A. Hartley

Report

on the

Proposed barring of the East and Sloe Channels of the Schelde


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REPORT

ON THE

PROPOSED BARRING OF THE EAST AND SLOE CHANNELS OF THE SCHELDE.

ADDRESSED TO

THE RIGHT HON. THE LORD STANLEY,

HER MAJESTY'S PRINCIPAL SECRETARY OF STATE FOR FOREIGN AFFAIRS;

BY SIR CHARLES A. HARTLEY,

MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS, AND ENGINEER-IN-CHIEF TO THE EUROPEAN COMMISSION OF THE DANUBE.

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REPORT.

My Lord, March 26, 1867.

As an introduction to my Report on the Schelde question, I have the honour to reproduce your Lordship's instructions to me thereon, as contained in Mr. Egerton's letter of the 9th ultimo:—

Instructions.

"Lord Stanley has selected you to proceed to Brussels, in order, after due investigation, to make a report upon the effect which will be produced on the navigation of the Western Schelde by some works which the Dutch Government are about to execute upon the Sloe and Eastern branches of the River Schelde.

"The Schelde in its downward course from Antwerp divides into two branches at Bath, being known respectively as the Eastern and Western branches. Further down, between Bath and the sea from the Western branch, another branch flows eastward again, and is known as the Sloe branch.

"The intended Dutch works are connected with a projected railway from Flushing to Venloo, and as this railway is to be carried over the Sloe and the East branch of the Schelde by means of embankments, and as these embankments would effectually stop up the channels of the branches they crossed, the Dutch Government propose to meet the requirements of the navigation by means of canals.

"The Dutch and Belgian authorities are at issue as to the effect on the Western branch of the Schelde, more especially used by Belgian commerce, by the stopping up of the two other branches, and various Commissions have been appointed and have come to conflicting decisions on the subject.

"In 1865 a Commission appointed by the Belgian Government reported that it would have a disastrous effect upon the navigation of the Western Schelde, but a Commission appointed shortly afterwards by the Dutch Government arrived at a precisely opposite conclusion.

"A Mixed Commission was then appointed, the members of which were unanimous in reporting that the East Schelde em-

bankment would have a beneficial effect upon the river above Bath, which is wholly Belgian, but differed as to the effect it would have below Bath, where it flows entirely through Dutch territory.

"The object of the inquiry which you are to make, is to give to Her Majesty's Government your opinion on the points in dispute, as an engineer having no bias towards either the Dutch or Belgian authorities, and you will receive every assistance in prosecuting your inquiries from Her Majesty's Legations at Brussels and the Hague.

"A French and Prussian engineer have been appointed by their respective Governments to conduct similar investigations to that you will be engaged in; but the position of each of the three engineers will be completely independent; and it is to be distinctly understood that they are not expected to act in concert, nor to be in any way considered as a joint Commission."

Visit to the ound.

In compliance with the above instructions I repaired the same day to Brussels, and a few days afterwards to the Hague, and at both of these capitals I received every assistance from Her Majesty's Legations, as well as from the Foreign Ministers of Belgium and Holland, who at once provided me with all the official documents which have been lately published relative to the object of my inquiry. They also placed me in immediate personal communication with the engineers and hydrographers of both countries who have taken any prominent part in the discussions concerning the probable effects which would be produced on the channel of the main Schelde by the construction of the projected dams (as I shall term them in future) across the Sloe and the East Schelde.

At Bergen-op-Zoom I met Mr. Conrad, the chief Director of the "Waterstaat," and President of the Royal Society of Dutch Engineers; Mr. Simon, the Engineer-in-chief of the railway from Flushing to Venloo; Captain Blommendal, the Dutch Hydrographer-in-chief, and Mr. Brunings, Engineer-in-chief of the "Waterstaat" (the two members of the Dutch Commission of April, 1866); and Mr. Caland, Engineer of the 1st class of the "Waterstaat," and one of the Dutch Members of the Mixed Commission of September, 1866. In the company of these gentlemen I visited at low tide the site of the proposed dam across the East Schelde, and then went with them to inspect the South Beveland Canal, stopping for the night at the town of Goes, between which place and the canal the railway is already constructed. On the following day, accompanied by Captain Blommendal, I crossed the Sloe branch, close to the site of the

projected dam, and, finally, I visited Flushing and the roadstead of Rammekens, which is situated at the mouth of the Sloe.

Having thus made myself as well acquainted with the character of the country in the immediate neighbourhood of the proposed dams as the limited time I had at command would permit, I proceeded to Antwerp, where I met Mr. Maus, Engineer-in-chief and Director of Ponts et Chaussées in the Province of Hainaut, and Mr. Boudin, Engineer of Ponts et Chaussées at Ghent (the two Belgian Members of the Mixed Commission of September, 1866), and also Mr. Stessels, Hydrographer and Permanent Belgian Commissioner for the Schelde. These gentlemen gave me all the information they possessed relative to the subject of my inquiry; and to them, as well as to the eminent technical authorities I had the honour to meet at Bergen-op-Zoom, my best thanks are due for their great courtesy to me, and for their evidently sincere desire to enable me to form an unbiassed judgment on the nature and effects of the works on which I have been called upon to report.

CHAPTER I.

Question of Barring the East Schelde.

Barring of East Schelde.

Before proceeding to lay before your Lordship the general result of my visit to the ground, and of my subsequent study of the whole question in England, I purpose first of all to refer exclusively to by far the most important part of my task, viz. the probable effect of the proposed railway embankment across the East Schelde; and in doing so I would, in the first instance, draw especial attention to the accompanying extracts from the Report of the "Mixed Commission" of September last, as they contain a statement of facts which both sides acknowledge to be correct, and at the same time set forth the opposite conclusions which have been drawn from these facts by the Belgian and Dutch members of the Commission, a divergence of opinion which has led to the technical inquiry on which I have been lately engaged.

Extracts from the Report of the International Commission, instituted by Decree of the Belgian Minister of Public Works, on the 13th August, 1866, and by Decree of the Dutch Minister of the Interior, on the 20th August, 1866, to inquire into the influence which the Dam of the East

Schelde will exercise on the navigation of the West Schelde, and on the river above Bath.*

eport of Inter- onal Commis- of September,

"Understanding the great importance of the opinion demanded of it, the Commission considered that the best means of accomplishing its mission was, in the first instance, to study the present rate and direction of the tidal currents in the West Schelde, as well as in the East Schelde, and then to study the changes which the construction of the projected dam between Bath and Bergen-op-Zoom would produce on the régime of the West Schelde, in order to judge of their favourable or unfavourable consequences to the present navigable state of the West Schelde and of the river above Bath. In order to ascertain the force and direction of the currents, the Commission repaired to the ground, and there engaged Mr. de Matthys, Engineer of the Ponts et Chaussées, and Mr. Vanden Santhevel, Engineer of the 'Waterstaat,' to ascertain as nearly as possible the nature of the phenomena which repeat themselves constantly in the East Schelde between Bath and Bergen-op-Zoom.

"The information obtained by these two engineers, who were attached to the Commission, agrees on the whole with the opinion of sailors and others who have made a special study of this question, and the Commission is able to admit that, under normal conditions, the currents are acted upon by the tides in the following manner:—

"The flood-tide, which comes in from the English Channel, makes itself felt on the coasts of Belgium and Holland, and penetrates successively into the West Schelde, and then into the East branch of that river. The tidal wave ascending by the West branch reaches Bath a quarter of an hour before the tide which ascends the East branch arrives at Berg-op-Zoom.

"Arrived at Bath, the tidal wave of the West branch divides itself, and forms two currents, one of which ascends towards Antwerp, and the other, entering the East branch, directs itself to Berg-op-Zoom, and meets the tide of the East Schelde, which from Berg-op-Zoom travels towards Bath.

"The union of the two tides takes place on a line nearly perpendicular to their course, at a distance of about 5500 mètres from Bath.

"The current furnished by the West Schelde predominates, so that the line which marks the junction of the currents is

* This commission was composed of two delegates from the Belgian Government—Mr. Maus, Engineer-in-chief and Director of Ponts et Chaussées; Mr. Boudin, Engineer of Ponts et Chaussées—and of two delegates from the Dutch Government—Mr. Beyerinck, Divisional Inspector of the Waterstaat; Mr. Caland, Engineer of the Waterstaat.

displaced, and retreats from Bath in proportion as the level of the water is raised; when the tide ceases to ascend, the line of junction of the two currents is found at nearly 6500 mètres from Bath, or at 1000 mètres from its first position.

"The diversion into the East branch of the waters furnished by the West branch is in operation at Bath during the whole duration of the flood-tide, and it ceases the instant that the tide has attained its greatest height.

"As soon as the tide falls at Bath there is observed in the East Schelde two currents flowing in directions opposed to their first course; one of these is formed by the water which returns into the West Schelde, and the other is produced by the ebb-tide, which descends towards the sea after passing Berg-op-Zoom.

"The line which marks the separation of these two currents passes in the first instance the Custom-house at Bath and the Sanvliet Tower; then, as the level of the waters falls, this line of separation retires from Bath to Berg-op-Zoom, and is found at mean low-water level at about 4500 mètres from Bath, or at 1000 mètres from the line marking the position of the first junction of the two ascending tides.

"The direction and force of the winds, the age of the moon, &c., necessarily cause the position of the lines which have just been described to vary within certain limits. These limits, however, according to the opinion of seafaring men acquainted with the locality, are of unimportant extent.

"According to this description, the East branch furnishes no water whatever to the West branch, and in no way contributes to swell the tide that ascends towards Antwerp.

"On the contrary, the West Schelde at each flood pours into the East branch a large volume of water, of which a part only returns to it as the tide falls, the other part being carried away by the current, which falling towards Berg-op-Zoom returns to the sea by the East Schelde.

"The portion of the bed of the East branch between Bath and the main line of junction of the two tidal waves may be described as forming a vast basin, which is filled up every flood-tide by the wave of the West Schelde. During the following tide this basin empties itself at its two opposite extremities, restoring to the West Schelde a part of the water it had received therefrom, and pouring into the East Schelde the remaining portion, which may be considered a veritable bleeding of the West branch.

"The dam projected across the bed of the East Schelde is to be constructed at about 4100 mètres from Bath, that is to say, at 1900 mètres to the south of the mean position of the line

which marks the junction of the two tidal waves between Bath and Berg-op-Zoom.

"This dam will form, after its construction, a regular partition wall, on which the waters will have no effect. The bleeding of the West Schelde will be thus completely suppressed, and the part of the East branch comprised between Bath and the Barrage will become an immense creek, which, being alternately covered and uncovered by the flow and ebb, will be silted up at a no distant period.

"After the silting up the dam will produce exactly the same effect as if it were an embankment constructed in such a position as to preserve the continuity of the right bank of the West Schelde from a point opposite Sanvliet to Bath.

"In order to appreciate the influence that these changes produced by the dam will exercise on the régime of the West Schelde above as well as below Bath, it appeared desirable to know, at least approximately, the volume of water that each flood-tide diverts from the West to the East Schelde, and to determine in what proportion this volume divides itself between these branches during a falling tide.

"The Commission thereupon begged the Assistant Engineers to make the observations they considered necessary to obtain these indications.

"Thanks to these gentlemen, the Commission has been able to estimate that a volume of water equal to 32,460,000 cubic mètres is delivered by the West Schelde into the East Schelde during every flood-tide that reaches ordinary high water-mark at Bath.

	Cubic mètres.
"During the falling tide this volume of	32,460,000
Is divided in the following manner :—	
Volume returning into the West Schelde	11,500,000
Volume which flows to the sea by the East Schelde ..	20,960,000
	32,460,000

"The members of the Commission unanimously admit the above exposé of facts and considerations, but this unanimity could not, to the regret of all, establish itself in the appreciation of the changes that the dam will produce on the régime of the West Schelde.

"Agreeing to admit that the effect of these changes will be favourable above Bath, the members of the Commission regard differently the result below this point; the Belgian Commissioners considering them unfavourable, while the Dutch Commissioners, on the contrary, consider them favourable."

Opinion of the Belgian Commissioners.

Opinion of the Belgian Commissioners.

"They cannot admit that the volume of water that enters a river during the six hours of the flood-tide has an absolute value, independent of the modifications of the river bed. According to them the current of the flood depends in reality on various circumstances, such as the length of the surface submitted to the action of the tide, the discharge of the river and of its affluents, the obstacles opposed to the progress of the tide, &c., so that the volume of water that enters during the six hours of the flood-tide varies with each of these elements. Considering the changes that the construction of the dam will occasion to the régime of the West Schelde, it will first of all be remarked that the flood-tide arriving at Bath finds there, at present, a large basin, in which is diverted a volume of water estimated at 32,460,000 cubic mètres.

"This diversion has, for a necessary consequence, the faculty of maintaining the liquid surface at a less elevated level than if it did not exist. Again, this less elevated level lessens the 'contre-pression' exercised below the basin on the ascending current, the progress of which becomes, therefore, more rapid, and the discharge greater. Thus the existence of this basin produces an augmentation in the volume of the waters in movement from the mouth up to Bath.

"On the other hand, this same basin, in diminishing the velocity of the waters which ought to ascend the Upper Schelde, and in maintaining at Bath the liquid surface at a less elevated level, is a cause of the retardation of the waters upwards; it diminishes in consequence the volume of the tidal wave, which from Bath ascends to Antwerp to re-descend with the ebb.

"The present diversion into the East branch in this way augments the volume of water that the flood-tide causes to enter the upper part of the river, and diminishes the volume that ascends to Antwerp; therefore the suppression of this diversion will reduce the volume of the rising tide between Flushing and Bath, and will augment it above Bath.

"Consequently, the régime of the Schelde, after the complete silting up of the east basin, will be improved above Bath, and deteriorated between Bath and Flushing.

"The 'bleeding,' that is to say, the volume of water that the West Schelde diverts into the East Schelde during the flood-tides, and which is not returned at the ebb, diminishes, it is true, the volume of the ebb between Bath and the mouth of the river; but this bleeding, the volume of which during an ordinary tide is 20,960,000 cubic mètres, has the advantage of ejecting

definitively from the bed of the West Schelde the 'troubles' with which these waters are overcharged in traversing the bed of the river for a distance of above 50 kilomètres.

"When it is considered that at each flood-tide the West Schelde diverts into the East branch a volume of water which, varying with the height of the high tide submitted to the influence of the lunar phases, represents at a mean-tide a volume of 32,460,000 cubic mètres; that this volume diverted in six hours would correspond, if the flowing was uniform, to a discharge of 1500 cubic mètres per second; and that this discharge, compared with that of the greatest rivers, is notably exceeded during the highest tides, the most efficacious for the cleansing of navigable channels,—one ought to acknowledge that the unfavourable change below Bath will be sufficiently great to provoke future deposits, which will be injurious to the navigation, in spite of the depth of the actual channels.

"These deposits below Bath, by diminishing the sections of the river-bed, will equally diminish the volume of tidal water entering therein, and a part of which ascends beyond Bath; it will thus lessen the favourable change that the construction of the dam will produce in the Upper Schelde.

"Such are the considerations which have caused the Belgian Commissioners to express the opinion that the construction of the East Schelde dam will be favourable to the régime of the river above Bath, and sufficiently unfavourable below that point to cause the formation of shoals injurious to the navigation.

