads in 1880 was 580½ million dollars; that of the canals was only 4½ million dollars. The canals had only one-fourteenth part of the traffic of the railroads, and scarcely more than $\frac{1}{130}$ of the gross income.

These results are very remarkable when the records of the charges made under each of the two systems are examined. When the controversy between them was raging most fiercely, the railroads were charging about three cents per ton per mile, while the canals only charged ·799 of a cent.* It was not, therefore, on the ground of greater cheapness that the railroads claimed or received the traffic. It was the same with through as with local traffic. During the six

* Poor's Manual for 1881, p. xxxviii.

years ending 1884, the receipts of grain and flour at New York by lake, canal, and Hudson River fell from 64 to 45 million bushels. In the same interval the quantity carried by rail only declined from 85¼ to 83 million bushels.* Between 1868 and 1884 the total traffic carried on the New York State canals fell from about 6½ million to little more than 5½ million tons. On the competing railroads—the New York Central, the New York, Lake Erie, and Western, and the Pennsylvania Railroad division—it increased from 10,476,000 tons to 36,700,000 tons. On the canals the traffic had decreased by over 15 per cent.; on the railways it had increased by over 350 per cent. The comparison is, of course, not strictly relevant and parallel, inasmuch as in the case of the railways traffic was gathered and carried over a very much wider area, and it was really only over a comparatively limited section of their several routes that competition existed. But the figures all the same serve to show "how the cat was jumping."

The decline of canal traffic is almost the despair of economists in view of the remarkably low range of rates charged on the canals over this period. No better example of this movement could be given than that of the rates charged for the transportation of wheat from Chicago to New York. This is a through traffic, carried over 1000 miles, without breaking bulk by either system, and therefore under conditions exceedingly favourable to economical transport. In 1857, when the State of New York, by the mouths of its chief executive officers, was proposing to prohibit the railways from carrying heavy freight, and suggesting the imposition of tolls on railway traffic by way of assisting to keep the canals alive, the average rate charged for transporting a bushel of wheat over this long route was a fraction over 26 cents. In 1868 the canal system was charging 24½ cents, as against 42½ charged by the railway for the same service. Ten years later still, the lake and canal rate had fallen to 9·15 cents, and the railroad rate to 17·9 cents. In 1884 the former amounted to 6·60 and the latter to 13 cents.† Throughout the whole period the railway-borne wheat has paid almost twice as much as the water-borne. And yet the trade of the canals declines, while that of the railroads increases. This is an enigma for which we must now endeavour to find a solution.

* Including in the latter year nearly 1½ million bushels of beans and oatmeal.

† 'Annual Report on the Commerce and Navigation of the United States' for 1884, p. xlxi.

The United States differ from Great Britain, and from most other countries, in their economic circumstances. They have developed their trade with a rapidity that is perhaps unexampled in the annals of commerce. They have found such a demand for their produce, alike at home and abroad, that they have not had time to take heed of cheeseparing economies. The question with the agriculturists and the manufacturers alike has been to secure the largest possible deliveries in the shortest possible space of time. They found a practically unlimited market for their agricultural produce in Europe, at prices which, while they were working on a virgin soil, paid them sufficiently well. Of that price, transport was no doubt an important element. When the railways were receiving 30 to 40 cents per bushel for transporting wheat from Chicago to New York, the sellers were receiving 40*s.* to 50*s.* per quarter in London. The railway transport was therefore only one-fourth to one-fifth of the entire ultimate cost of the product. If the ocean transport cost 15*s.* more, the total cost of transport only absorbed about one-half of the price paid by the consumer, so that 25*s.* was left to the grower, minus other charges, and at much less than this price wheat could be profitably grown in the West. The difference between 24½ cents by canal and lake and 42½ by railway was not then of paramount importance. On the other hand the exporter had the supreme advantage of quicker deliveries, the absence of equal risk of having the material spoiled by damp, the certainty of being able to meet his engagements "on the nail," and entire independence of the weather, which freezes up the canal and river navigation during one-half of the year. For the same reasons that the grower and exporter of wheat was willing to pay 9*d.* more per bushel to the railway in 1868, he has been willing to pay gradually diminishing differences since, until he has now to pay the railway no more than 3½*d.* per bushel in excess of the canal rate for more than a thousand miles of transportation.

All this, however, can hardly be said to prove anything against canals, although it undoubtedly proves that in the special circumstances of the wheat trade, and of the Erie Canal, the American freighter of cereals gives a preference to railroad transportation. In the case of heavier traffic, the position would probably be reversed, and especially if the navigation were open all the year round, as would be likely in a temperate climate like that of England, instead of being liable, as in the case of the Erie Canal, to be frozen up for one-half of the year.

Of the fifty canals that are now constructed in the United States, thirteen were completed, or at any rate begun, between 1825 and 1830. Some of the earlier canals were very expensive. The Erie Canal cost 90,000 dollars per mile, with a capacity for boats of over 250 tons. The more recently constructed Illinois and Michigan Canal which admits of the passage of boats of 2500 tons, from Chicago to the Mississippi river, was only 55,355 dollars per mile. The locks on this canal are now 350 feet long, and 75 feet wide, admitting twelve canal boats at a time.

From the Report of the Tenth Census of the United States, we have compiled the following details of the principal existing canals in that country :—

STATEMENT showing the extent, character, and cost of the principal canals in the United States.

Canal.	Miles.	No. of Locks.	Length of Locks.	Rise and Fall.	Cost of Construction.	Average Cost per Mile.
			feet	feet	dols.	dols.
Erie	365	72	110	656	51,609,000	141,394
Champlain	81	33	110	179	2,378,000	29,358
Delaware and Hudson	83	107	100	1,028	6,339,000	76,373
Raritan (ship)	44	140	220	150	4,735,000	107,613
Morris	103	46*	88	1,674	6,000,000	58,252
Schuylkill	58	71	110	619	12,580,000	216,893
Union	84½	93	90	501	5,907,000	148,946
Susquehanna	30	43	170	230	4,930,000	164,333
Chesapeake and Delaware (ship)	14	3	220	32	3,730,000	266,430
Chesapeake and Ohio	179½	75	100	609	11,290,000	62,869
Illinois and Michigan (ship)	102	15	110	141	6,557,000	64,284
Ohio Canal and feeders	323	150	90	1,207	4,695,000	14,536
Miami and Erie	284	93	87-89	907	7,144,000	25,155

* Consisting of 23 inclined planes and 23 lift locks.

The canal system of the United States now in actual operation extends over 2926 miles, of which 411 miles are slack water. The cost of constructing the whole system is officially stated at 170,028,636 dollars (34,005,727*l.*). Disregarding the slack water, this corresponds to an average of rather more than 13,500*l.* per mile, or approximately 2000*l.* per mile more than the average cost of the railways of the same country. The total gross income in 1880, the latest year for which there are complete returns, was 4,538,620 dollars, and the total expenditure was 2,954,156 dollars, or 65 per cent. of the gross income. This figure compares very unfavourably with that shown for the American railroad system in the same year, the working expenses having been only 39·2 per cent. of the gross earnings. The net income of the United States canals in 1880 was 1,584,000 dollars, which is less than 1 per cent. on the total expenditure. The commercial aspect of the canal system of the United States is not, therefore, an encouraging one. Hadley, indeed, declares that after 1870 "it became a question whether the canal could pay expenses of maintenance—a question which was finally decided in the negative."*

Besides the canals actually being worked in the United States, there are 1953 miles of canals that have been abandoned. The construction of these canals cost 8,802,630*l.* The longest of the abandoned canals is the Wabash and Erie, 379 miles in length, which was built between 1832 and 1851 for the purpose of connecting Evansville, Ind., with the Ohio State lines, at a cost of about 6½ million dollars. The James River and Kanawho is another important canal, 196½ miles long, which was constructed at different dates between 1785 and 1851, at a cost of close on 6¼ million dollars, and was abandoned in 1880, on account of its inability to "pay its way." The canal now belongs to the Richmond and Allegheny Railway Company. The Erie canal and branches between Bridgwater and Erie was built between 1833 and 1844 at a cost of about 6½ million dollars, and abandoned in 1871, and the Western Division of the Pennsylvania Canal, between Johnstown and Pittsburg, a distance of 104 miles, commenced in 1830, and constructed at a cost of about 3¼ million dollars, was abandoned in 1863. In almost every instance the reason assigned for abandonment has been the same—that the traffic has been insufficient to meet the working expenses of the canal.†

The Miami and Erie Canal.—This is the most important of the existing canals in Ohio, both with regard to navigation and to use for water-power. From Cincinnati it extends northerly, at a distance ranging from 15 to 35 miles from the western boundary of the

* 'Railroad Transportation,' p. 31.

† 'Report of the Tenth Census,' vol. iv. pp. 29–31.

State, into Defiance County, where it turns north-easterly and follows down the Maumee river to Toledo. The main trunk has a length of about 246 miles. It originally entered the Ohio river at Cincinnati, and the Maumee river close to its mouth, several miles below Toledo; but these termini have within recent years been cut off. The section traversed by the canal is fertile, thickly settled, wealthy, enjoys abundant railroad facilities, and has an established character as a manufacturing district. The structures on the Miami and Erie Canal appear to be in better condition than those on the Ohio Canal, and the hydraulic powers are favoured by a generally copious supply of water, derived from the Miami and Maumee rivers and from a system of large reservoirs in the summit-region between their basins. The water-powers along the whole line of the canal are generally taken up and in use. This is especially true between Dayton and Cincinnati, and it has been stated that probably no more power would be leased along that portion, from danger of interfering with the interests of navigation. The manufacture of flour is an important interest along the entire canal, and stands first as regards the number of mills. The paper industry ranks next in this respect, and has been most developed between Dayton and Cincinnati. There are small woollen-mills also at various points, as well as saw-mills, machine shops, agricultural implement factories, oil-mills, and other works. The greatest utilisation of power is found among the three counties of Hamilton, Butler, and Montgomery, and in the middle and northern counties of Miami, Anglaize, and Lucas.

At Maumee city, some 8 miles above Toledo, the canal is 63 feet above the level of the Maumee river and Lake Erie, and is connected with the former by locks. From this point for 15½ miles, up to the head of the rapids, where the Maumee is rendered tributary for feeding the levels below, there is no lockage. When the canal was built the question of water-power in connection with it was considered, and in the Sixth Annual Report of the Board of Public Works (1843) it was stated that "the capacity of this canal is such that from the head of the rapids to Manhattan 18,000 cubic feet of water per minute can be passed and used for hydraulic purposes without injury to the navigation. At Maumee city the water can be used over a fall of 63 feet; at the locks above Toledo the water can be used over a fall of 49 feet, and at Manhattan over a fall of 15 feet; between these points the canal is so located that the water can be used from it for hydraulic purposes with great convenience, occupying all the fall between the canal and river." A large amount of power is now used from this portion of the canal by several paper-mills and large flour mills.

From the pool above the rapids the succeeding 26 miles of canal, to Independence, is supplied from the river by means of a dam at that place, 9 feet high. From the long level below Independence, the report already quoted from mentions an opportunity to utilise a fall of 23 feet to the river. The portion of canal now referred to was originally known as the Wabash and Erie, being continuous with the Indiana canal of that name. From its junction with the old Miami Canal in Paulding County, to the outlet at Toledo, on the level of Lake Erie, a distance of 64 miles, there is a total descent of 148 feet, effected through 19 locks. This section of the canal was constructed 60 feet wide at the top water-line, and 6 feet deep. From Paulding County the canal takes a quite direct southerly course, and thence to Dayton, 113 miles below the junction, is utilised at frequent intervals for power by flouring-mills, and occasionally by small woollen factories, saw-mills, and other works.

A quantity of water is withdrawn from the Canal by the Cooper Hydraulic Company and utilised under a fall of 12 feet around a lock, being then returned to the canal. At a point below a certain amount is again withdrawn from the canal, and after it has been employed for power under a fall of 8 feet, is discharged into the Miami river. The Hydraulic Company owns a part of the water, acquired by purchase, and also leases from the State, at an annual rental of 1000 dollars, all the surplus running to supply the levels below Dayton. On this privilege a "run" is defined as 315 cubic feet of water per minute on the "middle," as it is called or 12 foot fall, and 400 cubic feet per minute on the "lower," or 8 foot fall. A run at the middle fall was originally 300 cubic feet, but in consequence of slight backwater, it was increased to 315 cubic feet. The rates for both temporary and permanent power vary from 150 dollars to 300 dollars per annum per run, but the larger portion is leased at 200 dollars per annum in the middle, and 150 dollars on the lower fall.

From the basin at Dayton to low water in the Ohio river at Cincinnati, a distance of 66 miles, the canal descends about 300 feet, through 32 locks. Water for feeding the various levels south of Dayton is introduced at that city, Mamesburg, and Middletown. The manufacturing along this section is extensive, the paper and flouring industries being especially prominent. For the former of these, as now developed, however, the power furnished from the canal alone is not sufficiently reliable, and the mills are generally filled with steam engines for use when the water supply runs short.

From the upper plane of the city of Cincinnati the canal descended formerly to the Ohio by means of ten locks, with a fall of 111 feet, measured to low water in the river. This terminal portion, though abandoned for navigation, is nevertheless utilised for power. Much of the way, it is covered from view, and in part of its course the water is divided between two separate channels. Water is used successively from one level to another, and is finally discharged into the Eggleston Avenue sewer.

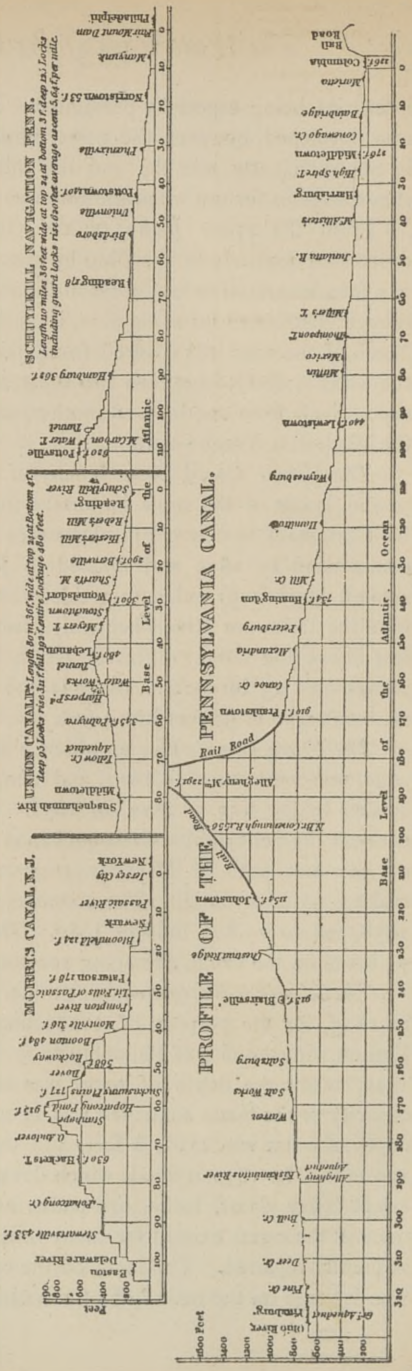
The Morris Canal, New Jersey, of which a profile is given at p. 206, is one of the most important in the United States. It was built originally to connect the Delaware River, with Newall. It was commenced in 1825 and opened to Jersey City in 1836. The summit level is 51 miles from tide water at Newall, and 39 miles from the Delaware River, being 914 feet above the former, and 760 feet above the latter. This elevation is overcome by 23 inclined planes, and 23 lift-locks. In 1841 the dimensions of the lift-locks were enlarged to 98 feet by 12 feet.

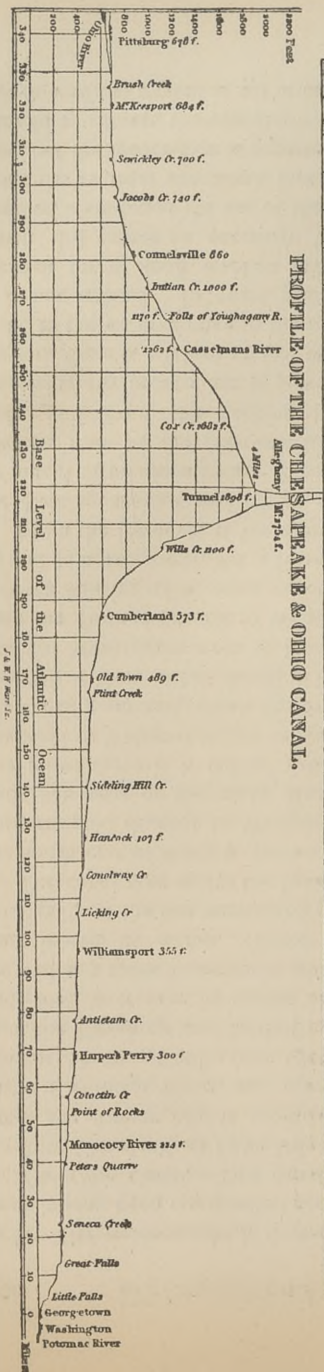
The Union Canal, Pa., of which a section is shown on the next page, was commenced in 1811, and completed, after a long stoppage caused by the war of 1812, in 1832. The canal was intended to connect the Schuylkill and Susquehanna rivers. There is a lockage of 501 feet, with 88 lift-locks 3 guard-locks, and 2 weigh-locks, making 93 locks in all. The tonnage, which was 207,500 tons in 1858, fell to 29,800 tons in 1880. There were in the latter year 73 boats on the canal, averaging 100 tons.

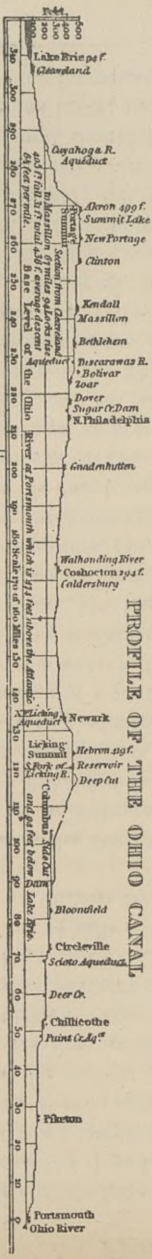
The Schuylkill Navigation (see profile, p. 206) Pa., was incorporated in 1815, for the purpose of connecting the coal region of Mount Carbon with the city of Philadelphia. The canal was completed in 1826, when the depth of water was three feet, and the carrying capacity of the boats employed was 25 tons. By 1847 the minimum depth of water was made 6 feet, and the boats employed averaged 170 tons. In 1850, a flood, which devastated the Schuylkill valley, swept away dams, locks, tow-paths, and banks, so that hardly a trace of the canal existed for many miles, but this damage was subsequently repaired. The locks on the canal are 110 feet by 18 feet. The lockage on the main line of the canal is 618½ feet. There are

47 waterways, two overflows, with 3300 feet in both, 121 bridges, 22 culverts, 31 dams, and 12 aqueducts. The company has had a chequered career, and the canal was, in 1870, leased to the Pa. and Reading Railroad Co., for 999 years, at a yearly rental of 655,000 dollars.

The Chesapeake and Ohio Canal, illustrated in profile, is one of the most important works of its kind in the United States, connecting the Potomac and Ohio rivers, piercing the Allegheny mountains by a tunnel 3118 feet in length, and having cost, on its completion in 1851, no less than 11,071,000 dols., or 60,000 dols. (12,001*l.*) per mile. The canal has a depth of 6 feet throughout. For about 60 miles it is 60 feet wide at the top, and 42 feet at the bottom; for 47 miles its surface width is 850 feet, and its bottom width, 32 feet; and for 77½ miles more the surface width is 54 feet, and the bottom width 38 feet. The locks are 100 feet long and 15 feet wide in the clear; they are capable of passing boats carrying 120 tons. There are 74 lift-locks and a tide-




PROFILE OF THE CHESAPEAKE & OHIO CANAL.
Feet
Pittsburg 678 f.
Ohio River
Brush Creek
Mc Keesport 684 f.
Sewickley Cr. 700 f.
Jacobs Cr. 740 f.
Connelsville 860
Indian Cr. 1000 f.
1170 f. Falls of Youghagany R.
1262 f. Casselmans River
Cox Cr. 1682 f.
Tunnel 1898 f.
4 Miles
Allegheny Mt. 1754 f.
Wills Cr. 1100 f.
Cumberland 573 f.
Old Town 489 f.
Flint Creek
Sideling Hill Cr.
Hancock 407 f.
Conolway Cr.
Licking Cr.
Williamsport 355 f.
Antietam Cr.
Harper's Ferry 300 f.
Cotoctin Cr.
Point of Rocks
Monococy River 224 f.
Peters Quarry
Seneca Creek
Great Falls
Little Falls
Georgetown
Washington
Potomac River
Base Level of the Atlantic Ocean
Miles


PROFILE OF THE OHIO CANAL.
Feet
Lake Erie 94 f.
Cleaveland
Cuyahoga R. Aqueduct
Akron 499 f.
Summit Lake
Portage Summit
New Portage
Clinton
Kendall
Massillon
Bethlehem
Tuscarawas R.
Bolivar
Zoar
Dover
Sugar Cr. Dam
N. Philadelphia
Gnadenhutten
Walhonding River
Coshocton
Caldersburg
Section from Cleaveland to Massillon 67 miles 94 Locks rise 405 ft. fall 31 ft. total 436 f. average descent 6¼ feet per mile.
Base Level of the Ohio River at Portsmouth which is 474 feet above the Atlantic
Scale 170 of 160 Miles 150
Licking Aqueduct
Newark
Licking Summit
Hebron
Reservoir
S. Fork of Licking R.
Deep Cut
Columbus Side Cut and 92 feet below Lake Erie.
Bloomfield
Circleville
Scioto Aqueduct
Deer Cr.
Chillicothe
Paint Cr. Aq.
Piketon
Portsmouth
Ohio River


PROFILE OF THE ERIE CANAL, N. Y.
Feet
Lake Erie 568 f.
Buffalo 578 f.
Black Rock
Tonnewanta
Tonnewanta Creek
Pendleton
Lockport 568 f.
5 Double combined Locks 62 feet
Middleport 506 f.
Road under Can.
Newport
Holly
Brockport
Spencer's Basin
Rochester 506 f.
GENESEE LEVEL
Erie Canal Length 363 miles 40 f. wide at top, 28 f. at bottom 4 f. deep
83 Locks on the main trunk entire lockage 688 feet declivity from Buffalo to Rochester 4 f. rise 63 f. fall 63 f. total rise & fall 692 feet.
5 Locks 37 f.
Brighton
Pittsfield 469 f.
Gr. Embankment
Palmyra 441 f.
Newark
Lyons 410 f.
Clyde 389 f.
Montezuma 389 f.
Weedsport 405 f.
Jordan 416 f.
Canton
Otisco 405 f.
Syracuse 399 f.
Manlius Land.
New Boston 425 f.
Lenox
Verona
Rome
The LONG LEVEL
Whitesboro
Utica 425 f.
Steels Cr. 401 f.
German Flats 385 f.
Lit. Falls 360 f.
Nowadaga Cr.
Fort Plain
Canajoharie 297 f.
Anthony's Nose
Schoharie Cr.
Flint Hill 300 f.
Plattekill Aq.
Schenectady 227 f.
Upper Aqueduct 206 f.
Low. Aq. Mohawk R. 185
Cahoos Falls
Champlain Canal
Albany
Hudson River
Base Level of the Atlantic
J. & E. H. Hart Sc.

lock. The water-supply is drawn entirely from the Potomac, seven dams having been constructed across the river for this purpose.

The Ohio Canal.—This canal has a length of 309 miles, extending from Cleveland on Lake Erie to Portsmouth on the Ohio river. From the former city it ascends the valleys of the Cuyahoga and Little Cuyahoga rivers, and reaches the north end of the summit-level at Akron, 38 miles from Cleveland. This portion is fed mainly from the Cuyahoga and Little Cuyahoga rivers, and has an ascent of 395½ feet, overcome by means of 44 locks. Of these, twenty-one are within 3 miles and sixteen within 1½ mile of the north end of the summit-level at Akron. Power is utilised by a number of mills, principally at the last mentioned place.

The canal now enters the basin of the Tuscarawas river, and from the south end of what is known as the Portage summit-level has an uninterrupted descent to Welsport, following the Tuscarawas valley and then that of the main Muskingum river. In this distance of 112 miles there is a fall of 238·6 feet, effected by 29 locks. The low-level at Welsport is also at the foot of a continuous descent from the Licking summit, which lies to the westward, the surplus waters entering it from either direction being discharged through a side cut into the Muskingum river at Dresden. On the division extending from the Portage summit to Welsport and Dresden, there are nearly a dozen flouring-mills, using various powers, ranging usually between 15 and 50 horse-power, but in two or three cases reaching 100 and 150.

From the low-level at Welsport the canal rises to the westward to the Licking summit, making an ascent of 160 feet in the 42 miles by means of nineteen locks. The water supply is derived from the Licking river at the Narrows, from one or two forks of the main river, and from the Licking reservoir. There are no returns indicating any present use of power on this section of the canal. At Newark there is a fall of 18 feet from the feeder and from the main canal to the water-surface in the north fork of the Licking river, but it is not utilised. In years past the feeder had been employed at Newark for a small woollen mill, a flouring-mill, and a saw-mill, which did rather an extensive business; but they have, one after another, abandoned the use of the water power. The feeder at that point draws from the north fork, and should take its entire low-flow, but the feeder-dam is reported as leaky, and the canal has been allowed to silt up, thereby diminishing its capacity, so that the available flow of the stream is not utilised.

The Sault St. Marie Canal.—One of the most remarkable canals in the world is that known as the Sault St. Marie, or St. Mary's Falls Canal, in the State of Michigan, which connects the waters of Lake Superior and Lake Huron, and thereby affords a means of communication between some of the most important territories and centres of population in the United States. The position of the canal is illustrated in the chapter on "Canadian Waterways."

The head of Lake Superior is 1400 miles from New York. Of this distance some 880 miles are deep water navigation by the Lakes, the outlet of which is St. Mary's River. The St. Mary's Strait is 75 miles long, and in this distance there is a fall of 20 feet 4 inches, of which 18 feet 2 inches occur at the Sault, while the remainder of the descent, 2 feet 2 inches, is distributed over the first 35 miles below that point. Hence the river is tortuous, and navigation is rendered unsafe by the rapids, although from a point 50 miles below the foot of Lake Superior navigation is good for the remainder of the distance of 25 miles to Lake Huron.

In 1855 the St. Mary Falls Canal was built for the purpose of overcoming the fall between the Lakes Superior and Huron. The length of the canal is only about one mile, so that, as compared with the Suez and other ship canals, its extent is unimportant. But so far as its traffic is concerned, this is the most important canal in the world. Commencing with an annual tonnage of only about 100,000 tons at the time of its construction, the canal now disposes of an annual tonnage of over six millions, thus exceeding the tonnage passed over the Suez Canal by nearly a million of tons.

In 1855, two locks were built on the St. Mary's Falls Canal, each 70 feet wide and 350 feet long between the gates. These locks could not accommodate vessels drawing more than 11½ feet. But in 1880, when the canal had been transferred by the State of Michigan to the United States, as a work of national importance, the Government undertook the construction of a new lock, which was opened in 1881, and which has been described by competent engineers as the finest piece of hydraulic engineering on the American continent. The lock is at the lower end, and is 515 feet long between the gates and 80 feet wide in the chamber, with 17 feet of water on the sills. The lift is 18 feet, more or less, according to the fall in the rapids between Lake Superior and Lake Huron. The gates are not set opposite to each other on the same axis, but on parallel axes 20 feet apart, so that the width between the gates is reduced to 60 feet, while in the chamber it is 80 feet, the difference being met by reverse curves on either side.

Advantage is taken of the natural water power created by the lock to establish by the side of it an accumulator for operating the gates and valves by hydraulic pressure—in the same manner as at the London and Liverpool docks—which works admirably.

The chamber is filled and emptied by culverts of large dimensions, under the mitre sills, without producing any disturbance of the vessel, because the tunnel or culvert runs the whole length of the chamber, with openings at the top, which are so arranged as to distribute the force of the inflowing current along the centre, entirely under the vessel's keel. In 1886, when the Canadian and Pacific Railway steamer *Arthabaska* passed through the lock, it took one minute and a half to close the upper gates, seven minutes and a half to empty the lock, and one minute and a half to open the lower gates. Altogether, from the time of entering the lock to the time of going out of it again, the passage was made in thirteen minutes, and there was no hurry about it.

It is only by the great initial pressure afforded by the accumulator, about 600 lbs. to the square inch, that the valves and gates could be commanded with so much ease and rapidity. This system has been seven years in operation, and its efficiency proves the great care and skill with which all the details of construction have been worked out. The lock was six years in building, and cost, including the enlargement of the canal, about three millions of dollars.

The two other locks, now called the "old locks," built by the State of Michigan, and first opened in 1855, are still in use. These old locks are combined, having lifts of 9 feet each to overcome the whole fall of 18 feet. The gates are suspended from pillars seated on the coping of the quoins, and the chambers are filled and emptied through the gates in the old-fashioned way. The old canals and locks were assumed by the United States Government in 1881. The shipping that goes through this canal all passes free, both domestic and foreign. The staple articles of the commerce using the canal are coal, copper, flour, grain, iron ore, pig and manufactured iron, lumber, salt, silver ore, and building stones. Before the opening of the canal the commerce here was nil. It now threatens soon to exceed the capacity of both locks, in view of which the United States Government has already commenced a second enlargement, the estimated cost of which is nearly five millions of dollars.

This new lock is to occupy the site of the old combined locks, and is to surpass all other locks in the grandeur of its dimensions. It will have a chamber 800 feet long between the gates, the width, both in the chamber and at the gates, will be 100 feet throughout, and the depth on the sills will be 21 feet. Of course there are no vessels on the upper lakes large enough to fill such a lock as this, but it is designed to pass a fleet through at a single lockage, including tug-boats, with their flotilla of barges. The canal is to be uniformly 20 feet in depth.

Previous to the construction of the St. Mary's Falls Canal, all the outside supplies for the upper lake had to be unloaded at the foot of the rapids, transferred over a portage road to the head of the rapids, and reshipped at great expense. Even the vessels which were sailing on Lake Superior had been handed out and dragged around the rapids in the same way. The transfer and supply business became the great industry, and as the mining fever developed, and the Lake Superior district began to boast of its few scattered but permanent settlements, it seemed as if Sault Ste Marie was destined to be the central and chief city of this region. The portage trade, in the very nature of things, could not last. The demands of Lake Superior were too urgent to admit of the delay and harassment incident to this method of transfer, and the construction of a ship canal around the rapids became a practical problem which demanded a speedy solution. Governor Mason in 1837, in his first message, advised the building of such a canal, and during the same year a survey was made for that purpose. In 1838 an appropriation bill was passed by the Legislature, and in the following year the contractors commenced the work. Much to their surprise, the military authorities considered the work an infringement upon the rights of the General Government, and an armed force from Fort Brady drove the contractors off the ground. This put a quietus to the work for several years, although the advocates of the measure did not cease to urge it upon the attention of the State Legislature and Congress. In 1852, however, the latter passed a Bill appropriating 750,000 acres of land to aid in the construction of a canal. In 1853 the Legislature authorised the commencement of the work. The contract was let to construct two consecutive locks, each 350 feet long, 70 feet wide, with a depth of 13 feet of water, and proper canal approaches.

These were the old State locks, now about to be removed and replaced by a single lock which, as already stated, will in its dimensions and capacity, be the largest in the world. This canal has resulted in adding Lake Superior to that system of waterways which is the pride and the chief commercial feature of the northern border.

The commerce of the great American lakes has enormously increased within recent years, as the statistics of the St. Mary's Falls Canal sufficiently prove. In 1872 the registered tonnage that passed through the canal was under a million tons; in 1880 it was only 1,734,000 tons; and in 1886 it had increased to 4,219,000 tons. The growth of the trade continues. The navigation, it will be remembered, is only open for about seven months of the year, usually commencing about the first week of May, and closing in the first week of December. If it were open all the year round, like that of the Suez Canal, the difference of business, in favour of the St. Mary's Falls Canal, as compared with the Suez and other great canals, would be much more marked than it is. The tonnage carried through the canal in 1886 was made up of—

Coal	1,009,000 tons.
Iron ore	2,089,000 ,,
Copper	39,000 ,,
Salt	159,000 ,,
Iron and steel	115,000 ,,
Wheat	18,991,000 bushels.
Flour	1,759,000 barrels

On the St. Mary's Falls Canal in 1888 there were carried no less than 6,411,000 net tons (2000 lbs.) of freight and 25,558 passengers, the freight including nearly 19 million bushels of wheat, over 2½ million tons of lumber (timber), about 2¼ million tons of coal, and 2,190,000 barrels of flour. The total number of vessels that used the canal in that year was 7803, of which 5305 were steamers. The average cargo carried by each vessel, large and small, was about 822 tons, being an increase of 40 per cent. on that of the previous year. This is a development that can hardly be paralleled in the history of transportation. Taking the navigation season at seven months, it means an average of 916,000 tons per month passing through the canal, or at the rate of about 11 million tons a year, which is roughly about double the tonnage that makes use of the Suez Canal.

On the first blush, it is by no means apparent that the St. Mary's

Falls Canal can do much to advance the maritime intercourse of the United States with the nations of the East. And yet it may become an important factor in this direction; so much so, that there are those who hold that New York is likely thereby to become the great distributing centre for the produce of India and China, not on the American continent only, but throughout European and African Atlantic ports as well. This conclusion is based upon circumstances that appear to be only imperfectly understood in Europe. The tunnelling of the Cascade Mountains, now in progress in Washington Territory, will bring Duluth within 1800 miles of Paget Sound, thus bringing the waters of the Pacific Ocean within 1800 miles of navigable waters flowing directly into the Atlantic Ocean, through Lake Superior, the Sault, and the Erie Canal. By this means New York will, it is claimed, be brought within 10,500 miles of Canton, while the distance between that city and London, Liverpool, or Antwerp is 17,000 to 18,000 miles. Between New York and Canton, *viâ* the Isthmus of Suez, the distance is 20,500 miles, and by the Cape of Good Hope it is 22,500 miles. The future is therefore likely to work some changes in the balance of Eastern trade, although it may not happen that the St. Mary's Fall Canal will, as some enthusiasts suppose, become the most important rival of the Suez Canal, and "one of the greatest factors in bringing about tremendous changes in the commerce of the world."

In order to give some idea of the remarkable key-like location of the "Sault" or "Soo," and the character of the locks, which are the prominent feature of the canal, we have reproduced, in the following chapter (that on Canada) from a recently published work on that locality, a sketch-map, showing the railway and waterway communications that are concentrated at this point (p. 226).

Projected Canals.

The Florida Ship Canal.—In 1869 the Board of Trade of Mobile memorialised the Congress of the United States for an appropriation for a survey for a ship canal, to open ship communication between the waters of the Gulf of Mexico and the Atlantic Ocean, through the Florida peninsula. The proposed canal, it was pointed out, might commence at Tamper Bay, on the Gulf side of Florida. At this point there is a naturally well-protected harbour, with ample depth of water for ships drawing 20 feet, and the channel could be permanently deepened. East of Tamper Bay, in a distance of 125 miles across the peninsula of Florida at its narrowest part, with one exception, the maps show on the Atlantic coast depths of 27 feet to 28 feet of water quite close to the shore, and thence to the broad expanse of the Atlantic a free and unobstructed way for vessels. It is believed by competent authorities that a very efficient ship canal, with adequate depth of water, could be made here without great cost. The land is level across the proposed route, with only a few feet elevation above tide-water. The importance of such a canal would no doubt be considerable. The passage around the southern point of Florida is narrow, is subject to tornadoes, and is beset with concealed reefs, upon which a rapid current tends to throw ships, besides which the long passage round the peninsula would be obviated.

Delaware and Chesapeake Canal.—Notwithstanding the comparative disuse of a great part of the existing American canal system, a proposal has been put forward quite recently to construct a waterway to connect Delaware and Chesapeake Bays. This canal, if it were carried out, would be about 17 miles in length, and it is estimated to cost 8,500,000 dols. (1,700,000*l.*). It is proposed to adopt the following dimensions:—width, 100 feet; depth at low-water, 26 feet; side slopes, 1½ to 1 foot.

Transportation in the United States.

The transportation problem continues to exercise the minds of the people of the United States in a way that the people of Great Britain can but imperfectly appreciate. The cost of conveying traffic from Chicago to New York has already been brought down to an average of 6·6 cents per bushel for water, and 10 to 12 cents for rail transport. In other words, the cost of transporting a ton of goods between the two greatest commercial cities of the New World has been brought down to ·09*d.* by water, and 0·11*d.* by land. So notable an achievement ought, one would naturally suppose, to satisfy the insatiable appetite of our American friends for cheap transportation, but so far from this being the case, they are now considering how far it is possible to reduce the 6·6 cent water-rate to five or even four cents, and the possibility is hinted at of reducing the rates to three cents per bushel,* which would be a fraction over 0·04*d.* per ton per mile. This would mean, if

* 'Transactions of the American Society of Civil Engineers,' vol xiv. p. 99.

actually accomplished, that a ton of goods might be carried between London and Edinburgh—a distance of over 400 miles—for 16*d.*, or, to put the matter in a way that may be readily appreciated, the cost of the transport of the 2,463,000 tons of coal conveyed by sea from Newcastle to London in 1888 would be reduced to 1*s.* per ton, and the inhabitants of London might thus reckon on having their coal supplies almost as cheaply as if they lived within thirty miles of the mines.

In order, however, to bring about the contemplated further reduction of the cost of transport between Chicago and New York, it is proposed to construct a New Erie Canal. The cost would be stupendous. It has been calculated at about 150 millions of dollars, but it would probably involve a still larger expenditure, inasmuch as ship canals seldom come within their estimates. A remarkable calculation has been made, by way of justifying this large outlay. It is reckoned that if one cent alone can be saved on the cost of transporting a bushel of wheat over this route, it would mean a total saving of about nineteen million of dollars on the products of the forest, the field, and the mine, which are tributary to the great American lakes.

The American Society of Civil Engineers were recently called upon to consider a project for "the widening, deepening, and necessary rectification of the worst curvatures of the present Erie Canal, from Buffalo to Newark, about 130 miles; the construction of a new canal from Newark to Utica, about 115 miles; the canalisation of the Mohawk River from Utica to Troy, about 110 miles; and the improvement of the Hudson river from Troy to Four Mile Point, in Coxsackie, a distance of about thirty miles."

The adoption of this programme would make the Erie Canal the most important artificial waterway in the world, the tonnage that would make use of it, when thus improved, being calculated at 20 to 25 millions a year. The cost of the undertaking (estimated at 25,000,000*l.* to 30,000,000*l.*), although a large sum, is not deemed to be too much for a great artificial river more than 300 miles long, 18 feet deep, 100 feet wide at the bottom, and having locks 450 feet long and 60 feet wide. These dimensions would enable the canal to float the largest vessels that navigate the great lakes from Lake Erie to the deep waters of the Hudson.

CHAPTER XVI.

THE WATERWAYS OF CANADA.

"Heads the running springs and standing lakes,
And bounding banks for winding rivers makes."—*Dryden.*

It appears to be among the "things not generally known" that Canada has, relatively to the trade and population of the Dominion, one of the most extensive and perfect systems of canal communication in existence. The really important canals are few in number, and the traffic that they transport is by no means so considerable as that carried on many of the canals of the United States and some European countries. But, all the same, the Canadian people, always appreciative of the advantages of cheap water transport, and looking to that agency as a means for the development of their internal resources, have neglected no opportunity that offered for advancing their waterways, and utilising them to the utmost extent.

The principal canals in Canadian territory are the Welland, the Lachine, the Cornwall, the Galops, the Murray, the Quebec and Montreal, and the Sault Ste Marie, or St. Mary's Falls, the latter being partly on United States and partly on Canadian territory. These canals have chiefly been constructed for the purpose of affording communication between the great lakes and the St. Lawrence river, whence vessels pass into the Atlantic.

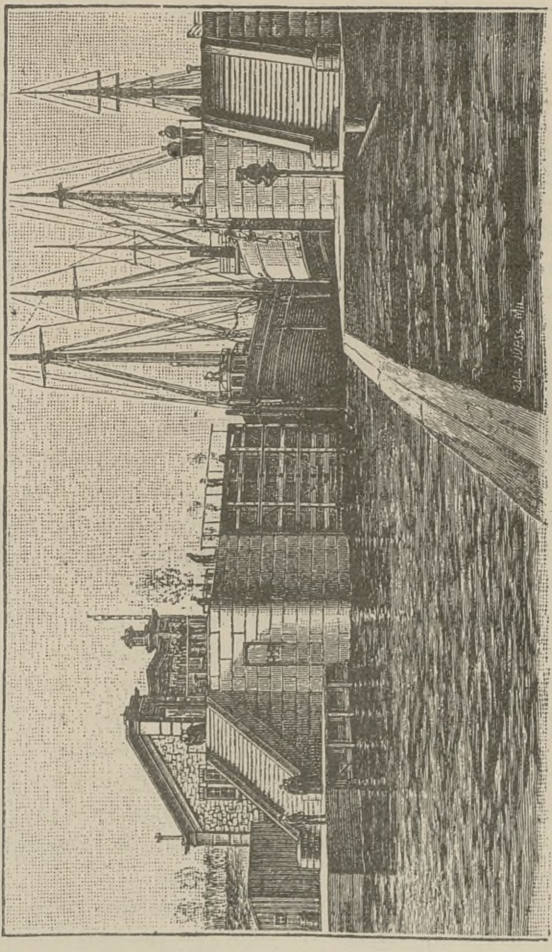
The Welland Canal.—The waters of Lake Erie empty into Lake Ontario through the Niagara river and over the Niagara Falls. The difference in the levels of the two lakes cannot be stated with any exactness, as the influences which cause the variations in the height of water in the two lakes are not identical. It is, however, as nearly as can be ascertained, 326¾ feet. The course of the Niagara river is due north, and its current is swift and turbulent.

The Welland river flows nearly at right angles with the Niagara river, and discharges into it at Chippewa, a village about 2 miles above Niagara Falls. It is navigable for deeply loaded vessels for a distance of 40 miles or more, and has scarcely any current. The

Grand River flows south-easterly, and empties into Lake Erie. Port Maitland, one of the safest harbours on Lake Erie, is situated at the mouth of the Grand River. Port Colborne, another very secure harbour on the same lake, is about 18 miles west of the upper end of the Niagara river. Port Dalhousie, on Lake Ontario, is about 11 miles west of the mouth of the Niagara. The desirability of connecting the two lakes by navigable water was, very early in the history of the country, admitted by all who gave the matter attention; surveys were made from time to time, and various plans were proposed and discussed, but nothing definite was done until, in 1824, a company was incorporated under the name of the Welland Canal Company. Their first intention seems to have been to establish a line of communication between the two lakes by a combination of canal and railway, the canal to be of comparatively small capacity; but this plan was soon laid aside, and it was determined to secure water communication throughout the whole length, and to build a canal sufficiently large to admit schooners and sloops.

The plan thus adopted contemplated utilising the Niagara river from Lake Erie to the mouth of the Welland river, the Welland river being followed for a distance of 8¾ miles, and building a canal from Welland river to Lake Ontario. The water supply was to be obtained from the Welland river, and a high ridge of land in the line of the proposed canal was to be overcome by a deep cut. There were many objections to this plan, the chief of which were the circuitous course necessitated by the use of the Niagara and Welland rivers, the swift current of the Niagara, and its unsuitability for heavily loaded boats, and the constant danger of slides, because of the unstable character of the soil through which the deep cutting would have to be made. Notwithstanding these objections, and various other obstacles which were developed by close inquiry and examination, the company adhered to their plans, and in July 1825 entered into a contract for the prosecution of the work. But the undertaking dragged from lack of funds.

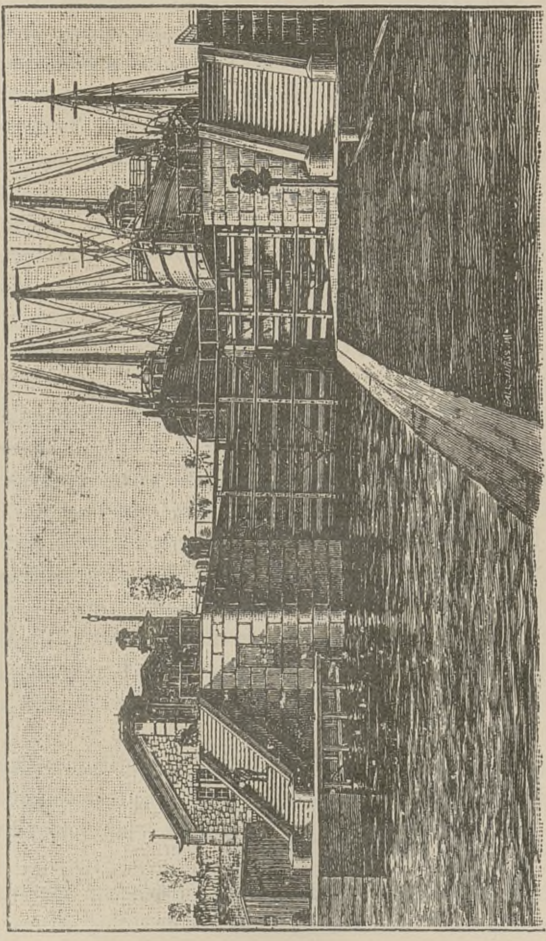
In the summer of 1828 the work of construction had made such progress that it was confidently expected that the water would be let into the canal by the autumn of that year; but just at this time the predictions of the opponents of the scheme were realised, and the completion of the enterprise was delayed by the falling in of a part of the embankment in the deep cut. The accident was so formidable as to seriously embarrass the company, already well drained of its resources, and working on a plan not generally approved. The directors, therefore, abandoned the design of using the Welland river as a feeder, and determined to obtain their water supply for the canal from the Grand River, through a new feeder to be constructed



THE WELLAND CANAL, WITH LOCKS OPEN.

for a distance of 27 miles. This necessitated raising the level of the canal, but the depth of cutting was at the same time diminished $15\frac{1}{2}$ feet, and the danger of a recurrence of the accident referred to was much lessened. Work was again begun, and on November 30th, 1829, two schooners ascended the canal from Lake Ontario to the Welland river.

Vessels drawing 7½ feet of water and not having more than 21½ feet breadth of beam then sailed down the river Niagara until



THE WELLAND CANAL, WITH LOCKS SHUT.

they approached about one-fourth of a mile from the mouth of the Welland river. There they entered a canal, 15 chains in length, which has been cut across a point of land into the Welland river, up which they passed a distance of 9½ miles. They then ascended two locks into the deeper cut, and passed through it for a distance of 16½ miles more into Lake Ontario.

The feeder was 20 feet broad at the bottom, 40 feet broad at water-level, and 5 feet deep. The Government, in 1831, granted the company a loan to assist in carrying out an extension of the main line over the Welland river to Port Colborne by enlarging the feeder for about five miles, so as to make it a navigable channel, and excavating a new canal for the remaining distance between the main line, as originally completed, and Lake Erie. This work was finished in 1833, the line thus constructed occupying nearly the same route as the enlarged line of 1841, and the old line of the present day having the same termini on the two lakes. It was 27¼ miles long, and the breadth at the bottom was 24 feet. There were forty locks, built of wood, all 110 feet long by 22 feet wide, except the first three ascending locks from Port Dalhousie, which were 130 by 32 feet, and one at Port Colborne from the canal into Lake Erie, which was 125 by 24 feet.

At the solicitation of the company, on Act was passed in 1839 authorising the purchase by the province of the rights of the private stockholders, and, shortly after the union in 1841, the purchase was made and the line was transferred to the new Board of Works of Canada. Up to this time it had cost the province of Upper Canada in loans (which were never repaid), in advances, and in the purchase of stock 1,751,427 dollars; in addition to which 100,000 dollars had been contributed to its construction in the purchase of the company's stock by the Government of Lower Canada, and 222,220 dollars in loans by the Imperial Government, making the total cost 2,073,647 dollars.

The Welland Canal, as originally built, had never been satisfactory, either in its location, in its dimensions, or in the character of the work, and it had never been looked upon as permanently completed.

From time to time surveys and investigations had been made, and changes and improvements suggested, but nothing of any moment had been done. As soon, however, as the line came wholly under the control of the Government, by the purchase of the interests of the private holders, it was determined by the Board of Public Works that all the locks should be rebuilt in stone, and their dimensions increased to 120 feet long by 26 feet broad, with 8½ feet water on the sills; that the aqueduct required to carry the canal over the Welland river should be rebuilt of stone; that the feeder should be converted into a navigable channel; that the harbours on both lakes should be improved; and, finally, that the projected Port Maitland branch should be undertaken and completed, with an entrance lock from Lake Erie 200 feet long, 45 feet wide, and having 9 feet depth of water.

These works were commenced in 1842 and completed in 1849. The original plan was modified during the progress of the work so as to make the locks 150 feet long by 26½ feet wide, and the bed of the main line 26 feet wide at the bottom.

As the Grand River gave evident signs that it could not be relied upon as a feeder, it was decided to obtain the water supply for the canal from Lake Erie. To do this it became necessary to lower the summit-level 8 feet to that of Lake Erie. This undertaking was commenced in 1846, but was not finally completed so as to render the canal independent of the Grand River until a few years ago. These enlargements and improvements cost the Government of Canada up to the 1st of July 1867, 4,900,810 dollars.

Even after its enlargement, no vessel drawing more than 10 feet of water, or over 150 feet in length, could pass through the Welland Canal. Increased accommodation being needed, a larger canal with a new set of locks was commenced in 1873, and completed in 1881. This canal branches off from the old canal 19 miles from Lake Erie, and rejoins it again at Lake Ontario. The old canal was deepened from Lake Erie to its junction, with the new canal, so that vessels having a draught of less than 12 feet can pass from one lake to the other. The new canal is 100 feet wide at the bottom, 12 feet in depth, and has side slopes of 2 to 1; but the excavation through rock has been carried down to 14 feet in depth, to facilitate the deepening of the canal if required in the future. It is 13 miles long, and cost 3,840,000*l.* The difference in level is 313 feet, which is surmounted by twenty-five locks, with lifts ranging between 12 to 16 feet. Regulating weirs have also been built, some attaining a width of 300 feet; the flow of water through them is regulated by sluice-gates, formed of sheet iron, which are raised and lowered by screws. The locks are 40 feet 4 inches wide, and have a length of 270 feet between the sills. The side walls are 29 feet high, with a batter of 1 in 24; they are built of limestone ashlar, and are strengthened by counterforts. The lock floor is planked with pine timber, and the gates are constructed of white oak. The gates are moved by chains, guided by rollers and winding round drums, and one man is able to move a gate. The sluice-gates are raised by lifting a small shutter (½ foot by 1 foot), which allows the current to work a small turbine, whose revolutions set in motion a screw which raises and lowers the sluice-gate. The rate of motion transmitted by the turbine is so much reduced in passing through a train of wheels and a revolving nut that 212 revolutions of the turbine are required to raise the sluice-gate 1 inch. The sluice-gates are 5 feet by 1½ foot, and are raised in two minutes.

It has been doubted by many men who have carefully studied the question whether the very large expenditure that has been incurred over the Welland Canal will ever be justified by the result. The canal is, of course, the main connecting link between the great lakes of the south and south-west and the principal maritime outlets of the Dominion, and the Dominion Government has no doubt been animated by the belief that the time would come when the great commerce that now passes from Duluth, Chicago, and other ports in the United States to New York, and thence to Europe, would take the Welland Canal route, instead of the Erie Canal, thereby making Montreal the chief port on the American continent. This impression has been supported by the consideration that Montreal is nearly 300 miles nearer to Liverpool than New York.

It is, no doubt, of the greatest possible consequence to Great Britain, to the United States, and last, but not least, to the Dominion of Canada, to consider how the immense traffic which is now carried on between the great North-western States and the markets of Europe is to be carried in the time to come.

At the present time we receive from the United States about thirty millions of cwts. of wheat per annum, of which two-thirds are brought to us from ports on the Atlantic, and one-third from ports on the Pacific. We also receive between twelve and fifteen million cwts. of wheat meal and flour, and ten to twelve million cwts. of maize or Indian corn, in addition to smaller quantities of barley and other cereals.

The great bulk of this immense traffic is transported from Chicago, which is the great gathering ground, to New York, which is the great distributing centre. There is no traffic in the world that is more fiercely competed for. Everything is done that can be done to draw it on to the railways on the one hand, and on to the waterways on the other, and as a consequence the rates of freight, as we have seen, are on both systems reduced to the lowest attainable limit. The Transatlantic traffic is competed for quite as keenly, so that grain has been carried between Chicago and the markets of Great Britain, a distance of over four thousand miles, for less than 20*s.* per ton, including a railway journey of 950 miles, or a lake and canal journey of 1200 miles, in addition to the ocean voyage.

It is, however, beginning to be felt that even this extraordinary outcome of the development of the means of efficient transportation may be threatened with successful rivalry. There are those who argue that the natural outlet for the grain grown in the North-west is not New York, but Montreal, which is 270 miles, or a day's steaming, nearer to Liverpool than New York.

The grain traffic is sent from Chicago to Buffalo in either case. But from Buffalo to Liverpool by way of the Erie Canal and New York is 3450 miles, while by way of the Gulf of St. Lawrence and Montreal it is only 3180 miles. In both cases, the grain is carried by water, so that there is practically no difference in point of cost at the port of departure.

It has been found necessary in Canada, with a view to meeting the competition of the Erie Canal route, to reduce the canal tolls and harbour dues. Prior to 1884, the rate of tolls on the grain shipped by way of the Welland Canal was 20 cents per ton, which allowed a vessel to pass through the St. Lawrence Canal without additional payment. But, as the tolls on the Erie Canal were abolished in 1883, it became increasingly difficult for the Montreal route to compete with that *viâ* the enfranchised Erie Canal to New York.

A remission of one-half of the tolls on grain has, therefore, since 1884 been allowed on the Welland Canal, so that the present rate is only 10 cents, or 5*d.* per ton. Other concessions have been made in the interval, until now the rate is only 2 cents per ton on grain passing eastwards to Canadian ports. This has had the effect of greatly stimulating the canal traffic. The quantity of grain carried into Montreal by railway was, in 1885, about 3½ million bushels more than that carried by canal. In 1886, however, the canal carried nearly five millions of bushels more than the railway.*

The Canadian port, however, notwithstanding its advantages in point of nearer proximity to Liverpool, and its equally good if not superior navigation from Buffalo, is very far behind that *viâ* New York. The receipts of grain at New York in some recent years have amounted to as much as 175 millions of bushels, or fully nine times as much as the quantity received at Montreal in 1886. It is manifest, therefore, that Montreal, whatever its geographical advantages, has not secured that share of this immense trade to which it has considered itself to be entitled. This fact is probably due to a variety of causes, one of which, the impediments in the way of the navigation of the St. Lawrence, the Canadian Government have recently been attempting to overcome. But the most serious drawback to Montreal is, no doubt, the climate, which closes up the navigation entirely for a great part of the year, while that of New York is always open.

The Cornwall Canal.—This canal, which is now being enlarged, between Moulinette and Milleroches, where several breaches have occurred in its banks, was originally constructed with a width of 100 feet at the bottom and 10 feet depth. The embankment was raised to 14 feet above the canal bottom, and was made 12 feet wide at the top with slopes on either side of two to one.

That portion of the canal embankment on the upper reach, which, for upwards of a mile in length (from Moulinette to Milleroches) holds the water in the canal at a level of about twenty feet above the branch of the St. Lawrence, which runs alongside, is in part founded upon the treacherous clay bottom in which were found springs of water, and in part in side cutting permeated by streaks of sand. The embankment over this ground was formed with extra care, the earth being laid on in courses with carts, and where the outer slope ran out into the river, it was protected by boulder stones along its outer

* The exact figures were—

Year.	Bushels of Grain carried by	
	Railway.	Canal.
1885	10,007,061	6,559,000
1886	6,685,000	11,366.000

edge. Where springs were found under the seat of the embankment they were led out to the river's edge by French drains, and where the streaks of sand were encountered in the side cutting they were cut off by puddle trenches, 6 feet deep or more, and the bottom and side bank were lined with puddle, 3 feet thick, from the puddle trench to high-water mark. This mode of protection was not continuous over the whole line, but was confined to such parts of the bank only as appeared to require it.

Since the opening of the canal, there have been several breaches in this bank, the last and worst of all, which occurred in 1888, inflicting serious damage upon the trade of the St. Lawrence in that year.

The enlarged canal is to be 6 feet deeper than the old one. Sixteen feet of water, instead of 10 feet, implies greater strain upon the bank, and a deeper searching after the hidden springs and streaks of sand that may be interposed between the canal bottom and the river.

It has been proposed, with a view of avoiding this risk, to substitute a lake three miles in length for a canal where the breaks have occurred, and to throw dams across the narrow channels at the head and foot of Speek's Island, in order to raise the water up to canal level.

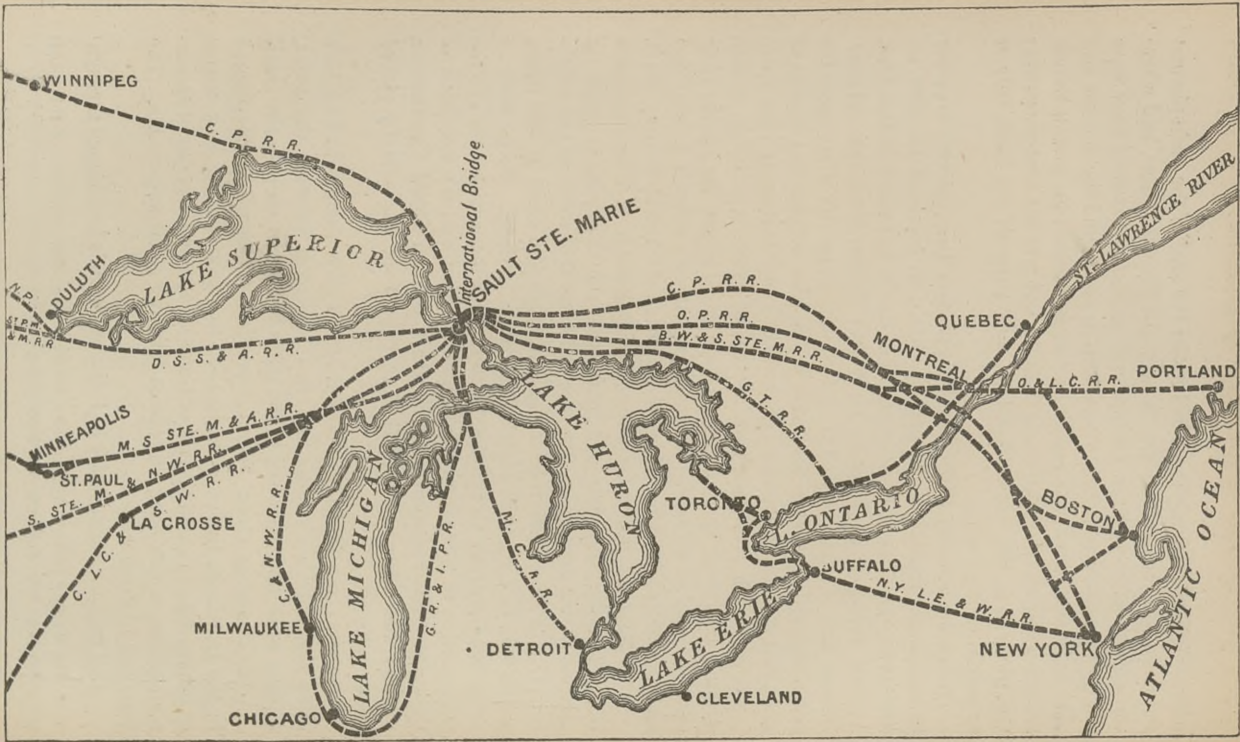
*The Sault St. Marie Canal.**—The Dominion of Canada, which borders on the Sault, has, or believes that she has, quite as great an interest in the development of the traffic on this route as her neighbours, and hence has resolved on constructing a canal at this point, which will, of course, be built on Canadian territory. So far back as 1852, the Canadian Government had surveys made with a view to the construction of a canal on the Canadian shore, and the execution of the project was recommended by the Canadian Canal Commission of 1871, but it was not until 1888 that the work was actually placed under contract.

On the Canadian side of the St. Mary's river there is to be a lock of 18 feet, with a chamber 600 feet in length between the gates, 85 feet wide, and narrowed at the gates to 60 feet on opposite sides.

The Canadian Canal System generally.—A Commission appointed by the Dominion Government in 1870 to report on the best means of improving the canal system of Canada, adopted a series of recommendations, which have since been followed as far as possible. The principal of these were :—

1. That one uniform size of locks and canals be adopted through-

* The leading particulars as to the location and characteristics of this canal are given at p. 209, and need not here be repeated.



MAP SHOWING THE POSITION OF THE SAULT ST. MARIE, IN RELATION TO THE AMERICAN LAKES, AND THE TRADE FROM WEST TO EAST.

out the whole of the St. Lawrence route; that the locks be made 270 feet long and 45 feet wide, with a depth of 12 feet clear on the mitre sills; and that the bottom of the canals be sunk at least 1 foot below the mitre sills of the locks, with a width throughout of not less than 100 feet. They stated that these dimensions would enable vessels of the usual build, carrying 1000 tons, to pass, and if their breadth of beam and sectional areas were increased, the canals might be navigable for vessels of 1500 tons.

In giving their reasons for fixing the greatest depth of water on this route at 12 feet, the Commission says:—

"While some of the writers who ought to be best informed on the subject recommend a draught of 14 feet, and others as much as 16 feet, regard must, nevertheless, be had to the capabilities of the harbours, and to the engineering characteristics of our canals, as well as the prudent suggestions of moderate and experienced men, who have limited their views to 12 feet. It would be extremely unwise to embark in magnificent schemes exceeding the resources of a young country, with the view of introducing ocean vessels into our canals and lakes."

2. That the locks on the proposed Bay Verte Canal be made 270 feet long and 50 feet wide, with a depth of 15 feet on the mitre sills.

3. That the locks on the Ottawa system be made 200 feet long and 45 feet wide, with a depth of 9 feet on the mitre sills.

4. And that the locks in the Richelieu river be made 200 feet long and 45 feet wide, with such a depth on the mitre sills, not exceeding 9 feet, as the channel of the Richelieu would afford.

The dimensions fixed upon for these routes were thought sufficiently large to accommodate the largest barges used for carrying timber, that being the main article transported through them.

The Ottawa River.—The Canadian Government a few years ago began the improvement of the Ottawa river, westward from Ottawa, with the design of opening up a waterway to Lakes Huron, Michigan, and Superior by means of the Ottawa and French rivers and Lake Nipissing. This undertaking, after being under discussion for a considerable period, was finally abandoned, after an expenditure of over 1,000,000 dollars. According to a report made by a Government engineer on the cost of the completion of the scheme, it would have involved about 24,000,000 dollars. A canal 6 miles long would be required to surmount the Chaudiere Falls at Ottawa, which are a barrier to continued river navigation above this city (and from which the valuable water power of the city is derived). Another canal 3 miles in length would be necessary to overcome the Chats Falls. This work, called the Chats Canal, was commenced in 1854 and abandoned in 1856, after an expenditure of 483,000 dollars.

The St. Lawrence River.—Only at the close of the year 1888, a work of river improvement, which was commenced fifty years before, was completed by the official opening of the 27½-feet channel between Montreal and Quebec, on the St. Lawrence river. This undertaking involved the deepening of the channel through the flats of Lake St. Peter, where there was only a depth of 12 feet in 1867. In 1873 the Dominion Legislature resolved to deepen the channel to 22 feet at low-water, and not less than 300 feet wide. In 1878 a minimum depth of 22 feet at ordinary low water had been attained. In 1882, the channel was further deepened to 25 feet at low-water, and in 1883, the Harbour Commissioners began to increase the depth to 27½ feet, which has now been completed. Between 1851 and 1882 upwards of eight millions of cubic yards had been dredged from the channel, at a total expenditure of 1,780,130 dollars, including 534,809 dollars for dredging plant. Vessels of 4000 tons can now go up the St. Lawrence to Montreal. The people of the latter city, as already indicated, mean to compete with New York for the European trade.

The inland canal and lake system of Canada, together with the United States Canals at the Sault St. Marie, have established an unbroken water communication, for vessels up to 1800 and 2000 tons (gross), from Duluth, at the western extremity of Lake Superior, to the Straits of Belle Isle, at the mouth of the St. Lawrence river—a distance of 2384 miles.

The difference in level between Lake Superior and the St. Lawrence, at Montreal, is about 600 feet, and fifty-five locks are required to overcome this, although the mileage of the eight canals is but seventy-one. The ordinary locks of the Canadian canals are 270 feet long, by 45 feet broad, and 14 feet on the sills, and the American locks at the Sault, as already mentioned, are 515 feet long, 80 feet wide, and 18 feet on the sills. These locks are all built specially wide, to accommodate the various classes of steamers and barges employed; for it has been remarked that although in England the trade is arranged to suit the boats, in America the boats must be built to suit the trade, and the locks accordingly.

CHAPTER XVII.

THE WATERWAYS OF SOUTH AND CENTRAL AMERICA.

"Whole rivers here forsake the fields below,
And, wondering at their height, through airy channels flow."
—*Addison.*

The Amazon.—Of the many navigable highways in South and Central America, the Amazon river is by far the most important. Nay, more, this river, which has a drainage area of 2,264,000 square miles, which has 10,000 miles of navigation for large boats, and which has a width of no less than four miles at a distance of 1000 miles from the sea, is in every respect the most extensive and remarkable river in the world.

The average depth of the Amazon river is 42 feet in the upper portion, and 312 feet near to its mouth. The influence of the tide is observable at a distance of 400 miles from the mouth of the river, the usual current of which is about three miles per hour. The flood rise is from 42 to 48 feet above the lowest level. At a distance of 3000 miles from its mouth the Amazon is only 210 feet above sea level. Reclus has estimated the average discharge of the river to be 2,458,026 cubic feet per second.*

The Magdalena River.—The river in Columbia known by the name of the Magdalena has its rise in the Lagunas de las Papas (Potato Lake), and is one of the boundary lines of six of the nine States into which Columbia is divided. The river runs nearly due north from its source until it empties into the Carribean Sea in latitude 10° 59′ north, and 70° 58′ west longitude. The length of the river, measured on a meridian, would be 569 miles, but according to the best information available the actual length of the stream is about 900 miles. The Boca de Ceniza is the only mouth of the stream open to navigation, the depth of water on the bar here varying from 10 to 20 feet. It has been proposed to construct jetties at the mouth, so that it would be navigable to the largest ships

* Van Nostrand's 'Magazine,' vol. xxiv. p. 66.

frequenting this part of the world. A channel of 40 to 60 feet in depth can be found for a distance of about 20 miles inside the bar.

Natural obstacles have compelled the navigation of the river to be divided into five different systems—the first, rafts and canoes from Bateas to Neiva; the second, steamboats, barges, rafts, and canoes from Neiva to La Noria; the third, steamboats, barges, and canoes from Caracoli to Barranquilla; and the fourth, barges, sailing ships, and small ocean steamers from Barranquilla to the ocean.

It was not until 1847 that a really successful attempt was made to navigate the Magdalena by steam. Between that year and 1852 four steamers, of American build, were placed on the river. Now there are twenty-seven steamers regularly employed, besides a fleet of barges.

The natural obstacles to navigation at the bar of the river have led the Government of Columbia at different times to expend considerable sums of money in trying to open a canal from the river at Calawar to Carthagena, known as the Dique. The project has not, however, been very successful. The distance of this route is about 90 miles, and, although the four steamers employed upon it by the Dique Company have been tolerably successful, a large expenditure is said to be still required to complete the means of transport. As it is, the Government have dredges constantly at work on this artificial waterway. The Government are, moreover, canalising the river throughout its entire length, the cost being defrayed by charges on the traffic, which is steadily increasing.*

The *Desague Real de Huchuetoca.*—This is a vast drain or cut that has been carried through the Cordilleras, that surround the Valley of Tenochillan, or Mexico, at Nochistongo, for the purpose of getting rid of the dreadful inundations which almost periodically came upon the city of Mexico. The Section of the Desague, for a considerable distance, is from 1800 to 3000 square metres (19,365 to 32,275 sq. feet). Its length from Vertideres to the Salts is 20,585 metres, or 67,535 feet. Near the old well of Don Juan Garcia, at the point where the ridge is highest, the cut in the mountain extends for a length of more than 2624 feet, to between 147 and 196 feet in perpendicular depth. For a length of over 3000 feet more, the depth of the cut is from 98 to 131 feet. Over a great part of the cut, however, the breadth is said to be by no

* Further details as to the navigation and traffic on the Magdalena may be found in the U.S. Consular Reports, No. 47, 1884, pp. 334–348.

means in proportion to its depth, so that the sides are much too steep and are every now and again falling in.

The *Desague* was constructed between 1607 and 1650, and with its dykes and two canals leading from the upper lakes, is stated to have cost 31,000,000 of livres, or 1,291,770*l.* According to Humboldt, however, 25,000,000 of livres "were expended because they never had the courage to follow the same plan, and because they kept hesitating for two centuries between the Indian system of dykes and that of canals—between the subterraneous gallery and the open cut through the mountain. Humboldt adds that "they neglected to finish the cut of Nochistongo, while they were disputing about the project of a canal of Tezaico, which was never executed." The meaning of Humboldt's reference to the cost of this undertaking is rather obscure. One writer has pointed out that if he means that the necessary cost of the work was only 6,000,000 livres, or 250,000*l.*, there falls to be deducted from this amount the cost of two other canals—those of Zampango and San Christobal, begun in 1796 and 1798—amounting to 41,670*l.* more.* This, however, is not at all likely to be Humboldt's meaning, since he elsewhere speaks of the *Desague* as "undoubtedly one of the most gigantic operations ever executed by man," and looks upon it with "a species of admiration, particularly when we consider the nature of the ground, and the enormous breadth, depth, and length of the aperture." The magnitude of the undertaking may be appreciated by the fact, mentioned also by Humboldt, that if the *Desague* were filled with water to the depth of 10 metres (32 feet), the largest vessels of war could pass through the range of mountains which bound the plain of Mexico to the north-east.

Of the other rivers in South and Central America none call for any special description. Few of them are navigable for any distance, being—like the Chagres river, which traverses the Isthmus of Panama, or the San Juan river, that is to be utilised for the Nicaraguan canal—too rapid, tortuous and subject to floods, to be convenient for purposes of navigation. In course of time, however, as wealth and population increases, we may naturally look for the artificial improvement of such waterways with a view to their adaptation for purposes of commerce, as in the European rivers already referred to.

* Pitman's succinct view and analysis of authentic information extant in original works, on the practicability of joining the Atlantic and Pacific Oceans by a ship canal across the Isthmus of America. London, 1825.

CHAPTER XVIII.

CHINESE WATERWAYS.

"But if, with bays and dams, they strive to force
His channel to a new or narrow course,
No longer then within his banks he dwells,
First to a torrent, then a deluge swells."—*Denham.*

THE most remarkable canal in the world is, in many respects, the Grand Canal of China. It is also, probably, the canal of all others of which the least is known. The fullest account hitherto extant, relative to this waterway, is that published by Marco Polo, and therefore dates as far back as the thirteenth century.* Several writers state that the Grand Canal of China was constructed in the tenth century, and Priestley—who does not, however, quote the source of his information—declares that it was completed in the year 980. Seeing, however, that Polo, writing from Tartary in 1278, speaks as if the canal were then in course of construction, this is hardly likely to be correct. "You must understand," he says, "that the Emperor has caused a water communication to be made from this city (Kwachan) to Camboluc, in the hope of a wide and deep channel, dug between stream and stream, between lake and lake, forming, as it were, a great river on which large vessels can ply." Polo is confirmed by other writers, and Dr. Williams, in one of the most recent and reliable works on China,† states that "the canal was designed by Kublai to reach from his own capital as far as Hangchau, the former capital of the Sung dynasty." This, again, seems to be at

* Marco Polo spent seventeen years at the court of Kublai, the great Khan of the Tartars. The first edition of his travels appeared in 1496, and the work has been translated into several languages. He gave a better description of China than had previously been written, and although much of what he wrote was at the time doubted, his narratives have been largely verified by subsequent travellers. Colonel Yule has published an admirable edition of Polo's travels for English readers.

† 'The Middle Kingdom,' vol. i. p. 31.

variance with the testimony of Pére Mailla,* who, writing in the last century, declared that he and his brother Jesuits gazed with astonishment and admiration at the chasms which the Emperor Yu caused to be cut through solid mountains for the waters of the Yellow River.† If this does not refer to the Grand Canal, it may be presumed, as a writer in the 'Encyclopædia Britannica' has pointed out,‡ that it was the water itself and not the Emperor Yu that opened these channels. The date of the construction of the Grand Canal of China is thus, like many other matters pertaining to the history of that country, involved in obscurity. But no such uncertainty hangs over its extent and importance. The canal is nearly 700 miles in length, and reaches from Hang-choo-foo to Yan-liang river, having connections with the rivers Yang-tse-kiang and Ho-hang-ho, or the Yellow River.§ Davis has given a description of the work,‖ from which it would appear that for some distance after the canal joins the Yu-ho, on its eastern bank, as that river flows towards the Peiho, it evidently follows the bed of a natural river. Its course is winding, and its banks are irregular and inartificial. It has, however, stone abutments and flood-gates for the purpose of regulating its waters. The distance between the stone piers in some of the flood-gates is often very narrow. The course of the water through these gates is arrested in rather a primitive fashion. Stout boards, with ropes fastened to each end, are let down edgeways over each other, through grooves in the stone piers. A number of soldiers and workmen always attend at the sluices, and shield the boats from danger by letting down coils of rope, in the same way as a ship's "fender," to break the force of the blows. The highest point of the canal appears to be at the influx of the Yun-ho, which enters the canal on its eastern side nearly at right angles, while part of its waters flow north and part south. At this point, where a strong facing of stone on the western bank sustains the force of the influx, there is an interesting

* Mailla was despatched by the Jesuits in 1703 on a mission into the interior of China, and had a good opportunity of knowing the country, where he lived for forty-five years, and of which he was employed by the emperor to construct a map.

