PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Navigation on the Thames

G. R. Rees and P. F. C. Satow

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Navigation on the Thames

By G. R. Rees and P. F. C. Satow
Port of London Authority,
Trinity Square, London, EC3P 3BX

The tidal Thames is flanked by a complex of industrial terminals and dock entrances which are used by a wide variety of vessels, ranging from deep-sea bulk carriers to tugs handling strings of barges. One of the biggest growth trades is oil, the inland distribution of which is by tank barge. There is a variation of the pattern of movement governed both by the tide and commercial considerations.

Navigation on the river will be affected by the size of opening since the level of movement needs the widest possible channel and for preference any constriction should be as far up river as practicable. Allied with this requirement is the need for maximum size of opening and the 61 m proposed, while adequate, introduces limitations, particularly for the larger vessel. During construction, special arrangements for navigation will be required to ensure the minimum of disruption to traffic both transitting the area and using terminals in the vicinity of the barrier site.

The closure of the barrier will halt all vessels bound through it and is likely to delay them for up to 12 h. It will also have some effect on vessels bound for docks below the barrier. Special arrangements will be required to enable all such vessels to wait. Running costs of vessels likely to be delayed range from £1500 to £300 per day and so the overall sum could be high.

Membership of the Navigational Working Party includes representation from all concerned with the movement of vessels on the river. Their initial deliberations were to conclude which site would be acceptable and whilst factors other than navigational had also to be considered, acceptance of the Woolwich site was governed by the forecast of the likely rate of closures to be initially no more than 2 per annum.

With opening widths of 61 m, a long straight approach is needed to ensure ease of navigation and the piers of the barrier must be alined to the direction of the tidal stream. To minimize disruption of navigation, the level of the sill must be low enough to ensure that vessels are not hindered. Sill level also needs to be considered in relation to the régime of the river. Use of the barrier other than for flood control could create problems of siltation and pollution and it is essential before using the barrier for other than its prime purpose to establish that there is no such possibility.

Arrangements for control of navigation remain to be finalized, but special signals, radio, visual and aural will be required. Also requiring further consideration is the precise timing of closures. Because of the vital need to prevent flooding, the number of closures may exceed the forecast. This is apparent from experience to date and the tidal pattern of initially indicating a surge which subsequently does not reach flood level.

While economic pressures have resulted in a design not necessarily ideal from navigational considerations, it is hoped that the Working Party's deliberations can minimize the impact on the trade of the Port while ensuring flood protection to London.

Richard Savage wrote some years ago

> 'O London, see
> Swelling with naval pride, the pride of thee!
> Wide, deep, unsullied Thames, meandering glides,
> and bears thy wealth on mild majestic tides.'

It is my purpose to try and indicate to you some of the effects which the barrier will have on the trade of the river whose tides are no longer so mild as in the quotation.

It would be appropriate to open by indicating the terms of reference of the Working Party involved as the title indicates. In fact research through the records available reveals little evidence of these having been defined.

At a Working Party meeting on 1 October 1961 the purpose was to discuss navigational

problems and requirements associated with a barrier sited in Long Reach. As has already been described, almost seven years later, the Thames Flood Prevention Investigation Steering Committee met and agreed the composition of various working parties to tackle the problem, included in which was the Navigational Working Party. At the first meeting of the latter – on 17 June 1968, the purpose given was to investigate all sites put forward by Professor Bondi in relation to the level of shipping at these sites.

However, before indicating from a navigational standpoint what factors affected the present solution it is necessary to give some explanation of the use of the Thames by shipping.

Pattern of traffic

The tidal Thames is a waterway with a public right of navigation. With the growth of industrialization over the years, factories, wharves and docks have been built along much of the riverside frontage from Hammersmith along either bank down to Canvey Island. This results in terminals for ships and barges being spread along the whole of this length.

The sizes of shipping which would pass through the barrier are indicated in table 1 for the two main sites considered, namely Long Reach and Woolwich Reach.