"The Belgian Commissioners, moreover, restrict themselves to examining the influence that the dam will exercise on the régime of the river, considered as a whole; it being understood that it is sufficient that this dam may have the effect of creating obstacles to the navigation in a single point, in order to consider it as injurious, allowing even that it would improve some of the existing channels."

Opinion of the Dutch Commissioners.

* * * * *

Opinion of the Dutch Commissioners.

"In the actual state of things, the flood-tide dividing itself at Bath loses its velocity there, and as it is the flood-tide that brings in the sands of the sea into the river, it is clear that as soon as, at any point whatever, there is a diminution in the velocity of the tide, the water deposits there the sand which, up to that time, is held in suspension. Hence the origin of the banks which at this point are so injurious to the navigation."

* * * * *

"We are of opinion that, after the damming of the East

Schelde, the Schelde above Bath will receive at high-tide not only the quantity of water which is now diverted from the West Schelde into the East Schelde, but also the greatest part of the volume that now loses itself in the East Schelde, although it is impossible to determine *à priori* the volume of this last quantity.

"In point of fact this volume may be considered a bleeding ('saignée') of the Schelde twice a day, and which, once the orifice closed by the dam, will reinforce in part the tide-current above Bath, and therefore the ebb below that point; because the East Schelde basin, in place of returning to the West Schelde all the water that it receives from it, retains two-thirds of it, and these two-thirds are irrevocably lost for the West Schelde.

"Besides, the diversion is the cause why the rising tide enfeebles itself precisely during the last two hours of its duration, an epoch when, in all the Zealand rivers, the flood acts with the greatest energy.

"It is possible that the diversion may be the cause why the East Schelde receives at present a part of the sands which the sea introduces into the river, and which after the construction of the dam will remain in the West Schelde, or in the river above Bath. But do not these sands deposit themselves below Bath during the different periods when there is a stagnation of the waters, owing to the meeting of the flood and ebb tides? And the remainder, does it not deposit itself at Bath even, where the current, owing to being suddenly turned aside, loses much of its velocity?

"It follows as a matter of course also that if, after the construction of the dam, the Schelde received less sea-water than at present, there would also be less sand introduced into it; so that, from this point of view, the loss of a quantity of sea-water would not be damaging to the state of the river.

"In our opinion the effect of the dam will be to raise the level of high water at the point of the separation of the two currents near to Bath; but this could not take place without strengthening the tide-current towards Antwerp, and that of the ebb in the West Schelde; because the raising of the level of high water at Bath would give rise to an augmentation in the slope of the surface up the river, as well as downwards.

"This observation appears to us the more important because it has reference to one of the most deteriorated parts of the river, and because the effects of the dam, according to our opinion, could only be beneficial to the whole régime of the Schelde, without which, indeed, we esteem a satisfactory improvement of this fine river impossible.

"However, we think ourselves obliged to enumerate the con-

siderations upon which our conviction reposes, and therefore for this reason we enter here into a certain development of our ideas.

"The maintenance of tidal rivers as navigable channels reposes entirely on the system of natural scours ('chasses naturelles'). The tide introduces a certain quantity of water into the river. It bars during six hours the fresh waters of the river, so that when its own waters return to the sea by the ebb-tide, it brings with it twice the 'debit' of the river.

"The tidal wave enters at the mouth, propagates itself towards the interior as far as the slope of low water will permit it. Consequently, the quantity of sea-water that enters into the river does not depend upon the level of the river at high water-mark, but on the successive differences between the heights of the tidal wave and the height of the waters in the river.

"A raising of the level of high water would therefore produce no injurious effect on the quantity of sea-water which at every tide fills the main Schelde.

"The wave or undulation of the tide being propagated towards the interior, there arrives a moment when the level of the sea at the mouth commences to fall ('il y a étale à l'embouchure'). At this instant, the lower part of the river being full of sea-water, the 'bassin de chasse' is full.

"In a moment afterwards the ebb commences to make itself felt at the mouth; it is the 'porte de chasse' that opens itself, and which gives to the waters introduced by the sea and to those of the river the opportunity to direct themselves towards the sea up to the time that a new tide re-commences the operation."

* * * * *

"The wave-current in the maritime rivers of the North Sea has a great velocity. It shaves down the sands of the coast and deposits a large quantity in the beds of the rivers, especially at those points where it loses its velocity.

"On account of the continual resistance opposed to it by the current of the ebb, it cannot act on the bottom of the bed; all its strength is expended in overcoming this resistance.

"The ebb, on the contrary, finding no resistance of this kind, and gathering itself together every instant in a narrower section, acts continually on the bed. It is the ebb that deepens the passes with the waters brought in by the flood-tide, augmented by the fresh waters.

"But in order that the ebb may act freely, it is necessary that it should be interrupted as little as possible in its progress.

"Among the obstacles met with by the ebb, there is nothing

so injurious as the contractions of the bed, and the existence of sudden bends or elbows in the river.

"The contractions and bends have for effect the obstruction of the current of the reflux, by which the slope is diminished, and in consequence thereof the velocity of the ebb is diminished, from which it results that the sand and mud brought in by the river deposit themselves above these points.

"Contractions and quick bends equally injure the free entry of the tide, and for this reason the consequences are none the less prejudicial to the régime of the river.

"Let us now apply these principles, which appear to us to be fundamental, and which are deduced from a profound study of the tidal rivers of the Low Countries.

"Is it not clear that at Bath there exists not only a bend, but an excessive contraction? And this circumstance, is it not the cause that precisely at this place is found the worst channel of the river between Antwerp and the sea?

"But, in our opinion, the Barrage of the East Schelde will improve this locality. If the Barrage is executed, what will result?

"It is believed that the shore situated between the Barrage and the West Schelde will silt up gradually, and will be transformed into alluvial ground or 'schorres.'

"These schorres will extend themselves eventually up to the principal channel, and will form along this channel a natural embankment.

"The ebb, being no longer able to flow over these embankments, will be obliged to act with all its energy on the pass in front of Bath, and the more so because the lands situated on its right bank, near Ossendrecht, raising insensibly their level above high water, the ebb will act on the width of the pass up to the moment of high water.

"On the other hand, the tide being no longer diverted towards the East Schelde, and finding itself obliged to ascend in its entirety towards Antwerp, it is nearly certain that it will abandon the Bath Channel, and will take the pass called 'Schaar Van de Noord,' which, being the channel where the ebb will find the greatest slope, will also inevitably be used by the reflux.

"It is useless to observe how the present bend at this point will be diminished, how the pass will be widened, and how vessels finding at the flux, as well as at the reflux, only a single channel, will be enabled to navigate with the greatest facility and security both up and down stream.

"At all events, whether after the dam has been constructed there will be formed a new pass or not, it is certain that the channel will widen itself, consequently that the tide will enter

more freely, and that the reflux being no longer obstructed, as at present, the state of the river at this point will be improved."

Absence of precise engineering information.

It is regrettable to find, on a close examination of what is likely to be the effect produced on the navigable channel of the main river by the construction of a dam across its east branch, that there exists so little precise engineering information to guide an engineer's opinion in the matter. I allude especially to the absence of any record of simultaneous observations made at a number of well-chosen stations in the river of the rise and fall of the tide during every hour or half-hour of low ordinary and spring tides; to the want of a register of the velocity of the surface and under-currents, taken also simultaneously at the same stations and at the same periods of time; and to the non-existence of any statement of experiments to determine the amount of detritus held in suspension in the sea, as well as in the land-waters under the various phases of the tidal and fluvial currents.

In the absence of this exact information, the opinion of an engineer under existing circumstances must mainly be based on the valuable hydrographical data so ably established and described by the Hydrographical Departments of Holland and Belgium. These data I have collected and classified together as concisely as I could; and as a technical opinion is only valuable in so far as it rests upon facts and figures, I think it desirable in this place to give the results of this part of my study, before proceeding to discuss the arguments made use of by the Dutch and Belgian members of the Mixed Commission in favour of their own particular views as to the effects that will be produced on the régime of the main Schelde by the damming of its eastern branch.

Data furnished by the Hydrographical Departments of Holland and Belgium.

Tidal Volume.

Tidal volume.

The approximative values of the volume of tidal water which passes the following places has been ascertained by Mr. Stessels to equal—

	Cubic mètres.
At Flushing (No. 1)	363,000,000
„ Bath (No. 2)	120,000,000
„ Lillo (No. 3)	75,000,000
„ Antwerp (No. 4)	55,000,000

The volumes of Nos. 1, 3, and 4, have been obtained by actual observation; but No. 2 has only been calculated in connection with the tidal capacity of the river above and below the meridian of Bath.

A still more approximative calculation of No. 3 has been made by Captain Blommendal, who estimates that about 140,000,000 is the flood delivery at this point, without counting the 32,500,000 diverted in the East Schelde. Now, after a due consideration of the relative tidal areas of various sections of the river, above and below Bath, I am of opinion that Mr. Stessels' estimate is too low and that Captain Blommendal's is too high, and that a volume of 140,000,000 would fairly represent the quantity of water which passes the meridian of Bath during ordinary flood-tides.

With regard to volume No. 1, the late Mr. Belpaire, an Engineer-in-chief of the Belgian Ponts et Chaussées, estimated that 533,000,000 of cubic mètres enter the river when the tide has a range of 4 mètres at Flushing; and Captain Blommendal has lately estimated, by calculating the extent of tidal area covered at the time of ordinary high water at Flushing and of low water near Termonde, that the volume is equal to 500,000,000 cubic mètres. My own calculation, based on Mr. Stessels' table of areas, yields 450,000,000 cubic mètres, and, as this volume is not far from being a mean of the quantities given by Messrs. Blommendal and Stessels, I shall assume it to be approximatively correct.

With this explanation I give the following figures, as representing the relative value of the volumes of the flood and ebb-tides at ordinary high water:—

	At Flood-Tides.	At Ebb-Tides.
At Flushing	450,000,000	429,000,000
„ Bath	140,000,000	119,000,000
„ Lillo	75,000,000	75,000,000
„ Antwerp	55,000,000	55,000,000

Discharge of Fresh Water.

Discharge of fresh water.

According to a note received from Messrs. Maus and Boudin, I find that the discharge of fresh water at Ghent, at times of low water, is 317,088 cubic mètres in six hours; at ordinary high water, 1,397,520 cubic mètres in six hours; at extraordinary high water, 2,086,128 cubic mètres in six hours; and that the discharge into the Schelde by its affluents, between Ghent and Antwerp at ordinary high water, is roughly estimated at 500,000 cubic mètres in the same period. By this account, therefore, the mean discharge of fresh water at Antwerp is equal to a volume of 1,897,000 cubic mètres in six hours.

Again, from information obtained from Mr. Stessels, I find that the mean discharge of fresh water at Ghent, calculated according to the mean velocity of the stream "à l'écluse de la

pêcherie" (beyond which ordinary tides do not flow), is equal to a volume of 2,207,430 cubic mètres in six hours.

In the third place, according to the late Mr. Belpaire's estimate, the mean discharge at Antwerp is 4,320,000 cubic mètres in six hours.

Taking the mean of these conflicting statements, I assume that the discharge of fresh water at Antwerp at times of ordinary high water amounts to a volume of 3,000,000 of cubic mètres in six hours, or to 6,000,000 of cubic mètres during ordinary ebb-tides in the lower part of the river.

The value of the fresh water of the Schelde as a scouring power at all tides, as compared with that of the tidal water at the same period, may be thus stated:—

At Flushing	$\frac{1}{71}$ or $1\frac{2}{3}$	per cent.
„ Bath	$\frac{1}{20}$ or 5	„
„ Lillo	$\frac{1}{12}$ or $8\frac{1}{2}$	„
„ Antwerp	$\frac{1}{9}$ or 11	„

Tidal Area.

Tidal Area. (Derived from Mr. Stessels' Observations.)

The area of the estuary between Flushing and Bath is 18,815 hectares at low water, and 35,088 hectares at high water, or 26,951 hectares at mean sea level. The area of the river between Bath and Antwerp is 2356 hectares at low water, 5408 hectares at high water, or 3882 hectares at mean sea level.

Tidal capacity.

Tidal Capacity.

From calculations deduced from Mr. Stessels' Table of Tidal Areas at page 9 of his 'Etude sur l'Escaut Maritime,' and by estimating the mean range of the tide between Flushing and Bath at 3·85 m., and between Bath and Antwerp at 4·00 m., I find that the total capacity of the Schelde between Flushing and Antwerp is 1,204,750,000 cubic mètres, divided thus:—

Flushing to Bath, 1,050,510,000; Bath to Antwerp, 154,240,000 cubic mètres.

Note.—There are no data from which to calculate the total capacity of the river from Antwerp to Ghent.

TABLE of Tidal Phenomena at Seven Stations between and including Flushing and Antwerp.

Station.	1. Distance between Stations.	2. Total Distance above Flushing.	3. Rise above Mean Sea Level, to Mean Level of High Water.	4. Mean Range.	5. Low Water of Mean Range below and above Mean Level of Low Water.	6. High Water, Full and Change.	7. Difference of Time of High Water.	8. Resulting Velocity of the Tidal Wave per Hour.	9. High Water later than High Water at Flushing.
	Kilomètres.	Kilomètres.	Mètres.	Mètres.	Mètres.	H. M.	H. M.	Kilomètres.	H. M.
Flushing ..	..	..	1·748	3·60	−0·052	0 54	—	—	—
Terneuze ..	22	22	1·750	3·78	−0·124	1 39	0 45		0 45
Welsoorden	23	45	1·766	3·93	−0·181	2 25	0 46	28·40	1 31
Bath	13	58	1·860	4·09	−0·185	3 12	0 47		2 18
Doel	11½	69½	2·024	4·09	−0·021	3 21	0 9		2 27
Lillo	2	71½	2·034	4·29	−0·111	3 33	0 12	19·41	2 39
Antwerp ..	14½	86	2·170	4·18	+0·080	4 12	0 39		3 18

The distances in Columns 1 and 2 have been obtained from the charts of Messrs. Blommendal and Stessels; and have been measured along the "thalweg" of the main channel. Columns 3, 4, 5, and 6 contain the exact figures given by Mr. Stessels; and Columns 7, 8, and 9 are deduced from these figures.

Mean Surface Velocities in Mètres per Second in different parts of the Schelde, in the centre of the Main Channel, according to recent Observations by Mr. Stessels.

FLOOD-TIDE.

Station.	Duration of Tide.	Tide Stationary.	H. M. 0 30	H. I.	H. M. 1 30	H. II.	H. M. 2 30	H. III.	H. M. 3 30	H. IV.	H. M. 4 30	H. V.	H. M. 5 30	H. VI.	H. M. 6 30	H. VII.
	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.
Flushing	5·47	0·0	0·23	0·44	0·65	0·75	0·82	0·95	1·13	1·27	1·32	1·00	0·54	..	..	..
Bath	5·59	0·0	0·33	0·47	0·57	0·64	0·75	0·88	1·06	1·16	1·11	0·90	0·50	..	..	..
Lillo	5·45	0·0	0·30	0·43	0·50	0·56	0·60	0·83	1·00	1·07	1·01	0·89	0·40	..	..	..
Antwerp	5·39	0·0	0·47	0·66	0·74	0·75	0·93	1·10	1·22	1·13	0·99	0·76	0·07	..	..	..
Termonde ..	5·08	0·0	0·05	0·15	0·26	0·43	0·66	0·77	0·75	0·67	0·53	0·40	..	..	..	..

EBB-TIDE.