† 'Histoire générale de la Chine, ou Annales de cet Empire, traduite du Tong-Kien-Kang-Mou.' 13 vols.

‡ 8th edition, art. "China."

§ The Ho-hang-ho, or Yellow River, sometimes described as "China's sorrow," is about 2000 miles in length, and its periodical overflowings cause frequent damage to the canal.

‖ 'Sketches of China,' vol. i. p. 245.

temple, erected to the Dragon King, or genius of the watery element, who is supposed to have the canal in his special keeping. The work of joining the Yun-ho, and the Grand Canal is attributed to Sung Li, who lived under Hungwa, the first Emperor of the Ming dynasty, about 1375. It was accomplished in this wise. A part of the canal in Shantung became so impassable in the time of Sung Li, that the roundabout coasting passage by sea had to be resorted to. An old man, named Piying, thereupon proposed to Sung a scheme for the concentration of the waters on the Yun-ho and neighbouring streams and their diversion into the canal, as at present. It is said that Sung employed 300,000 men to carry out the work, and that it was completed in seven months; but the Chinese historians are not, unfortunately, the most veracious.

For a great part of its route the Grand Canal runs through a level and marshy district. In some places, indeed, the canal becomes merged in the lakes and swamps which surround it. In other places, however, where there appears to be a special risk of inundation, the banks of the canal are well faced with stone. The canal, before leaving the lakes in the southern part of Shanting, used to run nearly parallel with that stream for more than a hundred miles, and between it and the New Salt River for a great part of that distance. This river, formerly described as one well adapted for navigation, has now become completely silted up, and at Kiafung the difference of level is so trifling that the siltage there has been enough to turn the current into the river Wei and elsewhere. At the opening of the canal there is a sluice nearly 100 yards across, through which the water is said to rush into the river like a mill-race. There is, however, a makeshift sort of appearance about the canal works generally. The banks are in many places constructed of earth, strengthened with sorghum stalks and strongly bound with cordage; and Davis, in speaking of the attempt made to repair the damage caused by the inundation of the Yellow River in this way, remarks very justly that if the science of a Brunel * could be allowed to operate on the Yellow River and Grand Canal, "a benefit might be conferred on the Chinese that would more than compensate for all the evil we have inflicted with our opium and our guns."

At about 70 miles from its mouth the Grand Canal reaches the

* Brunel, by the way, was not specially identified with canal construction. Perhaps the writer means Brindley. Brunel had, however, no doubt sufficient knowledge of his art to serve the purpose in view.

Yellow River, and between the Yellow and Yantsz' rivers, a distance of 90 miles, it is carried largely upon a raised work of earth, kept together by retaining walls of stone, which are in some places not less than 20 feet above the surrounding country. The width of the channel at this point is about 200 feet, and the current is stated to be three miles an hour. South of the Hwang-ho there are several large towns below the level of these walls, which would be overwhelmed with destruction if they were to give way. From these towns—the principal being Hwai-ngang and Pauying—the canal falls to the Yantsz', and at Yangchan its level is again below that of the houses on either side. Every stream or lake whose waters can be led into it has a connection with the canal, which has several inlets into the great river Yantsz', whence navigation is possible for a distance of 2900 miles. East of Chin Kiang the canal leaves the Yantsz', and proceeds through a rich and fertile country, highly cultivated, and supporting an enormous population, Suchan and Hangchan being among the principal towns on its banks.

The northern end of the canal is a channel, 14 miles in length, between Tung-chan and Pekin, which, passing under the city walls, finishes its course of some 600 miles at the palace walls, close by the British Legation. The section between Pekin and the Yellow River is said to have been opened by the Mongols about 1289, by merely joining the rivers and lakes to each other as they now exist. One of the old passages, from Hungtsih Lake northwards, has long been closed, but an attempt has been recently made to open it, so that boats can reach Tientsin from Kwachan.

In many works, some of them of considerable pretensions, a great deal more is claimed for this waterway than it really deserves. No doubt there was no work in the world equal to it when it was first opened, and probably in Asia it is still unrivalled. Dr. Williams is correct also in his statement that it reflects far more credit upon the monarchs who devised and executed it than the Great Wall.* But the whole structure is crude and primitive in a high degree, compared with more modern canals. Without efficient locks, the canal has to be conducted around the different elevations met with in its course. The boats that use the canal have to be dragged through and up the

* This enormous undertaking was, however, erected at least 1100 years before the Grand Canal, having been finished B.C. 204. Its entire length is 1255 miles in a straight line, and it was ten years in building.

sluices close to the banks, by large windlasses, whereby they are brought into still water by a very tedious process.

The canal is largely used for passenger traffic, but the rate of progress seldom exceeds 25 to 30 miles a day, and is often under 20. The greater part of the work has been expended in the simple labour of constructing embankments, and not, as in the case of the Panama and Suez Canals, in digging a deep channel. The rudiments, if not the complete essentials, of this waterway were already available when the Mongols joined the rivers and lakes to each other by means of the canal; but it is creditable to the successive dynasties that have ruled over China, and especially to the Ming and Tsing emperors, that they have always kept the waterway open and in tolerable repair.

Mr. William Chapman, in his 'Obervations on the various systems of Canal Navigation,' states that the "grand canal of China is in fact only a river or stream navigation, although greatly diverted by art from its ancient course in some parts; the current of the water being slow, and prevented from running off too rapidly by its descent being occasionally checked by flood gates, consisting of two abutments of stone, one projecting from each bank, and leaving a space in the middle just wide enough to admit a passage for the largest vessels employed upon the canal. To prevent unnecessary waste of water through the flood gates, the passages are occasionally closed by planks let down transversely and separately, one above the other, their ends resting in a vertical groove in each abutment." The same author has observed that it was probably between the years of the Christian era 605 and 618 that these were introduced. Again, he says:—"The Chinese method of overcoming ascents appears to be long subsequent to the attempts of the Egyptians, under the successors of Alexander, who, according to Mons. Huet, Bishop of Avranches, had the art of constructing sluices, or locks of one set of gates, so as to stop the impetuosity of the current, and be occasionally opened. Though termed gates, the openings were most probably closed with beams of timber, let down in grooves, as gates of large width and depth could not be opened without difficulty."

There are many subsidiary canals in China. In a country that has no railways and very few roads, water transport is of much more importance than in any European State. Canals have been cut from the Grand Canal in every direction, and are largely used.

CHAPTER XIX.

THE WATERWAYS OF BRITISH INDIA.

"Flies tow'rd the springs
Of Ganges or Hydaspes."—*Milton.*

It has long been a contested point between different sections of the officials charged with the government of India whether canals or railways were likely to provide the cheapest and the most suitable means of communication for that extensive country. The enormous area of British India, the generally level character of the immense plains that form so prominent a feature of her physical conformation, the generally slow pace at which everything is carried on, and the comparatively little importance that is attached to a high rate of speed, all seemed to mark out the Indian possessions of the British Crown as extremely favourable for the construction of an extensive system of artificial waterways adapted to the twin purposes of irrigation and navigation. Sir Arthur Cotton has even advocated the summary and indefinite suspension of nearly all railway schemes and works, in order that the attention of the Government might be concentrated upon canals, mainly for irrigation, but also adapted for purposes of navigation.* Irrigation is, indeed, one of the absolutely indispensable requirements of the country, and the State has expended many millions for this purpose. But the work has been carried out, for the most part, for agricultural purposes alone, and it was not discovered until too late that a valuable source of power and economy was lost in not, at the same time, adapting them for navigation purposes.† In some of the later canals this oversight has been repaired. In the great deltas most of the principal irrigation canals recently constructed have been adapted for navigation, as well as some of the larger canals in the North-western Provinces and the Punjaub. In the Madras Presidency, again, there is a system, com-

* Report from the Select Committee on East India (Public Works), 1879, p. xiv.

† Evidence of Sir Bartle Frere before the Select Committee on Canals, 1883, p. 159.

mencing with the Buckingham Canal, at the town of Sadras, and continuing along the Delta Canal and by the Kistna and Godavery lines, which affords 456 miles of unbroken water communication.* This canal, however, is, like the railway system of India, exposed to the serious disadvantage of a broken gauge.

The locks on this system are all of the same dimensions, viz. 150 feet long by 20 feet broad, with a minimum of 5 feet on the sills of the lower gate. That portion of it which is dependent on a tidal supply consists of level reaches, with only one lock, near Madras. When it leaves the coast, there is an ascent of about 50 feet to be overcome to the Kistna, a difference of about 20 feet between the low-water levels of the Kistna and Godavery, and a descent from the latter of 35 feet to the port of Cocanada.

In the Tida Section near Madras the surface width of the canal is 60 feet, and there is a minimum depth of 4½ feet. The tonnage of the boats plying on the Buckingham Canal was, in 1882, registered at 10,215 tons, and the receipts, consisting of licence fees and tolls, amounted to 12,000*l.*, showing an increase of 1000*l.* over the previous year. In the fresh-water reaches, the width varies from 120 to 60 feet, with an average depth of 6 feet, and a current varying from ½ to 1¼ mile per hour. Every variety of boat is to be found on this canal. ranging from 3 to 80 tons.

In the Delta canals there is a large number of passenger boats, built on improved English models, but the majority of the craft are built on native lines, clumsy in appearance, but good cargo carriers notwithstanding, and almost all are decked. The haulage is almost entirely carried on by men; no cattle are used. On the Godavery and Kistna, small steamers have run in connection with the Government works, but, practically, no steam towing, though practised on the river itself, has as yet been used on the canals.

The cost of traction cannot be accurately stated; but, as far as General Rundall could make out from independent inquiries, the cost of working native boats is about one-eighth of a penny per ton-mile; the charge varies with the demand and the description of cargo.

The carriage of material for the Government Works used to be contracted for at three-eighths of a penny per ton mile, and the charge made to native merchants was probably about the same; but to European traders it was higher.

There is no other purely navigation canal in the Madras Presi-

* Report made by General Rundall, to the Select Committee on Canals, p. 280.

dency, but there is a considerable boat traffic carried on in the lagoons on the western coast.

The Godavery Delta is composed of three principal tracts. A main canal is led off from the river to each tract, and from it are thrown off several main branches, most of which are fitted with locks.

The lines which skirt the edge of the Delta are carried with a very small slope, and therefore require no locks, except at the terminus, where, on one side (the right bank), the canal is connected with a similar line led from the Kistna, and on the left bank, at a distance of 30 miles, it is connected with the port of Cocanada by a short junction canal, in which are built the locks necessary to overcome the difference of level, about 30 feet above the sea, All the main lines are dropped into the tidal reaches of the respective branches of the Godavery, and are in this manner connected with one another.

The total length of navigable canals, exclusive of the tidal portions of the river, and the various salt-water creeks permeating the lower part of the Delta, extends for between 458 and 502 miles.

The canals are open to any carriers. Tolls are not levied generally, but only on unlicensed boats, as the water rates derived from irrigation yield a large return on the capital expenditure.

The majority of boats pay the small registration fee which is exacted in preference to tolls.

				s.
The fees on cargo boats, per ton of 50 cubic feet, were			..	4
,,	passenger boats, 1st class	,,	.. ..	8
,,	,, 2nd class	,,	.. ..	6

These rates were increased from January 1882 to:—

Cargo boats, per ton of 75 cubic feet		.. ..	7
Passenger boats, 1st class	,,	.. ..	14
,, 2nd class	,,	.. ..	10

These fees free boats over the whole system of canals during the calendar year. Unlicensed boats pay 6*d.* per ton for a single trip. The charge for third-class passengers on boats is one-eighth of a penny per mile.

Between the river Tumbaddra and the river Pennar there is a large canal, which was originally constructed by the Madras Irrigation Company, and, although intended primarily for an irrigation line, was fitted with locks, in order to enable it to be used for navigation. This canal is, however, only available for about eight months of the year, as the water supply in the river has to be passed on for use in the Kistna Delta.

The Ganges and the Brahmapootra are connected with the Hoogly by means of a number of creeks, which are really natural canals, and are connected by two artificial canals: the first called the Circular, or Baliaghatta Canal, and the other Tolly's Nullah.

The Calcutta Canal route for boats extends eastward for about 115 miles to Khoohia, the capital of the Sunderbunds, and is situated at the junction of the rivers named the Atharabanka and Bhoyrab, respectively. The former is an offshoot of the Madhumatti, down which comes all the produce from the north; the latter carries all that which comes from Backergunge on the eastward. The total number of laden boats registered on the canals in 1874 was 77,096, and the total tonnage of all the cargoes imported into Calcutta by the Sunderbunds route was 521,000 tons.

A large traffic is carried on along the three branches from the Ganges known as the Nuddeah rivers into Calcutta. In the years 1873–74 the total number of boats passing up and down was 32,887 and 27,242, conveying 378,200 and 323,000 tons respectively, of which over two-thirds was down traffic. The first canals met with in the Bengal series, other than the purely navigation lines, are those comprised in the Orissa Scheme. They are divided into three sections. The largest are those constructed in Orissa proper, the navigated portion measuring 162 miles, but when fully completed this system will extend to about 500 miles. There is a canal from Midnapore to Calcutta 70 miles in length, of which 53 miles are artificial, and the remainder follows the course of the Hoogly river. A canal about 30 miles in length has been cut at Hidgedee, in order to enable boats to escape the dangers of the lower reaches of the Hoogly. This canal is to be continued until it enables water communication to be established for the 250 miles that separate Calcutta and Cuttack. The canal varies from 120 to 60 feet, with a minimum depth of 6 feet, while the head locks and those on the main line are 150 feet by 20 feet. This canal cost 6200*l.* per mile, while the Orissa Canal is stated to have cost 3000*l.*, and the Midnapore Canal 4400*l.* per mile, attributable specially to navigation. In Bengal there is a system of canals connecting with the river Ganges, which passes through the province of South Behar. There are three principal branches in this system—named the Patna, the Arrah, and the Buxar—their total length being 217 miles. On this system there were 8613 boats in 1882, the aggregate tonnage of which was 88,657 tons. Navigation is carried on in the North-west Provinces and on the Upper and Lower Ganges Canal. The Agra Canal, which leaves the Jumna eight miles below Delhi, has also been adapted for navigation.

In the Presidency of Madras there are upwards of 53,000 tanks, or reservoirs for irrigation purposes alone, exclusive of small tanks near villages, all executed by the natives prior to the occupancy of the Deccan by the British. The aggregate length of the embankment of these reservoirs is fully 30,000 miles; bridges, culverts, sluices, &c., are more than 300,000 in number. The stored-up waters, sent forth at the proper season, still brings to the exchequer of the Madras Presidency a yearly income of a million and a half sterling (one-sixth of the whole revenue), although many of the finest of these reservoirs are in ruins, or useless from want of being properly kept up. One of them, the Ponairy Reservoir, in the district of Trichinopoly, has a superficial area of about 80 square miles, or say 50,000 acres; the banks are 30 miles in extent. Another, the Veranum Reservoir, has nearly 35 square miles of area, or upwards of 20,000 acres, and 10 miles of banks.

An expenditure of a considerable amount has been incurred for nearly half a century by the Government of the Madras Presidency in keeping open the existing narrow waterway through the rocky reef which connects the island of Ramisseram with the mainland of India. Even so, however, the navigation has been extremely unsatisfactory. The tide, when making southwards, heaps up the water at the northern entrance to the channel to such an extent that even full-powered steamers require to employ kedges and warps to surmount and pass it. The Madras Government, therefore, are favourable to a proposed new channel, which will at once relieve them of a serious outlay, provide greater security to navigation, and materially reduce the time now occupied in steaming between Ceylon and their own seaboard.

It has been proposed to increase the maritime facilities of India and Ceylon by cutting a canal through the island of Ramisseram, which at the present time excludes the possibility of ships drawing more than 12 feet of water from passing northward to the Bay of Bengal. For this reason ships proceeding to Madras or Calcutta have to steer to the east of Ceylon, which entails a voyage of 300 or 400 miles longer than would be required if the route by the Gulf of Manaar and the Palk Straits were open to them.

For some years previous to 1887 negotiations had been carried on between the parties promoting this canal and the Government of India, with a view of obtaining such concessions as were deemed necessary to the realisation of the scheme. Authority has been given to obtain land and cut the canal, and the aid of the Government has been promised towards obtaining from the railway companies in the south of India an extension of their system to the new port which it is proposed to establish at the Indian end of the canal.

The inland navigation of India is, however, chiefly carried on upon the great rivers—the Indus, the Ganges, the Brahmaputra. Taking the limit of the Ganges, and Jumna to the west and south, the Brahmaputra and Megna to the east, the country intersected by navigable rivers, &c., may be computed as covering an area exceeding 180,000 square miles.

There is an uninterrupted navigation of 1000 miles up the Indus from the sea to Lahore, which is situated on the Ravee, or Hydrastes, one of the most meandering of the five Punjab rivers or branches composing the Chenab. But, owing to the numerous shallows and sandbanks in some parts of the Indus, this extensive navigation can only be said to be open to the flat-bottomed boats of the country, which draw about four feet of water. There are, however, few rivers on which steam could be used with better effect than on the Indus, which is said to discharge four or five times as much water as the Ganges. It has no rocks nor rapids, and, unless when swollen, the current does not exceed 2½ miles an hour. The swell commences about the end of April, increases till July, and disappears altogether in September.

There are many canals connected with the Indus, but they are principally for the purpose of irrigation, and the greater part of them, being mostly natural creeks, have no water except during the swollen state of the river. Such canals intersect the Delta, and are likewise pretty numerous between the latitudes of 26° 20′ and 28°, particularly on the west side of the river; but the most ancient artificial canals connected with this river seem to belong to the Punjab district.

By means of the Ganges and its subsidiary streams all sorts of articles can be conveyed between the sea and the north-west portions of Hindustan over a distance of more than 1000 miles. The commercial capital, Calcutta, upon the Hoogly branch of the Ganges, is favourably situated for internal navigation. It is about 100 miles from the sea, and 130 from the Sandheads; but it has a very intricate and tedious navigation through the banks of sand and mud, which occasionally shift their beds in the Hoogly River, as well as in the other branches of the Ganges. The Nuddeah rivers, which connect the Ganges with the Hoogly, are likewise, for eight months in the year, so extremely shallow, that the water communication between Calcutta and the upper country is, during that time, maintained by the Sunderbund passages at a great expense of time and labour. To obviate this inconvenience, it has been proposed to construct a canal which, branching off from the Ganges at Rajamahl, shall join the Hoogly at Mirzapore near Kulna; for, owing to the difference of level at the extremities, amounting to 60 feet, and the height of the Ganges itself, varying 30 feet at different seasons, an open cut without locks would not suffice. The intended route, besides being 300 miles shorter than the present route, would traverse a country rich in iron-ore and limestone, and would pass near to extensive coalfields.

Among other works of the kind carried out in India during the present century may be named a canal to unite the Damrah and Churamunee; the re-opening of Feroze Shah's canal in Delhi; the restoration of Zabita Kahn's canal in the Upper Dooab; the course of Ali Murdher's canal drawn into Delhi; a new cut from the Votary Nullah; a canal at Chumnapore. A canal of 70 miles has been executed in the King of Oude's dominions, between the Ganges and its tributary the Goomty. There are several canals in Agra, but they are chiefly used for irrigation, some of them being of considerable antiquity.

South Malabar, and nearly all Travancore, are naturally provided near their coasts with a system of inland navigation called the Backwater, which extends from Chowghaut in Malabar on the north, to Trivanderam, the capital of Travancore, within 50 miles of Cape Comorin, on the south, a distance of 170 or 180 miles. A continuation of it is navigable 90 miles farther for small boats during the rains, from Chowghaut to Cotah, 16 miles south of Tellicherry. The Backwater runs nearly parallel to the sea-shore, sometimes at a distance of a few hundred yards, and at other times of three or four miles. Its breadth varies from 200 yards to 12 or 14 miles; its depth from many fathoms to a few feet. Into this Backwater all the numerous rivers flowing from the Western Ghauts are discharged and retained. The Backwater empties itself into the sea by six mouths; of which the only one navigable for ships is the mouth on the south bank of which is situated Cochin. There is a bar at this mouth, but on it there are 17 or 18 feet of water at spring tides.

In May 1871 an influential deputation waited on the Duke of Argyll, when that nobleman was Secretary for India, to urge the making of a new ship canal through the narrow neck of land projecting from the continent of India, which separates the Gulf of Manaar from the Palk Straits. At the close of the discussion, his Grace frankly admitted that if the statements made by the several members of the deputation were correct, which he did not doubt, and if the work could be executed at the cost estimated, or anything near it, it would doubtless be worthy of adoption, and he, therefore, would address the Indian Government with the view of obtaining an official estimate, and then give his best consideration to the subject. The project has not yet, however, been carried out.

SECTION II.

SHIP CANALS.

CHAPTER XX.

THE SUEZ CANAL.

"Let the wide world his praises sing
Where Tagus and Euphratus spring,
And from the Danube's frosty banks to those
Where, from an unknown head, great Nilus flows."
—*Roscommon.*

THE greatest artificial waterway constructed up to the present time has been the Suez Canal. Longer canals have been made both in Europe and in the United States, but no canal hitherto completed has been built of the same large dimensions, nor has any other canal cost so considerable a sum of money. It is not too much to say that no other waterway has been more important to commerce, nor has any other been attended with the same momentous and permanent political consequences. It is satisfactory to be able to add that few waterways of modern times have been so successful from a financial point of view.

The story of the Suez Canal has been often told. It has always, however, lacked completeness, which indeed is impossible of attainment in reference to an undertaking that is making history at the same rapid rate that this has done, and is still doing.

It is remarkable that some of the earliest canals of which we have any record were constructed between Suez and the Nile during the existence of the eighteenth dynasty (about fifteen centuries before Christ). But the communication thus opened was not apparently found of much service, seeing that the canals were allowed to fill up and fall into such decay as to compel their abandonment.* Another

* The immediate cause of this occurrence does not appear, but it is obvious that there would not be much employment for a canal at this early date. The first ship would no doubt be constructed anterior to this period, but the vessels of that day were rude and small.

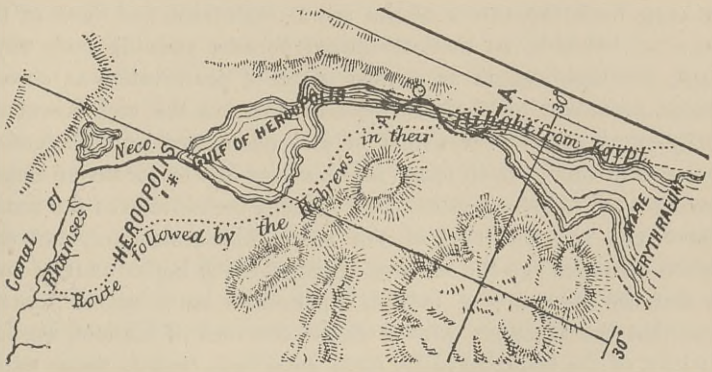
canal, probably over the same route, was opened some centuries later by Pharaoh Necho, with a view to facilitating the communication between Assyria and Egypt, which was then frequent and considerable. This canal was open, and in regular use, during the reign of Darius.

Ptolemy Philadelphus, finding the waterway neglected, reopened and completed it from the Pelusiæ, or Eastern Branch of the Nile, near Bubastes, to Arsinoe, on the Red Sea. This canal is stated by Strabo to have been 50 yards wide and 1000 stadia in length. The Romans, to whom this highway was known as the Trajanus Amnis, improved and widened it. At a later period the Arabs, after conquering Egypt, developed the canal for the purpose of carrying grain from Egypt to the holy cities of Mecca and Medinàh, and it was so employed for a century and a quarter.

It has been contended, as an argument against the Suez canal, that if it were practicable to keep open a great waterway between the two oceans, the canal which passed through so many vicissitudes would not have been allowed again and again to become obliterated, nor would cargoes have been discharged at Myos Hormos, the great port at the entrance to the Gulf of Suez, and carried overland to the Nile, a distance of some 80 miles, at a time when the canal appears to have been available, if it had been entirely satisfactory. But there are several considerations entering into the question of transport at that time that cannot be very readily appreciated now. The camel was then the ship of the desert to a much greater extent than it has been in more modern times. The knowledge of navigation was far from perfect, and the dangers of the Red Sea, which are now trifling, were then deemed so formidable that vessels discharged their cargoes in the harbour of Massowah, whence they were sent 1500 miles across the desert on the backs of camels, rather than face the Red Sea route *viâ* Suez, although, as the canal was then open, a vessel from the east might have made use of it and reached Alexandria or Ostia without breaking bulk. To our own times, and in the light of our fuller knowledge, this seems to be little short of incredible. Many centuries later than the time of which we write, St. Jerome, in speaking of the Red Sea, declared that mariners who had been six months at sea deemed themselves fortunate if they had traversed its full length, and reached a port of safety.*

* The Red Sea is 1500 miles in length, and, besides being narrowed in its middle channel, is so deep that there is hardly any place where a vessel can

The first recorded attempt at the construction of a canal was made in this very region, Neco, the son of Psammiticus, having connected the Gulf of Heroopolis with the Pelusiac branch of the Nile at Bubastis (Zigazig).* The narrow channel which here connected the Gulf of Heroopolis with the Red Sea, appears to have been closed by an upheaval of the soil. At the southern end of the gulf (Bitter Lakes) goods were landed and carried onward to the Red Sea. Darius subsequently dug a canal along the line of the ancient junction of the Gulf of Heroopolis with the Red Sea, as shown oin the annexed sketch by the letters A A. This canal, which was also called the canal of the Pharaohs and of Trajan, is understood to have finally disappeared in the eighth century.



THE CANAL OF RAMESES.

The last attempt at a passage from the Red Sea to the Nile was made by Amru ibn el Aas, the general of the Caliph Omar, who conquered Egypt in the seventh century. A great famine reigning in Mecca, Amru was ordered to take measures for forwarding thenceforth grain from Egypt by the quickest route. "He dug a canal of communication from the Nile to the Red Sea, a distance of 80 miles, by which provisions might be conveyed to the Arabian shores. This canal had been commenced by Trajan, the Roman

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anchor. Sailing vessels have to contend with currents that are blowing steadily to the northward for a great part of the year, while for some months there is little or no wind.

* Herodotus, book ii., secs. 159 and 160, Cary's translation.

emperor,"* who, the Pelusiac arm of the Nile being no longer navigable, joined his canal to the river at Cairo, instead of Bubastis or Zagazig. This occurred in the year of the great mortality A.D. 639, and in 767 the Caliph Abou Giaffar el Mansour, to prevent food being sent to the insurgents of Medina, caused the canal to be destroyed by filling up the junction of Neco's canal and the Bitter Lakes. The winds and the sands completed the work, and produced the ridge of Serapeum, which is believed by some to cover the site of the ancient city of Heroopolis.

The engineers of Ptolemy II. advised him not to cut a canal across the isthmus, because the land, being lower than the level of the Red Sea, would be laid under water; but that prince turned the difficulty by causing flood-gates to be erected at proper points, in order to keep back the waters of the sea at high tides, and those of the canal at low ebb, so that navigation became possible both ways. Now, this opening, in as perfect state of preservation at certain places, according to M. de Lesseps, as it was in the eighth century, really forms part, to the extent of four kilometres, near Shaloof, of the present canal, which opens into the Red Sea by means of sluices having a fall of three metres (9 feet), being the altitude of the mouth above the average level of the sea. This seems to prove that eleven centuries ago the sea was about as much higher as it is now, so that the isthmus has, indeed, experienced an upheaval. At the time that the Hebrews quitted Egypt the rock of Shaloof, the last offshoot of the Geneffay Hills, must have been entirely under water. When, by the gradual rising of the land, the top of this rock emerged from the water, it became covered with an accumulation of earthy or sandy matter, brought by wind and tide, until a barrier was formed which could only be swept over at high water. The lakes were consequently precluded from experiencing any ebb or flow. The slow upheaval of the soil continuing, the *terra firma* of Shaloof assumed a permanent shape, and the requirements of navigation led to the idea of cutting a canal. Herodotus speaks of it as having been open in his time: this fixes its date at 450 years B.C. It was repaired under the Ptolemies, improved during the Roman domination by a supply of water from Cairo, dredged by the Caliph Omar in the seventh century, and abandoned to decay in the eighth.

From this period, to the beginning of the present century, save for half-hearted projects of the Venetians, and, later, of the Porte

* Washington Irving's 'Successors of Mahomet.'

itself, we hear no more of the question till Napoleon invaded Egypt, and ordered an immediate survey of the isthmus with a view to the establishment of a maritime canal.* Napoleon was himself no mean engineer, and he employed on this work a man who seems to have possessed a remarkable grasp of the problem presented for solution, but who, nevertheless, shared the then common impression that the Red Sea was at a higher level than the Mediteranean, and that to join the waters of the two seas would be to submerge a great part of the country. This man was M. Lépère. He made a survey of the route between the two seas, and declared that he had found the Red Sea to be 30 feet above the Mediterranean.†

When Napoleon Buonaparte, at the time of the French expedition to Egypt, ordered a complete survey to be made of the isthmus between the Mediterranean and the Red Sea by M. Lépère, the latter proposed that vessels should ascend the Nile to Bubastis, and pass by a canal, 18 feet deep and 77 miles long, to the basin of the Bitter Lakes. Thence, a second canal, 13 miles in length, was to lead to the Red Sea. The cost of this undertaking was calculated at 691,000*l.*, but additional works in the mouth and bed of the Nile, and the restoration of the canals of Faroumah, Chebri-el-Koum, and Alexandria, was estimated to raise the cost to 1,200,000*l.* Surveys of the country were afterwards made by Captain Chesney, in 1830, and by Mr. Robert Stephenson in 1847, with a view to the opening up of a waterway between the two seas. Captain Chesney reported on the Isthmus of Suez as offering great facilities for the construction of a canal. "There are," he said, "no serious difficulties; not a mountain intervenes, scarcely what deserves to be called a hillock." Stephenson, however, who personally examined the ground, considered that any canal made across the isthmus should be provided with locks, as the absence of current would otherwise allow of silting. Admiral Spratt, ten years later, came to the same conclusion as Stephenson, but both were opposed by M. de Lesseps, who, in his final plan, resolved upon a dead level canal for the whole distance of 103 miles.

The plan ultimately adopted has no doubt been the most advantageous to commerce, inasmuch as it has facilitated the time and labour involved in passing vessels through the canal. It has, how-

* Rubino's "Statistical Story of the Suez Canal," in the 'Journal' of the Royal Statistical Society for 1887.

† 'Mémoire sur le Canal des deux Mers.'

ever, necessitated a considerable annual outlay for dredging. Nearly two millions of cubic yards of material have had to be removed in a single year from the bed of the canal, in order to maintain the requisite depth.

In advocating his plan for the construction of a canal across the Isthmus of Suez, M. de Lesseps calculated that in 1851 the value of the commerce with countries to the east of Egypt was a hundred millions sterling, and the tonnage employed in its transport was four millions of tons.* This figure he raised in 1855 to sixteen millions of tons; but he was content to adopt six millions as the tonnage that would represent the Eastern trade, of which he reckoned that one-half would make use of the canal. These were described by the 'Quarterly Review' as "preposterous speculations," and figures were quoted from the 'Revue des deux Mondes' to prove their fallacy. In the latter periodical, M. Baude had calculated the total trade with the East at that time (1850–53) at 1¾ millions, and M. Dupontès at two millions of tons. The calculations of M. de Lesseps do not seem to have been stated with much precision. There is no statement of the description of tonnage referred to, which is of very material importance. If gross tonnage was meant, then the estimate of M. de Lesseps was realised five years after the canal had been opened. If net tonnage, then it was not reached until 1880. In 1885, the gross tonnage was close on nine millions, and the net over 6½ millions.

In 1773, Mr. Volney walked over the country traversed by the present Suez Canal, for the purpose of endeavouring to reconcile the various opinions and reports made up to that time as to the practicability of constructing a ship canal across the isthmus. The conclusion come to by that engineer was that there would be a difficulty in preventing the silting up of the harbours, and that for that reason the scheme was a doubtful one.† M. de Lesseps himself appears, in 1855, to have repudiated the credit of being the author of the project, when he wrote to a friend a letter in which the following passage occurs:—

"Vous savez qui Linant-Bey est, de puis trente années en Egypt, et qu'il s'y occupe constamment de travaux de canalisation. Lorsque j'étais consul au Caire en 1830, c'est lui qui m'a initié à ses projets de

* 'Quarterly Review,' January 1856, p. 257.

† Since then, of course, this difficulty has been conquered by the use of steam dredgers.

l'ouverteure de l'Isthme de Suez, et qui a fait naître en moi ce violent désir que je n'ai jamais abandonné au milieu de toutes les vicissitudes de ma carrière de participer de tous mes moyens à la réalisation d'une ouvre aussi importante." *

The Suez Canal Company was incorporated in December 1858, with a capital of 8,000,000*l.*, divided into 40,000 shares of 20*l.* each. Interest at the rate of 5 per cent. per annum was to be paid to the shareholders during construction. A sinking-fund of $\frac{4}{100}$ per cent. was established, to be a first charge on the profits available for distribution.

Although the first sod of the canal was cut on the 25th April, 1859, it was two years before any real progress was made with the work of excavation. These years were not, however, unemployed. They were chiefly taken up with the work of preliminary preparation, which, on such a vast enterprise, was necessarily considerable. One of the most essential duties required to be undertaken was the construction of a fresh-water canal, for the purpose of supplying the wants of the vast number of labourers employed. Much of this labour was forced, or *corvée* labour, provided, under engagement, by the Egyptian Government. In 1864, however, after the works had been about four years in progress, the Egyptian Government claimed to withdraw the fellaheen, finding the supply of from 15,000 to 20,000 of the most able-bodied men in the country a serious tax on their resources. The difference between the company and the Government on this score was submitted to the arbitrament of the Emperor Napoleon, who awarded the company an indemnity of 1,520,000*l.*

In order to provide the ways and means for the prosecution of the work, and to fulfil concessions made to the company, the Egyptian Government made considerable sacrifices. It had given up its customs dues on the canal company's imports, its tolls on the fresh-water canal, its postal telegraph services, its fishery rights on the canal and lakes, the hospitals on the isthmus with their appurtenances, the quarries and port of Mex with their plant, the storehouses of Boulac and Damietta, and the right to half the proceeds of any of the lands on the maritime canal, which the company might offer for disposal. These rights the Egyptian Government recovered in 1869 on the payment of 1,200,000*l.*, represented by the coupons up to

* This letter is reproduced from an excellent article on the subject of the Suez Canal in *Engineering* of December 7, 1883, p. 52.

1894, on the 176,600 shares which it had acquired as an ordinary subscriber. The Egyptians have certainly not reaped the financial advantages from the canal which they ought to have done. They parted to England with their 176,600 shares (less the coupons to 1894) for something under four millions sterling. The value of these shares, deducting the detached coupons, is now close on ten millions. Again, in 1880 they sacrificed their royalties, which amounted to 15 per cent. on the net receipts of the company, to a French syndicate to cover a debt of 700,000*l.* In the seven following years, the syndicate received 1,212,025*l.* from this source, and it has been calculated that if the annual receipts of the canal never exceeded those of that period, the canal company would have paid in 1968 no less than fourteen millions sterling in respect of the advance of 700,000*l.*! Evidently the Egyptians did not know the value of the canal when they made this disastrous bargain, although the navigation receipts had increased from 228,750*l.* in 1870 to 1,599,700*l.* in 1880.*

For a number of years after it was fairly started the canal had to struggle with financial difficulties. The English had subscribed very little towards its completion, and the French appeared to have some doubts as to its ultimate success. M. de Lesseps then, as since, was full of enthusiasm as to the future of the enterprise, and predicted that it was to be an assured and notable success. Not so, however, his friends and allies. On the contrary, Prince Napoleon, in presiding at a banquet given to M. de Lesseps on the 11th February, 1864, declared that in his opinion "the canal would not be finished, the works would go to ruin, and nothing would be done." And then followed this remarkable prediction: "In fifteen or twenty years, when the Viceroy shall have shown his powerlessness, there will be some one all ready who will constitute a new company and make the canal. Do you know who it will be? It will be the influence, the capital, and the workmen of the English." Napoleon was partly right. Egypt found the greater part of the money required, but it is the shipowners of England who pay the dividends that enrich the owners of the canal, and enable M. de Lesseps and his friends to regard their triumph with so much complacency.

The Act of Concession for the construction of the Suez Canal was granted by the Viceroy, Said Pacha, to M. de Lesseps on the

* In 1886 the transit and navigation receipts were over 2,500,000*l.*

30th of November 1854, and was followed, on the 5th of January 1856, by a second Act, to which were annexed the Articles of Association of a company for working the concession. The charter thus granted to the Suez Canal Company gave it a ninety-nine years' lease (counting from the date of opening), to dig and work—

1. A maritime canal from sea to sea, with a northern port on the Mediterranean, and an inland port at Lake Timsah.

2. A freshwater canal from Cairo to Lake Timsah, with branches north and south supplying the two canal seaports.

For the carrying out of this undertaking the Government of Egypt granted the company :—

1. The lands necessary for the company's buildings, offices, and works on the canal, gratuitously, and free from taxation.

2. The lands, not private property, brought under cultivation by the construction of the fresh-water canal, gratuitously, and free from taxation for ten years.

3. The right to charge landowners for the use of the water of the fresh-water canal, which, on the other hand, it was bound to supply.

4. All mines found on the company's lands, and the right to extract from all State mines and quarries, free of cost, royalty, or tax, the stone, plaster, or other materials required for the construction of the canal and ports.

5. Freedom from duties on its imports.

It was provided that the canal and works were to be finished, save for unavoidable delays, within six years. Native labour was to be employed to the extent of four-fifths of the whole, a special convention settling the terms on which the Government supplied or authorised such labour. The tolls were fixed at 10 frs. per "ton of capacity" (an expression which gave rise to difficulties subsequently), and 10 frs. for each passenger.

A contract was made with M. Hardon for the execution of the works, under which the company were to receive 60 per cent. of the prices fixed by the original estimates of the International Commission. The drawing up of the plans, the general superintendence, and the supply of the machinery and stores, were, however, to be left in the hands of the company. This agreement was subsequently cancelled, and the company took the works under its own control, making contracts with four different firms, who undertook to complete the principal undertakings for a total sum of 4,588,800*l.** With these arrangements, the canal was fairly launched. From 1861 till 1869 the whole line of the canal was the busiest centre of industrial activity in Europe. The total amount of excavation required was 107 millions of cubic metres. This is a larger amount of digging than has been accomplished in the case of any other work on record.† The operations were required to be carried on at the same time with the fresh-water canal from Nefiche to Suez, and with the maritime canal from Suez to Port Said, so that two distinct undertakings were concurrently being constructed. Some details as to the annual progress of the works may here be suitably introduced.

In 1861, the works were chiefly confined to digging wells along the line of the maritime canal, to erecting sheds for 10,000 labourers, and providing dock basins, water condensers, forges and workshops, steam saw-mills, and opening a water supply by a canal which should join the Nile to Lake Timsah.

In 1862, the eastern mole at Port Said was begun, together with a landing stage 70 yards by 22, in 16 feet of water, and an arsenal dock

* The following are the details of the contracts for works on Suez Canal :—

Dussaud frères, Marseilles.	Aiton, Glasgow.	Couvreux, Paris.	Borel and Levalley, Paris.
20*th October*, 1863.	13*th January*, 1864.	1*st October*, 1863.	1*st April*, 1864.
250,000 blocks of artificial stone of 1 cubic metre each (35⅓ cubic feet), and weighing 20 tons, at 40 frs. each. 10,000,000 frs. 400,000*l.*	21,700,000 cubic metres of excavations at 1·35 fr. The plant ceded to the contractor by the company brings the price up to 1·60 fr. 34,720,000 frs. 1,388,800*l.* Contract afterwards cancelled, and transferred to Borel and Levalley.	9,000,000 cubic metres of excavations at 1·60 frs. 14,000,000 frs. 560,000*l.* Enlargement and deepening of the great El Guisr trench, over 8 miles long.	24,500,000 cubic metres of excavations at 2·28 frs. 56,000,000 frs. 2,240,000*l.* Continuation and completion of 53 miles of cutting from Lake Timsah to Red Sea. *Second contract.* Transfer of Aiton's contract.

† We do not, of course, include the Panama Canal, which is not, and may never be, completed.

160 yards by 135 and 5 feet depth. Seven Arab villages were built, and north of Lake Timsah, a sea-water cutting was continued from Kantara to El Ferdane. A large dredging plant ordered from various makers in England and France was delivered.

In 1863, four dredgers and cranes were got to work at Port Said, and south of Lake Timsah twenty-one dredgers were at work, and three others were nearly ready. Provision was made for adding twenty more dredgers, each estimated to be capable of raising 1,050,000 cubic feet per month. The fresh-water canal from Nefiche to Suez was begun, and 24 miles were finished. This canal was 64 feet at the water-line, 26 feet at the bottom, and had 6 feet draught of water. The excavations required were about 50 millions of cubic feet. On the north of Lake Timsah, 18,000 men were at work, digging a trench 50 feet by 4 to 6 feet deep, connecting the Mediterranean and Lake Timsah, and 153,600,000 cubic feet of excavation was done at 0·68 fr. per cubic metre, being within the original estimate, despite the heavy labour of carrying the earth up an incline of 70 feet. From Lake Timsah to Toussoum Plateau on the south, the canal was made 190 feet wide and 6 feet below the Mediterranean level, involving 21,200,000 cubic feet of excavation.

In 1864, 20 new dredgers, with barges and accessories, were fitted up, 43,000,000 cubic feet of excavation was done, from Port Said to El Ferdane, and 7,600,000 cubic feet between Timsah and Serapeum, as well as 4,500,000 cubic feet of gypsous stone along Lake Ballah. A large area of land was also reclaimed, in order to provide for new works, quays were extended, and the canal Cheikh Carponti, connecting Port Said with the lake and Damietta, was completed. The freshwater canal was also completed to the sea, over 55 miles, having occupied thirteen months, and involved 118,000,000 cubic feet of excavation. Corvées, or native forced labour, were abolished, and 7954 European labourers, with 10,806 others, were set to work.

In 1865 the general works of the Maritime Canal were extended.

In 1866 Messrs. Borel and Levalley got 32 trough dredgers at work along 35 miles of the canal, and the canal from Port Said to Timsah was widened to 325 feet, thus allowing of the formation of strands for the protection of banks from passing vessels, and economising the stone embankments. The Viceroy set 80,000 men to work at the canal from Cairo to Wady, so as to allow of the passage of the Nile waters at all seasons.

In 1867, 353,000,000 cubic feet of dredging was accomplished, and long trough dredgers were applied to the work between Port Said and Timsah, which was filled to sea level. The large lake to Chalouf, and the small lake to Suez, were excavated by hand labour. Of the contract of M. Couvreux to excavate 146,000,000 cubic feet, 122,500,000 cubic feet had been completed on 1st June.

In 1868 excellent progress was made. Messrs. Borel and Levalley had dredged at Port Said 123,000,000 out of their total quantity of 165,000,000 cubic feet. On the 15th April 1,200,000,000 cubic feet still remained to be excavated in the Maritime Canal. Between Port Said and Timsah, 5¼ miles had been done with 156,000,000 cubic feet of excavation, and at El Ferdane, 3¾ miles had been done with 34,000,000, Couvreux thereby finishing six months in advance of the contract time. The monthly work at this time was 74,500,000 cubic feet, accomplished with 8 elevator dredgers, 30 dredgers with barges, 22 long trough dredgers, 22 inclined planes, and 7500 labourers.

Besides the ordinary work of canalisation along the line of route, very extensive harbour operations had to be undertaken at Port Said and Suez. In the former case, two moles were erected, the western 2700 yards long, and the eastern 1950 yards, and requiring 250,000 blocks of artificial stone, each of 350 cubic feet and weighing 20 tons. A dock basin, 76 acres in extent had to be provided, and another basin, called the Basin de Commerce, of 10 acres extent and 37 feet deep. At Suez, the roadstead had to be dredged, and dykes and embankments constructed, the latter involving the submergence of 2,300,000 cubic feet of stone. The Suez breakwater, when finished, had over 1600 yards of stonework.

In 1869, early in the year, the moles at Port Said were completed, and the maritime canal, from Port Said to the Bitter Lakes Canal, was fully open. In March the flooding of the Bitter Lakes was commenced, and they were excavated to the Red Sea, for a distance of 22 miles, by hand, and for three miles by dredgers. Later on, the canal was fully opened.

The total length of quays at Port Said is over 3 miles. The inner port has an area of 130 acres, and the outer port an area of over 4000 acres. There are, besides, 120 acres of docks, and 10 acres of channel. Port Said has now a permanent population of over 17,000, and Suez one of 11,000, whereas the total population of the Isthmus in 1859 was only 150 inhabitants.

The Suez Canal can boast of having achieved many triumphs. It has abridged time and space in a way and to an extent that no other enterprise has ever before done in the history of the world. It has brought India and Australasia almost within half their former distance of Europe. It has revolutionised the shipping trade of the world. It has brought about remarkable changes in the values of Eastern produce. It has greatly reduced the cost of transport, and it has placed at the disposal of England, France, and Egypt a source of revenue which in its steady upward growth may properly be described as an El Dorado. But, after all, there is one of the phases of this remarkable work which is entitled to quite as much attention as any of these, although the world in general hears less about it. The canal gave an enormous impetus to engineering invention, skill, and enterprise, the effects of which have since then been felt in a hundred different works undertaken and carried out for the good of mankind. The appliances with which the canal was eventually completed were, for the most part, designed specially for the purpose. Until then, no such machinery was available. But the opportunity once found, the men were found who could utilise it. A description of the numerous different descriptions of elevators, dredgers, inclined planes, engines, and other appliances employed at Suez would fill a large volume. Compare some of these mighty machines, with their weight of 500 or 600 tons,* and extracting at the rate of a million and a half cubic feet of earth per month, with the *Couffins*, or rude Arab baskets, used by the native fellaheen, by whom the work was begun in 1860! † The contrast represents the void that divides barbarism from civilisation.

The effect of the opening of the Suez Canal has been to reduce the distance between England and the Australian and Indian possessions of the British Crown by distances varying from 545 to 4393 nautical miles, the greatest saving having occurred in the case of the voyage to Bombay. The voyage to India, China, and Australia has been so much shortened that some of the most important of the ports of those possessions are now reached in little more than one half

* One long trough dredger, set to work in June 1885, weighed 760 tons.

† It is stated that the number of these baskets used at the trench of El Guisr alone would, if extended in line, reach three times round the world. Of course when the fellaheen were withdrawn in 1864 these baskets were less largely used.

the time that was formerly taken up by the voyage round the Cape.*

The total cost of the Suez Canal at the end of 1870 was placed on the company's balance-sheet for that year at 16,613,000*l.*† At the end of 1886 this amount had swollen, with various items of expenditure incurred in the interval, to 19,782,000*l.* Of the former amount only 11,653,000*l.* were expended in the work of construction proper.

The financial success of the Suez Canal has exceeded the wildest dreams of its promoters. The increase of tonnage that has passed through it has been extraordinary. So, also, has been the income and the net receipts of the company. The net tonnage that used the canal in 1870 was only 436,609 tons. Ten years later the tonnage had

* The following table shows the principal distances and the saving by the canal :—

Ports.	By Cape.	By Canal.	Saving by Canal.	
			Amount.	Per Cent. of Voyage (Cape.)
	nautical miles.	nautical miles.	nautical miles	
Bombay	10,667	6,274	4,393	41·2
Madras	11,280	7,313	3,967	35·2
Calcutta	11,900	8,083	3,817	32·1
Singapore (*viâ* Straits of Sunda)	11,740	8,362	3,378	28·8
Hong Kong	13,180	9,799	3,381	25·6
Shanghai	14,050	10,669	3,381	24·1
Adelaide	11,780	11,100	680	5·8
Melbourne	12,140	11,585	555	4·6
Sydney	12,690	12,145	545	4·3
Wellington, New Zealand	13,610	13,055	555	4·1

† This amount was made up as follows :—

	£
Construction of canal	11,653,218
Transit, estate, and other services	533,552
Management charges (11 years)	567,296
Interest on shares (11 years)	2,673,864
Interest and repayment of debentures	585,118
Banking charges, stamps, loss in bonds, &c. ..	618,905
	£16,631,953

increased to 3,057,421 tons. In 1885 the tonnage had further increased to 6,335,752 tons, which was the greatest that had passed through in a single year up to that time. In the last-named year the shipping that used the canal was more than thirteen times as much as it had been fifteen years before.

The income and working expenses of the Suez Canal have varied as follows, compared with the annual income:—

Year.	Income.	Working Expenses.	Percentage of Working Expenses on Income.
	£	£	
1870	754,532	754,532	..
1875	1,233,785	717,860	..
1880	1,672,836	682,457	..
1883	2,740,933	758,861	..
1886	..	754,567	..

The heaviest items on the expenditure side are the interest and charges on capital, the administrative charges, transit, navigation, and telegraph charges, and maintenance of plant and warehouses. The two latter items, with water supply, make up the working expenses, less administration, and they amount unitedly to less than 180,000*l.* a year, or about 7 per cent. on the total gross annual receipts.

There is a not uncommon impression that the trade for the East is now carried on almost exclusively with steamships *viâ* the Suez Canal. Those who are actually engaged in the shipping trade, of course, know differently, but it is not unimportant that the general public should also know the facts, and we have, therefore, taken some pains to ascertain them.

	Total.	Steam Ships.	Sailing Ships.
	tons.	tons.	tons.
Vessels entered	1,957,000	1,112,000	845,000
Do. cleared	3,099,000	1,921,000	1,178,000
Totals	5,056,000	3,033,000	2,023,000

From the annual statement of the navigation and shipping of the United Kingdom, we have extracted the foregoing particulars of the tonnage of vessels that entered and cleared from the United Kingdom in 1884, in the Indian and Australian trades distinguishing steamers and sailing ships.

As sailing ships cannot make use of the canal, it is quite evident that there must be a use of sailing tonnage to the extent of over two millions of tons a year in the trade between the United Kingdom and her Indian and Australasian possessions. Such a fact is not a little remarkable when we remember that the opening of the canal has shortened the distance to Bombay by 41 per cent.; to Madras, by 35 per cent.; and to Calcutta by 32 per cent.* In some cases, the sailing tonnage employed was fully one-half of the whole. The following figures show how the proportions compare for the different provinces of India, as regards entrances into British ports:—

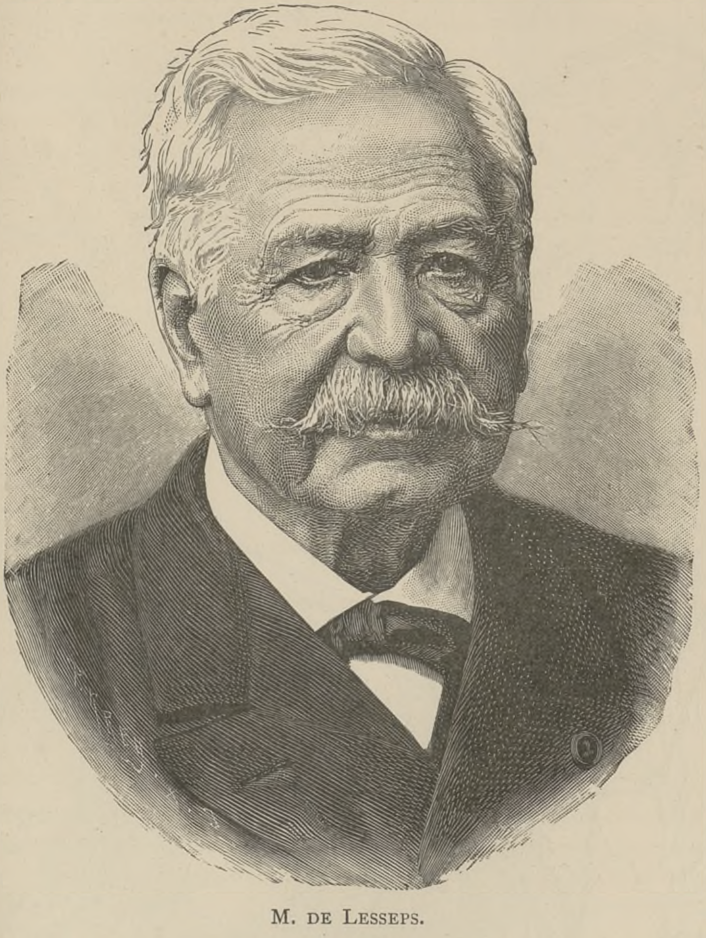
	Total.	Steamers.	Sailing Ships.
	tons.	tons.	tons.
Bombay	336,377	327,039	9,338
Madras	74,371	32,251	42,120
Bengal, &c.	810,946	426,524	384,222
Ceylon	18,373	5,483	12,890
Total	1,239,867	791,297	448,570

The clearances followed much the same course in the same period. Even with India, therefore, about 37 per cent. of all our trade passes by sailing ships round the Cape of Good Hope, instead of going through the canal, thus proving that the shortening of distance and of time is not the only consideratlon that determines the adoption of one route in preference to another.

One remarkable phase of the Suez Canal traffic is the great increase that has taken place in the size of the ships passing between the two seas. When the canal was first put forward by M. de Lesseps, it was seriously argued that all that was wanted was a canal from the Damietta branch of the Nile to Suez, which, "with a very little piling and dredging at either end," would be accessible to vessels of 300 or 400 tons burthen. Such a canal, it was maintained, "would suffice for all the wants of Egypt, and for all the local traffic of the

* "The Statistical Story of the Suez Canal," in the 'Journal' of the Royal Statistical Society for 1887.

two seas." * It was also maintained, that as the tendency was to increase the size of the ships employed on the Indian service, the canal would be compelled to refuse the only traffic ever likely to be



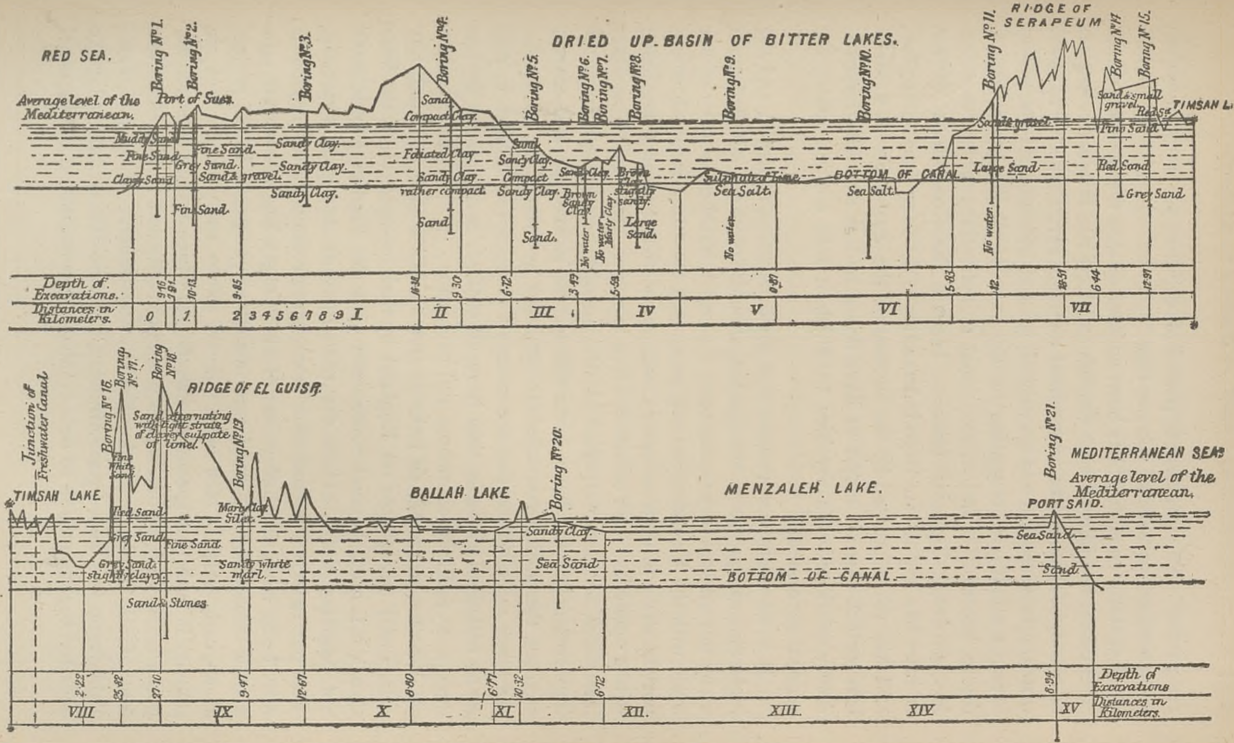
M. DE LESSEPS.

offered to it.† The average size of the vessels using the canal in 1870 was only 898 net tons. From this point a gradual increase of size has taken place, until in 1888 the average size had increased to

* 'Edinburgh Review,' January 1856, p. 245.

† It was assumed that the canal could not take vessels like the *Himalaya* and the *Persia*, or indeed any vessel over 350 feet in length.


MAP OF THE
SUEZ CANAL
AND PART OF
LOWER EGYPT.
MEDITERRANEAN SEA
Burlos
BURLOS LAKE
Achetim
Phantic Mouth
DAMIETTA
LAKE MENZALEH
GEMILEH
PORT SAID
Boundary of the Cultivated Lands.
MANSOURAH
Samanoud
Mehallet el Kebir
DAMIETTA BRANCH
Tantah
RUINS OF PELUSI
Kantara
ROAD TO SYRIA
ROAD TO CAIRO
Salihieh
BALLAH LAKE
ISTHMUS OF SUEZ
ZAGAZIG
ISMAILIA
NEW ISMAILIA CANAL
LAKE TIMSAH
TEL EL KEBIR
BENHA
Lighthouse
Lighthouse
SMALL LAKES
R. NILE
Old Railway taken up
Route to Mecca
CAIRO
SUEZ
GULF OF SUEZ



SECTION OF THE SUEZ CANAL.

1883 tons. The intervening period of eighteen years had therefore witnessed an increase of 109 per cent.

Singularly enough, it has been contended that the opening of the Suez Canal has injured both English and Egyptian interests—English interests, because it has economised tonnage, saved time, or in other words, minimised interest on capital, injured our entrepôt trade, and brought about our occupation of Egypt, with all the heavy expenditure, loss of life, and international complications which that fact has involved; Egyptian interests, because the Government of that country has had to pay large indemnities to the Suez Canal Company, and has really profited by the success of the enterprise to a much less extent than it ought to have done, had it not very improvidently sacrificed the royalties to which it was entitled under the original agreement.

It is, no doubt, unfortunate that our occupation of Egypt, and the inglorious campaigns in the Soudan, should have been entailed upon us by our interest in keeping open the canal, but the statistics of our trade with the East conclusively prove that the canal has had an important share in the enormous development that has occurred since it was opened. The movement has, however, been aided by other influences, and more especially by the opening of telegraph lines, the improvements that have been effected in steamships and marine engines, the smaller commissions accepted by merchants or agents, the lower rates of freight, the reduced charges for insurance, and many collateral changes, that have all tended, in a greater or less degree, to facilitate commerce and navigation.

Whether or no M. de Lesseps and his allies have conferred any substantial advantages on England by their completion of the Suez Canal, it is quite beyond controversy that the English people have not rendered much aid in the promotion of that great waterway. The part which England took when the preliminary arrangements were being made in 1856 is one of which many Englishmen are now a little ashamed. England was invited to co-operate in the project at an early stage. Not only did we refuse co-operation, but we refused it with that species of incivility of which we are occasionally guilty when we have our insular prejudices offended. The canal was first of all, opposed by the British Government, as such. Lord Palmerston was then Prime Minister. On the 8th of July, 1857, he declared the opposition to be—(1) that the construction of the canal would tend to the more easy separation of Egypt from Turkey, and would, therefore, be in direct violation of a policy "supported by war and the Treaty of Paris"; and (2) that there were "remote speculations with regard to easier access to our Indian possessions, only requiring to be indistinctly shadowed forth to be fully appreciated," which rendered the canal undesirable. How much better it would have been for the memory of genial "old Pam," if, in announcing his judgment, he had recollected the rule that "you should never give your reasons." History is rapidly made in the nineteenth century. It is not in the least discreditable to Palmerston that he should have failed to realise how completely his anticipations would be falsfied by events. No one at that time could have foreseen that, in less than thirty years from that date, the Suez Canel would not only have become an accomplished fact, but would have become perhaps the most successful industrial enterprise of modern times; that it would have revolutionised our shipping and transit trades; and that our Indian and Australian possessions would have participated in its advantages to an enormous degree. Prescience of this kind is given to few men. But while the lack of this ability to discern the "coming events" which "throw their shadows before" is not common, so neither is the example of the representative of a great nation describing as a "bubble," and denouncing with all the eloquence and power at his command, an enterprise which has conferred upon his country, as the first maritime power in the world, advantages which generally transcend those that are enjoyed by any other country.

But Lord Palmerston is very far from being a monopolist of this discredit. Robert Stephenson was at this time one of the leading English engineers. As the great son of a great father, he enjoyed vast influence, honourably and justly acquired, and employed, with one exception, discriminatingly and in a manner worthy of its possessor. That exception was the position which he took up in reference to the Suez Canal. Appointed to represent England on a commission of experts instructed to report on the question of isthmian transit, Stephenson satisfied himself that the idea of a canal was impracticable, and reported against it. So far, Stephenson was quite alone. His two colleagues on the commission—M. Talabot, representing France, and M. Negrelli representing Austria—were both in favour of the canal in preference to the railroad which Stephenson recommended.* His brother engineers in England appear to have stood loyally by Stephenson. They gave very little countenance to M. de Lesseps or his scheme. Both were, indeed, denounced from platform and press in the most unsparing manner. The leading daily journals, which write in haste, and the sober, scholarly quarterlies, which are supposed to write at leisure and after much reflection, were alike opposed to it. The *Edinburgh Review* spoke of it as "utterly impracticable," and urged that, "the available population or resources of Egypt could not execute such a work in a hundred years;" that "an army of foreign navvies would be required to keep in repair such a work, with its locks, viaducts, steam engines, and a floating capital hardly inferior to the original outlay"; that "a vessel in Aden harbour would rather take 3*l.* per ton for England, if allowed to go *viâ* the Cape, than she would take 5*l.* if forced to go through the canal"; that if the principles on which the *Great Eastern*, was then being built, were sound,† there was "an end, not only of the canal, but the Red Sea may again be restored to its pristine solitude, undisturbed even by the weekly visit of the passing steamers"; and, finally, that until different experiences were at command, "the Suez Canal may fairly be relegated among the *questions diseuses* which may interest and amuse, but can hardly ever benefit mankind." ‡

So also the 'Quarterly Review,' which believed the scheme to be "commercially unsound," and set forth a number of objections to it in categorical form. The great expense of building the masonry harbours at the two outlets of the canal, the difficulties and dangers of the navigation of the Red Sea, the cost of the embankments and the expense of maintenance, the "probability of steamers like the *Great Eastern* being built to perform the voyage round the Cape to the island of Ceylon in less time than would be occupied in performing

* The preference of Stephenson for a railway is not difficult to understand. He had "won his spurs" in railroad construction, and was familiar with every phase of their working and capabilities, but he had had comparatively little knowledge experimentally of canals. He was, indeed, the apostle of the new era —the railway against the canal.

† It was expected that the *Great Eastern* steamship would attain a speed of 25 knots an hour, and the proposition that a vessel's speed is almost in the direct ratio to her length having once been granted, that a class of vessels would come to be built that would be too large to make use of the canal.

‡ 'Edinburgh Review,' vol. ciii. (January 1856).

that through the Suez Canal,"* and the impossibility of ensuring the maintenance of the canal and necessary locks in proper working condition, were marshalled in battle array as a phalanx of obstacles that could not be overcome. But the opponents of the canal went further, and declared that, as a vessel using the canal would take about three days to get through,† would require one day to coal, and another to sail from Pelusium to the meridian of Alexandria, the saving on goods, as compared with the railway, would only be one to two days, while on passengers and mails there would be a loss of four to five days.

The British shipping interest have had some reason to complain of the way in which they have been treated from first to last by the Suez Canal Company. It is perfectly true that England did not contribute anything to the building of the canal, but English shipping has provided the shareholders with much the larger part of their revenue. France, which practically owns the canal, only contributes from 6 to 9 per cent. of its income, as against from 75 to 80 per cent. of the whole contributed by Great Britain. The shipowners of the latter country not unnaturally thought, some years ago, that they should have a larger share in the management of the canal, and threatened the construction of a rival waterway if the existing canal were not deepened, and other arrangements made for facilitating the shipping that used it. After a good deal of negociation between the canal company and the shipowners, a commission was appointed in 1884 to determine what new measures, in respect of works and navigation, should be undertaken to enable the ship canal to meet fully the exigencies of a traffic exceeding 10,000,000 tons per annum. Its report was presented in February 1885. The commission considered three methods of increasing the carrying capacity of the canal, namely:—(1) widening the existing canal; (2) construction of a second canal; and (3) doubling the capacity of the canal by a combination of the first two methods.

When the canal was first designed, in 1856, it was supposed that two vessels, being towed, could easily pass where the bottom width

* This seems an extraordinary assumption when we consider that the canal saves in the journey to Bombay 41 per cent. of the voyage by the Cape, and on the journey to Madras and Calcutta 32 to 35 per cent.

† In 1887 the average duration of the passage through the canal for the whole 3137 ships that made use of it was 34 hours 3 minutes. Between 1870 and 1873 the passage was frequently effected in 12 to 15 hours.

was 144 feet, or double the normal width adopted. At the present day, however, when vessels of nearly 200 feet in width propel themselves through the canal, a bottom width of 230 feet has been proposed for the 81 miles from Port Said to the southern end of the Bitter Lakes, where the tidal currents do not exceed one knot an hour, and 262 feet for the rest of the distance to Suez, where the currents often exceed two knots, in order that the vessels may pass each other freely. The cost of this widening was estimated at 8,240,000*l.*, supposing the depth of the canal remained as at present, 26¼ feet below low-water of ordinary spring tides, but it would be increased by 975,200*l.* if the depth was augmented to 29½ feet, unless the proposed width could be reduced to 18 feet.

The construction of a second canal, within the limits of the company's lands, having, like the existing canal, a bottom width of 72 feet, widened out to 131 feet through the small Bitter Lakes, was estimated at from 8,200,000*l.* to 8,920,000*l.*, with an additional cost of 698,800*l.* if made 29½ feet deep.

The third plan took into consideration the different velocities of the tidal currents north and south of the Bitter Lakes. Assuming that the greater velocity might lead to collisions between vessels passing on a single enlarged canal, it would be advisable to restrict the enlargement to the northern portion, and to form a second canal between the Bitter Lakes and Suez. For reasons which are fully set forth in their Report, the Commission decided in favour of the enlargement of the existing canal. The estimated cost of the works, which are now in progress, is rather over 8,000,000*l.*

It has been suggested, with some show of reason, that it would be to the advantage of the commerce of the world that the maritime Powers should make arrangements to acquire the Suez Canal, and throw it open, free of any charge or impost whatsoever, to the navigation of all nations, in the same way that the Scheldt and the Sound have been. The canal has hitherto been employed almost entirely for the transport of passengers, mails, and such traffic as will bear a high rate of freight, the charge of 7*s.* to 10*s.* per ton being prohibitory in respect to much of the commerce that passes from the East to the West. The proposal is one that is entitled to every consideration. There is, however, a high probability, amounting almost to a certainty, that the proprietors would demand a very large sum in excess of their original expenditure. The canal has cost from first to last, including financing, some 20,000,000*l.* At their recent prices, the canal shares may be considered as worth about four times that amount. If the property were to be purchased on such a basis, it would require an expenditure of at least 80,000,000*l.*, which sum, although by no means impossible, is yet little likely to be realised for such a purpose. If the canal had been taken over in 1880 it could have been purchased for one-half the sum that would now be required to buy it.*

At the same time that the Suez canal route was being advocated with all his wonted energy and enthusiasm by M. de Lesseps, other two routes to India were being seriously discussed. As one at least of these is still on the carpet we may fitly say something of it here.

Up to the sixteenth century the best known and the most frequented route to India was that by the valleys of the Euphrates and the Tigris. These two great rivers of Mesopotamia are among the most celebrated in the world's history. The Euphrates has its source in the northern highlands of Armenia; the Tigris in the southern slopes of the same mountainous region, being fed by many rivers that traverse the boundary line between Persia and Turkey. Almost at the dawn of recorded history, we find that the Assyrians and the Babylonians connected these two rivers by a series of canals. Two of these, constructed parallel to the rivers Euphrates and Tigris, were large enough to be navigated, but the system was constructed mainly with a view to irrigating the surrounding plains, which, for nearly six months, were liable to be burnt up by the scorching sun. As the Arabs and Turcomans gained greater ascendancy in this region, the arts of husbandry were less practised, and the canals and water courses were allowed to fall into desuetude and decay. Their embankments still, however, remain to attest the remarkable skill, labour, and industry with which, at this early date, the fertility of the soil was stimulated and increased, until the extraordinary productiveness of Assyria and Babylonia became a favourite theme of dotus and other historians.

Through this region, until the trade of the East was drawn into the newer channel *viâ* the Cape of Good Hope, European merchants sought an outlet for their trade with the East. Bagdad and Bussora were then great entrepôts of commerce. Mosul and Aleppo were the ancient counterparts of Suez and Port Said. The route was,

* The shares rose from a middle price of 306 francs in 1867 to 664 in 1877, 1021 in 1880, 2710 in 1882, and fell to 1989 in 1884, rising again to 2095 in 1886.

however, never a safe or a satisfactory one. The Syrian desert, close at hand, claimed many victims. The wild Arab tribes committed depredations on travellers. The "unspeakable" Turk was exacting and intolerant. The journey to India and back lasted for a lengthened period—often two or three years—where it now scarcely extends over so many months. But in spite of all this, the indomitable spirit and energy of the English race led it to establish a secure footing on such ungenial soil, and amid such inhospitable surroundings. An English factory long flourished at Aleppo. A fleet of boats was, in the reign of Elizabeth, maintained on the Euphrates for the use of British traders. When the Levant Company was founded in 1582, it was deemed a veritable Eldorado to have the exclusive privilege of trading with this part of the globe. All this has long ceased to be, but the proposal to have the Euphrates and the Tigris utilised as a trade route to India has been again and again revived. In 1834, the British Government determined to fit out an expedition to test the capabilities of the Euphrates for steam navigation. The expedition was placed under the charge of Colonel Chesney, upon whose recommendation it was adopted by Parliament. It was found that the Euphrates was in some places a broad and deep stream, and in others navigation was impeded by shallows, sand-banks, rapids, and stone dams of large size, built for irrigation purposes. One of the two vessels fitted out for the use of the expedition foundered in a storm, and many lives were lost. The Government, deeming the result unsatisfactory, declined to take any further part in exploring the Euphrates. In 1840, however, the East India Company commissioned Lieutenant Campbell to attempt the ascent of the river. This expedition sailed up the Tigris to within a few miles of Mosul. They found a canal uniting the Euphrates and Tigris near Bagdad, which, however, has long been closed. They also navigated the great canal which is said to have been constructed by the Emperor Valerian during his captivity, nearly as far as Shushtir, and several rivers in Persia. One of the vessels employed on this expedition was for many years afterwards accustomed to make occasional voyages between Bagdad and Bussora, mainly in order that our privilege to navigate the river should be maintained, and our influence in Western Asia preserved.

The proposal put forward by the promoters of the Euphrates Valley route in 1856, was to navigate the rivers Euphrates and Tigris from about the latitude of Aleppo to the sea, to construct a harbour at Suedia, and a railway thence to Kalah Jaber. From this point it was proposed that steamers should convey mails, passengers, and merchandise to Bussora, whence sea-going vessels should run to India.* The route to India would thus be reduced to 4715 miles, and the time necessary for the journey to less than sixteen days, giving a saving of thirteen days out and nine days home upon the Suez voyage.

The cost involved in this undertaking, not to speak of its mechanical and physical difficulties, led to its abandonment, although it is by no means certain that the engineering problems to be dealt with are more considerable than those which have had to be solved at Panama. One serious difficulty, which has been deemed all but insuperable, is the fact that the waters of the Jordan are just sufficient to balance the evaporation from the surface of the Dead Sea, so that if that sea were increased to five or six times its superficial area, as proposed, it would require a much larger volume of water than the Jordan can furnish to meet the deficiency. The project also labours under the defects of climate, a thin population, and an absence of food and water supplies.

In the last century the Marquis of Wellesley endeavoured to utilise the Euphrates Valley route; and the House of Commons has been asked to grant sums of money for various purposes in connection with it at different times. In 1871 the House of Commons ordered an official inquiry, with a view to place upon record all the useful information available, including the evidence of Colonel Chesney and others, as to this route.

It has not been supposed by the promoters of a railway to India that such a railway would be in any way antagonistic to the Suez Canal, which would, in all probability, monopolise the heavy traffic, and still exist as the chief means of communication with Southern India. But, on the other hand, the Euphrates line would benefit the north-west provinces, and, as far as passengers and mails are concerned, would effect a saving in time of at least a fortnight, taking the voyage out and home. The saving in distance would be about 1000 miles in a straight line, and, as vessels proceeding by way of the

* The distance from Suedia to Kalah Jabar, a small Arab settlement on the Euphrates, was put down at 100 to 150 miles, and the river journey from Kalah Jabar to Bussora at 715 miles. From Bussora to Kurrachee the distance is 1000 miles. The average time occupied in descending the Tigris was taken at seven days, and that of the ascent at twelve.