Table 1. Sizes of shipping

	Long Reach	Woolwich Reach
deep sea (includes tankers of up to 30000 tons and bulk sugar vessels)	$208 \times 26 \times 11$ ($680 \times 86 \times 37$)	$168 \times 22 \times 9.5$ ($550 \times 73 \times 31$)
coastal vessels (includes colliers and vessels trading to the Continent)	$91 \times 14 \times 6.1$ ($300 \times 46 \times 20$)	$91 \times 14 \times 6.1$ ($300 \times 46 \times 20$)
self-propelled barges (mainly oil-carrying but also includes dredgers and sludge carriers)	$51.5 \times 10 \times 3$ ($169 \times 34 \times 10$) $76 \times 15 \times 4$ ($249 \times 49 \times 13$)	$51.5 \times 10 \times 3$ ($169 \times 34 \times 10$) —
tugs with tows	107×14 (350×45)	
patrol vessels (includes Police, Fire Brigade, Customs, Port Health and P.L.A.)	9–21 (30–70) o.a.l.	
pleasure craft	4–9 (10–30) o.a.l.	

All lengths in metres (and feet).

Of the numbers of the various categories indicated, the highest proportion continues to be tugs with their lighters – although this is a falling trade, there are still over 4000 lighters registered in the Port. On a regular user basis the self-propelled barge traffic represents a high proportion of movement – oil traffic running at 6×10^6 tons a year is expanding at the expense of coal and the greater use of oil for heating and travel. The order of increase is 12 % per annum and since much of this is likely to be in river traffic the increase in movements could offset other reductions in numbers. Also important to remember is that movement goes on any time of the day or night every day of the year.

The smallest numbers are the deep-sea vessels but nevertheless the most important because of their size and limitations on movement. Coastal vessels are more prevalent than their larger counterparts but being smaller are less hindered – nevertheless such vessels still trade as far up river as Isleworth.

Turning to the pattern of movement, the tide – which is the very reason why we are all here today – also has a most significant effect on the movement of many of the categories of vessels outlined above. Because the tidal stream runs at an average of about 1.5 m/s ($2\frac{1}{2}$ to 3 knots), it results in vessels, particularly those of low power, moving in with the flood and out with the ebb. Larger vessels are likely to have a draught such that they cannot move unless the tidal level has risen to a certain height.

Also significant is the fluctuation in numbers of vessels moving. As the tide dictates the optimum time to move in or out, so the demands of trade govern the optimum time to arrive or sail. This tends to generate a pattern of heavy inward movement at the weekend to enable discharge to start on Monday and a corresponding heavy outward movement at the end of the working week. Any design of barrier must cater for the maximum situation.

TABLE 2. TRAFFIC MOVEMENT

Typical maxima in 12 h tidal cycle

	Woolwich	Long Reach
vessels over 3000 g.r.t.	6	7
vessels over 1000–3000 g.r.t.	7	13
vessels under 1000 g.r.t.	15	13
colliers	6	9
coastal tankers	4	5
ballast dredgers	7	5
self propelled craft	62	†
tugs with tows	64	†
local craft	70	†

† No recent figures available.

EFFECT OF BARRIER ON NAVIGATION

How navigation will be affected by the barrier can be divided into four aspects. These are: (*a*) the size of opening, (*b*) the type of barrier, (*c*) during construction, (*d*) once in operation.

The size of opening

As already explained, vessels are moving inwards and outwards at many stages of the tide. This combined with the quantity of traffic creates a requirement for the widest possible navigational channel.

It follows from this that any constriction in width of the navigational channel is most undesirable. The effect of any such hazard increases the possibility of collision as well as creating the chance of delay. The further up river the obstruction is placed, the less the hindrance to navigation. It was because of the high usage of the river that those concerned with the initial study on the barrier insisted on an opening for Long Reach of not less than 427 m in width.