Flushing	6·37	0·0	0·40	0·61	0·80	1·04	1·23	1·36	1·46	1·14	0·81	0·60	0·46	0·28	0·02	..
Bath	6·25	0·0	0·43	0·70	0·93	1·09	1·16	1·23	1·17	1·03	0·96	0·74	0·57	0·35	..	..
Lillo	6·39	0·0	0·50	0·76	0·98	1·08	1·16	1·20	1·24	1·23	1·16	0·97	0·83	0·51	0·12	..
Antwerp	6·45	0·0	0·60	0·81	1·02	1·09	1·16	1·16	1·12	1·15	0·97	0·86	0·76	0·57	0·30	..
Termonde	7·16	0·15	0·31	0·54	0·75	0·83	0·89	0·93	0·95	0·97	1·00	0·96	0·94	0·86	0·77	0·30

Note.—0·514 mètres equals a velocity of 1 mile per hour.

SURFACE Slope of the Schelde at different periods of the Tide.

Tides.	Authority for the Levels of the Water at Flushing, Bath, and Antwerp.	At the moment of Low Water at Antwerp.		At the moment of High Water at Flushing.		Rate of Surface Slope.					
						At the moment of Low Water at Antwerp.			At the moment of High Water at Flushing.		
		Level of Water at Flushing.	Level of Water at Bath.	Level of Water at Bath.	Level of Water at Antwerp.	Flushing to Bath, 58 kilomètres.	Bath to Antwerp, 28 kilomètres.	Rate due to a regular slope between Flushing and Bath, 86 kilomètres.	Flushing to Bath.	Bath to Antwerp.	Rate due to a regular slope between Flushing and Bath.
		M.	M.	M.	M.						
Flood ..	Capt. Blommendal	1·79	0·69	2·64	1·80	$\frac{1}{52727}$	$\frac{1}{40580}$	$\frac{1}{48045}$	$\frac{1}{60416}$	$\frac{1}{33333}$	$\frac{1}{47778}$
Flood ..	Mr. Stessels* ..	1·20	0·30	2·20	1·80	$\frac{1}{64444}$	$\frac{1}{127273}$	$\frac{1}{76786}$	$\frac{1}{42963}$	$\frac{1}{70000}$	$\frac{1}{49143}$
		At the moment of high water at Antwerp (4·26).				At the moment of high water at Antwerp.					
Ebb ..	Mr. Stessels* ..	1·40	1·30	..	..	$\frac{1}{30526}$	$\frac{1}{29167}$	$\frac{1}{30070}$			

* From Mr. Stessels' observations at pages 16 and 17 ("Annales des Travaux Publics, tome XXI."), which, however, do not quite agree with his figures in the same paper at pages 8 and 9.

Table of Surface Slopes.

Hourly Rate of Rise and Fall of Tides at—

Rise of Tide.	Flushing.		Welsoorden.		Bath.		Doel.		Lillo.		Antwerp.	
	Total Rise.	Rise per hour.	Total Rise.	Rise per hour.	Total Rise.	Rise per hour.	Total Rise.	Rise per hour.	Total Rise.	Rise per hour.	Total Rise.	Rise per hour.
	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.
1 hour ..	0·12	0·12	0·42	0·42	0·33	0·33	0·48	0·48	0·46	0·46	0·67	0·67
		0·26				0·52				0·62		
2 ,, ..	0·40	0·28	1·08	0·66	1·05	0·72	1·18	0·70	1·10	0·64	1·45	0·78
		0·38				0·70				0·72		
3 ,, ..	0·85	0·45	1·78	0·70	1·76	0·71	1·87	0·69	1·80	0·70	2·05	0·60
		0·47				0·77				0·66		
4 ,, ..	1·75	0·90	2·61	0·83	2·53	0·77	2·71	0·84	2·80	1·00	3·27	1·22
		0·68				1·00				0·84		
5 ,, ..	3·17	1·42	3·67	1·06	3·77	1·24	3·81	1·10	3·86	1·06	4·00	0·73
		1·19				0·96				0·96		
6 ,, ..	3·55	0·38	3·99	0·32	4·13	0·36	4·18	0·37	4·14	0·28	4·15	0·15
		0·56				0·33				0·44		

Fall of Tide.	Total Fall.	Fall per hour.	Total Fall.	Fall per hour.	Total Fall.	Fall per hour.	Total Fall.	Fall per hour.	Total Fall.	Fall per hour.	Total Fall.	Fall per hour.
	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.
1 hour ..	3·15	0·40	3·57	0·42	3·61	0·52	3·72	0·46	3·55	0·59	3·63	0·52
2 ,, ..	2·40	0·75	2·83	0·74	2·83	0·78	3·01	0·71	2·83	0·72	2·95	0·68
3 ,, ..	1·60	0·80	2·02	0·81	2·09	0·74	2·29	0·72	2·09	0·74	2·05	0·90
4 ,, ..	0·90	0·70	1·24	0·78	1·34	0·75	1·58	0·71	1·22	0·87	1·28	0·77
5 ,, ..	0·30	0·60	0·64	0·60	0·65	0·69	0·86	0·72	0·47	0·75	0·60	0·68
6 ,, ..	0·10	0·20	0·07	0·57	0·15	0·50	0·24	0·62	0·10	0·37	0·05	0·55
		0·10		0·07		0 15		0·24		0·10		0·05

The Roman figures are taken from Mr. Stessels' paper on the Tides of the Schelde, and
The French figures are taken from a statement furnished me by Captain Blommendal, the Chief Hydrographer of Holland.

WIDTHS, AREAS, and DEPTHS of Various Sections of the River from Flushing to Antwerp.

Authority, MR. STESSELS.

Position of Profile.	Distance from Flushing.	Mean Tide Level.		Width.		Surface of the Section at Low Water.	Over the Low Water width.	Width of the Foreshore.	Total width of Tidal Water.	Average Depth.	Maximum Depth.
		Low Water.	High Water.	Low Water.	High Water.						
	Kilomètres.	M.	M.	M.	M.	M.	M.	M.	M.	M.	M.
Flushing and Breskens	..	0·05	3·55	4,275	4,870	63,315	15,390	1,199	16,499	14·81	29·0
Ellewoutsdyk, Keet of the new Polder	18·30	0.10	3·65	2,290	4,930	34,450	14,852	1,842	16,694	11·52	32·0
Waarde Oude troofd beacon ..	46·74	0·19	3·74	3,000	3,030	32,490	11,790	60	11,850	10·83	32·0
Meridian of the Polder beacon	55·30	0·19	3·81	1,690	9,760	10,280	6,760	16,140	22,900	6·09	17·2
Eclusier Prosper, right beacon	67·00	0·10	4·00	1,190	2,370	6,410	4,223	2,790	7,013	5·38	13·0
Doel Kruisweg	71·50	0·03	4·07	555	1,445	4,104	2,275	1,267	3,542	7 39	16·0
Lieftenshock (Lillo)	73·46	0·11	4·18	745	840	5,262	3,196	137	3,333	7·06	15·2
Lower corner of Fort Pearl ..	78·91	..	4·20	637	747	4,005	2,675	111	2,786	6·28	16·1
Blue House	81·70	0·06	4·24	685	798	3,412	2,837	91	2,928	4·97	11·7
Austruweel	87·00	0·08	4·28	365	447	2,327	1,533	97	1,630	6·37	11·0
New docks at Antwerp	88·16	..	..	500	550	4,593	2,100	41	2,141	9·19	17·5

Table of Widths and Areas, Depths.

Bars.

Bars.

There are no bars at the mouth of the Schelde, and in the principal channel, the "Wielingen," * to the seaward of Flushing, the depth is never less than from 8 to 9 mètres at low water.

Between Flushing and Antwerp there are several shifting shoals in the main channel, the names of the principal of which, with the depths on them at mean low water, are given in the following statement :—

Name of the Shoals.	Depth in 1863.	Depths in 1867.	
	According to the Belgian Hydrographer.	According to the Belgian Hydrographer.	According to the Dutch Hydrographer.
	Mètres.	Mètres.	Mètres.
Red Buoy at Barland	5·7	5·8	5·3
Below Zuidergat	8·0	5·8†	..
Valkenisse	6·7	6·3	6·0
Bath	6·2	4·5†	..
Santvliet	5·4	6·0	4·8
Above Liefkenshock	9·0	7·8	..
Below Fort Pearl	7·0	7·6	..
Above Fort Philip	7·4	5·4†	..
Draijende Sluis	7·5	6·2	..
Boernine Sluis	6·4	6·4	..
Antwerp Canal St. Peter ..	6·4	6·4	..

Navigable Depth from Flushing to Antwerp.

Navigable Depth.

The worst shoal between these places is at Bath, where the depth has lately been reduced to 4·50 mètres at low water, and consequently to 8·59 mètres at high water.

Thus at the present time there is a navigable depth everywhere in the main channel of the Schelde between Antwerp and the sea of $14\frac{3}{4}$ feet at ordinary low water, and of 28 feet at ordinary high water.

Nature of the River Bed.

Nature of the River Bed.

The bed of the West and East Schelde is everywhere composed of fine sand, but this sand is occasionally mixed with a

* "The Wielingen Channel, or the French Pass, is an excellent channel, and by far the best passage into the Schelde. It is bounded by the Blankenburg flats to the southward, until they fall in with the north shore of Cadzand Island, and to the northward by the Ribzand and Hompel. The Channel, therefore, may be said to begin abreast Blankenburg, and to run in an east by south direction, about 18 miles to Flushing. Its breadth is generally $1\frac{1}{4}$ miles, and it has nowhere in mid-channel less than 5 fathoms, which depth will also be found in the entrance. Proceeding inwards the water increases in depth, and throughout its whole extent the Channel has soft ground."—'North Sea Pilot' for 1863.

† These shoals do not extend quite across the river. Below Zuidergat there is a narrow channel 7·0 mètres deep at the side of the shoal: at Bath, 6·2 mètres; and above Fort Philip, 6·4 mètres.

little mud, especially in great depths, in the false passes, or "culs de sac," called "schaar," and at the salient angles of sudden bends in the river's course.

At the sides of the river where the current has but little energy, the sand is rapidly covered with successive layers of mud; these deposits are called "schor" when their level is nearly equal to that of high tides.

Winds and Tides.

Winds and Tic

The range of the tide at various sections between Flushing and Antwerp has already been given in the Table of Tidal Phenomena. The height of the tide, as well as its duration, are naturally greatly influenced by the winds, those blowing from seaward giving the greatest range and duration of tide, and from north-east to south-south-west the least.

The highest tide recorded this century occurred on the 4th of February, 1825, when the level it attained was very remarkable, as will be seen by the following statement, which is taken from Mr. Stessels' hydrographic description of the river:—

Station.	High Water, Feb. 4, 1825.	Ordinary High Water.	Difference.
	Mètres.	Mètres.	Mètres.
Flushing	5·70	3·85	1·85
Liefkenshock (Lillo)	7·12	4·48	2·64
Antwerp	6·67	4·63	2·04

West Schelde.

Description the West Schel

The Schelde between Flushing and Doel possesses much more of the characteristics of an arm of the sea than of what is generally understood by a tidal estuary or a tidal river, as is shown by the following facts:—

1. The low-water slope is almost imperceptible.

2. The tide is propagated from Flushing to Doel, a distance of 43 English statute miles, in 147 minutes, which gives a resulting velocity of 17½ miles per hour.

3. The form of the tidal wave at Bath, which is situated at 36 miles from Flushing, is that of an ocean wave, its ebb and flow being of equal duration.

4. The average width of this part of the Schelde is 3 miles at high water, and 1½ miles at low water, and its mean depth at this latter period is 32 feet.

Lastly, the proportion of the volume of salt water brought in

by the flood-tide, as compared with the discharge of fresh water from the Schelde and its affluents, is 150 to 1 at Flushing, 46 to 1 at Bath, and 26 to 1 at Doel.

The Schelde, even between Doel and Antwerp, also partakes more of the character of an arm of the sea than of a river, but not to the same degree as the lower section just described.

1. The distance between Doel and Antwerp is 10½ miles, and throughout this length the low-water slope is also barely appreciable.

2. The tide between these places is propagated in 51 minutes, or at the rate of 12 miles per hour.

3. The outline of the tidal wave at Antwerp is not so favourable as at Bath; its range is 6 inches less than at Doel,* and the duration of its ebb exceeds that of the flood by 66 minutes.

4. The average width of the Schelde between Doel and Antwerp is 2300 feet at high water, and 1640 feet at low water, and its mean depth at low water is 23 feet, and—

Lastly, the proportion of fresh water at Antwerp is but one-eighteenth of the volume of salt water which every twelve hours is carried past that city.

East Branch of the Schelde.

Description of the East Branch of the Schelde.

This branch, which in ancient times was the principal channel of the Schelde, is now so shallow that at the Hetland Shoal the navigable depth at ordinary high tide is only from 8 to 9 feet, at neap tides with east winds 6 feet, and at high spring tides with west winds, from 11 to 12 feet; and at this part of the East Schelde its entire width can be crossed over dryshod at low water. The phenomena of the tides in the East Schelde have already been noticed in the Report of the International Commission.

At the point where the dam is being constructed the width is 11,808 feet, and its greatest depth is 16½ feet at high water; and when I visited the ground on the 15th of February last, I found that 3280 feet of this work had already been constructed from the east bank of the river in the direction of Flushing, and that hopes were entertained of being able to complete it before the end of the present year. The seat of the embankment is composed of fine sand, and towards the centre of the channel there is no trace whatever of recent deposit; indeed, it is generally believed, both in Holland and Belgium, that there has been no sensible diminution in the depth of the East Schelde for at least a century.

* The tide has the greatest range at Lillo, 1¼ mile above Doel. The range at Flushing is 11¾ feet, at Lillo 14 feet, and at Antwerp 13¾ feet.

Changes in the Channel of the West Schelde.

Changes in Channel of West Schelde.

That certain parts of the West Schelde have deteriorated within recent years is beyond a doubt; but data are wanting to prove whether or not the general depth has diminished. It appears from the representations of the Dutch Commission of April, 1866, that in the profile between Flushing and Breskens there has been an improvement in the sectional area, during the forty years ending in 1865, of 1·22 per cent.; and in the profile between West Kappel and the Sluissche Gat to the seaward of Flushing, an improvement of 1·3 per cent. As the changes of depth at the mouths of large open-mouthed estuaries like the Schelde are more affected by a combination of sea currents than by the regular action of the tides, the slight improvement noticed at the mouth cannot of course be taken as a criterion of a corresponding improvement in the general depth of the estuary itself. Since Mr. Beautemps Beaupre's survey of 1799-1800 (which I have had the opportunity of comparing with recent charts, through the kindness of Captain Blommendal), I find that at Barland, which is situated midway between Flushing and Bath, the depth has diminished from 42 to 18 feet; that in the main channel at Bath and Santvliet, where there used to be a depth of 32 feet and 20 feet, there is now only 15 feet and 16½ feet respectively. The deterioration at Bath has evidently been caused by the growth of the Santvliet bank, which has pushed the channel to the north, and consequently, by decreasing the radius of the bend at this point, has made the navigation gradually more difficult.

I have not come to any conclusion as to how far the above deteriorations may be due to purely natural causes, to diversions of fresh water in the upper part of the river, or to the conversion of parts of the foreshore of the estuary into cultivable land; neither have I formed any opinion as to the merits of the various plans which have, from time to time, been proposed with the sole view of improving certain deteriorated parts of the Schelde by the construction of works of art.