Red Sea are compelled to deviate from their courses to the extent of 500 or 600 miles during the monsoon months, the saving that might accrue, taking an average of voyages, would be somewhere about one thousand miles each voyage. On the other hand, the railway would always suffer from the fact that two trans-shipments would have to be effected in every case, and this, where the goods are bulky, is a serious consideration. Prior to the opening of the Suez Canal only goods of small bulk were sent to India by way of the Isthmus Railway, although the voyage by the Cape occupied eight days, and it is regarded as probable that the canal would still retain heavy traffic.

Besides the Euphrates Valley, two other routes to India have been proposed. One of these aimed at the substitution of the Black Sea for the Mediterranean, and making the terminus of the line at Trebizonde. By the champions of this scheme it is contended that the long and dangerous voyage necessitated by a Mediterranean terminus would be avoided, by making use of the Danube and the short passage across the Black Sea. On the European side, however, there is the liability to having the Danube, or, indeed, the Black Sea, closed, the effect of which would be that the railway would be simply useless, as long as the restrictions remained in force; and on the Asiatic side there would be serious practical obstacles in the mountain ranges near Trebizonde. The Tigris Valley route has also been recommended on the ground that it would open out a better country, and one peopled by more peaceful tribes. Of the respective advantages of the two routes in regard to facilities of construction, it is enough to say that the Valley of the Euphrates is practically flat, and that nothing better could be desired in the matter of level, while it is not easy to say what difficulties the Tigris Valley may or may not present. Mr. Eastwick has visited various parts of the Euphrates route, and he states that the facilities there for making a good road are great, and that in certain districts the local traffic would, in all probability, be very considerable.

Another plan was proposed some thirty-five years ago, for forming a water communication between the Red Sea and the Mediterranean.

This proposal, made by Captain W. Allen, of H.M.'s navy, was based on the knowledge we now possess that the level of the Dead Sea is at least 1300 feet below that of the Mediterranean or Red Seas, and that the Sea of Galilee is, in like manner, depressed to the extent of about 650 feet; so that the mean level of the valley of the

Jordan, with its two lakes, may be taken at 1000 feet below the neighbouring seas, and its extent as covering about 2000 square miles. This vast area Captain Allen proposed to convert into a great inland sea by cutting a canal from Acre across the plain of Esdraëlon to the Jordan, a distance of about 40 miles on the map, and another from Akabah, on the Red Sea, to the southern limit of the Dead Sea, a distance of about 120 miles.

The summit level of the plain of Esdraëlon may be as low as 100 feet above the sea level, or as high as 200 feet, and from the appearance of the banks of the brook Kishon, near its junction with the sea, and the hills that bound the plain on both sides, the ground is rocky nearly throughout its whole extent at a small distance below the surface. The proposal, therefore, as described in the 'Edinburgh Review,' was to dig a canal through a rocky country for 30 or 35 miles in length, and with a mean depth or 80 to 100 feet.

A plan has quite recently been put forward for the construction of a parallel canal to that across the Isthmus of Suez, by way of the Euphrates Valley, the Persian Gulf, and Syria. The proposal is to create a navigable highway from Sonëidich to the Persian Gulf, by making the Euphrates flow to the Mediterranean and Antioch. The river from Beles to Felondjah (near ancient Babylon) would be deepened, and the waterway would be carried from the Euphrates to the Tigris by the canal of Saklavijah. Thence the route would be by the Tigris from Bagdad to Kornah, Bassora, and Fao on the Gulf. The author of this proposal* estimates that the canal would shorten the route to Bombay by six days, and it would irrigate and restore fertility to a great part of the country through which it would pass. The estimated capital required would be 1,500,000,000 francs (60,000,000*l.* sterling).

* M. Emile Ende, in a communication to the French Academy of Sciences in 1886.

CHAPTER XXI.

THE PANAMA CANAL.

> "A little model the master wrought
> Which should be to the larger plan,
> What the child is to the man."—*Longfellow.*

If the question were asked, "What is the greatest constructive work that has yet been undertaken by man?" there would, without question, be a great many different replies. There can, however, be only one reply as to the most costly. Perhaps, also, there can be but one answer as to the most disastrous to human life. The Panama canal would almost certainly secure pre-eminence in these attributes. It might or might not rank equally high as a work of engineering genius and possible public utility.

There has probably never been a project that has so challenged the admiration and the approval of the world as that of finding a waterway between the Atlantic and the Pacific Oceans, at or near to the narrow neck of land that separates Limon from the Gulf of Panama in Central America. This enterprise has a long and a very eventful history. Many explorers, geographers, statesmen, engineers, and economists have either written on the merits and demerits of the undertaking, or have otherwise become associated with it. Some of the more notable episodes in the records of the isthmus may therefore be referred to, before proceeding to describe the various projects now either in progress or in contemplation, for opening it up for the purposes of trade, commerce, and navigation.

One of the earliest direct references to the importance of a waterway between the two oceans is that made by Cortez in his letters to Charles V. The great conqueror, however, does not seem to have contemplated the construction of such a waterway. He diligently searched for a natural waterway or strait between the two oceans, and declared that to be "the one thing above all others in the world I am most desirous of meeting with," on account of its immense utility. Some sixty or seventy years later, there was a project put forward by the Spaniards for uniting the two oceans by a waterway, but it does not appear to have been carried any length. The Spaniards, indeed, were hardly the people to achieve such a distinction. Unlike the ancient Romans, the Italians, and the Chinese, their skill was not very marked in hydraulics. They were, besides, much too superstitious to venture on interference with what many of them believed to be an ordinance having all the fixity of a law of nature.*

The American Isthmus next claims attention as associated with the ill-starred fortunes of William Paterson and the Darien scheme.†

The earliest, and in some respects the best, information yet available, relative to the topography of the country adjacent to the Panama Canal, is that furnished by Dampier,‡ who spent some time on the isthmus and noted all its chief physical characteristics. Dampier's observations, however, were chiefly made in and about the Gulf of St. Michael, which he describes as lying "nearly thirty leagues from Panama, towards the south-east," and as "a place where a great many rivers, having finished their course, are swallowed up in the sea." Dampier found the isthmus very low and swampy, "the rivers being so oosy that the stinking mud infects the air."

Lionel Wafer § has also made an early and valuable report on the character of the country bordering on the route of the present Panama Canal, describing it "as almost everywhere of an unequal surface, distinguished with hills and valleys of great variety for height, depth, and extent." He described the river Chagre, or Chagres, as

* In 1588 P. Acosta, an old Spanish historian, wrote, with reference to the proposal to construct a canal between the two oceans, that "it would be just to fear the vengeance of Heaven for attempting such a work."

† William Paterson, the originator of the Darien Expedition, was also the founder of the Bank of England.

‡ Dampier was born in Somersetshire in 1652. In 1673 he served in the Dutch war under Sir Edward Sprague. He was afterwards for some years overseer of a plantation in Jamaica. Several vicissitudes of fortune followed, and it is stated that for a time he was one of a band of pirates who roved about the Peruvian coasts. He made several voyages to the northern coast of Mexico, to the East Indies, and to the islands in the Pacific. His 'Voyages' have been many times reprinted.

§ Lionel Wafer was bred a surgeon in London, and in 1677 embarked as such on board a ship bound for Bantam. He afterwards engaged with Linch and Cook, two celebrated buccaneers, which brought him into the company of Dampier. The two did not, however, agree, and Wafer was left on shore on the Isthmus of Darien, where he spent some years among the Indians. He returned to England in 1690, and published an account of his adventures.

one which "rises from some hills near the South Sea, and runs along in an oblique north-westerly course till it finds itself a passage into the North Sea, though the chain of hills, if I mistake not, is extended much further to the west, even to the Lake of Nicaragua."

De Ulloas * and some friends in 1735 made an ascent of the river Chagres on their journey from Cruces to Panama. This voyage is interesting as being one of the first that is recorded over the river that has since played so prominent a part in the history of the canalisation of the isthmus. They found the banks of the Chagres impassable, for the most part, from the density of the vegetation and the velocity of the current. The vessels that were then more or less accustomed to navigate the Chagres were described by De Ulloas as *chatas* and *bongos*—the first carrying 600 or 700 quintals, and the latter 400 or 500. The river was found to be so full of shallows that even vessels of this small size had to be lightened every now and again until they had passed over them.

No one has taken a greater interest in the subject of a ship canal than Humboldt, who regarded Kelley's Atrato route with approval, and who, replying to the objections brought against the proposal in his time, declared that "there is nothing more likely to obstruct the extension of commerce and the freedom of international relations than to create a distaste for farther investigation by discouraging, as some are too positive in doing, all hope of an oceanic channel." †

A survey was made of the isthmus in 1827 by Captain Lloyd and Captain Falmark, the former an officer of engineers in the Colombian service, and the latter a Swedish gentleman acting in that capacity for the time being. Beginning at Panama, they followed the old line of road from that city to Porto Bello, a distance of 22¾ miles, where they found the surface of the water in the river to be 152½ feet above high-water mark at Panama. At Cruces they found a fall in the river of 114½ feet, leaving only about 38 feet as the height above the Pacific. It was found that at Panama there was a rise and fall of the tide in the Pacific of 27·4 feet, being 13·5 feet above the high-

* De Ulloas was born at Seville in 1716. He distinguished himself as an engineer and man of science. In 1730 he was sent to Peru to measure a degree of meridian, and remained nearly ten years in South America. Afterwards visiting England, he contributed several papers to the Royal Society, and was appointed by Ferdinand III. to collect information as to the condition of the arts and sciences in Europe.

† Letter to Mr. F. Kelly, in 'Proceedings' of the Royal Geographical Society for 1856.

water mark of the Atlantic at Chagres. These and other observations led them to conclude * that in every twelve hours, commencing with high tides, the level of the Pacific is first several feet higher than that of the Atlantic ; it becomes then of the same height, and at low tide it is several feet lower ; again, as the tide rises, the two seas are of one height, and, finally, at high tide the Pacific is again the same number of feet above the Atlantic as at first." †

In 1840 Mr. Wheelwright was commissioned by the directors of the Pacific Steam Navigation Company to examine the capabilities of the river Chagres, and the best means of communication with the South Sea. He made a lengthy report on the subject, in the course of which he confirmed many of Captain Lloyd's observations, giving the depth of high water on the bar of the Chagres at 15 feet. In 1843, again, M. Napoleon Garella received from M. Guizot, as Minister of Foreign Affairs, an order to make a survey of the isthmus, and he proposed a summit-canal of more than three miles long, the level being reached by thirty-six locks and three large aqueducts.‡

In 1853, Mr. Squier explored that section of the mountain chain which crosses the American isthmus to which Berghaus has given the name of the Honduras-Nicaraguan group. This range commences at the Col de Guajoca and extends to the valley of the Rio San Juan. Running at first close to the shore of the Pacific, it gradually approaches the centre of the isthmus. The eastern slope, broken by mountain offshoots and watered by rivers of the first order, terminates on the north-east in the point Gracias a Dios. The western slope forms a long, low, and, comparatively speaking, level valley, crossed by an irregular and independent series of volcanic peaks. This accessory line of volcanoes, which presents the most distinctive feature of the physical geography of Central America, is nowhere so distinct from the main line of rocky axis as in the Honduras-Nicaraguan district. Mr. Squier proposed to commence a railway at Puerto Caballos, in the Bay of Honduras, and proceed due south to Fonseca Bay, on the Pacific, a distance of some 160 miles. The harbours on this route are said to be very superior to those on the Tehuantepec route. The summit-level, however, is 2308 feet above

* Vide 'Philosophical Trans.,' 1830, p. 62 *et seq.*

† The details of the survey are in the library of the Royal Society, to which the author communicated a paper on the subject. Captain Lloyd also gave an account of the country and its productions to the Royal Geographical Society.

‡ 'Edinburgh Review,' April 1882.

the level of the sea. At such a height a canal would be practically impossible, and the project was never carried any further than a survey.

Among the many alternative routes suggested for a canal across the American isthmus, one that has found some favour in the United States was that *viâ* the isthmus of Tehuantepec. This locality has been repeatedly surveyed. Cortez had his attention called to it in the sixteenth century. Don Augustus Cramer went over at least part of the route in 1744. Again, in 1842–3, it was surveyed by Señor Moro, as will be found in a book called 'Survey of the Isthmus of Tehuantepec, executed in the years 1842 and 1843, under the superintendence of a scientific commission appointed by the projector, Don José de Garay. London, 1844.' In 1852 it was surveyed by Mr. J. J. Williams, on behalf of the Tehuantepec Railroad Company of New Orleans. The project was to ascend, from the Atlantic coast, the river Coatzacoalcos to its junction with the Malalengo, from which spot a canal was to be carried to the summit-level on the Mesa de Tarifa, through a series of locks, rising 525 feet in all, and descending 656 feet into the lagoons on the shores east of Tehuantepec. The canal would have a length of about 50 miles, and would require 19 additional miles of trench to convey water. The length of this line was stated by Mr. Kelly, of New York,* at "about 210 miles," and by M. Voisin, a director of the Suez Canal,† at 240 kilometres, or about 149 miles.

M. Moro estimated that 150 locks would be required on this route, and twelve days would be required for vessels to pass through the canal. The coast of Tehuantepec is, moreover, subject to fearful hurricanes and to subterranean movements of volcanic origin, while, finally, the supply of water at so high a level was believed to be doubtful.‡

At the first session of the Congress of Geographical Science, held at Antwerp in 1871, the question of constructing a canal across the American isthmus was presented for consideration. General Hame, of the United States, was present, and took part in the congress. He described the proposals of the two French explorers, MM. de Gogorza and de Lacharme, who proposed to cut the Isthmus of Darien between the navigable channels of the Tuyra, the Atrato, and the Caquiri. The congress recommended the project of these

* 'Minutes of Proceedings of the Institution of Civil Engineers,' vol. xv., p. 378.

† 'Bulletin du Canal Interocéanique,' An. 1, No. 2, p. 10.

‡ 'Edinburgh Review,' April 1882.

gentlemen to the attention of the great maritime Powers, and of the scientific societies throughout the world. There the matter rested for a time.

At the second congress of the same body, held at Paris in 1875, the question of the construction of a canal across the Isthmus of Darien was again considered. M. de Lesseps, who was present on that occasion, declared that all the authors of the various projects brought forward for piercing the isthmus up to that time had made a grave mistake in committing themselves to a canal with locks and sweet water. He urged that, in order to meet the wants of commerce, all maritime canals should be carried between the two oceans at the same level, in the same way as the Suez Canal had been. Again a resolution was adopted, urging on the various governments concerned that the utmost facilities should be given for the construction of a ship canal in this part of the world. The congress went a step further. In order to inquire into the subject of the possibility of constructing such a canal, and the conditions necessary for its accomplishment, a committee was appointed under the presidency of Admiral Noury, and including among its members MM. Daubrée, Levasseur, and Delesse, members of the Institute of France. A syndicate was at the same time formed for the purpose of exploring Central America, with a view to the adoption of the most suitable route.

The results of the exploration thus undertaken were made known in due time, and in 1879 an international congress was held at Paris under the Presidency of M. de Lesseps, to consider proposals for an interoceanic canal, when it was affirmed (1) that the construction of an interoceanic canal, at sea level throughout, so desirable in the interests of commerce and of navigation, was possible; and (2) that such a canal should be constructed between the Gulf of Limon and the Bay of Panama.* These resolutions were adopted by no less than seventy-eight votes against eight, there being, however, twelve who abstained from voting.

Five different projects were submitted for the consideration of the conference. It is, however, a remarkable fact that none of them, except the Panama Canal Scheme, proposed to provide for a canal without a tunnel and without locks. As the Panama scheme was that recommended by M. de Lesseps, the conference requested him

* At this congress Admiral Ammen represented the United States; General Sir John Stokes, England; Vice-Admiral Likhatchof, Russia; Commander Christoforo, Italy; and Colonel Coëlle, Spain.

to undertake the direction of the work. The veteran replied that his best friends had endeavoured to persuade him that after the accomplishment of his great work at Suez he should seek repose; but, he added, "if a general who has won a first battle is asked to engage in a second, he cannot refuse." Directly afterwards M. de Lesseps received from Victor Hugo a letter approving his course, and adding, "Astonish the universe by great doings which are not of wars. Is it necessary to conquer the world? No; it is yours. It belongs to civilisation; it awaits it. Go; do it; proceed." The press of Paris were jubilant over the new enterprise, declaring that France was continuing its great mission. In the Chamber of Deputies Mgr. Freppel declared that with the piercing of the Isthmus of Panama, a complete change will be effected in the relations of the entire world.

Thus encouraged on every side, M. de Lesseps sought the means for his second great enterprise. He did not find it difficult to raise a considerable sum. He pointed out to his countrymen that on the 250,000,000 of francs that they had contributed towards the actual expenditure incurred on the works of the Suez Canal, they had benefited to the extent of 1,220,000,000 of francs. The congress had made it appear that the Panama Canal would cost twice that of the Suez, but then it was expected to produce three times as good a result.

M. de Lesseps consented to occupy the position he did on the express condition that all the complex problems connected with the undertaking were fully and satisfactorily resolved by commissions of experts. Five such commissions were appointed—of statistics, of economics, of navigation, of construction or technique, and of ways and means. The Technical Commission having considered the various proposals submitted, drew up the following summary of their several merits.

Proposed Canal.	Length.	Obstacles.	Estimated Duration of Work.	Expense.	Length of Time occupied in going through Canal.
	kilometres.		years.	millions of fr.	days.
Tehuantepec ..	240	120 locks	..	..	12
Nicaragua ..	292	17 ,,	8	900	4½
Panama	73	none	12	1·200	1½
San Blas ..	53	tunnel 14 kilom.	12	1·400	1
Atrato	290	,, 4 ,,	10	1·130	3

The cost of the maintenance and working of each of the several schemes was estimated at the same sum—130 million of francs, or 5 per cent. of the anticipated receipts. No doubt appears to have been entertained that the enterprise would prove highly remunerative. M. Voisin Bey, Inspector-General of Ways and Bridges, calculated that the company would be able to obtain an average of 15 francs on at least four million tons of shipping expected to make use of the canal; and the Statistical Commission committed themselves to the view that the two canals of Suez and Panama would present the following comparison:—

	Cost.	Tonnage.	Annual Receipts.
	millions of francs.	millions of tons.	millions of francs.
Suez	500	3	30
Panama..	1,070	6	90

On the faith of these and similar statements, many of them, as we now know, largely illusory, the *Compagnie Universelle du Canal Interoceanique de Panama* was founded in 1879 with a capital of 600 millions of francs, or about one half the sum estimated as necessary, but with authority to increase or reduce the capital as might be deemed desirable.

At the outset of the undertaking, M. de Lesseps, following the example that he had set with the Suez Canal, and in order to mark the international character of the enterprise, offered to American capitalists the opportunity of providing one half of the amount required, and announced that whether the Americans subscribed towards the enterprise or not it would be begun with the 300 millions of francs which it was proposed to raise in Europe. Subscriptions towards this moiety were invited in Europe in December 1880, and 102,230 subscribers offered more than double the amount asked for, or 1,266,609 shares in all, of which 994,508 shares were subscribed in France alone. The financial outlook of the enterprise being thus encouraging, M. de Lesseps lost no time in proceeding to Panama, in order that he might study for himself, on the spot, the character of the work he had undertaken to perform. He was accompanied by an engineering commission of eight well-known experts, including MM. Dircks, the chief engineer of the waterways of Holland, Danzats, chief resident engineer at Suez, two

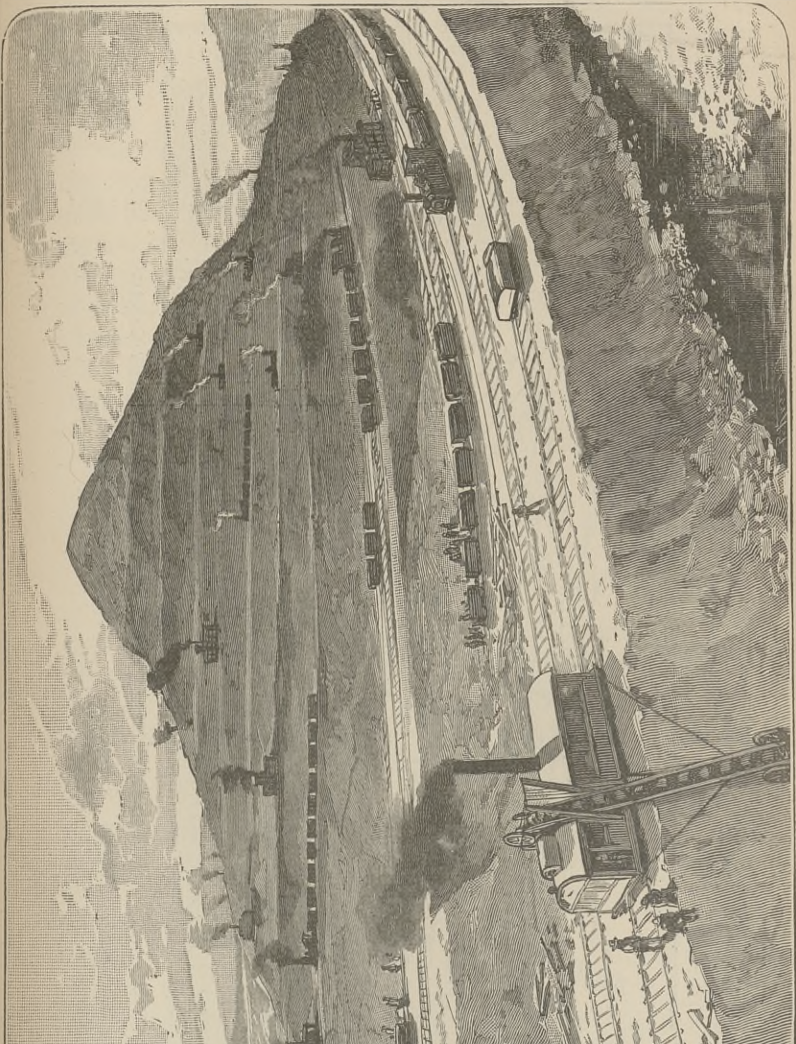
Colombian engineers, and others. The opinion unanimously arrived at by this commission was that the canal could be completed for 843 millions of francs, or about 34 millions sterling,* in about eight years.

Meanwhile a grand superior consultative commission, which had been convened at Paris, for the purpose of inquiring into the technical details of the scheme, and determining a programme for their execution, recommended that no time should be lost, and thereupon MM. Couvreux and Hersent, well-known contractors, were entrusted with the execution of the work to the extent of 500 millions of francs (20,000,000*l.*), for which sum they declared that the canal could be constructed. The work of levelling and dredging was prosecuted with vigour. There was, however, a vast amount of preliminary work to be done. Twenty-three different workshops and docks had to be provided along the line of the canal, with workmen's dwellings, hospitals, and other requisite equipments. The Culebra, a mountain in the middle of the isthmus, was selected for the erection of several considerable installations adapted to the study of the problems to be solved. Through this mountain the canal had to be cut to a depth of over 100 metres. It was calculated that the organisation of the works, the providing of the necessary materials of construction, the acquisition of the ground along the line of route, and the commencement of operations generally, represented something like one-third of the total work to be done. The Colombian Government, through whose territory the canal was to be constructed, did all they could to advance the project, offering to the company 500,000 hectares of land, with the minerals underlying the same, in such localities as the company might select. This concession was deemed at the time to be equal to about one-third of the cost of the canal.

The first important step towards the prosecution of the Panama

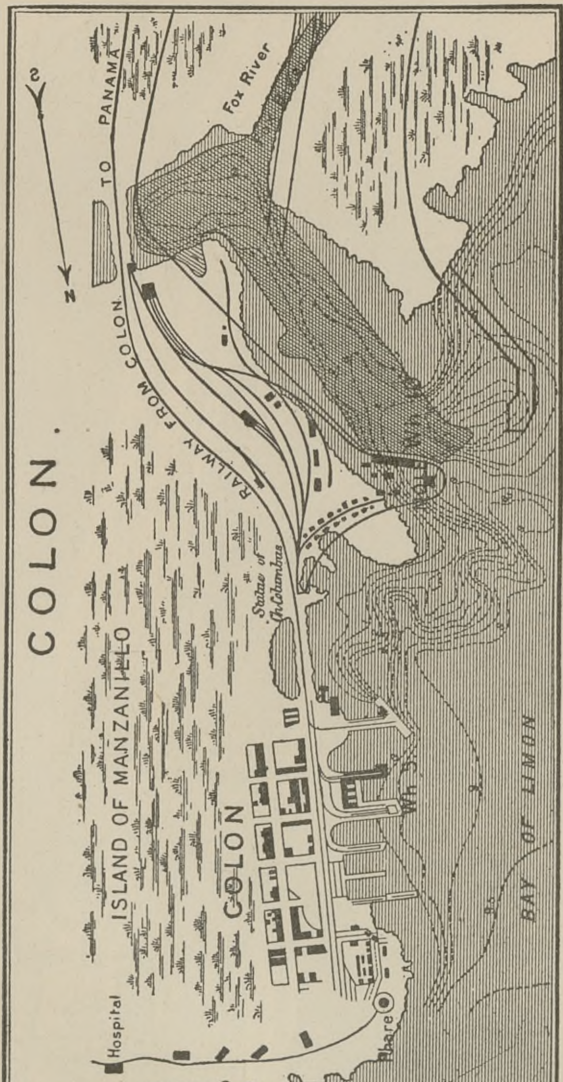
* The items adopted by the Commission as the probable cost of the undertaking were as follows :—

	Millions of francs.
1. Excavation	570
2. Barrage	100
3. Rigoles de déviation	75
4. Portes de marée	12
5. Jetées	10
6. Imprevus, 10 per cent.	76
	843



THE WORKS ON THE CULEBRA COL, PANAMA CANAL, IN 1888.

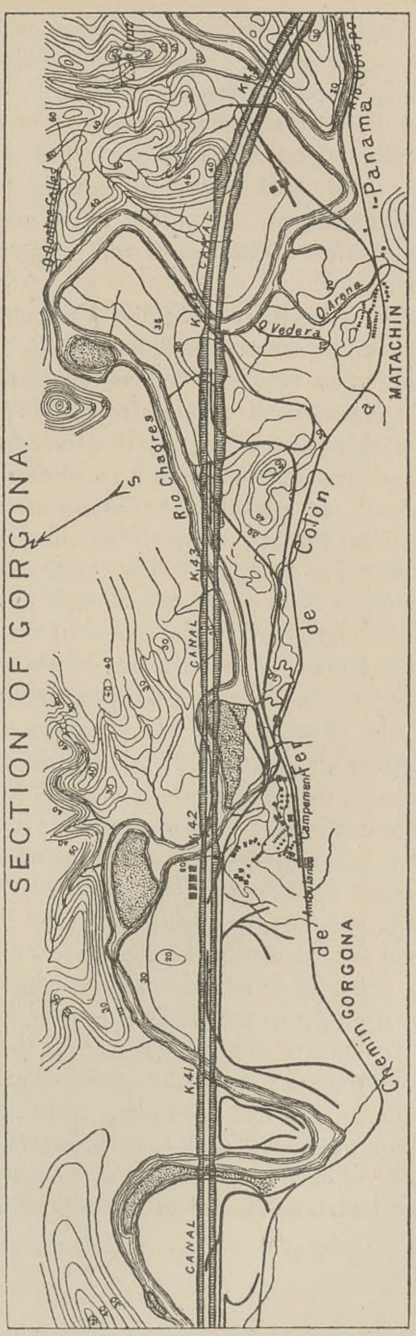
Canal works was the selection of a site for landing the necessary plant. The space in front of the town of Colon, at the north-eastern



Plan of Colon, Atlantic End of the Panama Canal.

extremity of the Bay of Limon, was occupied by wharves devoted to the existing trade brought by steamers to the Panama Railway, and, therefore, another spot had to be found. The village of Gatun was first chosen, being on the river Chagres, and close to the railway and the proposed line of the canal. It was supposed that this site would be healthier than the low island of Manzanillo, on which Colon is situated, and the river Chagres afforded communication with the sea, having a minimum depth of 13 feet over its bar, which might be increased by dredging. Owing, however, to the want of proper shelter, fever attacked the workmen at Gatun; and, finally, the creek separating Manzanillo island from the mainland was selected as a harbour for the works.

The outlet of the canal was to be situated in this creek; and in order to protect the mouth of the canal and provide a good harbour for the works an embankment was formed on the south-west corner of Manzanillo island, and was carried about 650 feet into the Bay



Section of the Panama Canal, showing its Intersection with the River Chagres.

of Limon to afford shelter, being protected along its exposed portion by rubble stone. This embankment contains 458,000 cubic yards of earthwork, obtained by the aid of excavators from some hillocks about three-quarters of a mile distant, adjoining the railway; it covers an area of about 74 acres, which was formerly partly marsh land, and partly covered by the sea. The projecting mole was estimated to shelter nearly 3000 lineal feet of wharfage.* The position of the works will be understood from the annexed drawing.

Up to February 1883 the work undertaken at the canal had been almost entirely preliminary. In that month M. de Lesseps, acting upon recommendations contained in a report made by M. Dingler, chief engineer of roads and bridges, proposed to the shareholders of the company that the definite programme of the work to be done should embrace a canal of a depth of nine metres below sea level, and a width of 22 metres throughout its course; the construction of large ports at Colon and at Panama; a great basin, five kilometres in extent, near Tavernilla, about the centre of the canal, in order to allow vessels to pass each other: a great dam at Gamboa, for the regulation of the course of the Chagres river; and a tidal port at Panama, in order to ensure access to and from the Pacific at all hours. In submitting this programme, M. de Lesseps calculated that the excavation necessary to the completion of such a canal would be about 110 millions of cubic metres, and that the work of regulating the Chagres river would be equal to a further 10 millions of cubic metres. This work, M. de Lesseps estimated, could be completed in 1888—the excavations of land in three years, and the dredging operations in two, so that "the canal could, with mathematical certainty, be opened on the 1st January 1888." In confirmation of this calculation, he appealed to the experience at Suez, where, with a total of 75 millions of cubic metres of excavation, 50 millions were done during the two last years of the work.

The state of affairs at the canal in the autumn of 1884 is described by the American Admiral Cooper, who reported that although comparatively little had been done in the actual work of excavation, in relation to the vast work to be accomplished, yet all the preliminary plans had been prepared, the soundings had been made, the line of route had been cleared of its tropical vegetation, large supplies of

* 'Minutes of Proceedings of the Institution of Civil Engineers,' vol. lxxiii., p. 421.

materials of all kinds were at command, dwellings and barracks for the employés had been erected in elevated and salubrious localities, hospitals had been established, and every arrangement requisite for meeting possible eventualities had been carried out so completely that he was confirmed in the belief that the canal would be finished in due time, although he doubted its completion in 1888. At this time no less than twenty different contractors, of eight different nationalities, were engaged upon the work of construction. These contractors had undertaken collectively to raise 62,691,000 cubic metres of excavation for a sum total of 219,295,000 francs (8,772,000*l.* sterling), being at the rate of rather less than 3*s.* per cubic metre. As the total quantity of excavation required was estimated at 120 millions of cubic metres, the opinion was held that the mere work of clearing the course of the canal could be accomplished for about 440 millions of francs, or rather less than 18 millions sterling.

Up to the end of 1884, the Canal Company had received a total sum of 471¼ millions of francs (about 19,000,000*l.*), and had expended 368¼ millions of francs * (about 14¾ millions sterling), leaving only about 4¼ millions sterling in hand. Even at this date it was confidently stated by M. de Lesseps and his colleagues, that the canal could still be constructed for the sum of 1070 millions of francs, or about 43 millions sterling. In other words, it was held that for 25 millions sterling additional, the work could be completed as originally planned.

The work proceeded, with occasional interruptions, due either to the difficulty of obtaining sufficient capable labour, to the delay in delivering the necessary dredging and other appliances, and to other

* It may be interesting to state how this sum had been expended. The items are as follows:—

	Francs
The purchase of the concession	10,000,000
Caution money to the Colombian Government	750,000
Expenses incurred before the company was founded	23,393,605
Repayment of advances to founders	2,000,000
Cost of administration at Panama	26,415,927
Expenses of the company	26,036,551
Interest on money advanced and shares	55,700,148
Construction, purchase of land, &c.	25,289,743
Purchase of materials and equipment	83,537,568
Installations, &c.	115,137,354
	368,260,896

causes. The result of an appeal made through the 'Bulletin du Canal Interoceanique' * in the latter part of 1884, was to place a further capital of 136½ millions of francs (about 5½ millions sterling) at the disposal of the company.† With this and the balance remaining of the previous issues, the company were enabled to carry on the work until 1886, when they had to make a further appeal for assistance. This time they made a larger demand than they had done on the last occasion, and they succeeded in raising a sum of 206½ millions of francs (8¼ millions sterling), making the total amount subscribed to the end of 1886 not less than 886 millions of francs, or about 35½ millions sterling. The company was by this time getting into deep water. The public did not take to the bonds offered so readily as they had formerly done, and the deep distrust that was beginning to be felt in the success of the enterprise was shown by the very low price at which the shares had to be offered.‡

Meanwhile the prospects and progress of the company had been seriously hampered by several exceptional sources of trouble. Political strife on the isthmus disturbed the progress of the works, and led to a large migration of the workmen employed. An act of incendiarism at Colon destroyed a number of the principal buildings erected for the purposes of the canal, and led immediately to the transfer of the headquarters of the company from Colon to a new town created by them, and called by the name of Christopher Columbus. At Culebra, again, where the great work of cleaving a mountain was being proceeded with, there were several unfortunate incidents which caused the *employés* to desert the place almost in a body. These events were the origin of some sinister, rumours most unfavourable to the company. It was stated in the United States that the political troubles had been expressly "got up" by the *personnel* on the canal, with a view to giving France a pretext for seizing the Isthmus of Panama. In Europe, on the other hand, it was reported, and largely believed, that the United States proposed to take advantage of the opportunity afforded by the disturbance at Colon to seize the State of Colombia, through which the canal is

* This was a journal, published at Paris, which, at an early stage of the enterprise, was issued periodically as the official organ of the Canal Company.

† This sum was raised by the issue of 409,667 4 per cent. bonds, sold at 333 francs on 500.

‡ 458,000 shares out of 500,000 offered, were taken at 450 on 1000 francs.

carried. It is no doubt true that the United States at that time intervened, with a view to the re-establishment of order on the isthmus, but in despatching Admiral Jouett with an expedition for that purpose, they distinctly declared that their only object was to protect the lives and property of American citizens, and that they would religiously fulfil their engagements to maintain the neutrality and freedom of transit between Colon and Panama.

Another difficulty with which M. de Lesseps and his colleagues have had to contend from the beginning has been the unhealthy character of the climate. In this respect Panama has always had a most unenviable notoriety. The danger was therefore not unknown. Dampier, nearly 200 years ago, spoke of the "malignity of the waters draining off the land, through thick woods, and savannas of low grass and swampy grounds;" and Wafer reported about the same time that "the country all about here is woody, low, and very unhealthy, the rivers being so oozy that the stinking mud infects the air." Walton, again, expressly declared that the unhealthiness of the isthmus was one of the greatest obstacles to the opening of a canal between the two oceans. "Disease," he said, "is a barrier against settling on the isthmus to improve it," and he found that "persons who have withstood every other climate there became languid." Humboldt appears to have made the climate of Panama a special subject of inquiry, and reports that "for fifty years back the *vomito* (black vomit of the yellow fever) has never appeared on any point of the coast of the South Sea, with the exception of the town of Panama." This is explained by the fact that "the tide, when it falls, leaves exposed for a great way into the bay a large extent of ground covered with *Fucus ulvæ* and *Medusæ*, the air is infected by the decomposition of so many organic substances, and miasmata, of very little influence on the organs of the natives, have a powerful effect on Europeans."

Accounts of the extraordinary mortality at the works of the canal have from time to time been circulated in Europe, which read like the description of a pestilence, or of a devastating war. To Europeans especially the climate has been highly fatal. M. de Lesseps and his friends have tried, not unnaturally, to reassure the public, both European and American, on this score. Even he, however, has been compelled to admit a serious mortality. In his report on the progress of the works in 1885, he stated that during the previous twelve months more than 1100 deaths had occurred, of which some 320 were Europeans.* In some of the rainy months the mortality was frightful. In October and November it rose to nearly fifty per week. The Canal Executive declared that this large number was swollen considerably by the mortality of sailors arriving at Panama, but, however this may be, the climate is without doubt one of the most malarious and deadly to European constitutions that exists in the world.

These things being so, two results not unnaturally follow—the first, that it was difficult to get the highest class of labour to undertake the work; and the second, that the rate of wages paid, and the cost of the work generally, were exceptionally high. During the years 1884–85–86, the *personnel* on the canal ranged between 12,000 and 25,000; and although M. de Lesseps announced in 1885 that the Company had undertaken to provide barrack accommodation for 30,000, it is doubtful whether that number was ever employed on the works at any one time. We have already seen that the first contracts made with a number of different contractors provided for the cost of excavation being brought under 3*s.* per cubic metre. Señor Armero, however, in a report made on the progress of the work in the latter part of 1887, stated that every cubic foot had cost at least 2 dollars, or 8*s.* 4*d.* for excavation, being nearly three times the amount at which M. de Lesseps stated the first contracts to have been placed, for something like one-half of the entire work.

With calculations so entirely falsified by results, the Panama Canal Company found it necessary in 1887 to procure fresh capital. They thereupon offered half a million shares, of the nominal value of 500 million francs at 440 francs on 1000 francs, and succeeded in raising a further sum of about 114 million francs, making the total amount of cash received to that date rather over 1001 million francs, or, in other words, within 200 millions of the total amount for which the canal was to have been completed. How far the canal still was from completion at this time we may learn from the report made to the Colombian Government in November 1887 by Señor Armero, who says that the total amount excavated up to August of that year was about 34 millions of cubic metres, out of a total of 161 millions; that the upper and easier part of the work had been accomplished, and that greater difficulties would be encountered in working as the tide-level was approached; that the

* The manual work is and has all along been performed mainly by West Indians and natives, the number of Europeans employed being relatively very small.

cost of controlling the water of the Chagres alone would amount to 471 million francs, or, roughly, one-third of the whole estimated cost of the enterprise; that the sum still required to complete the canal would be $3012\frac{1}{2}$ millions of francs, or 120 millions sterling, being nearly three times as much as the whole original estimated cost; and that the amount to be paid on capital loaned during the next six or seven years would add perhaps 40 millions sterling to this amount.

This unfavourable report had naturally a depressing effect upon the scheme when it was made public. And yet the reporter was not entirely unfavourable to the enterprise. On the contrary, he prefaced his report by the following remarks:—

"As up to date the sum expended is 818,023,900 francs, it is evident that the cost per metre of work has been exorbitant. Were we to base our calculations on these figures, the total cost of the canal would become fabulous, and it would probably never be finished. But this is not the way to calculate. We have to look at the costly preliminary works, the purchase of the railroad, the immense amounts of materials which had to be collected, and the purchase and erection of buildings, all of which were expenses which had to be met in order that a work should progress which is perhaps the most important and colossal of modern or any times. Thus the expense of work per metre has diminished as the work has progressed, and only when it shall have been completed shall we be able to determine the cost of all the excavations."

About the close of 1887, the canal was *in extremis*. The funds in hand had sunk to a low point, and there appeared to be but little prospect of raising more. M. de Lesseps, however, again proved himself equal to the occasion. Instead of abandoning himself to despair, as the vast difficulties, past, present, and to come, would have warranted, he announced to his fellow-countrymen in a letter to the Premier that he would proceed with the work piecemeal, providing in the meantime a sufficient passage through the canal for the $7\frac{1}{2}$ million tons of annual traffic then anticipated,* and looking forward to the completion of the canal, as originally designed, by means of small levies on the annual profits, as in the case of the Suez Canal. The Consultative Commission had, he added, declared the practicability both of constructing on the central mass an upper cutting which would allow of the continuance of the level works by

* The Consultative Committee of 1879 based their Report on an anticipated annual traffic of over 4 millions of tons.

dredging, and of opening the maritime transport between the two oceans as soon as these plans were completed. M. de Lesseps went on to say:—

"This approval leaves for extraction only 40,000,000 cubic metres, 10,000,000 being hard soil, and 30,000,000 dredgable soil. The carrying out of these reduced extractions being materially ensured, we entrusted the task of submitting to us a contract for the execution of the works to M. Eiffel, whose reputation has been established by engineering skill equally exact and bold, and by his great metallurgic works; imposing on him the obligation of applying exclusively to French industry for the supply of materials, and for all other co-operation.

"This morning (November 15) M. Eiffel has engaged to execute these works at his own risk within the period and on the conditions desired by the company. It now rests with the Government of the Republic, inasmuch as French law obliges me to apply to it, to insure definitively the execution of our programme, by authorising the Universal Inter-oceanic Company to issue lottery obligations."

On the 1st of January, 1888, the amount of money at the disposal of the company was stated by M. de Lesseps to be 110 millions of francs (4½ millions sterling), and it was calculated that 300 million francs (12,000,000*l.*) would be required by the end of the year. M. de Lesseps, in asking permission to raise this sum by a lottery, placed at the disposal of the French Government all the contracts and documents in the hands of the company, "whereby the execution of the programme drawn up is guaranteed."

During the first half of 1888, several discussions of a more or less stormy character took place in the French Parliament on the proposal to authorise on behalf of the Panama Canal Company an issue of lottery bonds. In the result M. de Lesseps got his own way, the Senate sanctioning a loan with 4 per cent. interest, and a deposit of rentes as a guarantee. Subscriptions were opened on the 23rd of June. The French people, backed by the most influential newspapers in the country, looked favourably on the lottery. There were a large number of prizes to be drawn, the chief being one of half a million francs (20,000*l.*), and there were to be six drawings a year. At the outset, with inducements that appealed so strongly to the French imagination, the loan seemed likely to be covered several times over. All at once, however, the flow of subscriptions stopped. It was then ascertained that the opponents of the canal had set afloat some sinister rumours with the object of frustrating the lottery scheme. One of these was the rumour that Lesseps was dead. The veteran projector, however, was never more entirely alive. Threatened with failure, he made almost heroic efforts to avert it. He arranged for attending and speaking at meetings in all the principal towns of France, beginning at Paris. The labours now undertaken by the octogenarian canal-builder are thus referred to by the *Times* correspondent at Paris :—

"I do not know what will be the fate of the millions of lottery bonds which still remain to be placed, but what is certain is that two men never gave themselves to a more laborious work of propagandism than M. de Lesseps's and M. Charles de Lesseps, his son, have undertaken. If ever the Panama Canal is finished, if it ever yields the results promised—as to which I can make no assertion—it would not be too much to raise statues to these men, who have spared themselves no toil, but have made almost superhuman efforts to bring the work to a successful close. For a month M. de Lesseps and his son have been visiting the industrial and commercial centres, delivering addresses, taking part in banquets, organising committees, and endeavouring to create a national movement favourable to the realisation of this gigantic scheme. In all places where they have been speaking they have had crowded audiences, which have eagerly listened to them, and have shown sympathy with their efforts to make the completion of the Panama Canal a national question. Frenchmen feel that success in this work must avert a rebuff for the constructor of the Suez Canal, who will continue to be styled 'Le Grand Français' so long as the Panama Canal Scheme has not collapsed."

On the 14th December, 1888, the Panama Canal Company suspended payment. Announcement was made in Paris that in consequence of the subscription not having extended to 400,000 obligations, the payment of all coupons and drawn bonds would be temporarily suspended. The intimation caused a severe shock in Paris, although it was not entirely unexpected. The French Cabinet deemed the matter one of such importance that they held a meeting to consider what should be done. It was decided to propose a suspension for three months only. This was proposed for a double reason—to gain time, and to prevent speculation on the Bourse. It was stated by M. Peytral, the Minister of Finance, that the Government wished to enable the old company, without going through the process of bankruptcy, to hand over the canal to a new concern.

There have been few warmer discussions, even in the French Chamber, than that which followed the proposal to interpose to this extent on behalf of the canal company. It was argued by the opponents of the Government that the canal should not be treated exceptionally; that the bankruptcy law should be allowed its ordinary course; that the Government had kept secret the report of its own engineer on the condition of the company when it was known to be in danger; that the Army Bill should not be delayed for the sake of a private company; and that if the company did come to grief, nearly a million bondholders would be ruined and a milliard of money would be lost.

On the 15th December the Chamber of Deputies, acting upon the Report of the Committee appointed to consider the Bill, resolved by 256 votes against 81 to throw out the Bill. This decision created intense excitement, not only in Paris, but throughout France—aye, and throughout Europe. The shareholders in the company, 870,000 in number, were threatened with disaster, many of them with ruin. The newspapers contained reports of the condition of panic that prevailed in the capital, which recalled the similar episodes of the South Sea Bubble and Law's Mississippi Scheme. The canal company's offices in Paris were besieged by eager and demonstrative crowds. They did not, however, vent their anger and disappointment on M. de Lesseps. It was the Government that was condemned. Lesseps was still the favourite of the people. "Vive Lesseps" and "Vive Boulanger" were the cries of the hour. There were not a few who regarded the occasion as one that justified the country in getting rid of so pusillanimous a Chamber. The opportunity of the Boulangists appeared to be at hand.* The greatest but one of European Powers seemed likely to be drawn into the vortex of revolution by the obscure problem of the cost of constructing a waterway in a territory over which it had no control, at thousands of leagues from its shores. The mutability of human affairs had surely never a more striking illustration!

* The *Times* of the 17th December declared, in a leading article, that "it would be surprising if the collapse of the Panama scheme had not a momentous effect upon French politics. The small investors who have lost their money would not be human if they omitted to turn and rend the Parliament which, after affording legislative facilities to M. de Lesseps, now refuses to lift a hand to save the colossal scheme from ruin. Some of the French journals are already beginning to say that Saturday was the beginning of the end for the Republic. It is possible to commend the action of the Chamber, and at the same time to feel that 'Parliamentarism' hardly realised the magnitude of the forces which he challenged with such a light heart. All the vague discontent which has been accumulating against Parliamentary government will now naturally be brought to a head. The Panama collapse will furnish a specific grievance which will appeal with irresistible force to the unfortunate subscribers, and send them crowding into the ranks of the enemies of the Republic."

According to a statement which appeared in the *Standard* of the 17th December, 1888, a *Figaro* reporter called on M. de Lesseps, and was received by him in a drawing-room, where seven of his younger children were having a romp with their mother. The following is a description of the scene that took place:—

"'You know the vote of the Chamber?'

"'No,' he replied very calmly, stretching out his hand.

"'The Government Bill is rejected; your application is defeated; the majority against you is nearly a hundred.'

"M. de Lesseps suddenly became very pale, but remained silent. His hand, quite cold, let mine go. He carried his handkerchief to his lips, as if to stifle a cry. Then, resuming all his calmness, and drawing himself up to his full height, he murmured, 'It is impossible.'

"'It is infamous,' exclaimed Madame de Lesseps.

"'I could not have believed,' he proceeded, in a sad tone, 'that a French Chamber would thus sacrifice all the best interests of the country. Have they then all forgotten that one milliard and a half of French savings (60,000,000*l.*) are jeopardised by this vote, and they could have saved everything by a reprieve? However, in this appalling crisis I have nothing to reproach myself with. I have done all that was humanly possible to safeguard the interests of each and all, because I know that the final collapse of the Panama Canal would be not only the ruin of the shareholders, but also a calamity for the country, and a disaster for the national flag. What consoles me is the frankness with which our new provisional administrators have hastened to acknowledge that in our operations everything has been clear, honest, and straightforward. They told me so this very day, only an hour ago, and I have no evidence to contradict that. I am also encouraged by the thousands of letters I receive from my subscribers and shareholders, those unknown friends who trust me as they ever did, and who support me with valiant hearts in this last battle. Their name is legion, and to save their earnings I am prepared to make every sacrifice. Nay, even monarchs have sent me telegrams to express their anguish and sympathy. See, I have just opened this letter from Queen Isabella. It is written in Spanish, but I will translate it for you:—

"'MY DEAR FRIEND, COUNT DE LESSEPS,—At the time when difficulties are accumulating around you I feel impelled to tell you how firmly I believe in your great work, which is an object of envy to the whole world, and how much I admire your energy.

"'(Signed) ISABELLE DE BOURBON.'"

"As he concluded the reading of this letter his children came round him and kissed him. 'But you will succeed all the same, won't you, father?' they kept on repeating; and one of the younger children, a little girl about seven, coming up to me, said, 'Did the Right vote against papa, Monsieur?' I replied, 'I do not think so, Mademoiselle.' She said, 'Ah!' and, delighted at having had her say, she rushed into her mother's arms, who, still thinking of the vote, repeated, 'It is infamous, and will drive six hundred thousand subscribers to revolt. It will be the ruin of all these poor folk.'"

The experience of the Panama Canal Company, has only been a repetition, on a large scale, of that of the Panama Railway projectors. That line was commenced in 1850 and completed in 1855. The distance which it traverses, between Aspinwall and Panama, is $47\frac{1}{2}$ miles, and the cost of construction was 48,600*l.* per mile, as compared with an average cost of under 12,000*l.* per mile for the railways of the United States as a whole. The great summit-level was attained at a height of 264 feet above the mean tide of the Atlantic, and the ascent required gradients of 1 in 18. The greatest source of the heavy expense of the Panama Railroad was the labour difficulty, resulting from the influences of the climate. Of this Dr. Otis * says:—

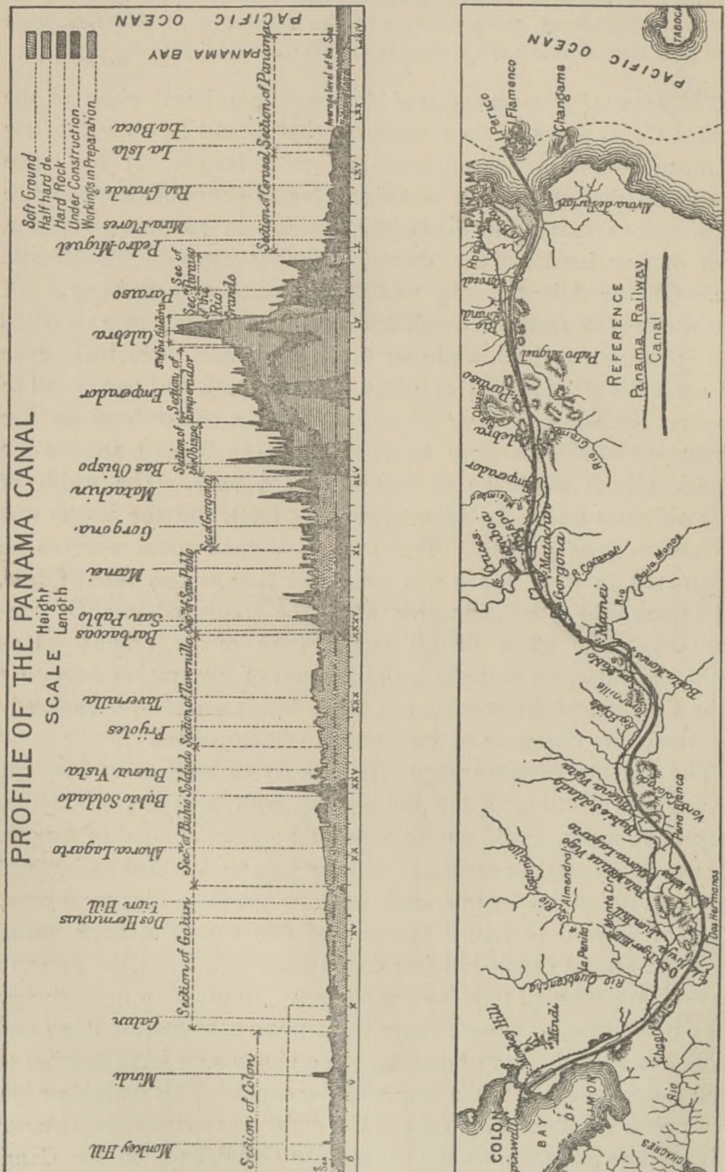
"The working force was increased as rapidly as possible, drawing labourers from almost every quarter of the globe. Irishmen were imported from Ireland, coolies from Hindostan, Chinamen from China, English, French, Germans, and Austrians, amounting in all to more than 7,000 men, were thus gathered in, appropriately, as it were, to construct this highway for all nations. It was now anticipated that, with the enormous forces employed, the time required for the completion of the entire work would be in a ratio proportionate to the numerical increase of labourers, all of whom were supposed to be hardy, able-bodied men. But it was soon found that many of these people, from their previous habits and modes of life, were little adapted to the work for which they had been engaged. The Chinamen, 1000 in number, had been brought to the isthmus by the company, and every possible care taken which could conduce to their health and comfort. Their hill-rice, their tea, and opium in sufficient quantities to last several months, had been imported with them; they were carefully housed and attended to; and it was expected that they would prove efficient and valuable men. But they had been engaged upon the work scarcely a fortnight before almost the entire body became affected with a melancholic suicidal tendency, and scores of them ended their unhappy existence by their own hands. Disease broke out among them, and raged so fiercely that in a few weeks scarcely 200 remained. The freshly-imported Irishmen and Frenchmen also suffered severely, and there was found no other resource but to re-ship them as soon as

* 'Isthmus of Panama,' p. 35.

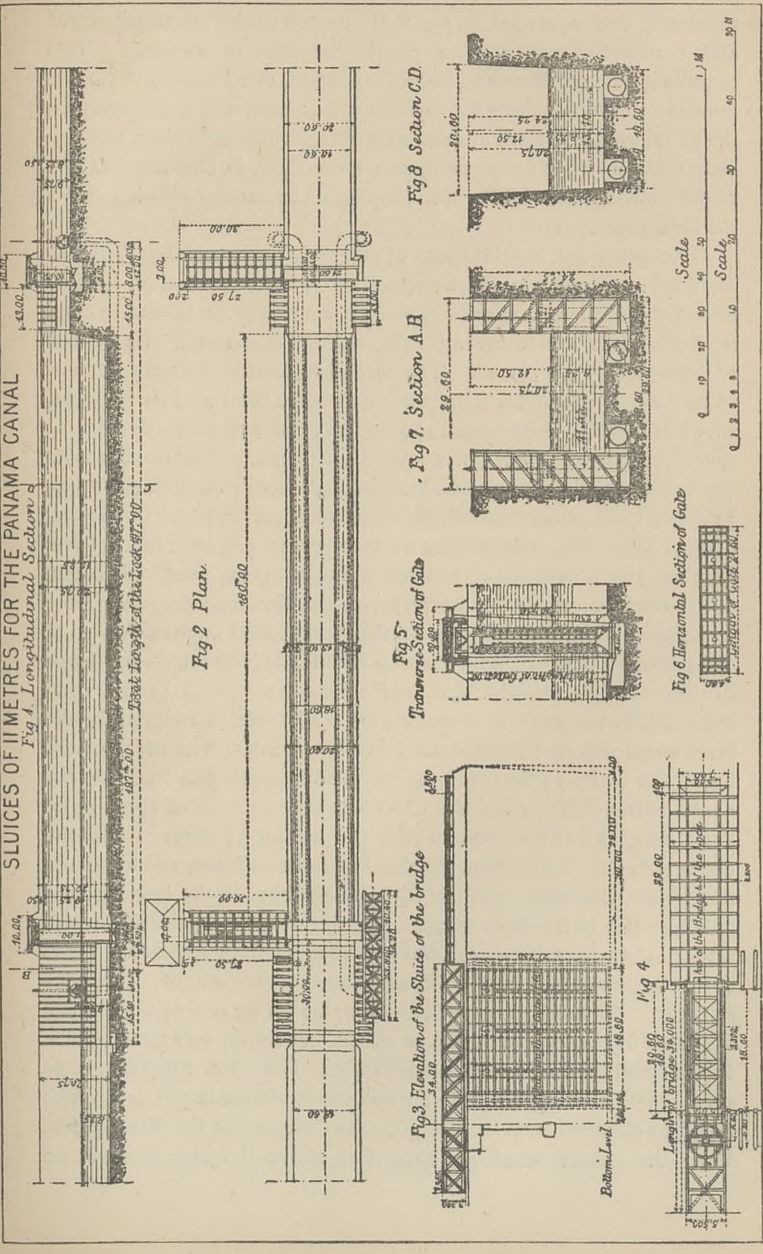
possible, and replenish from the neighbouring provinces and Jamaica, the natives of which, with the exception of the northmen of America, were found best able to resist the influences of the climate."

The proposed Panama Canal locks.—The original plans of the Panama Canal provided for a waterway that should be 28 feet below the mean ocean level throughout its entire length. It has since been found that this design would involve an enormous expenditure and a serious delay, and hence the decision in 1888 to provide a series of four locks on the Pacific, and four locks on the Atlantic side. On the Atlantic side, two of the locks were to have a fall of 8 metres (26 feet 5 inches), and two others a fall of 11 metres each (36 feet 3 inches), while on the Pacific side, three locks were to have a fall of 11 metres each (36 feet 3 inches), and one a fall of 8 metres (26 feet 5 inches). The height of the water level on the Pacific side would, therefore, be 41 metres (135·6 feet), and on the Atlantic side it would be 38 metres (125·7 feet). The width of the lock gates was to be 18 metres (59·5 feet), and the length was 180 metres (595·5 feet). The locks and their gates were to be constructed in iron, and it was estimated that 20,000 tons of cast, and 15,000 tons of wrought, iron would be employed in their construction. The effect of this modification of the original plans would, of course, be to reduce the amount of excavation necessary in the Culebra cut by at least one-third, but it would also obviously alter the entire character of the canal as first projected.

The opinion of some engineers appears to be that the frequent opening and shutting of the sluice-gates, with such a considerable pressure of water, would not be without a certain amount of danger. The pressure would be increased little by little until it had been raised to a breadth of 10 metres, and even as much as 15·40 metres. It is not unusual to find a pressure of this extent at dock gates, but in the largest canals hitherto constructed with locks, the pressure has seldom exceeded three to four metres. In order to meet similar cases, it has been proposed, where there was a constant use of a canal at all hours of the day and night, to employ a very large number of small sluices adapted to the slopes of the canal. This expedient has been put in practice in the case of the eight successive sluices known as Neptune's Staircase, on the Caledonian Canal, and, on the Canal du Midi in France, in the case of the seven sluices of the staircase of Béziers. It is, however, held by *Le Génie Civil* that such small sluices, although more easy to open and offering perhaps greater



Tracing and Profile of the Panama Canal.



M. Eiffel's Proposed Sluices for the Panama Canal.

resistance, are, nevertheless, not well adapted to the necessarily rapid and constant working of a canal like that of Panama. This expedient having, therefore, been abandoned, there remained that of movable caissons suspended by the upper part, which is known as the Eiffel system. This system, with its movable gate shut, and the recess into which it fits when open on the right, is illustrated in one of the drawings attached to this chapter, while another drawing shows the lock gate open.

The proposed modification of the original plans has been so designed as to enable the works of the tide-level canal to be continued without interruption. The lock canal was to be at sea-level from Colon to the fourteenth mile, where the first lock with a lift of $26\frac{1}{4}$ feet would be placed. The second lock with the same lift was to be placed $23\frac{1}{9}$ miles from Colon, and the third and fourth locks, with lifts of $36\frac{1}{11}$ feet each, at $27\frac{1}{4}$ and $28\frac{3}{4}$ miles respectively, making the summit-level $124\frac{2}{3}$ feet above the Atlantic. The canal was to descend to the Pacific by three locks of $36\frac{1}{11}$ feet drop, situated at $35\frac{1}{2}$, $35\frac{9}{10}$, and $38\frac{2}{5}$ miles respectively from Colon, and one lock of $26\frac{1}{4}$ feet drop at $36\frac{3}{4}$ miles, thus making up the difference in level of $134\frac{1}{2}$ feet between the summit-level and low-water of spring tides at Panama. It has been suggested that in the event of difficulties occurring in the excavation of the Culebra cutting, the summit-level might be raised to $160\frac{3}{4}$ feet, by inserting a lock with a lift of $36\frac{1}{11}$ feet on each slope of the Cordilleras, whereby time might be gained by a further reduction in the amount of excavation. The section adopted for the level canal was to be maintained in each reach. The width of the locks was to be 59 feet, and their available length 590 feet. At the Colon entrance, the canal was to have a bottom width of 590 feet for 1·86 mile, and at the Panama end, 164 feet for $3\frac{1}{4}$ miles; whilst the channel in the Pacific, from the shore at Boca to Naos, was to be 164 feet wide. Allowing a speed of $6\frac{1}{4}$ miles per hour in the long reaches, and $2\frac{1}{4}$ miles in the short reaches, and one hour for passing through a lock, a single ship would traverse the canal in seventeen hours twenty-eight minutes, and in a convoy in twenty-eight hours twenty-five minutes. Accordingly, ten vessels, or 25,000 tons, could pass through the canal in twenty-four hours, so that, if necessary, 9,125,000 tons of traffic could be accommodated annually. The water supply required for this traffic was estimated at 1,050,000 cubic yards per day, which could be obtained from the Chagres, the Obispo, and the Rio Grande. With the summit-level at $124\frac{2}{3}$ feet above the sea, it could be supplied from the reservoir created by the large dam at Gamboa; but if the summit-level was raised to $160\frac{3}{4}$ feet above the sea, pumps not exceeding 3600 H.P. would be needed for lifting the supply the additional height. The gates for the locks were designed to be hollow-iron counterbalanced caissons, suspended from a frame with rollers, running on a roadway supported by a swing-bridge across the lock, and continued above the recess at the side, into which the caisson was to retreat for opening the lock.

The watertight compartments at the lower part of the caisson, as well as the bottom portion, arranged to serve as a working-chamber, were to communicate with the outer air by shafts, provided with air-locks, so that water or compressed air could be introduced at pleasure. This arrangement would enable the counterpoise of the caisson to be readily adjusted, the different chambers to be easily reached for repairs, and the working-chamber at the base to be used for cleaning the sill from silt or *débris*. The caisson gates, in a lock of $36\frac{1}{11}$ feet lift, would be 69 feet high, 71 feet long, $13\frac{1}{8}$ feet broad at the tail, and $32\frac{3}{4}$ feet high, 71 feet long, and $9\frac{5}{6}$ feet broad at the head of the lock. The locks, being situated in rock, would have the sides of their chambers formed of the natural rock, with a slight facing of masonry where necessary; but the side walls below the gates were to be iron caissons, 18 feet broad, filled with concrete. The swing-bridges, of iron or steel, were to be 18 feet wide, and 112 feet long, the swing portion being 78 feet; and the recesses for the caissons were to be $98\frac{1}{2}$ feet long; and 23 feet wide at the top. The filling and emptying of the locks were to be effected by two cast-iron pipes, each $9\frac{1}{6}$ feet diameter, and it was calculated that the required volume of 52,300 cubic yards of water could be admitted or shut out in fifteen minutes *

Special Features of the Enterprise.—Probably no great engineering or constructive work of either ancient or modern times has been of such a gigantic and difficult character as that of the canalisation of the Isthmus of Panama. It is not that the length of the canal is exceptional; it is, on the contrary, shorter than that of many existing canals, some of which are of very small account indeed—being less than one-half the Suez Canal, less than one-third that of the canal of Languedoc, and less than one-fourteenth that of the Grand Canal of China. It is probable, also, that the building of the Great Wall of China, the Pyramids of Egypt, and several other works of antiquity that might be named,

* 'Proceedings of the Institution of Civil Engineers,' vol. xcii. p. 447.

extended over a much longer period, and involved the employment of a greater number of men. The *Royal* or *Grand Canal* of China, which was completed in the year 980, is said to have occupied the labour of thirty thousand men for forty-three years.* But none of the great works of previous epochs have been environed with so many difficulties as the Panama Canal. The scheme, on the face of it, does not look so formidable. It is only when we come to look into its details, and compare them with those of other similar undertakings, that we realise its magnitude. And it is only when we, in like manner, compare its engineering features with those of the other great engineering works of the world that we can appreciate the vast energy, enterprise, and resource that has ventured to essay so colossal a task.

The first and the most serious difficulty to be encountered was that of controlling the waters of a torrential stream, almost equal to that of some of the chief rivers of Italy, through which the canal was to run. This stream, which crosses and recrosses the line of the canal twenty-seven times, as shown in the drawing attached hereto, has several different levels, and would, if left to itself, be certain to destroy the canal in a very short time. It had therefore to be dealt with by constructing an enormous embankment raised 45 feet above the waters of the Chagres, so as to allow of their gradual escape. In this dam there are 26 millions of cubic yards of cutting; in the Culebra Col, a channel cut right through a mountain more than 300 feet above sea level, there were estimated to be 37 millions more; and in the entire line of the canal there were calculated to be about 75 to 100 millions of cubic yards of excavation, to accomplish which a serious writer in the *Edinburgh Review* maintained that it would require the labour of 20,000 men for forty-two years.

Worse than all, however, was the dreadful and deadly climate. Five months of the year are continually wet. There are few fine days in the other seven months. The annual rainfall is twelve to fifteen times that of Europe. The mortality is excessive. The cost of labour is consequently high,† but pay what they may, the company

* Prestley's 'Historical Account of Canals,' preface.

† In 1880, when the canal had been commenced, unskilled labour was paid 3*s.* 8*d.* per day. The supply at that rate was, however, insufficient, and the rate of wages was increased from time to time, until in 1877 they had reached a minimum of 7*s.* per day.

could not command the amount of labour it was anxious to employ. For the most part the labour has had to be imported from Europe and the West Indies. The men were brought to Panama at the expense of the Company, but a very large proportion of them left again immediately, for various reasons, so that the company has not been able to keep up the proper quotas of men with which they undertook to provide their contractors, who were left at liberty to throw up their contracts when they ceased to be remunerative. The cost of the undertaking was thus enormously increased beyond the original estimates. The difficulty of procuring ways and means, and the high prices that had to be paid for borrowed money, have also seriously added to the expenditure. Another serious element of cost has been the outlay incurred in providing hospital and other facilities, and the maintenance of the usually very considerable numbers who were stricken with illness, induced by their unhealthy surroundings. These and other difficulties have so seriously weighed upon the undertaking that its accomplishment has been pronounced impossible, and M. de Lesseps and his colleagues have been denounced for following a "will-o'-the-wisp." They have, however, persevered with their task for about eight years, and have made heroic, and almost superhuman efforts to keep the enterprise on its legs. In this effort they have had to depend absolutely upon their own countrymen, although they have much less maritime interest in the matter than the people of England and the United States of North America. In the latter countries the canal has all along been regarded with disfavour, not to say declared hostility. In the United States especially, M. de Lesseps has been told again and again that he was "beating the wind," and that nothing but failure could come of his project. For the time being it looks as if his candid friends were right, and M. de Lesseps was wrong.

As might be expected, there have been very conflicting calculations made as to the amount of traffic which an interoceanic canal on the American isthmus would be likely to carry. The Geographical Congress, held at Antwerp in 1871, did not venture to go beyond 4,000,000 tons per annum. When the Canal Company was started, the expected tonnage was raised to about 6,000,000 tons annually. In 1887 M. de Lesseps, in his letter to the French Premier, put the quantity at 7,500,000 tons. A writer in the *Revue-Gazette Maritime et Commerciale* (Paris) has estimated that if the

Panama Canal had been opened in 1884, there would have passed through it the following tonnage :—

	Ships.	Tonnage.
Europe	4,226	4,650,390
Asia..	2,255	1,212,178
America	2,987	3,441,598
Totals	9,468	9,304,166

This latter estimate appears to be greatly exaggerated. It is apparently founded on the assumption that the greater part of the Australasian trade would pass that way. But the fact is that the geographical distance to Sydney does not differ by quite 500 knots between any of the four routes that are, or would be, available—that is, the Cape of Good Hope, the Suez Canal, Cape Horn, and Panama, the distances increasing in the order stated. Nautical distance, moreover, as has been properly remarked, "is only one element in determining choice of route; prevailing winds and currents, avoidance of stormy seas or of rock-bound coasts, have all to be studied by the mariner; and the comparatively trifling difference in the length of the course from the Thames to Sydney by four such different routes is enough to show how important it is to have this question of routes illustrated by the experience of the skilled navigator. This consideration is enhanced by the remark that the dues for the passage of the canal would amount to as much as the cost of more than 800 knots of additional voyage."*

A much more reasonable and modest estimate than that of either of the foregoing, is that made in a recent report on the proposed Nicaraguan Canal. This estimate, based ostensibly on the United States Treasury Reports, puts the total tonnage that would have made use of the canal in 1885 at 4,252,000 tons, which is stated to be an increase of 53 per cent. in six years. At the same rate of increase, the tonnage available in 1892, when the canal was expected to be completed, would be 6,506,000 tons.†

The diagrams attached hereto show the enormous difficulties

* 'Edinburgh Review.'

† Paper read in 1887 before the American Association for the Advancement of Science.

that have just been referred to in a much more graphic way than any mere description could do. It will be observed from the illustration (p. 298) that the Rio Chagres crosses the course of the canal no fewer than five times in little more than five kilometres, and that the Rio Obispo also steps in to add to the complications of the situation. On the San Pablo section again, within a distance of three kilometres, the river crosses the line of canal three times.

The Chagres river, which is so great an obstacle in the project of the Panama Canal, rises on the western slopes of the Cordilleras, and runs through a broken and irregular country, to the north of the auriferous granite hills which branch off to Cruces and Gorgona. This river and its affluents is said to drain an area of about 1550 square miles.* From Matachin, where the Panama canal parts company with the valley of the Chagres, to the sea, there is a total distance of twenty-eight miles, in the course of which the river falls about 35 feet.† The rain of a single day is said to raise the waters of the Chagres from 35 to 40 feet, and below Matachin there is a cataract of 50 to 60 feet. It was part of the project to abandon at this point the valley of the Chagres, and to cut through the Cordilleras. The level of the bottom of the canal is here 100 feet below that of the bed of the Chagres, or 140 feet below the mean level of the nearest indicated points on the section of the plans above and below the intersection. In a length of nine miles, at the foot of the ascent of the Cordillera at Matachin, the lowest point is 166 feet, and the highest 333 feet above the bed of the canal. A tunnel of 7720 metres in length was at one time proposed to be cut through this section, but M. de Lesseps stood out for a cutting *á ciel ouvert*, and it has been remarked that according to the plans there has been an assumption that the sides of this vast cutting will stand so nearly perpendicular as to slope only one foot horizontal in every ten feet vertical. In a dry climate, with good firm clay or rock, this might not involve difficulty or danger, but the climate of Panama is exposed to a tropical rainfall. A rainfall of six or seven inches in a few hours is not uncommon.

The flood volume of the river Chagres has been estimated at 1600 metric tons of water per second, which is four times the volume of the highest flood ever measured on the Thames, and the rainfall, as a whole, has been known to exceed 120 inches in a single year.

* According to M. Reclus, 4010 square kilometres ('Comptes Rendus,' p. 265).

† This has been established by the levels of Col. Lloyd.

Besides all this, it was reported by M. de Lesseps himself,* that the borings on the Culebra range, had reached the depth of 100 feet without having met with rock. Some engineers have therefore condemned this part of the plans as faulty, arguing that such a cutting could not be expected to stand at a slope of one to one, even in a much drier climate—which means that the cutting through the Culebra would require to assume greatly larger dimensions, if it were to be of any value.

One of the most serious undertakings connected with the Panama canal was the proposal to retain the flood waters of the Chagres, by means of the enormous embankment already referred to, between the Cerro Gamboa on the south, and the Cerro Barneo on the north, thus raising the level of the waters from 40 to 45 feet above the river, in order to allow of their escape. Other two projects were submitted to meet this difficulty—the first, that of constructing a canal for the flood waters of the Chagres alongside of the navigable canal; and the second, that of tapping the Chagres at Matachin, and diverting its waters to the Pacific. As regards the first of these two alternatives, it was objected that, as large affluents flow into the river below Matachin, three parallel canals of large size would require to be constructed, in order to make the alternative of any real value; the second alternative, it was held, would afford no relief to the floods of the Trinidad, the Gatun, and the smaller affluents of the Chagres below Matachin, while it would be likely to increase the difficulties of construction at the one end as much as it reduced them at the other. Nor is it admitted by some authorities that the Gamboa dam would be likely to answer its purpose. It is contended that many embankments would be required, instead of only one, and that the construction of such an embankment from such a cutting could hardly by any possible effort be completed in twenty-six years, so that it would not be until after that time had elapsed that the canal could be commenced between Chagres and Matachin, with its bed 30 feet under sea level.

The low-water flood of the Chagres river, just below the site of the proposed Gamboa Dam, is 209 feet wide by 7 feet 6 inches deep, the bed being triangular in cross section. In November 1885, a flood occurred here, under the influence of which the river was swollen to a width of 1560 feet, with a maximum depth of 28 feet, so that it was twelve times as wide as the canal and almost as deep

* 'Comptes Rendus de l'Académie des Sciences,' vol. xciii. 1887.

at its deepest point. It is stated that the last four feet of the rise took place in four hours, and in thirty-six hours the water had risen about 20 feet. The general consensus of opinion among engineers appears to be that this immense flood has to be provided for in some way. M. de Lesseps originally proposed to meet the difficulty by constructing a dam, or embankment, two-thirds of a mile long, 1300 feet wide at the base, and 164 feet in height. This dam was to be designed so as to retain the floods which descend the Chagres river, storing the water and allowing it to escape gradually. The only alternative was to provide the flood waters with such a rapid means of escape to the ocean that they could not flood the canal.

From considerations of economy, it was recently determined to abandon the lock gates at the port of Panama. It was intended in the original scheme to provide these gates in order to control the rise and fall of the tide at this end of the canal. This movement of the tide varies from 20 to 27 feet, being at least twelve times as much as at the other end of the canal. Obviously, therefore, the canal would be seriously affected by a tidal movement of so considerable a character, and leading engineers have not hesitated to say that without the lock gates at Panama the canal is an impossibility.

American Views of the Enterprise.

"American engineers," we are told, "have never had but one opinion of the canal. As a general thing they have never believed that it could be built on the lines, within the time, nor for the money specified by M. de Lesseps." The same writer adds that "M. de Lesseps, having won fame by scooping out some sand hills and connecting some lakes and streams at Suez, thought it was a simple matter to make a canal anywhere. He has persistently refused to see any difficulties, or to squarely look the undertaking in the face, and to estimate the chances for and against its completion, and the collapse of all this will simply be a question of time." *

Another American writer adopts much the same view, in even more emphatic language, when he says † that, "of the final cost of M. de Lesseps's sea-level canal at Panama, if there could be anything

* *Engineering*, August 26, 1887.