When the second phase of barrier investigation was begun in 1968, widths of gap necessary were re-defined depending on the choice of site as follows:

	m	ft
Long Reach	427	1400
Halfway Reach	305	1000
Woolwich	275	900
Blackwall Reach	183	600
Limehouse Reach/Lower Pool	153	500

Type of barrier

Closely allied with the width of opening deemed necessary is the design of the barrier and its method of operation. In specifying an opening of 427 m, it was also a requirement that when open there must be no obstruction and the structure proposed for Long Reach was a retractable type offering the minimum of hindrance.

Navigationally there is no other type which so nearly meets requirements as the retractable design. Other types all involve a considerable reduction in size of opening. A drop type introduces a problem of overhead clearance and the need therefore to have the height of gate above that of the masthead of vessels expected to pass through. Rising sector gates as presently proposed, avoid this objection but are correspondingly restricted in width of opening. It can be argued that 61 m, that which is planned, is as wide as that between the piers of Tower Bridge; and that therefore this imposes no hazard. But it must be remembered that in fact ships passing through the bridge are within yards of their destination and if appropriate the vessel swings below the bridge and passes through stern first.

In the case of the Woolwich site, the distance from berth is considerably greater – as much as 7 km and making a stern board of this length is undesirable. Because of this and the generally increased hazard it is evident why this proposal has been accepted only with reluctance by those concerned with the navigational aspect. Poor visibility, a dark night and mid winter make the Thames a far from comfortable area in which to be underway – add to this the need to pass through a gap where the clearance on either side perhaps no more than the beam of the ship and it is apparent why a larger opening would be preferred.

During construction

Present proposals for construction are to build one half first, open that to navigation and then build the other half. To do this it will be necessary to remove moorings for both ships and barges and to carry out considerable dredging to provide the necessary width of navigable channel to offset that obstructed by construction works. In a number of ways the construction period will provide greater problems to shipping than those applicable to the constructed barrier.

Among these are the problems created by the movement of a large number of contractors' vessels and plant in the vicinity of the works. The likelihood is that this will result in frequent need to modify or vary the traffic programme or movement pattern.

Problems will also arise in respect of navigating in the vicinity of the works. These are:

The reduction in visibility created by the extent of the works. Fortunately the reach is reasonably straight and therefore this may not be serious.

Any unusual tidal effects created by the works – a consequence of such effects might be to necessitate single file movement of vessels.

The need to ensure that any flood-lighting of the works is so arranged that it does not interfere with vessels navigating or any traffic signals being displayed.

Another factor, which also will apply once the barrier is built, is the need to change the pattern of movement for vessels using terminals in the proximity of the works. Particularly affected will be vessels carrying sugar in bulk to the Tate & Lyle refinery. The effect of the construction will be to necessitate the swing at present made off the jetty to be made farther down river and then proceeding stern first to the berth.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Completed barrier

Once completed there will need to be specified a system of one way movement through the barrier openings. Because of the limitations in width of the openings, larger ships will require tug attendance, but as practice is for tugs to accompany vessels for the latter part of the voyage, this arrangement should be simply extended to cover transit of the barrier.

Applicable to all conditions is the incidence of fog. The present pattern of navigation is that in fog – which, thanks to the Clean Air Act is less prevalent on the river than in earlier years – vessels may complete their voyages using radar. However, it is unlikely they would do so in circumstances where they would have to negotiate a 61 m wide opening.

Effect of a closure

The immediate effect of a barrier closure will be to halt those vessels engaged in commercial trade whose terminals are such that they have to transit the barrier. This limitation will apply both to vessels above and below the barrier and its extent will depend upon the timing of the closure i.e. whether it is at low water or half tide and also how soon after the surge the barrier is re-opened. It will have its most serious effect should it be necessary to maintain the closed barrier through two tides.

Vessels bound to or from riverside terminals below the barrier should not be unduly affected; there will however be some restriction on vessels entering or leaving the Royal group or Tilbury Docks – this restriction will arise when the water level reaches a level where floodprotection measures have to be taken to prevent the level inside the docks causing flooding.