Discussion the question issue.

With the foregoing details for your Lordship's information and for my own guidance, I shall now proceed to state the conclusions I have drawn from them, and to notice the chief arguments which have been advanced in favour of their own particular views by the promoters of the dam scheme on the one hand, and by its opponents on the other.

It is allowed by both parties that the due maintenance of the depths of large estuaries, such as that of the Schelde below

Doel, is almost entirely dependent on the regular action of the tidal waters, and, consequently, all are agreed in admitting, as a general principle, that the rigid conservation of the whole volume of the tidal flow is of primary importance in all matters which refer to the improvement of tidal channels.

As there is no difference of opinion on this important point, it is needless for me to quote the published opinions of the eminent engineers who have ever been guided by the same theory, and who have therefore been the most successful in their treatment of tidal channels. The real question at issue is not as to the absolute value of a certain amount of tidal water as a scouring and maintaining power, but refers solely to the tendency of a proposed artificial barrier across the chief branch of the West Schelde to increase or diminish that power, a diminution being regarded by both sides as a positive evil.

In the extracts already given from the Report of the International Commission of September last, it will be noticed that at ordinary high tides 32,500,000 of cubic mètres of water enter the East Schelde at Bath, and that of this quantity only 11,500,000 return to the West Schelde during the succeeding ebb-tide. The promoters of the dam call this operation a bleeding ("saignée") of the West Schelde, inasmuch as a volume of 21,000,000 which enters the East Schelde every tide never returns to the West Schelde, and they affirm that the dam will ultimately cause the whole of the displaced 11,500,000 to ascend towards Antwerp, as well as the greatest part of the 21,000,000 that now escapes to the sea by the East Schelde.

In support of this assertion they maintain that the effect of the dam will be to raise the level of high water at the point of separation near to Bath, and that this cannot be done without strengthening the flood-current towards Antwerp as well as the ebb-current in the West Schelde, "because a raising in the level of high water at Bath will give a corresponding augmentation of the surface-slope upwards as well as downwards."

Now, with regard to this argument, it will be noticed that although the Dutch members of the Commission assume that in consequence of the raised level of the water at Bath there will be a quickened flood-current from that point upwards as well as downwards, no mention whatever is made of the counter effects which will be produced by a diminished slope, and, consequently, by a diminished current from Flushing to Bath. This omission is too important not to be more specially referred to hereafter; but for the moment I would here suppose, for the purpose of illustration, the impossible case of a raised level at Bath (which could alone account for the storage of the displaced 32,500,000) without any practical alteration in the force of the surface-currents.

Let it be assumed, then, that after the dam is constructed every particle of water which now enters at Flushing will still enter, that the tidal currents will not be appreciably altered, and that the entire volume of the 32,500,000 cubic mètres, which has been excluded from the East Schelde, will, on account of the raised level at Bath, be spread over the whole of the tidal surface between Ghent and the sea; the question would then arise as to the proportion of space that the displaced water would occupy in the upper and lower sections of the river, viz., above and below Bath.*

To answer this question correctly it is necessary to ascertain the relative values of the tidal surface of each section; but as observations have only been made of the extent of tidal area between Flushing and Antwerp, the tidal space between the latter and Ghent can only be roughly estimated. To accomplish this it appears to me a liberal award to apportion to the length above Antwerp an amount equal to that which has been calculated for the distance between that city and Bath. Now, the tidal area between these two points at mean sea level being 3882 hectares, the whole tidal space from Bath to Ghent, according to this calculation, would be 7764 hectares; and as the tidal area below Bath at the same level is 26,951 hectares, the proportion that the upper would bear to the lower section would be as 2 to 7, or, in other words, 9,000,000 of the displaced 32,500,000 cubic mètres would be found above Bath and 23,500,000 cubic mètres below Bath.† The effect of such a change, if it be for the present admitted, would be to benefit the upper section of the river; for from Ghent downwards there would be a gradual increase in the amount of the tidal flow and ebb which, near to the Belgian frontier, would be equal to a volume of 9,000,000 cubic mètres every six hours. The section below Bath, on the contrary, would be impoverished at the meridian of Bath by the loss of a volume of nearly 23,500,000 cubic mètres at flood-tide, and of 2,500,000 cubic mètres at ebb-tides; although lower down this loss would be gradually recovered, until at Flushing the strength of the flood-tide would be as great as ever, and that of the ebb-tide would be increased

* As some of the advocates of the dam consider that the anticipated raised level of the tide at Bath will be felt up to Ghent, which is situated at 108 miles from Flushing, and beyond which the tide does not flow, it is but logical to assume also that in like manner it will make itself felt downwards as far as the sea.

† If the level of ordinary high water had been assumed instead of mean sea level, the disproportion, of course, would have been still greater. The area at mean sea level is also more easily estimated than the amount of surface which is covered at the moment of high water at Flushing, and of low water at a point on the river nearly midway between Antwerp and Ghent.

by the volume of 21,000,000 cubic mètres which now escapes to the sea by the East Schelde.

Again, I would here advance another hypothesis, which regards from another point of view the effects which might be produced on the régime of the river, if the whole of the displaced 32,500,000 cubic mètres of water found its way above Bath after the construction of the dam.

Suppose that in the actual state of things a storm at sea gave to the tidal wave ascending the Schelde an extraordinary rise, and that the storm ceased when this extraordinary tide was at its greatest height at one of the higher stations of the river, say at Antwerp, this raised level of high water would cause the velocity of the ebb-current to be greater than usual, and would also cause a larger volume of water than ordinary to be discharged into the sea.

The following flood-tide which meets this extraordinary rapid ebb would be retarded in its progress, and consequently its volume would be less than usual. This reduction of volume would impoverish the river, and the sum of the volumes discharged by the augmented ebb, and the diminished flood which follows, would cause the level of high tide at Antwerp to fall lower than the extraordinary high tide which preceded it.

If the first tide that followed the latter still ranged higher than usual, the raised level would produce, but in a less degree, the same effects as have just been described, viz., expulsion by the ebb of a larger volume of water than usual, and a corresponding reduction in the volume of water introduced by the following flood.

These effects would continue to reproduce themselves during a certain number of tides, until the level of high water at Antwerp and elsewhere attained its normal condition.

The hypothesis of a tempest which raises the level of high water in the Schelde is realized at present, and is followed by the consequences just indicated. One may conclude, therefore, that the river is only in a normal state when the level of high tide in the upper portion of its course is high enough to eject at Flushing, during the ebb, the entire volume of water that entered there during the previous flood.

The fresh waters of the river, when they become more abundant, diminish the volume of the sea water during the flood, and consequently the volume that enters the sea during the following ebb.

Now, supposing that at the moment of low water at Bath the East Schelde is barred across, and that an accelerated current—caused no matter how—obliges the whole of the displaced

32,500,000 cubic mètres to ascend the river in the direction of Antwerp, this volume would naturally raise the level of the tide above Bath, and would have the tendency, as in the case examined above, to create a stronger ebb, followed by a weaker flood; so that the raised level would be less at the following flood, and would finish by disappearing completely, if the level of the sea at Bath remained at the same level as at present.

From this point of view, therefore, the 32,500,000 cubic mètres would be pushed back to the sea by the raised level they had provoked, and could no longer be reckoned upon as an efficient aid to the scour that maintains the navigable channel of the Schelde, till another extraordinary current caused a phenomenon similar to that above supposed to be repeated.

The theories just cited have only been advanced with a view to show that even supposing the whole volume of the displaced 32,500,000 cubic mètres continued to enter the West Schelde after the construction of the dam, it would by no means follow that an improvement of the main river would ensue. But as, in my opinion, after duly weighing all the arguments brought forward in favour of a contrary view, the displaced volume would not enter the river at Flushing after closing the East Schelde, I have the full conviction that the dam will produce a damaging, instead of a beneficial, effect on the régime of the river, as I will attempt to prove, after a further review of the arguments of the Dutch Commissioners in favour of their theory, that the dam will have a favourable effect on the entire length of the river from Antwerp to the sea.

To return to the discussion of the effect that will be produced by the anticipated raised level of the water, or the "surélévation," as I shall hereafter term it, at Bath:—

It is universally admitted that a flowing stream in passing large loops and creeks is lowered in consequence of the amount of water required to fill them, and that by closing these indentations the level of the stream is raised. Unfortunately, with regard to the particular case under consideration, one cannot satisfactorily determine, owing to the want of a record of simultaneous tidal observations at various stations on the river, the amount of depression that now exists at Bath, in consequence of the diversion from the West Schelde, at that place, of the large volume of water that enters the East Schelde.

It will be seen on referring to the table of surface slopes, and to the wave diagrams that accompany this Report, that, according to Mr. Stessels, a sensible depression in the surface of the water really exists at Bath, both at the moment of high tide at Flushing and of low tide at Antwerp; whereas, according to Captain Blommendal's observations, there is an actual "surélévation" at

Bath at these two periods.* With this conflicting testimony before me, I fall back on the assertion of the Belgian Commissioners, that the "diversion at Bath has for a necessary consequence the maintenance of the liquid surface at a lower level than if it did not exist."

Although all the members of the Mixed Commission admit the theory of a "surélévation" at Bath, the Dutch Commissioners consider that this "surélévation" will only take place at high water at Bath; while the Belgian Commissioners contend that it will be perceptible there throughout the whole duration of the flood tide.

The great difference between these opinions will be apparent when I state that, as the first assumes there will be no "surélévation" at Bath, and consequently no diminished strength in the tidal current at that place till high water, the inference is that the same amount of water will continue to enter the West Schelde after the construction of the dam as at present; whereas the latter, by assuming that there will be an appreciable "surélévation" during the whole rising of the tide, and not at high water only, implies that the tidal volume entering the West Schelde after the construction of the dam will be diminished.

My own opinion in this matter is entirely on the side of the Belgian Commissioners, and for this reason. I find by calculation that up to the time of high water at Flushing, when the water, according to Captain Blommendal, has about 15 decimètres (5 feet) to rise at Bath, that a volume of 9,750,000 cubic mètres,† or 30 per cent. of the total volume of 32,500,000 cubic mètres, has already been diverted from the West into the East Schelde; and I argue from this that during the whole period of the flow up to this time—viz., $3\frac{3}{4}$ hours—the level of the water at Bath is lower than it would be if the East Schelde were closed, and that this lowering must add to the momentum of the stream, by increasing the difference in level between Bath and the source of supply; for it is impossible to add to the head of water without at the same time accelerating the velocity of the whole stream below that head. The sole cause which, after the closing of the East Schelde, would tend to raise the level of

* Captain Blommendal estimates that the closing of the East Schelde will produce an extra "surélévation" of about 2 decimètres (8 inches) at Bath, at the moment of high water at Flushing. Now, a raised level of 2 decimètres would at this time of tide, according to Captain Blommendal's own observations, decrease the surface-slope between Flushing and Bath from an inclination of $\frac{1}{60416}$ to $\frac{1}{76315}$, supposing the slope to be perfectly uniform between these two places.

† As this volume enters the East Schelde at even the lowest tides, it follows as a matter of course that its value as a constant scouring power is of very great importance.

the water at Bath during the rising tide would be the suppression of the slight depression which is now caused by the waters spreading themselves laterally into the East Schelde; but this depression ceases with the diversion when the tide ceases to rise, so that one may doubt whether there will be any "surélévation" whatever at Bath at high water.

As a raised level at Bath would cause a diminished current with a flood tide below that place, it would necessarily tend to increase the current upwards between Bath and Antwerp, and, hence, I agree with the Belgian Commissioners in their opinion that, in the first instance, this accelerated current would have a favourable effect on the navigable channel above Bath.

After examining into the question of what would be the probable result of a "surélévation" at Bath, I find it impossible to admit that its effect would be to cause the same volume of water that enters at Flushing to-day to enter still when the tidal basin at Bath has been filled up. Because, if so, one might equally, without diminishing the volume introduced at Flushing, close up, one after another, all the other inlets and creeks of the estuary, and to hold the theory, that after each of these changes the high water will receive a new "surélévation," which will be an equivalent for the ejected water which formerly covered the bed of the said indentations, is, to me, incomprehensible. As bearing directly on this subject, I would here refer to a single instance, among many, of the injury that has been done to English rivers and estuaries by an injudicious system of embanking, without, at the same time, giving an equivalent in depth, either by dredging or otherwise, for the space encroached upon between high and low water mark.

'The Royal Tidal Harbour Commission of 1846,' in vol. ii., page 10, reports as follows:—

"The River Dee and the port of Chester afford a striking example of the dangers to which the interests of navigation may be exposed by placing the power over the river in the hands of a Joint Stock Company whose principal interest consisted in the successful reclaiming of land. The area of the estuary of the Dee, between Chester and Kelsterton, was, formerly, about 12,000 acres covered at every spring-tide; of this space 8000 acres have been reclaimed and the tidal water excluded; about 5000 acres of the land thus obtained, on the Cheshire side, now form the Dee Company's estate, and nearly 3000 acres on the Flintshire shore is the property of the adjoining landed proprietors. The Act of Parliament that sanctioned this extensive encroachment required that a depth of 15 feet at ordinary spring-tides should be maintained up to Chester. This condition has not been complied with. In 1844 a vessel drawing only

8½ feet could not go up to Chester on a spring-tide, and at Park Gate, twelve miles below Chester, which formerly was one of the principal mail-packet stations between England and Ireland, a dry sand now extends almost across the estuary."

Where, then, it may be asked, is the water that once covered the 8000 acres which have been reclaimed? That it has not ascended the river is certain, for the old quays at Chester are still unsubmerged. The answer is plain. The expulsion of the sea-water from the estuary kept pace with the reclamation of the land, and just in proportion as the demand for that water was decreased so was the supply diminished.

It has already been noticed that on the 4th February, 1825, the tidal wave raised by a high storm at sea ranged to an additional height of 1·85 mètres (6 feet) at Flushing, 2·64 mètres (8½ feet) at Lillo, and 2·04 mètres (6½ feet) at Antwerp. At this time, the diversion into the East Schelde, at Bath, must have exceeded 100,000,000 cubic mètres, for even by adopting the same line of junction of the tides at ordinary high water between the site of the proposed dam at Bergen-op-Zoom, I find, from the profiles of the East Schelde, that when the tide at Bath rises only 1 mètre higher than usual, that a volume of 54,500,000 cubic mètres is diverted from the West Schelde. Now, if it be assumed that nearly the whole of this augmented volume would, after the construction of the dam, also be pushed up the main river above Bath, who can determine, *à priori*, what would be the result at Antwerp?

To give some idea of the magnitude of the changes which would be involved by the construction of the dam, whether one adopts the theory of a "surélévation," which does not lessen the tidal volume, or the opposite theory, that a raised level at Bath would necessarily diminish it, I may state that the 32,500,000 cubic mètres, which is calculated to be the average amount of the diversion twice a day from the West into the East Schelde, exceeds the whole tidal volume that flows past London during a high spring-tide.

The navigable depth of the Schelde between Flushing and the sea is superior to that of the Thames between London and the Nore, and infinitely so to any other river in Holland or the North Sea. There is all the more reason, therefore, why its exceptional good condition should be watched over with the most jealous care, and that the improvement of its shoals, if they become worse, should be cautiously carried out so as to disturb as little as possible the equilibrium of forces, which, up to this time, has operated so favourably in maintaining the general depth of its navigable channels.