† Commander Taylor's paper on "The General Question of Isthmian Transit," read before the American Association for the Advancement of Science, August 1887.

about it save utter failure, nothing can be known, except that it will be a fabulous amount. . . . The great difficulties and expense of excavation are still before them, and the knotty, perhaps impossible, problem of the Chagres river is still unsolved."

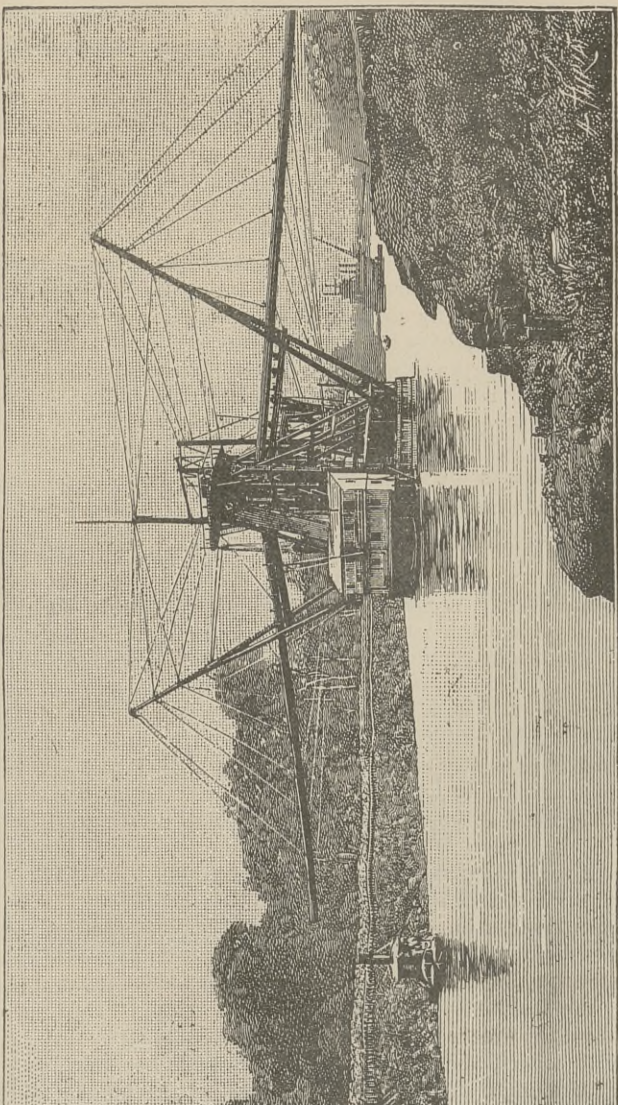
Further light on the difficulties in the way of the enterprise was thrown upon it in a report made by Lieut. Kemball, in 1887, to the United States Government. He found on the Pacific slope, a short distance west of the summit, that the route of the canal was here crossed and recrossed by the Rio Grande, which had been trained in a straight line down the north side of the valley, at a considerable height above the level of the canal.* It was found, however, when the rainy season had set in, that in different places the hillside began to slide into the cutting made for the deflection of the river, and that one bank moved almost intact across the cut, with the top surface unbroken, and without any disturbance of the vegetation. The existence of a substratum of a greasy clay bank was the cause of this trouble. Such a foundation is, of course, not to be relied on. It is ready, as has been pointed out, to "swell upwards, or glide sideways, on the slightest provocation, and it may easily develop into a difficulty of the most formidable character, requiring the river to be carried round the back of the hills away from the canal."†

In the summer of 1887, Lieut. Rogers, of the United States Navy, visited the canal works, and made a report on them. He declared that in 1886, 11,727,000 cubic metres of excavation had been done, bringing the total quantity completed up to that date at 30 millions of cubic metres. This had, however, been done in the face of tremendous odds. An American dredger of greater power was steadily engaged on the same spot for weeks, the pressure of the material laid on the bank forcing up the soft spongy bed of the cut so rapidly that the machine could do little more than merely hold its own. The canal bed had here and there been destroyed by floods. Lines and trucks had been buried under two metres of silt. In the Culebra cut, the mountain to the left hand of the cut was found to be moving towards the canal, at the rate of 11 to 12 inches per annum. Seeing that this was the case when not one-third of the excavation had been completed, the query is naturally suggested,

* The bottom of the canal is here 164 feet below the river, which, again, is 80 feet below the Panama Railway. The three courses run parallel at this point.

† *Engineering*, Aug. 5, 1887.

What will be the rate of movement when the bed of the canal is 250 feet or more under the level of the surrounding country?



AMERICAN DREDGER ON THE PANAMA CANAL.

Nor have English writers been slow to condemn the project both from its economic and from its engineering points of view. The following quotation is given as typical of much that has been written elsewhere :—

"We cannot avoid the remark that if the Interoceanic Canal be regarded, not as a Bourse speculation, but as an excavation which it is proposed to make by human agency, the question of its actual feasibility has not yet been really entered upon. An excavation which, if the last accounts of the borings be correct, would contain at least twenty times the bulk of the great pyramid; an embankment holding more than a third of the contents of that excavation, and requiring twenty-six years for its execution at the wholly unprecedented rate (from one end) of a million cubic yards in a year; a canal displacing for its execution a torrential river of four times the volume of the Thames in its heaviest flood, and with its bed at a depth of thirty feet below sea level—all this to be done while as yet the preliminary observations of rainfall, river discharge, and cross section of country have to be made—the proposal of such an enterprise seems rather worthy to adorn the name of Alexandre Dumas, or of the author of the tales of the Arabian Nights, than that of any person familiar with the practical execution of engineering work." *

With reference to the actual state of affairs at the Panama Canal in 1887, Mr. Froude has written in the following unmeasured terms† :—

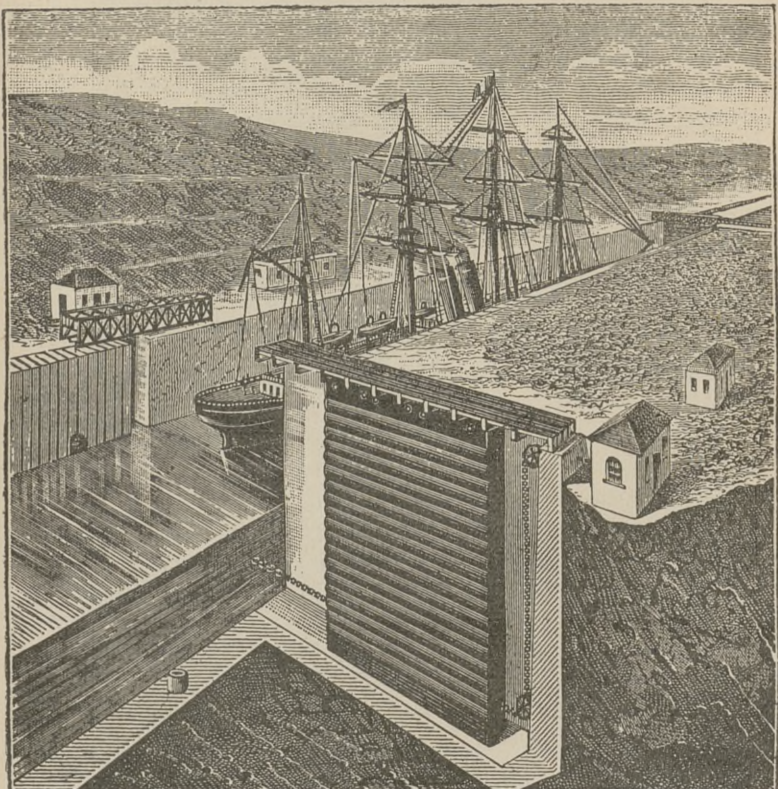
"If half the reports which reached me are correct, in all the world there is not perhaps now concentrated in any single spot so much swindling and villainy, so much foul disease, such a hideous dungheap of moral and physical abomination, as in the scene of this far-famed undertaking of nineteenth century engineering. By the scheme, as it was first propounded, £26,000,000 of English money were to unite the Atlantic and Pacific oceans, to form a highway for the commerce of the globe, and enrich with untold wealth the happy owners of original shares. The thrifty French peasantry were tempted by the golden bait, and poured their savings into M. de Lesseps' lottery box. Almost all that money, I was told, has been already spent, and only a fifth of the work is done. Meanwhile, the human vultures have gathered to the spoil. Speculators, adventurers, card sharpers, hell keepers, and doubtful ladies have carried their charms to this delightful market. The scene of operations is a damp tropical jungle, intensely hot, swarming with mosquitoes, snakes, alligators, scorpions, and centipedes; the home, even as nature made it, of yellow fever, typhus, and dysentery, and now made immeasurably more deadly by the multitudes of people who crowd thither. Half buried in mud lie about the wrecks of costly machinery, consuming by rust, sent out under lavish orders, and found unfit for the work for which they were intended. Unburied altogether lie skeletons of the human machines which have broken down there, picked clean by the vultures. Everything

* 'Edinburgh Review,' August 1882.

† 'The English in the West Indies.'

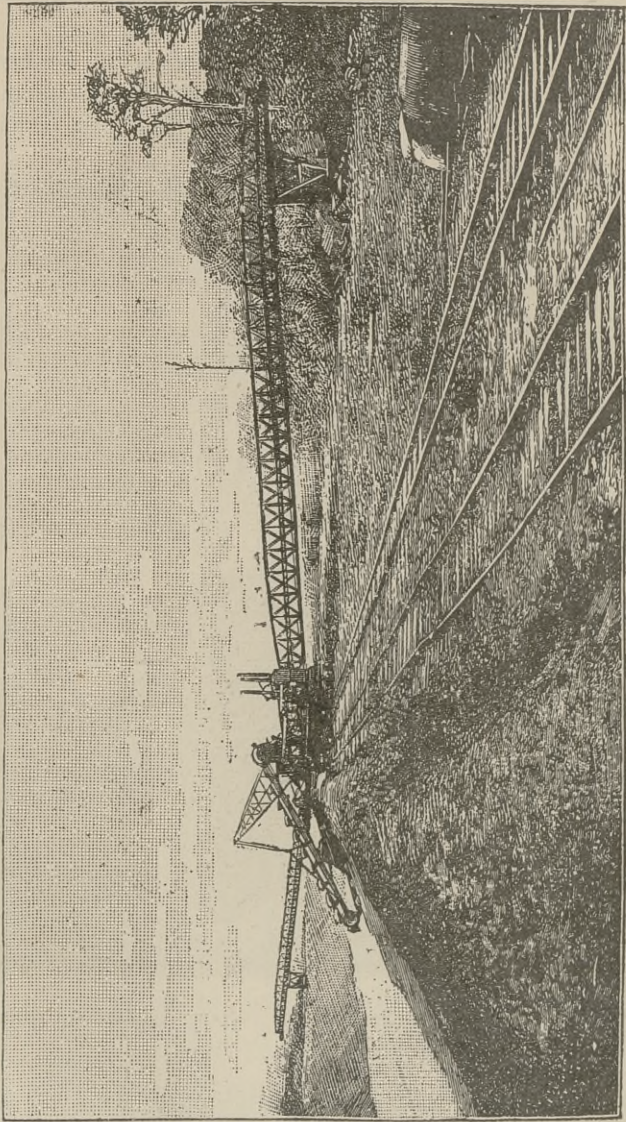
which imagination can conceive that is ghastly and loathsome seems to be gathered into that locality just now. I was pressed to go on and look at the moral surroundings of 'the greatest undertaking of our age,' but my curiosity was less strong than my disgust."

The time has not yet come when the true history of the Panama Canal Scheme can be written. It may have been an ill-judged project, or it may not. It has, however, had enormous difficulties



PROPOSED SLUICE OF 11 METRES ON THE PANAMA CANAL, SHOWING THE ROLLING GATE OPEN.

to contend with. Those difficulties began with the climate, continued with the administration and finances, and concluded with the open hostility of very many individuals and interests that were never very friendly to its success. The enterprise was essentially French, alike in its conception, initiation, engineering, and finances. The phenomenal success that attended the Suez Canal probably led the



Dingle's Dredger at Work at Gatun, on the Excavation of the Panama Canal.

majority of the unfortunate people who put money into the Panama Canal to suppose that it was to be another Egyptian Canal "writ large;" but there has also been a strong feeling of *esprit de corps*, which we cannot fail to admire, however disastrously it may have turned out for themselves, which the French have put into this matter. The truth is that the French people have come to regard themselves as a royal race in canal construction. The Languedoc Canal, which they constructed in the reign of Louis XIV cost 14,000,000 livres, and marked a new epoch in the history of canal construction.* Of the Suez Canal, the leading features of which are so well known, it is unnecessary to say more than that its success has not only been phenomenal, but has been achieved in the face of the most discouraging attitude on the part of the engineers of other countries, including England. At the time that the Panama Canal was being promoted, M. de Lesseps was able to point his countrymen to the fact that the shares in the Suez Canal, which had been issued at 500 francs, had risen to a value of 2200 francs, while the debentures issued at 300 francs were worth 565. The impressionable French people did not stay to recollect that the two enterprises were totally different in character, in cost, in accessibility, in practicability, and in prospects. And it is only fair to recollect that the original estimate of the cost of the canal has been largely exceeded by circumstances that were hardly capable of being foreseen. The repeated attacks made by inimical interests, led to the company having to borrow on higher terms, as well as to the suspension of work on the isthmus for nearly a year. A much larger amount and higher rate of interest has had to be paid to share and debenture holders than was ever expected. The Company have also had to contend with a want of navvies, and with labour disturbance, that told unfavourably on their interests.

The Report of the Special Commission appointed in 1889 to inquire into the affairs of the Panama Canal was published in May, 1890, and describes in detail the position of the undertaking. It is estimated that some 30 millions will be required to complete it, so that its ultimate construction does not appear at present very probable.

* The history of this canal, which crosses the isthmus that connects Spain with France, is told elsewhere in this volume.

CHAPTER XXII.

THE NICARAGUAN CANAL.

One of the most important and costly of isthmian canal projects that now looms on the horizon is that which is designed to afford a communication between the Atlantic and the Pacific Oceans *viâ* the Lake of Nicaragua. This is a purely American project. It is put forward by American citizens, it has been drawn up by American engineers, and it is in favour with the American people. After the Nicaraguan Canal project had been before the world in one shape or another for many years, and after many different routes had been proposed and considered, the plans for a canal have now been definitively adopted, and the work of construction has, it is stated, actually begun. It has not yet been announced whether the capital required has been subscribed, but the United States, which approves the scheme, and has raised from first to last some 9000 millions of dollars for railway enterprise, is perhaps hardly likely to allow the canal to drop for want of the 20 millions sterling required to complete it.

None of the many schemes for a canal across the American isthmus has obtained more extensive support, both in America and in Europe, than that *viâ* the Lake of Nicaragua. It had the very earnest support of the Emperor Napoleon between 1845 and 1848. In 1846, the Emperor, then Prince Louis Napoleon, wrote a pamphlet on the subject,* in the course of which he pronounced against the Panama route, and he once declared, as regards the rival Nicaraguan

* In 1842 several influential persons in Central America wrote to the Prince, then a prisoner in the fortress of Ham, suggesting that he should endeavour to obtain his liberation from the French Government, under an engagement to proceed forthwith to Central America. In 1845 this overture was more formally repeated in a despatch from M. Castellon, then Minister of the Central American States in Paris ; and a few months later, Senor del Montenegro announced to the Prince that the Government of Nicaragua had conferred on his highness full powers to conduct and execute the undertaking. The refusal of the French Government to liberate the Prince put an end to the scheme at that time; but after his escape and arrival in London he was not indisposed to renew the negotiation, and he then wrote the pamphlet referred to.

SECTION AND PLAN OF THE PROPOSED NICARAGUA CANAL.

scheme that, "from the embouchure of the river San Juan to the Pacific Ocean the canal would run in a straight line about 278 miles, enhancing the prosperity on either bank of more than a thousand miles of territory. The effect that would be produced by the annual passage through this fine country of two or three thousand ships, exchanging foreign produce with that of Central America, and spreading everywhere activity and wealth, would be almost miraculous." *

The expense of the Nicaraguan Canal was estimated by Napoleon at only four millions sterling; but it is obvious, from the Prince's own statements, that such a passage as he contemplated would only have afforded draught of water for vessels of 300 tons. Napoleon's object was, however, quite as much to promote emigration, trade, and civilisation in the State of Nicaragua, as to open a communication between the two oceans.†

The river San Juan de Nicaragua directly connects the Atlantic with the south end of the lake of the above name, from the northern end of which but a few miles intervene to the Pacific. Various surveys have been made of the river, with a view to the construction of a canal. In 1837–8 Lieutenant Baily ‡ was employed by the Central American Government to explore the route. He found that the surface of the lake of Nicaragua is 121 feet 9 inches above low water in the Atlantic. The river San Juan, in its course of 79 miles from the lake, varies in depth from 9 feet to 20 feet, and its course is broken by various rapids, some of which are of considerable length. The summit-level of the mountain chain which divides the valley of the lake from the Pacific is 487 feet above the lake, and a tunnel of nearly 16 miles long would have to be pierced through this wall in order to reach the port of San Juan del Sur on the Pacific. The total length of navigation, through river, lake, and canal, according to Mr. Baily's plans, would be 190 miles.

The port of San Juan del Sur is narrow at the entrance, but widens within the harbour. It is surrounded by high land, except from W.S.W. to W. by S. The depth of water at the entrance is 3 fathoms, and the width 1100 yards. Ships could thence go up for a mile and a half, but the amount of excavation required for a canal 30 feet deep and 50 feet wide was estimated at not less than 162

* Min. Proc Inst. C. E., vol. vi. p. 428.

† 'Edinburgh Review,' April, 1882.

‡ Vide 'Central America,' by John Baily, R.M., London, 1850.

million cubic yards, which has been stated to be more than that required for the construction of 2000 miles of English railway—a figure quite conclusive against this scheme.

In 1852 the route was surveyed by Colonel Childs,* who proposed to descend from the lake by fourteen locks to Brito, on the Pacific, where, however, there was no harbour. The length of this route was given as 194 miles.

To avoid the difficulty of cutting through the ridge, it has been proposed to continue the navigation from the extreme north of the Lake of Nicaragua, by the Estero de Panaloya and the river Tipitapa to the Lake Leon, or Managua, and thence to the port of Realejo, on the Pacific, or, yet more to the north, to the Estero Real, an arm of the Gulf of Fonseca. But it has been pointed out that the length of the navigation would thus be increased by a hundred miles, and it is doubtful whether Lake Leon could furnish the water necessary for lockage, in both directions, which it would have to supply.

The Nicaragua route, therefore, whatever may be its advantages, if any, over that of Panama, is liable to the objections of great length, large works, numerous locks, and the no less formidable danger, to use the words of Humboldt, that "there is no part of the globe so full of volcanoes as this part of America, from the 11th to the 13th degrees of latitude."†

The distance from ocean to ocean by the route that has recently received the approval of the United States Government, and is now in course of apparent realisation, is 169·8 miles. Of actual canal there will be 40·3 miles, the remaining 129·5 miles being free navigation through Lake Nicaragua, the Rio San Juan, and the valley of the Rio San Francisco.

Beginning on the Pacific side, the canal starts from the port of Brito, situated about 12 miles north-west of San Juan del Sur, the Pacific terminus of the famous gold-fever transit route, where there is a broad channel, 342 feet wide at high water, reaching inland about 1½ miles to the tidal lock. This lock lifts the canal 24·2 feet above high tide of the Pacific.

From this lock, which is really the beginning of the canal—the portion between the lock and Brito being in reality an extension of the harbour—the canal ascends the broad gently-sloping lower valley of the Rio Grande, which is to be diverted into the lake by an

* Min. Proc. Inst. C. E., vol. xv. p. 379.

† 'Edinburgh Review,' April, 1882.

artificial channel, rising by means of three or more locks of from 26 feet to 29 feet lift, till, at a point $8\frac{3}{4}$ miles from Brito, it reaches the western end of the summit level, 110 feet above mean tide; thence it proceeds through the upper valley of the Rio Grande and across a moderately rolling country to the summit or "divide," between the Pacific and the lake, 41·4 feet above the level of the water in the canal; then through the valley of the Guscoyol, a tributary of the Lajas, and along the bed of the diverted Lajas to the lake, a total distance of $8\frac{1}{2}$ miles from the last lock and 17·27 miles from Brito.

Between the lake and Brito one small stream is taken into the canal by a receiving weir. The river Tola and several small streams coming from the north are to be passed under the canal, and along its lower portion there will be ditches to intercept the surface drainage, which is inconsiderable, and convey it to the sea.

The material to be excavated in this division is sand, gravel, clay, and in the "divide" cut rock, which will be utilised in the construction of the breakwater at Brito, in pitching the canal slopes, and in concrete for the locks, culverts, weirs, and the dam across the Rio Grande. The location of the canal in this division is the same as that proposed by the engineer Menocal on his return from Nicaragua in 1880. The prism, however, has been increased, the number of locks reduced, and their location changed. The enlargement of the terminal section is also a new feature.

The canal enters Lake Nicaragua, an inland sea, 40 miles wide, and over 90 miles long, which forms its summit level, and with the Chontales Mountains on the left, the route is continued to Fort San Carlos at the outlet of the lake into the Rio San Juan. Throughout this distance of $56\frac{1}{2}$ miles, 28 feet of water can be carried to within 2400 feet of the mouth of the Lajas on the west shore of the lake, and within eight miles of Fort San Carlos on the south-eastern shore. In the former distance some dredging and rock excavation under water will be necessary, and in the latter, dredging in soft mud to an average depth of $3\frac{1}{2}$ feet. From Fort San Carlos the route proceeds 64 miles down the San Juan river, which, with the exception of the 28 miles from the lake to Toro Rapids, has a depth varying from 28 feet to 130 feet, to the dam thrown across the river at Ochoa just below the mouth of the Rio San Carlos. Throughout this stretch of river, the only work to be done is dredging in mud and gravel, and some rock excavation under water to an average depth of four feet along a distance of 24 miles, below Fort San Carlos, and light excavation above water on some points in the lower river in order to flatten the bends.

The dam just mentioned is located between two steep, rocky hills, at a point where the river is 1133 feet wide between the banks, with an average depth of 6·6 feet. Its length on the crest will be 1255 feet, its height 52 feet, the depth of foundations 20 feet below present water level, and it is to be constructed entirely of concrete, with timber-lined crest, front, and apron, and rip-rap protected back, forming a monolith wedged between rock abutments. This dam will back the water of the river the entire distance to Fort Carlos and into the lake, maintaining the water of the latter at the proposed level of 110 feet, and will convert the upper San Juan into an extension of the lake, with a fall of ¾ inch per mile.

The valley referred to, flooded by the back water from the dam, affords an excellent basin at the entrance of the canal, free from the influence of the river current, and the latter forms a natural, ready-made canal, 3300′ long, needing only slight excavation on the points of two or three spurs for rectifying the channel. From the head of this valley, a canal 1·82 miles long extends across a broken country of moderate elevation, intersecting one deep narrow ravine, debouching towards the San Juan, across which a short embankment will be necessary, and enters the valley of the river San Francisco. This river San Francisco flows east, north-east, and east, approximately parallel to the San Juan, and separated from it by a range of hills to a point about nine miles (in straight line) from the dam, then, receiving a considerable tributary (the Cano de los Chanchos) from the north-east, turns abruptly to the south-east and south, and enters the San Juan. Its valley thus forms an irregular flattened Y, with its foot or stem resting on the San Juan, one arm extending westerly to within a short distance of the dam, and the other easterly in the direction of Greytown.

Across the stem of this Y, just below the junction of the two arms, will be built an embankment 6500 feet long on the crest, and having a maximum height of 51 feet. This embankment will retain the water of the San Francisco and its tributaries, flooding the whole upper valley (the arms of the Y) to a depth of from 30 to 50 feet, and forming a large lake at the same level as the river above the dam—in other words, a continuation of the summit level.

Proceeding from the end of the short canal already described, the main canal passes down the westerly arm of this broad, deep, crescent-shaped basin, past the embankment, then up the easterly arm to the western foot of the divide between the San Francisco and the San Juanillo, 12·55 miles from the dam, and within 19·48 miles of Greytown. Here the eastern division of the canal is entered, beginning at the Saltos de Elvira, whence it proceeds nearly due east, through the broad, flat upper valley of the Arroyo de las Cascadas, cutting a spur here and there to the "divide," less than one mile from the Saltos, and 280 feet above the sea. Then curving gradually to the south-east, across the little plain at the summit, it cuts a steep, narrow spur, enters the valley of the Deseado, a stream flowing into the San Juanillo, follows its bed a short distance, then crosses to the left bank, and reaches the site of the upper lock of the eastern flight, 14,200 feet from the Saltos. The average cut for this distance is 149 feet.

At this lock, excavated in the rock foundations of a spur of the northern hills, the summit level, reaching back through the San Francisco basin, up the San Juan, and across the lake to the first lock on the west side, a distance of 144·8 miles, ends, and the canal, lowered 53 feet by the lock, passes by easy curves down the widening valley of the Deseado to the next lock, less than a mile beyond. Here another drop of 27 feet occurs, and then the canal follows the still widening and gradually descending valley in a north-easterly direction for less than three miles to the third and last lock at the mouth of the valley. This lock lowers the canal to the sea level, and from here it takes a direct course across the flat low basin of the San Juanillo and the Lagoon region, to the harbour of San Juan del Norte, or Greytown, about 11½ miles distant.

The surface drainage to be provided for in this division is not extensive, and it is especially small on the western slope of the "divide," where three short artificial channels will divert it all into the San Francisco Lake at some distance from the canal. Across the "divide," and as far as the first intersection of the canal and the Deseado, the natural drainage is away from the canal. From this point to the San Juanillo the canal will be protected on both sides by drains formed partly by the present bed of the Deseado, and partly by artificial channels. The remainder of the canal, through the low land from the San Juanillo to Greytown, will be protected by embankments formed by the material deposited by the dredgers, an artificial channel being cut on the south to divert the San Juanillo, and another on the north to give Laguna Bernard and its tributaries an independent outlet to the sea. From the last lock to Greytown the canal is enlarged, as at Brito, on the west side, forming an extension of the harbour 11½ miles inland. The material to be excavated in this division is sand, gravel, and alluvial soil (all dredgable material) for a distance of 12 to 15 miles from Greytown, then clay, gravel, and rock in the deeper cuts, and finally, in the "divide," cut rock, which will be utilised as on the west side, in the construction of the embankment, in the breakwater at Greytown, in pitching the canal slopes, and in concrete for the dam and locks.

About 27 miles of the actual canal will be ordinary excavation, and it is proposed that the remaining 13 miles will be largely, if not entirely, excavated by dredgers. In the western division, the excavation of the portion of the canal between the last lock and the Pacific by dredgers will solve the problem of the drainage of the work for that division, as on the remaining excavation, being above sea-level, the question of drainage will be perfectly simple.

In the eastern division, as in the western, the portion of the canal between Greytown harbour and the first lock, a distance of 11½ miles, will be dredged.

The "divide" cut from the basin of the San Francisco to the upper lock, 14,200 feet in length, and with an average depth of 149 feet, is admitted to be a serious work; but with the neighbouring streams offering water at a high head for removing the surface earth by hydraulic mining, with a large plant of power drills worked by compressed air from the same source, and the use of modern explosives to loosen the rock, with a large proportion of the excavated rock to be used in the construction of the locks and the dam, and in pitching the slopes of the canal, a still larger quantity utilised in the construction of the harbour at Greytown, and convenient dumping-grounds for the remainder, the engineers claim that the work can be accomplished.

The following description of the proposed locks is taken from the report of Mr. Menocal, one of the engineers:—

"The locks proposed have a uniform length of 650 feet between the gates, and at least a width of 65 feet between the gate abutments. Locks Nos. 1, 2, 4, 5, and 6 have lifts of 26, 27, 26·4, 29·7, and 29·7 feet respectively. No. 3 has a lift of 53 feet, and No. 7, being a combination tide and lift lock, its lift will vary between 24·2 and 33·18 feet, depending on the state of the tide. It is believed that Nos. 1 and 7 will rest on firm, heavy soil, but timber and concrete foundations have been provided for in the estimates. Nos. 2 and 4 are estimated to rest on solid rock, and as for Nos. 5 and 6, the borings taken in 1873 show that stiff clay, compact sand and gravel will be met with. No. 3 is proposed to be cut out of the solid rock in the eastern slope of the 'divide,' by which the maximum strength will be secured with the least expense, concrete will be used only to the extent required to fill cavities, to give the proper dimensions to the various parts, and to give a surface to the blasted rock. The other locks it is proposed to build of concrete, and all of them, No. 3 included, will have a heavy timber lining in the chambers and bays, extending from the top of the walls to 15 feet below the low-water level.

"Cribs on firm bottom, or fender piles, when piles can be driven, have been provided at the approaches to the locks for the protection and better guidance of ships into the locks. Provision has also been made for making ships f st to the lock walls, so that the lines will, by means of floats, rise or fall with the ship, thus preserving the same tension on the lines while the vessel is kept in the axis of the lock. Each lock will be filled or emptied by conduits extending from the upper to the lower reach of the canal, and branch culverts connecting the main conduit with the lock chamber. The only operation required for either filling or emptying the lock will be, irrespective of the movements of the lock gate, the opening and closing of the upper and lower main culvert-gates. The time required to fill or empty lock No. 3, of 53 feet lift, will be fifteen minutes, and for the other locks an average of eleven minutes. The question of the best style of gates for these locks has been a subject of much consideration. It is desirable to combine strength, economy in construction, rapid and simple movements, facilities for repairs or for renewing the gates, and the least danger of accident by vessels entering or leaving the locks. The necessary machinery for moving the locks and culvert-gates, for hauling ships in and out of the locks, for electric lights, and other purposes, will be worked by hydraulic power furnished by the locks themselves."

The chamber width of the locks will be 80 feet, so that these structures will contain almost any merchant vessel afloat.

In the plans proposed for the canal, not only have enlarged prisms been provided for, but large basins are proposed at the extremities of the locks. These basins, the enlargement of the canal at each end, with the lake, the river and the San Francisco basin, will permit vessels to pass each other without delay at almost every point on the route. Mr. Menocal states that —

"In 22·37 miles, or 57 per cent. of the canal in excavation, the prism is large enough for vessels in transit to pass each other, and of a sectional area in excess of the maximum area in the Suez Canal; the remaining distance in which large vessels cannot conveniently pass each other is so divided that the longest is only 3·67 miles in length; with two exceptions, those short reaches of narrow canal are situated between the locks, and can be traversed by any vessel in less time than is estimated for the passage of a lock; consequently, unless a double system of locks be constructed, nothing will be gained by an enlargement of the prisms. The exceptions referred to are the rock-cuts through the eastern and western 'divides,' 2·58 and 3·67 miles, respectively, in length. The possible detention in the transit, due to those narrow cuts, which should not in any case exceed 45 minutes, would not justify the necessary increase of expense involved in an enlargement of the cross-section proposed. Both the bottom width and the depth of the proposed canal are larger than those of the Suez Canal.

" In the lake and in the largest portion of the San Juan River vessels can travel almost as fast as at sea. In some sections of the river, and possibly in the basin of the San Francisco, although the channel is at all points deep and of considerable width, the speed may be somewhat checked by reason of the curves.

" Estimated time of through-transit by steamer.

	Hrs.	Mins.
38·98 miles of canal, at 5 miles an hour	7	48
8·51 miles in the San Francisco basin, at 7 miles an hour ..	1	14
64·54 miles in the San Juan River, at 8 miles an hour	8	4
56·50 miles in the lake, at 10 miles an hour	5	39
Time allowed for passing 7 locks, at 45 minutes each	5	15
Allow for detention in narrow cuts, &c.	2	0
Total time	30	0

"The experience of the Suez Canal shows that the actual time of transit is more likely to fall under than to exceed the above estimate.*

" The traffic of the canal is limited by the time required to pass a lock, and on the basis of 45 minutes (above estimated), and allowing but one vessel to each lockage, the number of vessels that can pass the canal in one day will be 32, or in one year 11,680,† which, at the average net tonnage of vessels passing the Suez Canal, will give an annual traffic of 20,440,000 tons. This is on the basis that the navigation will not be stopped during the night.

" With abundant water power at the several locks and the dam, there is no reason why the whole canal should not be sufficiently illuminated by electric lights; and with beacons and range lights in the river and lake, vessels can travel at all times with perfect safety. The estimated cost of the canal is 64 millions of dollars, or 13,000,000*l.* including electric lighting, &c., and it is calculated that the work can be completed in six years.

* The time of passage through the Suez Canal is now about 16 hours.

† In July, 1886, 1296 vessels passed through the St. Mary's Canal lock.

ESTIMATES OF COST MADE IN 1888.

TABLE OF PRICES.

		Per cubic yard. dols.
Excavation in earth		0·40
Excavation in rock		1·50
Excavation in rock (sub-marine)		5·00
Dredging	0·20 and	0·40
Concrete	6·00 and	9·00
Stone pitching		2·00
Stone in breakwaters		1·50
Puddle		0·75
Timber		0·50

Western Division:—	dols.
Excavation and embankment	8,496,292
Diversion of Rio Grande and Rio Lajas	1,870,447
Other auxiliary work, including R. R.	753,329
Locks (four)	4,762,480
Harbour of Brito	1,611,500
Total	$17,484,048

Middle Division:—	dols.
Lake Nicaragua	379,520
River San Juan	3,074,791
Valley of R. San Francisco	1,112,413
Dam across R. San Juan	1,858,975
Embankment across R. San Francisco	1,331,262
Embankment near Ochoa	45,578
Railroad	240,000
Total	$8,042,539

Eastern Division:—	dols.
The "Divide"	11,982,938
From the "Divide" to Greytown	8,077,294
Locks (three)	3,561,515
Railroad	320,000
Harbour of Greytown	1,766,625
Total	$25,708,372

RECAPITULATION.

	dols.
Western Division	17,484,048
Middle Division	8,042,539
Eastern Division	25,708,372
Total	$51,234,239
Surveys, hospitals, shops, &c.; management and contingencies, 25 per cent.	12,808,740
Grand total	$64,043,699

The Canal Company has received from the Nicaraguan Government a concession which allows a period of $2\frac{1}{2}$ years from 1887, within which to begin operations, a grant of 1,000,000 acres of land, and immunity from taxation and import duties for 99 years. The Canal Company estimate that by 1894, shipping to the amount of 8,000,000 to 9,000,000 of tons would avail itself of this route. The leading commercial bodies of New York, New Orleans, St. Louis, Cincinnati, Chicago, Indianapolis, and San Francisco, have expressed themselves favourable to the project, which has also been supported by the Legislatures of California and Oregon.

The great majority of the people of the United States are only interested in the construction of a canal across the American isthmus, in so far as it will tend to make them independent of the Pacific railway companies, which have of late years shown a disposition to work together and pool their traffic at the expense of the traders. There is, perhaps, very little to complain of in this respect, so far as the average range of American railway rates is concerned. But the Americans are 'cute enough to know that if they could play off the steamship against the railway, the ultimate result, though it might be disastrous to both transportation agencies, would be favourable to the trader so long as the competition lasted. The actual present sea distance from New York to San Francisco, with an isthmian canal opened, would be shortened by 8000 miles. The distance, therefore, would not be materially greater by canal than by railway. The ship, however, all other things being equal, will always carry more cheaply than the locomotive.* Whether the difference would be very material when the canal company's tolls have been paid remains to be seen.

It is probable, that with the opening of the canal, a great stimulus would be given to the coasting trade of the United States, and especially between the two ports of New York and San Francisco, to the probable detriment, at least for a time, of the trans-continental railways. The very large trade that is now being cultivated between the United States and Central America, the republics of Peru, Chili, and Ecuador, and something like one-half of Mexico, would be equally benefited by the new means of communication. With all this to depend upon, the promoters of the canal are probably not over-sanguine in expecting that its financial results would

* The cost of transport of a ton of traffic by an Atlantic freight steamer has been reduced to one penny for some forty miles.

be fairly satisfactory. The experience of the Suez Canal at least encourages that hope, although it is to be remarked that the cost of the Nicaraguan canal, will probably, when completed, have been more than that of the Suez waterway.

The local advantages of the Nicaragua route for a ship canal are generally recognised in the United States. A recent writer * on the subject states that—

" The range of what in other parts of Northern and Central America are mountains, and at Panama has proved one of the obstacles that have wrecked the French Company, on the Nicaragua line, dwindles to its lowest elevation, as if inviting a junction between the Atlantic and Pacific Oceans. The western shore of Lake Nicaragua is but fifteen miles from the Pacific, and the ' divide,' which north and south at this point assumes mountainous proportions, is less than 50 feet above the level of the lake, and about 150 feet above the mean level of the Pacific Ocean. Although so close to the Pacific slope, and with so slight a barrier holding back its waters, the great lake of Nicaragua drains through the river San Juan to the East into the Caribbean Sea. The lake itself is deep and unobstructed, and that portion of the river San Juan needed for navigation purposes requires but little work to adapt it for the heaviest draught vessels. The Lake of Nicaragua is undoubtedly the key to the situation, forming the summit level, and supplying the immense amount of water required to operate a lock canal on the large scale projected."

The route from Greytown, on the Atlantic, to Brito, on the Pacific, a distance of 170·099 miles, has been divided thus :—

	Free navigation.	Canal in excavation.
East side	..	16·048
West side	..	11·160
Six locks	..	0·759
Deseado basin	4·220	..
San Francisco and Machado basins	11·368	..
Tola basin	5·504	..
River San Juan	64·540	..
Lake Nicaragua	56·500	..
Total miles	142·132	27·907

The minimum radius of curvature is 2500, and the principal dimensions of the canal in excavation are as follows : rock, width,

* 'Engineering and Mining Journal' (New York), Map 4, 1889.

bottom, 80 feet; top, 80 feet; depth, 30 feet; earth—width, bottom, 120 feet, top, 180 feet; depth, 46 feet; sand and loose material —width, bottom, 120 feet; top, 360 feet; depth, 30 feet.

The most important parts of the work are the construction of the harbours—Greytown on the Caribbean Sea, and Brito on the Pacific; the damming of the San Juan river, for the purpose of raising and maintaining the level of Lake Nicaragua and the river at about 110 feet above mean tide level; the formation of artificial basins at different levels by means of dams, and the use of locks to pass from one level to another.

The harbour of Greytown is now closed by a sand bar, and nothing of greater draught than six feet can enter, but it is said that in three months or less from the commencement of the work vessels drawing 15 feet of water will be able to land materials. It is proposed to make this opening through the sand bar by means of a temporary jetty of brush and pile, to furnish protection to a dredger cutting through the bar. This jetty will also give the necessary protection for the maintenance of the passage by diverting the shore current which has deposited the sand.

The branch mouth of the river San Juan, which at present empties into the harbour, and is constantly, with every heavy rain, adding to the accumulation of silt in it, will be cut off, and, by a short canal, diverted so as to empty by the principal mouth of the San Juan some miles to the south.

The heaviest piece of work on the canal is a rock cut through the "divide" on the eastern portion of the summit level, commencing about four miles to the west of lock No. 3. This cut is about 2·9 miles long and the average depth is about 150 feet, involving a removal of about 2,150,000 cubic yards of earth, and 7,500,000 cubic yards of rock.

Lake Nicaragua has a watershed of 8000 miles. The only outlet of the lake is the San Juan river, which discharges, at its lowest stage, near the close of the dry season, 11,390 cubic feet of water per second. For thirty-two double lockages, it is estimated that $129\frac{1}{2}$ million cubic feet of water will be required, being little more than one-eighth of the total supply of the lake alone. It is claimed that as this supply is from the summit, a dry summit level is almost impossible, while importance is attached to the fact that the canal will be a fresh-water one.

The principal distances to be saved by the Nicaraguan Canal, as compared with the only existing alternative route by Cape Horn, are said by the Company to be:—

	By Cape Horn.	By Nicaraguan Canal.	Distance Saved.
New York to—	miles.	miles.	miles.
San Francisco	14,840	4,760	10,080
Hong Kong	18,180	11,038	4,163
Yokohama	17,679	9,363	6,827
Melbourne .. .. : ..	13,502	10,000	3,290
Sandwich Islands	14,230	6,388	7,842
Liverpool to—			
San Francisco	14,690	7,508	7,182
Guayaquil	11,321	5,890	5,431
Callao	10,539	6,461	4,078
Valparaiso	9,600	7,448	2,152

The promoters of the Nicaraguan Canal appear to have got fairly to work. A considerable quantity of machinery, as well as a number of surveyors and engineers, have been forwarded to the scene of operations, and the latest reports are favourable to the prospect of the enterprise being carried out. It will necessarily, however, involve several years of close work before it is available, even under the most favourable circumstances, for the commerce of the world.

CHAPTER XXIII.

THE MANCHESTER SHIP CANAL.

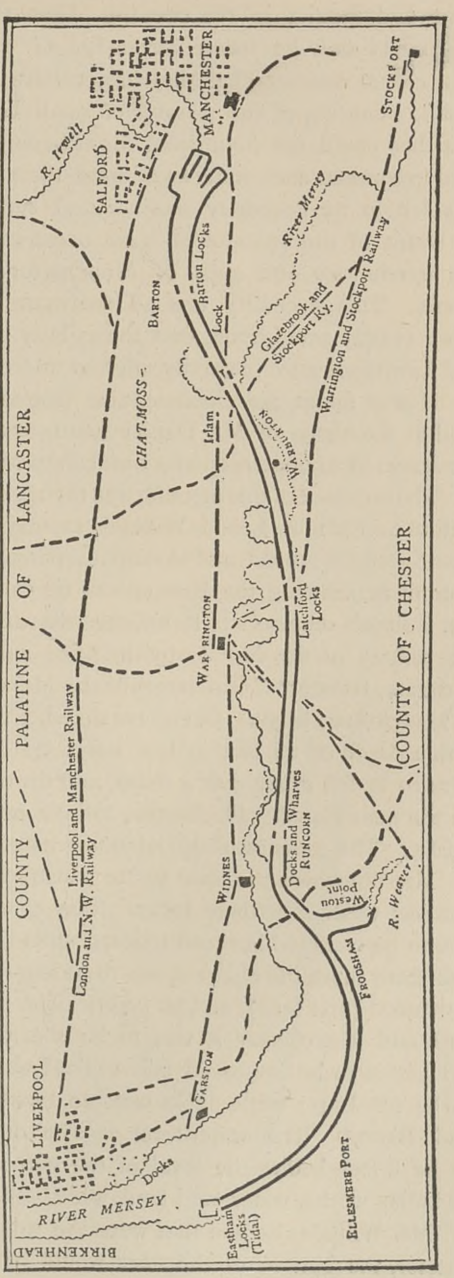
"Rivers diverted from their native course,
And bound with chains of artificial force,
From large cascades in pleasing tumult rolled,
Or rose through figured stone or breathing gold."—*Prior.*

WHETHER we regard the magnitude of the enterprise, the importance of the district it is intended to serve, the difficulties and opposition that have had to be surmounted, or the many and varied influences that it is likely to exercise upon the future of transport in the United Kingdom, the Manchester Ship Canal is undoubtedly one of the most remarkable undertakings of modern times.

It is not that the canal is unique in point of the expenditure involved, or in so far as the engineering problems to be dealt with are concerned. The Suez Canal is at once a much more costly and a much more extensive work, its actual cost having been about 20,000,000*l.* sterling, as against less than half that sum for the Manchester enterprise; and its length having been about 100 miles, as against 35. The Panama Canal, again, although approximately about the same length as the ship canal between Manchester and the sea, has cost, up to the present time, about 60,000,000*l.* sterling, including the expenditure on financing. The Nicaraguan Canal, again, which is now about to be undertaken in real earnest, is estimated to cost from 13,000,000*l.* to 20,000,000*l.*, and will involve the cutting of some 28 miles of canal, in addition to the almost equally serious work of canalising the St. Juan River. But these are all works of a different character, and having a different object in view. The Suez, Panama, Nicaraguan, and Corinth Canals are isthmian waterways, intended, or constructed with the view of connecting together seas or oceans that Nature had divorced, and thereby carried out with the primary, if not with the sole, object of abridging distance. The Welland and the St. Mary's Falls Canals, in Canada and the United States, are of much the same character, their object being that of uniting waters that were originally kept apart by natural barriers. But the Manchester Ship Canal has but few antetypes. The canals already in existence that most nearly correspond to it in character are the Erie Canal, which connects Buffalo with New York, and thereby secures an unbroken line of water communication between Chicago and New York, a distance of over 1000 miles; and the Poutiloff Canal, 38 miles in length, which connects Cronstadt with St. Petersburg, and has converted the latter city into a seaport. The design of the Manchester Ship Canal is to transform that large centre of population and industry from a land-locked city into a seaport, and to confer the same facilities on a number of other towns in the neighbourhood.

There is no district and probably no community that appears to offer better facilities for making the experiment of providing a great inland waterway of this description. Manchester and Liverpool, with their immediate suburbs contain at least a million and a half of souls. But the trade and industry of the two towns are even more important than their population, relatively to other districts. The cotton trade of the world is carried on in this part of Lancashire. Manchester and Liverpool together have obtained and maintained a great repute as the centre of large industrial operations of almost every kind: engineering works, shipbuilding works, alkali works, tobacco factories, chemical and copper works, and many others. Liverpool has to-day a larger export shipping trade than any other port in the world, and is only eclipsed by the Thames in the matter of imports. But this great business of imports and exports is not originated in Liverpool herself. She is only the distributing centre for a very large and a very populous district, and a centre moreover that did not appear to offer to that district the economical facilities and advantages to which it was entitled. The port and harbour dues at Liverpool were heavy and onerous, and the rates charged by the railway companies for the transportation of traffic between the Mersey and the interior of the country were deemed to be much higher than they should have been, having regard to the importance of the traffic.

The proposal to construct a canal is by no means a new one. Manchester, as every one knows, has for more than a century and a quarter been the foremost in all plans and operations designed to secure economy and facility of transport. Many years ago it was proposed to convert the Irwell into a navigable river, and this, of course, would have connected Manchester with the Mersey and so with the sea. But the Irwell—a tortuous, narrow, and in many respects unsatisfactory stream—did not readily lend itself to a grand proposal of this kind, and the little that was done to make it a maritime highway was never attended with any real advantage to trade and commerce. The Bridgwater Canal was a larger and more ambitious venture. It also connected Manchester with the sea by the Mersey, as well as with many inland towns by auxiliary canals—Bolton, by the Manchester, Bolton, and Bury Canal; Rochdale, by the Rochdale Canal; Blackburn and Accrington, by the Leeds and Liverpool Canal; Ashton and Huddersfield, by the Manchester and Huddersfield Canal; and so with some other large towns. The truth is that Manchester is, and has been for more than a century, the centre of a vast network of canals, whereby water communication was made possible with nearly every other important



TRACING OF THE MANCHESTER SHIP CANAL.

town and district in the country. But this possibility was one that could only be taken advantage of to a very limited extent. The canals surrounding Manchester have been of small size and depth, admitting of the passage of small boats and barges only, so that they could not be utilised for sea-going craft. For most practical purposes, such waterways were therefore of little use. What was felt to be necessary was a canal sufficiently broad and deep to admit of the passage of large ocean-going steamers right up to the warehouses and mills of Manchester and the neighbouring towns. This necessity was all the more keenly felt, and all the more readily acted upon, that the railway rates between Manchester and Liverpool were generally onerous and oppressive.

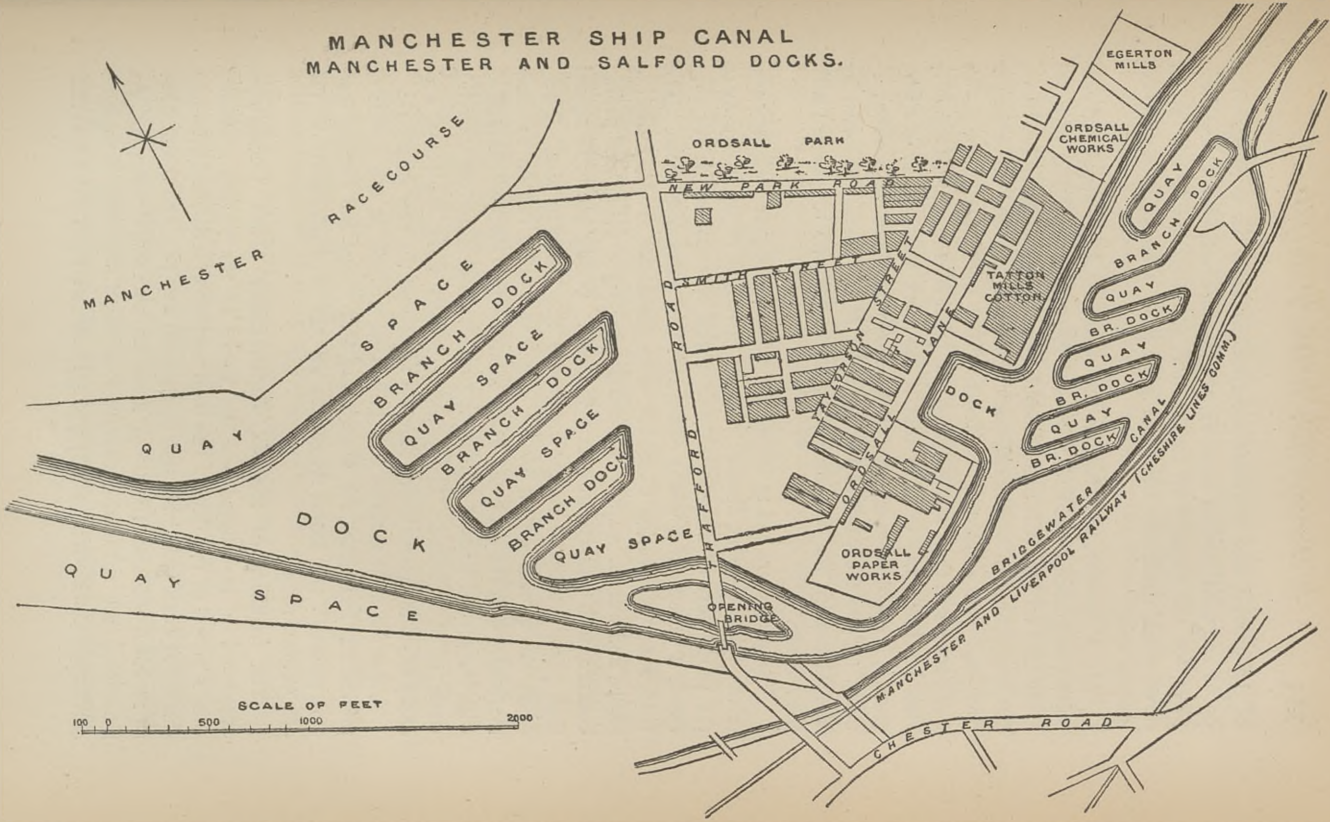
It was under the circumstances just stated that a meeting was held at the house of Mr. Daniel Adamson, in June 1882, to discuss the question of constructing a canal from Manchester to the sea.

The outcome of this meeting was the appointment of Mr. Hamilton Fulton and Mr. E. Leader Williams as engineers, with instructions to investigate the subject, and to submit separate schemes to a provisional committee showing the best means of carrying out such a work. Mr. Fulton's scheme was to improve the existing navigation through the estuary of the Mersey by dredging and retaining walls, and to excavate, straighten, and improve the Mersey and Irwell Navigation to Manchester, leaving, when completed, a tidal canal to Manchester, with a depth of 22 feet at low water spring tides. Passing places were to be left every 3 or 4 miles, and the traffic was to be worked as on the Suez Canal. Docks were to be constructed, and all necessary works. The gross estimate, including water and land, was 5,072,291*l.*

Mr. Williams's proposal was to construct a canal 22 feet deep and 100 feet wide, with three locks. The channel through the estuary was to be confined between training walls from Garston to Runcorn, and from there the channel was to be improved and straightened to Latchford (first lock), and be practically a tideway. Between Latchford and Manchester it was to be a canal with locks, the existing navigation to be improved and utilised where practicable, otherwise to be filled up; while docks were to be made at Latchford, Irlam, and Barton. The water-level in the docks at Manchester were to be 8 feet below the level of the quays. The estimate of cost, including works, water, and land, was about 5,160,000*l.*

Mr. Williams argued that were the tide to be brought to Manchester, the bottom of the dock would be 92 feet below the surface

MANCHESTER SHIP CANAL
MANCHESTER AND SALFORD DOCKS.



of the ground, and therefore most inconvenient for working. The docks and canal ending abruptly, would, moreover, form a depositing place for silt brought up by the tide, and the tide flowing up or down would materially affect the passage of vessels proceeding the reverse way.

Mr. Abernethy, who had, in the meantime, been appointed consulting engineer, considered both of these proposals, and reported favourably on Mr. Williams's scheme, practically endorsing his views, but suggesting an additional dock at Warrington, and some deeper dredging, and estimating the cost of the work at 5,400,000*l.*, or 240,000*l.* more than Mr. Williams had provided for. Mr. Abernethy also expressed the opinion that if the work was carried out with energy, it could be completed within four years from the commencement. Upon the basis of the report of Mr. Williams, endorsed by Mr. Abernethy, the committee decided in the end to proceed with the scheme.

The promoters had to secure the power to acquire "all the easements, rights, powers, authorities, and privileges of the company of the proprietors of the Mersey and Irwell Navigation," as the ship canal, if constructed, would clash with and extinguish these. The Bridgwater Navigation Company were possessed of the foregoing rights, and were a wealthy corporation, owning a going and paying concern, with a capital of over 1,300,000*l.* Notice had to be served that power would be sought to absorb this company also. Then, again, the powers sought by the ship canal were certain to clash materially with the dock and other interests in Liverpool, as well as with the several lines of railway at present dominating the carrying trade of Manchester. The property owners along the route, and many other interests, joined together to oppose the new enterprise.

After the most arduous and prolonged struggle in the annals of private bill legislation, the Manchester Ship Canal Bill became law, and received the Royal Assent as an Act of Parliament on the 6th August, 1885.

The inquiries of the six Parliamentary Select Committees appointed to investigate into the merits of the project extended over a period of 175 days. The total number of individual witnesses (including both promoters and opponents) was 285, and the number of repeated witnesses (including those on both sides) was 543. As illustrating the exhaustive character of these inquiries, it may be mentioned that no less than 87,936 questions were put and answered.

The Right Honourable W. E. Forster, Chairman of the Commons Select Committee, which was the last to deal with the Bill, in announcing that their decision was favourable, said, "The conclusion we have come to is unanimous," the Committee considering the preamble proved, subject to certain obligations being imposed upon the promoters, but none of an onerous character.

The House of Commons Select Committee, before which the first inquiry was made, acting entirely upon its own initiative, inserted the following clause in the Bill, a proceeding said to be without precedent:—"And whereas it appeared from the evidence adduced that if the scheme could be carried out with due regard to existing interests, the Manchester Ship Canal would afford valuable facilities, and ought to be sanctioned."

It is worthy of remark that though two Select Committees declined to take the responsibility of passing the Bill absolutely in the form in which it was presented to them, all the six Committees were satisfied as regards the necessity of the undertaking.

The Manchester Ship Canal Company is incorporated by 48 and 49 Vict. cap. 118, for the following amongst other purposes:—

To construct a ship canal from the river Mersey at Eastham, near Liverpool, past Ellesmere Port, Weston Point, and Runcorn, to Warrington, Salford, and Manchester, available for the largest class of ocean steamers, with docks at Manchester, Salford, and Warrington, and other incidental works.

To purchase the entire undertakings of the then existing Bridgwater Navigation Company (Limited), including not only the Bridgwater canals and the Runcorn and Weston canal, but the Mersey and Irwell Navigation, the Runcorn docks, the Duke's dock in Liverpool, and all that company's warehouses, wharves, buildings, lands, rents, rights, and privileges, as a going concern.

A further Bill, authorising the payment by the Manchester Ship Canal Company of interest at the rate of 4 per cent. per annum to shareholders during the construction of the works, became law and received the Royal Assent as an Act of Parliament on 26th June, 1886.

During the progress of this Bill, on a division in the House of Commons on a motion by a Liverpool member for reference to Committee and *locus* for opponents, the motion was negatived by 375 votes as against 61 votes.

The authorised share capital of the Manchester Ship Canal

Company is 8,000,000*l.*, with borrowing powers to the extent of 1,812,000*l.*, making the total authorised capital 9,812,000*l.*, a sum sufficient to enable the company to complete the construction of the works, to pay interest during their construction, and to carry into effect all the objects of the Act and leave an ample surplus.

The Act provides that the Bridgwater Navigation Company shall sell the whole of the Bridgwater undertakings for the sum of 1,710,000*l.*

These undertakings earn a net revenue of nearly 60,000*l.* per annum.

Under the auspices of the Manchester Ship Canal Company, a considerable development of the traffic on the Bridgwater canal system is expected to result from the abolition of the bar tolls, which obstruct traffic, and from throwing open the canal to general carriers.

Description of the Canal Works.

A brief description of the canal works may here be introduced. The engineering journals, from which we have mainly borrowed our facts, have dealt with them so fully as to render a detailed statement quite unnecessary.

The Manchester Ship Canal begins at Eastham, on the south bank of the Estuary of the Mersey, and about midway between its mouth and head near Runcorn. The canal follows this bank for 13½ miles, the greater portion being in entirely solid ground, but, sometimes going below high-water mark, it is confined by embankments and retaining walls until reaching Runcorn, where it leaves the waters of the Mersey, and takes an independent and almost direct course to its terminus in the docks at Salford and Manchester.

The total length of the canal is slightly over 35½ miles. This is practically one continuous cutting, but it has been subdivided into thirty lengths or sections, each with a local name and number; these vary in cubical contents from 223,000 cubic yards in the smallest, to 3,345,000 cubic yards in the largest. The total quantity of earthwork to be moved is 44,428,535 cubic yards, composed of 6,970,815 cubic yards of rock, and 37,457,720 cubic yards of soft materials. Of the rock, 1,591,570 cubic yards will be utilised for lock and river wall work, abutments of railway bridges, facing slopes of the canal in soft ground, and other operations, the remainder going to spoil. Of the soft excavations 3,603,690 cubic yards are to be used in forming the embankments of the canal, 5,176,278 cubic yards for forming embankments on railway diversions, 1,555,000 cubic yards in filling up what will be the disused bed of the Irwell and other watercourses; 552,000 cubic yards in raising quays and making roads; 800,000 cubic yards are to be stacked along the canal banks for future use in maintenance; and the remainder, amounting to 31,149,997 cubic yards, will go to spoil.

The carrying of the Bridgwater Navigation across the Manchester Canal at the distance of 32 miles, will be one of the most interesting works in the contract, because an entirely new departure will be undertaken in the aqueduct. It was on this navigation that Brindley made his famous viaduct, the precursor of the more splendid structures of Rennie and Telford.

As the level of the Bridgwater Navigation has to be maintained, and as the saving of water is a consideration, Mr. Williams proposes to make the aqueduct in the form of a swing bridge, which may be opened, swung, and closed again without losing any water either from the swinging portion or from the canal. Here also, parallel to the aqueduct, will be constructed a hydraulic lift, to lower barges and boats from the waters of the navigation, to the canal, where they will cross on its level to a similar lift, there to be raised to their former waters and level. A similar lift has been at work for some years with satisfactory results at Anderton on the Weaver Navigation, of which Mr. Leader Williams was formerly the engineer.

Throughout the entire length of the canal, hard red sandstone forms the bedrock, and the formation, of course, varies according to the nature of the stratification. For instance, at 1½ miles distance, where the canal works are inside high-water mark, all layers of deposit have been washed away, and only from 2 feet to 4 feet of black sludge overlies the rock. Occasionally the rock dips and leaves the bottom of the canal in the softer deposits, in some places beds of what has been termed black river sludges, but which are, in all probability, peaty deposits, are sandwiched in, and underlie deposits of from 15 feet to 16 feet of clean river sand. At 5½ miles between Stanlow Point and Ince Lighthouse, large beds of blue loam are met with, varying in depth to 25 feet; and at 6 miles black sludge comes in again, about 20 feet in thickness. At 6½ miles there is a peculiar erosion of the underlying sandstone, apparently from some creek having cut across the line of canal. At 8 miles the section overlies a bed of gravel, and at 9 miles the bottom of the canal runs into a large deposit of sand. From about 10 to 10½ miles the strata becomes very soft, being sludge, sand, and gravel mixed. At 11 miles 45 chains the bottom of the canal is again very soft ground, the sandstone suddenly dipping and not appearing again until about 12 miles.

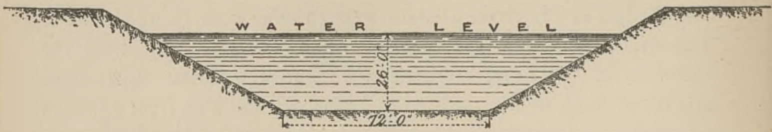
At 13 miles 70 chains the first of the deep cuttings begin, the bottom of the canal being 67 feet below the surface of the ground, and the strata is much less complex than along the estuary. It is near to this place that the canal leaves the waters of the Mersey, and takes an independent and almost direct course to its terminus.

From 15 miles, 50 chains to 16 miles there is again a very considerable alteration in the strata, the rock dipping sharply, and softer deposits coming in. At 15 miles 68 chains, where a bore was put down, no rock was encountered to a depth of 88 feet. Following along from 16 miles, where the bedrock rises, a fairly even contour of its surface is maintained, together with overlying strata of soil, sand, and gravel, to near 18 miles 20 chains, where the London and North-Western main line, and the Birkenhead, Lancashire, and Cheshire Junction railways are crossed.

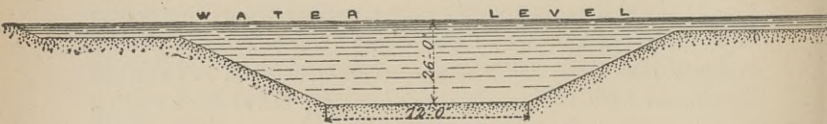
From this point the surface rises gradually to 19 miles, opposite the Warrington Dock entrance, where the cutting is 50 feet deep. Near Warrington the existing river bed will be shortened by a cut-off and diverted from the course of the canal. At 21 miles 20 chains Latchford Lock is reached; the section through it is very similar to that in the preceding 5 miles. At 21 miles 70 chains the bedrock again disappears, giving place to a deep bed of quicksand and marl. The Mersey is twice crossed between 22 miles 10 chains and 22 miles 35 chains. There is another cut-off and diversion of the river near 22 miles 50 chains, where the bottom becomes soft brown sandy clay, and sludge, being in a bed 24 feet thick, which reaches 18 inches or 20 inches below the bottom of the canal; this runs into gravel and clay at 23 miles 10 chains, which again dies into a large bed of quicksand from about 23 miles 25 chains to 75 chains. At 24 miles 2 chains the rock is again struck by a bore at a depth of 12 feet below the bottom of the canal. The Mersey is again twice crossed at 23 miles 40 chains, and 70 chains, and the river is to be diverted through the existing channel, called the "Butchersfield Cut." At 24 miles 20 chains the Mersey joins with the Bollin; from there the canal will become practically the river to Manchester, and the old river bed will be filled up. A sand and gravel formation continues to about 25 miles, where a bed of marl is reached, overlaid by hard and soft shale, but from the point where this runs out, about 25 miles 40 chains to Manchester, the canal follows more or less the bed of the river, wherein a much more complicated strata is met with than along the line of route which is away from the influence of the river, at between 14 and 25½ miles. Loam and streaks of sand, overlying hard red sand are met with from 25 miles 60 chains, to 26 miles 20 chains, where gravel and red rock come in, to 25 miles 15 chains, between which points the bottom of the canal by a strange coincidence follows almost parallel with the upper surface of the bedrock. At 27 miles 15 chains the rock dips and is not met with again for nearly half a mile. The Irlam locks are at 28 miles 50 chains; just at the entrance, rock again crops up and forms the bottom of the canal. At 29 miles a wedge-shaped layer of brown clay comes in which runs about half a mile, reaching a depth of 20 feet at the Manchester end; this suddenly ends in a deep bed of loam which it partially overlies—evidently it is a deposit from the river which flows above—then loam, sand, and gravel make the strata to about 29½ miles, when rock again appears, and runs almost to the surface at 29 miles 68 chains. At 30 miles 30 chains the rock runs out again from the bottom, and a heavy bed of loam, 36 feet deep, covers it, the cutting at this point being entirely in loam. A little further on, the rock bottom again rises, and from there sand and rock are chiefly met with to 31 miles 10 chains, where the rock dies out again, and blue loam comes in, forming a deep bed overlying sand, sludge, gravel and marl; near the Barton Locks this runs into heavy beds of loam near 33½ miles. At 34 miles soil, clay, and rock are the formations met with, each in nearly equal beds of 10 feet deep, until about 34 miles 50 chains, when much sand shows; at 34 miles 55 chains the bedrock dips, and sand over clay and loam form the strata to the terminal dock entrances at Throstle Nest. This completes the course of the canal proper.

The canal is to be constructed with a minimum width of 120 feet on the bottom. From Barton to the terminus, a distance of 3½ miles, the width on the bottom is to be increased to 170 feet; on the Salford side of this increased width of waterway, one mile of wharfage is to be built, giving a total length of 4½ miles of quay or wharfage frontage at the Manchester end, and leaving 2½ miles of frontage available for mooring lighters or vessels along this portion of the canal.

SECTIONS OF SHIP CANALS.

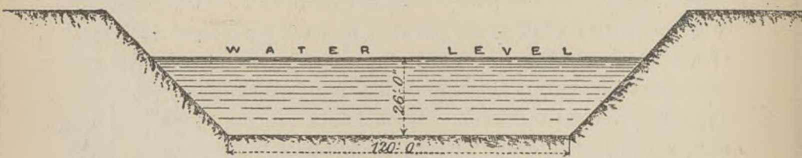


PANAMA CANAL

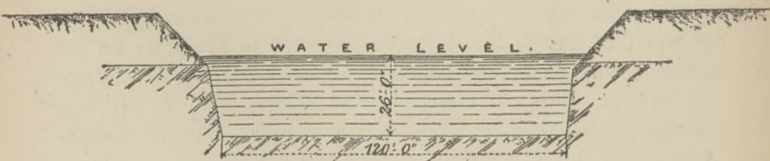


SUEZ CANAL

MANCHESTER SHIP CANAL

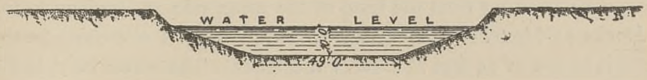


ORDINARY SECTION

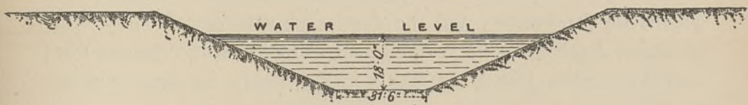


SECTION THRO ROCK

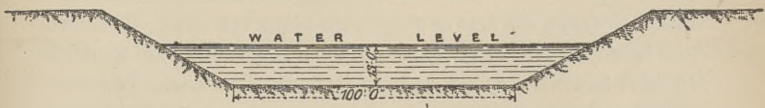
SECTIONS OF SHIP CANALS.



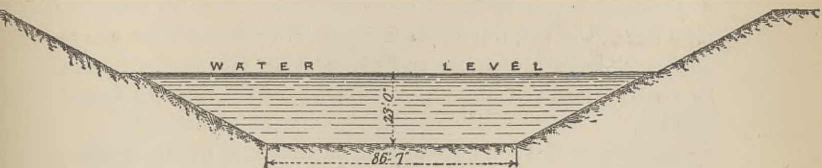
BRUSSELS CANAL



NORTH HOLLAND CANAL



WELLAND CANAL



AMSTERDAM SHIP CANAL

The sections of the canal are compared with those of other large ship canals in the diagrams at pp. 340–41.

The total rise from the level of the mean tide at Eastham to the Docks at Manchester is nearly 60 feet. This is overcome by the average rise of 15 feet at each of the locks. The water level in the Manchester Docks is to be the same as the present river level at this point.

The depth of the canal throughout is to be 26 feet, but the sills of the docks are to be put in at a depth of 28 feet, so as to allow for a deepening throughout should the traffic demand it.

As compared with existing large canals, the Manchester Ship Canal will be capable of carrying much the greatest traffic. The widths on the bottom, and the depths are: Ghent Canal 55 feet 6 inches, depth 21 feet 2 inches; Suez Canal, 72 feet, depth 26 feet; and Amsterdam Canal, 88 feet 7 inches, depth 23 feet. On the Suez Canal it has been necessary to provide passing places, otherwise the traffic could only be worked in one direction at a time, but on the Manchester Canal there will be ample room for two large-size vessels to pass at any point.

The estimates for the canal works include large docks in Manchester, Salford, and Warrington, as sanctioned by the Company's Act, with a water area of 114½ acres, containing more than five miles of quays, the area of quay space being 152 acres. There will also be a mile of quay space near Manchester on the Ship Canal, in addition to wharves at many places alongside its course. The docks will be of the most approved construction, and special provision will be made to secure the rapid loading and discharging of vessels. Extensive shed accommodation will be provided at the docks, and the cost of some fifty hydraulic cranes is included in the estimates.

The level of the docks at Manchester, which is 60 feet 6 inches above the ordinary level of the tidal portion of the canal, will be reached by four sets of locks. The locks will be of a size sufficient to admit the largest merchant steamers afloat. Each set comprises (*a*) a large lock, 550 feet by 60 feet; (*b*) a smaller lock 300 feet by 40 feet for ordinary vessels; and (*c*) one lock 100 feet by 20 feet, for small coasters and barges. All will be capable of being worked together.

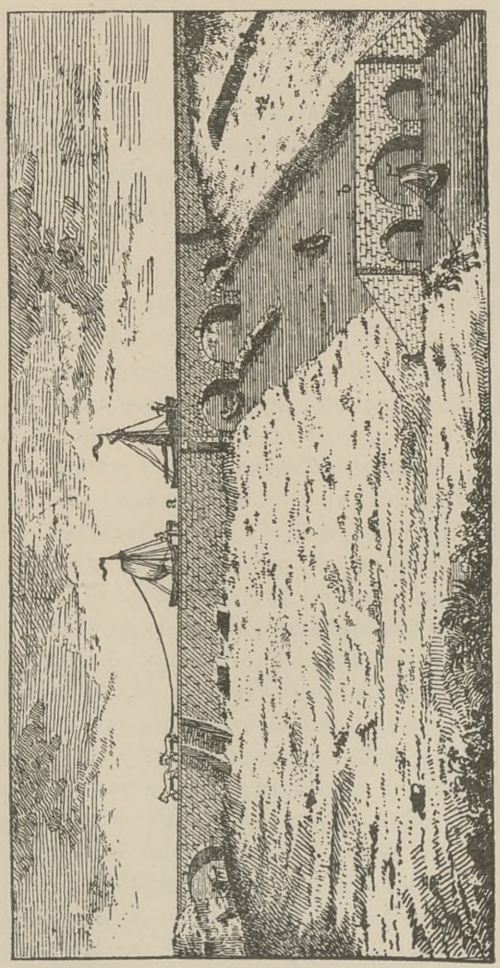
Each set of locks will be worked by hydraulic power, enabling vessels to be passed in 15 minutes. It has been ascertained by careful gaugings that the rivers Irwell and Mersey (which will be diverted into the upper reaches of the canal) will supply more than sufficient water for the locks, even in the driest season.

There will be tidal gates at the entrance to the canal, which will be worked as locks at low water, so that large vessels can enter and eave at almost any state of the tide, instead of only during a period of 40 minutes of each tide as at Liverpool. Small vessels will be able to enter and leave at any time.

It is claimed that vessels will be able to navigate the canal with safety at a speed of five miles an hour, and it is estimated that the journey from the entrance at Eastham to Manchester will be accomplished in eight hours, which is less time than is now taken to cart goods from ship to rail in Liverpool, and to carry them thence by rail to Manchester.

One of the most interesting operations to be carried out in connection with the canal works, will be the removal and rebuilding of the aqueduct which Brindley constructed for the Bridgwater Navigation in 1765. The aqueduct and the neighbouring viaduct (shown in the old print at p. 344) pass over the Mersey and Irwell Navigation at such a height as to allow the passage through the archways of small vessels. To accommodate the larger vessels that will pass up the Ship Canal, the archways of the aqueduct and viaduct would have to be more than double the height. This was the engineering difficulty which the Ship Canal promoters had first of all to encounter and by many it was regarded as insuperable. The suggestion was made that the Ship Canal should end at a point below the aqueduct. Mr. E. Leader Williams, the engineer of the company has, however, proposed to construct a short diversion of the Bridgwater Canal immediately over the line at which it would cross the Ship Canal. The length of the Bridgwater over the Ship Canal will then be formed in the manner of a long movable iron caisson or trough, somewhat deeper in the centre than at the two ends, supported by and turning (when required) upon a circle of live rollers. This caisson is to be filled with water to a depth equal to that of the canal itself, and is to be fitted at either end with watertight gates, which are also to be fixed at either end of the approaches from the canal.

Upon the completion of this work, the central portion of Brindley's aqueduct will be removed, the ends being allowed to remain. The manner of working the new aqueduct will be as follows:—The operator in charge of the machinery will, on descrying an approaching steamship, cause the four watertight gates at the ends of the caisson and of the approaches to be closed, and will then, by means of hydraulic machinery, cause the caisson to revolve for a quarter of a circle upon the live roller which will support it, thus leaving a



THE BRIDGWATER CANAL.—(*a*) Across the Irwell (*b*) Barton Bridge.

perfectly clear passage for the vessel. Through this passage, up- or down-going vessels will be able readily to steam, and when clear of the aqueduct the process will be reversed—that is to say, the attendant will cause the caisson to turn back into its original position, and will have his water-tight gates opened once more, when the line of the Bridgwater traffic will be clear again, after a very brief interval, and without any loss of the water in the canal.