Provision will need to be made for vessels underway and due to transit the barrier to wait during the period of closure. Special attention will need to be given to: deep draught vessels, vessels carrying hazardous cargoes, and vessels for or sailing from drying out berths.

Depths of water at low water in the Reaches adjacent to the barrier are such that in general deep-draught vessels cannot anchor in safety. Moreover, depending upon the time of barrier closure, a vessel of this size which has to stop is likely to be unable to complete its voyage on the ebb tide following the re-opening of the barrier and will therefore need to wait for the next flood tide. Under these circumstances such a vessel is going to be delayed for a period of some 12 h. Because of the reduction in traffic through closure it might be acceptable to allow vessels of this type to anchor in suitable anchorages, adjacent to the navigable channel. However such anchorages are limited – and accordingly the vessel may have to wait well down river with corresponding increase in delay.

Vessels carrying hazardous cargoes refers mainly to the self-propelled tank barges loaded with petroleum spirit or other low flash cargo. In addition to these there are a number of similar craft, but whose cargoes are high flash – that is to say they do not necessarily need to be berthed singly as do the former. The trading pattern of both types is to leave the oil terminals in the Shellhaven–Canvey Island area on the young flood tide – reach their up river discharge berth before high water – discharge their cargo over the high water and return downstream on the ebb tide to repeat the cycle.

A barrier closure will therefore have a serious effect on this movement cycle. They may be unable to pass through the barrier before closure and once the barrier re-opens on the ebb they will be unable to reach their discharge terminal until the following flood tide. The draught of

these vessels is comparatively shallow and it will be necessary therefore to ensure there are adequate mooring buoys to cater for the maximum number of vessels likely to have to wait.

The third category – coastal trading vessels destined for riverside wharves which dry out are likely, if having to stop below the barrier to be involved in similar delays.

These and the other vessels affected by a closure, such as tugs and tows and smaller craft will require moorings at which they can wait.

Economic effect

It is apparent that vessels who are forced to wait are likely to be delayed for a full tide – or 12 h in round figures. Such a delay is bound to be an expense which any trade will find difficult to bear. Operating costs of ships of the size of the large vessels using the West India Docks are some £1500 per day, so that half the sum is immediately at risk. There is also the consequential costs that are also significant – for instance a ship may be bound for a discharging berth and a succeeding vessel planned to follow it on a certain date. A delay to the first will therefore disrupt the programme of the second and so on.

Equally undesirable is the effect of delays on such vessels as the self propelled tank barges. Closures are most likely during the winter months and this is a period when such vessels are at their busiest. A break in the pattern is therefore bound to result in a number of consequences apart from the expense of keeping such vessels at a standstill for the order of 12 h. Running costs for such a vessel are up to £300 per day and when as many as 31 of these may be delayed, the total sum involved is considerable.

Membership of the Navigation Working Party

The navigational authority for the River is the Port of London Authority. It is the duty of the navigational authority to ensure conditions for safety of navigation are maintained at their highest level. Closely involved in providing for navigational efficiency and the safe movement of trading vessels is the lighthouse authority (responsible for provision and maintenance of shore lights and light buoys) and the pilotage authority. Both of these latter functions are vested in the Thames in Trinity House.

Particularly concerned with their safe and timely movement are the owners or agents of the vessels trading to the port. It is the Chamber of Shipping of the U.K. which speaks corporately for them, and they therefore are members.

Associated with an over-riding interest on navigational matters are the Department of Trade and Industry (previously as the Board of Trade) and the Department of Environment (previously Ministry of Transport) with their responsiblity for ports. Also associated with the Working Party have been the Consulting Engineers. In recent years the Greater London Council have coordinated the work of the Working Party in place of the Department of Trade and Industry. Department of Environment representation has changed from Ministry of Transport to the Ministry of Housing and Local Government.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Work of the Navigational Working Party

The working party sitting between 1961 and 1965 confined their attention to a site in Long Reach. Their deliberations resulted in highlighting the problem of finding a satisfactory design of structure to meet their requirements. In consequence it assisted in narrowing the field of investigation when the working party was convened in 1968.