The Dutch Commissioners, after remarking that all introduc-

tion of the tide ceases at Flushing two hours twenty minutes before it is high water at Bath, proceed to inquire what influence the level of high water at Bath can have on the introduction of the tidal waters.

I have already attempted to show that, during the first three and three-quarter hours of the flood-tide, there will be a reduction in the volume of water admitted at Flushing, on account of the suppression of the diversion at Bath during that time.

In the second period, the resistance offered by the "surélévation" at Bath will continue to diminish the velocity of the affluent waters, although they have entered at Flushing during the first period, and the effect of this general retardation will, in my opinion, be injurious to the régime of the whole river, as it will diminish the salutary action exercised by the current, for the due maintenance of its navigable channels.

Although it is possible that the closing of the East Schelde may ultimately cause a local improvement at Bath, and thus be the means of accelerating the propagation of the tidal wave thence to Antwerp, the velocity of its progress being proportional to the square root of its depth, I am of opinion that such an augmentation would be no real equivalent for the diminished flow below Bath.

The additional volume of water that would result from the suppression of the diversion, and the "surélévation" that would be consequent thereon at Bath, during the whole duration of the rising tide, would form but a small fraction of the volume that now penetrates the East Schelde, because at a short distance above Bath the river is considerably narrowed, so that the mass of the fluid directed towards Antwerp, the movement of which would at first be encouraged by a quicker flow, by the mere local improvement I have mentioned would be very much less than the volume between Flushing and Bath, the movement of which would be discouraged by the "surélévation" at Bath.

It has been asserted that the diversion at Bath accounts for the enfeeblement of the current of the flood-tide at that point precisely during the last two hours of its duration. On referring to Captain Blommendal's Table of the rise of an ordinary high flood at intervals of half-an-hour at Bath, I find that his observations support the accuracy of the above statement; but if I refer to Mr. Stessels' Tables, and to the Wave Diagram deduced from them, I find no sign whatever of enfeeblement at Bath during the last two hours of the tide. On the contrary, by Mr. Stessels' observations, it appears that during the fourth and fifth hours of the flood-tide, when the diversion

towards Berg-op-Zoom is in full operation, the water rises 12½ decimètres (4′ 2″); and during the sixth hour the rise at Bath is as rapid as at Welsoorde and Flushing.

I quite agree with the Dutch Commissioners in their appreciation of the injurious effects that are produced on the action of the ebb-tide by the existence of sudden bends in a river, and by the forcible ejection of a large volume of water across such bends from a lateral channel; and I at once admit that if the Bath basin were entirely filled up, so that the right bank of the Schelde formed an uninterrupted line between Fort Frederick and Bath,* that the action of the ebb at this place would be improved. I do not, however, agree with the opinion of the Dutch Commissioners as to the extent of the improvements they predict here solely in consequence of the construction of the dam; for I believe that the beneficial changes they point out as likely to arise in the width, depth, and direction of the Bath channel consequent on the existence of the dam, could only be effected by training works ("travaux d'arts") constructed with the special view of confining the currents in a single channel throughout the entire length of the Bath and Salftinge bend.

It ought to be remembered, moreover, that although the promoters of the dam assume "that the Schelde above Bath will receive not only the quantity of water that is now diverted into the East Schelde from the West Schelde, but also the greater part of the volume which now loses itself in the East Schelde," they make no provision whatever to guide this large volume of water, which is equal in bulk to nearly one-half of the whole tidal flow past Antwerp, upwards and downwards, in a proper direction, by means of training walls; nor yet do they contemplate the construction of similar works in the neighbourhood of Bath to insure the upholding of the navigable channel in case the greatest proportion of the 32,500,000 should not be disposed of in the way they predict. Should the dam be constructed, and should no such provision be made to prepare for eventualities until the new shoals caused by the dam shall palpably have shown themselves, it appears to me that the remedial measures which might then be planned to repair the evil would come too late, and that the mischief already done to the régime of the river would in a great degree be irremediable.

The loss of a volume of 21,000,000 of cubic mètres of tidal water, which now escapes from the West Schelde during the flood, and does not return at the ebb, is called a "bleeding" of

* That the natural formation of this "junction length" of the right bank of the river at Bath will sooner or later be the result of the dam, has either been openly or tacitly admitted in all the discussions concerning its construction.

the West Schelde, and the Dutch Commissioners seem to attach no value whatever to this volume as a scouring agent, although in amount it is three times greater than the whole volume of fresh water, which likewise every twelve hours flows through the estuary between Bath and Flushing.

I agree with the Belgian Commissioners in their opinion that the "bleeding" just referred to, exercises a very useful effect on the régime of the West Schelde, for the following reasons:—

The sands which form the banks in the bed of the Schelde at Bath and elsewhere are so fine that the wind easily displaces them. As these sands lose a great part of their weight in water, they are held in suspension by a very languid current. If the current of the rising tide rolled along the bottom of the river grains of sand which would be too heavy to be held in suspension by the current which penetrates into the East Schelde, these sands would be stopped at the entrance of this channel, where they would long since have formed a considerable deposit. But in place of a deposit, there is formed at the entrance of the East Schelde the principal navigable channel; and one is therefore led to conclude that this transport of heavy grains of sand along the bottom does not take place, and that the current, which in entering the East Schelde contributes to deepen this pass (and which also maintains a channel in the East Schelde, and keeps it from silting up), ought to be capable of carrying towards Zericksee all the detritus that it holds in suspension on arriving at Bath.

The water which at ebb-tide leaves the East Schelde to return into the West Schelde, tends to force over to the left bank the current of the ebb from Antwerp, so that if the maintenance of the navigable channels depended solely on the action of the ebb-current, the principal pass in the neighbourhood of Bath would be found near to the left bank, whereas it is close to the right bank, at the entrance to the East Schelde; and as this pass appears to be principally due to the flood-tide, it may be admitted that the current of the flood is favourable up to this point. It may also be remarked that if it be assumed that the volume of 21,000,000 brings in sand from the sea which is deposited between Flushing and Bath, one would expect to see this part of the Schelde in a worse condition than between Bath and Antwerp, where this volume of water does not penetrate; but the fact is otherwise, and causes one to believe that this volume of water does not deposit sand, and that it exercises a favourable influence on the régime of the river.

I believe with the Dutch Commissioners that as a general rule, where under-currents do not exist, the ebb-tide is a more

efficient agent of scour than the flood-tide, for not only is the former favoured by the natural declivity of the river bed, but its volume is swelled by the upland waters which descend with the ebb to the sea.

But the case of the Schelde between Bath and the sea is not an ordinary one, for its bed has no declivity, and the volume of its flood-tide preponderates over the combined volumes of the salt and fresh waters which descend with the ebb.

If it is really true, therefore, that the deepest channels of the Lower Schelde are formed by the ebb, the phenomenon must be due to the superior velocity of the ebb, and not to its greater volume. A reference to Mr. Stessels' Table of Surface Velocities would seem to favour this view, for the result of his observations shows that the velocity of the flood is greatest between the third and fifth hours, when it sometimes equals $2\frac{1}{2}$ miles an hour, whilst the velocity of the ebb is greatest between the second and fourth hours, when it sometimes reaches 3 miles an hour.

The possession of data to establish the velocity of the under-currents taken simultaneously at various periods of the tide in connection with the surface velocities, could alone determine the question as to the relative values of the ebb and flood of the Lower Schelde as scouring agents, and until these are provided I think it is safest to rest on the broad belief that as the volume of the flood is greatly in excess of that of the ebb, especially a little to the west of Bath, it exercises a superior influence to the latter, in maintaining the depths of the navigable channel; and I may add, that the several blind channels opening to seawards, which are obviously due to the action of the flood, bear out this inference.

Having now reviewed all the arguments brought forward by the promoters of the dam in favour of that work, and having noticed incidentally the arguments on the other side, it only remains for me to give my own opinion as to the probable effects that the dam would produce on the régime of the river.

The low water profiles, Plate IV., figs. 1 and 2 (No. 1 taken at five miles above Bath, and No. 2 at two miles below that place) have been prepared from Captain Blommendal's chart, in order to illustrate the effect that has mainly been produced on the area of the lower profile, by the volume of 32,500,000 of cubic mètres, which it is now proposed to exclude from the East Schelde at Bath.

It is evident by a glance at these profiles, that if from any circumstance the flow of the tide in their immediate neighbourhood is reduced, a certain deterioration in the entire course of the river will follow. Now, in my opinion, the construction of the dam jeopardizes the integrity of the low-water areas in the

vicinity of both these profiles, but to make my meaning plainer I must again have recourse to figures.

The volume of water that now passes the meridian of Bath during the ordinary flood-tides is about 140,000,000 of cubic mètres, and of this volume 32,500,000 are diverted into the East Schelde.

If this diversion is totally suppressed, I am of opinion, for the reasons already given :— Conclusions drawn from foregoing discussion.

Firstly. That the action of the flood-tide on the bed of the river at the meridian of Bath will be reduced 23 per cent., and that the action of the ebb will be reduced 8 per cent. at the same place.

Secondly. That the effect of this great diminution in the tidal scour will be felt, though of course not in the same ratio, throughout the entire length of the channel from Bath to Flushing.

Thirdly. That the diminished velocity and volume of the flood-tide, and the diminished volume of the ebb-tide below Bath, will provoke a slow but certain silting up of the main channel, first of all between Bath and Flushing, and afterwards, as a natural consequence, between Bath and Antwerp.

Fourthly. That the effect of the dam will not be immediately apparent, as the volume of the ebb will not be reduced in the first instance by the closing of the East Schelde.

Fifthly. That the silting up of the basin to the south of Bath will be a very slow process, unless aided by artificial works.

And Lastly. That when the silting up of the basin is completed, and the right bank of the river between Santvliet and Bath is continuous, that the greatest part, if not the whole, of the 11,500,000 which was at first stored there, will be lost for the West Schelde, and that no more water will enter the river above Bath than at present, unless a general lowering of the low-water line takes place between Doel and Bath—an improvement which can only be insured by extensive dredging, by the construction of submerged training walls, or by both combined. In short, that although the construction of the dam may possibly bring about a local improvement, it will have a decidedly injurious effect on the régime of the river from Antwerp to the sea.

Although the above considerations have irresistibly led me to regard with an unfavourable eye the construction of an embankment over the East Schelde, I conceive that no valid objection, in an engineering point of view, can be raised to the construction of a viaduct in place of a dam, a plan which was actually proposed by the Dutch Government in the year 1846. I believe there are no physical difficulties to overcome in establishing safe

foundations for the piers of a viaduct, and that if they consist either of groups of piles, iron cylinders, or light columns of brick or stone masonry, they will offer no practical obstacle to the free flow of the tide.

I am of opinion, therefore, that the best solution of the question which has just been discussed is the substitution of a viaduct for the solid earthen dam by means of which it is now proposed to carry the Flushing and Venloo Railway across the Eastern branch of the Schelde.

CHAPTER II.

Question of Barring the Sloe Branch.

Barring of the loe Branch.

Description of he Sloe.

The Sloe branch of the Schelde has a length of fourteen English miles from its northern mouth, which abuts on the Rompot Channel, to its southern mouth, which communicates with the West Schelde near to Fort Rammekens, and at a distance of three miles to the east of Flushing. About midway between the two mouths a channel called the Zandkreek branches off from the east bank of the Sloe, and, taking an east direction, the Zandkreek divides the islands of North and South Beveland, and communicates with the East Schelde at a point about three miles north-west of Wemeldinge.

The Sloe was in ancient times of much more importance than at present, for, owing to extensive reclamations of its foreshores and to natural decay, it is no longer a large arm of the sea, but simply a narrow and contracted channel, which divides the islands of North and South Beveland from the Island of Walcheren.

The proposed railway embankment or dam is to cross the Sloe at a point about two miles to the south of the Zandkreek entrance, where the width of the channel at high water is 3300 feet, and its greatest depth 42 feet.

Report of the utch Commis- on of 1866 in .vour of closing ıe Sloe.

The diminished sectional area of the Sloe Channel and the cause of its deterioration are thus referred to in the Report of Messrs. Brunings und Blommendal, the members of the Dutch Commission of April, 1866:—

"A chart of 1814 indicates that the depth of the Sloe was at that time not less than from 39 to 40 decimètres ($12\frac{3}{4}$ to 13 feet), and the experience of the last twenty-five to thirty years proves to us that the channel has lately become gradually narrower, and that its shoals have gradually increased in height.

"There is, moreover, a special cause which encourages the gradual silting up of the Sloe, viz., the stagnation of its current

at the point of junction of the tides from Flushing and from the Wersche Gat. In consequence of this, the shoals are continually getting worse in the neighbourhood of Arnemuiden. During the first part of the flood there is no sensible current between Zuidkrayer and Scloesche Dammen, and it is only during the last two hours of its flow that it directs itself to the north, so as to arrive at Veere at the commencement of the ebb."

Deterioration of the Sloe.

On comparing the profile of the Sloe branch at Fort Rammekens with the profile of the West Schelde between Rammekens and Hoofdplaat, Messrs. Brunings and Blommendal find that the relative capacity of the two channels bore the proportion of 1 to 9 in 1800, and of 1 to 18·2 in 1865.

The volume of tidal water which enters and leaves the Sloe has not been ascertained, and therefore I am only able to judge of its importance by referring to one of the facts just stated, viz., that two years ago the sectional area of the Sloe at Rammekens, and of the West Schelde at the same place, held the relative values of 1 and 18·2.

On this assumption, and considering the close proximity of the Sloe to the mouth of the West Schelde, I am of opinion that the régime of the river would not be affected to any notable extent by the complete closing of the Sloe by means of the dam proposed by the Dutch Government.

The Dutch Commissioners of April, 1866, are convinced of the complete innocuity of the Sloe dam, and the members of the Belgian Commission of 1865 * are also of opinion that the closing of the Sloe will not be prejudicial to the navigation of the Schelde; for in their second Report of September, 1866, they state, "We do not oppose the construction of the dam for fear of its producing modifications at the mouth of the West Schelde, and we admit that in this respect it will have no serious effect."

It seems to be generally admitted, therefore, that the Sloe branch may be closed by a solid earthen dam, without any detriment to the régime of the West Schelde.

Rammekens Roadstead.

Rammeken Roadstead.

The members of the Belgian Commission of 1865 oppose the construction of a dam across the Sloe, solely because, in their

* This Commission was composed of Messrs. the Chevalier Pycke, Governor of the Province of Antwerp, President; A. de Cock, Senator and Shipowner; Petit, Capitaine R.N.; Wellens, Inspector of Ponts et Chaussées; Houbotte, Engineer-in-chief, Inspector of Ponts et Chaussées in the Province of Liége; Catteaux Wattel, Merchant, Antwerp; A. Neyt, Merchant at Ghent (afterwards replaced by A. Stessel, Hydrographer); De Boninge, Sub-Inspector of Pilotage at Flushing; V. Lignen, Merchant at Antwerp, Secretary.

opinion, it will destroy the Roadstead of Rammekens; and the following extracts are taken from their Report on this subject:—

Arguments advanced by the Belgian Commission of 1865 in favour of the Rammekens Roadstead.

"The Roadstead of Rammekens is an indispensable refuge for ships, schooners, and brigs, which seek an anchorage there, to be sheltered from west to north-west winds, as well as to be out of the way of vessels, principally steamers, which ascend the Schelde at night.