At the ends of the existing line of the canal (after the removal of Brindley's old aqueduct) it is proposed to construct hydraulic lifts as already stated, by means of which it will be competent to lower barges with full cargoes (the barges remaining afloat throughout the whole operation) from the Bridgwater to the Ship Canal, or, *vice versa*, to raise them from the Ship Canal to the Bridgwater, thus making Barton a point of interchange of traffic between the high and the low level navigation.

The works on the Manchester Ship Canal were commenced in 1886, and are to be completed, under contract, in 1892. The estimate of the promoters is that the canal will have a traffic of 3,000,000 tons per annum, from which a net annual income of 709,000*l.* may be expected. This estimate, however, did not include any coastwise traffic, nor such goods as coal, salt, and iron, and took no account of the future expansion of trade. Another estimate, submitted to Parliament, which included these items, calculated on a revenue of over 9½ millions of tons, and a net revenue of over a million and a half sterling.

Whatever the financial results of this great undertaking may be, its future can hardly fail to be well assured, and Lancashire has reason to be satisfied with the energy, capacity, and public spirit that have placed such a valuable means of communication at the disposal of its principal industrial centres.

CHAPTER XXIV.

THE ISTHMUS OF CORINTH CANAL.

ONE of the many schemes that have been put forward from time to time, with a view to affording a more direct communication between the Ægean and the Black Sea, appears likely to become an accomplished fact by the cutting of the Isthmus of Corinth, which at the point where the ship canal has been undertaken, is about $3\frac{3}{4}$ miles in breadth. The scheme now being carried out, is understood to have originated with General Tarr, who obtained a concession from the Greek Government for the purpose. The required capital was estimated at some 30,000,000 francs, and this sum was readily subscribed. The undertaking does not present any very considerable engineering difficulties, although it has involved a considerable amount of excavation, the earthwork requiring to be removed being estimated at 10,000,000 cubic metres.

The Isthmus of Corinth obliges vessels passing from the Mediterranean and Adriatic Seas to the Archipelago and the Black Sea to make a considerable bend to the south. The idea of piercing the isthmus originated several centuries before the Christian era, and the works were actually commenced before the reign of Nero. The route across the isthmus will shorten the distance between the Piræus and Marseilles 11 per cent.; Genoa, 12·2 per cent.; Venice and Trieste, 18·4 per cent.; and Brindisi, 32·4 per cent. The probable traffic through the canal has been estimated at over 4,500,000 tons. The works were commenced in 1882, following the straight course indicated by the traces of Nero's canal. The canal will have a depth of $26\frac{1}{4}$ feet, and a bottom width of 72 feet, like the original section of the Suez Canal; but, as the Corinth Canal has a total length of only about four miles, the transit of vessels through it will be effected without the aid of passing places. The principal mass of the excavation is concentrated within the central $2\frac{1}{2}$ miles, and the greatest depth of cutting is 285 feet. Alluvial soil is mostly found for about two-thirds of a mile from each end; but the central portion consists of close chalk underlying hard calcareous conglomerate and compact sand, necessitating blasting and the use of the pick. Depths of 33 feet are reached within 550 yards of the coast, both in the Bay of Corinth and the Gulf of Egina, and the dredging required at the entrances of the canal is not large. The west entrance, at Poseidonia, is protected by two converging jetties, forming a roadstead; and the east entrance, at Isthunia, is sheltered by a single curved jetty on the northern side. These three jetties, formed with natural blocks, are nearly completed. The canal will be open throughout, as the variations in the level of the sea are very slight; and the only large work of construction is the metal bridge of 262 feet span, which crosses the canal at a height of 170 feet above the water level, and will carry the Piræus and Peloponesus Railway and the road to Corinth over the canal.

It is not a little remarkable that both the Greeks and the Romans proposed to make a canal across the Isthmus of Corinth, in order to obtain a navigable passage by the Ionian Sea into the Archipelago. Demetrius Poliorcetes, Julius Cæsar, Nero, and Caligula renewed the attempt, but without success.* Before their time, the Cnidians had made the same endeavour, which called forth the famous reply of the Pythia—a reply that may be translated thus—

> "Delve not, nor towers upon the Isthmian pile:
> Had Jove so wished, himself had made an isle."

The Isthmus of Corinth Canal has been cut through the tongue of land which is situated between the gulfs of Athens and Lepantus and unites the classic mainland with the shores of the Morea. By its geographical position, this isthmus, as we have seen, bars the union between the Adriatic and the Archipelago, and obliges all vessels passing from the one sea to the other to round Cape Matapan. Its existence materially lengthens the voyages of all ships bound from the western parts of Europe to the Levant, Syria, Asia Minor, and Smyrna. The last-mentioned port is the emporium to which the numerous caravans from the interior of Asia, from Persia, and the Caucasian regions have long transported the rich products of oriental countries still more distant. In a similar manner it lengthens the route from Europe to the Black Sea, which is a matter of serious

* Plin., t. iv. c. 4.

importance, as from the ports on the latter are shipped the enormous quantities of wheat and other cereals which supply a considerable portion of Western Europe. The junction of the waters of the Adriatic with those of the Archipelago is expected to effect a saving in time of two days in the voyage from the harbours of Brindisi, Ancona, and Trieste, to the Levant. It will also greatly facilitate the establishment of local traffic, and probably lead to the adoption of a regular system of steam communication, of which Greece is much in want. At present, the coast is not particularly well furnished with harbours, but those that do exist are said to be easily capable of extension, and there is some inducement to construct new ones, as the adjoining bays are deep, and afford a secure anchorage for vessels of heavy tonnage.

The extreme points of the Isthmus of Corinth are Heapolis and Kalamakis, and supposing them, like Suez and Port Said, to represent the respective mouths of the canal, its length would not exceed three miles at most—an insignificant cutting, so far as the actual lineal dimensions are concerned. It was anticipated, and experience has now demonstrated, that the nature of the material through which the Suez Canal is excavated will constitute the principal and possibly the sole difficulty to be contended with in future. As it is, the reduction of the present batter of the side slopes is imperative. If not performed by excavation, the operation will proceed spontaneously by the gradual sliding of the sand into the water, whence it will be removed by the dredgers, which, under any circumstances, will have a busy time of it for some years to come. Fortunately this difficulty does not exist in the canal in the Morea. The earth is of a tenacious character, which will offer a better resistance to the disintegrating action of the water agitated by the passage of ships, and the motion of screws and paddles, and thus reduce the cost of maintenance and repair. It was estimated that this important work could be carried out at the moderate cost of half a million sterling. Without taking into account the number of contingent steam and sailing ships which would avail themselves of the passage *viâ* the Corinth Canal, a regular traffic of the boats of the Messageries Impériales, of the Company of Marseilles, of those of the Austrian Lloyd's, and of those belonging to the Italian service was looked for. With the canal completed, Kalamakis, which at present is but a village, was expected to speedily become a maritime town of importance, and numerous cities, long since abandoned, and, as it were, buried, were to be disinterred, restored to life, and ultimately to become commercial centres, from which the mineral wealth with which the country abounds may be exported.

On the 19th February, 1870, the concession for the construction of the Isthmus of Corinth Canal was given to M. Maxime Chollet, on the understanding that the works should be commenced within eighteen months, and completed within six years. The Hellenic Government granted to the concessionnaires all the land required for the canal, and 12,350 acres on each side, as well as the privilege of working the mines, quarries, and forests of the State, within a distance of 19 miles of the canal.* It was not, however, until 12 years afterwards that the work was actually proceeded with, so that the terms of the original concession were not carried out.

The canal was not formally commenced until the 23rd of April, 1882, the first mine being fired by Her Majesty Queen Olga, in the presence of His Majesty King George, the Diplomatic Corps, and the principal Greek Government officials.

According to the plans ultimately adopted, the entrances to the channel will be 100 metres in breadth, diminishing to 22 metres, and the depth will be 8 metres.

The nature of the ground through which this channel has to be cut is composed, according to the report of the engineers of the company, of three distinct kinds :—

Firstly.—From the Gulf of Corinth, through a plain, consisting of sand and alluvial soil, for the distance of $1\frac{1}{4}$ kiloms.

Secondly.—Through a mountain range, varying in height from 40 to 80 metres, of the length of $4\frac{1}{2}$ kiloms.

Thirdly.—Beyond the mountain range to the sea, in the Bay of Kalamaki, the canal will traverse a little plain of the length of 600 metres, composed of alluvial soil and rocks.

The excavation of those parts of the canal situated in the plains presented no difficulties, but this was not the case as regards the mountainous part, where a mass of 8,000,000 metres of solid rock has had to be excavated and transported to a distance, which labour, according to the contract, had to be done within the comparatively short period of three years.

The following plan of executing the works was decided on by the engineers of the company, M. Gerster and M. Kauser :—

1. That part of the canal situated in the plains to be excavated

* 'Moniteur de la Banque et de la Bourse.'

by ordinary means, namely, hand labour, dredging machines, and sand pumps. This portion of the work was to be finished at the end of 1883.

2. At the same time as the above-mentioned work was in progress, the upper portion of the rocky crest to be blasted, and the refuse carried away by railway.

3. Towards the end of the year 1883 several large dredging machines, constructed on the most approved principles, were delivered to the company. These machines were capable of removing 5500 cubic metres of soil in ten hours. They were each of 300 horse-power, and were constructed by the firm of Messrs. Sâtre and Demange, of Lyons. They cost 550,000 fr. each.

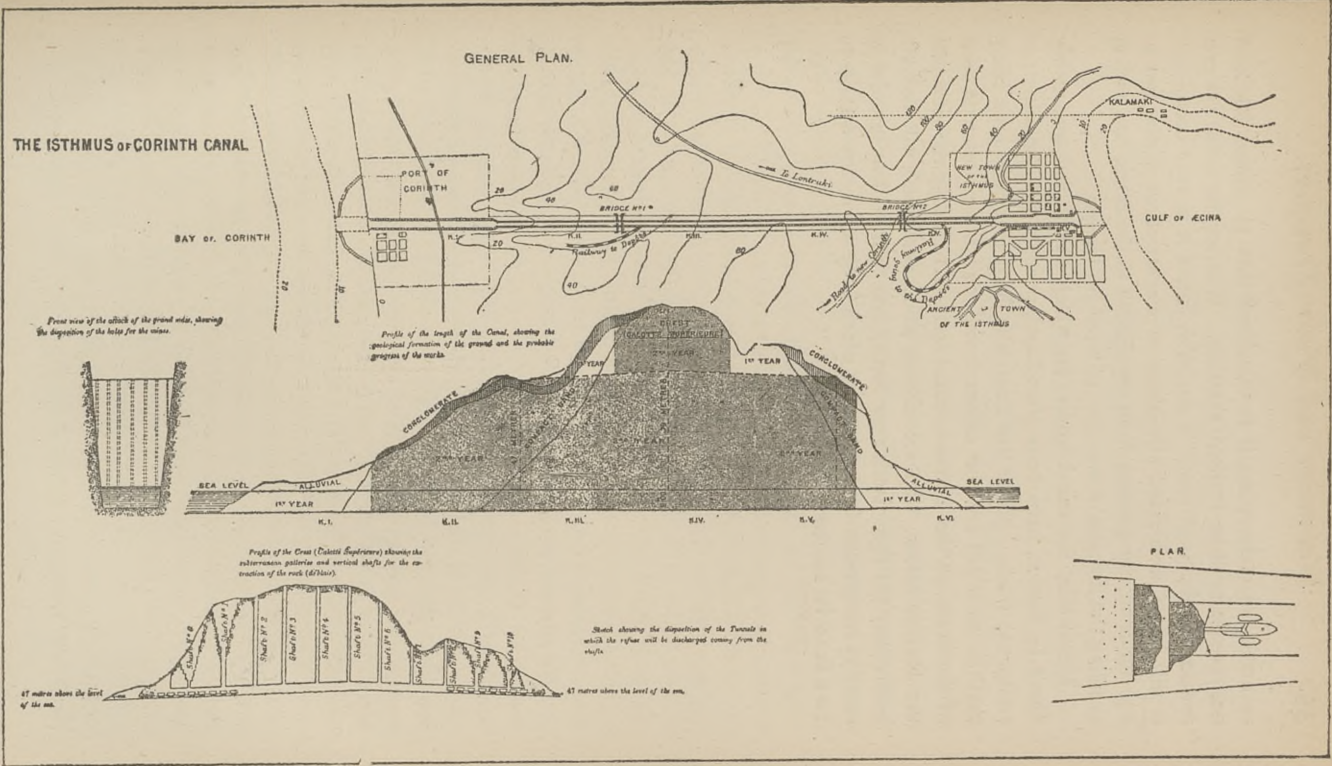
As regards the system of excavating the rock, M. Gerster's plan was to sink vertical shafts to the level of the canal, by means of machines constructed for the purpose, for which cartridges of dynamite were to be employed at distances of 2 to 3 metres from each other, which were to be exploded simultaneously.

The execution of this enterprise was confided to the Société des Ponts et Travaux en Fer (ancienne maison Joret et Cie), in conjunction with L'Association des Constructeurs. These two companies engaged to undertake the cutting of the canal for the sum of 24,600,000 fr., under forfeit if it is not completed within the prescribed time.

The annexed general and sectional diagrams (p. 351) explain the method by which it was proposed to carry out the execution of the enterprise.

The Isthmus of Corinth Canal Company was compelled, in consequence of unforeseen delays in their works, to obtain in 1887 an extension of three years for their completion. The canal was to have been opened in 1888. The geological strata to be passed through in excavation does not appear to have been accurately ascertained, and as a consequence of having to work to some extent upon rock, instead of in sand or gravel, the progress made was less than had been anticipated. For this reason also it has been found necessary to raise additional capital to the amount of double the original capital; that is to say, by an issue of 60,000 additional shares of 500 francs each, bearing 6 per cent. interest. In order that the canal may become a

* These particulars are taken from a report made to the Foreign Office by Her Majesty's Secretary of Legation at Athens.


THE ISTHMUS OF CORINTH CANAL
GENERAL PLAN.
BAY OF CORINTH
PORT OF CORINTH
BRIDGE No. 1
BRIDGE No. 2
Railway to Depôt
To Loutraki
Road to new Corinth
Railway going to the Depôt
NEW TOWN OF THE ISTHMUS
ANCIENT TOWN OF THE ISTHMUS
KALAMAKI
GULF OF ÆGINA
Front view of the attack of the grand mine, showing the disposition of the holes for the mines.
Profile of the length of the Canal, showing the geological formation of the ground and the probable progress of the works.
CREST (CALOTTE SUPÉRIEURE)
CONGLOMERATE
COMPACT SAND
ALLUVIAL
SEA LEVEL
1st YEAR
2nd YEAR
K. I.
K. II.
K. III.
K. IV.
K. V.
K. VI.
Profile of the Crest (Calotte Supérieure) showing the subterranean galleries and vertical shafts for the extraction of the rock (déblais).
47 metres above the level of the sea.
Sketch showing the disposition of the Tunnels in which the refuse will be discharged coming from the shafts.
PLAN.

remunerative undertaking, it is calculated that $3\frac{1}{2}$ million francs of net revenue must be realised annually. Whether the canal will ever realise this financial result is doubtful, but, if it is ever completed, it will be of undoubted advantage to commerce in saving 100 to 250 miles in the passage from the Ægean to the Black Sea, and in avoiding the dangers of the coast of Southern Greece.

Meanwhile, the canal works, for which the capital was chiefly found in France, have been abandoned, pending the acquisition of additional funds. There are those who hold that it is little likely that the canal will ever be consummated, and the unfortunate issue of the works on the Panama Canal appears to justify the view that the French nation, who are almost alone concerned, will hesitate before they put their hands very deeply into their pockets in order to carry to completion an undertaking which is by no means certain to be a financial success.

CHAPTER XXV.

THE RIVER THAMES.

"My eye, descending from the hill, surveys
Where Thames along the wanton valley strays."—*Denham.*

THE river Thames is in many respects one of the most remarkable in the world. No other river has so large a commerce, no other river can boast such a display of shipping, no other river is the highway for such a large population, no other river has such a romantic and interesting history. The Thames is, however, eclipsed by many other waterways as regards natural advantages for maritime commerce. It has an extremely tortuous, irregular, and dangerous channel; it is subject to great fluctuations of tides; it is liable to be silted up with the deposits of sand and sewage from its lower reaches; and it is inadequately provided with artificial light to enable the mariner to find his way up the stream after nightfall. These disadvantages have again and again been the subject of serious accidents to life and limb, heavy losses to shipping and marine insurance companies, complaints and proposals on the part of the shipping interest, and representations to the Trinity House, the Board of Trade, and other constituted authorities. Only quite recently, the Chamber of Shipping sent a deputation to the Board of Trade, in order to urge that the Duke of Edinburgh channel should be better lighted, and it was then stated that the shifty and temporary character of the channel made the lighting of the Thames difficult at this point. For this reason, and owing to the influence of the tides, steamers have generally to cast anchor off Gravesend, if they reach the Thames after darkness has set in. This is so unpleasant an alternative for passenger steamers that they frequently brave the dangers of the river —much more serious, as a rule, than the dangers of the ocean—and run the risk of grounding or collision, in order that they may reach their destined berth or dock. Those who have had the misfortune to be on board a vessel under such circumstances must have felt devoutly thankful that they ever reached their destination without accident, and must have registered a vow that they would never repeat the experiment. Within the last few years, search lights have been shown from some of the docks, which, although intended to assist the navigator to his intended haven, have been found to produce the opposite effect, inasmuch that they cast into deeper shadow a great part of the intermediate channel. These dangers and difficulties are increasing, as it is natural they should do, when no adequate provision is made to overcome them.

The importance of this matter can only be fairly appreciated by giving an idea of the magnitude of the trade that is now carried on between the Thames and other ports. The largest amount of tonnage that entered and cleared from the Thames in any recent year was as under :—

	Entered.	Cleared.	Total.
Foreign	6,591,225	4,127,045	10,718,270
Coastwise	5,025,724	1,756,565	6,782,189
Totals	11,616,949	5,883,610	17,500,559

This represents nearly one-fifth of the total shipping trade of England in the same year, and an average of about 48,000 tons of shipping per day. The total value of our imports from, and exports to, foreign countries and British possessions has in some recent years amounted, for the port of London alone, to upwards of 200 millions sterling. The value of our coastwise trade is not recorded, but it will probably be sixty or seventy millions more, which would bring up the total annual value of the shipping trade of the Thames to close on 300 millions. The extent to which this trade has increased within the last twenty-five years has been quite phenomenal. In 1860 the total entrances and clearances of the port of London amounted to only 9,506,000 tons, so that the trade has nearly doubled within twenty-seven years. The tonnage entered and cleared over the last few years represents an average of over four tons per head of the population of the metropolis—taking the latter at, say, 4 millions over the four years ending 1887.

For a considerable period, the population of London has been increasing at the rate of about half a million in each decade. If the same rate of increase is continued, the shipping entering and clearing from the port of London in twenty years should amount to five millions additional, which would bring the annual total up to about 22½ millions of tons. Will the river Thames be equal to carrying on this enormous traffic without serious inconvenience and danger? This is at least doubtful, and that being so, the duty is cast upon us of considering what steps should be taken, in order to meet the requirements of a possible congestion of traffic, and to minimise the dangers of river navigation. This is all the more important and urgent that the tendency now is to provide much larger vessels than formerly, both for the foreign and the coasting trades. A few years ago, the average size of the vessels that entered the port of London did not exceed 300 tons. In 1860, the average was not over 210 tons. But in 1886, the average was not less than 620 tons. In about twenty-five years, therefore, the average size of the vessels using the Thames has been increased by about 200 per cent. There is little doubt that this movement will continue. It has been established as the result of the experience gained in the navigation of ships of large size that, all other things being equal, the larger vessels are the more economical. The average size of the ships now entering the port of Liverpool has risen to over 1000 tons, where a few years ago it was not over one-half of that tonnage. Probably the average size of the ships frequenting the Thames would be materially increased if larger vessels could be admitted with safety at all states of the tide. But the condition of the tide, except at high water, does not admit of ships of very large size coming far up the river. There have been cases of the tide ebbing so low that it has been possible to walk across at London Bridge. This occurred in 1114, 1158, and 1717. Since the removal of Old London Bridge, there has been a much greater scour, and the systematic dredging of the river has permitted of a moderately good depth of water from the bridge downwards in ordinary times. But the depth is not uniform, it is liable to fluctuation, and it would be difficult to adapt the river for the entrance of vessels of the largest size at any state of the tide. The consequence has been that Liverpool has been leaving London somewhat behind in the competition that has for many years been carried on between the two towns. In 1825 the aggregate foreign tonnage of Liverpool was only one-half to five-eighths that of London. In 1850 the two ports were nearly abreast, and in 1870 Liverpool exceeded London. From that date the two ports have been running a nearly equal race. London having had the start for some two or three years past. But when the enormous distributive facilities of London are considered, it seems remarkable, and almost unnatural, that Liverpool, with only about one-sixth the population, should be in the running at all, and it is extremely probable that London would have a much greater start if the Thames navigation were only made equal to the requirements of the trade.

The question of how far it would be expedient to construct a ship canal that would relieve the congested traffic of the river, and permit of vessels entering the docks at all times, has been mooted, but has never been very seriously entertained. It is not, however, improbable that this may, after all, be the true solution of the problem. Ship canals are now the order of the day. They are being either projected, as we have already seen, or constructed for the purpose of aiding navigation to an extent that is quite remarkable, not in this country only, but in most continental countries as well. A ship canal has been proposed to connect Birmingham with the river Trent; another to connect Bristol with the English Channel; a third to connect Sheffield and Goole; and a fourth to connect the Thames and New Haven. The Manchester Maritime Canal will soon be an accomplished fact. On the Continent canals are actually under construction across the Isthmus of Corinth, to connect the Adriatic with the Archipelago; and in Schleswig-Holstein, to connect the North Sea and the Baltic, not to speak of the great enterprises of Panama and Nicaragua, designed to connect the Atlantic and the Pacific. In Russia, a canal has recently been constructed between Cronstadt and St. Petersburg, whereby the latter city has been converted into a seaport, and a canal is now being talked of to connect the Volga and the Don. In the United States ship canals are being promoted to connect Lakes Michigan and Erie, and the Gulf of Mexico with the Atlantic Ocean, through the Florida Peninsula. In India, it is proposed to connect the Gulf of Manaar with the Palk Straits, by a maritime canal, and in other countries the same movement has been apparent. In most of these cases the object has been to save distance and time. In others it has been to facilitate navigation generally. Both ends would be served by a canal to connect London with the English Channel. It is more than a hundred years since a similar project was recommended by Brindley to the Corporation of London, who employed the great engineer to make a survey of the Thames above Battersea, with the object of having it improved for purposes of navigation. Brindley's recommendation was not adopted, although he declared that a canal would cost less than the improvement of the river, that it would give the command of cheaper transport, and that it would reduce distance and economise time.* Probably Brindley's scheme would have been adopted long before now, but for the construction of the Grand Junction Canal.

It is likely to be objected to the suggested Thames canal that the necessity for it has recently been obviated by the construction of the docks at Tilbury, opposite to Gravesend, and within a few miles of the estuary of the river. The Tilbury Docks have no doubt been a great relief to the congested condition of the traffic, and they are entitled to every consideration. But they do not by any means meet the case, any more than the port of Cronstadt met the requirements of St. Petersburg previous to the construction of the Poutiloff Canal, or the docks at Havre or Rouen now meet the requirements of Paris, which it has been proposed to convert into a seaport. The Tilbury Docks are about 20 miles from the centre of the metropolis. They are 30 miles from the western and southern limits of the city, being, indeed, almost exactly the same distance as that which separates Cronstadt from St. Petersburg. In the latter case, it was found that the cost of transporting goods over this distance was often as great as the cost of carrying them to or from England, not to speak of the inconvenience and delay which were involved.

It may not, possibly, be quite so bad as this in the case of the Tilbury Docks, but it is obvious that the traffic unloaded there must, to a very large extent, go through two subsequent breakages of bulk —the first, from the ship to the railway truck, and the second from the truck to the wagon or van that is to deliver the goods at their ultimate destination. It would be difficult to fix an average sum that would fairly represent what this process adds to the ultimate cost of the traffic, but if it is put at 10*s.* per ton all round it is not likely to be much under the mark; and 10*s.* per ton, as we know, represents the full amount that is frequently charged for the conveyance of a ton of goods from Antwerp or Liverpool to New York.

There is no good reason why the people of London should continue to pay as much for the carriage of their food and fuel from the ship's side at Tilbury to their own doors as they would pay for its transport across the Atlantic. It may now be unavoidable, but the necessity is not imperative.

* Smiles' 'Lives of the Engineers.'

If a canal were carried alongside the Thames, into the heart of the city, the west end and the southern suburbs, a great deal of this outlay might be avoided. The vessel carrying the traffic could be stopped at any one of twenty places on the route of the canal, in order that she might be enabled to unload, and the relatively short distance for which the traffic would thus require to be transported from the ship's side to the ultimate destination of the traffic would not add much to the cost of its water transport.

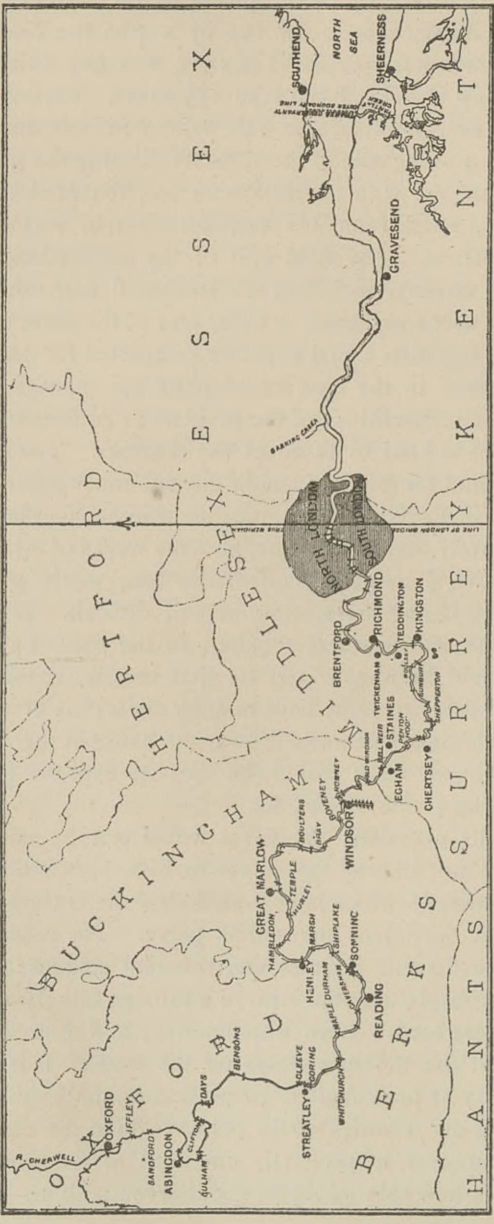
The question that those interested in this question would be likely first to ask themselves would be—At what cost could such a canal be constructed? The next question would be—Could it be made to pay? On both points there is much that is reassuring.

If we take the cost of the Suez Canal as a criterion, we find that for a distance of about 100 miles the expenditure actually incurred in construction proper was 11,653,000*l.* The total outlay appearing in the yearly balance-sheet at the end of 1886 was 19,782,000*l.*, but a great deal of the difference was expended in financing, in interest on shares during the eleven years that the canal was under construction, in transit, telegraph, and sanitary services, and in other items that would only be necessary, if at all, to a much more limited extent in the case under consideration. The actual outlay in construction represents an average of about 116,530*l.* per mile, and at this rate a Thames Navigation Canal could be built for a length of twenty-five miles for, approximately, about three millions sterling. This would, of course, be the cost of a canal capable of taking the largest vessels like the Suez Canal, and constructed on the same principle—that is, without intermediate locks, and at tide-level.

It will, however, be fairly objected that the Suez Canal is not a parallel case. The land was given by the Khedive, and the labour of the fellahs, which was largely *corvée* or forced labour, cost very little. In the neighbourhood of London, on the contrary, the price of land is high, and labour is much more expensive, although, at the same time, much more efficient. This would no doubt greatly modify the force of the application of the experience gained in the construction of the canal at Suez, although the item of land, for a considerable distance in the county of Essex, would be comparatively trifling—land being exceptionally cheap in that county—while higher wages would be counterbalanced by the more general and effective use of labour-saving machinery. Let us, however, rather be guided by the more recent, and more parallel experience of the Amsterdam

Ship Canal, which was constructed in 1870–76, for the purpose of affording a direct outlet from Amsterdam to the North Sea, through Lake Y and Lake Wigker Meer (inlets of the Zuyder Sea). The distance from Amsterdam to the sea by way of the North Holland Ship Canal, which was completed in 1825, was 52½ miles, while the Amsterdam Ship Canal reduced it to 15½ miles. Saving of distance and time was not, however, the only reason for adopting the latter project. The growing size of the ships frequenting the port, and the frequent interference with navigation by ice, rendered a new waterway necessary, apart from the considerations of saving time and shortening distance. The total cost of the undertaking was about three millions sterling, including all incidental expenses. This is approximately about 200,000*l.* a mile, and at the same rate of cost, the Thames Navigation Canal could be completed for 5,000,000*l.* as against 2,913,000*l.* in the case of adopting the mileage cost of the Suez Canal. The conditions of the problem in Amsterdam were not greatly different in kind to those of the Thames. The land had to be purchased, and the price of labour did not much differ from what would be paid in England. The quantity of material to be excavated would be relatively much the same, and the works of art required in the form of locks, sluice-gates, cofferdams, &c., would probably not be much more, if any more, onerous and difficult. It is probable that some of the heavier works required in the case of the Amsterdam Canal would be unnecessary for that on the Thames, such as the large dam that had to be built to keep the waters of the Zuyder Zee from overflowing, and washing away the banks of the canal; but, on the other hand, there would be heavier expense incurred in providing passing places, docks, &c.

Whatever its necessity, the canal would not be undertaken if capitalists were not assured that it was to be a "good thing" financially, unless, indeed—which is very unlikely—the Government put a hand somewhat deep into the public purse. The revenue of the canal would be derived from several different sources: from tolls, which would probably take the form of a through rate; from haulage, by means of tug-boats; from warehousing; and from delivery of goods *ex* ship at the different quays on the route. It is, of course, impossible to say at present what proportion of the total number of ships now using the Thames would prefer to take the canal, if constructed. If, however, it were only one-third of the whole, in ten years' time from now that would be about seven millions of tons per annum. The revenue that would thus be obtained, if a uniform charge of a shilling per ton were made, would be 350,000*l.* a year,



COURSE OF THE RIVER THAMES FROM OXFORD TO THE SEA.

which would, after deducting 10 per cent. for working expenses, yield a net revenue of 315,000*l.*, equal to more than 6 per cent. on the larger estimate of 5,000,000*l.* If, however, the canal were carried right into the heart of transpontine London, a large revenue might be expected from the delivery of goods. The principal docks are now such a long way from the west end and the southern and south-western suburbs that a very heavy charge is made for delivery of merchandise, whether by railway or by van. In many cases, indeed, as we have already pointed out, the delivery charge is higher than the ocean freight, and instances are not uncommon in which a parcel which has been carried from a port 400 or 600 miles distant for a charge of 4*s.* or 5*s.*, cost double that amount between the docks and the houses of the recipients. This is a serious grievance with the people of the metropolis, and one that they would gladly get rid of. A long step would be taken in that direction if water communication for large steamers could be brought nearer to the west end. For such a purpose the river Thames above London Bridge is practically useless. The only considerable traffic that is carried on in the upper reaches of the river is the transport of coal in barges from the Great Western Railway Company's depots at Brentford to the docks, and this is about as unsatisfactory as it could well be, involving the repeated breaking of bulk, and the damage of the coals from frequent handling. A well organised and economical system of delivery between the point of the receipt of shipping traffic in London, and the point of its ultimate consumption, would be certain to prove both successful and remunerative, whether undertaken by a canal company or otherwise.

But the lower reaches of the Thames are not more in want of some artificial relief of the kind suggested than the upper reaches.

The Thames, as we have seen, is commercially the most important river on the earth's surface, although far from being the largest the broadest, the deepest, or the longest. It takes its rise in Gloucestershire, about 375 feet above sea level. As the crow flies, the length of the river is about 119 miles, but as the river runs it is about 193 miles from its source to the sea. About 74 miles of its actual length are therefore made up of windings, the character of which will be appreciated by the plan on the opposite page.

The river is only navigable for large vessels up to London Bridge, which is about 18 miles from Gravesend. Above London Bridge a good deal of traffic is carried on by means of barges. The only steamers, however, that navigate the river above that point are the shallow-draught passenger steamers that ply between the various piers that lie alongside the banks up to Chelsea, with occasional trips in the summer months to Kew and Hampton Court. Above Hampton Court a small part of the river is canalised, and it has also been necessary to construct a small canal at Teddington, where the first lock occurs. Small craft may navigate the Thames as far as Oxford, but above Hampton Court there are numerous locks and weirs that have to be overcome, and navigation is tedious. The influence of the tide extends from the outer boundary line of the Thames Conservancy, near Southend, to Teddington lock, a distance of 57 miles. The Conservancy Board, however, control the river as far up as Lechlade, in Gloucestershire, a distance of 173 miles from its estuary.

Practically the whole of the large population on the river Thames above London Bridge are shut out from the benefits of the navigation, except by means of barges. Above Hampton Court the navigation is difficult, even for these, especially when propelled by a tug-boat. The difficulty is increased by the fact that there are over thirty locks and about twenty-two mills on the river between Oxford and the sea.

It has been suggested more than once that the Thames should be made navigable for a much longer distance, and there is, indeed, no insuperable obstable in the way of the navigation being carried up as far as Oxford. Between that city and London there is only an average fall of about 1 foot in 4100, which interposes no obstacle. The cost of cutting canals through the most obstructive windings of the river would not be serious, and it is more than probable that it would be cheerfully borne by those whom it would be most likely to benefit.

There would probably be an outcry raised that the upper reaches of the river, whicn are now largely consecrated to rural sports and pastimes, and are in many cases remarkable for their sylvan beauties, would be threatened. But in this utilitarian age—when steamers ply on the Grand Canal of Venice, when railways are carried up Vesuvius and the Righi, when the Alps are pierced by tunnels, and engineers are drawing the water supply of our great towns from the Lakes of Cumberland and Westmorland, heretofore the chosen retreat of our poets and philosophers—the test of most things is that of use and convenience; and, after all, the passage of steamers up the river Thames above Hampton Court, if it would disturb the inmates of the house-boats, and interfere with the *dolce far niente* fancies of a favoured few, would more than compensate for such drawbacks by bringing to the masses who cannot afford to gratify such luxurious tastes, more abundant commodities at a cheaper rate, and, what is quite as necessary, by getting rid of the weirs which at the present time are a great hindrance to navigation, by deepening the river, and by improving its channel generally.

The latter important requirement could probably best be met by diverting the course of the river, where it is most tortuous, or by constructing canals which would at the same time allow of the navigation being shortened, and the flood-water (which now and again plays sad havoc with the surrounding country) being carried off. By either diverting or canalising the Thames between Tadpole in Berkshire, and Sutton Pool, near Abingdon, the distance could be shortened by some 16 miles. Another saving of fully 13 miles could be made by a new cut between Reading and the river above Staines, while a third saving of 11 miles could be effected by a cut between Staines and Brentford.

The effect of giving to the numerous Thames-side towns and villages above London such facilities as those indicated would be almost certainly to develop trade and industry in the counties of Oxford, Berkshire, Buckinghamshire, Surrey, and Middlesex, through which the river flows. In those counties there is a population bordering on the Thames, which can hardly be put at less than two millions. It is, perhaps, of still more importance that the course proposed would secure for them immunity from the devastating floods to which they are now habitually exposed. Four great floods have overtaken the folks that dwell by the Thames since 1821. The most recent of these occurred in 1876, and caused damage which has been estimated at 300,000*l.* to 400,000*l.*, not to speak of the terrible hardships, inconvenience, misery, and disease which were entailed on those whose dwellings were inundated. If the ideas and proposals now put forward should contribute, in how small so ever a degree, to obviate the recurrence of such disasters, the writer would be abundantly satisfied.

SECTION III.

TRANSPORT AND WORKING.

CHAPTER XXVI.

RAILWAYS AND CANALS.

"Canals are to the inhabitants of a country what seas are to nations; they equally serve to assist the wants of society and benefit commerce."—*Cresy.*

THERE is no movement of modern times that has been more pregnant in its results, or more interesting in its course of development, than that which has given to the world its existing system or systems of transportation. Of that movement, the competition of the railway and the canal for the traffic that has been equally open to both has been a phase that has received less attention than it deserved. The railways have now had a long innings. They have been productive of immense advantage to the world. The transportation of both goods and passengers has enormously increased as a result of the facilities they have afforded. But whether railways or canals are the best adapted to economical transport is still a problem which is exercising the minds of traders, economists, politicians, and engineers, in most of the leading countries of the world.

It is probably among the things not generally remembered, if it is among the things generally known, that railways were first projected and sanctioned as feeders to canals. They were designed as the humble handmaidens of the canal system. The preamble to the earliest railway Acts recites that they would be of "great advantage to the extensive manufactories of earthenware" established in the Potteries and elsewhere. In 1792, the Monmouthshire Canal Navigation Company were anthorised "to make railways or stone roads,"* from their canals to various ironworks and mines in the counties of Monmouth and Brecknock.† In the following year, the Grand

* Stone blocks were used instead of wooden sleepers on the earliest railways.

† One section of this Act enabled the company to charge a toll for cattle driven along the line, as on an ordinary highway.

Junction Company were authorised to make a railway at Blisworth, and "a collateral communication by cuts, railways, or other ways and means," with their canal at Gayton, and the navigation of the river Nene at Northampton.* Up to 1825, indeed, canals were the absolute masters of the situation. Their owners could afford to smile at the idea of competition from railroads, and they did in many cases actually do so.

In the construction of canals, as in the promotion of railway projects, there have, in most European countries, been periods of speculative operations on a large scale, culminating in crises more or less acute. In England, the canal mania was at its height between 1791 and 1794. In those four years eighty-one canal and navigation Acts were passed by Parliament.† This was only seven years before the first railway Act was obtained for the construction of the Wandsworth and Croydon Railway.

In Holland and Russia, this epoch had been reached many years before. In Holland many canals had been constructed early in the seventeenth century, and in Russia, the same movement, initiated and carried to a certain degree of development by Peter the Great, culminated in a great number of canal projects being put forward about the same time that the canal mania was raging in England ‡ over the question whether a railway or a canal should be built for the purpose of carrying coals from the inland collieries to the sea at Stockton. In 1768, a survey had been made for a canal for the purpose by one George Dixon and one Robert Whitworth. In the following year, Brindley surveyed the same route and reported that a canal about 27 miles in length could be constructed for 63,722*l.* No action, however, was taken upon either survey, nor upon a subsequent report by Rennie on the same scheme. In 1818, we find the project still exciting the attention of Darlington and Stockton, and the inhabitants of the district divided as to the merits of the two systems. In the latter part of that year, a meeting held at Darlington pronounced a judgment which closed the controversy. It was decided that a "rail or tramway was, under existing circumstances,

* 33 George III.

† Clifford's 'History of Private Bill Legislation,' vol. i. p. 41.

‡ Oddy's 'European Commerce' gives a list of the canals that were either being promoted or constructed at the commencement of the century. Some of them were of very considerable extent. Oddy remarked in 1805 that "by means of the canals already finished a great part of European Russia has communication with one or other of the seas by which it is bounded."

preferable to a canal." The expectations of the friends of railway transport were not, however, very high. They were advised by a committee which had been appointed to consider the subject, that "one horse, of moderate power, could easily draw downwards on the railway about ten tons, and upwards about four tons, exclusive of empty waggons." Small as this outlook was, it was a great advance on the then existing system of coal transport, the towns of Tees-side having been, up to that date, supplied with fuel by droves of asses and mules, which stood in the principal thoroughfares until their burdens had been disposed of—

> "Here colliers stood with coals from distant parts,
> Some having two, and some but one-horse carts."

Even then, however, the railway had not made much impression, and the canal interest had as yet little to fear. The promoters of the Stockton and Darlington Railway, as we have seen, had no idea of employing locomotives, or of providing for passenger traffic. No mention of either was made in their original bill. The railway was intended only "to facilitate the conveyance of coal, iron, lime, corn, and other commodities" from the interior. "It had no congener for years. The impression of most people, while it was under construction, was that it was more or less of a mistake. While the line was in progress, a vigorous agitation for the construction of a canal for similar purposes was going on in the adjoining county of Northumberland." When the locomotive engine was introduced upon the scene, the friends of canal navigation hailed it with ridicule. "Who," it was said, "would ever dream of paying to be conveyed in something like a coal-wagon, upon a dreary wagon-way, by a roaring steam-engine?" The question appeared to carry its answer written on its face. The *Quarterly Review*, of March 1825, ridiculed the idea of the people of England trusting themselves to the mercy of "such a machine" as a locomotive engine on the then proposed London and Woolwich Railway, and declared its readiness "to back old Father Thames against the Woolwich Railway for any sum." Nicholas Wood, the author of the first really scientific treatise on railway locomotion, denounced the idea that locomotives could be worked at the rate of 12 miles an hour.* So recently as 1830, when the Manchester and Liverpool Railway was opened, the railway system was intended for the transport of merchandise alone, and a

* 'Practical Treatise on Railroads,' first edition.

speed of more than 12 miles an hour was not dreamt of. In this case, as in that of the Stockton and Darlington Railway five years before, the transportation problem was still unsolved.

> "The barge ne'er came, but in its place
> Shot into view the great fire-dragon,
> And entered on his world-wide race,
> With fairy coach and grim coal-waggon."

But at coal-waggons, or rather at heavy traffic generally, the enterprise was expected to stop.

The Rainhill locomotive contest, and the convincing proofs afforded thereby of the practicability of applying railway transport alike to goods and passengers, at a high rate of speed, impressed men's minds with the conviction that, if canals were not already doomed, they were, at any rate, by no means so superior as they had seemed up to that time. The Stockton and Darlington Railway had been opened for the purpose of bringing the coalfields and the ports of Durham together. There was no idea of competing with any other means of transport, because no other means of transport existed, except the packhorse. But in the case of the Liverpool and Manchester Railway, the object in view was that of antagonism to the canals, which had proved impracticable in their dealings with the merchants and manufacturers of those towns. If the canal companies had met the just and reasonable demands of the traders of Lancashire, the probability is that the Liverpool and Manchester Railway would not have been constructed until many years later. As it was, the high-handed proceedings adopted by those companies, raised the Frankenstein of railway competition, and the difficulty now was, how to lay it. Sisyphus, himself, had no harder task to perform. The issue for a time appeared to be doubtful, but not for long. The new system of transport fulfilled every expectation formed by its most sanguine promoters, and disappointed every apprehension entertained by its enemies. The canal companies found it necessary to undertake experiments, in order to demonstrate the greater economy of their system of transport. They also attempted to introduce steam propulsion, to improve their lines of communication, and in some cases to reduce their rates of charge. They did not, however, greatly mend matters. Nicholas Wood analysed their experiments, and declared that "coals and minerals were conveyed on railways equally cheap, if not at a less rate, than on canals," and in opposition to those who maintained the greater economy of waterways, he declared that "in no instance has it been shown that canal navigation is conducted at a cheaper rate, including every charge.* He thereupon argued that "the slow, tardy, and interrupted transit of canal navigation must, therefore, of necessity yield to other modes, affording a more rapid and certain means of conveyance."†

In 1825, Charles Maclaren of Edinburgh wrote an elaborate pamphlet on the comparative merits of railways, canals, and common turnpike roads, in which he maintained that the effect obtained by the draught of a single horse was ten times as great on a railway, and thirty times as great on a canal, as on a well-made road. He argued, further, that a canal cost about three times as much as a railway, so that it would require "nearly the same rates or dues per ton to make the capital yield the same interest." The relative conditions of working canals and railways were at that time very imperfectly understood, and probably the author of this interesting pamphlet would have been amazed, had he lived, to see the average expenditure per mile of railway constructed in England and Wales returned, as it now is, at close on 50,000*l.* per mile, or fully four times the outlay incurred on our canal system, relatively to mileage.

An engineer of great experience, speaking of the contest between railways and canals, has observed ‡ that the introduction of railways proved, in the first instance, a practical bar to the extension of the canal system, and, eventually, a too successful competition with the canals already made was the result. Frequently the route that had been selected by the canal engineer was found (as was to be expected) a favourable one for the competing railway, and in the result, the towns that had been served by the canal, were served by the railway, which was thus in a position to take away, even the local traffic of the canal. For some time it appeared as though canal undertakings and canalised river navigations must fail, for although heavy goods could be carried very cheaply on canals, and although, in the case of the many works and factories erected on their banks, or on basins connected with them, there was with canal navigation no item of expense corresponding to the cost of cartage to the railway stations, yet the smallness of the railway rates for heavy goods, and the greater speed of transit, were found to be more than countervailing advantages.

* 'Practical Treatise on Railways,' third edition, p 699. † Ibid., p. 18.

‡ 'Minutes of Proceeding of the Institution of Civil Engineers,' vol. lxxx. p. 11.

Canal companies, therefore, set themselves to work to add to their position of mere owners of water highways, entitled to take toll for the use of those highways, the function of common carriers, thus putting themselves on a par with the railway companies, who were, in the outset, legalised only as mere owners of iron highways, and as the receivers of toll from any persons who might choose to run engines and trains thereon—a condition of things which was altered as soon as it was pointed out that it was utterly incompatible either with punctuality or with safe working. This addition to the legal powers of the canal companies, made by the Acts of 1845 and 1847, had a very beneficial effect upon the value of their property, and assisted somewhat to preserve a mode of transport competing with that afforded by the railways.

In most of the leading countries of the world, a time arrived when the canal system and the railway system came into strong competition, and when it seemed doubtful on which side the victory would lie. This contest was necessarily more marked in England than in any other country. England had not, indeed, been the first in the field with canals, as she had been with railways. On the contrary, we are told by Smiles that "at a time when Holland had completed its magnificent system of water communication, and when France, Germany, and even Russia, had opened up important lines of inland communication, England had not cut a single canal."* But England, having once started on a career of canal development, followed it up with greater energy and on a more comprehensive scale than any other country. For more than half a century canals had had it all their own way. They had in their time done good work, in spite of much opposition.† Coming as they did on the back of an era of very dear transport, they easily proved their claims to make transport cheaper. Baines states that they carried traffic for about one-fourth of the rate that was paid previous to the introduction of such waterways.‡ They were upheld and protected by large vested interests. They offered the facilities which were desired by many inland towns of being brought into direct connection with the sea. But the railway system, first put forward as a

* Preface to the 'Lives of the Engineers,' p. 7, 1st Ed.

† Johnson was a declared enemy of canals, believing that they would interfere with country seclusion, make living dearer, displace pack-horses and waggons, and injure the trade of towns near which they might be carried.

‡ 'History of the Commerce and Town of Liverpool.'

tentative experiment, and without the slightest knowledge on the part of its promoters of the results that were before long to be realised, was making encroachments, and proving its capabilities. This was a slow process, as the way had to be felt. The first railway Acts did not contemplate the use of locomotives, nor the transport of passenger traffic. The Stockton and Darlington Railway, constructed in 1825, was the first on which locomotives were employed. Even at this date, there were many who doubted the expediency of having a railroad instead of a canal, and in the county of Durham, as we have already indicated, there was a fierce fight, carried on for more than twenty years.*

In the United States, the supremacy of waterways was maintained until a much later date. As we have elsewhere shown, a keen and embittered struggle was kept up between the canal and the railroad companies until 1857; and even in the latter year the Legislature of the State of New York, finding that railway competition was making serious inroads upon their canal traffic, were considering whether they should not either entirely prohibit the railways from carrying freight, or impose such tolls upon railway tonnage as would cripple the companies in their competition with canals.† Finding also that a large part of the traffic that had been diverted from the canals to the railroads had been carried by the latter "without profit, if not at an absolute loss," the Legislature was recommended to enact that the railway companies should be "compelled to transport at no less than fairly remunerative rates such freight as would naturally seek the cheapest mode of transit." The canals were said to have been "despoiled of their income by a semblance of legal enactment, and their rightful heritage bestowed upon chartered competitors." ‡ We may smile in this year of grace at such interpretations of the fundamental laws of political economy and of the liberty of the subject. No doubt John Stuart Mill would have set the rights of *meum* and *tuum* in a clearer and more logical light. But in those days vested interests fought hard, and distinctions were not so clearly drawn as in these. The element of speed, to which such great importance has

* Some particulars of this controversy will be found in the work entitled, 'The Jubilee Memorial of the Railway System,' which the writer prepared, at the request of the North-Eastern Railway Board, for the occasion of the jubilee of the first passenger railway, held at Darlington, September 1885.

† Poor's 'Manual of Railroads for 1881,' p. xxvii.

‡ Ibid., p. xxx.

since been attached, was only then beginning to be appreciated.* The vested interest of canals had the Government on its side, the canals having been largely constructed with State aid. The railways, on the contrary, were entirely the products of private initiative, which had to make a bold fight in order to establish any footing at all. The two systems were, moreover, essentially antagonistic in their characteristics. "The infernal activity of railroad men was naturally most repulsive to gentlemen of the old school, whose stately decorum was well reflected in the placid and unostentatious movement of the boats on the canals." † The railway companies were accused of having entered into a conspiracy "deliberately to break down these great public works, upon which the State has spent forty years of labour," and to "crush the canals into a kind of atrophy, which might result in making them odious to the State, and to transfer them eventually at a vile price to the managers of this highly creditable scheme." The public press took up the cudgels on behalf of the canals. A mighty wave of popular indignation against the railroads swept over the land. "Danger to the canals!" was the shibboleth of political parties and commercial cliques. The leading New York journal declared that "the whole community is aroused as it never was before." Prominent men of all parties demanded, through the press, that the canals should be rescued from the danger with which they were threatened. The agitation, however, came to nothing. It had no solid bottom. It was an agitation similar in kind to that which had disturbed Europe when Arkwright's spinning machine and Compton's mule were taking the place of hand labour. The clamour suddenly collapsed, and was never heard of afterwards.

Meanwhile the railway system proceeded apace. The records of human progress contain no more remarkable chapter than that which tells of the growth of American railroads. The State of New York, in which the canal interest was the strongest, had, in 1845, 721 miles of railway. In 1877 it had about 6000 miles. In the United States, as a whole, the railway mileage increased from 4633 miles in 1845 to 78,000 miles in 1877, and 160,000 miles in 1889. The growth of

* One of the advocates of the canal, as against the railroad, remarked that, "very possibly it may be vital, as it certainly is characteristic, for a live American to hurry his person at racehorse speed across the continent; but it certainly is not vital, nor in any respect necessary or expedient, thus to hurry his fuel, his timber, his building materials, his food, nor any very large proportion of his merchandise or manufactures."

† Poor's 'Manual for 1881,' p. xxxiii.

the system was attended, as it always is, by a corresponding growth of trade, and what was of more importance to the people, by a diminution of the cost of living. The total freight traffic carried on the railways of the United States in 1881 was 350 million tons, being an average of 6·7 tons per head. In 1888 the total freight carried was 589½ million tons, being an average of 9·8 tons per head. In 1870 the cost of conveying a barrel of flour from Chicago to New York was 6*s.* 5*d.*; in 1880 a working man was only called on to pay 3*s.* 3½*d.* for the same service.

From the date when the Liverpool and Manchester Railway was fairly established, canal navigation in England, with a few notable exceptions, appears to have fallen into a slumber which recalls the long night of depression and inactivity that settled down upon the arts and sciences during the middle ages. After a few years, hardly a single apologist could be found for the system of internal navigations. Railways were all the vogue, and were built everywhere. The covering of the country with a network of iron roads was made the business alike of engineers, economists, financiers, and manufacturers. The results of the railway mania of 1845–46, did something to stem the torrent of new projects, many of them of an almost impossible character. But only for a time. The canal system never again appeared to look up. One by one, canals dropped out of the race, and were bought up by railway companies, either with a view to getting rid of their competition, and so securing absolute control over the traffic, or in order to make way for new railway lines. The canals that thus fell into the hands of railways were, perhaps naturally enough, not particularly well looked after. But for this the public did not seem to care. The country had for many years been enjoying an exceptional amount of prosperity. The start that our mechanical and manufacturing superiority had given us in the race of nations, aided and abetted by the locomotive engine and the steamship, and the awakening of foreign countries to a sense of requirements previously ungratified, if not unfelt, created an enormous demand for our industrial products. In many industries, indeed, we had hardly any competition. In most others, there was a sufficient margin of profit to make it of little consequence what rates were charged for railway transport, so long as the transport was effected. In such a race as this, the slow movements of canal boats were not deemed worthy of attention, and the railways had it all their own way.

But a time was now at hand when all this was about to be changed. Foreign nations had learned our arts and manufactures, had adopted our processes, had purchased our machinery, and had instituted systems of technical instruction that caused industrial knowledge to be generally diffused and thoroughly appreciated. The development of the modern steamship, acting in concert with the improvement of railway transport in the United States, inflicted upon British agriculture a blow from which it has not rallied, and possibly never may. The prices of agricultural produce in England, hitherto almost unaffected by the range of prices elsewhere, were now controlled by the cost of producing wheat in Dakota, mutton in New Zealand, beef in Texas, butter and cheese in France, and other commodities elsewhere. Almost suddenly, a very remarkable fall took place in the profits of agriculturists at home. Our agricultural population, with its purchasing power thus seriously crippled, did not bring orders into the manufacturing districts to the same extent as formerly. Coincidently with this falling off in the home demand, foreign nations, having learned to supply their own wants, sought fewer English-made goods than before. A little later still, and they were competing "brow to brow" with English industrials in neutral markets. Our import and export returns, which had been advancing with portentous strides, suddenly dropped down in a way that caused serious alarm. It was found that the decline was one of price rather than of volume, and manufacturers, having to accept much less profits than formerly, were compelled to strain every nerve to make ends meet. This could only be done in one or other of three different ways—by the command of cheaper materials, by more economical processes of manufacture, or by cheaper transport. The railways of the United States, the telegraph system, and our own steamship lines provided the first desideratum. The second were diligently looked after by the manufacturers themselves. As regards the third they were powerless. Inquiry revealed the fact that the railway rates charged in England were generally higher than those charged in competing countries. In some cases they had damaged once-flourishing industries, and imperilled the very existence of large centres of population. Complaints against railway monopoly and railway exactions became universal. The railways were for a long time inexorable, and as they turned a deaf ear to the remonstrances of traders, the latter had to seek elsewhere for relief.

At this stage in the remarkable annals of recent industrial progress, attention was once again turned to the comparative merits of canals and railways for the transport of heavy traffic. A committee of the House of Commons was in 1882 appointed to inquire into the subject of British canals. This committee sat for a considerable time and took a great deal of evidence, most of it of an extremely unsatisfactory character, as showing how greatly British canals had passed under the domination of the principal railway companies. The report of this committee directed renewed attention to the advantages of canals as a means of transport, and gave an impetus to canal construction, of which the Manchester Ship Canal, now approaching completion, is the latest and most signal triumph. New ship canals are, however, being talked of; and it is more than likely that Sheffield and some other inland towns will, before long, be able to float large vessels to the sea.

The Railway and Canal Traffic Act of 1888 contained certain provisions that specially affected canals. One of these requires returns to be made annually to Parliament by canal companies. This provision will enable us to ascertain that which has heretofore been a sealed book—the extent to which British canals are now utilised. The concurrent proposals of the railway companies as to maximum rates and terminal charges will be likely to help the canal system, if it has any vitality left, towards resuscitation.

CHAPTER XXVII.

COMPARATIVE COST OF WATER AND LAND TRANSPORT.

THERE is no matter connected with the trade and commerce of a country that is of greater importance to its welfare than cheap transport. The business of transportation, both by land and by sea, is now one of the most gigantic in the history of the world. The railways of the United Kingdom received in 1887, for the transport of goods and passengers together, not less than 71 millions sterling, which is approximately about 6 per cent. of the whole national income from all sources. The railways of the United States in the same year had a total income of about 1000 millions of dollars, or 200 millions sterling, which is probably a still larger percentage of the total income of that country. It is the same in other European countries. Transportation is becoming a larger factor than before in the income and expenditure of all civilised nations.

The same considerations apply to the over-sea trade. The tonnage of vessels that entered and cleared from British ports in the foreign trade of 1889 was over 67 millions of tons, which would probably represent at least as many millions sterling for freights. In addition to this enormous business in the over-sea trade, our coasting trade was represented in 1889 by over 90 million tons of entrances and clearances, which would probably add 20 to 25 millions additional to the gross income of our shipping interest, bringing up the total tonnage that entered and cleared from our ports in 1889 to 157 millions, and the gross income resulting from the business of transportation by sea to, approximately, about 90 millions sterling.

The United States have no such record as this to show for their foreign trade, their foreign entrances and clearances for 1888 having amounted to only 31 millions of tons. But the internal trade of the United States, on the lakes, rivers, and canals, will probably be at least double this figure, so that the traffic dealt with is enormous. The foreign trade of the United States has more than trebled since 1864, and is still increasing at a very rapid rate.

These figures are quoted in order that the vast character of this business of transportation, and its consequent importance, may be duly appreciated. Manifestly, it is of great moment that the technical conditions which influence the cost of transport should be as perfect as possible, and that the most economical methods of carrying on the business of a country from this point of view, should be put into operation.

There is, however, a great absence of agreement, even among experts, as to what those conditions are, resulting, no doubt, from the great variety of circumstances by which they are governed. On land, the cost of haulage is necessarily determined by such considerations as the cost of fuel, the proportions of tare to live load, the character of the gradients, the adaptability of the rolling stock to the traffic, and other elements of a more or less technical description. These introduce so much variety of experience, and such conflict of results, that the cost of transport is seldom or never in any two cases exactly the same; and the figures that would be given by one authority on the subject would probably be disputed by another, so that it is to this day, after the railway system has been at work for over sixty years, and has become the dominating factor in our commercial, social, and political organisation, an extremely difficult matter to arrive at reliable data, or, at any rate, at such data as would be generally accepted as correct, relative to the actual cost of transport under given conditions.

It may, of course, be argued that the actual charges imposed by the railway companies is a likely criterion of the cost of the service. But there could hardly be a greater fallacy. In the United Kingdom the railway companies openly proclaim that the amount that a particular traffic will bear, and not the cost of the services rendered, is their basis of charge.* In no two countries, moreover, are the charges even approximately the same, and finally the charges vary in the same country, and vary considerably from year to year. As an example, it may be remarked that in the United States the average freight charge per ton per mile in 1887 was only 1·06 cents, or roughly a halfpenny per ton per mile, for all kinds of traffic, whereas in 1868 it was as much as 2·45 cents, or 1·22*d.* per ton per mile.† It is not pretended, of course, that this striking difference

* Mr. Grierson, in his work on 'Railway Rates' (p. 68) remarks that the railway companies aim at making rates conform "to the requirements of trade, or according to a popular expression, to charge what the traffic will bear."

† Statistical Abstract of the United States for 1888, pp. 185–188.

represents the difference that has, in the interval, occurred in the actual cost of transport. That the cost of transport has been reduced goes without saying, but the American railways are also now content to accept much smaller profits than formerly.

In the United Kingdom, however, the average ton-mile rates for the transport of railway traffic are much higher than in the United States, or in any of the principal countries of the Continent. This higher rate of charge is defended on the ground that the cost of railways has in England been much higher than in any other country. The charges are fixed, therefore, not according to the actual cost of the haulage and working of the traffic, but according to the amount required to perform that operation, plus the payment of dividends upon an abnormally, and, as some think, unnecessarily and unjustifiably, large capital outlay.*

Under these circumstances, there has been a constant conflict between the traders and the railway companies relative to traffic charges. The trading community has naturally been desirous of paying only for services actually rendered, and have sought to ascertain what those services have cost. The railways, however—at any rate in the United Kingdom—have withheld this information, and as they have also declined, in the main, to bring down their charges to a level that would give traders more chance in competition with foreign countries, the latter have in some directions sought to fall back upon water transport, which is generally believed to be a cheaper mode of transport than that provided by any railway, however cheaply constructed or well managed.

Even, however, in the matter of water transport there are differences that appear to render perfectly hopeless any attempt to ascertain what is the actual cost of working per unit of traffic, and what is, accordingly, the charges that the traffic ought to be called on to pay. It will be found that this cost, like that of railway transport, is affected by many elements—by the size of the canal and of the vessels employed, by the number of locks and their mechanical arrangements, by the rate of speed, by the system of traction employed, and by other obvious differences that we shall refer to later on. It is these differences, and their effect on the cost of working canal traffic,

* In 1888 the average capital per mile of railway open in the United Kingdom was 43,210*l*., but for England and Wales alone the expenditure per mile was about 50,000*l*. In the United States the cost of construction and equipment per mile of railway open in 1888 was 52,699 dollars, or roughly, 10,600*l*.

and on the consequent rates charged, that we now propose to consider.

In the annals of transportation, there is no more interesting chapter than that which deals with the contest that has been carried on for nearly half a century, between the railways and the lakes and canals for the grain traffic between Chicago and New York. This contest is interesting, not only to Americans, as the people who are engaged in it, and whom it more directly concerns; but also to the people of Europe, and of Great Britain in particular, the cost of whose food supplies is affected thereby.

Up to the end of 1874, the rate charged by railways for the transport of grain from Chicago to New York was seldom under 50 cents per 100 lbs., which is equivalent to about ·58*d.* per ton per mile—taking the distance at 950 miles. Ten years previously the average rate was rather more than double this amount. But from 1875 onwards there commenced what is called a "war of rates," in the course of which the cost of transportation was subject to the most sudden and violent fluctuations, apparently without the slightest reason or excuse, except that of the caprice of the competing companies. Thus, in 1879, the year started with a rate of 85 cents, which fell in February to 20, in April to 15, and in May to 10 cents per 100 lbs., the latter rate being exactly sixteen times more than the rate which obtained in January 1865. By the end of the year, the rate had risen again to 40 cents, and in 1880 it never fell below 30 cents. In 1881 the maximum was 40 and the minimum 12 cents; in 1882 the extremes were 30 and 12½ cents; in 1883 there was only a difference of 5 cents in the recorded maximum and minimum; and in 1884 the fluctuations ranged between 15 and 30 cents.*

At the lowest rate quoted over this period—the 10 cent rate of May 1879—the railways were actually carrying grain between Chicago and New York for rather over 0·11*d.* per ton per mile. At the same rate of transport, goods should be carried between London and Edinburgh for 3*s.* 8*d.* per ton, a fact which will perhaps bring home to the British trader what such a low rate would mean to him. The average rate over the last three or four years has, however,

* The rates have been taken from an interesting table published in the *Railroad Gazette*—an admirable and ably conducted paper—of January 9th, 1885. It is to be observed that down to 1879 the rates were quoted in a depreciated and fluctuating currency.

been about double this figure, while for the American railways as a whole it has been nearly four times as much.

The promoters of the improved Erie Canal claim that the cost of transport of wheat between Chicago and Buffalo by the large steamers that now navigate the lakes is now only 2 cents a bushel, or 8*d.* per quarter for a distance of about 800 miles. The remainder of the distance between Chicago and New York being by canal, the cost of transport has been over 4 cents per bushel for about 400 miles, being more than twice the cost, with more than twice the time in transit, for only one-half the distance.

The circumstances of the Erie Canal are, however, exceptional. Seldom, indeed, do railway freights run so low as they do on the 950 miles of railway that separate Chicago from New York. Over this distance, the great trunk lines have recently been carrying freight at the rate of 15 cents, or 7½*d.* per 100 lbs.* This is equivalent to about 14*s.* per ton, or exactly 0·174*d.* per ton per mile. There is probably no such low rates for railway transport in the world. But this low rate is due entirely to the competition of the lakes, rivers, and canals. It is very exceptional even in the United States. The average rate charged for transport in the United States in 1888 was ·45*d.* per ton per mile,† which is 164 per cent. more than the Chicago to New York rate already quoted. The railway companies do not admit that the competition of the canals was the cause of the remarkable difference here shown, but allege that it was due to "the very active competition that existed among the three main lines of railroad all striving for the business." This has been an element in the case, without doubt; but no one who is familiar with railway pools, conferences, and arrangements, is likely to suppose that if the water route had been closed, the railways would have continued rates that were most probably highly unremunerative, notwithstanding that 1131 tons of paying freight have been brought from Buffalo to New York in one train.‡

Mr. W. Shelford points out § that in the United States one half of

* Transactions of the American Society of Civil Engineers, vol. xiv., p. 44.

† According to the returns published by Poor, the total tonnage carried was 589½ million tons, and the number of ton miles was 70,423 millions. The gross receipts from freight were 639½ million dollars, and by dividing the ton-miles into the gross receipts, we get at the approximate ton-mile average.

‡ Trans. Am. Soc. C. E., vol. xiv., p. 50.

§ Report of the Conference on canal navigation at the Society of Arts, 1888.

the exports of wheat are from districts whose nearest point is 1400 miles from the Atlantic seaboard. This wheat is carried by water and rail, which are in independent hands, and form alternative routes. The routes between Chicago and New York are:—Rail, 912–990, say 950 miles; water, lakes, 985 miles; river and canal, 420–1405 miles; that is, the water route is 50 per cent. longer than the railway. Yet the water route rules the rate, because the water transport costs $\frac{1}{8}d.$ per ton per mile, while the railway transport costs nearly $\frac{1}{5}d.$ per ton per mile, and the total rate by water between Chicago and New York is two-thirds of the rate by rail. So far, there is a *prima facie* case in favour of canals.

But if the cost of transport by water be taken separately for the lakes and Erie Canal, it appears that the cost on the lakes is $\frac{1}{12}d.$ per ton per mile, and the cost on the Erie Canal and Hudson River is $\frac{1}{6}d.$ per ton per mile, so that the cost of transport on the Erie Canal is double that on the lakes, and is nearly the same as the transport by railway.

Notwithstanding the very low rates charged for transport on the canals of the United States, the Interstate Commerce Commission reported in 1887 that "the experience of the country has demonstrated that the artificial waterways cannot be successful competitors with the railways upon equal terms."

The transport of wheat grown in the Western States of America, between Chicago and New York is the largest business of its kind in that country. There are in the United States between 35 and 40 millions of acres of land under wheat crops, an area about one-half that of the whole surface of England, Ireland, and Scotland. On this vast area there was grown, in 1886, 459¼ millions of bushels of wheat, and of this quantity 129½ millions of bushels were transported from Chicago, the great warehousing centre, to New York, in the proportions of over 46 millions by canal and river and over 80 millions by railway. For many years there has been a great scramble for this traffic between the two rival systems of transportation. The predominance has lain now with the railway and then with the canal, and both, as we have seen, have had to reduce their rates from time to time in order that they might have their share of the traffic. The fluctuations in the quantities carried by the two systems within recent years have been remarkable. In 1881 only 38 millions of bushels out of a total of 139¾ millions were carried by canal, but in 1887 the canals carried 46 millions out of 127½, showing a remarkable advance in the interval. This advance is, no doubt, mainly due to the fact that in 1883 the tolls on the New York State canals were abolished.*

Appended is a table showing the estimated cost of transportation of freight between Buffalo and New York (400 miles) by different systems of water conveyance, inclusive of tolls.†—(From the Report of State Engineer of New York for 1878.)

	Cost per Ton.	Mills.	Per Bushel of Wheat.
	dols.	per ton mile.	cents.
By animal power	8·96	4·53	7·37
By Baxter steamers ‡	9·04	4·58	7·45
By Belgian system §	8·32	4·21	6·91
Do. do. §	7·76	3·92	6·48
By steamer and consort ‖	7·68	3·88	6·41
Do. do. ‖	7·56	3·83	6·34

The economists and engineers of Germany have devoted a considerable amount of attention to the question of the cost of transport by water as compared with the cost of railway transport. For such an inquiry they have had ample facilities, having not only an economically-worked railway system, but having also several navigable rivers, on which a large traffic is carried, in addition to their system of canals. The results which have been brought out by these inquiries

* According to the "Statistical Abstract of the United States" for 1887, the rates on the principal trunk railroads and the New York State canals at different periods were respectively :—

Year.	Railroad Average.	Canal Average.
	cents.	cents.
1868	2·45	·87
1878	1·40	·42
1880	1·29	·49
1882	1·18	·42

† Tolls, 1·04 cent.; elevating at New York, ½ cent.; trimming, $\frac{15}{100}$ cent.
‡ Simple steamers propelled by screws.
§ Cable in bottom of canal; steamer and tow.
‖ Screw steamer pushing consort ahead, both loaded.

are instructive, if they are not final. Their effect has been to create a very considerable agitation in Germany on behalf of additional waterways, which are described as essential to the transport of heavy traffic, and which the Government has taken up as a measure of State. Hitherto, however, the amount of traffic carried on the waterways of Germany has been very much less than the traffic carried upon the railways, thus confirming the experience of the United States, Great Britain, and France, in so far as it shows that cheapness of cost of transport is not the one thing needful.

The quantity of traffic carried over the German navigable ways in 1884 is estimated to have been close on 19½ millions of tons.* In the same year the total quantity of traffic carried over the railways of Germany amounted to 107 millions of tons, so that the railways carried 5½ times more than the waterways. For other countries the proportions of the total traffic carried in the same year were as follows :—

	Railways.	Waterways.
	tons.	tons.
United States		
France	..	30,000,000
Belgium	..	20,000,000

There does not exist any exact information as to the quantity of traffic carried on English canals. C. von Scherzer has put the quantity at 30 to 35 millions of tons.† This, however, is only conjecture. There is no authoritative record of the extent of canal traffic in this country, and no estimate of the tonnage actually carried was even attempted by the Canal Committee of 1883.

* The details are as under :—

	Tons.
Basin of East Prussia, Niemen, Vistula, Pregel, and Passarge	2,227,000
Basin of the Oder	861,000
,, ,, Elbe	7,767,000
,, ,, Weser	218,000
,, ,, Ems	176,000
,, ,, Rhine	7,565,000
Lake of Constance	338,000
Basin of the Danube	210,000
	19,362,000

† C. von Scherzer's 'Economic Life of Nations.'

A canal from the Westphalian coal district to Emden having recently been projected, a German economist was led to compare the cost of carriage upon canals and on a single-line mineral railway with few stations and a small staff. Assuming eight trains of sixty loaded waggons per day to the port, of which twelve are returned loaded, and a cost of 6000*l.* per kilometre for building the line, as actually incurred for similar lines in the district, he calculated the cost per train-kilometre as follows:—

	d.
Repairs and renewals of locomotives	1·20
Fuel	2·40
Cleaning, oil, &c.	0·54
Repairs, and renewals of wagons	2·88
Lighting and heating of guard's van	0·02
Drivers' wages, including mileage	1·41
Guards and brakesmen's wages, including mileage	2·46
Inspection, &c., of rolling stock	0·13
Station-service	3·12
Permanent-way, repairs, and signalmen	4·32
General management	1·56
Interest on capital account for line, locomotives, and wagons, at 4 per cent.	14·52
Total	34·56*d.*

$$\text{or } \frac{34 \cdot 56}{3 \cdot 60} = 0 \cdot 096d. \text{ per ton-kilometre} = 0 \cdot 16d. \text{ per ton mile.}$$

The carriage on the Elbe canals costs 0·35*d.* per ton-mile, and on the canal from the Belgian coalfields to Paris the rate was 0·29*d.* in the spring and 0·34*d.* in the autumn of 1883, without paying interest.* These figures do not, however, appear to agree with those found to work out in similar cases elsewhere. On the Aire and Calder Canal, for example, steamboat trains of barges, recently introduced by Mr. Bartholomew, have reduced the cost of haulage with a speed of 4½ to 6 miles per hour to $\frac{1}{119}$th of a penny per ton per mile for minerals, and $\frac{1}{34}$th of a penny per ton per mile for general merchandise, including return empties.† On the Leeds and Liverpool Canal, however, the cost of steam haulage, towing two 40-ton barges, fully loaded, has been given at $\frac{1}{6}$ penny per ton per mile, and on the Gloucester Canal the charge for steam towing is given at $\frac{1}{10}$th penny per ton per mile.

* Minutes of Proceedings of the Institution of Civil Engineers, vol. 78, p. 485.

† Ald. Bailey's address to the Manchester Association of Engineers, January 1886.

Cost of Horse Towing.—On two Belgian canals, the Louvain and the Charleroi, horses are employed for towing. The Louvain Canal is semi-maritime, with $3\frac{1}{2}$ metres = $11\frac{1}{2}$ feet depth of water, and runs north-west from Louvain to the river Senne, which flows into the Rupel about 1 kilom. or $\frac{5}{8}$th of a mile further north-west. Its length is 30 kilom. = $18\frac{3}{4}$ miles, divided into five levels; the total tonnage of the boats and ships passing through it in 1878 was estimated at 273,000 tons, and the charge for towing averages 6 millimes per tonne-kilom. = 0·093 penny per ton per mile. The Charleroi Canal, winding northwards from Charleroi to Brussels by a circuitous route of 75 kilom. = 47 miles, is of small section, and its boats carry only 70 tons; hence the charge for towing is higher, amounting to 8 millimes per tonne-kilom. = 0·125 penny per ton per mile. Including the return of empties, a recent writer has estimated that horse-towing might be done on free canals for 5 millimes per tonne-kilom. = 0·078 penny per ton per mile.

Cost of Steam-towing.—On the Willebroeck Canal, which runs north from Brussels past Willebroeck and enters the river Rupel opposite Boom, all boats, except steamers, are towed by a steam tug working on a chain. The length of the canal is 28 kilom. = $17\frac{1}{2}$ miles, divided into five levels; and the locks are large enough to take in six or seven boats at a time, along with their tug. The towing is done by a company, from whose scale of charges and year's balance-sheet a recent writer has calculated 0·078 penny per ton per mile as the price paid for towing, the total annual traffic amounting to about 15,400,000 ton-miles. But if the actual dividends were reduced to the rate of four per cent., which prevails for Belgian Government securities, and if certain economies were effected which are believed to be practicable, the charge for towing might be brought down to 0·047 penny per ton per mile, including empties.*

The 110-ton boats in general use by the carriers on the Willebroeck Canal make weekly the double journey from Brussels to Antwerp and back. The distance by the canal, the Rupel, and the Scheldt, is $45 \times 2 = 90$ kilom. = 56 miles there and back. The boatman gets 70 francs = 56*s.* per week for himself and his boat. With a full load both ways, this would give 7 millimes per tonne-kilom. = 0·109 penny per ton per mile. When the Charleroi Canal is enlarged, a large traffic right through from Charleroi to Antwerp is anticipated, a distance of 120 kilom. = 75 miles. A single journey

* Pro. I.C.E., vol. 78.

per week would then bring the cost down to 5·2 millimes = 0·081 penny. German estimates by Dr. Meitzen range from 4·8 to 6·4 millimes = 0·075 to 0·100 penny; whence 5 millimes per tonne-kilom. = 0·078 penny per ton per mile has been calculated as the cost of boats and boatmen, with a full load both ways, travelling 17 kilom. or 11 miles per day, including all stoppages.

After all, however, there is no case of cheap transport rates abroad that is more remarkable than the rate of sixpence per ton charged for the transport of salt on the river Weaver, between Northwich and the Mersey—a distance of thirty-six miles. This corresponds to an averge of ·17*d.* per ton per mile.

In 1888, 265 vessels were trading on the river Weaver, not including canal boats, 65 of these being steamers. These made an average of 25 trips per day, carrying a gross tonnage of 1,300,000 tons per annum, chiefly salt. The rates charged vary from a penny per ton for cinders and gravel, to a shilling per ton for white salt—rock salt, which is the staple, being charged sixpence per ton. No charge is made for dock dues, and vessels are towed up the Mersey free of cost.

Sea-transport.—There is, of course, no system of transport that is so cheap as that of ocean carrying. The rates of freight now ruling for ocean transport, low though they be, are not by any means a true criterion of the actual charges involved. Thus, it appears that at a recent date, a large quantity of grain was carried between European and United States ports for 10*s.* per ton, or ·04*d.* per ton per mile. Between Newcastle-on-Tyne and German ports, coal cargoes have been carried rather largely for about 4*s.* 10*d.* or ·12*d.* per ton per mile. Between North Sea and Baltic ports freights have ruled over considerable periods at 5*s.* per ton, or between ·04*d.* and ·08*d.* per ton per mile. The daily expenses of a large steamer may be taken at about sixpence per ton register, and as such a steamer will run from 190 to 250 miles per day, the actual cost of transport will probably not exceed ·03*d.* per ton per mile, which, however, will be increased by port stoppages, and other inevitable circumstances to ·05*d.* Mr. Bailey has ascertained that the transport of a cargo of 2360 tons of cargo, in an ordinary steamer, allowing for interest, depreciation, insurance, fuel, wages, and food, was only one penny per forty miles of journey.* This figure seems, no doubt, to be exceptionally low, but of course much would depend upon the

* Address to the Manchester Association of Engineers, p. 19.

condition of the steamer and the character of the cargo. The Erie Canal charges for sea transport are only $\frac{1}{18}$ penny per ton per mile, as compared with $\frac{1}{4}$ penny on the canal. This may, perhaps, be accepted as the measure of the differences in the cost of transport, and, if so, it would mean that the cost of working canal traffic is about four and a half times that of working such traffic on the sea. This figure is verified by many others, which are worthy of consideration. On lakes like Erie, Ontario, and Superior, the traffic costs more to work than on the sea, but less than it costs on canals. The Erie Canal charge for lake transport is $\frac{1}{9}$*d.* per ton per mile, being twice the amount charged for sea transport.

Theoretically, there is no sound reason why a modern steamship on a sufficiently large tide-level canal should not transport traffic almost at the same rate as it can do on the ocean. The resistance on the canal would be less than that usually met with at sea, but, on the other hand, the dangers of steaming too quickly compel a slow rate of speed. The actual cost of transport at sea has been variously put at from 0·03 to 0·07 per ton per mile. This does not probably include interest on capital and wear and tear, although the steamers in the Transatlantic trade were content over a long period to accept rates of freight which averaged no more than 0·04*d* per ton per mile. If this rate of freight were possible on inland waterways for our heavy traffic, it would make a wonderful difference in the total cost of transport in the United Kingdon. In 1888, there were 200 millions of tons of minerals carried in the United Kingdom alone. The total receipts from this traffic amounted to rather over 16 millions sterling, which, taking an average of a penny per ton all round, would be equivalent to 3700 millions of ton miles. If this enormous traffic were carried by canal, as it possibly might be (or at least the greater part of it) for ·25*d.* per ton per mile, there would be a possible gain to the trade of the country of $7\frac{3}{4}$ millions sterling per annum.

As things are at present, the trader who desires to make use of canal navigation in Great Britain is compelled to deal with a number of small companies, every one of which has its own rate of toll, and none of which is disposed to give too muchf acility to the others. Thus, a trader desiring to send iron-work from London to Liverpool, or *vice versâ* by canal, would have to deal with no fewer than six canals, who charge tolls varying from *2d.* to *1s. 9d.* per ton* to Preston Brook within 20 miles of Liverpool. If, however, the traffic is to be carried 20 miles further, it has to be transhipped into larger craft, and carried on the Bridgwater Canal, the owners of which charge *7s. 6d.* per ton, or more by *2s. 4d.* than the other six companies charge for the whole of the distance of 220¼ miles over which they have carried the goods. It is not, therefore, surprising that the canals compare unfavourably with railways, instead of being more favourable to the trader. For the transport of iron-work, the canal companies now make a charge of *20s.* or more per ton between London and Liverpool,† which is at the rate of over a penny per ton per mile. This is not only a prohibitory rate, but it is one that is quite unjustifiable. The actual cost of transport, including all charges, is seldom, as we have seen, more than three-tenths of a penny on English waterways. In the case of steam colliers it has been given as 0·15*d.*; in the case of steam barges on the river Lea, it is 0·33*d.*; and on the French canals it is 0·38*d.*‡ In the case of ocean steam navigation, the cost of transport is so much lower that an ocean steamer often conveys cargo across the Atlantic for about one half the price at which cargo is carried from London to Liverpool by canal, although the distance in the former case is about seventeen times that in the latter. In Germany again, where

* The tolls are as under:—

Canal.	Per Ton.	Miles.	Total per Ton per Mile.
	s. d.		*d.*
Grand Junction	1 8	96	$\frac{1}{5}$
Oxford	0 8	24	$\frac{1}{3}$
Coventry..	0 5½	22¼	$\frac{1}{4}$
Birmingham	0 5¼	5½	1
Coventry..	0 2	5½	$\frac{1}{3}$
North Stafford	1 9	67	$\frac{1}{3}$
Total	7 6	220¼	

† The principal elements of this charge are:—

	Per Ton.
	s. d.
Actual cost of transport	10 0
Tolls from London to Preston Brook	5 2
Bridgwater Company's charges .. *5s. 6d.* to	7 6

‡ Appendix to 'Report of Select Committee on Canals,' p. 236.

much more effectual use is made of the inland waterways than in England, the rate varies from ·18 to ·48 of a penny per ton per mile.* Hence, it is not surprising that in Germany "for valuable goods a preference is shown for water over railway transport." There, we are told, that "artificial waterways carry the mass of cheap goods for two-thirds of the regular railway tariff, and valuable goods for one-third or two-thirds of this tariff.† It is the same in other continental countries.

At present, our canal traders are paying four times the amount they require to do for the carriage of their heavy goods between our largest centres of population. The case of the traffic between London and Liverpool is only typical of the trade of the country generally. Between the Lancashire coalfield and the metropolis, the railway charge for transport is about 7*s.* per ton. By the canal it should, as we have seen, be brought, with a profit of 25 per cent. to the transportation agency, for a fraction over 2*s.* 6*d.*; and when we consider that the metropolis now receives about eight million tons of coal annually by railway, this difference should exercise a sensible influence on the trade of that part of the kingdom.

The great secret of cheap transportation is to handle and carry large quantities. It is this, and this only, that has enabled the United States to achieve such remarkably cheap transport, both on railways and canals—on land and on water. In 1850 the capacity of the trains which carried grain from Chicago to New York was only twenty-five cars or waggons, carrying eight tons each, or a total train-load of about 200 tons. It is now, however, no uncommon thing to see train loads of 1000 to 1200 tons between Buffalo and New York. In 1850 the largest craft employed for transporting traffic on the lakes and rivers between Chicago and New York did not exceed 600 tons, whereas now the maximum is not less than 3000 tons.‡ In both cases the maximum load has been increased to five times as much as it was in 1850.

* The inland navigation rates of Germany are established according to the following scale ('Journal of Statistical Society, 1888,' p. 391):—

	Per Ton per Mile.
(*a*) Goods in bulk, loaded in boats and towed in trains ..	·18*d.* to ·29*d.*
(*b*) Goods in bales, towed in trains	·24*d.* to ·38*d.*
(*c*) Goods in bales, carried by steam carriers	·39*d.* to 1·0*d.*

† 'Bulletin du Ministère de travaux publics,' Nov. 1887.

‡ 'Proceedings of the American Society of Civil Engineers,' vol. xiv. p. 55.

Mr. Conder* has pointed out that a feature of prime importance in which the economy of transport by canal differs from that by railway, is the incidence of the expenses of maintenance. The cost of railway maintenance, as soon as anything like an adequate amount of traffic is brought on a line, is remarkably steady, rising and falling, to a certain extent, with the increase or diminution of the volume of transport. On canals, the fixed expenses demand, in any case, a certain cost, and this cost is very little increased by a large increase of traffic. The annual cost of maintenance in the Suez Canal was actually less from 1876 to 1881 than it had been from 1871 to 1876. But the traffic had considerably more than doubled, so that the cost of maintenance per ton per mile fell from 0·35*d.* to 0·134*d.*

Bearing in mind this peculiar feature of water traffic, it is necessary, in speaking of the cost of transport by canal, to indicate the approximate amount of transport for which the calculation is made. Mr. Conder † holds that a traffic of 600,000 units of net load may be taken for this purpose, though it is far beneath the capacity of a canal of very moderate size. At this amount of duty, in order to allow a dividend of 4¼ per cent. on the capital cost, the rate of freight on an ordinary English canal comes to 154*l.* per 100,000 units, or 0·37*d.* per ton per mile. On the French canals, providing for sinking fund as well as interest, the cost of freight is 0·33*d.* per ton per mile. In Belgium it is reduced to 0·20*d.*, and on the lake and large canal navigations of the United States to 0·10*d.* But on the Aire and Calder Canal, where very special arrangements have been made for the transport of coal, it was stated in evidence before the Select Committee on Canals, that the cost of freight has been reduced to the very low figure of 0·05*d.* per ton per mile. On English railways coal transport is charged for at the rate of 0·5*d.* to 1*d.* per ton per mile.

Mr. Conder has further estimated that in order to obtain the mean return of 4¼ per cent. on capital, which is all that the English railways have secured since they stopped the canal traffic, the normal charge must be, for passengers 0·67*d.* each, for goods 1·164*d.*, and for minerals 1·838*d.* per ton per mile.‡ He adds that the charge at

* Paper on "Inland Transport in the Nineteenth Century by Land and by Water," 'Journal of the Society of Arts,' 1888.

† Ibid.

‡ Report on Wilts and Berks Canal, 1882.

which the long coal traffic is conveyed to London from Wales, over the Great Western Railway, is 0·43*d.* per ton per mile; the loss to the Company being to some extent recouped by charges of from 1·5*d.* to 1·75*d.* per ton per mile made to those towns which have no alternative means of supply. The positive loss to the Company is thus about 0·4*d.* per ton per mile, and about one-half that loss is inflicted on the purchasers or freighters.*

It is only right to point out that Mr. Conder's calculations are not accepted by railway managers, nor endorsed by independent experts. Mr. Price Williams, a well-known railway engineer, who has very closely investigated this subject, has come to the conclusion that railway companies can carry coal on an ordinary road at about 0·25*d.* per ton per mile, including return empties. This, however, is merely the cost of haulage, and it must, of course, be added to the cost of management, depreciation, interest, &c., before the exact figure is capable of ascertainment.

There is, however, even more authoritative evidence as to the actual cost of mineral traffic to the railway companies. Sir James Allport has had the candour to admit * that on the Midland Railway it is about 2*s.* 6*d.* per train mile with a train of 320 to 350 tons, which corresponds to rather under 0·2*d.* per ton per mile. This has been confirmed from other railway quarters.

* Paper on "Inland Transport in the Nineteenth Century by Land and by Water." By F. R. Conder.

† Select Committee on Canals, Report, 1883.

CHAPTER XXVIII.

SYSTEMS OF TRANSPORT AND HAULAGE.

THE cost of transport, whether by land or by water, is necessarily largely affected by the method of propulsion or traction employed. On the ocean, on lakes, and, for the most part, on rivers as well, steam and wind are the systems available. On canals, however, the wind is practically impossible as a motive power, and steam is not always convenient. It has, therefore, become necessary and customary to employ other methods. Of these, the most common in Great Britain is horse traction, which, however, is often varied by manual labour on the towing path. In either of these forms, traction is slow, tedious, and costly, but there are many cases in which it is not possible to make use of any other system. Much depends upon the width of the canal, the number of locks that have to be passed through, and other conditions that affect the problem. It has, however, been placed beyond all doubt that where steam traction can be introduced, it is much more economical than either horse or manual labour. Steam may, of course, be employed in either of two ways —either in the form of a tug-boat, with a number of barges in tow, as on the great lakes of the United States; or, where the locks are not long and wide enough to permit of this system, in the form of a locomotive, instead of a horse, on the towing-path. The former system is, of course, much more general, and, so far as it is possible to judge from recorded experiments, much more satisfactory than the latter. But there are few towing paths that could not be adapted for a narrow-gauge railway, and a small locomotive engine might, therefore, be frequently employed where a steam-tug was out of the question.

Besides the systems of traction already named, there are various systems of chain towage that have been employed, especially on the Continent, with more or less satisfactory results. These usually take the form of ordinary chain towage, by an endless chain or rope, laid along the bottom of the canal in lengths of two or three miles, the tug being drawn along by the engine pulleys engaging with the rope or chain; or endless chain towage, by which, as practised on the Rhone, the tug carries two independent engines, each of which puts in motion an endless chain drawn along by the tug. This chain, on the Rhone, receives a motion like that of the bucket chain of a dredge, but the upper part remains horizontal, while the lower follows the bottom of the canal, the length and weight of the chain being determined by the adhesion necessary to draw the tug.

Another system which is practised in France to some extent, and especially on the Rhone, is that of a keel carrying at the stem or prow a large wheel with cams, which draws the boat along by pushing against the bottom, the initial motion being given by a steam engine.

The moving of boats upon canals or narrow rivers, where sailing is impracticable, has always been attended with difficulties. Where the width and depth of water will admit, long oars have been used, worked by one or two men on each side of the vessel, as is done on the coal barges or lighters on the Thames. On the Tyne, at Newcastle, these keels are said to have been in use ever since 1378, and are rowed by an immense oar on one side, another being used at the stern to steer by, and so to counteract the tendency of this strange mode of rowing.

It is said that the large oar is hung by an iron ring, so as to admit of its being laid on the gunwale of the keel, when not in use, but not of its being removed. Owing to the want of any regular and proper path on which horses could travel by the sides of rivers, the first hauling or towing of boats was performed by men. This still continues to be the case on the canals of China and some other countries; and in this country most of our navigable rivers were without horse towing-paths until the early part of the present century. Formerly ten or fifteen men were seen tugging at the hauling line of a barge on the Thames in the meadows of Twickenham. A good horse-path now begins at Putney bridge, on the south side, and continues uninterruptedly on one side or other of the river to the extreme points of the navigation. These essential appendages to navigation were even more recently adopted on the Severn river. The towing path on many of our old navigations is continually interrupted and broken off by mills and other obstacles without any bridges for the crossing of the towing horses and boys. On the Ouse river, below

Bedford, the towing-path used to be interrupted at the end of almost every field by high and dangerous stiles, over which the ill-fated navigation horses had to leap, encumbered by their harness and the heavy rope.

The records of the machines approved by the Academy at Paris, and the Cabinet of M. de Servier, printed in 1719, contain plates and descriptions of many different contrivances, designed for the propelling or rowing of boats on canals and rivers. One of these systems depends upon gaining an impulse or hold against the ground at the bottom of the river or canal, in one of which a small boat moved by oars was proposed to be employed in successively carrying forwards and dropping anchors whose ropes were to be attached to a horse-gin, on board of a barge, which was designed to tow or drag a great number of others. In another, a spiked wheel was proposed to roll on the bottom of the canal, attached by a frame, movable on hinges, at the stern of a barge, where a roller, turned by a winch, was to give motion to the spiked wheel, and propel the barge by means of an endless rope or chain. A second kind depended upon the same principles as an oar, except in the construction and mode of applying the power.

On the 20th of July, 1796, one Thomas Potts took out a patent for the use of a large flap or oar moving upon a horizontal hinge, attached to a framed lever at the stern of a barge, intended, when the handle of this lever was lifted up by several men, to turn on its hinge and present but little resistance; but on the descent of the lever, its whole surface was, by the action of the men at the lever, to be exerted on the water for propelling the barge.

In the year 1801, one Edward Steers took out a patent which seems to have differed but little from the above, except in having two paddles or oars. Robert Beatson took out a patent for applying the principle of luffer boards or Venetian blinds to several purposes, which he has explained at length in an essay printed in 1798; and he proposed to propel ships by large oars or fins of this kind to be hung on the sides thereof by hinges, and worked by a lever, as a rudder is by its tiller-poles, with square frames fixed on their ends, to push against the water behind the vessel. A third kind, depending on the reverse of the action of an undershot water-wheel, has had many advocates.

Thomas Savery, in 1698, proposed the use of six or eight paddles, like those of a water-wheel, on each side of the vessel, fixed on an axis across the same, by the force of a capstan to be turned by men.

In the year 1781, the Abbé Arnal proposed to apply the power of a steam engine on board of a vessel for working paddles.

Soon after this period, there was employed on the Thames, at Westminster, a small barge with a water-wheel in a cavity in its stern, with a steam engine for working it, which was said to be the contrivance of Earl Stanhope, and had been tried with success against the tide in the river. In the year 1797 a vessel having rowers by its side, that made 18 strokes per minute, from the action of a steam engine on board, was tried on the Sankey Canal near Liverpool, by which it was propelled 10 miles and back again to the same place.* About the year 1800, Messrs. Hunter and Dickenson, took out a patent for a propeller for ships, which was tried in January 1801, on board of a Government sloop off Deptford on the Thames, and the sloop thereby made way against the tide at the rate of three knots an hour.†

In the Journal of the Royal Institution, about the year 1802, there is a description of an improved application of the steam engine to the turning of a wheel for propelling boats; the cylinder of this engine was horizontal, and the wheels with paddles were in a cavity in the stern of the boat, which, therefore, had two rudders, one on each side of the wheel, connected together by cross rods. A vessel of this kind was constructed for the Forth and Clyde Company under the direction of Mr. Symington, the inventor, and, in a trial made in December 1801, drew three vessels of 60 and 70 tons burthen each, at the rate of 2½ miles per hour on their canal.‡

Robert Fulton exhibited a vessel on the Seine at Paris, in August 1803, having two wheels with paddles, worked by a steam engine, and it was reported that two other vessels were towed by it against the stream at the rate of three miles per hour. A fourth kind of boat propellors, depended upon the rotary motion of a screw or fliers, like those of a jack. Daniel Bushnel, in his attempts to navigate sub-marine vessels,§ used oars, placed near the sides and top of the vessel, formed upon the principle of a screw, the axles of which entered the vessel, and by turning the same one way, the vessel was made to advance or descend by a contrary motion of the screw.

* 'Monthly Magazine,' vol. iv. p. 75. † Ibid, vol. xi. p. 195.

‡ 'Agricultural Magazine,' vol. vii. p. 152.

§ 'Transactions of the American Philosophical Society,' vol iv. p. 303.

John Vidler contrived a vessel—which was tried in the Thames at Westminster, about 1810—that had a boom hung by a universal joint (hooks) at the stern to a rotative axis, turned by a capstan upon the deck of the vessel. At the end of this boom was fixed a circle of strong flyers, just like those of a jack, which, by striking the water obliquely as the boom was turned round, propelled the vessel forward. Near to the flyers there was a collar on the boom that turned easily therein; to this collar ropes were attached, which were carried to different parts of the stern of the vessel, and by means of which the boom could be stopped when in motion, if it was desired to stop its propelling action on any temporary occasion, or the flies thereof could be let down into the water to any depth required, or be turned aside from the direct line of the vessel to steer her on any course, without expending so much of the propelling power upon the rudder as was usually done in steering.

These are but a few of the many services that have either been proposed or applied to the propulsion of boats on rivers and canals. Most of them, it need hardly be added, were found to be failures, although in some cases they contained the germs of the remarkable progress that has since taken place in the matter of propulsion generally. The number of patents that have been taken out with a view to overcoming the difficulties incidental to canal haulage have been legion. The real gist of the matter is that no two waterways present exactly the same conditions, and no system of transport will be found to answer equally well in all cases, unless the circumstances under which it is applied are identical and parallel. Hence, it becomes important to show what has been done on different waterways to meet the special conditions that have existed, and the results of these different applications.

In the earliest traction experiments made on the Elbe in 1720 a hempen rope was fastened on shore, the other end being wound up on board, and vessels were thus propelled. Nothing better than this rough system obtained for a hundred years, when, in 1820, Messrs. Tourasse and Courteaut designed special flat-bottomed tugs, 75 feet long and 17 feet wide, with a horse capstan for winding up the rope; and subsequently, on the Seine, a 6 horse-power steam-engine was substituted for the horse capstan.

Chains next took the place of hempen ropes, and between 1820 and 1830 many chain-tugs were employed on French rivers; but the first systematic service was carried out in 1846 between Paris and

Montereau (65 miles) with tugs designed by Mr. Dietz, which in their essential features are similar to those in use at the present day. These tugs drew 18 inches of water, and were fitted with engines of from 35 to 40 horse-power, actuating the drum on which the chain was wound, two sets of gear being provided for going up and down stream, respectively. The boiler pressure was 5½ atmospheres, and the expenditure of fuel 5½ lbs. per horse-power per hour. Subsequently the chain was laid further up the Seine, and it was also applied to some rivers in France.

In Germany, in 1866, chain-tugs were running on 200 miles of the Elbe, and in the next ten or twelve years this system was in use on the Saale, the Brahe, and the Neckar.

The Elbe tugs are 138 to 150 feet long and 24 feet wide, with 18 inches draught. On the other rivers of Germany they are somewhat smaller. The sides are of ¼-inch iron plate, and formerly the bottoms were of ½-inch iron, but now they are built of 4-inch pine planks, as suffering less from abrasion on dragging over a rough bed. There is a rudder at each end, the wheel being amidships. The engines are from 60 to 70 horse-power, and work with a pressure of from 5 to 7 atmospheres. In slight currents a single drum is sufficient, the chain being kept pressed against it by rollers, and the drum is nicked to prevent the slip of the chain, but ordinarily there are two drums, to which the engine power is transmitted by two sets of gearing with different rates of speed—one for working up stream, with great power and small speed; the other for down stream, with less power and greater speed. Projecting over each end of the tug are booms furnished with guide-rollers for the chain, which give increased steering facilities.

The chains are from ¾ to 1 inch thick. When fractures occur, which is seldom, it is generally at the moment of the chain being first wound round the drum. Each drum is fitted with a brake, and at the ends of the booms there are clips, designed to prevent a running out of the chain in case of the brake failing to hold.

Chain-towing has so increased on the Elbe that in 1874 there were twenty-eight tugs running regularly between Hamburg and Aussig (420 miles). On the Neckar, at the same date, five tugs were employed on 56 miles of chain, and this was to be extended for 30 miles more, from Heilbronn to Cannstatt. Experience has shown that chain-tugs have great advantages over paddle-tugs, even in smooth water, for in the latter 60 to 70 per cent. of the power is lost in slips.

Another advantage of chain-towing is that it produces no wash or swell. The charge for transport by this system is said to average about $\frac{1}{4}$*d.* per ton per mile.

In 1865 Mr. de Meseil, a Belgian, introduced a system of transport where a wire rope was substituted for the chain. The same system was taken up and improved by Max Eith of Wurtemburg, and worked with success on a 40-mile section of the Maas (from Namur to Liège). It was subsequently employed on canals in Holland and Belgium, and also on the Rhine. Extensive trials were also made on the Danube with satisfactory results.

A wire-rope tug company in 1873 laid down the line from Bingen to Rotterdam, but worked the upper section only themselves, viz. from Bingen to Ruhrort (155 miles), From Ruhrort downwards a concession was granted to a Dutch company, who employed a special kind of tug, in which the rope passed over drums inside the vessel, similar to the chain-tug system; but the usual arrangement of having the rope outside the tug has been found most convenient, as it enables it to be easily cast off and taken up again when two tugs meet.

The wire rope generally used on the Rhine is formed of forty-nine wires 0·189 inch thick, is 1·7 inch in diameter, and weighs $4\frac{3}{4}$ lb. per yard. It usually costs 10*d.* per foot, which is about one-third the weight and cost per foot of an iron chain of equal strength.

The first wire-rope tugs at work in Holland and Belgium had a 20 horse-power engine for the driving wheels, and another 10 horse-power engine to work a screw when going down stream clear of the rope. At each end, outside the tug, there are guide-wheels to keep the rope clear of the vessel, and at the centre are two large wheels which lead the rope on to a Fowler's clip-drum, against which it is kept pressed by small rollers. To pick up the rope and pass it over the wheels and drum takes a quarter of an hour.

The Danube Company's tug *Nyitra*, which resembles the Rhine tugs, is 140 feet long, $24\frac{1}{2}$ feet wide, and draws $3\frac{1}{2}$ feet of water; the clip-drum is $10\frac{1}{2}$ feet, and the adjoining wheels about 9 feet, in diameter. Against a current of $4\frac{1}{4}$ feet per second, it can draw eight barges, with a total load of over 2000 tons, at a speed of 3 miles an hour, with useful effect of 75 per cent. In chain-tugs this percentage is higher on account of the greater flexibility of the chain. Fractures of the rope seldom occur, in spite of the rocky bottom in certain sections of the river. The life of a wire rope may be taken at from four to six years.

It has been found that wire-rope tugs cannot work in less than 3 feet of water, or only with difficulty, whereas chain tugs can work in one-half of that depth. As regards steering facility, they are much alike. The delay caused by fractures is an important item in the comparison. Repairs to chains usually occupy considerably less time than repairs to wire ropes. Chain tugs in any depth under 3 feet, and in sharp curves, are said to be preferable to rope tugs; in moderately strong currents, and in larger curves, they are about equal; but in canals, and in large deep rivers, rope tugs are the best, and both are superior, in ordinary circumstances, to paddle tugs.

In canal tunnels, as in the 4-mile section between Mons and Paris, where steam cannot be used on account of the smoke, chain tugs, worked by a horse capstan, tow a barge through in one-third the time, and at one-fourth the cost, of the former system, when men were employed for towing.

Where strong rapids are met with, special appliances called "grapins" are sometimes employed. This consists of an iron wheel of about 20 feet in diameter and 17½ tons weight, furnished with projections or picks, fixed in a well-hole at midships, and worked by a chain attached to the paddle-shaft. On ascending a river the "grapin" is lowered till the picks grip the bed, on which the wheel slowly turns, and the paddles, working at the same time, in this way tow barges over the strongest rapids. Busquet's tug, which is used in France, works on a chain, though it is similar to a wire-rope tug. The *Baxter* steamboat, used on the Erie canal, was the outcome of a competition invited by the State of New York for a prize of 20,000*l.* for the steamer which best fulfilled the following, viz. a mean speed of 3 miles per hour with a load of 200 tons, small cost, and no wash or swell. This steamboat is 100 feet long, 17½ feet wide, and about 9 feet deep, with a flat bottom and vertical sides, and, including engines and coal, weighs 52 tons. It carries a load of 200 tons, with a draught of 6 feet of water, and has an average speed of about 4 miles, but can work up to 7½ miles an hour.

On the Saar coal canal Jacquel's steam-tug system is in use, where the screw is within the body of the vessel, and surrounded by a cylinder, and is fed with water by two large channels leading from the sides of the vessel to the front of the screw.*

* These particulars are abstracted, through the "Minutes of Proceedings of the Institution of Civil Engineers," from the 'Zeitschrift für technische Hochschulen' for 1881.

The tugs of the Rhine are large, very tapering vessels; some of them have engines of from 600 to 700 horse-power, and they are provided with all the latest improvement for economising fuel. Vessels with two screws are preferred, as combining adequate power with small draught; nevertheless, when the river is very low, paddle-wheel tugs of the old type have to be resorted to. Towing by aid of a submerged cable was started some years ago, but it has since been abandoned, except in the most difficult part of the river between St. Goar and Bingen, where it has proved serviceable, especially when the water is low. A serious disadvantage of this system is that in descending the river the tug has to let go the cable, and act simply as a tug, for which it is not well suited.

Improvements have been introduced in the vessels as well as in the tugs. Narrow iron vessels have been substituted for the broad wooden barges in order to reduce the tractive force. Some of these vessels are 1000 tons register; but vessels from 400 to 500 tons are the most common. On the Rhine, vessels forming one convoy are not connected together in trains, as in France, but each is provided with its tug, which is a great advantage where the navigation is difficult.

Human labour is still employed for towage on some of the Dutch, Belgian, and German canals. Boats of from 15 to 26 tons are towed by men at a speed of 1 to $1\frac{1}{3}$ miles per hour. Dr. Mitzen, a German authority, allows for this system of transport a duty of 11 miles a day, including all stoppages. Steam-tug boats on the Belgian canals are restricted to a speed of $2\frac{2}{3}$ miles per hour, and on the wider rivers to $4\frac{1}{2}$ miles per hour. On the canal joining the Tiege to the Vistula, steam-tugs draw trains of barges 410 feet long, the speed being restricted to three miles per hour. The steam-tugs put by Mr. Beardmore on the river Lea towed from 50 to 60 tons, at from two to two and a half miles per hour, in the cuts, three to three and a half miles per hour in the larger sections, and five miles per hour in the Thames. On the Grand Junction Canal the speed of a steamer towing one vessel is put from three to three and a half miles per hour. On the Rotterdam Canal, four boats, of 130 tons each, are towed by a screw steamer.

Several attempts have been made on the Leeds and Liverpool Canal to introduce steam towage, and in the year 1879 the company tried a screw steamer with compound condensing engines, to tow six 40-ton barges on a river or deep canal.

It was very quickly discovered that the vessel was next to useless on a shallow canal—the section of that particular waterway only averages from 40 feet to 50 feet in width at the surface, with flat sloping sides under water, tapering down to a mid-channel or gutter with an average depth of only 4½ feet—inasmuch as with that depth (in mid-channel only) a screw propeller of sufficient diameter could not be used to utilise the power of the engines without a very great amount of "slip" and churning of the water instead of doing useful work. It was also found that when the least obstruction took place by meeting other barges near bridges or sharp curves, causing the slowing up or stoppage entirely of the tug, the barges in tow would, so to speak, insist on running pell-mell into one another, for the simple reason that they could not apply a brake, and besides they used to get zig-zagged across the canal in every direction, which often caused a delay of fifteen or twenty minutes before all could be marshalled and got under weigh again.

Another attempt has since been made, which utilised the power of the engines with more success. Two narrow boats of about five feet beam were braced side by side under one deck, with a longitudinal space of about three feet between each, and in this space was one paddle-wheel with a long-stroke horizontal engine on deck over each boat (two engines) driving a crank on each end of the paddle shaft, set at right-angles, and across the deck stood a locomotive boiler, each boat carrying its own proportion of the weight of the boiler. The funnel had to be placed at an angle of 45 degrees, so as to get under the very low bridges. This steamer towed fairly well five barges of coal, but caused a great waste in the canal, to the injury of the banks, and was subject to the steering difficulties whenever any obstruction took place, which in this canal are frequent, owing to its very tortuous character.

The ordinary barges on the Leeds and Liverpool Canal have been utilised as tugs by putting in small engines of just sufficient power to drive a screw propeller as large as could be made available without a large percentage of positive "slip," each tug carrying a paying cargo. When the first barge was fitted up in this way, it was found that it would tow two others very well at two miles an hour. In some parts of the canal where the depth is a little greater the speed would rise to 2½ and 2¾ miles an hour; and under similar conditions, with only one barge in tow, as high as 3¼ to 3½ miles an hour. At the latter speed, however, the displacement sets up a rolling wave along banks, which does injury, whereas at 2 to 2½ miles an hour there is no perceptible disturbance of the water at the sides, and only a very slight disturbance in the centre.

A number of these steam barges are now employed on this canal, in addition to one for towing through Foulridge tunnel, one mile in length. This tug has both ends alike, with two propellers, one at the bow and one at the stern, as well as a rudder at bow and stern, so that the boat does not require to be turned about at each journey. Prior to the adoption of this tug, all barges had to be worked through the tunnel by men, who lay on their side on the gunwale of the boat, pushing it along with their feet against the tunnel wall, and taking 2 to 2¼ hours to travel the mile, whereas the tug tows two and three loaded barges at a time the same distance (one mile) in twenty to twenty-five minutes, the only hands required being the engineer and helmsman. The engine and boiler are placed as far aft as possible. The form of propeller is the result of a very exhaustive and costly series of experiments. With full-size ones in actual work, it gives the best results in shallow waters. It would not, however, be well adapted for deep-water towage. The helmsman can perform the following duties without leaving his helm, viz., start, stop, or reverse the engines, lower the funnel at bridges, blow the whistle and use the auxiliary steam jet for funnel. He can also observe the conditions of his boiler, for he has the water-gauge and steam-gauge in full view before him.

Mr. Ald. Bailey, of Salford, has given the following interesting details of the cost of a steamer for twenty-four hours' work, towing two barges fully loaded, on the Leeds and Liverpool Canal :—*

	£	s.	d.
COST OF STEAMER.			
One captain	0	4	8
One mate	0	4	8
Two ordinary hands	0	8	0
Gas coke for engines: 24 cwt. at 6*s.* 8*d.* per ton	0	8	0
Tallow (2 lb.) at 5*d.*	0	0	10
Oil (2 quarts) at 10*d.*	0	1	8
Stores, waste and lights	0	1	0
COST OF TWO BARGES.			
Two captains at 4*s.* 4*d.*	0	8	8
Two ordinary hands at 4*s.*	0	8	0
Five per cent. interest, and 10 per cent. depreciation, on first cost of steamer and barges (£1000) for one day	0	8	3
Fifteen per cent. of steamer and barges for repairs per day	0	8	3
	£3	1	8

* Paper read before the Manchester Association of Engineers.

The distance averaged in twenty-four hours (including locks) was 40 miles. The weight carried was—steamer, 35 tons; barges, each 40 tons; total 115 tons. The cost was about one-sixth of a penny per ton per mile.

Mr. Bartholomew, of the Aire and Calder Navigation, has introduced a system of a train of boats about ten or twelve in number, each carrying about 40 tons, 20 feet long, 16 feet wide, and 7 feet 6 inches deep, propelled by a steam tug.

By having a tug behind the train of boats, greater control of the steaming power is obtained. The boats are threaded together by means of wire rope controlled by two cylinders which are self-acting, and are under the charge of the man who is steering. By lengthening and shortening the wire ropes on each side of the train, it can be guided to go to any curve by making it convex or concave, the train being left to rise and fall vertically according to any little variation of headline. Buffers are attached to the ends of the boats, which have a tendency to bring them back again into line in case of any slight disorganisation caused by wind or water, the full control of the train and its direction being under the guidance of the steerer.

This system, however, could not be introduced on many of the canals in England, unless larger locks were made, or inclined planes to get from one level to another. The system has been well described as a train of waggons on water without wheels

On the Gloucester and Berkeley Canal, Mr. Clegram found that, after allowing 15 per cent. for interest and depreciation, the cost of steam haulage amounted to $\frac{1}{11}$th of a penny per ton per mile, being a saving of two-thirds as compared with horse power. With a heavier trade, however, which allowed the barges to be more generally employed, the work was done for $\frac{1}{16}$th of a penny per ton per mile.

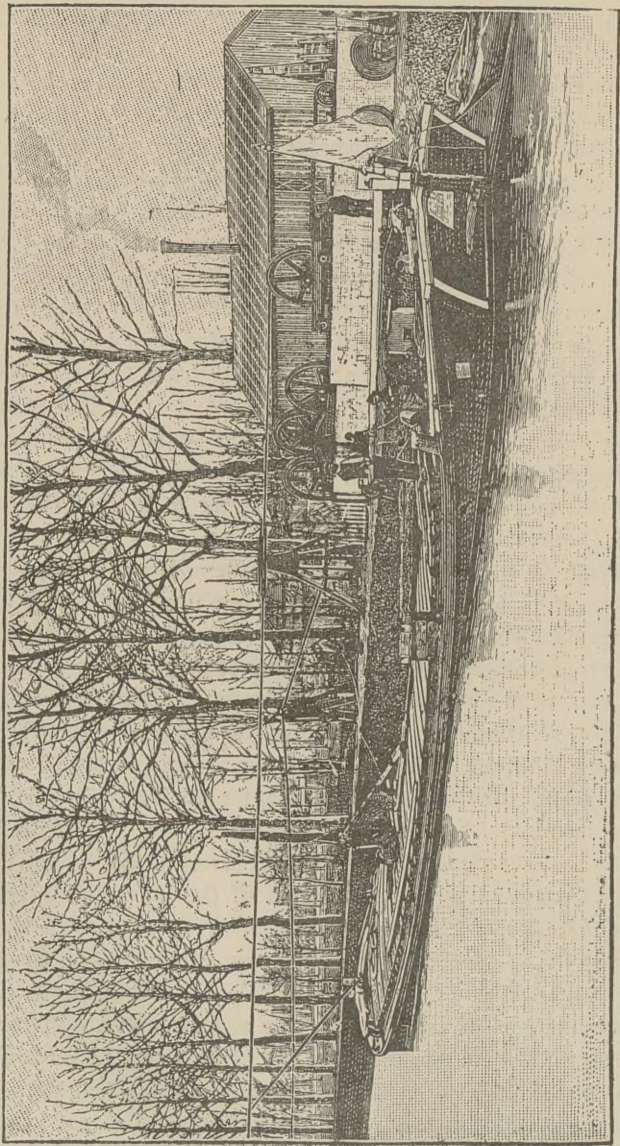
In a number of cases both chain and wire rope haulage has been tried unsuccessfully on English canals, but that, no doubt, has been owing to their peculiar local circumstances. The wire rope system has been tried on the Bridgwater Canal and found unworkable owing to the large number of bends and turns and the difficulty of working the traffic in different directions. The chain system of haulage was tried on the Grand Junction Canal of Ireland as far back as 1860, but it was soon abandoned as impracticable, and steam power was substituted.

On the canals of Deule and Neufossés locomotive haulage is employed for a total length of about 50 miles. The line is of metre gauge, and the locomotives, of which there are twenty-two, weigh from six to ten tons each. The speed employed, however, is only about $1\frac{1}{4}$ miles per hour, at which rate each locomotive can draw about 1000 tons.

In some interesting experiments lately made on French canals, a railway was laid down on the towing-path, about a yard from the brink of the canal, and a small locomotive of about four tons weight was placed upon it. The wheels were coupled and geared, with a driving wheel making 140 revolutions per minute, and allowing a maximum speed of 7 miles per hour. The engine, which was worked by one man, was attached to a cable about 80 yards long, and then drew a team of barges with complete success. It was found capable of drawing a net load of 100 tons of goods for each ton of its own weight. The actual speed was 2·4 miles per hour, and the average speed, allowing for stoppages, 1·8 miles per hour. With horses the average speed on the same canals was only 0·9 mile per hour, so that an important saving in time, as well as of expense, was obtained. The system has since been tried on a larger scale upon the canals between Dunkirk and Paris.

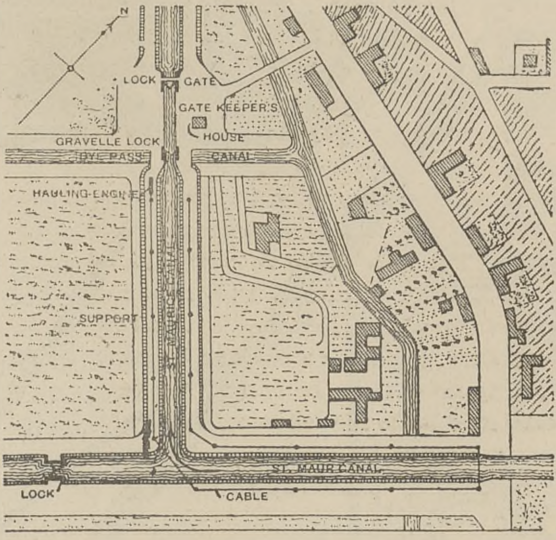
It seems, on a survey of the various systems heretofore applied to canal towage, that they may be divided into two categories. In the most important of these, the fulcrum lies out of the water, as in chain and wire-rope towage, in the employment of grapplers, in locomotive towage, and in the use of horses and men. In the other category, we find paddle-wheels and screw-propellers, which have their fulcrum in the water. In the former category, the amount of power utilised is much greater than in the latter, and, for that reason, chain, wire-rope, or locomotive towage would appear to be preferable, more especially so, as the use of screw propellers or paddle-wheels has a tendency to damage the embankments of the canal, and thereby to increase the expense of maintenance.

During the year 1888, experiments were carried out on the Saint Maurice canal with a system of cable haulage introduced by M. Levy, which seems to be of some value. An endless cable, supported by pulleys on posts along the banks of the canal, is set in motion by a hauling engine situated at some convenient point, and the barges which are attached to this cable are thus drawn along. On one side of the canal the cable runs in one direction, and on the other side it runs in the opposite direction, so as to accommodate both up and down traffic. Notwithstanding the extreme simplicity



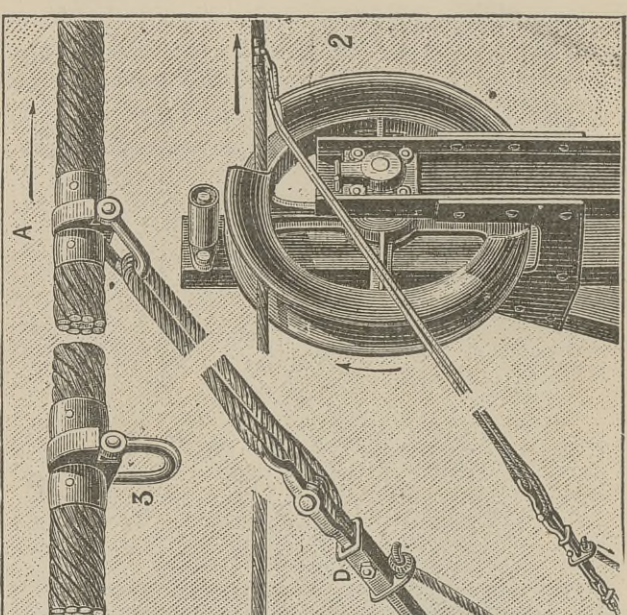
Cable Traction on the St. Maurice Canal.

of the idea, there occur considerable difficulties in its practical application, the most formidable of these being the danger that, by the oblique pull from the barges, the cable may be thrown off its supporting pulleys into the water, especially where there occurs a bend in the canal. To prevent the cable from leaving the pulleys, the latter are provided with deep flanges; but as these would prevent the easy passage of the oblique hauling rope, some special provision



PLAN OF THE ST. MAURICE CANAL, SHOWING CABLE TRACTION.

had to be made for this purpose. The flange on the water side of each pulley has two gaps, as shown in the drawings (pp. 405–406), and as the cable with its hauling rope passes into the groove, one or the other of these gaps engages the oblique rope, but not the cable which passes on in a straight line. The rope passing through the gap is thus shunted out of the groove, and passes clear of the pulley. The attachment of the rope to the cable is shown at 3. At certain intervals along the cable are attached ferrules, between which is a shackle A, which can freely revolve. Through this shackle is passed the hauling rope, made fast upon itself by an easily detachable clamp D, from which a line is taken on board. By a pull at this line the clamp is unfastened, and the hauling rope is slipped through the shackle, so that the man in charge of the barge can at any



Cable Traction on the St. Maurice Canal.

moment disconnect the latter from the cable. The speed of the cable is from $2\frac{1}{4}$ to $2\frac{1}{2}$ miles per hour, and with this speed no difficulty was experienced in making the attachment. The difficulty, however, was to impart motion to the barge without unnecessarily straining the cable. It will be easily understood that when a weight of 200 tons to 300 tons has to be set in motion, even at a comparatively slow speed, the acceleration must not be too great, otherwise the strain on the cable and hauling rope would be excessive. The attachment must therefore not be an absolutely rigid one, and, to give time for the gradual starting of the barge, the hauling rope is taken round a brake drum, and allowed to slip at first, so that the barge may be gradually set in motion; the brake is then locked, and the only further attention required is the steering. At the end of the length of canal served by the rope, the bargeman simply pulls the line, and the momentum of the barge is sufficient to carry it on to the next section, where it would be similarly attached to a running cable.

The illustration on p. 404, reproduced from *Industries*, shows the engine house by the side of the canal bank: and a plan of the experimental installation as at present carried out is shown on p. 405. The results have been so encouraging, that it is intended to equip about $6\frac{1}{2}$ miles of canal with this system. Compared with horse haulage, there is said to be a considerable gain in speed; and, as far as can be judged at present, the cost of haulage is reduced from 10 to 30 per cent.

CHAPTER XXIX.

LOCKS, PLANES, SLUICE-GATES AND LIFTS.

THE main difference between rivers and canals, is that the former are usually capable of being navigated without any artificial provision for overcoming differences of level, whereas canals are so constructed that differences of level are overcome by locks or lifts. There are, of course, many cases in which the navigation of a river is suddenly and effectually obstructed by differences of level which are unsurmountable. This is notably the case on the Niagara river, where the falls of that name interpose a bar to the further navigation of a stream which would otherwise be the natural connection between lakes Erie and Ontario. The same sort of obstruction is interposed to the navigation of the Gotha river in Sweden, by the Falls of Trolhatta. There are many cataracts on the Mississippi river and its tributaries which render navigation all but impossible. These natural barriers have in many cases been got over by the risky and difficult operation of "shooting the rapids"—a feat in which the red Indian navigators have long excelled. But while it may be possible with a canoe to overcome such obstructions without absolute disaster, it is manifest that such risks could never be run in the everyday business of commercial transport.

For these reasons, it has, in not a few cases, been found expedient to overcome the obstructions to river navigation that are interposed by rapids or cataracts, by constructing an artificial waterway parallel to the falls, on which the rise or fall of the natural waterway is surmounted by locks or lifts. The Welland Canal performs this function in Canada, and the Gotha Canal in Sweden. There is practically no limit to the differences of level that may be met by this arrangement, always assuming that water supply can be commanded at the summit.

Obviously, however, on canals, as on rivers, the fewer locks or lifts the better. The process of passing through a canal lock is tedious, and while it involves a considerable expenditure of time, it

E. & F. N. Spon, London & New York.

"INK-PHOTO" SPRAGUE & CO. LONDON.

VIEW FROM THE NIAGARA ESCARPMENT, LOOKING DOWN THE WELLAND CANAL TOWARDS LAKE ONTARIO.

involves also a corresponding amount of cost. For ship canals, it is much better to have no locks or lifts whatever. This aim was kept in view in the laying out of the Suez and Panama Canals, but on the latter canal, the cost of cutting through the Culebra mountain was found to be so very considerable, and the financial position of the company was so unsatisfactory, that M. Eiffel submitted a proposal to make use of locks, which was adopted by M. de Lesseps and his colleagues as a *dernier ressort.** The Panama Canal has proved that the avoidance of locks can only be purchased in an uneven country at an immense cost, and the canal engineer has therefore to consider whether the resources at his disposal will enable him to pay the price involved. The proposed Nicaraguan Canal is another enterprise that presents some interesting problems of this description. This canal will make use for a great part of the total distance between ocean and ocean—169 miles—of Lake Nicaragua, and as that lake is 600 feet above sea level, it is manifestly necessary to make use of locks. In other words, as the lake cannot be brought to the tide level of the canal, the canal must be carried up to the level of the lake.

A lock chamber, enclosed by a double pair of gates is said to have been employed for the first time in Italy in 1481, the designers and builders having been two clock-makers in Viterbo of the name of Domenico. The State of Venice was the first to adopt the system, but before the end of the fifteenth century, Leonardo da Vinci had united the two chief canals of Milan by six such locks, having a fall of 17 braces.†

On one of the canals constructed in Italy, between Padua and Vicenza, about the fifteenth century, there are several sluice-gates, or *pertuis*, which are said by Cresy ‡ to have been thus contrived :—

"The lower beam of each gate was framed with the head and heel posts, so as to allow a space of 6 inches between it and the sill. From the middle beam to the top, the gates were planked over in the ordinary way ; the lower part was left open, or in skeleton framing, and was closed by paddles or sluices, which were moved up and down by a rack and pinion. When the paddles were let down, they descended 3 or 4 inches lower than the surface of the floor on the

* These locks will be found described and illustrated in a previous chapter.

† Zendrini's 'Della Acque Correnti,' c. 12.

‡ 'Encyclopædia of Civil Engineering.'

lower side, which acted as a rebate, against which they pressed, and effectually shut the lock. They also had a bearing against the lower cross-beam of the gate, and the head and heel posts rested on square stones made fast in the sill.

"To make use of gates upon this construction, it was necessary first to raise the paddle as high as the lower cross-beam, which permitted the water to pass through at the foot of the gate. The paddles were then elevated to the height of the middle beam, which was placed at the ordinary level of the water, usually 4 or 5 feet deep upon the sill.

"These gates were easily opened, as the boarded part was entirely out of the water, and a deposit on the floor of the chamber of the lock could form but little obstruction, as from the scour of the water the greater part would be washed away. The only serious objection to this early contrivance in aid of internal navigation is the injury that vessels might sustain at the time they were passing through, when one half of their length would be out of the water, producing a considerable strain upon them. The water passing through a space, walled in on both sides, would, to a certain extent, allow the barge or vessel to slide down an apparent plane; but, before it could again resume its level position, it would be subjected to another strain. These side walls were, however, made of considerable length, a foot being usually allowed for every inch of fall; a timber floor was laid throughout, to prevent the force of the water from deepening and undermining the foundations."

The Chinese, who have early distinguished themselves in many inventions that have been worked out and improved upon under our Western civilisation, introduced piers into their rivers and canals, in order to overcome the difficulties incidental to falls or shoal water. These piers have been termed by De la Lande half locks, and it has been remarked by Chapman that the casual position of two pairs of piers near to each other has no doubt suggested the invention of locks, as it would be seen, when the gates of the lower piers were closed, and of sufficient height, that the water would be nearly still between the upper pair of piers, and afford an easy passage, so that, in place of a single pair of piers, two pairs would be erected sufficiently near to each other for the purpose, and capacious enough to hold a fleet of a boats. It would soon afterwards be found that in dry seasons the waste of water was greater than could be conveniently afforded, and the operation was tedious for single boats. Thus would progressively arise the invention of locks with walled chambers and sluices through their gates and walls. There are, or were recently, on some rivers, locks of the first construction, composed simply of two pairs of piers, without any connection of walls or pavement between them. The Kennet and the Lea have unwalled locks. Thomas Telford, when projecting the Inverness and Fort William Canal, on account of the great plenty of water, and size of the vessels to be used, proposed not to wall the locks the whole length, but to have earthen banks between the two pair of piers of masonry that support the upper and lower gates of the locks.

It appears from M. De la Lande's 'Traité des canaux de Navigation,' that the first lock was supposed to be erected in the year 1488, upon the Brenta, near Padua; and that shortly after, the two canals of Milan, between which there was a fall of nearly 34 feet were joined by means of six locks, similar in principle to those at present in use. The first lock that James Brindley erected appears to have been at Compton, on the Stafford and Worcester Canal; but they were not at that time uncommon in England, on several of the rivers, and on the Sankey Canal.

Planes.

William Reynolds, of Ketley, in Shropshire was the first who contrived and executed an inclined plane (which was completed in 1788) for the passage of boats and their cargoes. It was found to answer the purpose, and continued in practical use. Thomas Telford has thus described the plane, in 'Plymley's Agricultural Report of Shropshire' (p. 291): "Mr. Reynolds having occasion to improve the mode of conveying iron, stone and coals, from the neighbourhood of the Oaken-gates to the ironworks of Ketley, these materials lying generally at the distance of about a mile and a half from the ironworks, and at 73 feet above their level, he made a navigable canal," called the Ketley Canal, "and instead of descending in the usual way, by locks, continued to bring the canal forward to an abrupt part of the bank, the skirts of which terminated on a level with the ironworks. At the top of this bank he built a small lock, and from the bottom of the lock, and down the face of the bank, he constructed an inclined plane, with a double iron railway. He then erected an upright frame of timber, in which, across the lock, was fixed a large wooden barrel; round this barrel a rope was passed and was fixed to a movable frame; this last frame was formed of a size sufficient to receive a canal boat. These boats were 20 feet in length, 6 feet 4 inches wide, 3 feet 10 inches deep, and each carrying 8 tons, "and the bottom upon which the boat rested was preserved in nearly a horizontal position, by having two large wheels before and two small ones behind, varying as much in the diameters as the inclined plane varied from a horizontal plane. This frame was placed in the lock, the loaded boat was also brought from the upper canal into the lock, the lock gates were shut, and on the water being drawn from the lock into a side pond, the boat settled on a horizontal wooden frame, and as the bottom of the lock was formed with nearly the same declivity as the inclined plane, upon the lower gates being opened, the frame with the boat passed down the iron railway on the inclined plane on to the lower canal, which had been formed on a level with the Ketley iron works, being a fall of 73 feet. Very little water was required to perform this operation, because the lock was formed of no greater depth than the upper canal, except the addition of such a declivity as was sufficient for the loaded boat to move out of the lock; and in dry seasons, by the assistance of a small steam engine, the whole of the water drawn off from the lock was returned into the upper canal by means of a short pump. A double railway having been laid upon the inclined plane, the loaded boat in passing down brought up another boat containing a load nearly equal to one-third of that which passed down. The velocities of the boats were regulated by a brake acting upon a large wheel placed upon the axis, on which the ropes connected with the carriage were coiled. It appears that this plane has an inclination of about 22°, except near the extremities, where it diminishes to about 11°; and that about 400 tons of coals usually descend thereon daily." In 1789 a copper medal, or half-penny, having a representation of this plane on one side, and of the cast-iron bridge at Coalbrookdale on the other, was struck and issued by the Coalbrookdale Company. After the practicability of inclined planes had been established, by the success of the Ketley plane, few Acts were passed for a new canal, without a clause authorising the company to erect inclined planes, instead of locks, if they should be found most advisable.

At Walkden Moor, an underground plane was completed in October 1797, upon the Bridgwater Canal, similar to the Ketley plane above described.

Reynolds introduced another form of inclined plane on the

Shropshire Canal, where there were three planes employed of 120, 126, and 207 feet rises. The Act for this canal was obtained in 1788, and it was completed and opened in 1792. These planes were of the same construction as those at Ketley, except that there were no locks at the top of the descending planes, but the latter were continued above the surface of the water in the upper canal and terminated in a cross beam, from which another plane and railway descended into the upper canal, this being intended to avoid the waste of water which locks at the top of the planes occasion.

The first incline up which barges were conveyed in a large caisson containing water was at Blackhill, on the Monkland Canal, near Glasgow, the system having been previously introduced, on a small scale, on the Chard Canal in Somersetshire. The Blackhill incline, with a rise of 96 feet, and a gradient of 1 in 10, replaced two flights of four locks each. The wrought-iron caisson, 70 feet long, and $13\frac{1}{3}$ feet wide, runs on twenty wheels, and carries barges of 60 tons on the incline. An incline with larger caissons was constructed at Georgetown in 1876, in substitution for two locks connecting the Chesapeake and Ohio Canal with the Potomac. This incline rises 39 feet, with a gradient of 1 in 12; and barges of 115 tons are transferred from the lower to the upper reach in 8 or 10 minutes. The caisson is 112 feet long, $16\frac{3}{4}$ feet wide, and $7\frac{5}{6}$ feet high. It is carried on three trucks, with twelve wheels each, and is drawn up by wire cables worked by a turbine.

A canal incline, as described by Mr. Vernon-Harcourt,* consists of two lines of way, laid on a steep uniform gradient, on which barges are drawn up or let down, by wire cables, from one reach to the next, either resting on a cradle, or water-borne, in a caisson, running on wheels on the incline. The cables wind round a drum at the top of the incline; and the ascending barge is generally more or less counterbalanced by another descending, whereby the tractive force required to pull the barge up is considerably reduced. Primitive inclines exist on the Bude Canal in Cornwall. Inclines are often used, as alternatives to locks, as at Hampton Court, on the Thames. Inclines, up which barges are drawn in cradles, were carried out on the most extensive scale on the Morris Canal in America, where there are twenty-three inclines with gradients of 1 in 10,

* Report of the Conference on Canals and Inland Navigation, held at the Hall of the Society of Arts in 1888, p. 5.

and an average lift of 58 feet. The largest of these is 1100 feet long, and rises 100 feet; and barges of 70 tons are drawn up the inclines.

Locks.

In the great majority of cases, however locks are the means adopted for overcoming differences of level. In Great Britain it is calculated that on the existing canal system of 2240 miles, there are 1901 locks, being at the rate of one lock to every 1·37 miles of canal, of which 931, or nearly one-half, are 80 feet long or more.* This, of course, means very slow transport and great loss of time. On the canal system between Birmingham and London there are about 130 locks in all.

The loss of time due to the passage of locks arises from two causes, one of which, as Mr. Conder points out,† it is easy to calculate, while the other varies extremely according to the management of the line, and the nature and volume of the traffic. The rise or fall of the water in the lock occupies an ascertainable time, ranging from three to six minutes; but the time lost in entering and leaving the locks is less easy to calculate. With perfect arrangement the loss is very small; frequently it is, in fact, very considerable. "In the event of a heavy traffic being thrown on our canals, it will probably be advisable to double the locks, a communication being made practicable between the pair, in order to save half a lock full of water at each passage. With this arrangement much time as well as much water may be saved. The average retardation due to the hydraulic requirements alone of the locks on the English canals is from 1¾ to 2 minutes per mile, the average rise to be overcome being under 6 feet per mile of canal."

In France, on all the more important canal routes, the locks are designed to accommodate the large *péniches* or boats of 270 tons burden, 116 feet long, and 16 feet beam, which are the usual craft employed. In cases of exceptional traffic, the locks are made 130 yards long by 13 yards wide, in order to allow of several vessels passing through together. These arrangements are very favourable to the transport of large quantities of freight, so much so, that it is no unusual thing to see 25 to 30 barges, each laden with 270 tons of coal, towed by a small tug of 20 horse-power, working a submerged

* Report of the Select Committee on Canals, 1883, p. 125.

† Paper on "Inland Transport in the Ninteenth Century by Land and Water."

chain or wire rope, which the tug raises from the bottom as it progresses, the rope being nipped between revolving pulleys.

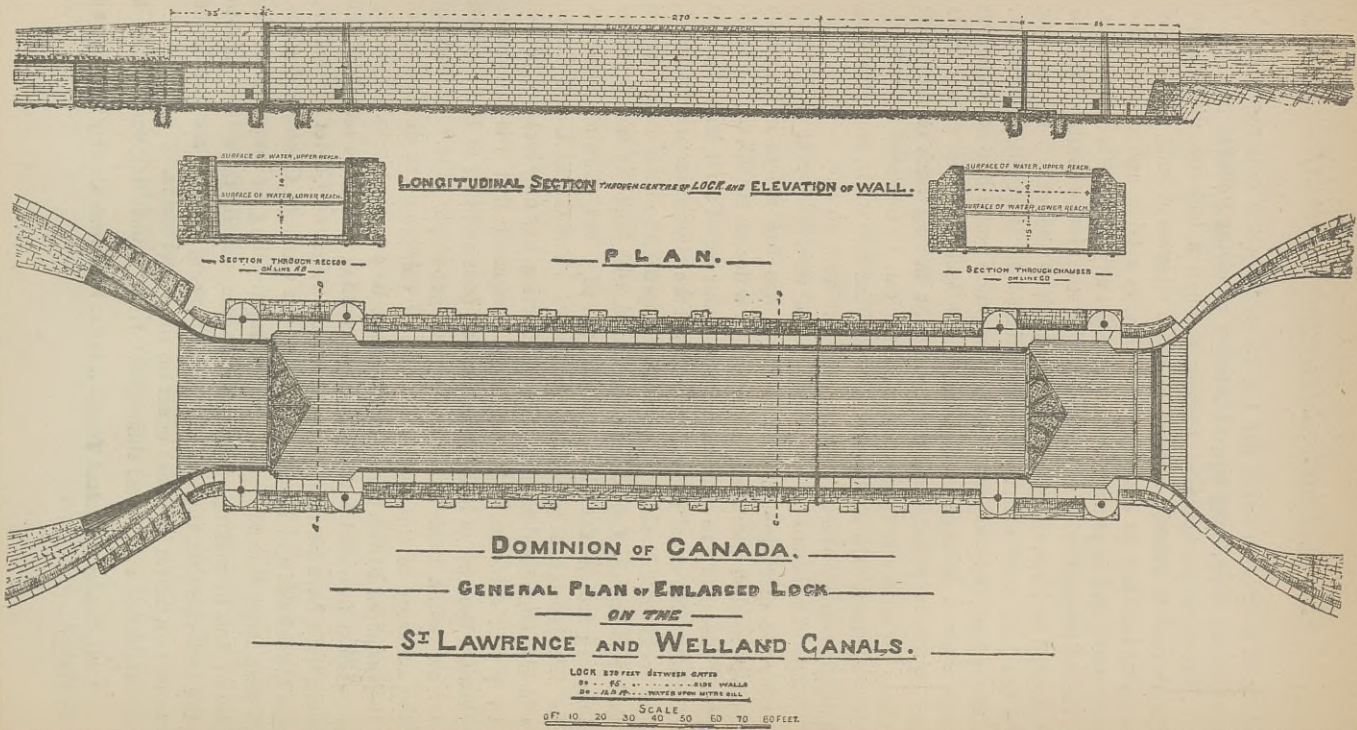
The time occupied in passing through a lock on the French canals used to amount to from 16 to 20 minutes at least. The time is spent in filling or emptying the lock, in closing and opening the lock-gates, and in passing the barge into and out of the lock-chamber. The adjustment of the water-level in the lock-chamber may be hastened by large sluices in the side walls of the lock. The moving of the lock-gates can be rapidly effected by hydraulic machinery. Delays have been experienced in dragging a barge into or out of the lock when it is nearly the width of the lock-chamber, owing to its acting like a piston, and preventing the flowing back of the water along the sides; but this inconvenience can be obviated by carrying the culverts for the sluiceways all along the side walls, and providing lateral openings through which the water finds an exit.

The dimensions of the canal locks resolved upon in France, under the extension scheme of 1878, was 126·2 feet in length by 17 feet in clear width, and 6·56 feet of water on the sill of the lock-gate. Boats of 120 tons burden can make use of such locks without difficulty. No canal in England, except the Gloucester and Berkeley, has locks of this size. The nearest approach to such dimensions is that made by the Grand Junction Canal, with locks 87 feet 6 inches long, 15 feet in the clear, and a depth of 5 feet, allowing, however, for the passage of an 80-ton boat only. The Grand Union Canal, which is connected with the Grand Junction, has only locks of 78 feet by 7 feet 2 inches. It has been computed that the difference between the cost of locks for a 120-ton boat and that of locks suited for an 80-ton boat is not more than 3000*l.* per mile.* Assuming the accuracy of this figure, the cost of enlarging the dimensions of the principal British canals ought not to be a serious item.

Locks provided with sluiceways running the whole length of the side walls have been constructed on the Aire and Calder navigation, on the Scheldt and Meuse Canal, and the Canal du Centre of France. These large sluiceways ensure the rapid filling or emptying of the lock; and by making several side openings along the side walls into the lock-chamber, the inflowing or outflowing currents are distributed so as to have no injurious effect on the vessel inside.

Balanced cylindrical sluice-gates, rising and falling vertically in a

* Mr. Conder on 'Inland Transport in the Nineteenth Century by Land and by Water.'


35
270
55
SURFACE OF WATER, UPPER REACH.
LONGITUDINAL SECTION THROUGH CENTRE OF LOCK AND ELEVATION OF WALL.
SURFACE OF WATER, UPPER REACH.
SURFACE OF WATER, LOWER REACH.
SECTION THROUGH RECESS ON LINE AB
PLAN.
SURFACE OF WATER, UPPER REACH.
SURFACE OF WATER, LOWER REACH.
SECTION THROUGH CHAMBER ON LINE CD
DOMINION OF CANADA.
GENERAL PLAN OF ENLARGED LOCK
ON THE
ST LAWRENCE AND WELLAND CANALS.
LOCK 270 FEET BETWEEN GATES
DO - - 45 - - - - - - - SIDE WALLS
DO - 12.0 Ft. - - - WATER UPON MITRE SILL
SCALE
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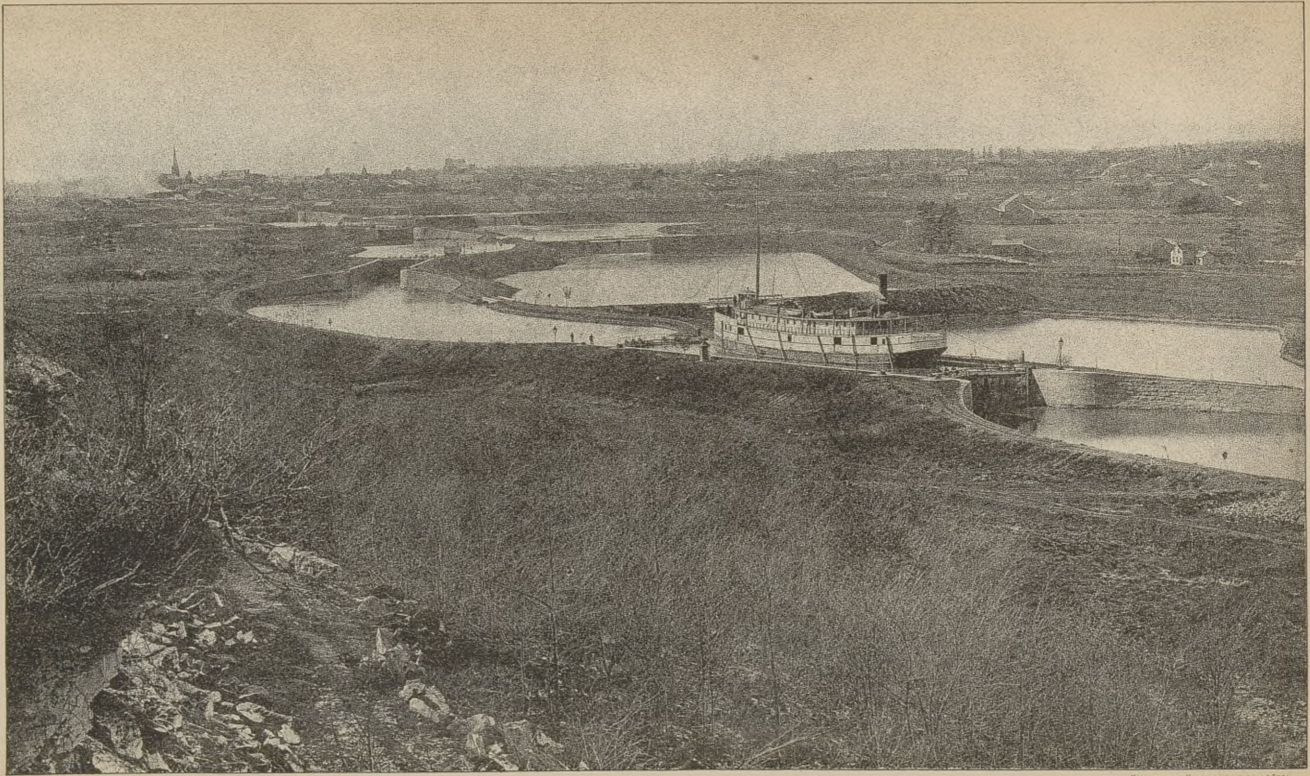

E. & F. N. Spon, London & New York

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VIEW FROM THE NIAGARA ESCARPMENT, LOOKING UP THE WELLAND CANAL TOWARDS LAKE ERIE.

circular well communicating with the sluiceways, have been adopted at the new locks of the Scheldt and Meuse Canal, and the Canal du Centre, for opening and closing the sluiceways easily and rapidly. The enlarged locks on the Canal du Centre can be filled or emptied in two minutes; and the passage of vessels through the locks takes less than half the original time.

Mr. E. J. Lloyd, speaking from experience of canals in the Midlands, is of opinion that a multiple of the present size of lock which prevails throughout the Midland district would be best. This would enable the existing craft on those canals, and also most of the barges on larger navigations, to be used in the most economical way possible. It would greatly simplify the conduct and management of low-class mineral traffic, which does not require any care, and could be treated in a similar manner to traffic of the like description on railways—no crews being attached to the boats, which could be detached from the trains, and left at any roadside wharf, until they could be unladen at the convenience of the owners.

There is, no doubt, as Mr. Lloyd points out, a distinct advantage in small craft for such traffic, as it is obvious that a coal merchant could purchase small boat-loads of different classes of coals, to suit his customers, who could not find capital and wharf space for large cargoes of one class of coal only, and this would apply in equal degree to traffic in road-stone, bricks, drain-pipes, building materials, and many other classes of undamageable goods, and these small craft might also ply successfully on short branch canals, in districts which would not produce a sufficient traffic to warrant a large expenditure in improvement. Such locks would also, of course, accommodate craft sufficiently large to cross the estuaries of rivers, and to approach any docks with safety, and if sufficient depth of waterway is provided in the improved main lines, say 8 feet, or thereabouts, short coasting voyages might also be undertaken by craft specially constructed to do so, and also to navigate the canals.* Mr. Lloyd thinks that the heavy cost involved in constructing canals of sufficient size to pass craft suitable for coasting and short continental voyages would be fatal to cheap conveyance.

The largest locks hitherto constructed are those on the St. Mary's Falls Canal, in the United States, and the Welland Canal in Canada. On the former canal the lock opened in 1881 is 515 feet in length

* Report of the Conference on Canals and Inland Navigation, 'Journal of the Society of Arts,' for 1888.

and 80 feet wide. The great tidal lock at Eastham, on the Manchester Ship Canal, will be 600 feet long and 80 feet wide.

The Welland Canal, which is in some respects the most important in Canada, was begun by a private company in 1824 and opened in 1829. The original locks were of wood, 110 feet by 22 feet by 8 feet, and they bulged out on each side of the chamber to such an extent that they had to be hewn down from time to time to let vessels pass through. The canal was enlarged in 1841, and again in 1871, the depth of the canal having, on the occasion of the last enlargement, been increased to 14 feet. The drawing (p. 415) shows the general plan of the enlarged lock on this canal. It is 270 feet between the gates, 45 feet between the side walls, and has 12 to 14 feet of water upon the mitre sill.

The entire system of locks on the *Manchester Ship Canal*, now under construction, will be as under :—

Three locks at Eastham, namely, one 600 feet long by 80 feet wide; one 450 feet long by 50 feet wide; one 150 feet long by 30 feet wide.

Two locks at Latchford, namely, one 600 feet long by 65 feet wide; one 450 feet long by 45 feet wide.

Two locks at Irlam : similar to Latchford.

Two locks at Barton : similar to Latchford.

Two entrance locks to docks : similar to Latchford.

Small lock (Weston Marsh Lock), 229 feet long by 42 feet 8 inches wide, to connect the ship canal with the Weston canal.

Weston Mersey Lock, opposite Weston Point ; 600 feet long and 45 feet wide.

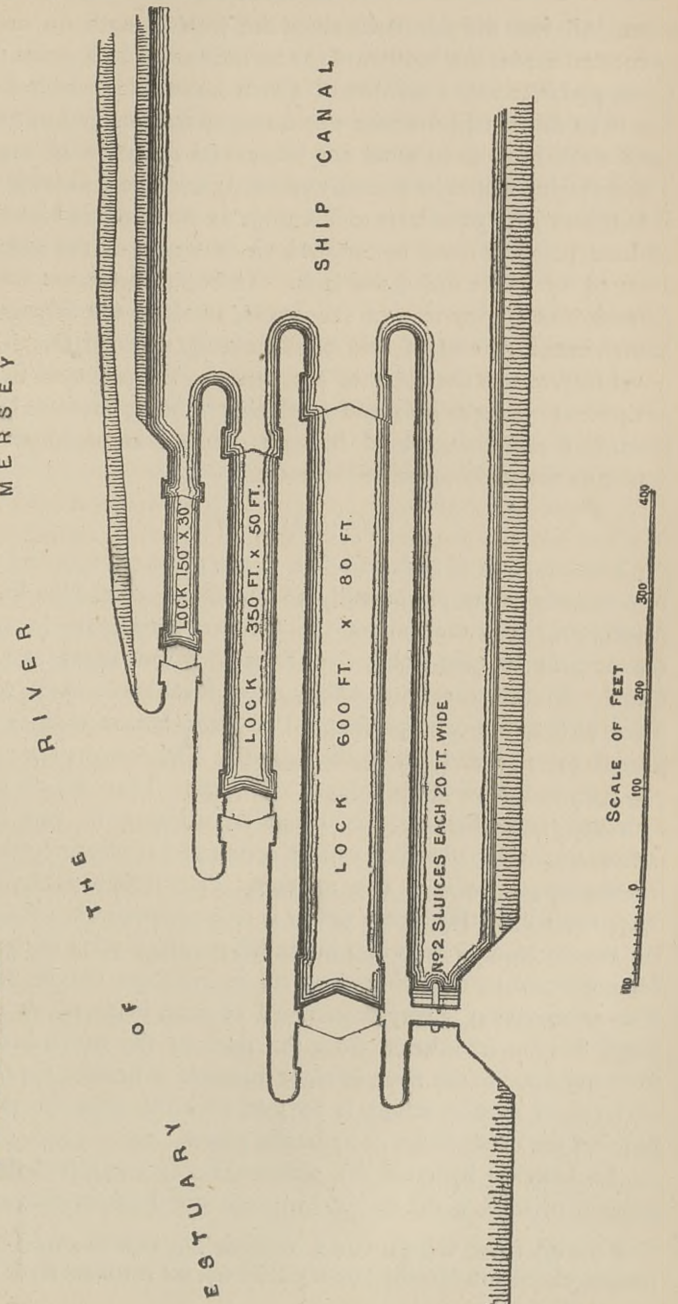
Bridgwater Lock, opposite Bridgwater Dock, Runcorn, 300 feet long and 45 feet wide.