Navigationally the attraction of Long Reach was that it was long and straight and that the extent of riverside usage was in general less than sites up river. At the same time by being farther down river, additional problems were generated. By being nearer the estuary, there was a higher level of traffic – an increase of the order of a third, and with deeper water, larger ships would be either passing or berthing in the vicinity.

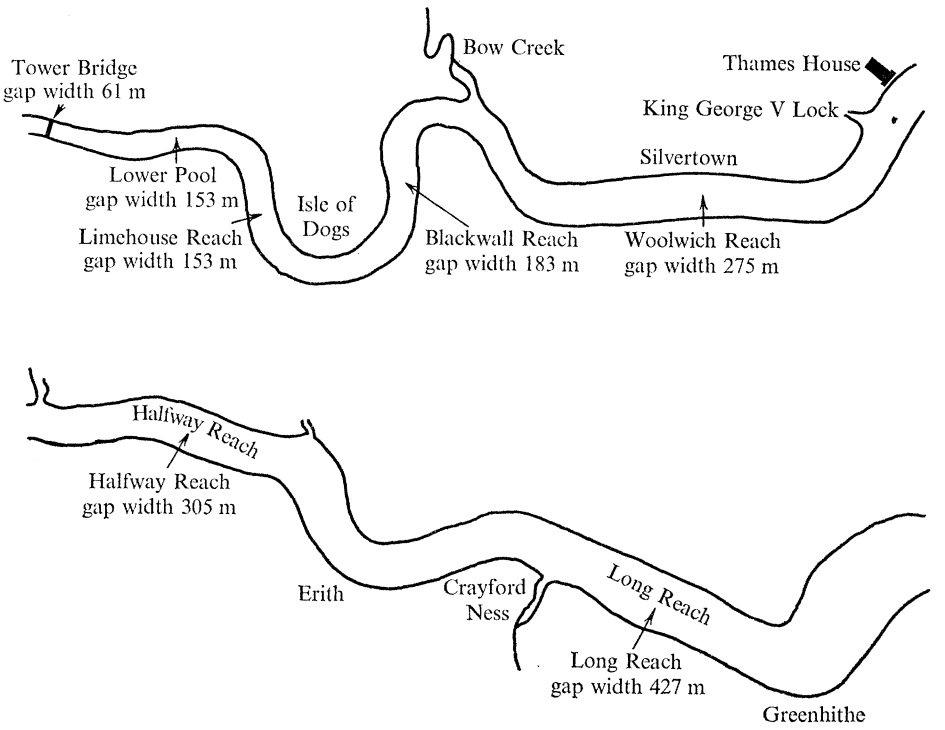

Figure 1. Reaches considered for barrier sites.

In accepting the solution proposed the conclusion was drawn that it would place a considerable burden on ships using the Port, on the P.L.A.; and on the national economy and it was therefore recommended that every alternative should be looked at afresh. And indeed, when the matter was brought under review again in 1968, the Navigational Working Party did just this.

As will have been apparent from an earlier speaker, factors other than navigational inevitably contributed to the site ultimately selected. While from the aspect of providing flood protection to the largest area possible demands a site furthest down river, as already explained such a site increases problems of navigation. The objections to the Long Reach site put forward by the earlier working party were found to be still valid and in consequence resulted in its elimination. Halfway Reach was rejected on grounds other than navigational and this also applied to a proposal to combine the construction of the barrier with that of the Thamesmead Tunnel.

Attention then focused on Woolwich Reach and above. Like Long Reach, Woolwich has the merit of length, thus simplifying navigational aspects – but it is not completely straight and this results in the tide not running true or in a constant direction along the line of the Reach.