"In case of accidents, vessels anchored at Rammekens are always within easy reach of succour, and of all the materials they may want for repair.

"In destroying the roadstead, not only will all these advantages be lost, but the majority of vessels will no longer be able to find a safe anchorage at the entrance of the Schelde during winds blowing from south-west to north-west; for it is to be remarked that from Flushing up to Vande Caloobank, a space which forms the Roadstead of Flushing, and where there is a depth of from ten to fifteen fathoms at low water, few vessels will run the risk of anchoring, especially with winds from west to north-west, which bring in the highest tides and the heaviest seas, and which cause the current at times to run at a velocity of nearly four miles an hour. However, if large vessels resist bad weather for a longer time, they occasionally either drag their anchors, lose them, come into collision with other vessels, or run ashore.

"To prevent such accidents the Dutch men-of-war prefer wintering in the Roadstead of Terneuze (Neuzen) to that of Flushing.

"If, therefore, large vessels seek a refuge at Terneuze, there would be still more reason, when the Roadstead of Rammekens is silted up, for small vessels, which are now sheltered there, to be ready at the shortest notice to repair to Terneuze also, a chance which bad weather does not always give to sailors, because, once overtaken by south to south-west winds, they would not be able to reach Terneuze, and there would be nothing left for them but to resist, as well as they could, the violence of the storm, or to seek shelter at Middlegat, so that more than one of them, in taking this last course, would run his vessel aground before reaching this anchorage, on account of his having no pilot on board, and of his being unacquainted with the river.

"The roadstead of Terneuze or of Middlegat, could not, therefore, sufficiently replace the roadstead of Rammekens, even when the new system of lights shall have been applied to the Schelde.

"Moreover, vessels anchored at Terneuze, besides being sub-

jected to a delay in their voyage, would not be able to find there, in case of serious accident, the succour that they could have obtained at Flushing.

"The Middlegat, in addition to these drawbacks, presents this disadvantage: vessels would not be able to anchor there without having a pilot on board, and they would be in the way of vessels, principally steamers, which navigate the Schelde by night."

Counter arguments by Dutch Commission of 1866.

In reply to these observations of the Belgian Commission of 1865, the Dutch Commission of April 1866, after remarking on the gradual deterioration of the Sloe, to which I have already referred, contend that the roadstead of Rammekens has ceased to exist, and, to maintain this view, they report as follows: "Below or to the west of Rammekens, the Kaloot (a sandbank which extends itself from the west point of South Beveland) was formerly situated at a much greater distance from Walcheren, and the part of this bank which was left dry at low water extended itself to the west of Schoone Waardin. In 1750 one finds that the Kaloot, from Fort Rammekens nearly up to Fort Ruyter, was situated at a distance of about 1000 mètres from the shore. In 1818 and 1825 the non-submerged part extended itself to the south of Fort Ruyter, the space being then narrowed more than one-half, and, according to the chart of 1842, the Kaloot was again sensibly shifted towards the shore. At the present time the non-submerged point has not only retreated completely towards the east, but the channel near to the pretended roadstead of Rammekens is more contracted than ever. The contour line of 8 mètres is now continued without a curve along the southern shores of the Kaloot and Walcheren; so that there is actually no shelter whatever from the south-west. As this shelter gave formerly the chief value to the veritable roadstead of Rammekens, which then extended itself to a great distance into the Sloe, one can no longer attach the same importance to this place as an anchoring ground; because the roadstead has for a long time been very dangerous when the winds blow from the south. Although it will be some little time before the limited anchoring space for small vessels near Zoutman becomes still more sensibly contracted than at present, it is beyond a doubt that without the dam the silting up will continue; for the deposits between Walcheren and South Beveland have already formed a natural bar in the bed of the Sloe—a formation which renders the existence for any length of time of this anchoring ground impossible. In order to give a tolerably exact idea of the situation, we annex to the Report a series of comparative drawings of the roadstead between Flushing and Rammekens. These charts clearly indicate that the great expanse of water which

formerly existed between North and South Beveland and Walcheren occasioned a much more rapid current than at present; and the facts of the successive contractions which the channel has undergone between the point of the Kaloot and the south shore of Walcheren, and the diminished depth of the channel, prove that the latter is gradually silting up. The series of charts, with their profiles, also show that the roadstead between Flushing and Rammekens, even to the west of the town, where formerly there was no shelter, is now completely sheltered against the north-west winds, and that the depths along the shore of the port of Flushing are reduced nearly one-half. (The elevated part of the Nolleplaatje now gives the real shelter.) The anchorage, therefore, is now safer than formerly, although the interior navigation has become slightly more difficult on account of the Nolleplaatje. We cannot share the opinion that steamers which ascend and descend the river during the night will be inconvenienced by the vessels anchored in the navigable channels. In the first place, vessels are generally found in great numbers everywhere in the river, and the smallest of them naturally seek a shelter beyond the 'thalweg;' so that they have nothing to fear from steamers, especially when the system of lights has been improved. Moreover, the law obliges vessels anchored in the stream to show lights. If this measure is neglected, or if steamers run when the weather is too foggy, accidents are unavoidable in any case.

"The Belgian Commissioners draw special attention to the great advantages that small vessels find in the roadstead to the east of Flushing, because they can anchor there without a pilot, obtain assistance, buy provisions, &c. As it has already been shown the limited anchorage space now left open for small vessels is in process of being silted up. If therefore the advantages indicated, diminish in future, one ought not to attribute this circumstance to the dam, but to causes over which we have no control."

Discussion of question at ue.

On examining the profiles of the Sloe attached to the above-named Report, I find, with the Dutch Commissioners, that the sectional area of its channel opposite Fort Rammekens diminished 50 per cent. between 1800 and 1865. I also find, however, that this diminution took place almost entirely between 1800 and 1818.

If these profiles, therefore, be taken as a criterion of comparison, one may conclude, that, owing to some exceptional cause, the deterioration of the Sloe Channel was remarkably rapid during the first eighteen years of this century, and that since then the changes in the bed of the channel have been comparatively unimportant.

This apparently undiminished capacity of the Sloe Channel of late years does not seem to justify the prediction that it will shortly be silted up, and that, as a consequence, the small roadstead at its mouth will speedily share the same fate.

Although there is reason to doubt the correctness of the theory that the Sloe is still undergoing the process of being rapidly silted up, it is beyond question that the roadstead which is still known by the name of Rammekens has no longer the same importance as formerly, and that by far the most valuable portion of it has gradually disappeared in the course of the present century.

On the other hand, it appears that the growth during the same period of the Nolleplaatje bank to the west of Flushing, and the consequent local shallowing of the channel, thence to Fort de Ruyter, have considerably improved the roadstead of Flushing (which is now completely sheltered from north-west winds), so that to a considerable degree the advantages that have been lost at Rammekens by the silting up of the Sloe have been regained by the improvements which have recently taken place in the extensive anchorage-ground in front of Flushing and Fort de Ruyter.

Conclusions drawn from the foregoing discussion.

This improved condition of the Flushing roadstead ought, I think, to be considered when the question of the complete stopping up of the Sloe below the Zandkreek entrance is discussed; for, in my opinion, this improvement is in many respects a compensation for the deprivation of a refuge against violent west and west-north-west winds which small vessels will experience when cut off from their present anchoring-ground under Fort Zoutman — an eventuality which will undoubtedly be hastened by the closing of the Sloe; but I do not think that this objection alone is of sufficient weight to call for the substitution of an open viaduct for the solid embankment by means of which it is now proposed to carry the railway across the Sloe.

CHAPTER III.

Comparative Merits of the Water Routes of Communication between Belgium and Holland and the Rhine.

Comparative merits of the water routes of communication between Belgium and Holland and the Rhine.

The proposed closing of the East branch of the Schelde has often given rise to controversy between the Belgian and Dutch authorities as to the relative values of the South Beveland Canal and the East Schelde Channel as routes of communication between Antwerp and Holland and the Rhine.

As the arguments that have been made use of for and against the canal have since lost much of their significance, owing to the subsequent opening of this new route, I need not review at any length the principal objections which were raised to it by the Belgian Commission of 1865, or give anything more than a brief summary of the counter arguments which were advanced in its favour by the Dutch Commission of April 1866.

The Belgian Commission alleged:—

1. That if the East Schelde were closed, vessels would be obliged to make use of the new canal, and thus their voyages would be retarded.

2. That in the actual state of things, vessels starting from Antwerp with a west wind reach Bath in a single tide, so as to be able to profit by the flood to pass through the East Schelde Channel; whereas they could not reach Hansweert in a single tide, and would therefore be compelled to anchor at Zenkenisse or the Old Polder, and by doing so they would lose a whole tide.

3. That if the wind freshened vessels would be obliged to leave their anchorage ground to seek refuge at Bath or at Old Doel, because between Bath and Hansweert there is no shelter whatever from west and north-west winds.

4. That small vessels, which are generally badly manned and equipped, will encounter danger and delay in entering and leaving the canal entrances, because, if the wind is favourable to vessels leaving the West Schelde, it will be unfavourable to vessels entering from the East Schelde.

5. The navigation will be subject to interruption more or less frequent, on account of repairs to the canal and to difficulties caused by the ice.

The Dutch Commission advanced the following arguments and counter-allegations:—

1. That if the East Schelde is closed, vessels from Antwerp must necessarily repair to Hansweert, and as they could not, as a general rule, drop down much lower than Bath, they would be obliged to wait for the next reflux to reach Hansweert.

2. That, having passed the canal, they would arrive in a large channel, which would take them up to the entrance of the Vlye, and thence by the Brabansche Vaarwater to the Keeten Channel, which leads directly to Holland and the Rhine.

3. That on passing by the Berg-op-Zoom Channel vessels must remain at anchor near to Bath during the first four hours of the flood-tide, when they could, of course, proceed on their voyage during the remainder of the flood.

4. That the channel of the Verdrouken Land is so difficult that vessels cannot reach Wemeldinge before the end of the

flood-tide, and must therefore wait during the whole duration of a flood-tide in order to pass the Vlye at the moment of the reflux, so as to arrive at the entrance to the Keeten Channel, hence making the voyage by the old route quite as long as that by the proposed new route.

5. That if bad weather sets in from the north-west or west during the voyage from Bath to Hansweert, vessels might be compelled, it is true, to return to Bath; but in what situation are vessels found at such a time between Bath and Wemeldinge, where there are likewise no places of shelter? They are, doubtless, worse off on account of the shallowness and the great intricacy of the channel.

6. That vessels bound for Antwerp, by making use of the canal, could calculate to a nicety how long it would take them to make the voyage; but in navigating by the East Schelde they generally arrive too soon at the places where there is the least water, and where on that account they are often obliged to wait for high water.

7. That, on the other hand, if south winds prevail, vessels cannot calculate the length of time they will require to traverse across the limited space near to the site of the proposed dam, where the tides of the East and West Schelde meet each other; therefore, vessels of a draught of five feet and more remain in that locality for days together sometimes, waiting for the opportunity to pass the Verdrouken Land shoals: so that, in point of fact, the voyage to Antwerp with the prevailing winds is subject to great delays.

8. That vessels bound to and from Ghent and Neutzen would always take advantage of the new canal, because by doing so they will greatly shorten their voyage; and that as the distances between Neutzen and Rammekens and Neutzen and Hansweert are about the same, the actual détour by the Sloe route, as compared with the South Beveland Canal route, is five good hours, or seventeen miles.

9. That if 600, or 5 per cent., of the vessels that now trade between Antwerp and the north pass by the Sloe, it is obvious that they will do so no longer when the new canal is opened.

10. That it is evident that vessels surprised in mid-winter by the ice will be less delayed in the canal than in the East Schelde Channel, because ice in a canal can always readily be cleared away, but there is no such possibility in the Berg-op-Zoom branch. Moreover, all communication between Holland the Rhine by the interior waters will be impossible the moment that the canal is obstructed by the ice.

The following is a "résumé" of the Belgian Commission's

statement of the water traffic between Belgium and Holland and the Rhine, and *vice versâ*, in the year 1864:—

Eleven thousand nine hundred and eighty-three vessels, of which 558 were steamers, passed Bath by the East Schelde Channel on their way to and from Antwerp and other ports of the Schelde.

T this number must be added 5951 vessels, which passed by Neutzen on their way to and from Ghent.

The total number of voyages, therefore, amounted to 17,934, which gives an average of about 50 vessels a-day.

Description of the South Beveland Canal.

Description of the South Beveland Canal.

On the 14th of February the vessel in which I visited the canal was towed by horses, in less than an hour, from the Wemeldinge entrance, which abuts on the East Schelde, to the Hansweert entrance, which abuts on the West Schelde. The canal runs almost due north and south, so that as the wind blew from the east during my tour of inspection, I noticed several vessels navigating, by aid of their sails only, in opposite directions. Midway between the two entrances the canal is already crossed by a swing railway-bridge.

As the wind was moderate we did not experience the least difficulty either in entering or leaving the lock basins, and on the day of my visit fifty-four vessels, which is above the average daily number of the whole Belgium traffic, passed inwards and outwards without any delay.

The canal has the following dimensions:—

	Ft.	In.
Total length	30,000	0
(Or 5¾ miles, or 9150 mètres.)		
Length of each lock	394	0
Bottom width of the locks	85	0
Top „ „	90	0
Width of the bottom of the canal	33	0
„ „ water surface	131	0
Depth at ordinary low water	19	8
„ „ high water	24	8

The South Beveland Canal is a fine specimen of engineering skill, and reflects the highest credit on Mr. Simon, the Dutch engineer who designed it and superintended its construction.

Proposed Walcheren Canal.

As the proposed canal from Flushing to a point in the Sloe Channel nearly opposite to the north entrance to the Zandkreek Channel is to be both wider and deeper than the South Beveland Canal, there can be no question of its proving superior in

every respect to the tortuous and shallow channel of the Sloe between Rammekens and the Veere Gat; and it may here be stated, as another set-off to the impending loss of the remains of the Rammekens Roadstead, that the Dutch technical authorities are of opinion that the damming of the Sloe below the Zandkreek entrance will have the effect of improving the channel thence, and, consequently, the continuation of the Walcheren Canal northward to the Rompot Channel and eastward to the East Schelde.

Discussion of the question at issue.

That the East Schelde route between Antwerp and Holland and the Rhine possesses some advantages at certain times of tide and wind over the South Beveland Canal route is not denied; but these partial advantages are, in my opinion, far more than counterbalanced by the vastly superior general advantages which the latter route possesses over the former. It appears to me that the canal has only two drawbacks: first, the want of a good anchoring-ground between Bath and Hansweert; and secondly, the difficulty of entering and leaving the canal in stormy weather. That these drawbacks are not of great import is shown by the fact that since the opening of the canal the practice of the navigation has already decided that this route is the best channel of communication between Antwerp and Holland and the Rhine, and *vice versâ;* and as monthly returns have been published of the traffic that has lately passed by the canal as well as by the East Schelde Channel, it appears to me that no better standard can be taken to weigh their relative merits; and, with this object in view I have compiled the following Tables from the said returns, for your Lordship's information:—

TABLES.

TABLE No. 1, showing the Number and Tonnage of Vessels of all descriptions which navigated the South Beveland Canal and the East Schelde Channel from the 15th October, 1866, to the 28th February, 1867.