Runcorn Old Quay Lock below Old Quay Docks, Runcorn, 300 feet long and 45 feet wide.

The three locks above mentioned connect the ship canal with the Mersey Estuary at their several points.

Two small barge locks at Walton and Stockton Heath, Warrington.

The largest canal locks hitherto contemplated are those designed by Col. Blackman for the proposed *Nicaragua Canal.* They are 700 feet long, 100 feet wide, and with 30 feet depth of water over the sill; whilst the lift proposed is from 50 to 120 feet. The filling of the lock-chamber was to be rapidly effected through 18 feet cast-iron



MANCHESTER SHIP CANAL
ENTRANCE LOCKS AT EASTHAM.

pipes, built into the side walls along the whole length on each side, connected across the bottom of the lock-chamber by a series of 3-feet pipes, perforated by a number of 2-inch holes, from which the water was to be distributed over the whole area of the chamber in numerous small streams, so as to avoid any prejudicial agitation of the water. The emptying was to be similarly effected; and where a saving of water is important, the pipes were to discharge at the lower end into a series of long ponds, formed in terraces, so that most of the water might be used again for filling the lock. These arrangements are a large extension of the system of sluiceways, all along the side walls, with lateral openings, and of side ponds, already referred to. The most novel feature was the form of the caisson-gate, proposed to be constructed of wrought iron and steel, which, being increased in width towards the bottom, would become stronger in proportion to the depth, as the water-pressure increases.

Hydraulic Lifts.

The adoption of hydraulic lifts, in the place of locks and inclines, has recently come prominently to the front. The first lift of this description* was erected on the Weaver Navigation in 1875, for the purpose of connecting that river with the Trent and Mersey Canal. In this case the difference of level between the canal and the river is rather over 50 feet. Two wrought-iron troughs are employed to raise and lower the barges. The troughs are 75 feet by 15½ feet, and have 5 feet depth of water. They rest on a central hydraulic ram, three feet in diameter, working in two hydraulic presses underground, which can be connected at pleasure, making the troughs counterbalance one another. One trough ascends as the other descends. Hydraulic power is only required when the descending trough reaches the water in the lift-pit, the motion of the troughs being effected by removing about six inches from the lower trough. This arrangement is very economical of time, inasmuch as a 100-ton barge can be transferred from the river to the canal, and another from the canal to the river, in eight minutes. Although the difference of level, as already stated, is 50 feet, only the final lift of 4½ feet requires the expenditure of hydraulic power.

La Louviere hydraulic lift, which was only completed during the summer of 1888, is the largest hydraulic canal lift in the world. It

* On the Great Western Canal, a simple lift, with two counterbalancing troughs, was used in the early part of the century, but it was not found successful.

was constructed for the Belgian Government by the Société Cockerill, of Seraing, from the designs and under the superintendence of Messrs. Clark, Stanfield and Clark, of Westminster, the consulting engineers of the Government, and the patentees of the system. The difference between the levels of the upper and lower canals—that is, the height the boats are raised—is 50 feet 6¼ inches. The lift consists of two pontoons or troughs, each 141 feet long by 19 feet broad, with 8 feet draught of water, and are capable of holding the largest size of barge that navigates the Belgian broad-gauge canal system. Such barges are capable of taking 400 tons of coal or other cargo, so that the total weight of the trough, water, and barge is not much under 1000 tons. This immense weight is supported on the top of a single colossal hydraulic ram of 6 feet 6¾ inches diameter, and 63 feet 9½ inches long, working in a press of cast iron, hooped continuously for greater security with weldless steel coils. The working pressure in this press is about 470 lb. to the square inch. The time actually occupied in the operation of lifting or lowering is only two and a half minutes. (See illustration at p. 141.)

It is probable that there is a greater liability to accidents, with lifts than with either locks or inclined planes. Where a dead weight of some hundreds of tons has to be moved bodily, it must, of course, be necessary to provide correspondingly strong machinery, and this is not to be done without considerable cost. Several accidents have, indeed, recently occurred in hydraulic presses for lifts. One of these occurred with a steel press which burst under a pressure of 70 atmospheres. Another happened with a riveted steel-plate press, which leaked and rent under pressure.

On the Brussels and Charleroi Canal it was recently proposed to apply an hydraulic lift, for which the Cockerill Company made a cylinder, in which tightness was obtained by the use of cast iron, and strength by the use of steel, the cylinder being cut with projecting rings, turned to receive steel hoops, which were bored to a slightly smaller diameter, put on hot, and allowed to contract. A cylinder 2·06 metres (6 feet 9 inches) in diameter and 2 metres (6 feet 7 inches) high, was subjected, by means of force-pumps, to an internal pressure of 131 atmospheres, or four times that which would be required in practice. The French engineers, following the Seraing system, formed their cylinders of a series of steel hoops fitting one into the other, and with the flanges of the two outside hoops drawn together by tie-rods, the inside being lined with brass 0·0025 metre thick, applied with the mallet, so that the water may not come into contact with the joints. A trial cylinder was tested up to 170 atmospheres without yielding. On the Brussels and Charleroi Canal, however, it was decided to substitute a tunnel for the intended lift, so that the Cockerill cylinders were not applied.

Inclines, or lifts, are said by some authorities to effect a great economy, both in time and water, as compared with flights of locks. Much, however, must depend upon local circumstances.

One problem that is likely to press for solution in the immediate future is that of constructing locks or lifts that will enable ship canals to be worked with facility and economy. The proposal of the late Mr. Eads to construct a ship railway across the Isthmus of Tehuantepec was intended to overcome the necessity of such a canal, and was, indeed, a form of lift, of the practicability of which, however, we still await a conclusive demonstration. There is, of course, a natural limit to the size of locks that it is possible to work. That limit, however, does not appear to have been reached in any locks hitherto constructed. The Eastham locks on the Manchester Ship Canal will be the largest hitherto made; but we have seen that locks, even 100 feet longer, have been proposed for the Nicaraguan Canal. Of course, by the application of steam power, canal locks may be made of larger dimensions, and there are some instances in which such power has been attended with much advantage.

In 1868, steam-power was applied to the locks of the Delaware and Raritan Canal, and is said to have increased their capacity for traffic, and therefore that of the canal, by 50 per cent. The engine has two cylinders, 6 inches diameter, 12 inches stroke, and works a 3-feet drum, actuating a 1-inch wire rope, which passes over rollers, along the face of the lock, and round sheaves above and below. To this rope the boats are attached and hauled in and out, two at a time. The engine also raises and lowers the valves, opens and shuts the gates, and in one case works a swing bridge. For large docks (e. g. 600 feet by 800 feet) it has been proposed* to admit and take off the water by channels the full width of the length of the lock, the water entering and leaving the lock by a number of small sluice-ways, through the walls at right angles to the axis. This water should, if possible, be supplied, not from the reach above, but from separate reservoirs. There will thus be two waterways at right angles to

* Min. Proc. I. C. E., vol. lxiii. p. 350.

reach each other, one longitudinal for the passage of vessels only, and one transverse, for the passage of water only. This avoids the expense of maintaining the paddles in the lock gates, and all the risks attending longitudinal currents. The canal should be widened above and below by floating pontoons, not by fixed walls. The height of the lift may be varied as required up to 30 feet; a lift of 33 feet has been worked for twenty-five years with ease and safety.

CHAPTER XXX.

TUNNELS, VIADUCTS, EMBANKMENTS, AND WEIRS.

In the laying out of a canal there generally comes a juncture at which the engineer has to choose between a tunnel, a flight of locks, a lift, or series of lifts, and, finally, an embankment. There are also cases, although these are comparatively rare, in which a valley has been crossed, and the level of the water maintained, by aqueducts.

Tunnelling is always a costly operation, and it seldom happens that it gives a considerable advantage, if any, over locks in the matter of speed. Nevertheless, many of the early canal engineers were partial to tunnels, and hence there are many examples of such structures on the canal system of Great Britain. Of some of these we may suitably furnish particulars before proceeding to refer to more recent works of the same character.

One of the earliest canal tunnels of which we have any record was constructed by Brindley on the Bridgwater canal. This tunnel gave the Duke access from his canal into the coal works at Worsley, and after it had proceeded for some way straight into the hill, came at a great depth to be under a small brook or constant stream of water, by the side of which a large water-shaft was sunk, and a drum and a large brake-wheel erected over it, of such size that a man who stood before the lever had his two hands at liberty to pull the lines which connected the valves, and give signals to those below, while by lunging or stepping forwards, with his breast against the lever, he could in an instant stop the machinery in any part of its motion, or regulate the same at pleasure. There were two water-tubs, which were very large, and had a valve and pin to empty themselves quickly when they arrived at the bottom. They were suspended by large ropes or cables from the drum, while other large ropes descended therefrom through another or coal-shaft, by the side of the middle or principal tunnel, into and over the navigable tunnel, which is there at some 60 yards lower level. On this level, canal boats were used, similar in their dimensions to those above, and containing boxes, which being filled with coals at the several terminations of the canal, in the seams of coals, were pushed along by means of rings fixed along the roof of the tunnel at the proper height for a man, who walked on the top of the coals, to lay hold of, and shove the boat along by. The boat having arrived under the coal shaft, and one of the water-tubs being at the top of its shaft, the coal rope answering thereto was hooked on to the box of coals, and the descent of the water-tub, immediately on the ringing of a bell, drew up the same to the level of the principal canal, where, being drawn aside over an empty boat, it was lowered into the same by a slight reversion of the motion of the machine, when the interval of emptying the tub at the bottom by its valve gave time for hooking another box to the other rope which was at the bottom, when the other water-tub was filled, and the machine was suffered to move by the man who leant against the brake.

This arrangement was contrived and erected by James Brindley, and it was so constructed that when coals were not drawing, the alternate descent of the water-tubs worked some very large pumps, which were sufficient to lift all the mine water of the lower level into the middle canal, and to keep the lower canal always at the proper height for navigation.

The same tunnel of the Bridgwater canal was continued a considerable way farther into Worsley Hill, until, under Walkden Moor, another subterraneous canal or tunnel begins, at 35½ yards higher level, being nearly 60 yards from the surface. From the surface two shafts were sunk, one terminating in and over the upper tunnel or canal, and the other in and over the middle or principal canal. There is another canal still lower, and after passing close by the canal above. Between these shafts a large drum was erected on the surface, with a brake-wheel and a pair of strong ropes. An old account of the working of this tunnel states, that "two boats being arrived at the shafts on the upper canal, one of them loaded with boxes of limestone that was wanted at the furnaces, and another with boxes of coals intended to be transferred into an empty boat in the middle canal, the ends of the two ropes were fastened to a box of coals and a box of limestone, when the superior size and weight of the coal boxes drew the limestone to the surface, to be there landed and deposited, at the same time as the box of coals was deposited in the lower boat, ready to proceed on the canal to Manchester or other places."

This method was, in 1797, superseded by an inclined plane for letting down the boats laden with coals from the higher to the middle level, and returning the empty boats and boxes.

At Brierley Hill, near Coalbrook Dale, the extremity of a branch of the Shropshire canal, great quantities of coal and iron, in crates made of iron, were let down one of two shafts, which connected with the termination of the canal above, and the ends of a railway in a tunnel below, from which limestone in similar crates was drawn up the other shaft to be placed in the boat. A barrel and brake-wheel were fixed between the tops of the shafts, and cranes with jibs, by which the crates could be raised and moved from the boat over the shaft or the reverse. These shafts, which were 120 feet deep, were not found to answer, in point of expense, so well as inclined planes, and Mr. Telford informs us ('Plymley's Report,' p. 296–307) that "inclined planes have been substituted, on which crates of coal or iron pigs, or goods descend, and draw up other crates containing limestone for the use of the ironworks above, by means of ropes, a drum, and brake-wheel, with a much less portion of manual labour, and more expedition, than was done by the shafts above mentioned."

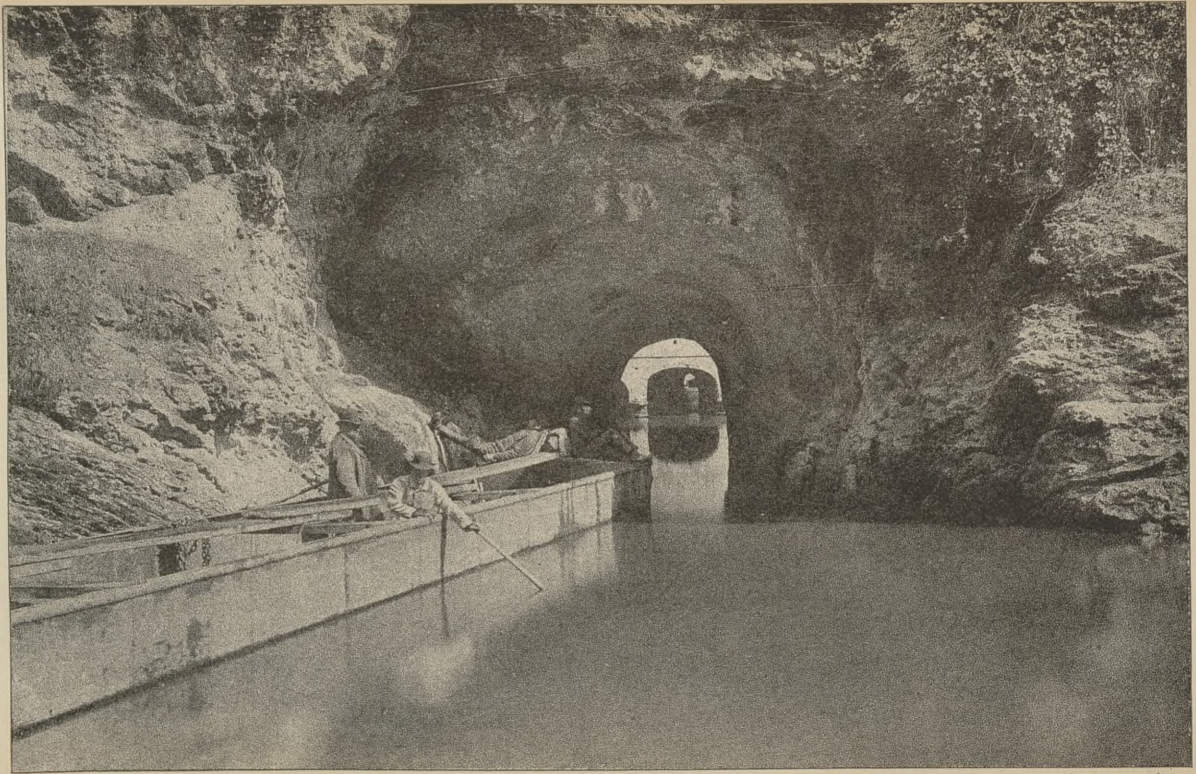
Marsden tunnel, on the Huddersfield Canal, is 5280 yards in length; Sapperton, on the Thames and Severn, 4300 yards; Penfax, on the Leominster and Kington, 3850 yards; Laplat, on the Dudley Canal, 3776 yards; Blisworth, on the Grand Junction Canal, 3080 yards; Ripley, on the Cromford, 3000 yards; Dudley, on the Dudley Canal, 2926 yards; Harecastle, on the Trent and Mersey canal, 2888 yards; Norwood, on the Chesterfield Canal, 2850 yards; Westheath, on the Worcester and Birmingham Canal, 2700 yards; Morwelham, on the Tavistock Canal, 2500 yards; Oxenhall, on the Hereford and Gloucester Canal, 2192 yards; and Braunston, on the Grand Junction, 2045 yards.

The longest tunnels that have been proposed, besides those stated above, were one of 5 miles on the once proposed extension of the Manchester, Bolton, and Bury Canal to the Calder river; and one of $4\frac{1}{4}$ miles on the Portsmouth and Croydon Canal, through the chalk hills to the south of the latter place.

The towns of Manchester, Kidderminster, and Southampton have been partly tunnelled under by the Bridgwater, the Stafford and Worcester, and the Southampton and Salisbury Canals respectively.

There are several long tunnels on the Birmingham Canal system,

* Paper by Mr. G. R. Jebb in the 'Journal of the Society of Arts,' for 1888.



E. & F. N. Spon, London & New York. "INK-PHOTO." SPRAGUE & CO. LONDON.

DUDLEY TUNNEL ON THE BIRMINGHAM CANAL (SHOWING MEN IN POSITION FOR "LEGGING" having an aggregate length of 6¼ miles. Two of these—the Dudley Tunnel and the Netherton Tunnel—pass under the Rowley Hills, and are each about two miles in length. The former was constructed in the last century. The waterway is about nine feet in width, and there is no towing-path, the boats being propelled by two men, lying on their backs on the boat, their feet performing a sort of walking motion against the sides of the tunnel, this is called "legging." The Netherton Tunnel was constructed in the year 1858; it has a waterway 17 feet in width on either side. Both of these tunnels have, from time to time, been seriously injured by mining operations, and in the case of the Netherton Tunnel, the injury is stated to have been caused by the mine-owner illegally working minerals that had been previously purchased by the canal company. (See illustration of Dudley tunnel.)

VIADUCTS.

Sir Walter Scott spoke to Southey of the viaduct on the Ellesmere Canal as the most impressive work of art he had ever seen. This viaduct is situated about 4 miles to the north of Chirk, at the crossing of the Dee, in the romantic vale of Llangollen. The north bank of the river is very abrupt; but on the south side the acclivity is more gradual. The lowest part of the valley in which the river runs is 127 feet beneath the water-level of the canal; and it became a question with the engineer, whether the valley was to be crossed, as originally intended, by locking down one side and up the other which would have involved seven or eight locks, or by carrying it directly across by means of an aqueduct.

The aqueduct is approached on the south side by an embankment, 1500 feet in length, extending from the level of the waterway in the canal until its perpendicular height at the "tip" is 97 feet. Thence it is carried to the opposite side of the valley, over the river Dee, upon piers supporting nineteen arches, extending for a length of 1007 feet. The height of the piers above the low water in the river is 121 feet. The lower part of each was built solid for 70 feet, all above being hollow, for the purpose of saving masonry as well as ensuring good workmanship. The outer walls of the hollow portion are only two feet thick, with cross inner walls. Upon the top of the masonry was set the cast iron trough for the canal, with its towing-path and side rails, all accurately fitted and bolted together, forming a completely watertight canal, with a waterway of 11 feet

10 inches, of which the towing-path, standing upon iron pillars rising from the bed of the canal, occupied 4 feet, 8 inches, leaving a space of 7 feet, 2 inches for the boat. The whole cost of this part of the canal was 47,018*l.*, which was considered by Telford a moderate sum compared with what it must have cost if executed after the ordinary manner. The aqueduct was formally opened for traffic in 1805. "And thus," says Telford, "has been added a striking feature to the beautiful vale of Llangollen, where formerly was the fastness of Owen Glendower, but which, now cleared of its entangled woods, contains a useful line of intercourse between England and Ireland; and the water drawn from the once sacred Devon furnishes the means of distributing prosperity over the adjacent land of the Saxons."

The Barton Aqueduct on the Bridgwater Canal, is about 200 yards in length, and 12 yards wide, the centre part being sustained by a bridge of three semi-circular arches, the middle one being of 63 feet span. It carries the canal over the Irwell at a height of 39 feet above the river—this head room being sufficient to enable the largest barges to pass underneath without lowering their masts. The bridge is entirely of stone blocks, those on the faces being dressed on the front, beds, and joints, and with cramped iron. The canal, in passing over the arches, is confined within a puddled channel to prevent leakage, and is in as good a state now as on the day on which it was completed.

The embankments formed across the low grounds on either side of the Barton viaduct were considered very formidable works at that day. A contemporary writer speaks of the embankment across Stretford meadows as "an amazing bank of earth, 900 yards long, 112 feet in breadth across the base, 24 feet at the top, and 17 feet high." The greatest difficulty anticipated was the holding of so large a body of water within a hollow channel formed of soft materials. It was supposed at first that the water would soak through the bank, which its weight would soon burst, and wash away all before it. But Brindley, in the course of his experience, had learnt something of the powers of clay puddle to resist the passage of water, and he finished the bed of this canal, so as to make it impervious to water.

Not the least difficult part of this undertaking was the formation of the canal across Trafford Moss, where the weight of the embankment pressed down and "blew up" the soft oozy stuff on either side; but the difficulty was again overcome by clay puddle. Indeed, the execution of these embankments by Brindley was regarded at that time as something quite as extraordinary in their way as the erection of the Barton Aqueduct itself.

Embankments and Weirs.

Mr. Jebb has pointed out * that one of the most important duties of the canal engineer, and certainly one of the most anxious, is to take all practicable precautions for the prevention of any of the embankments giving way by the overflow of water during heavy rainfalls.

In some districts at such times an enormous volume of water discharges directly into the canal; this has to be got rid of. Self-acting weirs are constructed at convenient points, and these are sufficient to keep the water within bounds at ordinary times; but in times of flood other means have to be used. The old canal "let-off," as it was called, consisted of a wooden frame (fixed in the bed of the canal), to which was attached a hinged lid; this lid was pulled up by a chain fixed to the lid when necessity required—that is, if the chain could be found, and also sufficient power obtained for the purpose; for when the let-off had not been used for a considerable time it became covered with mud, and it was often as much as half-a-dozen men or a horse could do to pull up; this accomplished, however, the water rushed out at once with great force (as there was no means of regulating the discharge), the sudden rush often causing trouble with the owners and occupiers of the adjoining lands. Mr. Jebb has replaced some scores of these let-offs by sluice valves of similar capacity, worked by racks and pinions. The discharge of water can thus be exactly regulated, and one man only is required to work them. The valves are tested every month to see that they are in working order.

For the proper and economical maintenance of the towing paths, it is necessary to have a staff of experienced men. Mr. Jebb recommends, as a material for metalling, limestone *débris*, or what is locally known in Birmingham as "raffil" or "bavin." He finds that it sets soon, and lasts for years if properly laid down—broken furnace cinders, covered with good ashes, are largely used in the Black Country—the paths should, of course, be well drained.

* Paper on "The Maintenance of Canals," in the 'Journal of the Society of Arts' for 1888.

On the Birmingham canal, between Longford and Manchester, the sidelong ground was cut down on the upper side and embanked upon the other by means of the excavated earth. This was comparatively easy work; but a matter of greater difficulty was to accommodate the streams which flowed across the course of the canal. For instance, a stream called Cornbrook was found too high to pass under the canal at its natural level. Accordingly Brindley contrived a weir, over which the stream fell into a large basin, from whence it flowed into a small one, open at the bottom. From this point a culvert, constructed under the bed of the canal, carried the waters across to a well, situated on its further side, where the waters, rising up to their natural level, again flowed away in their proper channel. A similar expedient was adopted at the Manchester terminus of the canal, at the point at which it joins the waters of the Medlock. It was a principle of Brindley's never to permit the waters of any river or brook to intermix with those of the canal, except for the purpose of supply; as it was clear that in a time of flood such intermingling would be a source of great danger to the navigation. In order, therefore, to provide for the free passage of the Medlock, without causing a rush into the canal, a weir was contrived, 306 yards in circumference, over which its waters flowed into a lower level, and thence to a well several yards in depth, down which the whole river fell. It was received at the bottom in a subterranean passage, by which it passed into the river Irwell, close at hand.

In the earlier attempts made in the last century to deal with the cataract of Trolhätta, in Sweden, it was determined to distribute the whole fall of $113\frac{1}{3}$ feet among three sluices only: the first to consist of 28, the second of 52, and the third of $33\frac{1}{3}$ feet. These sluices were to be constructed alongside of the three cataracts, and were to be each 18 feet wide by 72 in length. The work advanced successfully, until the attempt to throw a weir across the river at the gulf of the last cataract, to raise and retain the water above it. The impetuosity with which the whole stream is precipitated had prevented the builders from sufficiently examining the bottom. They had conjectured, from the nature of the neighbouring mountains, that the bottom must be rock; and it was further supposed that there could not be more than 10 feet of water. Both these suppositions proved to be erroneous. The depth of the water was from 20 to 25 feet at least, and the bottom was composed of large detached stones, which were incapable of being fixed by any efforts of art.

The caissons of stone, although fastened together with cramps 4 inches thick, and attached by great piles to the mountains on both flanks, were swept off and dispersed by the impetuosity of the current; and in this manner all the works were destroyed.

Subsequently it was determined to avoid the pass entirely, and construct a canal 8200 feet long; and the total fall of 113⅓ feet was to be distributed, in the space of the last 3000 feet, among seven sluices or locks, each 36 feet in breadth by 200 in length.

The first sluice was to be 17⅓ feet in height; the others, 16 feet. The first sluice was to stand alone; but the four following were to be close to each other, as were also the last two. Between the fifth and sixth sluice the canal was to be protected by a strong dyke against the floods of the river. There was to be a great discharger between the first sluice and the water entrance, not far from the centre; and at the entrance itself two doors or gates, to lay the canal dry when required. This plan proved more successful than the first.

Forty wholly removable, regulating weirs were constructed in the Seine several years ago. When wholly closed up in summer, they maintain the required depth of water for steamboat navigation. When wholly open in floods, they cause no stoppage in the river surface. A remarkable barrage mobile has been in action for several years at a place called Port à l'Anglais, above Paris, and above the junction of the Seine and the Marne. When all is open there is not a ripple on the river flowing by. M. Gambuzat, the chief engineer of the river Seine, informed Mr. Lynam that all those wholly removable regulating weirs in the Seine were remarkably effective, and suitable for regulating that great commercial river. Mr. Lynam declared that, if in July 1861, a month previously to the great flood, the Killaloe weir-mound had been wholly removed, and a wholly removable weir, like that in the Seine at Port à l'Anglais, had been constructed, and subsequently been properly manœuvred, during the month of August, none of the crops in the level of the Shannon, above the Killaloe weir-mound, would have been materially injured.*

The cost of high weirs on large rivers is considerable. For instance, the most recent weir on the Seine at Poses, retaining a depth of 16½ feet of water, cost 151*l.* 5*s.* per lineal foot; and the Mulatière weir, on the Saône at Lyons, retaining a depth of water of 10 feet, cost 118*l.* 11*s.* 7*d.* per lineal foot.

On all navigations and canalised rivers liable to floods, the great

* Paper read before the British Association, 1878.

difficulty is to be able to pass away the water without impeding the traffic, and without flooding the surrounding country. This has been accomplished on the Weaver to a very great extent by means of what are, practically, movable weirs, at Dutton, Saltersford, Hunts, and Valeroyal. They are flood-gates, or sluices, capable of being lifted clear of the water, and thus allowing an uninterrupted passage, and consist of doors 15 feet by 14 feet deep, built of rolled iron beams with timber sheathing. These are supported by masonry piers, and are lifted by means of overhead gearing, so that the attendants are entirely above water and on a permanent bridge. Friction is practically dispensed with, owing to their working on rollers. The rollers hold the doors from their seating, and would thus allow the passage of the water. To prevent this, "stopwaters" have been introduced, consisting of pieces of hard wood weighted at one end, until the specific gravity is about the same as that of water; they then float vertically, and are held in such a position that the pressure of the water forces them into the angle formed between the door and the masonry.

This plan of sluice has practically reduced by one-half the flood-level at Northwich, and instead of having floods of 8 to 12 feet, the highest that has occurred since their erection is one of 6 feet.

On the Aire and Calder Canal a form of sluice has been invented and applied by Mr. Bartholomew which appears to have merits and originality. A large culvert is made alongside the whole length of the lock, with a very large sluice at the upper end, measuring 7 feet by 5 feet, the ordinary sluice being 2 or 3 feet square. Another sluice is provided at the other end, and when this is closed and the lock is empty, the upper sluice, which is self-balanced, like a throttle-valve, is raised. Three orifices are made into the elongated lock, which are arranged in such a way that the vessels are divided, and do not knock against each other while in the lock. In emptying the lock, the upper sluice is let down and the lower sluice is drawn, the water entering the culvert through the orifices and discharging at the lower end. In working the sluices, a man only requires to turn the handle and it raises itself, while with three turns in the other direction it is lowered. The locks on this system are 215 feet long, 22 feet wide, and have 9 feet of water on the sills.

Dams.

The proposed dam on the Nicaraguan Canal is to be of concrete, faced with timber, and will be 1225 feet long on the crest, and 52 feet high. The embankment will be 6500 feet long and 51 feet high in the centre. There are, however, much larger dams than this. Of masonry dams, Verviers, a small city of Belgium, near the frontier of Prussia, with a population of about 38,000, has one—that of Gilleppe—154 feet high and 771 feet long. The water supply of the town of St. Chaumonde, in France, has a dam about 140 feet high, and the water supply of St. Etienne is held by the Furens dam, 170 feet high.

The Villar dam, 162 feet high, holds the water supply of Madrid and other dams in Spain, some of them dating back to Moorish days—Puentes, Alicante, Val de Infierno, Nijar, Elche, and Almanza range from 164 feet to 68 feet in height. In England the Vyrnwy dam, at the Liverpool waterworks is 136 feet high and 1255 feet long. The San Francisco waterworks dam, 170 feet high and 700 feet long, and the Quaker Bridge dam, 278 feet high and 1300 feet long, will, when built, be still larger.

Of earthen dams or embankments, some of the most notable are the Montaubry dam, on the Canal du Centre, 54 feet high; the dam, 66 feet high, by which the water supply of Dublin is impounded; the reservoir dam of the Bolton waterworks, England, over 120 feet high; the Oued Muerad dam in Algeria, 95 feet high. In India and Ceylon such examples are very numerous; the embankment of the Ashti reservoir is 58 feet high and 12,709 feet long; the Karakvasla dam is over 70 feet high; the Tansa reservoir dam (water supply of Bombay) is to be 8500 feet long and 118 feet feet high; the embankment of the Cummum tank in the Madras Presidency is 102 feet high, and although it ranks among the earliest works of Hindoo history, it is still in such condition as to fulfil its original intention. In Ceylon there are old tanks with embankments from 3 to 12 miles long and 50 feet to 70 feet high.

The materials used for the construction of a weir or dam across a river are principally earth, timber, fascines, stone, &c. The most simple form of dam is that made of gravel protected by fascines kept in place by piles. Such dams are principally used for temporary works. Dams are often made of timber, stones, and earth combined, and covered with planking laid parallel to the current, and the bottom of the channel at the foot on the down-stream side should be protected by an apron formed of a platform of planks resting on piles, or by a stone pitching. Dams of this kind built of dry stone and timber often do not become weirs except during floods; that is to say, the water does not pass over their crests except at such times, and at other seasons of the year any surplus finds its way through the interstices between the stones.

Dams may be built of caissons of strong timber, filled with loose stones and covered with planking; others are filled with earth instead.

A recent writer states that weirs of solid masonry, like other hydraulic works, should be founded on the natural ground on a bed of concrete, or on piles, according to circumstances. The masonry may be built in cement or hydraulic lime; the face-work is usually in dressed stone or blocks. The stones, besides being fastened together by metal cramps, are sometimes bonded by dovetailing.

A good example of a masonry weir is that built across the Dora Baltea for obtaining a supply of water for the subsidiary canal of the Canal Cavour. This work consists of a mass of concrete faced with ashlar and blocks in courses roughly dressed. The crest is 1·20 metre in width, and the total length 200 metres. This dam cost 237,682 francs, or at the rate of 1188·41 francs per lineal metre. A layer of concrete alone forms a very effectual protection to a river or canal embankment. In rivers subject to excessive floods a rock-work consisting of large irregular-shaped blocks of stone—not less than one-third of a cubic metre each—is exceedingly useful for protecting the bottom of embankments or walls from scour.

CHAPTER XXXI.

SPEED OF TRANSPORT.

ALL other things being equal, the system of transport that is able to afford the greatest average speed will be certain to command the lion's share of business. There are, however, both natural and economical limits to speed, alike on water and on land. The natural limit up to the present time may be put at 50 miles an hour for railway travelling, 20 knots per hour for sea transport, and four or five miles an hour for canal navigation. The economical limits are, however, very different. A goods train cannot be worked economically at a greater speed than 20 to 25 miles an hour, and many railway companies decline to work their mineral traffic at a higher speed than 15 miles. At sea, the ordinary rate for a cargo-carrying steamer will vary from 10 to 14 knots, but seldom exceeds the latter figure. On an artificial waterway it is not possible, even in the absence of locks or other obstructions, to maintain a higher rate of speed than 4 or 5 miles without doing serious injury to the banks.

A very excellent paper on the rate of speed which it is possible or usual to attain in canal navigation, under varying conditions of towage, locks, depth, and other elements that influence the question, was submitted to the Institution of Civil Engineers some years ago by the late Mr. Conder, who devoted much attention to the subject.*

On the Belgian canals, where human labour is employed for towage, the rate of speed does not exceed 1 to $1\frac{1}{3}$ mile per hour, against $2\frac{2}{3}$ miles on the same canals with steam towage. On the Grand Junction Canal the speed varies from 3 to $3\frac{1}{2}$ miles, and on the Rotterdam Canal it is 5 miles per hour. The limiting speed on the Suez Canal is about $5\frac{3}{4}$ miles per hour, but there is a loss of speed on that waterway, due to the trapezoidal form of section, which is estimated at about half a mile per hour. The average retardation of speed on English canals, due to locks, has been calculated at between 1·75 and 1·95 minute per mile.

The greatest difficulty that lies in the way of extending canal

* Conder on "Speed on Canals," 'Minutes of Proceedings,' vol. 76.

navigation is the uneven character of the country that has usually to be traversed, and the consequent necessity of overcoming elevations and depressions by locks, lifts, inclines, or other costly mechanical devices. In crossing England, between the Thames and the Severn, a height of 358 feet has to be overcome on the 204 miles of the Wilts and Berks route; a height of 474 feet on the 180 miles of the Kennett and Avon route; and a height of 392 feet on the 206 miles of the Thames and Severn Canal route. The average difference of level on these routes, counting ascent and descent, is 4·14 feet per mile, or a little more than one-fourth of the ruling gradient laid down by Mr. Robert Stephenson for the London and Birmingham Railway. Canal lifts would overcome these differences better than locks, but then they are much more costly, and perhaps not, on the whole, so convenient. Tunnelling or cutting, as in the case of a railway, is in a large number of cases out of the question. There is, therefore, only the alternative of making locks, which involve tedious delays, and add largely to the cost of transport.

In the year 1825, the same year that saw the opening of the first passenger railway, Charles Maclaren undertook to prove that for all velocities above 4 miles an hour, a railway was much more economical than a canal. At 6 miles an hour he calculated that nearly three times as much power would be required to move an equal mass on a canal, while at 20 miles an hour he computed that twenty-four times as much power would be required. At 8 miles per hour the same writer estimated that the resistance in water increased so much that two horses on a road would do as much as one on a canal, although at 2 miles an hour the same amount of horse power that is required to drag one ton on a good road would drag 30 tons on a canal.

It is not a little amusing, in the light of our present experience, to find this author gravely stating that "the tenor of the evidence given before the Parliamentary Committee (on steam navigation) renders it extremely doubtful whether any vessel could be constructed that would bear an engine (with fuel) capable of impelling her at the rate of 12 miles an hour without the help of wind or tide;" while as for railway speed, he asserted that, "in speaking of 20 miles an hour it is not meant that this velocity will be found practicable at first, or even that it should be attempted."

Canal engineers have found that where they can concentrate the rise of level on a canal by the use of lifts, or inclined planes, they can usually obtain a considerable increase of speed. Thus, on the river Weaver, a height of 51 feet is cleared by the Anderton lift in about eight minutes. On the incline of the Morris Canal, again, a height of 51 feet is overcome in three and a half minutes; while on the Forth and Clyde Canal the Blackhill incline enables a height of 96 feet to be overcome in ten minutes. This averages about three times the speed that could be attained in overcoming the same rise or fall by means of locks.

We have already seen it computed that there are in Great Britain one lock to every 1·37 mile of canal.* Mr. Conder has calculated that there is, at this rate, "an average rise or fall for the system, as far as it is represented by the time returned, of 5·84 feet per mile." On the more uneven sections a running speed of 5 knots, or 5·76 statute miles per hour, will be reduced on an ordinary English canal by the delays caused by the locks, to a speed of 4·9 miles per hour. In other words, the rate of speed should be nearly double the speed of prompt canal service at the present time. Between Gloucester and Birmingham the merchandise sent by river and canal is delivered as quickly as that despatched by railway.†

Speed on canals is regulated by the effect of breaking waves on their banks. In narrow canals or rivers, such a wave first appears at from 3 to 3½ miles per hour, and it has been found that at 4 miles per hour it exercises an injurious effect on the banks of the canal. When the speed is increased to 5 miles an hour, the effect becomes much more marked, the waves breaking over the towing-path, and rendering navigation destructive.

Mr. Conder appeared to think that a speed of 5 miles an hour, or 8·37 feet per second, which is the limit of speed fixed for the Suez Canal, may be taken as the normal speed to be sought on the canals of England; and he adds that, "on the determination of the normal speed, and of the tonnage of the boats to be accommodated, will depend not only the steam-power required, but the sections of the canals and of the dimensions of the locks."‡

In Sweden, as well as in Holland, where the channels are narrow, the usual speed is 3½ miles per hour, but 5 miles an hour is frequently attained, the difference depending on the area of cross-section.

In curves and shallows, in narrow canals or rivers, a breaking

* 'Report of the Select Committee on Canals,' p. 125.

† 'Minutes of Proceedings of the I. C. E.,' vol. lxxvi. p. 171.

‡ Ibid., p. 169.

wave first appears at from 3 to $3\frac{1}{2}$ miles per hour. At 4 miles an hour the effect of the wave on the banks becomes injurious. At 5 miles an hour the wave increases, breaking over the towing-path, and being followed by other waves in succession. In parts of the Clyde, from 120 to 150 feet wide, and about 10 feet deep, vessels of from 120 to 150 feet long, with from 16 to 18 feet beam, and from 5 to 6 feet draught, are propelled by engines of from 80 to 100 horse-power, at a speed of from 8 to 9 miles per hour. At this speed a surge rises at from 2 to 3 miles ahead, and a wave is caused, which measures 8 or 9 feet from the crest to the bottom of the trough.*

A speed of 5 knots per hour, or 8·37 feet per second, corresponding to a head of 1·08 foot of water, is the limit of speed fixed for the Suez Canal. This may perhaps be taken as the normal speed to be sought on the canals of England. On the determination of the normal speed, and of the tonnage of the boats to be accommodated, will depend, not only the steam-power required, but the section of the canals and the dimension of the locks. A speed of 30 miles a day, including stoppages, is even now attainable on English canals.

The rate of speed on a canal is, of course, affected by the size as well as by the number of the locks, by the depth of the waterway, and by the tonnage of the craft that navigates it. On some English canals there is a lock to be passed through about every half mile, and the rate of speed is under a mile per hour.† On others, however, a speed of 3 miles may be kept up pretty well. The economical rate of speed is often put at $2\frac{1}{2}$ miles. At a higher rate of speed the cost of maintenance of the canal would be likely to counterbalance the saving due to quicker transit. Speed is also affected by differences of gauge, which in some cases compels cargo to be transhipped with much loss of time that might be obviated with a uniform gauge.

The size of craft which can traverse a through route depends on the least navigable depth in the canal and over the sills of the locks, and the least width and length of any lock along the route. Unfortunately, very few through canal routes exist in England which are not obstructed by some narrow locks, or shallow portions of canal, rendering the comparatively good width and depth of the remainder quite unavailable for a larger craft. In France, the same want of uniformity of gauge on the waterways has hitherto existed;

* 'Minutes of Proceedings of the I. C. E.,' vol. lxxvi. p. 168.

† Ibid, p. 161.

but as almost all the waterways are under the control of the State, improvements and extensions have been constantly in hand; and we have already seen that in 1879 a law was passed for providing a uniform depth of $6\frac{1}{2}$ feet, locks $126\frac{2}{3}$ feet long and 17 feet wide, and a clear height of 12 feet under the bridges, throughout the principal lines of waterway in France. The works for securing this uniformity are being gradually carried out; and when they have been completed, 300-ton barges, $126\frac{1}{3}$ feet long, $16\frac{1}{2}$ feet wide, and 6 feet draught, will be able to traverse all the principal waterways of the country.

The depth of English canals ranges, for the most part, from 3 feet to 5 feet; but the Severn navigation to Gloucester affords a depth of 6 feet; the Gloucester and Berkeley Canal, 15 feet; the Aire and Calder navigation, 9 feet; and the Forth and Clyde Canal, 10 feet. The locks range in size from 72 feet length, 7 feet width, and $3\frac{1}{2}$ feet depth of water over the sills, up to 215 feet by 22 feet by 9 feet on the Aire and Calder navigation.

It goes without saying that if the average rate of speed that can be maintained on a canal does not exceed 3 or 4 miles per hour, the canal will never compete with the railway as a quick means of transport. The use of such waterways would thereby be limited to heavy traffic, in the delivery of which time was a matter of minor importance. But more than two-thirds of all the traffic carried on British railways, and indeed on railways generally, is of this character. The question thereupon arises, Is the economy of water transport sufficient to compensate for a slower rate of speed? Sir James Allport, who, of course, held a brief for the railway interest, informed the Canal Committee of 1883 that the railway engine would accomplish ten times as much work as a canal boat, and would do in an hour what would occupy a day on a canal.* Mr. F. Morton, on the other hand, speaking as a railway and canal carrier of experience, declared that, in conveying minerals between North and South Staffordshire, railway waggons and canal boats averaged about the same time—seven to eight days.† However this may be, there can be no doubt that where canal transport is efficient it is much cheaper, and that is the main thing for the trader.

Mr. Bartholomew has made an elaborate series of inquiries and experiments upon the Aire and Calder Canal, with a view to deter-

* Report, q. 1620–1622. † Ibid, 2, 2617.

mine the cost of different systems of canal haulage, and has found the results to be as under :—

With steam tugs, carrying cargoes, $\frac{1}{34}d.$ per ton per mile.
,, ,, ,, not carrying cargoes, $\frac{1}{7}d.$ per ton per mile.
,, horse haulage, $\frac{1}{5}d.$,, ,,

The lowest of these charges is not comparable with the lowest railway rate of which we have ever heard, while the highest is much below what railway managers usually state to be the cost of carrying their cheapest traffic.

It will, however, be impossible either to greatly increase speed or to reduce rates on British canals unless the system undergoes reconstruction. The rates given above for the Aire and Calder Canal are no doubt exceptionally low, because that is one of the best managed and best equipped canals in the country. On the average of the English canals the cost of transport will be a good deal more, and it must continue to be so until they have been brought up to the level of efficiency maintained on the Aire and Calder. In the majority of the canals of England it is either impossible, or economically impracticable, to employ steam power, without which the ultimate extent of possible economy cannot be realised. Mr. F. Morton has correctly expressed the position of affairs when he stated that "the present method of employing steam on narrow canals is about comparable to a locomotive capable of taking thirty loaded waggons, having only four or five behind her." This must remain so until steps have been taken to do in England what has been done in France and other countries—to secure a uniform gauge and a depth sufficiently great to enable boats to be navigated that carry loads of 100 to 200 tons, so that the canal boats may be the counterpart of a railway train. If the Aire and Calder system of working trains of boats, carrying 700 to 900 tons per train can be introduced, so much the better.

CHAPTER XXXII.

CANAL TRAFFIC: ITS CHARACTER AND ITS DENSITY.

There is a very prevalent impression that railways and canals have each their proper and natural function in the transport of merchandise—the railways in the carrying of goods of considerable intrinsic value, or of a perishable character, in which speed is an element of value; and the canals in conveying heavy merchandise, such as coal, iron ore, pig iron, building stone, timber, and other traffic, of relatively low intrinsic value, and incapable of being deteriorated by delay.

In accordance with this idea, the canal traffic of most European countries has usually taken the form of coal, iron, and other heavy merchandise, while the railways have carried goods that were charged a high rate of freight, on the grounds that they were damageable, and of high intrinsic value.

This, however, is by no means a universal rule. On many waterways, and especially in countries which have limited railway facilities, like Russia, canals are found as well adapted as railways to all purposes of transport. On the canals of the United States, the canals compete with the railways in carrying wheat and other agricultural produce. On the Aire and Calder canal, the canal boats are adapted to carry, and as a matter of fact do carry, considerable quantities of general merchandise, as well as minerals.

The French Government and Chambers, guided by the well-informed engineers of the Ponts et Chaussées, have controverted the idea that there is necessarily any real rivalry between railways and canals. "Each of these two ways of communication," reported M. de Berigny to the Chamber of Deputies in 1833, "has its distinct and special domain." "Nothing," says another French writer, "is to-day more true. Almost everywhere that navigable routes and railways run side by side, the development of industry and commerce has been such that after a brief crisis the traffic of the older line of communication has notably increased. Far from being enemies, railways and canals aid one another in the performance of their natural duties. The former transport passengers, costly merchandise, manufactured products—all that cannot endure long delay.

The latter, on the other hand, transport raw materials of small value, for the transport of which speed is of secondary importance, which cannot bear high rates of charge, and which in consequence do not form a remunerative traffic for railways."* "The delay of a week or a fortnight in the delivery of these articles," reported the Commission named by the Chamber of Deputies in 1878 to examine the project for improving the inland navigation of France, "is a matter of little importance, while the difference of freight for long distances between the lowest rate at which a railway can carry and that which is attainable on a canal is equal to half the price of the goods." "Coal," the Commission stated, "cannot be carried on railways, even for long distances, at a less cost than from 0·54*d.* to 0·62*d.* per ton per mile, but can be transported by canal for 0·22*d.* per ton per mile."

"In France, in Germany, in Belgium, and in England," says another writer,† "the round price of one-third of a penny per ton per mile will pay for transport on canals of adequate section and volume of traffic, and this price includes, not only a fair interest on the capital, but also provision for sinking fund, which within a determinable time will render these inland waterways the property of the nation, to be used free of charge, except the trifling amount necessary for maintenance of the works and attendance on the locks. On a traffic of 600,000 tons per annum this charge does not exceed 0·022*d.* per ton per mile." The cost of towing, to be borne by the users of these national waterways, has been found to be as low as from 0·065 to 0·079 per ton per mile for horse towing in Belgium, including the return of empty boats.

There is no record of the traffic that is carried on the canals of the United Kingdom at the present time. On the Birmingham Canal, which has a mileage of 162 miles, and some hundreds of private basins, the tonnage carried in 1887 was not less than 7,000,000 tons. This is an average of about 43,200 tons per mile, and if the whole of the canals constructed in the United Kingdom had been equally useful and successful, the total quantity of traffic carried on the 3000 miles of canals constructed would have been close on 130,000,000 of tons, or more than one-half of the total tonnage carried on the railways of the United Kingdom in 1887. Of course, however, the Birmingham Canal traffic is altogether exceptional, as is also that of the Bridgwater Canal, and the Aire

* M. Picard in 'Les Chemins de Fer de France,' in 1884.

† 'Edinburgh Review,' for October, 1882.

and Calder Navigations. These three canal systems compete very successfully with the railways for the heavy traffic of the districts through which they pass, and have been able for years to earn large dividends, with comparatively low rates of freight.*

There is a widespread belief that railway transport represents a very considerable proportion of the total ultimate cost of the heavy traffic carried in this country. Of some descriptions of heavy traffic this is no doubt true. It is not, however, equally true of mineral traffic. The average receipts earned by the railway companies per ton of minerals transported in 1888, irrespective of distance, was 1·6*s.* On the great bulk of the coal and iron ore carried, it must have been very much less, seeing that a large quantity of coal—as for example the supply of London, which is alone an item of over seven millions of tons a year—is carried for over a hundred and fifty miles at 6*s.* to 7*s.* per ton freight.† There is no similar record of traffic for other countries. In the United States the census returns show that in 1880, 89½ millions of tons of coal were carried on all the railways then open. The gross income earned thereby is not, however, separately stated, although it may be possible to arrive approximately at the figure we want by taking the statistics that are given for the group of States of which New York, Pennsylvania, and Ohio are the chief. In this group 192 millions of tons were carried in 1880, of which 76 millions of tons were coal. The revenue derived therefrom was 208 millions of dollars, so that the average amount paid to the railways per ton carried was 4·3*s.*, or nearly three times as much as in Great Britain.‡

The chief canal in the Russian empire is that of Vishni Volotchok, which connects the Baltic and the Caspian Seas, and thereby affords communication with Siberia and China. In the early years of the century the principal part of the internal trade of the empire was conveyed along this canal. In 1777, the number of barges that passed through this canal was stated to be 2641. Twenty years later, the number of vessels that navigated its waters was returned at 6264,§ conveying merchandise of the weight of over 8 millions of poods,

* Paper by Mr. G. R. Jebb, on "The Maintenance of Canals, with special reference to Mining Districts," 'Journal of Society of Arts,' 1888.

† The London coal supply is largely carried, in competition with the sea, at the remarkably low rate of ·5*d.* per ton per mile, and even less.

‡ 'Report of the Tenth Census,' vol. iv. p. 133.

§ Of this number there were 3958 barques, 382 half barques, 248 boats, 1676 floats; 6264 in all.

and yielding tolls of the amount of 34,192 roubles (6840*l.*). The tendency of late years has been to divert the lighter and more expensive traffic from the canals to the railways where the latter were available; but to this day, all descriptions of traffic make use of the canals of Russia, and usually at remarkably low rates of freight.

As we have elsewhere pointed out, however, the preference for one form of transport over another is not always a mere matter of rates. If proof were needed of this fact, it would be furnished to the fullest extent by studying the history of the struggle that has been waged for many years past between the New York State Canals and the various railway systems that connect that city with Chicago, for the wheat supplies intended for export to Europe and consumption in the Eastern States. The rates of freight have all along been much lower on the lakes and the Erie Canal than on the railways. Usually, indeed, the water transport has not cost more than one-half what has been charged by rail. And yet the amount of traffic forwarded by lake, river, and canal has diminished, while that carried by railway has enormously increased. In other words, freighters have been for some years past content to pay 12 or 14 cents. per bushel to the railway companies when the canal companies offered to perform the same service for 6 or 7 cents. The question naturally arises—Why should the canals not absorb the whole traffic? The answer is that the inconvenience and uncertainty due to interrupted navigation, and the inevitable slower rate of speed, have been sufficient to induce the American wheat grower to pay double the sum in order that he might secure quick and certain despatch. The same phenomena may be witnessed elsewhere. But much, of course, depends upon the traffic. Wheat may afford to pay a few cents more under the circumstance stated, when coal and lumber could not. It is manifestly more important that wheat should be carried to its ultimate destination in good condition, and without preventable delay.

The Density of Traffic on Waterways.—One of the most interesting problems connected with the working of either railways or waterways, is that of the density of the traffic transported, or, in other words, the quantity carried, relatively to the length of the line. The law of averages, which is very often inapplicable, and likely to lead to erroneous conclusions, is, in the case of the density of traffic, capable of being applied with some amount of success. But even in apparently so simple a matter as this, it must be applied with caution, and with certain rather important reservations. It must be borne in mind, for example, that as railways are performing the double function of transporting both passengers and goods, their traffic per mile, measured in terms of merchandise, cannot be fairly compared with that of canals, which carry goods traffic alone. Nor can the traffic of a canal, where the speed is necessarily slow, be rightly compared with that of a river like the Thames or the Rhine, where there is almost no limit to the speed that may be safely applied, except the limits imposed by mechanical laws.

The density of traffic on waterways has a very wide range of variation. On the Thames, where the annual tonnage of the entrances and clearances of vessels amounts to about 18,000,000 of tons a year, it may be put at something like 1,000,000 tons per mile, if we take the average distance between the mouth of the river and the docks as about 18 miles. This, however, is a case that stands alone. No other waterway has anything like the same amount of traffic, and for purposes of comparison the Thames may be disregarded entirely. The same remark applies to the Mersey.

The complete statistics of the inland navigations of France and Belgium enable comparisons to be made of the different waterways, which are very interesting. We find that some canals have a very considerable traffic, while others have only a traffic of limited dimensions. From recent returns relative to the canals of France, we have abstracted particulars which illustrate these differences, and which are given in the tables that follow.

The following French canals have an exceptional density of traffic:—

DENSITY OF TRAFFIC ON SOME SHORT CANALS IN FRANCE IN 1886.

Name of Canal.	Length in Kilometres.	Tons of Traffic Carried in 1886.	Average Traffic per Kilom. in Tons.
Aire (Baudin to Aire)	28	2,255,000	80,535
Bourbourg (Guindal to Dunkerque)	13	1,042,000	80,123
St. Denis (Paris to La Briche)	4	1,722,000	430,500
Deûle, Haute	38	3,652,000	96,105
Mons to Conde	3	705,000	235,000
Neuffossé (Aire to St. Omer)	11	1,198,000	108,999
Oise (Janville to Chauny)	21	2,804,000	133,523
St. Quentin (Cambrai to Chauny)	58	3,606,000	62,172
Seusée (Etrun to Courchelettes)	16	1,955,000	112,187
Totals and average	192	18,939,000	98,129

These are, for the most part, short waterways connecting important centres of industry or population. The larger canals, however, are by no means so well provided with traffic, and on some of them the traffic is almost ludicrously small. On 1125 miles of these longer canals, the average density of traffic per kilometre was only 2724 tons, as compared with 98,129 tons per kilometre on the 192 kilometres of shorter waterways contained in the above table. The particulars are appended :—

STATEMENT SHOWING THE DENSITY OF TRAFFIC ON SOME OF THE LONGEST CANALS IN FRANCE IN 1886.

Name of Canal.	Length in Kilometres.	Tons of Traffic Carried in 1886.	Average Traffic per Kilom. in Tons.
Berry (Fontblisse to Noyers)	88	384,181	4,365
Burgogne (Laroche to St. Jean de Losne)	151	424,559	2,811
Est (Belgian frontier to Troussey)	170	648,471	3,820
Est (from Messlin to the Saône)	75	276,065	3,680
Garonne (Toulouse to Castel)	134	243,815	1,819
Midi (Toulouse to Thau)	152	167,985	1,105
Nantes and Brest..	167	111,558	668
Ourcq (Port-au-Perches to Paris)	68	528,048	7,765
Rhône au Rhin (to German frontier) ..	120	279,957	2,332
Totals and average	1,125	3,064,639	2,724

CHAPTER XXXIII.

THE MAKING OF ARTIFICIAL WATERWAYS.

"When, with sounds of smother'd thunder,
On some night of rain,
Lake and river break asunder
Winter's weakened chain;
Down the wild March flood shall bear them,
To the saw mill's wheel,
Or where steam, the slave, shall tear them,
With his teeth of steel."—*Whittier*.

THERE is no direction in which the triumph of man over the material forces with which he has to deal may be studied with greater advantage, even by the casual reader and the unscientific observer, than in that of the making of railways, the deepening or widening of rivers, the construction of artificial waterways, and the maintenance of ports and harbours. Each of these operations involves the employment of machinery and appliances that were quite unknown to our forefathers. The modern processes of excavation of the soil, in order to form or deepen the bed of a waterway, or of the construction of an embankment, in order that a railway or a canal may be carried above the level of the surrounding country, are now so familiar and commonplace, that we are accustomed to think but little of the slow and laborious steps whereby the means of carrying them out have been evolved from the necessities, the experience, and the scientific acquirements of modern times. Had the engineers of the present day been limited to the rude and imperfect appliances that they had alone at command a hundred years ago, such works as the making of the Suez, the Panama, and the Manchester canals; the deepening of the harbours that are now scattered up and down our extensive coast-line; and the adaptation to the requirements of modern shipping of the navigable rivers that have done so much for our maritime supremacy would have been all but impossible.

Let us take only a single instance, by way of illustration, and it shall be one that is very familiar, and easily capable of verification. On the works of the Manchester Ship Canal, in a length of only 35½ miles, and over a comparatively level country, 45 million cubic yards of excavation are necessary. More than one-half of this vast quantity had been accomplished up to the end of 1889, by the employment of 95 steam navvies or dredgers, 180 cranes, 160 locomotives, using 205 miles of temporary railway, 5500 waggons, and 220 portable and other steam engines, the number of employés being about 4000. To have executed this amount of work by any other system would have involved, perhaps, twenty times the amount of labour and more than twenty times the amount of time, if we are to judge by the accounts that have been handed down to us from ancient records as to the period over which the great works of antiquity extended.

It is not, however, in the mere work of excavation, that economy and progress have been effected. Another notable economy has resulted from the employment of large hopper barges, whereby 1000 tons or more of the dredged or excavated material may at once be removed to sea. The economy resulting from this source is stated to have enabled a saving of 40,000*l.* per annum to be effected in the works connected with the port of Dublin, without which economy the improvements actually carried out there would have been impossible.* In larger spheres of operations the economy must, of course, have been correspondingly greater.

Ralph Dodd appears to have contrived a machine to be worked by men, by means of levers, for excavating canals, which was tried in the year 1792, in the deep cutting at Dawley, near Hayes, on the Grand Junction Canal. Carne's machine, for the same purpose, but worked by a horse at length, appears to have been used in 1794, in the deep cutting near Cofton Hacket, on the Worcester and Birmingham Canal. In the 'Monthly Magazine' (vol. ii., page 594) we have the following account of the operation of E. Haskew's patent excavator :—

"This machine takes the soil from the bottom of the canal at 40 feet deep with equal facility as at six feet from the surface. One of them is at work upon the Gloucester and Berkeley Canal; by the assistance of two men only it removes 1400 loaded barrows from the bottom of the canal, to the distance of 40 feet, in twelve hours, and is so contrived as to take up the loaded barrows, leave them at the top, bring down the empty ones in regular rotation, and leave them at the bottom; it can be moved along the canal to the

* Paper on 'Recent Improvements in the port of Dublin,' read in 1878 before Section G of the British Association.

distance of 26 yards in ten minutes by the two men that work it." In October 1793 Joseph Sparrow took out a patent for a machine, consisting of a box, with its bottom opening on hinges, suspended by a sort of universal gib or crane, the whole moving upon wheels, which he strongly recommended for elevating and discharging the soil dug out of the canal.

Among the most considerable deep cuttings in England up to the end of the last century were those at Ashton, on the Lancaster; Tring, on the Grand Junction; Coston Hacket, on the Worcester and Birmingham; Burbage, on the Kennet and Avon; Littleborough, on the Rochdale; and Smethwick, on the old Birmingham canals.

As the development of the processes of excavation and embankment forms one of the fullest chapters in the history of both civil and mechanical engineering, we shall not here presume to enter upon it at any length. A history of dredgers would be almost as serious an undertaking as a history of steamboats or locomotive engines. Their actual number is legion; but the dredgers that are now used on a large scale are comparatively few. Of course, everything depends upon the amount of work to be done, its locality, and other surrounding circumstances; but for operations on a scale of magnitude, few dredgers appear to have a better reputation than that which bears the name of Couvreux.

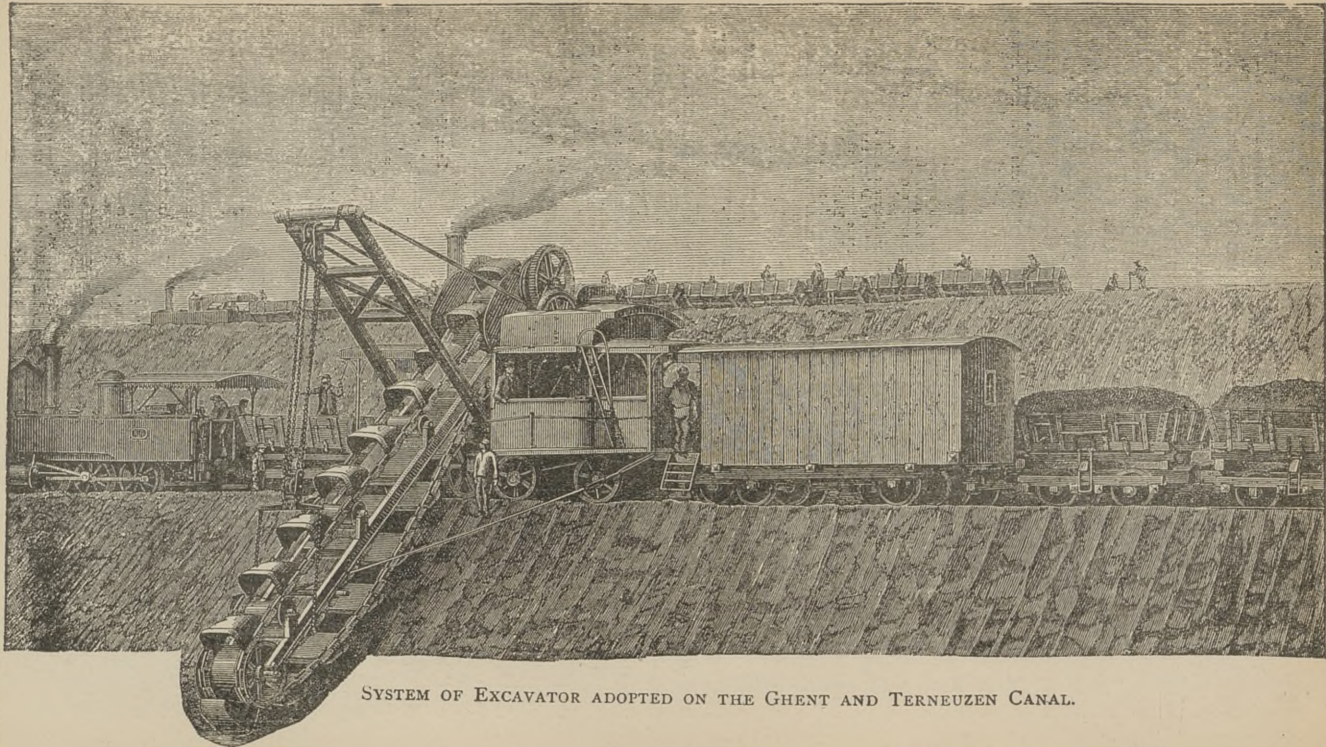
In the case of the improvement works undertaken on the Belgian Ship Canal, the Couvreux excavator removed, in 1875, 218,400 cubic yards of material in 166 days, being at the rate of 1316 cubic yards per day. Notwithstanding this, hand labour was very largely employed upon the work, a large quantity of water having to be dealt with at a depth of about 10 feet.

The earth excavated was carried to spoil, and in many cases was employed to form dykes enclosing large areas, which served as receptacles for the semi-liquid material excavated by the dredging machines with the long conductors; the Couvreux excavator used had already done service on the Danube regulation works. The material with which it had to deal in this case was, however, of a more difficult nature, being a fine sand, charged with water, and very adherent. The length of track laid for the excavator was about three miles along the side of the old canal, which had been previously lowered to the level of the water. The floating dredgers employed were 88 feet 7 inches long, 19 feet 8 inches wide, and 7 feet 9 inches deep; the arm was 39 feet 4 inches long, and passed through the hull. The form of the buckets was the same as that used at the Vienna regulation works, but the staging was higher, the axis of the driving-wheel of the bucket-chain being 26 feet 3 inches above the water-level. This increased elevation was necessary on account of the different methods employed for transporting the dredged material. To a large extent the same method of transport that was adopted on the Suez Canal was repeated in the case of the Belgian Canal Works. The conductor used allowed the sand and mud excavated to be delivered at a point 140 feet and 150 feet from the dredge, and at a height of 13 feet from the water-line. The excavated materials fell into the concave conductor 6 feet below the point of their discharge, and on falling they encountered the action of a stream of water which was constantly pumped along the conductor, and by which they were converted into semi-liquid mud. The slope of the conductors was generally 1 in 2000; it was supported by cables attached to a staging connected with the framing of the dredge, and the base of which rests on the deck of the vessel. The conductor is counterbalanced by a platform, on which was placed the portable engine and pump used for lifting the water into the conductor. This platform was suspended to the dredge in the same manner as the conductor itself. The general arrangement is shown on the engraving at p. 453. The supply and the maximum incline depend on the facility of disintegrating the ground, and on the quantity of water contained in the mixture. The proportions generally used were three parts of water to one of sand.

When the excavators met with compact clay which disintegrates slowly, or not at all, under the action of the water, the fragments raised were carried along in the current running through the conductor, but, of course, at a slower rate than the sand. Stones even of large size were also easily dealt with in the same manner. These materials were, however, only occasionally met with, the ground being chiefly composed of the fine sand, already referred to, mixed with a little clay, which was easily reduced to the required consistency.

Deposits were formed for the reception of the excavated material, which constitute filtering basins enclosed within vaults formed by the solid materials previously removed. Where it was not possible to discharge direct into their depôts by the long conductor, barges received the mud and carried it to a convenient destination.

The floating excavators were placed on two hulls carrying an



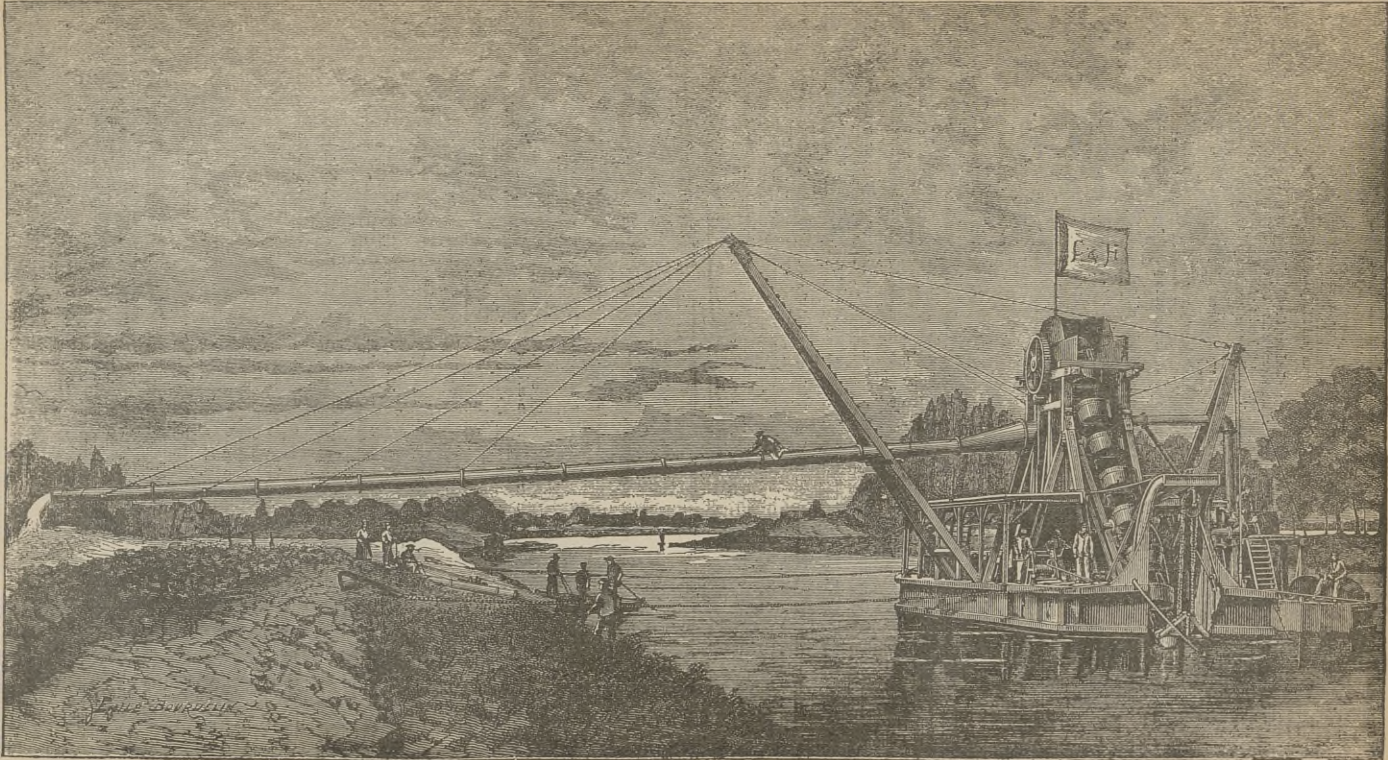
System of Excavator adopted on the Ghent and Terneuzen Canal.

iron framework, on which the staging supporting the bucket wheel was mounted. The engines and boiler were installed in one of the hulls, and in the other was placed the pump and engine for driving it. The upper level of the conductor was 78 inches below the bucket wheel. The conductor, 100 feet in length, was of the section corresponding to that of the buckets, $17\frac{3}{4}$ inches in diameter. It was supported by three cables attached to a staging, resting on the boat and secured to the bucket-wheel frame. The slope was 1 in 400, which allowed the material to be deposited at a level 22 feet 3 inches above that of the water. These excavators performed excellent duty; they could be easily transported from place to place, and were not affected by changes in the water level.

The position of the depôts often involved the necessity of transporting the dredged material distances of 1200 or 1500 feet from the excavator. In such cases supplementary conductors were added. These were open, and were laid on the ground with a slope of 1 in 1000. Not unfrequently large blocks of old masonry, which formed the *revetment* of the sides of the canal, were raised by the excavator. These were generally carried down with the rest of the material, but occasionally they stopped, choking the channel, and requiring hand labour to remove them.

When this mode of transport could not be adopted, barges were employed to receive the dredged material and remove it to convenient points of discharge. These boats were built of iron, with double sides; they were 82 feet long and 15 feet 8 inches wide. Barges of similar dimensions were employed in the formation of earthworks under water, which were required at various parts of the canal. In these boats, holes 12 inches in diameter were placed 13 feet apart, iron tubes connecting the inner and outer shells. These holes were closed by means of valves while the boat was being loaded, and they were opened when it was brought over the place where it was desired to discharge.

One of the most remarkable and successful dredgers of the present day is employed on the Montreal harbour and ship channel improvements, and is known as the Canadian dredger. This machine, instead of being like the ordinary St. Lawrence dredgers, attended by a tug and scows, has an internal mud-hopper, and is self-propelling, thus being in fact dredger, tug, and scows combined, and requiring a proportionately large hull. In a recent comparison of this dredger



Excavator on the Ghent and Terneuzen Canal.

with one employed at Otago, it was stated that the Otago dredger cuts to 35 feet deep, as do those of the St. Lawrence, but the latter have buckets a third larger, and arranged so as to be very nearly twice as effective. The Otago dredger is reported to have raised at the rate of 400 tons an hour, while filling her hopper, but the improved St. Lawrence dredgers easily fill their scows at the rate of 750 tons per hour, or nearly double the working rate of the "largest dredger in the world." For the hourly capacity for consecutive hours, something must be deducted for time lost in going to dump or to change scows, and in the case of the St. Lawrence dredgers this reduces the hourly rate to about 650 tons, still, leaving them, however, better than the best rate of the Otago dredger.

Average rates for a day, or longer periods, are further reduced, for both kinds of dredgers, by detentions for shifting anchors, moving out of the channel for passing vessels, and other contingencies, not present in a mere trial of speed. The St. Lawrence dredgers, however, often raise 4800 cubic yards in twelve hours, or an average of 500 tons per hour, while, according to the published reports for a recent month, two of them raised an aggregate of 117,525 cubic yards of clay, giving an hourly average of 336 tons per dredge for 69 hours of duty per week.

As a combined steamship and dredger which can be turned out complete on the Clyde for export, the Otago dredger is said to be the largest and the best thing yet built, but as a machine to dig a channel, one of these St. Lawrence dredgers is better still.*

Another comparatively modern machine is known as the La Châtre dredger, 92 feet long, and 20 feet width of hull. It has an engine of 50 H.P., which works the chain of buckets. The material falls $2\frac{2}{3}$ feet from the buckets into a long steel shoot $2\frac{1}{4}$ feet in width and depth, and semicircular at the bottom, extending out $15\frac{1}{3}$ feet rom the axis of the dredger, and supported by twenty-four steel cables from shear-legs 80 feet high, standing on two iron pontoons fastened to the dredger; a pontoon on the opposite side, weighted with 32 tons of ballast, counterweights the shoot. The material is drawn along the shoot (which has a general inclination of 1 in 20, increasing close to the dredger) by water pumped into the shoot, at least double in volume the amount of material. The dredger, shortly after starting work, lifted and transported 183 cubic yards of

* Mr. Kennedy, chief engineer of Montreal, in *Engineering*, September, 1881.

excavation per hour. It cost about 10,800*l.* Another dredger deposited the material from the buckets on a divisor formed of two sets of revolving sharp blades, turning in opposite directions, which cut up the large pieces and discharge the material on gratings of sharp blades, through which it falls, mixed with about 85 per cent. of water, on a sheet-iron inclined plane, along which it is conveyed to the pipe of a suction pump. This Dumont 1-foot pump, specially designed for silt, stands with its engine on a pontoon alongside the dredger. Another similar pump draws along the silt discharged by the first, and discharges it into a 1-foot iron pipe. The silt is deposited from 650 to 1000 feet away, at a height of 16 to 20 feet, with a velocity of about 13 feet per second. The mound formed at the outlet of the pipe has a very flat slope, but the settlement is rapid and complete. The dredger was able at once to lift and transport 130 cubic yards per hour, and this amount will probably be eventually raised to 160 cubic yards. This dredger is said to have cost 12,800*l.*, with its accessories.