Users of the port naturally sought a solution offering the minimum of disruption. Their preference was therefore for a site as far upriver as possible, subject to navigational feasibility. Bugsby's Reach was too short to be practical, but both Blackwall and Limehouse Reaches were worth serious consideration because they would avoid any disruption to traffic bound for the Authority's enclosed dock systems, and would therefore interfere only with ships, tugs and tows and self-propelled tank barges for terminals above the site. There were a number of navigational difficulties related to Blackwall Reach, but Limehouse Reach offered less objection. However, Blackwell Reach would necessitate additional protection works in Bow Creek, and Limehouse Reach both there, and in Deptford Creek and it was therefore mainly on economic grounds that these two were eliminated.

In reluctantly accepting that Woolwich Reach would have to be the choice, acceptance by the Port Authority was on advice on an aspect not yet considered. This was the forecast of frequency of barrier closure. Evidence offered by the Ministry of Agriculture Fisheries and Food was that initially this was unlikely to exceed 2 per annum. While this total is bound to be subject to more critical examination, and is indeed only a forecast, it did mean that advantages other than navigational could be given greater weight; and indeed led to a solution which has been indicated in an earlier paper.

Size of opening and alinement

Stress has been laid earlier on the navigational advantages of the widest possible opening. At this stage it is therefore necessary to indicate that representations were made both by Trinity House and the Port Authority and in adopting the Woolwich site, there was a requirement for at least one opening of not less than 107 m. On grounds of economy, however, the Government and their advisers apparently felt unable to accept this recommendation and navigation therefore will be through four 61 m openings, with 30 m openings on either side for use at certain stages of the tide by smaller vessels of restricted height.

With the adoption of the 61 m opening, there are two navigational features which are important – first, and this is why there is a need for a long straight reach – the approach to an obstacle should be such that a vessel can get onto a steady course and therefore transit the obstruction in a line parallel or nearly so to the sides of the obstruction. Secondly and equally important, particularly if the vessel is proceeding with the tide, is the need for the alinement of the piers of the barrier to correspond with the direction of flow of the tide. It has already been said the Woolwich Reach is not straight – and in fact the site lies close to the bend at the middle. Model and float tests are being conducted to ensure that this alinement is correct. Failure so to do would result in eddies around the barrier structure, with resulting hazard to vessels.

Depth of opening

In the explanation of the pattern of trade, mention was made of the use made by ships of the tide. Another benefit from entering on the flood tide is the rising level of water provides a margin of safety in that, should a vessel take the ground, it is only a short period before she is lifted off. Conversely, it is necessary to ensure that depths of water along the length of the river enable them to make the optimum use of it. It is therefore a navigational requirement that the

depth over the sill of the barrier should accord with the ruling depths in its vicinity. An important aspect of this requirement is that the sill is a solid structure likely to cause damage to and be damaged by a vessel making contact. This is not the case when the bed of the river is soft – as is much of the river. Taking the ground when under way is something that all concerned do their utmost to avoid but with soft mud the hazard is minimal. It is appropriate to expect that the sill does not create a hazard to vessels transitting from being at the wrong level – moreover, once built, it establishes a ruling depth in that area for all time.

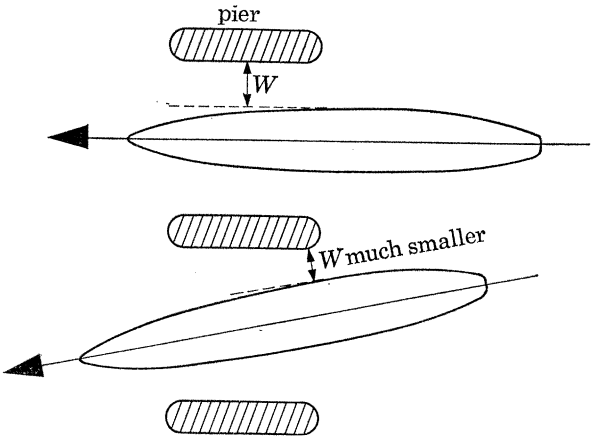

FIGURE 2. Passage through barrier.