Date.	Sea-going Vessels.		Rhine Vessels.		Lighters, &c.		Steamers.		Total.		Authority.
	Number.	Tonnage.	Number.	Tonnage.	Number.	Tonnage.	Number.	Tonnage.	Number.	Tonnage.	
By the South Beveland Canal:—											
October 15 to December 31, 1866	19	3374	95	13,337	2824	147,269	97	15,517	3035	179,497	"Staats Courant," Newspaper.
January 1867	16	3222	55	6,963	505	27,491	39	5,360	615	43,036	
February 1867	9	2904	46	7,011	1040	54,895	38	5,484	1133	70,294	
								Total	4783	292,827	
By the East Schelde:—											
October 15 to December 31, 1866	..	..	..	..	724*	49,569	43	7,196	767	56,765	M. Van Lansberge.
January 1867	5	599	..	..	82	4,117	3	319	90	5,035	"Staats Courant," Newspaper.
February 1867	..	..	6	691	190	11,115	5	647	201	12,453	
								Total	1058	74,253	

* This number includes sea-going vessels, Rhine vessels, and lighters.

TABLE No. 2.—Deduced from Table No. 1, showing the relative Percentage of the Vessels, with their Tonnage, which made use of the two Routes of Communication, from October 15, 1866, to February 28, 1867.

Date.	Canal Traffic.		East Schelde Traffic.		Total Traffic.		Percentage of Shipping.		Percentage of Tonnage.	
	Vessels.	Tons.	Vessels.	Tons.	Vessels.	Tons.	By the Canal.	By the East Schelde.	By the Canal.	By the East Schelde.
October 15 to December 31, 1866	3035	179,497	767	56,765	3802	236,262	80	20	76	24
January 1 to February 28, 1867	1748	113,330	291	17,488	2039	130,818	86	14	87	13
	4783	292,827	1058	74,253	5841	367,080	82	18	80	20

These Tables show that since the opening of the canal the proportion of tonnage which has taken this route, in preference to that of the East Schelde, is exactly 4 to 1, and that the proportion of vessels is 4½ to 1; but, as has already been noticed, one-third of the total traffic between Belgium and Holland and the Rhine is in connection with Ghent. A deduction, therefore, equal to this amount must be made from the total number of vessels, less sea-going ships, that have passed by the canal, in order to arrive at the total number of vessels trading to and from Antwerp that have preferred the canal to the old route.

By adopting this process I find that since the opening of the canal to the 28th February, the relative traffic of Antwerp vessels by the two routes may be estimated thus:—total number of vessels that have passed by the canal, less 44 sailing-vessels 4739; from which deducting one-third for the Ghent traffic (all of which as a matter of course prefers the new route to the old one), 3159 remain. Therefore this number of Antwerp vessels may be said to have preferred the canal route, as only 1053, exclusive of 5 sea-going ships, took the old route, or say 1 in 3.

The proportion is even greater during the first two months of this year, a fact which tells forcibly against the correctness of the ice-obstruction theory, as applied to the new route, as the following calculation indicates:—1720 vessels passed by the canal, exclusive of 25 sea-going ships, from the 1st of January to the 28th of February, from which number, by deducting one-third for the Ghent vessels, 1149 remain; therefore 1149 Antwerp vessels preferred the canal, as only 286, exclusive of 5 sea-going ships, passed by Berg-op-Zoom, or say 1 in 4.

This ordeal of figures fully proves the superiority of a route which is completely independent of tides, and renders it unnecessary for me to discuss further the arguments which condemned it on the one hand and favoured it on the other before its real value had been ascertained; neither need I enlarge on the contingent advantages which will hereafter accrue to Belgian commerce when it is carried on to a greater extent by steamers and large vessels, the number of which navigating the West Schelde in consequence of the new route will no doubt soon be greatly increased.

Conclusion drawn from the foregoing discussion.

For the above reasons I am of opinion that the South Beveland Canal is a better channel of communication between Antwerp and Holland and the Rhine, and *vice versâ*, than the route by the East Schelde and the Sloe Channels.

Summary of Conclusions.

The following is a summary of the conclusions which are embodied in this Report:—

Traff No. 1 a

1. That the closing of the East branch of the Schelde by means of a solid embankment will produce an unfavourable effect on the régime of the West Schelde from Antwerp to the sea.

2. That the construction of a viaduct in place of this embankment is quite practicable, and would involve no disastrous consequences.

3. That the closing of the Sloe branch by means of a solid embankment will not notably affect the régime of the West Schelde.

4. That although a solid embankment across the Sloe branch will hasten the already impending destruction of the Rammekens roadstead, this objection is not of itself of sufficient weight to call for the substitution of a viaduct for the said embankment.

5. That so far as regards the means of water communication between Belgium and Holland and the Rhine, the South Beveland Canal is a full equivalent for the East and Sloe branches of the Schelde which it is proposed to close.

I have, &c.

(Signed) CHAS. A. HARTLEY.

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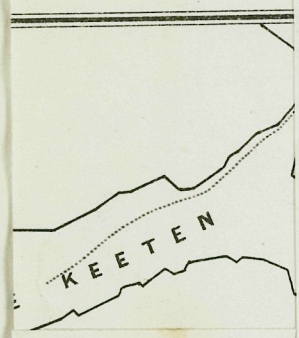


PLAN OF THE SCHELDE FROM FLUSHING TO ANTWERP.

PLATE. 1

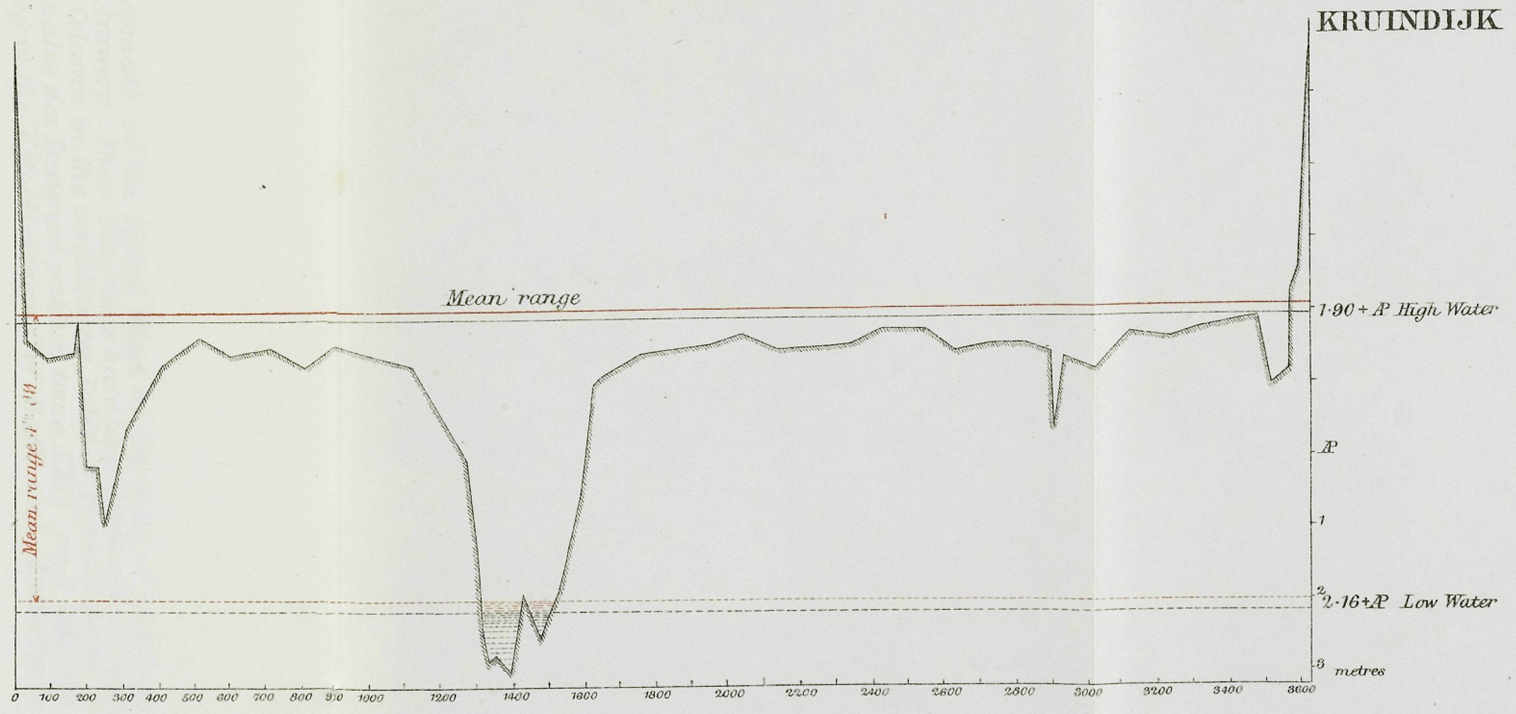
ZIERIKZEE
THE ROOMPOT
VEERGAT
THE KEETEN
NORTH BEVELAND
Oost Kappelle
Domburg
VEERE
West Kapelle
LANDKREEK
Sas van Goes
BRABANTSCH YAARWATER
EAST
THOLEN
Gorishoek
THOLEN
NORTH
WALCHEREN
Canal
ARNEMUIDEN
MIDDLEBURG
Wemeldinge
GOES
Railway to Venloo
Projected
Projected Railway
BERGEN-OP ZOON
SLOE BRANCH
St. Jousland
SCHELDE
SOUTH BEVELAND
Rammekens
Pte Zoutman
Pte de Buyter
FLUSHING
Kaloot
VERDRONKEN LAND.
BRABANT
Hansweert
Borselem
Hoedekenskerke
Waarde
WILLINGEN CHANNEL
THE HONT
Baarland
BATH
Ellewouts dijk
WEST SCHELDE
Vinkenisse
BRESKENS
Walsoorde
Hoofdplaat
Saeftinge
FRONTIER
Santvliet
Biervliet
NEUZEN
Ship Canal to Ghent
BRAKMAN
Prosper polder
Frederic Henry haven
Kruisweg
STAATS VLAANDEREN
Doel
Liflo
Liefkenshoek
LINE OF FRONTIER
Callo
BELGIUM
ANVERS

Dams
South Beveland Canal
New Line of navigation by the canal from HANSWEERT to WEMELDINGE.
Line of navigation on the Sloe & the canal of BERGEN-OP ZOOM to the East Branch.

SCALES
METRES
FEET
Cables
NAUTIC MILES

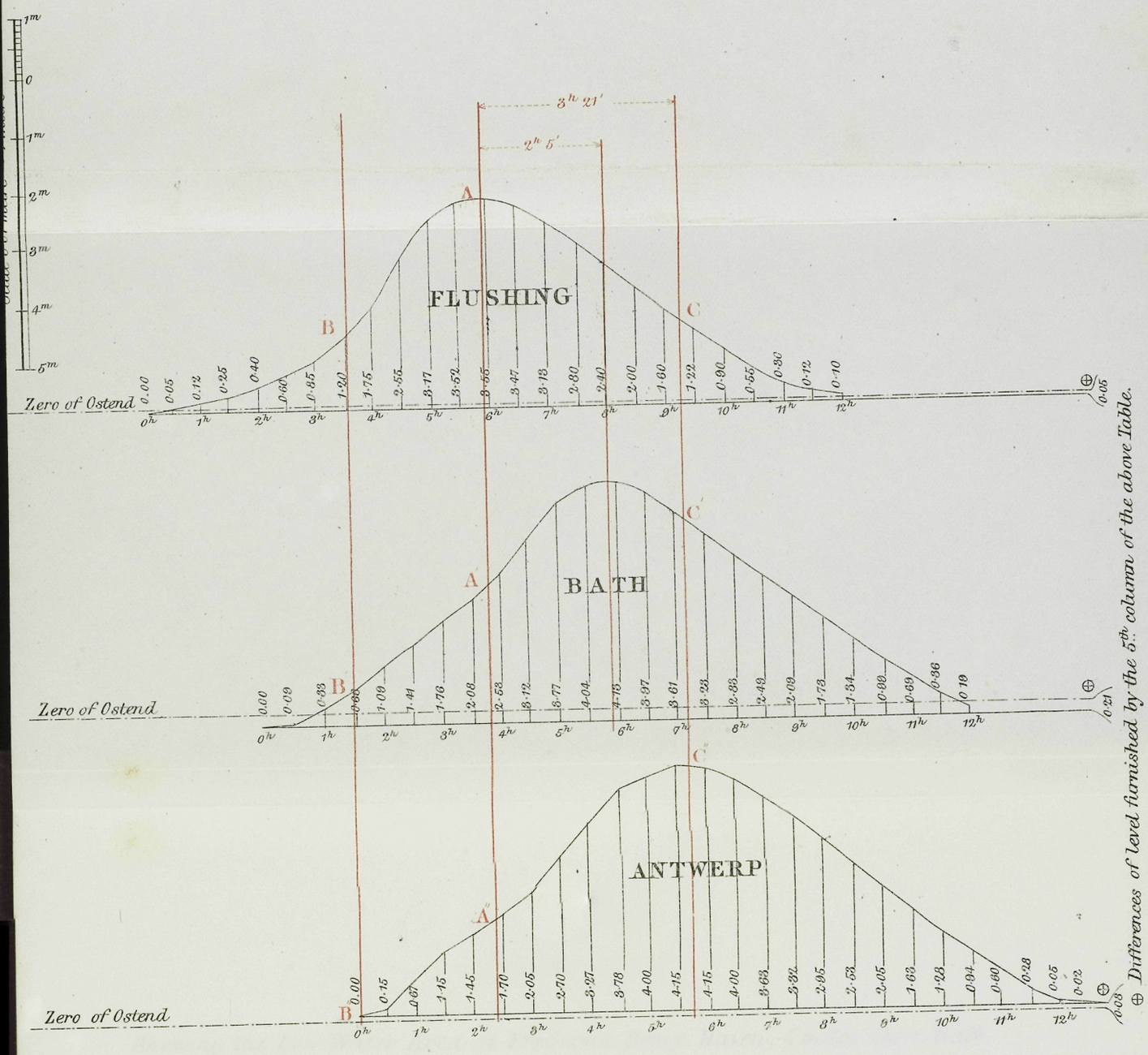
Harrison & Sons lith. St. Martins Lane.

Profile of the East Schelde on the site of the proposed Dam.

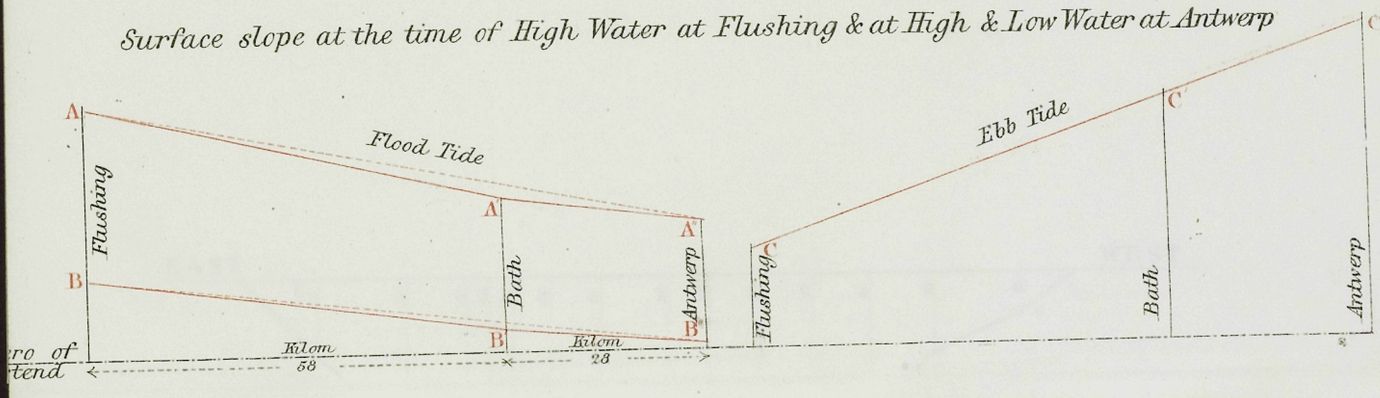


Harrison lith. St Martins Lane.