In the construction of the Amsterdam Ship Canal, the excavations had to be deposited on the banks some distance away from the dredgers; and after being raised by the ordinary bucket dredger, instead of being discharged into barges, they were led into a vertical chamber on the top side of a sand-pump, suitable arrangements being made for regulating the delivery. The pump known as Burt and Freeman's was 3½ feet in diameter, and made about 230 revolutions per minute; it drew up the water on the bottom side, and mixing with the descending mud on the top side, the two were discharged into a pipe 15 inches in diameter. The discharge-pipe was a special feature in this work, and consisted of a series of wooden pipes jointed together with leathern hinges, and floated on buoys from the dredger to the bank. In some cases the pipe was 300 yards long, and discharged the material 8 feet above the water-level. Each dredger and pump was capable of discharging an average of 1500 cubic yards per day of twelve hours. A centrifugal sand-pump, designed by Mr. Hutton, was also used on those works.

At Hull, the cost of dredging on the Humber, including everything except interest on capital and depreciation, is stated to be 2·1*d.* per ton. The material is mud, varying in consistency, and it is discharged about 1½ miles from the docks by steam hoppers, and by ordinary mud-barges and tugs.

On the Clyde, the average cost, including everything—depreciation, interest, and carrying in hopper barges 27 miles—is as follows:—Very hard clay, boulders, and sand, 30·15*d.* per cubic yard; hard silt, gravel, and sand, 24·17*d.*; silt, clay and sand, 8·49*d.*; silt, gravel, sand, clay, and mud, 8·08*d.*; and silt and sand, 7·94*d.* per cubic yard.

On the Tyne, the cost varies from 2*d.* to 6½*d.* per ton, according to the nature of the material. One dredger has dredged over 1,000,000 tons in one year, and, including discharging a distance of 17 or 18 miles, the cost per ton was a little over 3½*d.*

The cost of removing the bar at Carlingford Lough, including everything—Parliamentary expenses and insurance of plant—was about 1*s.* 9*d.* per ton. Taking the cost for one season, it was 1*s.* 4*d.* to 1*s.* 5*d.* per ton, or 2*s.* to 2*s.* 3*d.* per cubic yard. The material was hard clay and boulders.

At Aberdeen, the cost of dredging and transporting about 2 miles beyond the bar, including insurance, but not depreciation and interest, is 1*s.* 2*d.* per ton for dredging, and 2·9*d.* for discharging, giving a total of 4*s.* 1*d.* per ton.

On the Wear, at Sunderland, the total cost of dredging, including every item of depreciation and interest, is 2·37*d.* per ton. The material consists of sand, gravel, and clay.

On the Tees, at Stockton and Middlesbrough, the cost of dredging sand, gravel, and occasionally boulders, including the conveyance of deposits out to sea, a distance of about 12 miles, is 4·96*d.* per cubic yard or about 2½*d.* per ton. This amount includes everything except interest on capital expended on dredging plant.

On the Birmingham Canal. when there has been any slipping of the sides, or a discharge into it of water laden with silt and detritus from cuttings and high lands, the material, if soft, costs 5*d.* to 9*d.* per ton to dredge; and if hard, from 10*d.* to 14*d.* per ton. With a "spoon dredger" the cost is about 8*d.* per ton, and with a grab dredger it is about 5*d.* where the circumstances are favourable.* Where hard material has to be dealt with, the water is taken out of the canal, and the material is excavated by pick and shovel. On narrow canals dredging costs more, owing to the necessity of having a narrow beam, to enable the dredger to enter the canal. The beam

* Paper by Mr. G. R. Jebb on "The Maintenance of Canals," &c., in the 'Journal of the Society of Arts' for 1888.

is, however, sometimes increased when the machine is working by attaching baulks of timber or iron pontoons to the sides, to prevent its capsizing.*

The dredging machines that were chiefly employed on the Danube regulation works were, on an average, from 25 to 30 H.P., and had one inclined arm, which could be depressed to work in a depth of 22 feet of water or more. They were high enough to load direct into the waggons, by means either of a distributing table or an elevating endless chain bucket. The dimensions of the machine, which was found to be very economical, were:

	ft.	in.
Length of boat	88	7
Breadth ,, ...	19	8
Height ,, ...	7	9
Draught of water	3	11

The working steam pressure was six atmospheres, and the power consisted of a vertical engine of $15\frac{3}{4}$ inches cylinders and $35\frac{7}{16}$ inches stroke; the main shaft was $7\frac{1}{16}$ inches in diameter, and the ratio of the pinion to the driving-wheel was 1 to 7. The buckets were of steel, having a capacity of 8·75 cubic feet. The links of the chain were $31\frac{1}{2}$ inches long, $1\frac{3}{4}$ inch by $3\frac{1}{2}$ inches for those to which the buckets were attached, and $\frac{15}{16}$ inch by $3\frac{1}{2}$ inches for the others. These machines were employed in several different ways on the Danube works. They load direct into waggons, running upon a side track, either by means of a transporting apparatus or of an elevating wheel and buckets. The transporting apparatus was attached to the dredge, and consisted of a girder about 46 feet long, guiding and carrying an endless band formed of steel plates mounted on chains, which were driven by wheels at each end of the girder. The buckets of the dredging machine discharged their contents upon this band, to which a forward motion was imparted by an independent six-horse power engine, and the forward movement thus given discharged the ballast in the waggons alongside. The whole of this system rested at one end on the deck of the drag, and at the other on trestles, secured in a small auxiliary boat fastened alongside the machine. It was afterwards considered that a useful alteration might be made in the means of transferring the ballast, and with this object a large wheel,

* On the Birmingham Canal, which has an average top width of 36 feet, and an average depth of 5 feet, this has to be done with a Priestman Grab Dredger, but it causes very little trouble.

fitted with buckets, was mounted on the dredge, and driven by an independent engine. The wheel was of wrought iron, 19 feet 8 inches in diameter, and furnished with buckets which received the ballast from those of the dredging machine, and, after raising, discharged it into an open channel, whence it fell into the waggons. The buckets of this wheel were fixed to the periphery, and were so arranged as to discharge automatically into the channel. It was found that this mode of loading produced excellent results, but the full capacity of the dredgers could not be developed, both on account of the loss of time incurred, and because the material dredged was not always easily transferred into the waggons. A large quantity of the material excavated was also loaded into barges and taken by them to suitable points of discharge.

The amount of work performed by the dredging machines depended greatly on the means available of removing the earth excavated, and to do this with regularity, and without loss of time, was one of the most difficult portions of the work of excavation.

During 1870 and 1871 the dredging machines loaded almost exclusively into the waggons by means of the endless bands already described. Two of them were worked exclusively in this manner; other two began to load into boats in 1872, and the following year this method was entirely adopted with them, and their production was remarkably large. Another machine loaded the waggons by means of the large wheel. The dredging machines employed on the first and third sections of the works, and which also loaded into boats, gave remarkable results.

The Condreux excavating machine consists essentially of a carriage carried upon three lines of rails. A lateral projecting arm carries an endless chain with buckets, passing around a wheel at the lower end of the arm. This chain is driven by a 20 horse-power engine, mounted on the frame of the carriage, and the whole machine is caused to traverse on the rails by means of a small four-horse locomotive. The buckets, which become filled in succession in traversing the face of the slope, being excavated, are of steel plate or of wrought iron mounted with steel edges. The buckets are mounted on two pitched chains, which, in rising, pass over a loose pulley placed at the level of the road, and serve as a support to the loaded buckets. This arrangement largely reduces the friction, and prevents excessive torsion of the chain. The loaded buckets are discharged automatically, by means of flap openings in their bottoms, and their contents fall either into the waggons alongside, or into inclined conducting channels. These machines run alongside, and at the top of, the excavations they make, and the earth which they raise can be either deposited alongside so as to form a continuous embankment, or be loaded into waggons.

On the Mersey Dock Estate, which extends over a total water area of 520 acres, the dredgers used up to 1875 were of the ladder type, five of them having double, and one single ladders. A double set of hopper barges was attached to each dredger. The barges were 50 feet long by 20 feet beam, and contained 82 cubic yards. The expense of towing the barges out to the Seacombe Narrows, where they deposited their silt, rendered the operations costly, and in 1874 a steam hopper barge was brought into use, 144 feet long, 23 feet beam, 11 feet 9 inches depth of hold, and with a hopper capacity of 285 cubic yards. In 1876 two other hopper barges of the same size were brought into use. Subsequently, larger barges, with a hopper capacity of 414 cubic yards, were introduced. These have been found much more economical than the old system.

CHAPTER XXXIV.

CANAL BOATS.

"Instructed ships shall sail to quick commerce,
By which remotest regions are allied;
Which makes one city of the universe,
Where some may gain, and all may be supplied."—*Dryden.*

One of the most important matters that the canal engineer and manager has to deal with, is the adoption of the form of boat best suited for the gauge of his canal and the character of the traffic to be dealt with. The majority of canals are of too limited dimensions to admit of the employment of boats of large size. Even on some of the largest rivers—such as the Thames, the Danube, and the Rhine—the size of vessels employed has to be kept down to a limit which would be deemed ridiculous for ocean-going steamers. This fact alone renders the cost of transport on inland waterways much greater than the cost of sea transport. There is also the great drawback to be met, that on many through lines of communication, as on the through canal routes from Birmingham to London, and from the same midland capital to the Severn, the break of canal gauge renders it necessary to employ the size of boat suited to the minimum gauge, and this is, of course, a great waste of power.

The modified French canals of $6\frac{1}{2}$ feet depth admit barges of 300 tons; and a depth of $8\frac{1}{2}$ feet, on the Canal du Centre, of Belgium, allows of the passage of 400-ton barges. The large traffic on the Erie Canal, between Lake Erie and the Hudson River, is conducted in barges of 250 tons; the canal has a depth of 7 feet, with a bottom width of 56 feet, and pitched side slopes of 1 to 1·5; and the locks are 110 feet long and 18 feet wide. The Welland and St. Lawrence Canals are on a larger scale, as they provide access to the coast for the large inland lakes of North America, with vessels of 1000 to 1500 tons, and therefore, like the Ghent-Terneuzen Canal, occupy a sort of intermediate position between inland and ship canals.

The "river steamer," as the stern-wheel shallow draught vessels on Canadian waters are called, is a boat of peculiar construction.

Three things are absolutely necessary. First, a perfectly smooth bottom; second, an absence of rigidity in the hull and motive-power; third, a propelling-power on the surface of the water—three points, apparently easy of accomplishment, but in reality very difficult, and which to understand requires long practice with the steamers, and their uses. Indeed, no inconsiderable portion of a captain's or pilot's life has passed before he has learned the "handling"; but when once the lesson has been learned, it is wonderful what can be done with these wheelbarrow steamers.

Mr. Shelford * holds that these are by far the most useful class of boats employed on the canals of Canada. The absence of a keel or any such obstruction enables the boat to be turned like a dish on the water; while the four rudders (sometimes 20 feet long) will guide her with a nicety in rapids and currents where an ordinary steamer would be helpless. The absence of rigidity in the hull and machinery enables the steamer to be driven ashore on any soft bank, the cargo discharged or loaded, and the boat without difficulty backed off.

The propelling power is a large diameter wheel at the stern of the boat, the full width of the vessel, resembling the undershot wheel of a mill, and driven by two cylinders, one on either side. The floats of this wheel are but 8 to 10 inches in the water when light, and 30 inches when loaded, and do not therefore produce those destructive currents which come from the screw or paddle steamer.

The boats which are used on the rivers of the north-west of Canada are about 220 feet, 38 to 40 feet beam, and 10 to 12 inches draught when light, and carry themselves about 400 tons, and will push (not tow) three times as much more on barges built like the steamers.

Perhaps the most efficient system of canal boats and of canal transport generally known in the United Kingdom is that adopted on the Aire and Calder Canal. Steamers are employed to tow a fleet of canal boats or barges, varying from ten to twenty in number, each carrying about 40 nett tons of traffic. The locks, which are 215 feet in length, take the steamer, tender, and eleven boats all at one time; but if there is a longer train of boats, it has to be broken in two. The boats are 20 feet long, 16 feet wide, and 7 feet or 7 feet 6 inches deep. When loaded, they draw from 6 feet to 6 feet 6 inches of water, and the whole train carries from 700 to 900 tons. Usually,

* Paper on the canals and shallow draught steam navigation of Canada, Journal of the Society of Arts,' 1888.

instead of towing these boats, they are pushed from behind, which offers an advantage in the steering. The steamer has two direct-acting cylinders—one on each side, and a wire rope is carried round a pulley direct to them, being afterwards threaded through guides attached to each boat. The steering arrangements are so contrived that the train can go to any curve by the two convex surfaces, and yet it is free to rise and fall vertically. The boats are coupled together by wire ropes, which run alongside the whole of the boats through guides at each corner of each boat. The ropes are then passed over the steering wheel upon the steamer. The boats are really iron boxes, which, when traffic is carried, say from Leeds to Goole for shipment, are placed in a hoist, inside which there is a cage with a cradle, in which the boat is secured. When the boat has been raised to the height of the shoot it turns over automatically and discharges the coal or other cargo into the ship through the shoot or spout employed for that purpose. The boat and cradle, having resumed their original position, are then lowered back again to the canal-level by the same hydraulic arrangement employed to raise them. Mr. Bartholomew, the Manager of the Aire and Calder Canal, has stated * that the cost of mineral transport by this system, including the return empties, was only 0·0119*d.* per ton per mile; the cost of tugs carrying general cargo and merchandise being ·034*d.* per ton per mile; whereas the cost of the same traffic on the Leeds and Liverpool Canal, where similar facilities do not exist, would be ·30*d.* per ton per mile. The difference of cost is mainly due to the difference in the number of men employed. Usually, two men are employed on each boat, and four men are employed for tugging, making 28 men in all for 12 boats, whereas a train of boats can be worked by the system described by the tug crew of four men only. The Aire and Calder Company have now arranged their boats in such a way that they may carry general merchandise as well as minerals, having fitted them with decks and hatchways for that purpose.

Mr. E. J. Lloyd submitted to the Select Committee on Canals (1889) a statement showing the size of the craft that the various canals of England and Wales were capable of carrying.† The figures are instructive, and are worth perusal by any one interested in the subject. It showed that there are very few cases in which the existing

* Select Committee on Canals, 1883, Report, p. 44.

† Report App. 2, p. 206.

navigations can carry craft over 100 feet in length. The most usual dimensions are 70 or 75 feet by 12 or 14 feet width. The Aire and Calder Canal, which takes boats of 212 feet by 22 feet, is a notable exception to the general rule. Boats of 163 feet by 29 feet 6 inches can also travel on the Gloucester and Birmingham Navigation, while the Severn can take craft of 270 feet by 35 feet, and the Thames, from London Bridge, can carry vessels of 140 feet by 22 feet. Again, on part of the Kennett and Avon Canal, craft of 120 feet by 18 feet can be navigated. Mr. Lloyd, who has had a great deal of experience in canal navigation, has proposed the adoption of improved locks on the leading English canals capable of taking boats 110 feet long, 11½ feet wide, and 6 feet draught, the carrying capacity being about 120 tons.* Mr. Abernethy has proposed that the canal boats should be capable of carrying 200 tons, and the canals adapted thereto;† while Sir James Allport has contended that for facility of handling traffic small boats are better than large ones, and should be preferred accordingly.‡

In India, steamers have been placed by Government on the Sone canals, and will continue to run until the task is taken up by private enterprise, as is now being done on the Orissa canals.

The following is a description of one of them named the *Koel*:—

Length	114 feet
Beam over all	16½ ,,
Draught, full loads..	3½ ,,
Coal bunker capacity	7 tons

Of which 5¾ tons are used on the trip between the head of the canal and Arrah and back, being a run of 116 miles, occupying about 26 hours, or at the rate of 7·450 lbs. per hour, a very large consumption for an engine of 25 nominal H.P.

Accommodation is provided for 8 first-class passengers and 150 second-class passengers, with a cargo capacity of 2500 cubic feet, or 50 tons of 50 cubic feet.

The engine of 25 H.P. was one of the locomotives used on the Quarry Tramways. The pressure of the steam is 120 lbs. The vessel is built with a single paddle-wheel, 11½ feet diameter, at the stern with 20 floats, 5 feet long by 1 foot broad.

The hull of the boat is 3-16ths iron, perfectly flat-bottomed and

* Report App., 2, 117–119

† Ibid, 2, 1281–1283.

‡ Ibid, 2, 1548-1550.

rectangular in section, with rectangular bilge. The bow is curved, with a vertical stern, and the stern is sloped off for 24 feet to a vertical depth of 1 foot, for the purpose of enabling the backwater to escape when the wheel is reversed. There are two rudders, and the steering is managed from the fore part of the boat. Her speed is between 6·5 and 7 miles an hour in the canal, but the run of 58 miles occupies from 11 to 12 hours down stream, and 13½ to 15 hours up stream, owing to the delay in passing the locks, of which there are six.

These steamers last year carried 42,900 passengers and 2500 tons of goods, earning 3175*l.*

The cost of working the different steamers, inclusive of all charges but that of interest and depreciation, amounted to from 9·36*d.* to 36·48*d.* per mile run.

The total earnings of the canal for the past year was 7080*l.*, against 9300*l.* in 1881–82.

The tolls levied on boats are from ⅛*d.* to ⅕*d.* per ton per mile.

The charges by the steamer amount to about ⅜*d.* per ton and per passenger per mile. The charge by native boats varies with the demand, and is high. The bulk of the traffic is carried in native boats, which are worked by men. The sections of the two main canals in the Sone system are very large. They have to provide for the irrigation of 1,295,000 acres. They are about 200 feet broad, with a depth of 9 feet in full supply, diminishing to about 7 at the minimum. The branches vary from 90 to 60 feet at surface, with a minimum depth of 6 feet.

The time occupied by a boat in passing through a lock comprises the entrance and exit of the boat, and the operations in locking. By the adoption of sluices in the side walls the locks on the Bourgogne Canal can be filled or emptied in two minutes; but the time employed in taking in and bringing out a boat varies considerably, depending on the speed of the boat, its draught, and its method of traction. Steamboats, carrying from 100 to 150 tons of merchandise, traverse a lock in from six to eight minutes, whilst yachts and torpedo-boats have passed in four to six minutes. The main water traffic between Paris and Lyons is carried on by new boats 125 feet long, and having a draught of 4½ feet, being limited by deficiency in the depth of the Yonne. These boats can carry 210 tons. but their load is usually between 130 and 180 tons; they perform the journey between Paris and Lyons in 11 to 12 days, traversing the Bourgogne Canal in six or seven days.

Boatbuilders often err in constructing boats of the largest size that the locks will admit, thus rendering the entrance and exit of the boats both slow and troublesome. A boat of 200 tons, travelling 22 miles per day, is more serviceable than a boat of 275 tons which can only go 12½ miles. The greater speed entails a somewhat greater cost in traction; but it admits of more voyages, the transport of more freight, and a more regular service. The lengthening of the locks on the Burgoyne Canal, by enabling the tonnage to be increased by one-third, without diminishing the speed of transit, or notably increasing the cost of traction, has proved a profitable work for the inland-navigation commerce of France.

In 1871, the Legislature of the State of New York, with a view to enabling the Erie and other canals under their jurisdiction to be more profitably utilised, passed an Act to foster and develop the internal commerce of the State, by inviting and rewarding the practicable and profitable introduction, upon the canals, of steam, caloric, electricity, or any motor, other than animal power, for the propulsion of boats.

The first section of this Act appointed a commission to practically "test and examine inventions, or any or all devices, which may be submitted to them for that purpose, by which steam, caloric, electricity, or any other motor than animal power, may be practically and profitably used and applied in the propulsion of boats upon the canals; said examination and tests shall be had by the said commissioners at such time or times during the season of canal navigation, for the year 1871–72, as they may order and direct; said commissioners shall have the right, and they are hereby expressly required, to reject all such inventions or devices, if, in their opinion, none of the said inventions or devices shall fully and satisfactorily meet the requirements of this Act; but said commissioners shall demand and require,

"1. The invention or devices to be tested and tried at their own proper costs and charges of the parties offering the same for trial.

"2. That the boat shall, in addition to the weight of the machinery and fuel reasonably necessary for the propulsion of said boat, be enabled to transport, and shall actually transport, on the Erie Canal, on a test or trial exhibition, under the rules and regulations now governing the boats navigating the canals, at least 200 tons of cargo.

"3. That the rate of speed made by said boat shall not be less than an average of three miles per hour without injury to the canals or their structures.

"4. That the boat can be readily stopped or backed by the use and power of its own machinery.

"5. That the simplicity, economy, and durability of the invention, or device, must be elements of its worth and usefulness.

"6. That the invention, device, or improvement can be readily adapted to the present canal boats; and,

"Lastly, that the commissioners shall be fully satisfied that the invention or device will lessen the cost of canal transportation, and increase the capacity of canals by any means of propulsion or towage, other than by a direct application of power upon the boat, which does not interfere in any manner with the present method of towage on the canals, and complying in all other respects with the provisions of this Act, may be entitled to the benefits thereof." The system known as the Belgian system, or any mode of propulsion by steam engines or otherwise, upon either bank of the canal, was, however, excluded. A number of attempts have been made to meet these desiderata, of which the system known as Baxter's is, perhaps, the most successful.

On the running canals of China, Sir George Stainton observed a boat of light construction, with only 14 tons lading, of 8 feet width of floor, about 10 feet width of water-line, and 50 feet of extreme length, drawing 2 feet 3 inches of water, and sharp at the ends, dragged against a stream whose velocity was 5½ English miles per hour; and, although there were twenty-eight trackers, or men hauling at the line, fastened to the boat, besides three men in the boat, poling it on, it advanced only at the rate of a quarter of a mile an hour, notwithstanding that the channel was not materially contracted, in either width or depth of waterway, in proportion to the section of the boat.

Many suggestions have been made, and not a few experiments carried out, with a view to enabling canal boats to navigate waters covered with ice—the use of canals in cold countries being usually limited, from this cause, to about one-half of the year only. None of them appear, however, to have been very successful.

About the year 1796, the Chevalier Bentancourt Molina presented to the Society of Arts a model of a barge, having a windlass in its stern, which gave a circular motion to a pair of knives or scythes, or a lever giving an alternating motion to knives, for mowing off weeds close to the bottom of a canal in which the barge is to float, or on the sloping sides of the canal; for which purpose the knives could be made to revolve at any depth below the surface of the water, and either horizontally or inclined at any angle. In most winters it happens that an ice not more than 1 or 1½ inches thick continues for a considerable length of time on canals and other stagnant waters. This, or even a less thickness of ice, is sufficient to stop the trade upon the canals unless the ice is broken; and for this purpose it is advisable, every morning of a frost, unless the ice should be found more than usually thick, and the frost increasing and likely to continue, to break the ice. This was in some cases done by a strong and square-headed barge, whose sloping or projecting head was covered with strong iron plates. One of these barges, being drawn along the canal and into each lock by several horses, has a tendency to rise upon the ice, and thereby breaks it down before the boat. About the lock-gates it was necessary to break the ice by stamping with the end of a pole. Mr. Symington provided the head of his steam-barge with stampers, to be worked by the engine, for breaking the ice before it in frosty weather.

The tempting prospects of towing a train of ten 100-ton barges with scarcely any more power than would be required to tow only one of them, and the alluring advantages of speedily loading each separate barge, and of detaching and attaching barges at intermediate wharves along the canal's course, were held out in a proposal recently discussed in France for adopting single-width canals.

On the other hand, however, it has been argued that in this case a regular time-table would have to be strictly enforced; all boats would have to be made up into trains, involving loss of time at starting; there would be delays at the turn-outs, where the canal was widened for allowing the return trains to pass; and steamers could no longer go where and when they pleased. Bridges and locks, being already of single width, could be built no cheaper; while the proposed long locks, of 150 metres = 490 feet length, to take a train of barges, would cost much more than the present French locks of 126 feet length. Even with very few locks, a single-width canal would not come more than one-ninth cheaper than the ordinary canals of double width. At the outside, therefore, it would not take off more than 1 millime per tonne-kilom. = 0·016*d.* per ton per mile from the tolls. Under the head of towing, the only possible saving would be in consumption of coal in the steam-tugs, which on the Willebroeck Canal costs about ¼ millime per tonne-kilom = ·008*d.* per ton per mile; if half this were saved in a single-width canal, ¼ millime = 0·004*d.*, would be all the economy thereby effected. As for dispensing with barges on all except the tug and the rear barge of a train, it has been argued that it would be practically impossible to work a train of rudderless barges round the bends of a canal, and it would be a most tedious and difficult job to handle the barges separately at the wharves and docks where the train has to be made up or dispersed; moreover, the cargoes would not get properly watched, with so few men to look after them. The total saving possible on a single-width canal, 0·020*d.* per ton per mile, would be likely to be swallowed up by the extra management expenses consequent upon having to organise the canal service on a similar plan to that of railways.

CHAPTER XXXV.

THE STATE ACQUISITION AND CONTROL OF WATERWAYS.

"The march of the human mind is slow. It was not, until after two hundred years, discovered that, by an eternal law, providence had decreed vexation to violence and poverty to rapine, Your ancestors did, however, at length open their eyes to the ill husbandry of injustice. They found that of all tyrannies, the tyranny of a free people could the least be endured; and that laws made against a whole nation were not the most effectual methods for securing its obedience."—*Edmund Burke.*

England is the only nation in the world that has not either reserved to itself State control over the means of communication, or provided railways and waterways at the public cost. The United States, Government have no proprietary interest in the railways of that country, but individual State Governments have such interests in canals. In France the canals are largely owned, and almost wholly controlled, by the State. In Germany, the State owns the greater part of the railways and a great part of the canals, while it is extending the latter system largely at the public cost. In Italy and Russia, the same remark applies to the existing state of affairs. In the British Colonies, and especially in India and Canada, both the railways and the waterways have been and are being provided at the public expense, and are administered by officials responsible to the people generally. England, on the contrary, has allowed both railways and waterways to be monopolised by private enterprise, with results disastrous to the latter, as we have already seen, and with consequences, as regards the former, that threaten to be almost as serious to the public, who are held fast in the iron grip of a monopoly which they are powerless to control.

Seeing that the proposal that the State should purchase the railways of the United Kingdom, and carry them on as they are carried on in Germany and Belgium, with a view to public interests, has not hitherto appeared to find much favour in political circles, and has been discouraged by several important Royal Commissions and other authorities, it is perhaps worth while to consider whether the time has not arrived when the State should make some attempt to undo part of the mischief that it has done to the trade and traders of the country in neglecting the acquisition of the railways, by aiding the movement for the reconstruction of our waterways. The present moment is highly opportune for such a step. The canals could, no doubt, be purchased cheaply, and they could be enlarged and improved at comparatively little cost.

In some very pertinent remarks on the subject of the control of Waterways by the State, Mr. M. B. Cotsworth has observed* that, "considering the immense influence which the cost of transport has upon the trade and progress of a nation, it is but natural that this remedy should first suggest itself, especially when the advantageous results of Government management are so strikingly shown in the working of the Post Office and telegraphs, as also in the example of Government control of canals in France. All who look solely to the interests of the community must admit that this course offers the highest national advantages, and will ultimately prove the best solution.

"Amongst the chief advantages of Government control are the following:—

"1. The whole system of 'inland navigation' would be developed and worked for the benefit of the nation by a complete scheme, and thus secure for the first time a genuine and permanent competition with railway charges, and so hold them in check.

"2. All chances of monopoly and trade restriction by private interests, would be avoided.

"3. Government security would ensure capital being raised at a minimum interest—say $2\frac{3}{4}$ or 3 per cent., and so keep the costs down at a low figure.

"4. By adopting a 'sinking fund,' these navigations might ultimately become free from toll, except a very small charge for maintenance and management.

"5. Would facilitate uniformity of classification, toll, and through-rate arrangements.

"6. The question of railway-owned canals would thus be settled.

"7. Also the difficulty of floods would be removed as far as practicable, and storage of water, for town and other public uses, encouraged by the abolition of vested interests in water rights. fishery obstructions, &c.

* Paper on the present condition of inland navigation in the United Kingdom, with suggestions for its improvement, 'Journal of the Society of Arts,' 1888.

"8. The above advantages, whilst affording unbounded relief to commerce and the public, would result in increased employment for the labouring classes, and add to the wealth of the nation by creating a revival and permanent expansion of trade—thus relieving our present burdens without imposing new ones."

The same writer thus expresses the disadvantages and difficulties in the way of State management of canals:—

"1. Public opinion is not yet ripened to enable such a proposal to be carried.

"2. To successfully compete with railways (who have now such a firm grip of the heavy traffic), it is essential that a strong carrying company should be established, on a broad basis, to work the navigations and interchange traffic for towns on the sea-board with the coasting steamers at through rates.

"3. If the Government did not undertake the carrying, private traders would have great difficulty in meeting railway competition, as, owing to the heavy terminal charges they would incur, and costs of agencies, &c., they would be handicapped, whilst railways could sustain their competition against canals by means of their passenger and other traffic.

"4. The patronage being placed in the hands of Government, might be abused for party purposes, and lead to political jobbery, &c.

"5. For the good canals a very high price would have to be paid, whilst some of the poor ones would be looked upon as a bad bargain at any price.

"6. In justice to the railways, the Government could not assume the responsibilities of carrying, without also taking over the railways at their present inflated prices, notwithstanding the 100,000,000*l.* of unproductive capital (land and under-issued stock) with which they are burdened.

"5. The present enormous capital of railways, constituting such vested interests in Parliament, and through the shareholders over the country generally, is too strong to allow the Government to take over the canals."

A recent writer in the *Edinburgh Review* declares that "the mode in which the railway companies of the United Kingdom have been allowed to ruin the canal property is a mark of the indifference of Parliament to an important feature of public policy. It would have been as justifiable, on the score of public welfare, to allow the railway companies to buy up the turnpike bonds, and to charge what tolls they pleased on the turnpike roads, as it was to wink at the purchase and stoppage of the canals. The danger of allowing such a change of mastership is admitted by the clauses inserted in several Acts of Parliament regulating the maximum tolls—clauses which have been allowed to remain a dead letter. The Board of Trade declared that it had neither advice nor assistance to offer to complainants in the matter. Mr. (now Sir Thomas) Farrer, then Secretary to the Board of Trade, expressed his opinion, in 1872, that the actual state of canal property, which was held by the railway companies just so far as to enable them to destroy the traffic, was the worst possible, as regarded the public interest. It is now too late to attempt to remedy the evil. Nothing but the conviction on the part of the railway companies that they are financially wrong in forcing the slow heavy traffic on to the metals, will render possible the rehabilitation of the canal system, however fully all other persons may be convinced of the national importance of our internal navigation."

Among the many current questions relative to transport, none is more urgent than that of how far the waterways of a country can be profitably and conveniently utilised in competition with railways. This is a question that has come up again and again in all the leading countries of the world, and one which is still unsolved. In Continental countries—and especially in France, Germany, Belgium, and Holland—the greatest possible importance is attached to having the command of cheap and adequate water transport, and it seems to have been allowed that there is a natural function for each system of transport—that of the railways being the conveyance of passengers and traffic that will bear a high rate of freight, while that of the waterways is to convey heavy luggage or traffic, of low intrinsic value, from point to point at a low rate of speed. Unfortunately, however, there is no common agreement as to the average cost of service in each case. The fact is, as we have seen, that the cost of water transport, under the most suitable conditions, is almost ridiculously low. It has been proved in Belgium, in France, and in Germany, to be under one-tenth of a penny per ton per mile, whereas the cost of railway transport is seldom less than double that amount. But, of course, much necessarily depends upon the local conditions, and upon the means of transport employed.

The State should take care, by enactment or acquisition, that the country does not lose the immense economic advantage that accrues from the cheapness of water transport. Hitherto, this advantage has been almost absolutely lost to the people of these islands: first, by the neglect into which the canal system has been allowed to fall: and, secondly, by the authority given to the railway companies to acquire canal properties which they have allowed to become derelict or converted into railway lines. Nor have the canal proprietors themselves been free from serious blame. In their palmy days they paid immense dividends by keeping up high tolls and charges, and thereby materially assisted the development of the railway system and their own partial or complete extinction.*

Parliament behaved to the canal companies much as it has since done to the railway corporations. It granted them monopolies and excessive powers, which were used, in a very great majority of cases, in much the same way—to extort the utmost possible sums from freighters—both against traders and against themselves.

One of the most remarkable privileges granted by Parliament to the earlier canal companies was a right to levy bar and compensation tolls on the traffic of the newly-constructed canals, in order to protect their monopolies. In some cases, within a few years, canal companies received more than the amount of their original capital by way of compensation for injury to their traffic. On this point Mr. E. J. Lloyd has observed that, "the fact that all these new lines of canal could only succeed by bringing tributary traffic not otherwise attainable to the older canals seems to have been completely lost sight of by the Legislature, and no excuse appears to have been too absurd as a reason for granting these oppressive and unjustifiable exactions on the trading public. Many instances might be mentioned, but it may be stated by way of example that in one case 11½*d.* per ton was granted where the traffic did not pass within four miles of the existing canal, and in another 6*d.* per ton where the distance exceeded five miles. To these may be added bridge tolls, which were exactions payable by goods, which having been landed, or were intended to be carried, on one canal, passed over the bridges of another and older company.† Whilst the canals had practically a monopoly of all the traffic of the kingdom, it was not so serious a matter to their interests

* In 1833, when railways were beginning to be generally projected, the dividends of seven of the principal canal companies in Great Britain, ranged between 25 and 124 per cent per annum, while it is probable that others yielded a still higher return.

† Two Warwickshire canals, with a capital of 250,000*l.* have in this way paid in compensation tolls, to three other canal companies, more than a million sterling.

that these heavy burdens were placed upon their traffic. No doubt the public were the sufferers, but the weight of traffic passed was, in most cases, such as to enable the canals to earn dividends satisfactory to their shareholders, and they were therefore, more or less careless of the public interests, and viewed restriction of trade very differently from what they can now afford to do, when they have to keep up a constant competition with railway companies for their traffic." Mr. Lloyds contends that the total abolition of all bar and compensation tolls, and the establishment of free trade by the introduction of through mileage tolls, is imperatively demanded if cheap canal transport is to be attained in the public interests.

It would easily be possible to greatly extend the consideration of the subject of this chapter. But that does not appear to be called for. Time will show how far the practice of England, which is at variance with that of nearly every other European country, is justified by results. So far, it must be confessed, that the justification is far from obvious. The waterways have been grievously neglected, while the railways have been authorised to impose very heavy rates and tolls. These are hardly likely to become much lighter as time goes on, while the controlling interest acquired by the railways in transportation arrangements will almost certainly make it difficult to recur to canal transport on a large scale.

APPENDIX.

I.

CHRONOLOGY OF RIVER IMPROVEMENT AND CANAL NAVIGATION IN ENGLAND UP TO 1852.

Fifteenth Century.

1423. River Thames Navigation.
1425. River Lea Navigation.
1462. River Ouse (Yorkshire) Navigation.

Sixteenth Century.

1503. River Severn Navigation.
1504. River Stour (Essex) Navigation.
1531. Rivers Humber and Ouse Navigation.
1531. River Exe Navigation.
1570. River Lea „
1571. Welland „
1572 Exeter Canal „

Seventeenth Century.

1623. River Colne Navigation.
1662. River Itchin „
1662. River Wye „
1664. River Avon „
1664. River Medway „ (upper).
1670. River Wey „
1670. Rivers Bure, Yare, Waveney Navigation.
1670. River Ouse (Suffolk) Navigation.
1670. Foss Dyke Navigation.
1672. River Witham „
1678. Rivers Fal and Vale Navigation.
1699. Rivers Tone and Parrett „
1699. Rivers Aire and Calder „
1699. River Trent Navigation

Eighteenth Century.

1700. Rivers Avon and Frome Navigation.
1700. River Dee Navigation (and 1732).
1700. River Lark Navigation.
1701. River Derwent „
1702. River Frant „
1705. River Stour „
1714. River Nene „
1715. River Kennett „
1716. River Wear „
1720. Leeds and Liverpool Canal.
1720. Rivers Mersey and Irwell Navigation (and 1794).
1720. River Weaver Navigation.
1720. River Dane „
1721. River Eden „
1726. River Dun „
1726. Beverley Beck „
1730. Stroudwater Canal
1737. River Roden Navigation.
1737. Duke of Bridgwater's Canal (and 1759).
1749. Rivers Ley and Lane Navigation.
1751. River Narr Navigation.
1751. River Avon (Warwickshire).
1753. River Cart Navigation.
1755. Sankey Canal.
1757. River Blyth Navigation.
1757. River Ivel „

1758. Rivers Calder and Hebble Navigation.
1759. River Stort Navigation.
1759. River Clyde „
1763. Louth Navigation.
1766. River Soar Navigation.
1766. Trent and Mersey Canal.
1766. Staffordshire and Worcestershire Canal.
1766. Rivers Chelmer and Blackwater Navigation (and 1793).
1767. River Ure Navigation.
1767. Driffield „
1767. River Ancholme Navigation.
1768. Droitwich Canal.
1768. Coventry Canal.
1768. Birmingham Canal.
1768. Forth and Clyde Canal.
1769. Oxford Canal.
1770. Monkland Canal.
1770. Leeds and Liverpool Canal.
1771. Chesterfield Canal.
1771. Bradford Canal.
1772. Ellesmere Canal.
1772. Market Weighton Canal.
1773. River Bure Navigation.
1774. Sir John Ramsden's Canal.
1774. Bude Canal and Haven.
1775. Gresley Canal.
1776. Dudley Canal.
1776. Stourbridge Canal.
1778. Basingstoke Canal.
1778. Bedford River.
1783. Thames and Severn Canal.
1785. River Arun Navigation.
1788. Shropshire Union Canals.
1789. Andover Canal.
1789. Cromford Canal.
1790. River Ouse (Yorkshire) Navigation.
1790. Glamorganshire Canal.
1791. Hereford and Gloucester Canal.
1791. Leicester Navigation.
1791. Wreak and Eye River Navigation.
1791. Manchester, Bolton, and Bury Canal.
1791. Leominster Canal.
1791 Melton Mowbray Canal.
1791. Neath Canal.
1791. Worcester and Birmingham Canal.
1792. River Medway (lower) Navigation.
1792. Nottingham Canal.
1792. Monmouthshire Canal.
1792. Horncastle Canal.
1792. Lancaster Canal.
1793. Gloucester and Berkeley Canal.
1793. Aberdare Canal.
1793. Brecon and Abergavenny Canal.
1793. Stratford-on-Avon Canal.
1793. Leicestershire and Northamptonshire Canal.
1793. Grantham Canal.
1793. Grand Junction Canal.
1793. River Foss Navigation.
1793. Derby Canal.
1793. Stainforth and Keadby Canal.
1793. Ulverston Canal.
1793. Shrewsbury Canal.
1793. Warwick and Birmingham Canal.
1793. Caister Canal.
1793. Barnsley Canal.
1793. Oakham Canal.
1793. Dearne and Dove Canal.
1793. Cruian Canal.
1794. Montgomeryshire Canal.
1794. Warwick and Napton Canal.
1794. Peak Forest Canal.
1794. Rochdale Canal.
1794. Huddersfield Canal.
1794. Kennett and Avon Canal.
1794. Mersey and Irwell Navigation.
1794. Swansea Canal.
1794. Wisbech Canal.
1794. Somersetshire Coal Canal.
1794. Ashby-de-la-Zouch Canal.
1794. Sleaford Navigation.
1795. Wilts and Berks Canal.
1795. Ilchester and Longport Navigation.
1795. Newcastle-under-Lyme Canal.

1795. Derby Canal.
1796. Dorset and Somerset Canal.
1796. Grand Western Canal.
1796. Aberdeen, or Don and Dee Canal.
1796. River Tamar Navigation.
1796. Salisbury and Southampton Canal.

Nineteenth Century.

1800. Thames and Medway Canal.
1801. Grand Surrey Canal.
1801. Leven Canal.
1802. River Exe Navigation.
1803. Glenkennie Canal.
1803. Tavistock Canal.
1803. Caledonian Canal.
1803. Thames and Severn Canal.
1805. River Mersey Navigation.
1805. Ashton and Oldham Canal.
1806. Glasgow and Paisley Canal.
1807. River Adur Navigation.
1807. River Ribble „
1807. Royal Military Canal.
1808. River Tees Navigation.
1810. Grand Union Canal.
1811. Bridgwater and Taunton Canal.
1812. London and Cambridge Canal.
1812. Regent's Canal.
1813. Bure and Dillon Canal.
1813. Wey and Arun Canal.
1815. Pocklington Canal.
1816. Sheffield Canal.
1817. Portsmouth and Arundel Canal.
1817. Edinburgh and Glasgow Canal.
1819. Carlisle Canal.
1819. Bude and Launceston Canal.
1820. Macclesfield Canal.
1824. Kensington Canal.
1824. Hertford Union Canal.
1825. English and Bristol Channels Canal (Liskeard and Looe)
1826. Alford Canal.
1826. Macclesfield Canal.
1826. Birmingham and Liverpool Canal.
1827. Norwich and Lowestoft Navigation.
1828. Avon and Gloucestershire Canal.
1828. Nene and Wisbech Canal.
1829. Oxford Canal.
1830. Ellesmere and Chester Canal.
1842. River Severn Navigation.
1852. Droitwich Junction Canal.

II.

CANALS AND INLAND RIVER NAVIGATIONS IN ENGLAND, SCOTLAND, AND WALES, DISTINGUISHING THE MILEAGE UNDER, AND THE MILEAGE NOT UNDER, THE CONTROL OF RAILWAY COMPANIES.

(*From the Report of the Select Committee on Canals*, 1883, *p.* 225.)

	Not under Control of Railway Companies.		Under Control of Railway Companies.	
ENGLAND:	M.	F.	M.	F.
Aire and Calder Canal	80	0	—	
Ancholme Drainage and Navigation	19	0	—	
Ashby - de - la - Zouch Canal (Midland Railway)	..		26	4
Ashton-under-Lyne Canal (Manchester, Sheffield, and Lincolnshire Railway) ..	..		17	4
Barnsley Canal (Amalgamated with the Aire and Calder Navigation)	15	1	—	
Baybridge Canal	3	3	—	
Beverley Beck	0	6	—	
Birmingham Canals (London and North-Western Railway)	..		160	0
Bradford Canal	3	0	—	
Bridgwater, Duke of	39	6	—	
Bridgwater and Taunton Canal (Great Western Railway)	..		15	2
Bude Canal	35	4	—	
Caistor Canal (County of Lincoln)	4	0	—	
Calder and Hebble Navigation (Leased to the Aire and Calder Navigation)	22	0	—	
Carlisle Canal	11	2	—	
Chesterfield Canal (Manchester, Sheffield, and Lincolnshire Railway).	..		46	0
Coventry Canal	32	4	—	
Cromford Canal (Midland Railway).	..		18	0
Dearne and Dove Canal (Manchester Sheffield, and Lincolnshire Railway). ..	..		14	0
Derby Canal	18	0	—	
Driffield Navigation Canal	5	4	—	
Driffield River	6	6	—	
Carried forward	296	4	297	2

CANALS AND INLAND RIVER NAVIGATION—*continued.*

	Not under Control of Railway Companies.		Under Control of Railway Compnnies.	
ENGLAND—*continued.*	M.	F.	M.	F.
Brought forward	296	4	297	2
Droitwich Canal	5	6	—	
Droitwich Junction Canal	1	3	—	
Erewash Canal	11	6	—	
Exeter Canal	5	0	—	
Foss Navigation, York	..		12	4
Foss Dike Navigation, Lincolnshire (Great Northern Railway)	..		11	0
Gloucester and Berkeley Canal (now part of Sharpness New Docks and Gloucester and Birmingham Navigation)	164	0	—	
Grand Junction Canal	135	0	—	
Grand Surrey Canal	4	6	—	
Grand Union Canal	26	0	—	
Grand Western Canal	..		12	0
Grantham Canal (Great Northern Railway	..		33	6
Gravesend and Rochester Canal (South-Eastern Railway)	..		6	6
Gresley Canal, including Newcastle-under-Lyne Canals	..		9	0
Grosvenor Canal	1	0	—	
Hertford Union Canal	6	0	—	
Horncastle Canal	11	0	—	
Huddersfield and Sir John Ramsden's Canal	..		23	6
Hull and Leven Canal	3	0	—	
Ilchester and Langport Canal	7	0	—	
Kennet and Avon Canal (Great Western Railway)	..		57	0
Lancaster Canal (London and North Western Railway)	..		60	0
Lea River Navigation and Branch Canals ..	33	4	—	
Leeds and Liverpool Canal	143	4	—	
Leicester Navigation	16	0	—	
Leicestershire and Northamptonshire Union Canal	24	0	—	
Leven Canal	3	0	—	
Liskeard and Looe Canal	6	0	—	
Carried forward	904	1	523	0

CANALS AND INLAND RIVER NAVIGATION—*continued.*

	Not under Control of Railway Companies.		Under Control of Railway Companies.	
ENGLAND—*continued.*	M.	F.	M.	F.
Brought forward	904	1	523	0
Louth Canal (Great Northern Railway) ..	..		12	0
Macclesfield Canal (Manchester, Sheffield, and Lincolnshire Railway)	..		26	2
Manchester, Bolton, and Bury Canal (Lancashire and Yorkshire Railway)	..		16	0
Market Weighton Canal (North-Eastern Railway)	..		9	0
Newcastle-under-Lyne Canal (North Staffordshire Railway)	..		2	0
North Walsham and Dilham	7	4	—	
North Wilts (part of Wilts and Berks Canal)	8	4	—	
Nottingham Canal (Great Northern Railway)	..		15	0
Nutbrook or Shipley Canal	4	4	—	
Oxford Canal	91	2	—	
Peak Forest Canal (Manchester, Sheffield, and Lincolnshire Railway)	..		15	0
Pocklington Canal (North-Eastern Railway)	..		9	2
Portsmouth and Arundel	4	0	—	
Regent's Canal	9	6	—	
Rochdale Canal	35	0	—	
Royal Military or Shorncliffe Canal	30	0	—	
St. Columb Canal	6	0	—	
St. Helen's Canal (London and North-Western Railway)	..		16	6
Sankey Canal	..		12	0
Sheffield Canal (Manchester, Sheffield, and Lincolnshire Railway)	..		4	0
Shropshire Union Canals (London and North-Western Railway)	..		204	0
Sleaford Chapel	13	4	—	
Soar River or Longboro' Navigation	8	4	—	
Somersetshire Coal Canal	11	0	—	
Staffordshire and Worcestershire Canal ..	50	0	—	
Stamforth and Keadby Canal (South Yorkshire Railway)	..		13	0
Stourbridge Navigation	7	1	—	
Stourbridge Extension Canal (Great Western Railway)	..		3	0
Carried forward	1190	6	880	2

CANALS AND INLAND RIVER NAVIGATION—*continued.*

	Not under Control of Railway Companies.		Under Control of Railway Companies.	
ENGLAND—*continued.*	M.	F.	M.	F.
Brought forward	1190	6	880	2
Stratford-on-Avon Canal (Great Western Railway)	..		25	2
Stover Canal (South Devon Railway)	..		1	7
Stroudwater Canal	8	0	—	
Surrey Dock Canal	4	4	—	
Tavistock Canal	4	0	—	
Thames and Medway Canal	..		9	0
Thames and Severn Canal	30	0	—	
Thanet Canal	0	3	—	
Tone and Parrett Navigation (Great Western Railway)	..		27	0
Trent and Mersey Canal (North Staffordshire Railway)	..		118	0
Ulverston Canal (Furness Railway)	..		1	2
Warwick and Birmingham Canal	22	4	—	
Warwick and Napton	14	3	—	
Wey and Arun	18	0	—	
Wey River	20	0	—	
Wilts and Berks Canal	60	2	—	
Wisbech Canal	6	0	—	
Worcester and Birmingham (now part of Sharpness New Docks and Gloucester and Birmingham Navigation Company)	29	0	—	
TOTAL	1,260	2	1,062	5
SCOTLAND:				
Aberdeenshire Canal	19	0	—	
Borrowstowness Canal	7	0	—	
Caledonian Canal	23	0	—	
Crinan Canal	9	4	—	
Edinburgh and Glasgow Union (North British Railway)	..		32	0
Forth and Clyde (Caledonian Railway) ..	..		53	0
Glasgow, Paisley, and Ardrossan (Glasgow and South Western Railway)	..		11	0
Glenkenn's Canal	25	6	—	
Monkland Canal	..		10	0
Total	84	2	106	0

CANALS AND INLAND RIVER NAVIGATION—*continued.*

	Not under Control of Railway Companies.		Under Control of Railway Companies.	
	M.	F.	M.	F.
WALES :				
Aberdare Canal	6	6	—	
Brecon and Abergavenny Canal (Great Western Railway)	..		33	0
Briton Canal	4	2	—	
Glamorganshire Canal	25	4	—	
Kidwelly Canal	3	4	—	
Monmouthshire Railway and Canals (Great Western Railway)	..		20	0
Montgomeryshire Canal (now part Shropshire Union)	—		—	
Neath Canal	14	0	—	
Pembrey Canal	0	4	—	
Penelawd Canal	4	0	—	
Swansea (Great Western Railway)	..		17	0
Total	58	4	70	0

RIVERS IN ENGLAND.

Axe River	9	0	—	
Adur River, Sussex	14	0	—	
Arun River, Sussex	13	0	—	
Avon River (Lower), Tewkesbury to Evesham (now leased to Sharpness New Docks, and Gloucester and Birmingham Navigation Company)	25	0	—	
Avon River, Bath to Hanham Mills	..		11	0
Blyth River, Suffolk	9	0	—	
Bourne Eare River, Lincolnshire	3	4	—	
Bure or North River, Norfolk	9	0	—	
Colne River, Essex	3	4	—	
Chelmer and Blackwater Navigation, Essex	14	0	—	
Dee Navigation	10	0	—	
Derwent River Navigation (North Eastern Railway)	..		38	0
Carried forward	110	0	49	0

RIVERS IN ENGLAND—*continued.*

	Not under Control of Railway Companies.		Under Control of Railway Companies.	
	M.	F.	M.	F.
Brought forward	110	0	49	0
Dun River Navigation (Manchester, Sheffield, and Lincolnshire Railway)	..		39	0
Gippen River, Suffolk (Great Eastern Railway)	..		16	0
Idle River, County of Nottingham	10	0	—	
Itchen Navigation	14	0	—	
Ivel River, Hertford and Bedford	11	0	—	
Kennet River, Reading to Newbury (Great Western Railway)	..		18	4
Larke River, Suffolk	14	0	—	
Medway River, Lower Navigation	7	6	—	
Medway River, Upper Navigation	15	0	—	
Leicester and Melton Mowbray Navigation	14	6	—	
Mersey and Irwell Navigation	57	0	—	
Narr River, Norfolk	15	0	—	
Nene River Navigation	50	0	—	
Norwich and Lowestoft Navigation (Great Eastern Railway)	..		30	0
New Bedford Level	20	0	—	
Ouse River Navigation (York)	60	0	—	
Ouse River Navigation (Sussex)	30	0	—	
The Little Ouse or Brandon and Waveney River	22	4	—	
Rother River, Sussex	11	0	—	
Stour River, from Manningtree, Essex, to Sudbury, Suffolk	20	0	—	
Stowmarket Navigation (Great Eastern Railway)	..		17	0
Stort River Navigation	13	4	—	
Severn River	44	0	—	
Sankey Brook Navigation	3	3	—	
Tamar Manure Navigation	22	0	—	
Thames River	146	0	—	
Trent River Navigation	72	0	—	
Ure River Navigation	..		7	6
Weaver Navigation	24	0	—	
Welland River	26	0	—	
Witham Navigation	..		32	0
Wye and Lugg Rivers	99	4	—	
Total	932	3	209	2

CANALS AND NAVIGATIONS ABANDONED OR CONVERTED INTO RAILWAYS.

	M.	F.
Alford Canal	6	4
Andover Canal, converted into Railway	22	4
Avon River, above Evesham	18	3
Basingstoke Canal	37	2
Coombe Hill Canal	3	4
Croydon Canal	9	4
Glastonbury Canal, converted into Railway	14	2
Grand Western Canal	25	0
Grosvenor Canal, part of	1	0
Hereford and Gloucester, converted into Railway	34	0
Kensington Canal, part of	2	0
Leominster Canal, converted into Railway	22	0
Monmouthshire Canal, near Newport, part converted ..	0	6
Newport Pagnell	1	2
Oakham Canal, part converted into Railway	15	0
Portsmouth and Arundel (part abandoned since 1855) ..	8	0
Somersetshire Canal (part of), converted into Railway ..	7	2
Wey and Arun Junction Canal	18	0
Total	250	1

SUMMARY.

	Not under Control of Railway Companies.		Under Control of Railway Companies.	
	M.	F.	M.	F.
Canals in England	1,260	2	1,062	5
Canals in Scotland	84	2	106	0
Canals in Wales	58	4	70	0
	1,403	0	1,238	5
Rivers in England	932	3	209	2
Total	2,335	3	1,447	7
Canals and Navigations abandoned or converted into Railways	250	1	—	

III.

THROUGH ROUTES OF CANAL AND INLAND NAVIGATION IN ENGLAND AND WALES.

(*From the Report of the Select Committee on Canals*, 1883, *p.* 210.)

Note.—An asterisk (*) against the name of a Navigation indicates that it is owned or controlled by a Railway Company.

Note.—Draft, in the dimensions of locks, denotes the greatest immersion at which any craft can pass through the Navigation.

Route.	Name of Navigation.	Mileage.	Size of Lock.		
			Length.	Breadth.	Draft.
			ft. in.	ft. in.	ft. in.
London to Liverpool (First Route.)	*Regent's	8½	90 0	by 15 0	by 5 0
	Grand Junction	101	80 0	,, 14 6	,, 4 6
	Oxford	5	No lock.		
	Warwick and Napton ..	15	72 0	by 7 0	by 4 0
	Warwick and Birmingham	22	72 0	,, 7 0	,, 4 0
	*Birmingham	15	72 0	,, 7 0	,, 4 0
	Staffordshire and Worcestershire	1¼	72 0	,, 7 0	,, 4 0
	*Shropshire Unions	68	80 0	,, 7 6	,, 4 0
	Mersey	10	Open navigation.		
	Total	245¾			
London to Liverpool (Second Route.)	River Thames	20	Open navigation.		
	Grand Junction	94	80 0	by 14 6	by 4 6
	Oxford	24	72 0	,, 7 0	,, 4 0
	Coventry	27	72 0	,, 7 0	,, 4 0
	*Birmingham	5½	No lock.		
	Coventry	5½	Ditto.		
	*North Staffordshire	67	72 0	by 7 0	by 3 6
	Duke of Bridgwater's ..	5¼	84 0	,, 15 0	,, 4 6
	River Mersey	15	Open navigation.		
	Total	263¼			
London to Liverpool (Third Route.)	River Thames	20	Open navigation.		
	Grand Junction	94	80 0	by 14 6	by 4 6
	Oxford	5	72 0	,, 7 0	,, 4 0
	Warwick and Napton ..	15	72 0	,, 7 0	,, 4 0
	Warwick and Birmingham	22	72 0	,, 7 0	,, 4 0
	*Birmingham	15	72 0	,, 7 0	,, 4 0
	Staffordshire and Worcestershire	23	72 0	,, 7 0	,, 4 0
	Carried forward ..	194			

THROUGH ROUTES OF CANAL AND INLAND NAVIGATION—*continued.*

Route.	Name of Navigation.	Mileage.	Size of Lock. Length.	Breadth.	Draft.
			ft. in.	ft. in.	ft. in.
	Brought forward ..	194			
	*North Staffordshire	55	72 0 by	7 0 by	3 6
	Duke of Bridgwater's ..	$5\frac{1}{4}$	85 0 ,,	15 0 ,,	4 6
	River Mersey	15	Open navigation.		
	Total	$269\frac{1}{4}$			
London to Hull .. (First Route.)	Regent's	$8\frac{1}{2}$	90 0 by	15 0 by	5 0
	Grand Junction	96	80 0 ,,	14 6 ,,	4 6
	Grand Union	24	72 0 ,,	7 0 ,,	4 0
	Leicester and Northampton	18	80 0 ,,	15 0 ,,	3 6
	Leicester	16	70 0 ,,	14 0 ,,	3 6
	Soar	8	70 0 ,,	14 0 ,,	3 6
	Trent	100	90 0 ,,	15 0 ,,	3 6
	Humber	$18\frac{1}{2}$	Open navigation.		
	Total	289			
London to Hull .. (Second Route.)	Thames	20	Open navigation.		
	Grand Junction	94	80 0 by	14 6 by	4 6
	Oxford	24	72 0 ,,	7 0 ,,	4 0
	Coventry	27	72 0 ,,	7 0 ,,	4 0
	*Birmingham	$5\frac{1}{2}$	No lock.		
	Coventry	$5\frac{1}{2}$	Ditto.		
	*North Staffordshire	26	72 0 by	7 0 by	3 6
	Trent	$102\frac{1}{2}$	90 0 ,,	15 0 ,,	3 6
	Humber	$18\frac{1}{2}$	Open navigation.		
	Total	323			
London to Severn Ports. (First Route.)	Thames	$78\frac{1}{2}$	Open navigation.		
	Kennet	$1\frac{1}{2}$	120 0 by	18 0 by	5 0
	*Kennet and Avon	74	75 0 ,,	14 6 ,,	4 6
	*Avon to Hanham	11	108 0 ,,	18 6 ,,	4 6
	Avon Tideway	$15\frac{1}{2}$	Open navigation.		
	Total	$180\frac{1}{2}$			
London to Severn Ports. (Second Route.)	Thames	$106\frac{1}{2}$	109 0 by	17 8 by	4 0
	Wilts and Berks	37	78 0 ,,	8 0 ,,	4 0
	Thames and Severn ..	$20\frac{1}{2}$	{ 72 0 ,, / 86 0 Altered to 72 0 } ,,	17 6 ,, / 12 3 ,,	4 0 / 4 0
	Stroudwater	7	72 0 ,,	17 6 ,,	4 6
	Sharpness Docks, Gloucester and Berkeley, Section to Sharpness	9	No lock 18 feet deep.		
	Total	180			

THROUGH ROUTES OF CANAL AND INLAND NAVIGATION—*continued.*

Route.	Name of Navigation.	Mileage.	Size of Lock. Length.	Breadth.	Draft.
			ft. in.	ft. in.	ft. in.
London to Severn Ports. (Third Route.)	Thames	141½	140 0 / 109 0 / 90 0	by 22 0 / ,, 17 8 / ,, 14 0	
	Thames and Severn ..	28¾	72 0	,, 12 6	by 4 0
	Stroudwater to Tideway ..	8	72 0	,, 17 6	,, 4 6
	Total	178¼			
London to Severn Ports. (Fourth Route.)	Thames	20	Open navigation.		
	Grand Junction	94	80 0	by 14 6	by 4 6
	Oxford	5	72 0	,, 7 0	,, 4 0
	Warwick and Napton ..	15	72 0	,, 7 0	,, 4 0
	Warwick and Birmingham	7½	72 0	,, 7 0	,, 4 0
	*Stratford-on-Avon	12½	72 0	,, 7 0	,, 4 0
	Sharpness Docks, Worcester Section	24	72 0	,, 7 0	,, 5 6
	Severn	30	150 0	,, 30 0	,, 6 0
	Gloucester and Berkeley to Sharpness	16	100 0	,, 24 0	,, 6 0
	Total	224			
Liverpool to Severn Ports. (First Route.)	Mersey	10	Open navigation.		
	*Shropshire Union	68	80 0	by 7 6	by 4 0
	Staffordshire and Worcestershire	26½	72 0	,, 7 0	,, 4 0
	Severn	44	99 0	,, 20 0	,, 6 0
	Gloucester and Berkeley ..	16	100 0	,, 24 0	,, 6 0
	Total	164½			
Liverpool to Severn Ports. (Second Route.)	Mersey	15	Open navigation.		
	Duke of Bridgwater's ..	5¼	84 0	by 15 0	by 4 6
	*North Staffordshire	55	72 0	,, 7 0	,, 3 6
	Staffordshire and Worcestershire	21½	72 0	,, 7 0	,, 4 0
	*Birmingham	15	72 0	,, 7 0	,, 4 0
	Worcester and Birmingham	30	72 0	,, 7 0	,, 5 6
	Severn	30	150 0	,, 30 0	,, 6 0
	Gloucester and Berkeley ..	16	100 0	,, 24 0	,, 6 0
	Total	187¾			
Liverpool to Hull .. (First Route.)	Leeds and Liverpool ..	127	70 0	by 16 0	by 4 0
	Aire and Calder	35	212 0	,, 22 0	,, 9 0
	Ouse	8	Open navigation.		
	Humber	18½	Ditto.		
	Total	188½			

THROUGH ROUTES OF CANAL AND INLAND NAVIGATION—*continued.*

Route.	Name of Navigation.	Mileage.	Size of Lock.		
			Length.	Breadth.	Draft.
			ft. in.	ft. in.	ft. in.
Liverpool to Hull .. (Second Route.)	Mersey	15	Open navigation.		
	Duke of Bridgwater's ..	26¾	84 0	by 15 0	by 4 6
	Rochdale	33	73 0	,, 14 0	,, 4 6
	Calder and Hebble (in course of improvement)	22	53 0	,, 14 0	,, 4 6
	Aire and Calder	35	212 0	,, 22 0	,, 9 0
	Ouse	8	Open navigation.		
	Humber	18½	Ditto.		
	Total	158¼			
Liverpool to Hull .. (Third Route).	Mersey	15	Open navigation.		
	Duke of Bridgwater's ..	26¾	84 0	by 15 0	by 4 6
	Rochdale	1	73 0	,, 14 0	,, 4 6
	Ashton	6	83 0	,, 8 6	,, 4 6
	*Huddersfield	19¾	70 0	,, 7 0	,, 4 6
	*Sir John Ramsdén's ..	3¾	53 0	,, 14 0	,, 4 6
	Calder and Hebble	13	58 0	,, 14 6	,, 5 6
	Aire and Calder (original improved)	35	212 0	,, 22 0	,, 9 6
	Ouse	8	Open navigation.		
	Humber	18½	Ditto.		
	Total	146¾			
South Staffordshire Mineral District to London.	*Birmingham (average) ..	12	72 0	by 7 0	by 4 0
	Warwick and Birmingham	22	72 0	,, 7 0	,, 4 0
	Warwick and Napton ..	15	72 0	,, 7 0	,, 4 0
	Oxford	5	No lock.		
	Grand Junction	101	80 0	by 14 6	by 4 6
	Regent's	8½	90 0	,, 15 0	,, 5 0
	Total	163½			
South Staffordshire Mineral District to Liverpool. (First Route.)	*Birmingham (average) ..	10	72 0	by 7 0	by 4 0
	Staffordshire and Worcestershire	21½	72 0	,, 7 0	,, 4 0
	*North Staffordshire	55	72 0	,, 7 0	,, 3 6
	Duke of Bridgwater's ..	5	84 0	,, 15 0	,, 4 0
	Mersey	15	Open navigation.		
	Total	106½			
South Staffordshire Mineral District to Liverpool. (Second Route.)	Birmingham (average) ..	10	72 0	by 7 0	by 4 0
	Staffordshire and Worcestershire	1¼	72 0	,, 7 0	,, 4 0
	Shropshire Union	68	80 0	,, 7 6	,, 4 0
	Mersey	10	Open navigation.		
	Total	89¼			

THROUGH ROUTES OF CANAL AND INLAND NAVIGATION—*continued.*

Route.	Name of Navigation.	Mileage.	Size of Lock. Length.	Breadth.	Draft.
			ft. in.	ft. in.	ft. in.
South Staffordshire Mineral District to Hull.	*Birmingham (average) ..	27	72 0 by	7 0 by	4 0
	Coventry	5½	No lock.		
	*North Staffordshire	26	72 0 by	9 0 by	3 6
	Trent	102	90 0 ,,	15 0 ,,	3 6
	Humber	18½	Open navigation.		
	Total	179			
South Staffordshire Mineral District to Severn Ports. (First Route.)	*Birmingham (average) ..	10	72 0 by	7 0 by	4 0
	Worcester Section	30	72 0 ,,	7 0 ,,	5 6
	Severn	30	150 0 ,,	30 0 ,,	6 0
	Gloucester and Berkeley Section	16	100 0 ,,	24 0 ,,	6 0
	Total	86			
South Staffordshire Mineral District to Severn Ports. (Second Route.)	*Birmingham	7	72 0 by	7 0 by	4 0
	Stourbridge	7	72 0 ,,	7 0 ,,	4 0
	Staffordshire and Worcestershire	12	72 0 ,,	7 0 ,,	4 0
	Severn	44	99 0 ,,	20 0 ,,	6 0
	Gloucester and Berkeley Section	16	100 0 ,,	24 0 ,,	6 0
	Total	86			
South Staffordshire Mineral District to Severn Ports. (Third Route.)	Birmingham	10	72 0 by	7 0 by	4 0
	Staffordshire and Worcestershire	25	72 0 ,,	7 0 ,,	4 0
	Severn	44	99 0 ,,	20 0 ,,	6 0
	Gloucester and Berkeley Section	16	100 0 ,,	24 0 ,,	6 0
	Total	95			

IV.

STATEMENT OF THE CANALS, ETC., IN THE UNITED KINGDOM, OWNED OR CONTROLLED BY RAILWAY COMPANIES ON 31ST DECEMBER, 1882, ARRANGED UNDER THE DATES OF THE SPECIAL ACTS AUTHORISING THE ARRANGEMENTS.

Years.	England.	Scotland.	Ireland.	Total.
	miles	miles	miles	miles
Under Act of 1845	78¼	..	92	170¼
,, 1846	774½	..	..	774½
,, 1847	96¼	..	..	96¼
,, 1848	20¾	32	..	52¾
,, 1852	86½	..	..	86½
,, 1862	3¼	..	..	3¼
,, 1864	74	..	..	74
,, 1865	34	..	..	34
,, 1866	15¼	..	..	15¼
,, 1867	..	53	..	53
,, 1870	50	..	..	50
,, 1872	17	..	..	17
,, 1882	9¾	..	..	9¾
Total	1259½	85	92	1436½

V.

THE PRINCIPAL RIVER SYSTEMS OF EUROPE AND THE UNITED STATES.

The actual and direct lengths of all the principal rivers in Europe, with the areas of their basins and the principal towns on which they are situated, are shown in the following tabular statement. The European river basins are inclined to the Arctic Ocean, to the Atlantic and North Sea, to the Baltic, to the North Sea, to the Mediterranean, to the Black Sea, or to the Caspian.

The remarkable differences between the total length of the basins and their direct length will be noted. The Danube, for example, is, in actual length, nearly double its direct length; and so also with the Don, the Salembria, the Charente, the Rhone, the Po, and others; while the Volga is more than twice its direct length, and the Ural more than three times as much.

The Volga, with a total length of 2400 miles is the longest river in

Europe, but its direct length of 1080 miles is but little superior to that of the Danube with a length of 980 miles. Twenty-one basins in all incline to the Atlantic, five to the Arctic Ocean, thirteen to the Baltic, eight to the North Sea, thirteen to the Mediterranean, three to the Caspian, and five to the Black Sea. The enormous length of the basins inclining to the two latter seas, makes their aggregate mileage and area drained larger than those of any other.

RIVER BASINS OF EUROPE.

River or Estuary.	Length in English Miles.	Direct Length of Basin in English Miles.	Area of Basin in Square Miles.	Capital of States and Provinces in each Basin.
		Basins inclined to the Arctic Ocean.		
Petchora	900	520	114,400	
Mezen	400	300	30,100	
Dwina	700	500	134,400	Archangel.
Onega	300	250	21,000	
Alten Fiord	150	80	..	Altengard.
		Basins inclined to the Baltic.		
L. Mälar	170	130	..	Stockholm.
Dal	250	200		
Angerman	150	120	..	Hernösand.
Umea	250	220		
Neva, and Gulf of Finland	625	500	99,700	St. Petersburg and Helsingfors.
Düna	400	300	34,700	Riga.
Niemen	400	270	35,700	Erodno and Wilna.
Pregel	120	120	6,800	Königsberg.
Vistula	530	360	72,300	Warsaw, Lemberg.
Oder	445	360	45,200	Stettin, Breslau.
Stör	95	55	..	Schwerin.
Trave	50	40	..	Lubeck.
Schleifiord	25	20	..	Schleswig.
		Basins inclined to the North Sea.		
Lymfiord	100	90	500	Aalborg.
Elbe	550	420	55,000	Hamburg, Gotha, Weimar.
Weser	230	250	17,700	Bremen, Brunswick.
Ems	160	130	..	Münster.
Rhine	600	400	75,000	Bern, Cologne, Amsterdam.
Scheldt	210	120	..	Antwerp, Brussels.
Meuse	580	230	..	Liége, Namur.
Hunse	50	40	..	Gröningen.
Vecht	90	60	..	Zwoll.

RIVER BASINS OF EUROPE—*continued.*

River or Estuary.	Length in English Miles.	Direct Length of Basin in English Miles.	Area of Basin in Square Miles.	Capital of States and Provinces in each Basin.
Basins inclined to the Atlantic.				
Trondhjem Fiord ..	100	60	..	Trondhjem.
Torrisdals	120	100	..	Christiansand.
Christiania Fiord ..	60	55	..	Christiania.
Gotha	400	300	17,000	Göteborg.
Loire	530	350	44,500	Tours, Orleans.
Seine	414	250	28,500	Paris, Rouen.
Garonne	300	230	31,000	Bordeaux, Toulouse.
Somme	115	90	..	Amiens.
Charente	200	110	..	Rochelle.
Vilaine	125	80	..	Rennes.
Douro	450	340	34,200	Oporto.
Tagus	540	450	33,000	Lisbon, Madrid.
Guadalquiver	300	270	19,500	Seville, Granada.
Minho	220	150	14,700	
Sado	100	70	..	Evora.

Also the basins of the Adour, the Nervion, the Ria d'Este, the Ulla, the Nalon, the Guadiana, and the Mondego.

River or Estuary.	Length in English Miles.	Direct Length of Basin in English Miles.	Area of Basin in Square Miles.	Capital of States and Provinces in each Basin.
Basins inclined to the Mediterranean.				
Rhone	645	340	37,900	Lyons, Grenoble.
Segura	180	120	..	Murcia.
Po	450	280	34,600	Turin, Milan.
Tiber	185	130	..	Rome.
Arno	90	75	..	Florence.
Vardar	170	125	..	Salonika.
Salembria	110	65	..	Larissa.
Ebro	340	280	32,900	Zaragoza.

Also the basins of the Guadalaviar, Dobregat, Narenta, Bojano, and Maritza.

River or Estuary.	Length in English Miles.	Direct Length of Basin in English Miles.	Area of Basin in Square Miles.	Capital of States and Provinces in each Basin.
Basins inclined to the Black Sea.				
Danube	1,795	980	306,000	Vienna, Buda, Gräz, and Munich.
Don	995	500	176,500	Stavropol, Kharkos.
Dneister	500	400	27,300	Kamilnetz.
Dnieper and Bug.. ..	..	640	195,500	Kiev, Ekaterinoslav.
Kuban	380	280	..	Ekaterinodar.
Basins inclined to the Caspian.				
Volga	2,400	1,080	527,000	Astrakhan, Nijni-Novgorod.
Ural	1,800	550	85,000	Orenburg.
Kur	520	400	80,800	Tiflis, Erivan.

RIVER BASINS OF THE UNITED STATES AND CANADA.

River or Estuary.	Length in English Miles.	Area in Geographical Square Miles.	Principal Towns on the Rivers.
Basins inclined to the Atlantic.			
St. Lawrence	1,400	297,600	Ottawa.
Delaware	290	8,700	Trenton.
Chesapeake	450	12,000	Washington.
Hudson	210	7,000	Albany.
Connecticut	280	8,000	Hartford.
Basins inclined to the American Mediterranean.			
Mississippi	1,820	982,400	New Orleans, Nashville.
Rio Grande del Norte ..	1,050	180,000	Santa Fé.
Colorado	900	..	Denver, Cheyene.
Santandar	245	10,000	San Luis, Potosi.
San Juan	275	8,000	Leon.
Tobosco	245	12,000	Ciudad Real.
Basins inclined to the Pacific.			
Rio Colorado	750	170,000	Tucson.
Columbia	800	194,000	Salem.
Frazer	480	90,000	New Westminster.
Sacramento	350	20,000	Sacramento.
Culiacan	280	7,000	Culiacan.
Youcon	1,150	100,000	
Basins inclined to the Arctic Ocean.			
Mackenzie	1,200	441,000	
Nelson and Saskatchewan	1,000	360,000	Fort York.
Churchill	1,300	73,600	
Back, or G. Fish	420		

SOUTH AMERICAN RIVERS.

Basin.	Length in English Miles.	Area in Geographical Square Miles.	Chief Towns.
Magdalena	700	72,000	Bogota.
Amazon	2,100	1,512,000	Santa Cruz.
Paraná	1,600	886,400	Monte Video and Buenos Ayres.
San Francisco	900	187,200	Duro-Preto.
Tocantins	1,260	294,480	Pará.
Essequibo	400	61,650	George Town.
Orinoco	1,000	252,000	Angostura.

NAMES AND AREA OF LAKES IN THE UNITED STATES AND CANADA.

Name.	Area in Square Miles.	Height above Sea-level.
		feet.
Ontario	6,300	231
Erie	9,600	565
Huron	21,000	578
Michigan	22,400	578
Superior	32,000	627
Winnipeg	9,000	628
Winnipegoos	2,300	650
Great Bear Lake	14,000	230
Great Slave Lake	12,000	..
Athabasca	3,400	..
Great Salt Lake	1,800	4,210
Total area	133,800	

COMPARATIVE AREA OF SEAS.

	Square Miles.
Total area of Caspian Sea	178,000
,, ,, Black Sea	172,500
,, ,, Mediterranean	976,000
,, ,, German Ocean	244,000
,, ,, Baltic	135,000
,, ,, White Sea	40,000

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