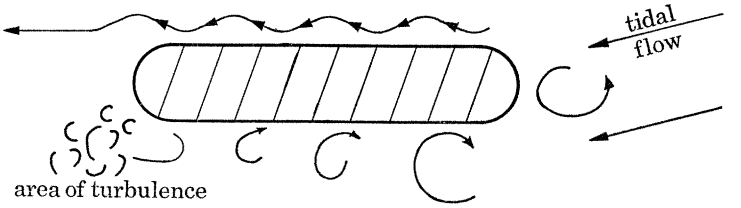

FIGURE 3. Eddies round piers.

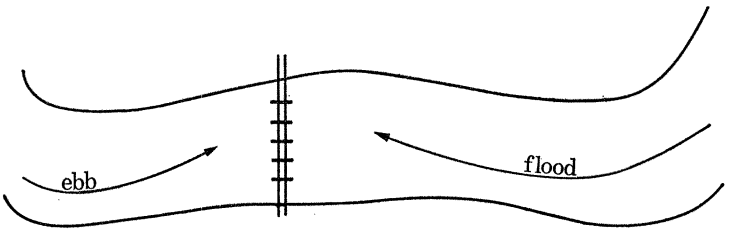

FIGURE 4. Tidal tendencies in Woolwich Reach.

There is another aspect over the depth of sill which needs to be explained. Whether or not dredging or construction of river works has contributed to an increase in tidal range, it is the endeavour of the Port Authority to seek a stable régime in the waters they control. Stabilization in this sense refers to a balance where such changes as do occur are cyclic and yet the likelihood of reaching an idealized equilibrium can be seen as a possibility.

By controlling over a long period the building of jetties, embankments, dredging and dumping, there is some evidence of success – but there have been instances when a degree of instability

has been introduced by river works not complying with the natural requirements. A case in point could be the recent sensitivity within Woolwich Reach.

Great importance is attached by the Port Authority to the need to maintain the optimum condition, and in so doing it has to be remembered that the whole is affected by the natural parameters of the river which are closely related. These include width, depth, cross-sectional area, tidal range and the imposition of a restriction on one is likely to affect the balance of the other.

Because of their responsibilities, the Port Authority are bound to apply the foregoing when considering the proposed design of the barrier. The parameters of width, depth and cross-section are all inter-related and of importance, and it is because of this that they are requiring at least two of the openings to have a sill depth of 6.7 m below chart datum and the other two 6.1 m. (10.1 and 9.5 m below Newlyn).

In some ways allied to régime, though not in fact directly connected is the aspect of pollution control. Since the Port Authority has a statutory responsibility for this control, it is appropriate to touch on certain aspects, though in no way intending to pre-judge what might be said by the next speaker whose whole paper is confined to the subject. The efforts of the Port Authority have for a number of years been directed towards improvement in the standards of industrial discharges and main sewers. The results, thanks to the common spirit, and engendered by voluntary consultation that has developed between the staff of the various authorities concerned has been most encouraging. Fish are appearing in greater numbers over the whole length of the tidal Thames – only 10 days ago a rudd was caught by accident at Tower Pier. The present proposals are for a tidal barrier and from the aspect of pollution control this would therefore have no effect on the improved situation just quoted. It is considered important however that the search for better amenity and recreational facilities such as might be available by use of the barrier as a half tide barrage should be resisted unless it is absolutely certain that there will be no detriment to the present or planned improvements to the quality of the water. The establishing of a half tide barrage would make the provision of a lock essential – the availability of the latter might have certain advantages in the event of a closure – but as it is not planned to provide one, no further comment will be made.

Control of navigation

Before so doing, it must be stressed that final agreement on arrangements required for the control of navigation has not been reached so some of the points made are in the nature of comment only.