Diagrams shewing the development of the Tidal Wave at the time of ordinary high water at Flushing, Bath, and Antwerp. These Diagrams have been prepared according to the figures furnished by the 8th. Column in the comparative Table of Tides at pages 16 & 17 of the paper of Mr. Stessels (Annales des Travaux publics tome XXI) and are placed relatively to each other according to the "Establishments" of Bath and Antwerp in connection with Flushing.

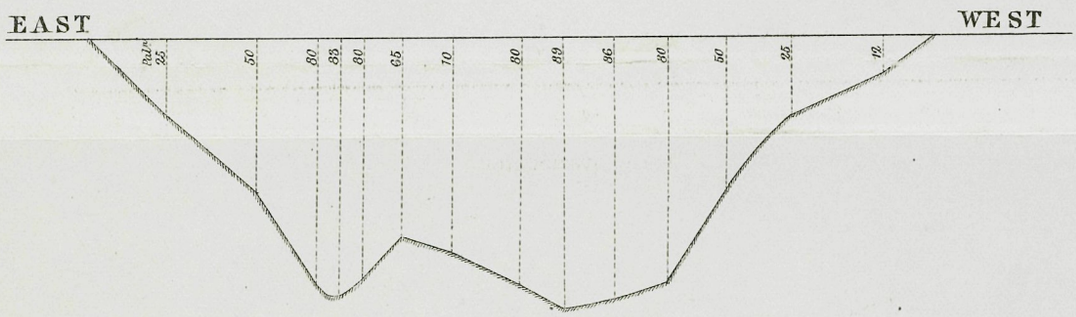


Surface slope at the time of High Water at Flushing & at High & Low Water at Antwerp



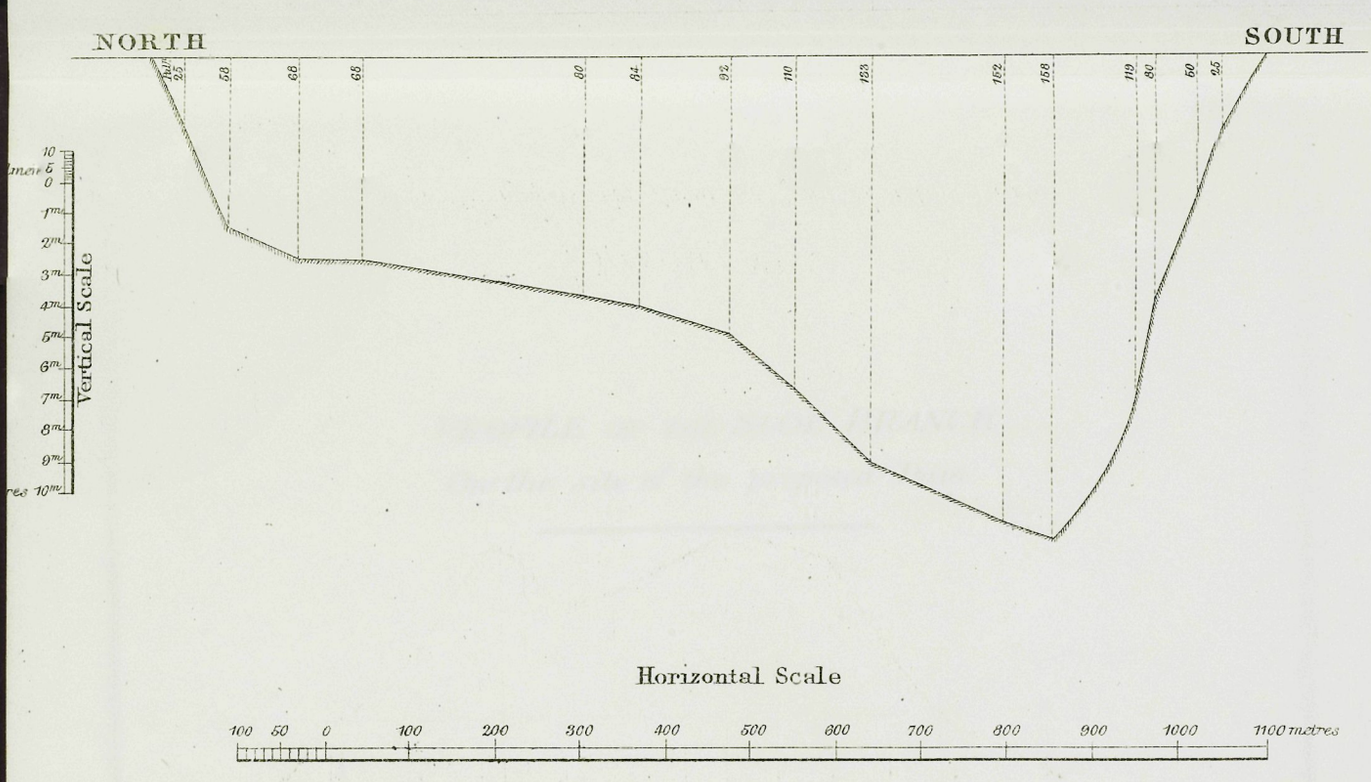
Profile N°. 1.

Shewing the Low Water Area at Frederick Henry Haven, 5 miles above Bath



Profile N°. 2.

Shewing Low Water Area at 2 miles below Bath.

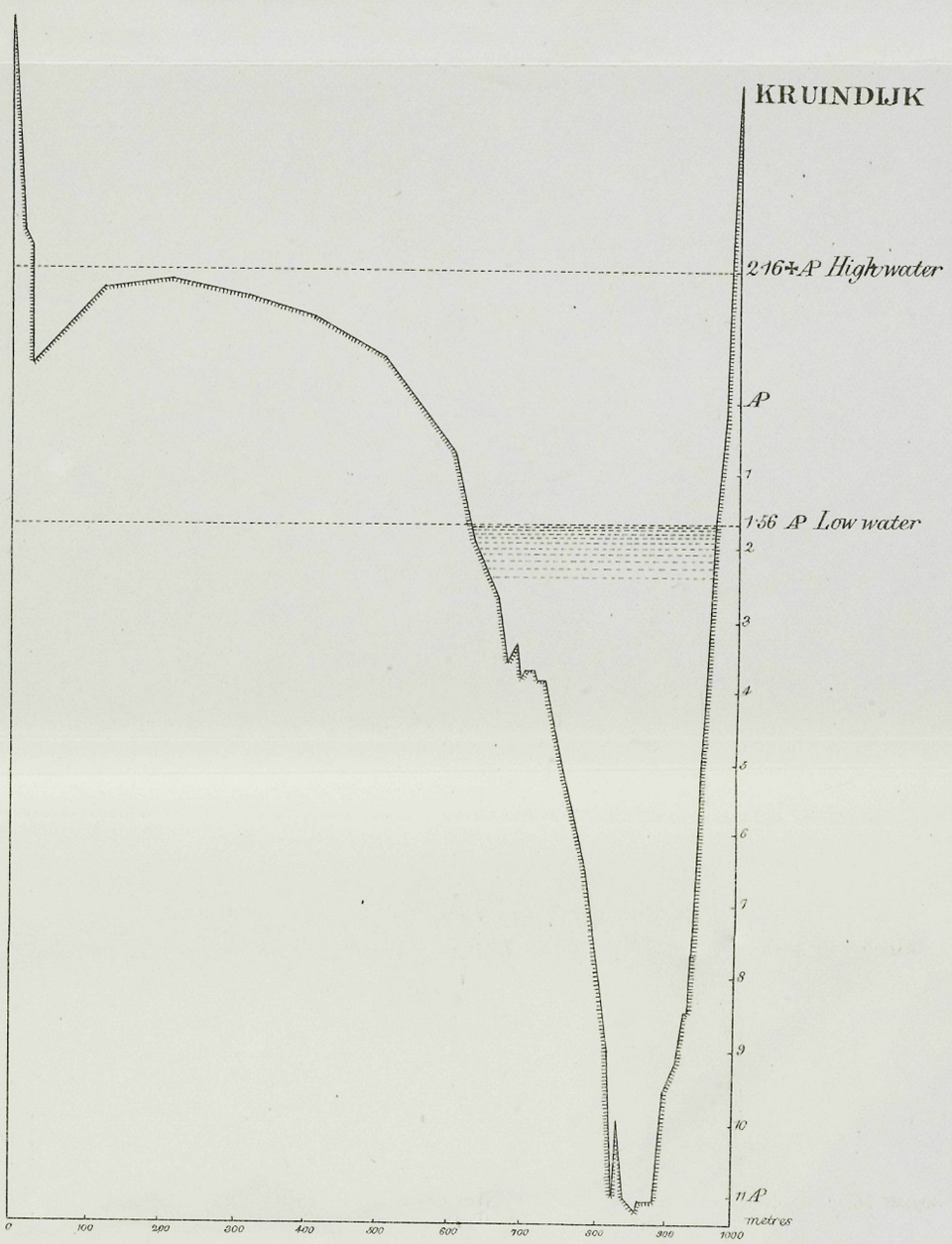


Horizontal Scale

Harrisons, lith. St. Martins Lane.

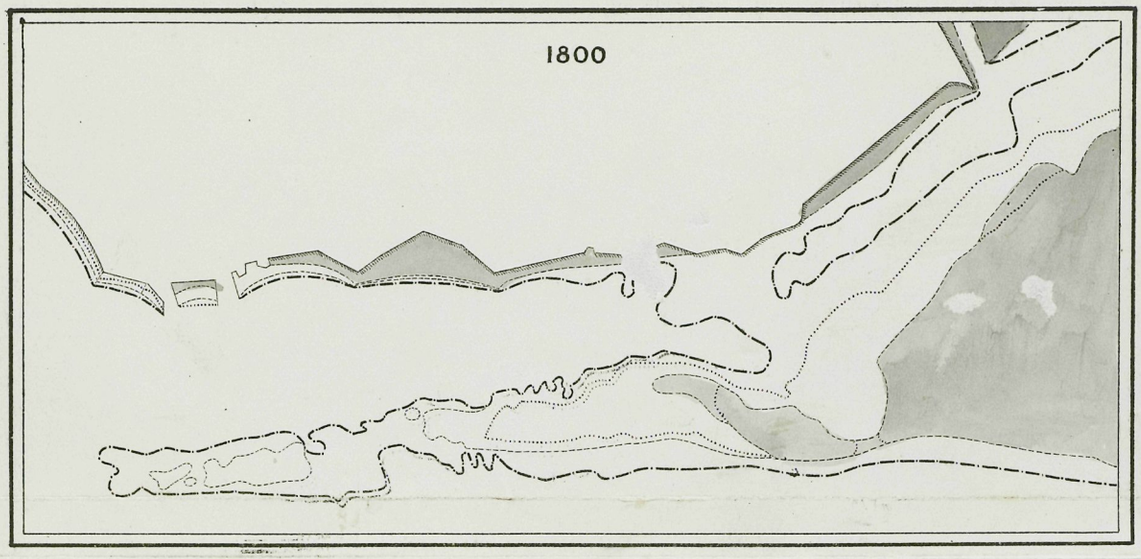
PROFILE OF THE SLOE BRANCH

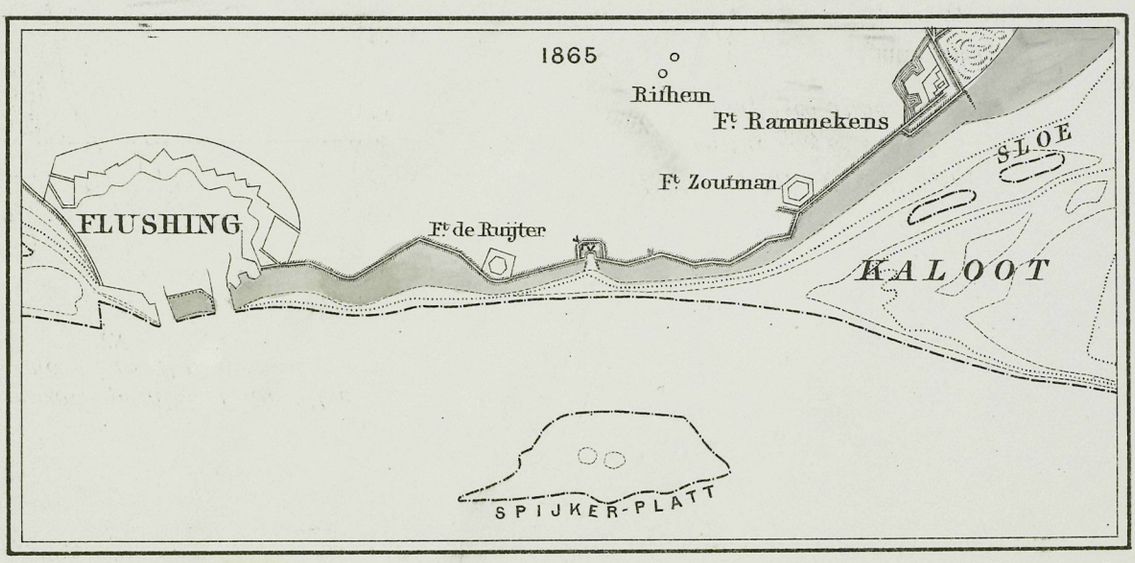
On the site of the proposed Dam.



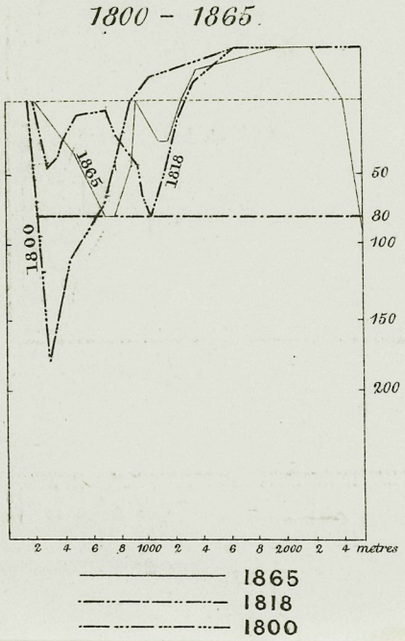
Harrison & Sons lith. St Martins Lane

Comparative Plans shewing the state of the Flushing & Rammekens Roadsteads 1800-1865.

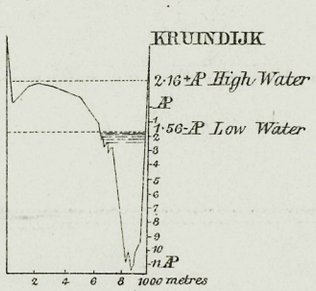




Comparative profiles of the Sloe near Fort Rammekens 1800 - 1865.



Profile of the Sloe Branch on the site of the Proposed Dam.



Harrisons lith. St. Martins Lane.