The Port Authority as navigational authority have powers to regulate the movement of shipping. With the Thames Navigational Service they have introduced a comprehensive system of radio communications, radar surveillance, information and advice which serves to promote a high degree of safety of movement. A base already exists therefore from which an extension, albeit possibly to a degree independent, on which to build the control required for the barrier.

Before considering the method of control at the barrier, it may be helpful to enlarge on the tools available for this purpose.

Radio used by the T.N.S. is v.h.f. Fitting of this equipment is not yet compulsory in all ships and for this reason will need to be supplemented by visual/aural signals. Visual signals will normally serve, but aural are also required in case of low visibility. However carefully the

significance of such signals is promulgated, there is always the possibility of the uninitiated failing to appreciate their import and patrol launches will also be required. These last could be alerted from a study of the surveillance radar, the coverage of the latter requiring to be extended up-river as far as Blackwall Point. Provision will also be required for emergency arrangements for the towage of any vessel getting into difficulties in the vicinity of the barrier.

During the construction it will be necessary to route traffic clear of the associated works and this is likely to require single file traffic. This will be simplified by additional attention being given to the programming of vessels through the reach. To facilitate this pattern it may be necessary to place marker buoys indicating route limits and to have at peak periods of traffic a launch to supervise lane discipline. Once construction has reached the stage where barrier openings are in their final form, visual signals will be needed for two main purposes. One type, will indicate openings available and direction of flow through these openings. The other type, necessary once construction is complete, would be so placed as to give adequate advance warning of expected closure and in addition, the interval remaining, in terms of say 2 to 1 h, until closure.

The precise timing of barrier closures is another matter not yet finalized. Investigations to date have indicated that a 2 h warning should allow sufficient time to stop shipping on the basis that closure will be required 2 h before surge time. This presupposes a warning of a surge not less than 4 h before the peak reaches Woolwich. The problem which will face those responsible for closing the barrier will be to be certain that their decision to close is justified. Experience with the Port Authority of flood warnings to date is that on occasions the tide will be running at a flood warning level at the time a decision to close has to be made, but subsequently the surge falls away to below flood level. Moreover, it is easy to assess the situation on what has happened – what is not so easy is at the time to be sure that there is no danger. Inevitably the tendency will be to err on the side of caution. While surges may occur in no greater numbers than forecast, this does not rule out more closures, since inevitably there will be uncertainty about the possibility of a flood level being reached.

Another factor and one which may have already been indicated, is that the time of a surge reaching its peak does not necessarily correspond with the predicted time of high water – it may be $1\frac{1}{2}$ to 2 h early. This factor will require the provision of arrangements for what would be termed a 'crash closure' – where it is not possible to allow the full warning period. This indicates a requirement to reduce the time taken to stop shipping before closure. Only experience can show whether the 2 h provision for stopping shipping is excessive.

Conclusions

In the time available it seemed preferable to outline the pattern of movement of trade on the Thames and the problems which will arise concerning commerce with the advent of the barrier rather than explain in detail the deliberations of the navigational working party. Many of the discussions of both of the working parties have centred around the same factors, and opinions and requirements have been consistent. Of these the most significant is the endeavour to retain the widest possible opening because of the safety factor. The solution now intended while not in any way unsafe does have built in an element of risk to vessels passing through it and inevitably the conclusion has to be drawn that this element is there as a result of economic pressures. Also apparent will be that there still remain a number of matters concerning operation of the barrier and arrangements for control of shipping to be resolved – so long as these can be considered in

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

detail by representatives of all involved with shipping using the river then it is likely that the outcome will be to minimize the impact on the trade of the Port, yet ensure the safety of London and its inhabitants from a disastrous flood.

May I close with one further quotation whose source I have been unable to trace.

'And down where commerce stains the tide,
Lies London in her dusky pride,
Deep in dim wreaths of smoke enfurled,
The wonder of the modern world.'

While dim wreaths of smoke are all but a thing of the past, may the barrier have no effect on that stain of commerce, and the whole continue to make London the wonder of the modern world.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES