Research and commissioned projects 1981

Hydraulics Research Station Limited Wallingford England

This booklet gives brief details of the commissioned investigations and research projects carried out at Hydraulics Research, Wallingford, during 1981.

In many instances reports may not be available either because the research is incomplete or because the results must remain confidential to the client. The techniques used in an investigation may, however, be applicable in other circumstances, and readers may have problems similar to those described. Where such is the case readers are invited to write to the Managing Director stating clearly their needs and giving as much information as possible about the topic of interest.

Further information about the work of Hydraulics Research, Wallingford, is given in various brochures, summary sheets and other leaflets. For details of these, or for information on any part of the Company's work, contact:

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Abstracts of commissioned investigations and Station research projects in 1981

Offshore engineering division

Wave recording and analysis at Perranporth

Throughout the past year the Station has been maintaining two Waverider buoys off the coast of Cornwall near Perranporth. These buoys have been making simultaneous observations of wave conditions at two different depths on a line perpendicular to the beach. The deployment of the inner buoy, together with the analysis and comparison of the data, has been commissioned by the Ministry of Agriculture, Fisheries and Food as part of their research into the forecasting and prediction of extreme waves. Preliminary results have shown that the transformation of waves between the recording stations can be well described by existing mathematical techniques, which are based on simple linear wave theory. This result is both surprising and gratifying because the inner buoy is in rather shallow water, and in severe wave conditions virtually within the breaker zone.

Viking gas field — wave refraction study

The Viking gas field lies in the southern part of the North Sea, north-east of the Norfolk coast, in an area where the sea bed is dominated by a series of long banks and intervening deeps. To assist Conoco Ltd with structural design problems associated with re-certification of gas platforms, the Station undertook a wave refraction exercise to determine the effect of the irregular sea bed topography on extreme wave conditions in this area (Report EX 1026). Initially only the Station's standard wave refraction program was used, but at present discussions are taking place to see whether the loss of wave energy caused by breaking over the submerged banks can be incorporated into the analysis.

Stability of submarine cables

Additional work has been undertaken for the Standard Telephone and Cables Co Ltd to establish the boundary layer conditions in oscillating flow with an added steady current. The tests were carried out at full scale in the Station's oscillating water tunnel for a range of flow conditions.

Pressures, velocities and accelerations under random waves

The pressures, velocities and accelerations under regular waves can be estimated using a variety of analytical formulae. When random waves are considered however contributions from the whole range of frequencies existing in the sea have to be included, and a deterministic approach is not possible. Nevertheless, the dynamic properties of the waves can be estimated by calculating the root mean square of each parameter by applying the relevant frequency response function to the surface wave spectrum, and then using the well established statistical relationships, to give predictions of extremes. Dimensionless curves from which the rms values are easily derived are being prepared.

Scattering of finite - amplitude waves

A second-order theory has been developed for the diffraction of plane waves by a vertical circular cylinder. Numerical results for a range of cylinder sizes and water depths show that the second-order terms increase the peak forces and moments acting on the cylinder, and that the proportional increases are of the same order as the wave steepness. Work is in progress to evaluate the second-order scattered wave pattern around the cylinder

Drag regime in real seas

The boundary between the non-linear drag and the linear inertia regimes of wave loading on a vertical cylinder is well established forsimple sinusoidal waves. In real seas however, there is a wide variation of wavelengths, periods and directions, and the boundary established for regular waves is not readily applicable. Measurements have been made in the laboratory of the forces and moments on a vertical cylinder when subjected to various unidirectional and multidirectional random sea states; the tests were designed to give loads across the inertia-drag boundary. Sea states in which the loads are drag dominated are identified by the divergence of the measured forces and moments from those predicted by the linear theory for the inertial regime. The results show that, as for regular waves, the boundary can be defined in terms of the dimensionless ratio of orbit length divided by cylinder diameter, and that errors in estimating the maximum forces and moments by linear methods will occur when the maximum value of that ratio in a random sea state is the same as the boundary value used for regular waves. Dimensionless curves are presented giving the root mean square force and moment on a vertical cylinder in a random sea state, and the drag boundary is superimposed showing designers where drag effects cannot be ignored and the linear theory is inadequate for estimation of design maxima. This study was funded by the Offshore Energy Technology Board on behalf of the Department of Energy (Report EX 982).

Mooring for wave energy devices

An experimental study of various compliances for the moorings on wave energy devices has been undertaken for the Department of Energy (Report EX 1009). Tests were carried out in both long crested and short crested random waves with and without steady currents. Devices moored in beam seas and in line with the main wave direction were investigated. Compliances that exhibit an increase in stiffness with an increase in extension and those that show a decrease in stiffness with an increase in extension (tube pump characteristic) were studied. Amongst the many results obtained it was found that provided an optimum characteristic was chosen for the tube pump mooring, a significant reduction in the maximum mooring loads was obtained over those measured with more conventional characteristics. This reduction in mooring loads was achieved without a significant increase in movement of the energy device in the waves. It was also found that dissipation of energy in the tube pump moorings did not reduce mooring line loads.

Forces on sea-bed pipelines

Pipelines in a trench

The North Sea Gas Gathering Consortium was formed to study the feasibility of connecting a number of new and existing installations in the oil and gas fields of the North Sea to a pipeline system designed to transport the gas ashore. BP International Ltd, who are designing the pipeline system for the Consortium, asked the Station to investigate the wave and current loading on a pipe resting in a ploughed trench. Model tests, at ¼ scale, were carried out to establish design wave force coefficients for a range of trench depths.

Part-buried pipelines

Further work in the oscillating water tunnel was commissioned by BP International Ltd, on behalf of Woodside Petroleum Development Co Ltd of Australia, to establish wave and current force coefficients for a part-buried pipeline. This work was required in connection with the development of the North Ranking gas field off the coast of North Australia. The effects of an open trench with bed material deposited each side by the action of a plough was also studied.

Test rig at Perranporth

Work has continued on the wave force measurements on a submerged pipeline in 22m of water at Perranporth, Cornwall. The measurement of wave forces on the 760mm dia rough pipe has been completed and the test installation has been realigned to establish drag and lift force data for a pipeline perpendicular to the shore. The work is partly funded by the Department of Energy.

Terminals for deep sea production system

The feasibility of producing oil in deep water (in excess of 500m) has been studied by the Deep Sea Production System consortium comprising Sir Robert McAlpine & Sons Ltd, Humphreys and Glasgow Ltd and BICC Ltd. Their proposals applicable to these depths centre upon an atmospheric sea bed environment for production. Nevertheless, associated with this scheme it is necessary to have surface piercing structures to accommodate environment support systems for the sea bed structure facilities for flaring and for transportation purposes. Tests have been carried out for Sea Bed Engineering, on behalf of the consortium, of two types of surface piercing terminal — an articulated tower and a permanently moored storage tanker. Models of both types were tested at two scales so that the largest possible model could be tested at water depths of 500m and 1000m. The limiting factor was the 6m depth of the wave basin, and so the two model scales were 1:80 and 1:160. Each of the four models was subjected to the survival seas typical of the worst expected with a 50 year return period. Lesser but more frequently occuring storms were also used. Further, each model was tested with a shuttle tanker moored to it, in seas typical of the worst expected to be endured during mooring and transfer operations. The prime objective of the tests was to measure the forces in various parts of the systems under the different loading conditions, and to assess whether the movement of the floating structures led to any obvious design or operational problems. A further objective was to compare the performance in long and short crested seas. It was found that, for this type of system, it is essential to use short crested seas if a true and accurate representation of behaviour in a natural sea state is to be obtained. (Report EX 1022).

Coasts and port division

Finite-amplitude gravity waves

Accurate solutions for limiting gravity waves, with a 120° angled crest, have been developed from an integral equation approach using two leading terms to represent the crest singularity (Reference — WILLIAMS J M, 1981. Limiting gravity waves in water of finite depth. Phil. Trans. R. Soc. Lond. A 302, 139-188, Issue No. 1466). The work extends naturally to finite waves of all amplitudes and in all depths of water. It thus covers the range of moderate to large wave heights for which previously published tables such as those derived from the Stokes or Dean Stream Function theories are inaccurate. For waves very close to the limiting height, having a rounded crest of very sharp curvature, special care is needed to maintain the accuracy achieved for the highest waves. Within this range some wave profiles have a local slope exceeding 30°; while the existence of such solutions has been previously inferred they do not appear to have been explicitly computed before.

Long wave study at Port Talbot

Research into long waves with periods greater than 30 seconds has continued at Port Talbot. Since May 1981 pressure sensing wave recorders have been installed both within and outside the harbour. The offshore site is equipped with two independent self-contained systems each recording to magnetic tape — an NBA controls unit and an HRS-adapted version of the Bass Engineering wave gauge. Analysis of the data is in progress to determine the complete spectrum of waves from storm waves and swell to 'surf beats'.

Sediment measurements in waves and currents

Pump sampling equipment has been developed for use in the Station's oscillating water tunnel to study the movement of sediment near the sea bed under wave and current action. The water tunnel produces rectilinear oscillating flow in a working section using a hydraulically powered ram.

Suspended sediment concentrations near a sand bed will be measured by sampling continuously during the wave cycle for a range of full scale orbital amplitudes and periods. A nest of 10 filter trays are rotated to sample a steady discharge of water/sediment mixture pumped during the wave cycle from a range of heights above the mobile bed. A stepper motor driven by the signal controlling the ram movement is used to rotate the filter table in precise synchronism with the wave motion. Each filter accumulates sediment over a number of wave cycles from a specific part of the wave cycle.

Loch Long, Scotland — estimation of extreme wave heights

The Property Services Agency of the Department of Environment required estimates of maximum wave heights in Loch Long, Scotland, to assist them in designing a jetty. HRS was commissioned to record wave heights in Loch Long and to use this data to predict return periods of maximum wave heights. These predictions were made by fitting a Fisher Tippett I distribution to the data. Other distributions were considered but did not fit the data as well as the Fisher Tippett I. For a return period of 100 years a storm with a maximum wave height of 1.9m was predicted (Report EX 1021).

Wave hindcasting along the Somerset and Avon coastline

The Station's recently developed numerical model of waves in the Severn Estuary/Bristol Channel was used to hindcast wave activity at six locations along the Somerset and Avon coastline between Avonmouth and Porlock. The model uses windspeeds and directions measured at Rhoose, Milford Haven and St Mawgan, and was calibrated for 11 major storms against wave heights and periods measured at three sites in connection with the proposed Severn Barrage. The calculated wave heights at each site were related to those at a standard reference location where three years' measurements were available. By this means tables could be presented showing the expected values of significant wave height and mean zero-crossing wave period at each site for given return periods. The study was commissioned by the Somerset Division of the Wessex Water Authority (Report EX 1024).

Mathematical models of wave transformation

Over the last few years the Station has developed a very sophisticated model which is now in common use for calculating the refraction and shoaling of directional wave spectra as waves propagate over an irregular sea bed. There are however known to be situations where processes other than refraction and shoaling also become important. For example, a coastline fringed by a coral reef is largely protected from violent wave activity because the incident waves partially reflect and partially break over that reef; similarly in certain areas of the world, such as the Gulf of Mexico, the viscous dissipation of wave energy at the seabed can be an important factor in determining wave heights at a coast. None of these phenomena are included in the present mathematical model. To include such effects a new mathematical model is under development which uses finite difference approximations to the equations governing wave propagation. It is intended that this model should be developed not only to include the effects mentioned above, but also to incorporate the effects of currents, and eventually to predict sediment movement. Although the main effort is devoted to the theoretical aspects of developing the model, the Station is also using results from various wave recording exercises carried out at different places around the coast of the United Kingdom. This basic research work is being sponsored by the Department of the Environment.

Wave refraction study, Livorno, Italy

Early in 1981, the Italian consulting engineers, Societa Italiana per Condotte d'Acqua, commissioned the Station to investigate the effects of a proposed extension to the harbour at Livorno on the adjacent coast. Livorno is an important port on the north-west coast of Italy and is protected by several substantial breakwaters. Although the town itself is built on rocky terrain, the coastline immediately north of the harbour is sandy, and it was feared that the construction of another breakwater may have detrimental effects

upon that coastline. Preliminary analysis was carried out using the Station's standard wave technique, but in order to answer subsidiary questions about the shelter provided by a large rocky shoal lying offshore, a more advanced method was required. For this purpose a finite-difference wave refraction method was used, in which it was possible to incorporate the effects of waves breaking in shallow water (Report EX 986).

Transformation of waves off South Uist

As part of a major investigation into the feasibility of deploying wave power converters to provide an alternative energy supply, the Department of Energy has commissioned a study into the transformation of waves as they approach the coast of South Uist, in the Outer Hebrides. Wave records are available, in various water depths, for this area which has been identified as having a severe wave climate. The Station's wave refraction computer program has been employed in order to explain the observed decrease in power density of the waves as they travel into shallower water. The same technique has also been used to examine whether the chosen recording sites were likely to be giving a representative view of wave conditions along a particular depth contour, and to transform a wave climate appropriate to the 42m depth contour into a set of conditions more likely to occur in shallower water depths.

Monitoring of Solent Bank dredging

In 1976 the Hydraulics Research Station studied the data available at that time to determine whether any possible environmental side-effects to the Isle of Wight coastline could be attributed to the dredging for marine aggregate in the West Solent. The report submitted to the Crown Estate Commissioners in March 1977 stresses the difficulty of differentiating between coastal erosion due to natural, or other causes, and that element which could result from a single enterprise, such as dredging. It recommended that any further removal of sand and gravel from Solent Bank should be combined with an effective form of monitoring. As a result of this recommendation, a 3-year programme jointly financed by the Commissioners and the dredging companies was started in 1978. This included six-monthly hydrographic surveys, three-monthly beach profiling surveys between Gurnard Bay and Hamstead Ledge, and less frequently the recording of sonar side-scans, current metering and bed sampling. Dredging was also monitored monthly. It is concluded from this study (Report EX 1018) that the four beaches under review on the Island shoreline have remained generally stable throughout the 1978-81 period, and that the tidal currents at the extremities of the licensed area are virtually unchanged. However, the analysis of the remaining data and surveys with the dredging records suggest that the Bank could not sustain the recent rate of extraction (it was 260 000m^3 in 1980) and it is recommended that in future the annual total removed should not exceed 150 000m^3 from the licensed area. A modified form of monitoring should continue.

Cross-channel cable link

A new cross-channel electric cable link is being planned between England and France, and the Central Electricity Generating Board commissioned a desk study to examine the likelihood of movement of seabed material on the inshore part of the proposed cable route between Folkestone and Dungeness. The study considered long term, medium term and short term events. For the long term a comparision was made of bed levels taken from Admiralty Charts for the years 1803 to 1978. A theoretical approach, using wave data from the Varne Light Vessel, was used to assess medium term changes — that is, seasonal changes in bed level due to the onshore-offshore movement of sediment. Computational studies were made to determine the disturbance of sedimentary deposits by short-term wave action. The results of the study were published in HRS report EX 971 and also at a public inquiry held in February 1981.

English Channel crossing

The Station has been commissioned by Messrs Mott, Hay and Anderson, consultants to Redpath Dorman Long Ltd, to carry out a pilot physical model study to investigate the major effects on flow of the civil engineering

works associated with the construction of a combined road and rail crossing of the English Channel. A fixed-bed model has been designed and built to scales of 1/3000 (horizontal) and 1/300 (vertical). It will be operated in a non-tidal mode, ie the flow controls will be set to reproduce the conditions obtaining at a particular stage in the tidal cycle whilst the strength and direction of currents is recorded both with and without the works being represented on the model. The tidal stage can then be changed and the process repeated. A mathematical model is planned for later in the study to examine the effect of the near-shore works on the adjacent beaches.

Reclamation in Nigg Bay Scotland

A proposed reclamation of industrial land in Nigg Bay in the Cromarty Firth, Scotland would be carried out by pumping dredged material behind a phased series of bund walls. The fill material would be discharged from a dredger at a re-handling site near the mouth of Nigg Bay. Because Nigg Bay is an ecologically sensitive area, designated a Site of Special Scientific Interest, the Station was asked to advise on the possible dispersion of fine sediments into the Bay during reclamation, and the optimum location for the re-handling site. An appraisal was made by site inspection and the construction of circulation patterns from existing field data.

Cooling-water intake, Dounreay

The operation of the cooling-water intake at the UKAEA Prototype Fast Reactor at Dounreay in Scotland has been seriously hampered by large masses of seaweed which block the intake channel and chokethe drum screens. The weed grows profusely on the rock bed below low water mark at the site but is believed to be detached by severe storms. Once loose it can be moved inshore under the normal action of waves and tidal currents. The UKAEA are seeking a permanent solution to prevent the bulk of the seaweed reaching the offshore end of the intake channel. HRS have been commissioned to build a physical model of the site (natural scale 1/60), in which the conditions giving rise to the mass transport of the seaweed can be studied and alternative remedies tested. A preliminary wave-flume study, to the same scale, to select a model material to represent the seaweed has been completed. A satisfactory material in the correct size range and with the right shape factor can be made from braided nylon cord.

Heat dispersal from power generation on the British coastline

An outline study of the heat-dispersing potential of the British coastline was commissioned by the Department of the Environment's Directorate of Development Plans and Regional Policy. Long-term planning studies of coastal utilisation include the consideration of power generation and other developments releasing waste heat into the sea. It is desirable to assess the probable equilibrium increases of sea temperature arising from such developments in relation to their distribution on the coastline. The study was based on a highly-idealised treatment in an attempt to elucidate the principles involved and establish orders of magnitude of dispersing mechanisms and resulting temperatures. It was concluded that the most uniform possible distribution of heat rejection should be aimed at. While zones probably exist which provide locally greatly enhanced offshore dispersion they cannot be exploited unless identified with certainty by extensive and costly field work. The possible benefit from such zones is not considered sufficient to justify either the field work or a more ambitious numerical modelling study.

Beach mathematical study, Pisa, Italy

The Station has recently started a mathematical model study of the changing plan shape of the Tuscony coastline each side of the seaside town of Marina di Pisa. This study has been commissioned by the Town Council and Chamber of Commerce of Pisa, within whose province the coastline falls. Both north and south of the mouth of the River Arno, the coastline is eroding and the purpose of the investigation will be to explain previous changes along the coast, predict its future evolution, and suggest coast protection measures which might reduce any further shoreline retreat.

Beach nourishment

The Station continues to monitor changes following the completion of beach nourishment schemes in the United Kingdom. At Portobello, Scotland, a sand nourishment scheme, completed in 1972, was supervised by the Station. The nourished beach continues to protect the sea wall although in recent years there has been a noticeable lowering of beach levels at the toe of the wall. In 1979, the Station advised the Lothian Regional Council to steepen the beach again, by mechanical regrading. The effects of this are being monitored. In 1974-5 a sand nourishment project was completed in Bournemouth; until recently this, too was monitored by the Station. The scheme has so far proven to be successful. Monitoring is now being carried out by Southampton University with the Station retained as advisors.

Beach changes caused by coastal structures

The Station has developed a numerical model for predicting changes caused by the interruption of longshore movement of beach sand. It can be used for example to predict changes likely to occur in a shoreline adjacent to a harbour or groyne system. At present the model is calibrated for predominantly sandy beaches but it is to be extended so it can be applied to shingle. Data for the calibration will be obtained from an historical analysis of shoreline changes along the south coast of England (for example between Littlehampton and Dover) where there are large accumulations of shingle: the rate of volume change at these locations will be related to wave conditions.

Low-cost shore protection

A literature review is being carried out for the Department of the Environment into various forms of low cost shore protection. A variety of structures are being assessed for their effectiveness under coastal conditions with the emphasis placed on those which have both low construction costs and low maintenance costs. As well as studying reports it is intended to inspect existing schemes in the United Kingdom. Those structures which appear to have the greatest "potential" will be monitored.

Runup on shingle beaches

A large part of south-eastern England is low-lying and is protected from flooding by the sea by shingle beaches. These beaches are in many areas undergoing long term erosion and to maintain the existing degree of protection it is necessary either to renourish them with shingle or to shape the crest by mechanical means. At present there is very little field or laboratory information on the expected height of runup under different wave conditions. The height at which the shingle crest is at present maintained is therefore somewhat arbitrary. HRS is carrying out a programme of field measurements into the runup of waves on typical shingle beaches. Field measurements are also being carried out by the Canterbury City Council's engineers. The information will be used to produce a wave runup formula suited to a wide variety of beaches and conditions of wave exposure. It may also be possible to extend the formula to predict wave runup on a combined form of protection incorporating a sloping concrete apron and shingle beach. Enquiries are welcome from local authorities willing to co-operate in this study.

Breakwater stability study

An extension to a Mediterranean port has been proposed, part of which will require the construction of an extension to the existing rubble-mound breakwater. Models of various alternative designs have been tested at a scale of 1:50 under random waves in a deep wave flume. The different armouring considered includes tetrapods, antifer cubes and rock armour. Damage to the armour layers is measured using a photographic technique. It is anticipated that, on completion of these two-dimensional studies, a three-dimensional model will be commissioned to study the final design of breakwater, the roundhead and various construction phases.

Riprap protection for slopes subject to wave attack

Evidence of scale effect in model experiments of wave action on riprap armoured slopes is conflicting. To clarify the issue Messrs Binnie and Partners and the Central Water Planning Unit carried out field trials on test

riprap panels built onto the offshore trial bank in the Wash Estuary. The Station has subsequently modelled the riprap panels, subjected them to the principal storm conditions producing damage, and demonstrated within the limits of the available data that the model reproduces the field measurements. An extension of the earlier HRS tests, to higher and lower Reynolds numbers confirms the conclusion of the earlier study (CIRIA Report 61) that no allowance for Reynolds scale effect is necessary. However, some of these extended tests were made with model stone sizes and waveheights at the very lowest level at which it was practicable to test. Carefully controlled repeat tests showed significant differences in the resulting damage.

Stability of dolosse armoured slopes

With breakwaters now being built in very deep water, the wave directionality becomes an additional parameter in the stability of the primary armour. The Station is testing the stability of dolosse armoured slopes subjected to both long crested and short crested seas. The tests will identify the preferred method of model testing of breakwater sections.

North Wales coast road at Penmaenmawr

A model study has been carried out to investigate the rate of overtopping of a retaining wall at Penmaenmawr, North Wales. The wall is to protect a new section of the North Wales coast road (A55) which is to be built along the promenade. The study, which was commissioned on behalf of the Welsh Office by Messrs R Travers Morgan and Partners, predicted return periods for overtopping discharge rates of the retaining wall using results from a physical model at a scale of 1:64 (Report EX 1004).

North breakwater, Warkworth Harbour

Messrs R T James and Partners have commissioned the Station to advise on a proposed design for the protection of the dilapidated North breakwater to Warkworth Harbour against further scour and damage. This work follows model studies for the Property Services Agency of the breakwater as part of the FDGR Amble Scheme. Since the shelving of that scheme the local authority has gone ahead with plans to repair and stabilise the root and trunk of the breakwater as part of a coast protection plan. Design for this protection has been considered in the light of the earlier model studies.

Isle of Sheppey sea defences

Model tests were carried out with random waves at several angles of approach to assist in the design of improved sea defences on the Isle of Sheppey near the town of Sheerness. Two particular stretches of seawalls were studied — the northern seawalls protecting Sheerness from waves in the Thames Estuary, and the western seawalls giving protection from waves in the Medway Estuary. Several different seawall designs were examined, measuring the percentage of waves and the volume of water overtopping the wall for a number of wave heights, periods and water levels. Tide records at Sheerness and wind records at Shoeburyness were also examined to determine the correlation between high water levels and strong onshore winds, and hence to produce the joint probability distribution for water levels and wave heights. Combined with the model results, this enabled the return period for given overtopping discharges to be calculated for each of the alternative seaweall designs. The work was carried out for the Southern Water Authority (Report EX 947).

Alderney Breakwater Channel Islands

A physical model investigation is underway to examine proposals for the protection of Admiralty Breakwater in Alderney Harbour. Since its construction in the middle of the 19th century constant repair work has been needed to prevent its collapse. The PSA, who are responsble for the maintenance, first approached HRS in 1963 for advice on the problem of continued maintenance (EX 217) and again in 1981 with proposals for a final repair scheme. This involved the addition of a 'stub' breakwater on the inner face to protect the commercial berths, armouring of the outer face of the shoreward half of the breakwater with Tetrapods, and allowing the outer part of the

structure to decay naturally. The present model study is to investigate the likely effect on the harbour and bay due to the increased wave activity after the decay of the outer section. A 1:100 scale model was constructed in September 1981 which included the main breakwater, the harbour structures, the exposed bay and the cliffs to the west. Advice is also being given on the suitability of the proposed Tetrapod armouring, based on wave heights measured in the model.

Ballast Pond, Torpoint

The Ballast Pond, an old walled harbour situated on the foreshore at Torpoint, was formerly used as a shelter for ballast barges. Torpoint Yacht Harbour Ltd have consulted the Station on the effects their proposal to transform it into a yacht harbour would be likely to have on the movement of water and sediment in the area. Before recommending a programme of field measurements, an examination is being made of existing records of suspended solids concentration obtained for other purposes by the Institute of Marine Environmental Research and of measurements of the strength and direction of tidal currents provided by the Hydrographic Department of the Ministry of Defence.

Douglas Harbour breakwater

Design studies

Sir William Halcrow and Partners were retained by the Isle of Man Harbour Board to design a new breakwater to provide greater protection to Douglas Harbour. The proposed breakwater is about 375m long, and the original design called for 18 tonne 'Stabit' units as the primary armour, overlying 4-8 tonne rock, itself placed on a core of quarry run material. The Station was commissioned by the consulting engineers to investigate various aspects of the design, including improvements to wave disturbance in the harbour, and the stability of the breakwater (Report EX 1013). Wave disturbance tests and two-dimensional testing of breakwater stability were completed in 1980, and three-dimensional testing of stability was completed early this year. These last tests were carried out with the aid of a 1:90 scale model of the harbour and its approaches, examining the stability of the complete, breakwater under design wave conditions. Particular attention was paid to the stability of the roundhead, and the interfaces of the new breakwater with the existing Battery Pier and with the line of cliffs. As a result of the tests the consulting engineers derived a final design which differed from the original design principally by having a raised breakwater crest elevation and larger 'Stabit' units (23 tonnes).

Construction phase tests

French Kier Construction Ltd were awarded the contract to build the new breakwater, and in May 1981 they commissioned the Station to carry out a series of tests to examine the stability of the breakwater at various stages of its construction. Particular attention was paid to the winter close-down phase of construction, when sufficient primary armour would not be available to protect the exposed seaward end of the structure. The 1:90 scale model used for the design studies was used for then further tests which were mainly of a qualitative nature involving extensive use of video recording and still photography (Report EX 1014).

Proposed fishing jetty, Masirah, Sultanate of Oman

A brief investigation has been carried out into the possible siltation problems which might occur along the flanks of a proposed jetty on the island of Masirah, which lies in the Indian Ocean off the coast of Oman (Report EX 1034). The work was carried out for Messrs Brian Colquhoun and Partners who were acting on behalf of the Ministry of Agriculture and Fisheries of Oman. A futher aspect of the study was the specification of wave conditions to be used as a basis for designing the armouring for the landward portion of the jetty. The project was of brief duration, but included a visit to the proposed jetty site.

Seaton sluice harbour, Borough of Blyth Valley

The Station has been asked to advise the Borough of Blyth Valley on plans to improve navigation conditions at the entrance to this small harbour. A site visit and discussions with users will now be followed by an assessment of current and wave action and their effects on sediment movements. Recommendations leading to a reduction in wave disturbance at the entrance will be put forward.

Port Qasim, Pakistan

The Station is providing a continuing advisory service to the Port Qasim Authority. The work is funded by the Overseas Development Administration. Topics under this heading include: (1) advice on the acquisition of a position fixing system for hydrographic survey and pilotage purposes; (2) prediction and analysis of siltation in the dredged approach channel (Report EX 1003); advice on proposals for developing Bakran Creek, provision of shallow-water berths, reclamation of local catchments, alignment of the creek and preventing siltation in the canalised channel (Report EX 844); development of a computer program for calculating under keel clearance of a 25 000dwt vessel entering Port Qasim during the south-west monsoon period (Reports EX 916 and EX 1005).

Dammam ship repair yard, Saudi Arabia

The existing port at Dammam is to be extended to provide a ship repair yard with two floating dry docks. HRS was commissioned by Messrs PRC Harris Associates to carry out a wave prediction study for the site and to use the results as input to a random wave physical model which is being used to measure the mooring loads for the floating docks. A number of wave conditions with return periods up to once in 100 years originating from five different directions offshore are being used in a wave basin in which the dock site and models of the floating docks have been constructed at a scale of 1 to 100. It has been possible to reduce, to some degree, wave heights at the dock site by optimising the position of an offshore breakwater. However, the mooring forces (measured by specially designed force measurement equipment which simulates the proposed prototype mooring system) are still greater than specifications allow. As a consequence the breakwater has been moved much closer to the dock site and a revised, more compliant mooring system has been presented for evaluation.

Proposed coastal jetty at Sellafield

As part of a study by British Nuclear Fuels Limited to assess the feasibility of providing a jetty on the West Cumbrian coast adjacent to BNFL's Sellafield works for the transfer of large plant items from a sea going vessel to shore, HRS was asked to assess the effects of such a jetty on material transport along the foreshore. The work was based upon a site visit, a calculation of littoral drift, an analysis of tidal exceedance values and some experimental work on the response of a barge with small under-keel clearance to wave action.

Approaches to New Ross Harbour, Eire

In 1977 the Harbour Commissioners of New Ross requested a desk study to determine whether the navigation channel of the River Barrow could be improved to allow the port to accept larger vessels. Field survey work carried out in 1977-78 included the measurement of tidal levels and velocities, salinity and temperature ranges, together with the collection of suspended solids and bed material samples. This data was analysed and considered alongside other hydrographic and dredging information available. Recommendations were made with reference to two important reaches (Report EX 831). In the Red Bank Reach a trial dredge area was proposed in the hope that it could lead to the use of an alternative route while also providing information as to local deposition rates. Within the Whitehorse Reach a modest increase in depth of the existing navigation channel was suggested. In 1981 dredging was carried out in both these areas and a number of surveys have been analysed and predictions made as to possible future maintenance dredging within the two reaches.

Port Sally, Ramsgate

The cross-channel ferry between Ramsgate and Dunkirk is served by a terminal situated at the West Docks, outside Ramsgate's Royal Harbour. Although well sheltered from northerly and south westerly gales the terminal is exposed to wave attack from the east to south quadrant. Proposals were therefore made to construct an offshore breakwater to give protection from these directions. The Station was commissioned to calculate the wave climate at the ferry terminal, to assess the degree of shelter provided by the breakwater, and to estimate the effect of the breakwater on the strong tidal flows in the area. The study (Report EX 1019) was carried out by calculation and field measurements, and the results showed that because of various practical constraints on the location and alignment of the breakwater the reduction in downtime at the terminal was minimal, while at the same time the effect on tidal flow and associated siltation patterns was quite significant. The proposals have therefore been abandoned, and the Station has been further commissioned to carry out a feasibility study for a complete re-design of the ferry terminal area and the dredged approach channel. The studies have been carried out for the Sally Line Ltd, operator of the ferry service.

Port of Belawan, Indonesia

The Indonesian Government has commissioned Majufilm Production Pte Ltd of Singapore to make a documentary film covering all aspects of the research, design and construction of port development works at Belawan. The Station was sub-contracted to film the hydraulics research elements. These included general views of HRS tests being carried out on the physical model of Belawan and shots taken during the 20 months of field data collection.

Sea Port, Nigeria

During this year the Station concluded a major study for a new harbour to be constructed on the Nigerian coastline east of Lagos (Report EX 961). The total scheme consisted of an inner harbour to be constructed within a lagoon, accessible from the sea via a canal to be cut through the coastal strip of land. To provide anchorage and cargo berths and to protect the canal entrance a large outer harbour would be formed by a long western breakwater overlapping a much shorter eastern breakwater. On behalf of the Nigerian Government the consulting engineers Olawoye Waterman Associates (Lagos) in association with Coode and Partners (London) commissioned a series of studies, as follows:

Wave climate

Wave data in the form of site measurements and ship observations were used to estimate wave conditions with return periods ranging from once in 100 years to 28 occurrences in any one year. The predominant wave condition was a swell accompanied by underlying long waves with periods longer than 30 seconds that approached the harbour from a direction just west of south.

Wave disturbance in the outer harbour

A physical model to a scale of 1:120 was used to establish the most suitable length for the outer breakwater with regard to wave conditions at the anchorage, at the cargo berths and at the entrance to the canal leading to the inner harbour (Reports EX 962 and 983). The full swell wave and long wave spectra were generated in the model, and care was taken to model the waves overtopping the breakwater and being transmitted through its porous construction.

Wave disturbance in the inner harbour

A separate physical model, also at a scale of 1:120, was used to study wave conditions in the inner harbour (Reports EX 962 and 983). Wave spectra measured from the outer harbour model were used as input to the canal leading to the inner harbour. It was found that the construction of a resonating basin part way along the canal was effective in reducing the amount of long wave activity in the inner basin.

Stability of the breakwater trunk

The main breakwater will be of rubble mound construction, armoured with 6—10 tonne rock at a slope of 1:2. The breakwater design was unusual in having a relatively low crest elevation and no concrete roadway or parapet. A model of a typical cross-section of the breakwater trunk was constructed at a

scale of 1:36 in a long random-wave flume, and the stability of the seaward and landward forces determined. Movement of the rock armour was recorded using a photographic technique, and after a slight re-design following the first test the chosen cross-section was found to suffer very little damage at wave heights in excess of the 100 year design storm (Report EX 963).

Stability of breakwater roundhead

The breakwater roundhead, armoured with 6—10 tonne rock at a slope of 1:2, was constructed at a scale of 1:64 in a wave basin equipped with a random wave generator. Again movement of the rock was determined by photographic techniques, and the results showed that satisfactory stability could only be achieved by increasing the armour stone to 12—15 tonnes (Report EX 964).

Siltation in the harbour

Siltation in the harbour was estimated by desk calculations based on field measurements. The measurements, carried out by survey contractors to HRS specifications, consisted of vertical profiles of suspended concentrations and current strengths and directions. The results showed extremely low current strengths, wth suspended concentrations governed primarily by swell wave conditions. Calculations were performed to estimate siltation rates within the outer and inner harbours for different wave conditions (Report EX 1023).

Beach movements after harbour construction

The Station's beach mathematical model was used to predict accretion of the beach on the western, updrift side of the harbour, and the consequent erosion on the downdrift side. The downdrift erosion was particularly serious, amounting to a shoreline recession of 310m in 50 years at the worst location. The model was used to assess the effectiveness of beach nourishment in reducing the rate of shoreline recession, and also to examine the effects of constructing a series of groynes to translate the point of maximum erosion to a less unacceptable location (Report EX 984).

Collaboration with University of Lagos

The consulting engineers commissioned the Hydraulics Research Unit of Lagos University to carry out tests on the stability of the breakwater trunk, using the Unit's regular wave flume. As the main purpose of the tests was a comparison of the results with those obtained from the Station's random wave flume the Station provided considerable advice and practical assistance in constructing the model breakwaters, preparing the test programme, measuring the armour layer damage, and analysing the results. Firm conclusions have not yet been drawn, but it appears that for breakwaters with a very high degree of overtopping the differences between regular and random wave testing are small.

Mathematical model of a moored vessel

A computational model capable of estimating the response of a vessel moored in waves is being developed. Recent modifications to the model have been made to improve predictions when the vessel underkeel clearance is small. Comparison with results of previous physical model experiments is very encouraging, although more research is necessary to improve in particular, the simulation of pitch, roll and heave damping.

The effect of set-down on moored ships

Last year a series of experiments was carried out for the Department of Energy (Report EX 958) which showed that in water depths of up to 60m at least, set-down beneath wave groups could make a significant contribution to the slowly varying drift force in severe sea states. An improved version of the set-down generator (which adds an appropriate long period movement to the wave-maker) has now been developed. The frequency range of the set-down generator has been extended well into the 'surf beat' range of 1 to 4 minutes at full scale. Trials are now in progress.

Reflections within harbours

Experiments have been completed to investigate the effect of dredged channels on the wave climate within a harbour (Report IT 219). It has been found that resonances occur at certain periods with increased wave heights over the channel. The effect is most pronounced for waves approaching at normal incidence to the centre line of the channel but dies away rapidly for waves ap-

proaching at quite small angles to the normal. For much larger angles of incident the almost complete reflection of waves from the channel was observed much as predicted by wave reflection theory. For these large angles of incidence, wave heights over the channel are very much reduced.

Mathematical models of waves in harbours

Ray method

A mathematical harbour model based on a ray method is under development (Report IT 214). The model can describe the combined effects of wave refraction, diffraction around breakwaters and reflections (complete or partial) from harbour boundaries. The harbour ray model is most suitable for studying the response of harbours to storm and swell waves, conditions for which other types of mathematical model can become prohibitively costly on computing time. The model has been tested against an already-proven finite element type of model, with good agreement. A comparison of the ray model with results obtained from a random wave physical model is being carried out.

Long-wave propagation

Long waves, generated by set-down beneath wave groups, and having periods ranging from 30 secs to many minutes, are important in harbour studies because of their ability to excite resonant harbour modes close to the natural periods of horizontal oscillations of vessels on their moorings, thereby causing excessive mooring loads. A numerical model, simulating long wave propagation in shallow water, has therefore been developed, from an existing tidal model. The new model parallels the development of physical models already used in similar studies. Thus a long period random sea with a given incident wave energy spectrum is used to drive the model from an open boundary near the harbour mouth. Attention has been paid to the modelling of energy dissipation mechanisms within the harbour, and the radiation of energy from the harbour mouth, in an attempt to predict the amplitudes of the resonant modes more accurately.

Proposed harbour — long wave disturbance study

A random sea, long wave mathematical model study of a proposed harbour was carried out for British consulting engineers, Messrs Posford, Pavry and Partners (Report EX 1029). The newly developed model was calibrated against results of a previous physical model study of an earlier design for the same harbour. The calibrated model was able to reproduce, qualitatively, the changes in response measured when harbour boundaries were altered in the original physical model. The long wave response of the new harbour design was then studied. Several modifications to this layout were also investigated. It was found that there was no significant increase in overall long wave activity (periods 30 secs to many minutes) compared with the layout tested in the earlier physical model study, but a relatively short period (55 sec) resonant response in one region of the harbour may result in large surge motions of the larger commercial vessels moored there, when offshore wave conditions are severe. Some modifications of the original design were found to reduce this resonant response.

Estuaries division

Port of Brisbane study, Australia

The Port of Brisbane Authority is developing a new port facility at the entrance to the Brisbane tidal river at Fisherman Islands. The Station was commissioned to undertake a field and mathematical model study to predict

the effect of the proposed engineering works on sediment transport and siltation in the river navigation channel. The project had about 12 constituent parts involving 15 different specialists at HRS. The investigation involved a carefully phased schedule of desk, field, laboratory and mathematical model investigations. Reports have been written on (EX 807) Analysis of dry-season observations, August 1977; (EX 833) Geometry of the tidal reaches; (EX 829) Tidal propagation during the dry season; (EX 899) A two-dimensional depth-averaged mathematical model of peak tidal flows and sediment transport patterns in the swing basin; (EX 860) Depositional and erosional properties of Brisbane mud; (EX 892) An analysis of wet season observations, April 1978; (EX 873) Distribution and source of sediments causing siltation; (EX 893) A historical analysis of dredging in the port; (EX 917) Mathematical model studies of sediment transport along the tidal river; (10) Effects of mud accretion in the old port resulting from the cessation of dredging and (EX 977) Radioactive tracer studies on the movement of mud from the dredged spoil dumped ground in Moreton Bay. The frequency of fluvial floods is being assessed in terms of their volume and sediment carrying capacity. A multi-layer model is being used to calculate the trapping efficiency of the estuary for floods of different magnitudes, the aim being to determine the most damaging class of flood as regards siltation in the estuary and the prediction of the effect of the proposed works on the pattern of siltation.

Mathematical models of estuaries in New South Wales, Australia

In 1980, the Coastal Branch of the Public Works Department of New South Wales, Australia, commissioned HRS to supply them with a suite of programs for analysing and simulating tidal propagation in the estuaries in New South Wales. The Coastal Branch required a one-dimensional model which could calculate variations in water levels, discharges and velocities within a branched or looped system of channels with multiple ocean outfalls and fluvial inflows. There was to be an option to calculate saline intrusion and sand transport if required. Programs were supplied with comprehensive documentation together with an example of an application to the Port Hacking Estuary. Preliminary results from the example model of the Port Hacking Estuary indicated a marked net landward movement of sand along the Hacking Channel which agrees with the observed pattern of sand transport. The Public Works Department of New South Wales proposes to use the model as a tool to help them investigate the effects of proposed works in estuaries within the State. HRS has been asked to act as consultants for particular applications of the model techniques (Report EX 993).

The development of Port Kelang, Malaysia

In January 1980, the Port Kelang Authority commissioned HRS to carry out a detailed assessment of the hydraulic aspects of three sites for the possible extension of the Port on Pulau Lumut. Whilst two of the proposed schemes — that on the north-west of Pulau Lumut and that in South Kelang Strait were considered to pose few siltation problems, the third scheme ie development of a long wharf in Anchorage Reach, required investigation regarding its long-term viability. It was considered that siltation may become a problem later in the life of the scheme if the tidal flow to and from an adjacent channel decreased as a result of long-term siltation in what was thought to be a slowly deteriorating region of the Kelang Delta. In May 1981, HRS were commissioned by Messrs Coode and Partners, Consultants to the Port Authority, to carry out further hydraulic studies to predict the long-term changes in the depth of Anchorage Reach after the construction of the proposed wharf. A one-dimensional mathematical flow model was constructed which simulated tidal flows in all the major channels in the delta system. The proven model was used to predict the effects of siltation and engineering works in channels adjacent to the port developments on tidal discharges and hence flow areas and bed levels in Anchorage Reach. The model was also used to predict the effect of constructing a bridge and removing an island in an adjacent channel. The results indicated that depths would be adequate for both turning and berthing of vessels with a maximum draught of about 8m for about 70 years (Reports EX 889, 968 and 1031).

Radioactive tracer studies, Thailand

The Station was commissioned by Messrs Maunsell and Partners to advise on radio-active tracer experiments to measure short-term spoil dispersal during dredging operations in the access channels to the ports of Ban Don and Pattani, Thailand.

Outfalls to the River Tiber

A mathematical model of the outfall plumes of the River Tiber has been calibrated against data from infra-red photography and on-site surveys. The model has been supplied to Istituto di Ricerca sulle Acque (Rome) who are now comparing it with further data.

Shatt al Arab — siltation

The Station has been requested by the Salvage Association to provide an estimate of the depths to be expected in the two major deposition zones of the Shatt al Arab following 12 months without maintenance dredging — a consequence of the hostilities between Iran and Iraq. From the scant information available, a mechanism of siltation has been tentatively proposed for each of the two zones. The evidence suggests that depths in the main area of deposition, the approach channel, are primarily a function of wave activity over the shallow offshore mud banks flanking the Gulf shore, superimposed by the effect of seasonal variations in the amount of river-borne sediment transported down the Shatt al Arab. Depths on the Karun Bar above Abadan are considered to depend on the prevailing balance between sediment transport down the Karun and river discharge down the Tigris.

Belfast Lough, Northern Ireland

The Station was approached by the Department of the Environment for Northern Ireland for advice, first on long-term reclamation proposals and the location of drains and sewage outfalls in Belfast Lough,and later on the effects of tide control works to be constructed on the River Lagan upstream of Belfast harbour. A three-stage investigation was recommended involving (a) the analysis of existing field records; (b) the collection and analysis of further field measurements to provide necessary information in areas not covered by existing records; (c) a hydraulic investigation employing the appropriate method for studying the problems identified in (a) and (b) — most probably physical or mathematical models or a combination of the two.

Money Point generating station, River Shannon

The Electricity Supply Board, Eire, is developing a site for a coal-fired power station at Money Point on the north shore of the River Shannon, some 40km from the sea. HRS was commissioned to investigate the recirculation performance and configuration of the hot cooling-water plume throughout the tide for various stages of site development. This "near-field" problem was — quite exceptionally — considered to demand the use of a hydraulic model, built without distortion and to the largest possible scale. An area some 3km along the shore and 2km offshore (thus extending only half-way across the river) was chosen for modelling at a scale of 1:100. The restricted area covered by the model brought a corresponding complexity in the boundary conditions and control systems required. In particular, flow directions at the site differed markedly between flood and ebb and between spring and neap tides. The boundary conditions were identified as well as possible by field measurements and reproduced by 6 independently controlled sets of axial flow pumps, in addition to a pneumatic tide generator. The model was successfully proved to reproduce observed field float tracks. The model was first tested for an initial 1200MW development incorporating a 350m long jetty for coal-carriers. Subsequently the jetty was extended to 650m and increased generating capacities of 2400MW and 3000MW were studied. The results were presented principally as recirculation records for the intakes and coloured contour plots of the thermal plume, recorded throughout the tide by colour photography with dye and an array of thermistors (Reports EX 975 and 1017). Although recirculation performance was found to be generally satisfactory the jetty, especially with ships berthed, proved to be a serious impediment to the dispersal of the plume.

Mathematical modelling of siltation in tidal channels

Many ports were originally founded some distance inland along estuaries, which then became the shipping channel to the port. These natural channels have often had to be dredged deeper and deeper to accommodate each new generation of larger ships. Such deepening changes the pattern of tidal propagation and saline intrusion, sometimes causing increased siltation in the navigation channels. Chronic or seasonal siltation often burdens ports with heavy maintenance costs. The problem of determining which are the main factors which influence siltation in a particular navigation channel in an estuary has in the past been the cause of heated debate by engineers. The advent of the computer has enabled engineers to formulate mathematical models based on sound principles, which can be used to simulate and predict the movement of water, salt and sediment in tidal channels and hence the pattern of siltation. HRS has recently developed a model capable of simulating vertical variations in velocities, salinities and suspended solids in a new type of two-dimensional-in-depth model. It has been applied to the problem of predicting siltation in the Brisbane tidal river. The practical application of the technique has now reached a stage when it can be employed as an almost standard procedure for investigating and solving siltation problems in narrow estuaries. However, port works often involve the construction of dredged re-entrant and turning basins which give rise to sudden expansions in an otherwise narrow channel. At present this problem is usually handled by undertaking a separate calculation with a two-dimensional-in-plan model to calculate the distribution of siltation predicted by the channel model.

Numerical solutions of selective withdrawal flows

Selective withdrawal, in which an intake at depth in a two-layer stratified flow system draws fluid from the lower layer only, has been studied at length from both the analytical and practical engineering points of view. Many previous analytical and numerical solutions are considered to be less than satisfactory owing to their improvised treatment of the flow condition at the cusp, developed by the interface in a selective flow. The present study employs an integral equation technique, similar to that used for limiting gravity waves, which incorporates the correct analytical form of the flow at the cusp.

Properties of muds

Through basic research and repayment contracts over a number of years, the Station has gained a wide and varied knowledge of the physical properties of cohesive sediments. This has been further extended by contract studies during 1981. Data on the rate and density of consolidations of various muds haved been reviewed and re-analysed as an aid to the design of settling lagoons for the disposal of alluvial sediments to be dredged during construction of the tunnel crossing of the Conwy estuary. In addition, an experimental study of the progressing development of the density structure in a consolidating mud deposit under a range of conditions has begun in the re-commissioned 10m x 92mm dia settling column. In the field, a systematic evaluation of the effect of salinity and suspended solids concentrations on sediment settling velocity has been undertaken. This data is obtained by in-situ measurements in the Thames estuary, where the estuary regime is sufficiently well understood so that predetermined salinity and solids concentration combinations can easily be found.

Estuarine transmission of pollutants

The Station has been engaged on a two year study of the estuarine transmission of heavy metal pollutants, to determine to what extent the metals are trapped and stored within the estuary in the estuarine sediments, and how much passes out to sea. The study has been carried out in the tidal River Parrett, a tributary of the Severn Estuary. The field programme has consisted of sampling newly deposited bank sediments in March and September of each year, and of sampling sediments in suspension in the water. A 5m thick historic mud deposit at a disused riverside berth has been sectioned and sampled through its depth. The surface sediments of Bridgwater Bay, at the mouth of the River Parrett, and the shoreline sediments of the Severn

Estuary within 60km of the Parrett tributary, have also been sampled. All sediment samples have been analysed for concentrations of Fe,Mn,Zn,Pb,Cr,Cu, and Cd. The results from this study have combined to give a clear insight into the transmission of metal pollutants in a muddy estuary. The measured pollutant distributions are only slightly influenced by the local distribution of estuary sources. They are strongly influenced by the wider distributions in the Severn Estuary system, and observed systematic seasonal variations accord with the known sedimentary regime. The understanding emerging from this continuing research programme is of direct application to the legislative control of marine pollution from freshwater sources.

Tidal pollution models

The Hydraulics Research Station is developing a series of standardised mathematical models of the physical dispersal and biochemical degradation of pollutants which can be used to simulate and predict conditions in a range of classes of estuary. During the past year the Station has completed the development and testing of a one-dimensional mathematical model which simulates tidal propagation, saline intrusion, mud transport and oxygen balance in any network of tidal channels. The theory behind the interaction involved in the oxygen balance was developed by the Water Research Centre at Stevenage. A novel aspect of the model is that it simulates the transport and degradation of particulate pollutants attached to mud flocs. The model has been used to simulate conditions in the Parrett Estuary which has very high concentrations of mud in suspension. The particulate carbonaceous material and mud are assumed to be deposited and eroded together. At slack water the settling mud forms a layer of fluid mud which slowly dewaters to form a denser bed deposit if there is sufficient time. The model allows the carbonaceous material to continue to oxidise both within the fluid mud layer and in the denser bed below. If the deposit remains on the bed for long enough the porewater can become anaerobic. When such anaerobic deposits are re-eroded during high spring tides it exerts a sudden oxygen demand on the water column. The model shows that particulate BOD tends to accumulate in the zones of mud deposition in an estuary whereas the dissolved BOD fraction is distributed upstream and downstream of the outfall. The zone of mud deposition in an estuary does not alway lie close to the outfalls. It is proposed to extend the model to simulate the movement and accumulation of heavy metals which attach themselves to the clay fraction of mud in estuaries.

Deposition of sludge on sandy ripples

Following completion of a preliminary pilot study of the depositional behaviour of sewage sludge in suspension in flowing water, a more detailed experimental investigation has begun. Sewage sludge is being introduced into suspension in water flowing over a rippled sandy bed in a 0.60m wide x 34m long recirculating flume. The range of attainable flows spans the condition under which the sand ripples move. The critical conditions under which the sludge is deposited and blankets the sand bed are being determined, as an aid to the licensing and control of the disposal of sewage sludge by dumping in tidal waters.

Measurement of fluid mud layers

An equipment package is being developed which will enable high resolution vertical density profiles to be made in near-bed fluid mud layers. The package includes (a) a modified "Harwell" nuclear transmission gauge for density determinations, (b) a differential pressure transducer for accurate depth measurement and (c) a two-component electromagnetic current meter for measurement of mud velocity.

Sewage sludge disposal in Liverpool Bay

The eighth bed sediment survey was undertaken early in the year as part of the DOE-sponsored monitoring of the effects of sewage sludge disposal. Since 1973 short sediment cores have been recovered from a number of selected stations in Liverpool Bay to determine whether any trends in bed

composition can be detected. In addition to the usual size grading and organic content of the surface sediments, the mud component has been analysed for heavy metal concentrations. Comparison with earlier surveys continues and a further survey is planned for the near future.

Models of buoyant plumes

Mathematical models have been developed at HRS to investigate buoyant plumes from outfalls of various kinds. A one-dimensional model can represent river or thermal outfalls into a tidal flow which causes the plume to be deflected. The critical flow region at a river mouth is represented by an analogy with open channel flow at a sudden expansion. The flow downstream of a submerged discharge after is has risen to the surface can also be modelled in this way.

Numerical two-dimensional models of sediment transport

Work is proceeding in bringing the new two-dimensional sand and mud transport models in line with the two-dimensional depth-integrated tidal flow model system. Previously these sediment models could only cope with a uniform grid size, but it is now possible to obtain the full benefit of patched grids ie the facility to refine the grid size to provide detail in regions of interest. In addition the physics of the sediment transport processes built into the model is being improved and extended to allow erosion of mud and areas of inerodible bed to be represented.

Numerical two-dimensional models of tidal flows

The Station has continued to improve its two-dimensional flow modelling system. This system is capable of having a number of different sized finite difference grids in order to provide good resolution in areas of interest. These grids are joined dynamically and research was carried out into the effects this has on the calculation of tidal flows. One-dimensional (area averaged) representations of rivers may also be dynamically joined and the method of doing this was improved so as to eliminate the possibility of local instabilities at the join. The representation of the friction term has been improved enabling bed roughness to vary both spatially and temporarily. This last effect is a function of the water speed and corresponds to ripples on a sandy bed being possibly washed out at high flows.

Numerical three-dimensional models

A programme of research into the numerical formulation of three-dimensional models of flow and transport of salt, heat or sediment is being carried out. This involves testing the numerical representation of non-linear advection processes and of vertical turbulent exchange. The ICL distributed array processor at Queen Mary College, London will be used in this study. A design study has been carried out for a three-dimensional numerical model of water, salt and mud movement in the Severn Estuary. The model incorporates the results of HRS investigations into vertical turbulent exchange and into the deposition, consolidation and erosion of mud beds. This model has a very large computer storage requirement and is run on an ICL DAP, CRAY I or similar computer.

Thames Estuary — Barking Barrier construction

The Station has continued to give advice to Messrs Binnie and Partners, consultants to the Thames Water Authority, as construction of the surge-excluding barrier at the entrance to Barking Creek nears completion. During 1981, French Kier, the main civil engineering contractor, claimed that the siltation that has occurred during construction has been much greater than could reasonably have been foreseen at the time of tendering. To assist in assessing the claim, HRS were asked what siltation they would have predicted assuming implementation of the construction programme as planned, given only the information available to them in early 1979. Siltation was calculated using average values of suspended silt concentration interpolated from continuous measurements made previously at monitoring stations located upstream and downstream of Barking Creek, particle fall velocities obtained

from former laboratory tests on Thames mud and information on flow behaviour recorded during earlier model studies of different barrier construction stages. As a check on calculation procedure, the exercise was repeated using the values of silt concentration actually recorded during the period in question and taking account of the fact that the construction stage lasted six months longer than previously envisaged. Because untypically high river flows had been experienced during this time, both flood and ebb concentrations were higher than could reasonably have been foreseen at the time of tendering. The volume of siltation thus calculated lay within 5% of that which occurred.

Thames Estuary — Thames Barrier construction

The Station has continued to give advice as requested to Messrs Rendel Palmer and Tritton, consultants to the Greater London Council as construction of the Thames Barrier nears completion (Reports EX 981 and EX 1002). During the year the main civil engineering contractors, the consortium formed by Costain, Tarmac and Hollandsche Beton Maatschapij (CTH), proposed that a temporary sheet pile wall should be constructed to exclude the flow from a span of the barrier during installation of the sill so that essential diving work could be continuous instead of being restricted to slack water periods at high and low tide. The Station was asked what effects such works might have on conditions in Woolwich Reach, especially in the main navigation channel. Flow measurements were made in the river and a desk study was undertaken to determine the likely changes in current strengths and directions. Following the construction of the temporary wall a second survey was undertaken to check the validity of the predictions and to forecast the conditions likely to obtain in the navigation channel during subsequent span closures.

Thames Estuary — Brentford Aits Marina

A scheme for the development of a small boat marina on the north bank of the Thames just above Kew Bridge was referred to the Station by Messrs K A Lock and Partners. Advice was required on the effects the associated reclamation and dredging would be likely to have on the regime of the estuary. The results of earlier field measurements and hydraulic model tests undertaken by the Station in Syon Reach provided information on present conditions in the river at Brentford Aits. A desk study examined how tidal movements would be modified by the works (a) during the normal seasonal variations in river flow and (b) during abnormally high river flow. It was concluded that provided there was some realignment of the eastern sluice and the introduction of at least 20% permeability to the reclamation boundary above a level of +3.5m ODN, then the development should have no adverse effects on the river.

Thames Estuary — silt monitoring

The Thames Estuary silt monitoring programme commissioned by the Greater London Council in 1970 as part of the Thames flood barrier studies has continued at four sites — in Woolwich Reach above and below the barrier and in Halfway and Gravesend Reaches. The new logging equipment installed during the previous two years has performed well, affording a high level of data recovery. The siltmeter mounting and lowering assembly at the Gravesend site was completely refurbished during the summer. Following complaints of local siltation, the records of suspended silt concentration are being examined in conjunction with bed level surveys to determine whether there is any justification in allegations that hydraulic conditions in Woolwich Reach have changed significantly as a consequence of the construction of the Thames Barrier. The findings to date are that they have not.

River Trent inland port

The British Waterways Board have plans to build a new inland port on the River Trent at either Newark or Nottingham and to reconstruct sections of the lower Trent to allow sea-going vessels up to 92m in length and with 4m draught to navigate to the port at most states of tide. A major feature of the

plan is the provision of two barriers in the tidal section to maintain minimum water levels. A preliminary study has been made of the hydraulic effects of channel reconstruction and barrier operation on low water levels in the 85km tidal reach, using an existing physical model of the Trent, which was built for the Severn-Trent Water Authority in 1979 to study flood defences. A simple computational procedure has been used to assess the likely magnitude of siltation on the seaward side of the downstream barrier. (Report EX 1030). If the project is to proceed, the full engineering study will need to include a more rigorous analysis of the hydraulic problems.

Conwy Estuary tunnel

Following feasibility studies in 1978 and 1979 a route was chosen for a new crossing of the Conwy Estuary by tunnel, and in 1981 the Station was commissioned by Messrs R Travers Morgan and Partners, on behalf of the Welsh Office, to undertake further work. The objectives are to supplement the information obtained during the earlier studies and, in particular, to determine the optimum level for the vertical alignment of the tunnel. For this purpose a field survey has been made to investigate reports that bed levels in the low water channel fluctuate over short timescales, and the 1979 numerical model has been "taken off the shelf" and re-used to study various aspects of the latest layout.

Severn tidal power — sediment transport processes

In 1979, the Department of Energy commissioned HRS to undertake a desk study to assess the feasibility of mathematical modelling the sediment transport processes in the Severn Estuary. The main aim of the study was to establish to what extent it was possible to define and represent the various physical processes and phenomena that have been observed to take place in the Severn Estuary in a mathematical model. It was concluded that the present state of knowledge of the processes governing sediment transport in the Severn Estuary would make it feasible to construct deterministic mathematical models capable of predicting the important effects of the proposed engineering works on that regime (EX 969). It was proposed that two types of model should be used to solve the problem. Firstly, a modified type of two-dimensional, depth-averaged model which would use the results from the existing two-dimensional flow model with a 500m grid. The main features of this new type of model would be its ability to calculate the movement of several sand fractions and an idealised depth-averaged representation of the transport of mud simultaneously and to take into account the effects of unsteady flows and discontinuous distributions of sand and mud fractions on the bed of the estuary. Secondly, HRS proposed that an entirely new, three-dimensional (layered) model should be developed which would simulate the three-dimensional flow, salt and mud transport regime in the estuary. The proposed model would simulate all the significant non-linear interactions between tidal flows and the three-dimensional unsteady density fields generated by suspendedmud and dissolved salt. The model would therefore simulate the processes of vertical turbulent exchange, settling, consolidation and erosion of mud and the formation, flow, dewatering and re-suspension of fluid mud.

Sedimentation and salinity in Birkenhead Docks

The North West Water Authority would like to divert the freshwater flow of the River Birket away from the existing culvert in which it by-passes Birkenhead Docks, and instead discharge it into the dock system. The Station has been studying the effect of this proposed diversion on salinity and sedimentation in the docks (EX 1028). A field survey has measured the input and distribution of sediments from both the lock opening and the compensation water pumped in from the Mersey, and the existing salinity profiles. The data on sediment input in the pumped compensation water has also been applied to an appraisal of outline proposals to re-develop the Wirral Docklands. For this project the Station has assessed the effect on sedimentation of moving the point of discharge of compensation water, so that part of the dock system could be closed and re-developed.

Reclamation at Pyewipe, Humberside

The disposal of colliery waste from the Yorkshire Coalfield is a matter of great concern to the Local Authorities, and the County Councils of West Yorkshire and Humberside are considering the feasibility of using inter-tidal mud-flats at Pyewipe in the Humber estuary as a disposal site. Controlled tipping of colliery waste would progressively provide reclaimed land for industrial use.

Hydraulic model study

The promoters of the scheme have to satisfy the estuary conservators that the reclamation in all its stages will have no detrimental effects on the hydraulic and sedimentary regime of the estuary. In particular navigation to Grimsby and Immingham needs to be safeguarded and the possible effect of the reclamation on the dispersal of sewage from an outfall planned by the Anglian Water Authority needs to be evaluated. For these purposes, the Station has constructed a hydraulic model of part of the estuary including the reclamation site. It is a steady-state'frozen tide' model, in which the changes resulting from the reclamation scheme are being measured at a number of tidal states. In addition to the evaulation of the basic reclamation scheme the limits of acceptable variation to the scheme are also being assessed.

Erodibility of colliery spoil

The colliery waste would be tipped in the water of the estuary and would temporarily be subject to the local action of tidal currents as the reclamation advanced. The erodibility of reclamation materials under flowing water has been investigated at full-scale velocities in a flume. A range of materials, including both new spoil and old, weathered colliery waste, have been tested, and their performance interpreted in terms of the hydraulic conditions anticipated at the reclamation site.

Wave protection

The outer face of the reclamation will need to be protected against erosion by wave attack. The Station has calculated and analysed the local wave climate, and thence drawn up a family of design curves relating specified stable embankment slopes to the median size and density of protective stone required. This data is being used by the client to establish the availability and cost of suitable local materials that will provide adquate protection of the reclamation face.

Dredging of Restronguet Creek, Cornwall

The bed of Restronguet Creek is overlain by thick deposits of tailings brought down from ancient tin-mine workings. There is a proposal to dredge the tin-bearing alluvium for re-processing: the results would be a restoration of the creek to its original, deeper topography. The Station has been advising the promoters of the scheme on the hydraulic and sedimentary consequences of progressively dredging the creek. The existing regime of the creek has been established by field survey, and the erodibility of the tailing deposits has been investigated in the Stations mud research facility. From this data, the probably changes in tidal velocities have been calculated for alternative dredging schemes and the results applied to check that increases in velocity will not cause tidal erosion of the undredged deposits while the scheme proceeds. The likelihood that material dispersed into suspension in the water by the dredging process will be carried out of the creek into the main estuary of Carrick Roads has also been studied. The completed scheme will more than double the tidal volume of the creek. An analysis of historic charts going back to the year 1588, which spans the period when the creek silted up, was carried out to assess the likely changes in the navigational channel of Carrick Roads.

Severn Estuary silt monitoring

As part of the pre-feasibility studies for the Severn tidal power scheme,commissioned by the Department of Energy, suspended sediment concentrations have been continuously monitored and recorded at two sites in the Severn Estuary. The sites were chosen to be the island of Steepholm and the disused tidal oil jetty at Avonmouth, being representative of the lower and upper reaches of the estuary respectively. Monitoring was carried out concurrently at both sites over a period of 12 months. Computer analysis of the monitor records reveals characteristic patterns of sediment concentration peaks and

troughs through the tidal cycle at each site. The concentration peaks are interpreted in terms of sediment being transported from specific source areas in the estuary. A close correlation is found between mean suspended solids concentrations and tidal range. The results of this pilot study (EX 995) give a first insight into the tidal movement of silt in suspension and provide a sound basis for planning a more comprehensive exercise in any further study of tidal power in the Severn Estuary.

Silt monitoring at Ferry Bridge, Portland

A recording silt monitor was installed at Ferry Bridge, which joins the Isle of Portland to the mainland. It recorded the tidal and seasonal variations of suspended solids concentrations in the waters entering and leaving the Fleet behind Chesil Beach from June 1980 to January 1981. The resulting data have been analysed in conjunction with local wind records, to provide a data base against which any changes following construction of a new, realigned bridge can be identified.

Dredging technology

A simple numerical representation of the dispersal of dredged spoil from a point discharge to the water surface has been constructed. It has been tested and tuned against field data measurements from the River Plate,Argentina and the Severn Estuary, both of which it represents well. At present it is suitable only for steady or quasi-steady flow conditions, but it is proposed to develop a capability to model dispersal in varying tidal flows.

Lateral variations of constituents in tidal channels

A lateral variation of salt concentration has been observed in waterways and estuaries. This is believed to occur when the flow becomes asymmetrical, due to a channel bend, a lateral diversion or a confluence. The effect of asymmetrical flow may persist for a considerable distance downstream from such disturbances. Asymmetrical flows distort the simple boundary layer shear flow, mainly due to the existance of an extra lateral mean rate of strain in addition to the basic strain rate in the simple shear flow. It becomes, therefore questionable how the extra rate of strain affects the parameters of the turbulent flow, and the empirical constants to be used in the numerical simulation of turbulent flows. Field experiments were undertaken on a bend section of one of the deep flumes at Didcot Power Station, with dimension 6m wide and a 45° bend of radius 55m; water depth and velocity were about 3m and 1.5m/s respectively. Further field measurements were carried out in a natural stream with mild curvature. The water depth was 0.6m, the mean velocity 0.5m/s and the flow width at the free surface was about 3m. Velocity measurements, using both electro-magnetic and propellor current meters were carried out on the straight sections and also on the curved part. The results indicate an increase of the turbulence intensity and the turbulent energy in the outer region of the curved section. Furthermore they reveal the appearance of double peak in spectra indicating the existance of large coherent flow structure in the outer region, which may be responsible for the transport of the constituent.

Surface plume in a cross-flow

In calculating the spread and dilution of an effluent discharged from an open channel into a cross-flow, it is customary to assume that the velocity and scalar quantity profiles are self-similar everywhere, including the bent-over region of the plume. It is usual to introduce one or more non-universal constants ie the entrainment and drag coefficients, so that the predicted quantities fit the measurements. Similarly it is usually assumed that the pressure field is hydrostatic, which is questionable in the bent-over region. A physical model study is therefore being undertaken by discharging heated water from a channel into a cross-flow of cold water for a range of channel and cross-flow velocities. The trajectory and mean velocity and temperature profiles will be measured in the model. The experiments will be carried out for various initial conditions of the warm water discharge and of the ambient velocity.

Stratified flow

The Station has started to examine the dynamic behaviour of estuaries where the flow becomes stratified. It has been found that stratification affects the mechanism of turbulence and its related parameters such as the coefficient of the turbulent diffusivity, the drag coefficient and the roughness length. Field survey data have been obtained in the Great Ouse and River Forth estuaries when the tidal currents were stratified and unstratified. They have been analysed to improve the understanding of the behaviour of stratified estuaries and the numerical simulation of tidal flows.

A study of simulated tidal flows

Good agreement has been found between turbulence measurements in simulated tidal flow in the laboratory, and field measurements from the Great Ouse and both the deep and the shallow parts of the Irish Sea. A more detailed study of turbulent dispersion has therefore been initiated in the Station's tidal flume, in which measurements can be made under closely controlled conditions to determine the terms that are used in the numerical simulation of tidal flows. In this study, the tracer fluid is warm water emitted from a point source. The warm water matches the unsteady flow and instantaneous velocity and temperature measurements are made at sections downstream from the point source.

Saline intrusion in complex channel systems

The pattern and limit of saline intrusion in a tidal channel system is determined by the balance between the rate of longitudinal mixing causing the landward movement of dissolved salt and the seaward movement induced by residual freshwater discharges. The presence of branches and loops in a tidal system gives rise to a complicated pattern of residual discharges. The interconnected character of such systems also allows salt to penetrate into some areas from both the seaward and landward directions. The Station has developed two types of one-dimensional model to simulate and predict saline intrusion in such systems (EX 1025). The first model calculates the seasonal variations in the limit of intrusion during high spring tides and is used to predict the effect of droughts and upstream abstractions on the pattern of saline intrusion throughout a dry season period lasting many months. It has been successfully applied to simulate and predict conditions in the Irrawaddy Delta. The second model calculates the movement of water and salt within a tidal cycle and has a timestep of about 20 minutes. The main use of this type of model is to simulate the intermittent intrusion of saltwater round looped systems which have a fairly high fluvial flow and in which the pattern of saline intrusion reacts quickly to changes in the fluvial flow rates. This model has been used to simulate saline intrusion in the lower Meghna Delta in Bangladesh.

Mixing processes in estuaries

Vertical, lateral and longitudinal mixing processes play an important role in the physical dispersal of suspended and dissolved material in an estuary. These processes are not well understood at present. A co-ordinated programme of field observations and theoretical analyses have been undertaken in co-operation with the Tidal Waters Research Group at the Department of Civil Engineering at the University of Birmingham. Observations of vertical turbulent fluctuations in partially stratified flows in the Great Ouse Estuary made in 1979 were analysed. The results showed that the set of mixing length functions devised and used by HRS are probably adequate for prescribing vertical mixing in gradually varied stratified tidal flows. They also indicate that damping effect of stratification is not well represented in the present generation of multi-parameter turbulence models. However, the mixing length approach cannot take into account the effects of the unsteadiness of the flow which may be important in some estuaries. The University of Birmingham undertook a review of theories for calculating longitudinal dispersion in area-averaged, one-dimensional models. A full set of observations of the time-varying transverse distributions of velocity and salinity were made in the

Conwy Estuary in September 1981. The value of the effective coefficient of longitudinal dispersion calculated from the observations will be compared with the values derived from theories. However, transverse variations of velocity and solute concentrations are only one of the causes of longitudinal dispersion and it may be some time before there is a generally accepted theory for prescribing dispersion coefficients in estuaries in terms of local area-averaged parameters.

Mersey Estuary —
General studies

At the instigation of the Acting Conservator of the Mersey Estuary HRS has held a series of meetings throughout the year with the respresentatives of nineteen different organizations having an interest in the estuary, with the aim of designing a programme of studies which would examine both current problems and the impact on the estuary of future projects. The organizations fall within the broad categories of statutory undertakings, local government, port authorities, oil companies and local industry. The object of tackling the issues in this way is to establish where several different problems can be examined by the same method of study, eg using a physical or a mathematical model, and so effect economies which are not possible when specific investigations are commissioned only after the need for answers has become urgent. The Station is currently formulating proposals enabling a variety of aspects to be investigated including flooding, scour and siltation, land reclamation, channel training, the disposal of dock silt and the effect of a Mersey barrage.

Dredging and dumping

For many years it has been obligatory for all channel and dock dredgings to be dumped outside the known influence of the Mersey Estuary system. As a result, with each load, over 50 miles had to be travelled to and from designated spoil grounds in Liverpool Bay. The inner estuary authorities and localities mainly affected were the British Transport Docks Board in Garston Docks and the Garston approach channel, and the Manchester Ship Canal Company in the approach channel to Eastham Locks, the ship canal and the QEII dock. Periodic requests to the Acting Conservator of the Mersey to permit dumping within the estuary were refused because it was feared that the tidal capacity of the system would decline if dredged material were not removed completely, as opposed to being merely redistributed. Over the past five years, during continual consultation with the Station, the Acting Conservator has sought ways of modifying this policy with the following outcome:

(1) *Garston Channel* Following consent given in June 1977 to the British Transport Docks Board to dump sand dredged from the Garston Channel in a depression in an adjacent area of sand banks, the Station has this year continued its monitoring of the monthly bed level surveys and sediment sample results obtained from the dredging and dumping zones. So far no evidence suggests that the practice should be discontinued.

(2) *Eastham Channel* Following a similar request from the Manchester Ship Canal Company to dump sand dredged from the Eastham Channel in a depression in the Eastham Sands, the Station is examining the viability of the proposal and is formulating a field survey to examine conditions at the proposed deposit site. If satisfactory, carefully controlled dumping will begin and regular bed level surveys and sediment sampling will be carried out.

Reclamation at Ince Banks

The Cheshire County Council has sought the Station's advice on the studies needed to determine the hydraulic effects of reclaiming increasingly large areas of Ince Banks for waste disposal. The main questions being asked are:

(1) What will be the effect of reclamation on tidal propagation and hence on the tidal volume of the estuary?

(2) What are the chances of the low water channel coming into contact with the reclamation boundary?

(3) If (2) occurs, how can it be ensured that the low water channel will not remain pinned to the reclamation boundary?

(4) What will be the effect of the reclamation on scour and siltation in the estuary?

The Station is proposing to undertake physical and mathematical model studies to investigate (1) (3) (4) and a desk study for (2)

Severn tidal power

Hindcasting extreme waves

The wave climate, particularly extreme waves, would influence the design, construction and working of a tidal barrage in the Severn Estuary. The Station has therefore carried out a three-year wave recording programme at selected sites. However it is economically possible to obtain measurements from only a few sites. To supplement these results the Station has set up a numerical model to hindcast wave heights for additional locations using wind speeds and directions recorded at Rhoose, Milford Haven and St Mawgan. The model was calibrated against wave heights and periods measured at three sites during nine storms when windspeeds at Rhoose equalled or exceeded 30 knots. Wave heights and periods were then hindcast for many additional sites covering possible alternative barrage lines. The work was commissioned by the Energy Technology Support Unit at Harwell, as part of the Severn Barrage pre-feasibility studies, on behalf of the Department of Energy.

Wave climate

Data collected during the wave recording programme has also been used to produce gross short term statistical information and to predict the probability of extreme values of significant waveheight. A good waveheight/windspeed calibration was obtained thus allowing the more extensive available wind data to be transformed into a 21 year waveheight data set. The standard methods of predicting extremes have been evaluated using this longer waveheight data base. An alternative solution is presented which is a better fit to the data.

Sediment flux measurements

Sediment flux measurements were carried out at two selected sites in the Severn Estuary throughout a mean tide, using the Station's standard pumped sampling equipment (HRS Annual Report 1977). At the same time, preliminary trials were carried out on a new sediment flux measuring system aimed at dispensing with the need for a pumping line between the underwater unit and its attendant vessel. Instead submerged pumps, filtration units and flow meters are mounted on the underwater unit thus allowing the tether to be reduced to a single suspension/electrical cable. The new unit will offer considerable advantages for utilisation in high velocity flows and its development is continuing.

Current metering and water sampling in fast deep flows

Further development work has been carried out on the equipment originally designed for measurements in the Severn Estuary (HRS Annual Report 1980).

Design studies for physical model

Experimentation on a physical model of the Severn Estuary has been envisaged as forming part of a full feasibility study of Severn tidal power but because of the long lead time before results from such a model become available, detailed design studies were commissioned during the pre-feasibility stage. The Station has examined the information obtained during the implementation of a specifically designed programme of field measurements which, together with a study of available hydrographic surveys of the Bristol Channel, has enabled decisions to be made about model scales, tide generating equipment, salinity and fresh water control systems and the best method of reproducing the required discharge through the barrage. An appraisal was made of previous attempts to reproduce Coriolis effects on physical models either by mounting them on turntables or by installing rotating cylinders in the flow to generate a lift force.

Numerical model of the Severn Estuary

The proposed tidal barrage will affect tidal flows and sediment transport over a large area of the estuary. The Station's numerical model of the estuary provides a means of adequately quantifying these effects because of its fine scale (500m) resolution over the areas of interest.

The model was used to predict potential changes in mud deposits and sand transporting capacity arising from an operating tidal barrage for two alternative alignments near the Holm Islands. The conditions arising during the closure sequences were also modelled; this is when most of the barrage has been built but with the remaining gaps causing high flows with possibly damaging effects on existing muddy areas.

The effect of not including Coriolis forces in modelling the estuary was examined in order to determine the discrepancies which would arise in a future physical model of the area, as it would not be possible for such a model to satisfactorily include these forces.

Rivers and drainage division

Brantas River

A simulation model of the Brantas River is being developed for water resource management studies. The model will include the effects of releases from reservoirs, abstrations for water supply and irrigation, and the operation of flood control structures.

Wimborne bypass, River Stour crossing

A proposed bypass for Wimborne involves embankment crossings of the flood plain and a bridge across the river channel. Dorset County Council requested the Station to investigate the effects on flood levels of (1) the new crossing and (2) removal of a disused railway embankment. Calculations indicated that increases in flood water levels upstream in Wimborne would be very modest and that no significant reduction in these levels would result from the removal of the railway embankment.

Blandford bypass, River Stour crossing

A study to determine afflux across a proposed crossing of the River Stour was commissioned by Dorset County Council. A numerical model was used to calculate the increase in water level upstream of the structure for flood flow conditions.

Flood relief scheme, River Medway

A desk study, undertaken for British Railways Board, Soil Mechanics Section, was made to determine hydraulic conditions at flood times which would obtain at the intersection of a railway embankment and a flood bank forming part of the Medway Flood Relief Scheme. The results were used to check the design of protection for the railway embankment.

Ipswich bypass — Western section

The Western section of the Ipswich bypass will cross the River Gipping near the village of Sproughton. It is important that the new bridge does not adversely affect flood levels upstream or create unsatisfactory hydraulic conditions near the bridge. A physical hydraulic model, commissioned by the Eastern Road Construction Unit, has been used to study two alternative routes for the crossing. The results of the investigation were used to ensure that the requirements of the Anglian Water Authority were met with regard to flood conditions and that the alternative bridge structures were both economic and hydraulically satisfactory (Report EX 1016).

Flood plain flows

The investigation has continued into the use of the finite element method in models of steady flow on river flood plains. Several mathematical descriptions of the flow and numerical treatments of the resulting equations have been compared. A new technique of evaluating the velocity gradients has been developed and its characteristics are being investigated. The resulting models will be tested against laboratory and field data.

Flow in embanked rivers

The computational hydraulic model studies of the Lower River Severn and the River Avon have highlighted some problems in the modelling of flow over river embankments. The Station is developing a more accurate and stable method of predicting such flows. Existing software will be enhanced in the light of these improvements.

River model graphics

The Station is developing a set of flexible, modular computer programs to plot results from its computational river model software. The programs use the GHOST graphical routines developed by UKAEA at Culham which can drive a variety of graphics devices.

Revision of FLUCOMP river model

The Station has completed a substantial revision of the software and documentation of the FLUCOMP river model. This work was funded partly by Severn-Trent Water Authority, Southern Water Authority, Welsh Water Authority, Yorkshire Water Authority and the Greater London Council. The revision incorporates user's experience of the original version of the model together with recent advances in modelling and programming techniques (Report EX 999).

Documentation of the River Severn model

Severn Trent Water Authority have commissioned HRS to document the model used in the Lower Severn study for use within the Authority. This documentation contract covers the transfer to STWA of the model and its results stored on the HRS computer, and the production of a user's and programmer's guide to the software developed during the study.

Lower River Severn

The study of the River Severn between Worcester and Avonmouth, commissioned by Severn Trent Water Authority, has been completed. A two part report (EX 945) has been delivered to the Authority who are planning flood alleviation works in the river valley based on the Station's model results. The works may involve major improvements to the main river channel and the installation of control structures and outfalls.

River Avon

The Severn Trent Water Authority is considering means of improving land drainage and flood protection in the Avon valley between Evesham and Tewkesbury. The Station's model of flow in an embanked river is being used to assess the effects of various design proposals. The topographic data for the study has been processed with the Station's digital terrain model, which also produces maps of the predicted flood extent.

River morphology

Progressive changes in the regime of rivers are commonly induced by engineering works such as dams, regulation structures, flood relief channels and river training schemes. These works often cause changes in water flow and sediment transport and this in turn results in long term changes to the river bed. One-dimensional mathematical models have been developed to determine long term accretion and erosion including effects due to armouring and sediment sorting caused by differential sediment transport rates for different sediment sizes. Visitors to the Station have applied these models to reaches of the River Nile and the River Rhine. (Report IT 221).

River Stour

The Wessex Water Authority has commissioned the Station to undertake a study of the Dorset Stour, with particular attention given to flooding at Blandford, Wimbourne and Christchurch. Models of river reaches are being developed using the revised FLUCOMP package. Results from the models will be used in the design of flood alleviation schemes. Input discharges for the models are provided by a FLOUT model for the whole river. This model will also aid flood forecasting.

Accidental releases of pollutants

A study was carried out for the JET Laboratories at Culham on the effect of accidental releases of pollutants on concentration levels in the neighbouring groundwater and river flow. Two possible paths of the waterbourne pollutant were considered; one where the water entered the storm drainage system and then into the adjacent river and the second where the water passed into the groundwater and was slowly released into the river. Predictions of concentration levels of pollutant as a function of time were made at various locations along the River Thames (Report EX 998).

Trends in current meter characteristics

Progress has been made in establishing the trends of the calibration characteristics of current meters with time. Sufficient data on individual current meters are now available and the data analysis and report are in preparation. The effect of servicing on the calibration characteristics is also being studied.

Uncertainty of current meter calibrations

Current meters with a rotating element are calibrated by towing at a succession of known speeds through still water and measuring the corresponding rate of revolution of the impeller. If an observation is repeated at a particular speed there is usually a variation in the values obtained, even under carefully controlled conditions. In order to determine this uncertainty of the calibration, multiple measurements were made at selected speeds over the range of calibration. From these data the uncertainty of the calibration relation synthesised from the individual points has been determined.

Calibration of current meters

The Station has continued to calibrate current meters on behalf of clients in the United Kingdom and overseas. In addition, at the request of the Water Data Unit, group calibrations were developed for the Braystoke 002 meter and for the recently produced 001 meter with modified impeller and nylon body (Report DE 53).

Bridges over alluvial channels

In association with Messrs G Maunsell and Partners the Station is preparing a state of the art review of the hydraulic factors affecting the design of bridges over alluvial channels. References are being listed and examined and a report compiled.

Sediment transport in rivers

When a dam is constructed on a river a proportion of the sediment is trapped in the lake behind the dam and the supply of sediment to the river downstream is reduced. The way in which a river adjusts to this deficiency has been investigated in a 2.4m tilting flume. The resultant decrease in bed load and change in composition of the bed material measured in the flume will be compared with predictions from a numerical river model. Another aspect of sediment transport in rivers that is little understood is the motion of particles where there is a wide range of grain sizes present on the bed of a channel. Field measurements are being carried out in collaboration with the University of Canterbury, Christchurch, New Zealandto study sediment movement in this type of river. For this purpose the Station has developed a vortex extractor to separate sediment from samples pumped from the river.

Hydraulic roughness of weeds

Many rivers support the growth of aquatic weeds during summer. In some ways this vegetative growth is desirable in that it provides cover for wild life, and may protect the banks from erosion. It does however increase the hydraulic roughness of the channel, and this may cause more frequent or more serious flooding. As the vegetation is flexible, its hydraulic effect is not readily calculable. Flow measurements are to be made at selected sites and flume studies are to be undertaken using synthetic vegetation to determine and express in some useful way the hydraulic effect.

Flow forecasting in tidally influenced rivers

The Water Research Centre has commissioned HRS to produce a simple model of bulk flow in a tidally influenced river. The purpose of the model is to forecast water levels in the reach where flooding may be caused by tidal or fluvial events. A model based on existing software was developed and applied to the Rivers Trent and Ribble. Severn Trent Water Authority have sponsored refinement of this model for operational use on the River Trent (Report EX 1001).

Buenos Aires access channel,Argentina

The main navigation channel in the River Plate connecting the part of Buenos Aires with the sea is being improved by capital dredging to increase its depth and width. The Station is providing technical advice and assistance to the consortium of Argentine consulting engineers responsible for the supervision of the dredging contract. A small sedimentiation laboratory has been set up in Buenos Aires and the strategy of the field survey programme to monitor and control the environmental effects of dredging and spoil disposal has been drawn up in consultation with the Station.

River Ribble — cessation of dredging

In conjunction with consulting engineers Sir W Halcrow and Partners, the Station has examined the consequences of the closure of the Port of Preston on flood protection and the drainage of low-lying land (Report EX 948). The cessation of dredging will result in a rise in bed levels along some reaches of the estuary, and a consequent change in high and low tide levels. A mathematical flow model was used to determine water levels under various tide and river conditions, for both the present and the estimated future bed levels. The results showed that changes in high tide levels would be restricted to a 10km length in the upper estuary, while low tide levels would be affected over a longer length of the channel. The sensitivity of water levels to bed levels was also examined. The Station's advice culminated in the presentation of expert evidence to a House of Lords Select Committee examining the proposed legislation.

Drainage function of the Manchester Ship Canal

Due to the decline of shipping activity in the upper reaches of the Manchester Ship Canal it may become unnecessary to maintain the present canal dimensions for navigational purposes. The canal does, however, have an important land drainage function since it provides part of the courses of the Rivers Irwell and Mersey which drain a large area of Lancashire, Greater Manchester and Cheshire. On behalf of the Manchester Ship Canal Company, HRS is investigating the feasibility of allowing the canal to revert to a more natural, less controlled, regime without diminishing the flood protection it provides. A study of the 12 km reach from central Manchester to the Mersey confluence has been completed, and a complementary investigation from the Mersey confluence to the tidal limit at Warrington is being considered. In the first study sediment transport rates and dredging quantities were determined and flow profiles were computed using a mathematical model. It was concluded that the present canal dimensions are more than adequate to convey all known flood discharges but that if dredging ceased the channel could not transport the sediment load arriving from upstream. Flood protection would

therefore gradually diminish. Some siltation in the canal could be permitted, but in the future dredging would have to be resumed to maintain the present standard of flood protection (Report EX 1015).

Vaivase headrace, Western Samoa

The assistance of the Station was sought by Messrs Mander, Raikes and Marshall to determine the performance of an intake and tortuous pipeline system designed to carry water from a river to a small reservoir. The analysis indicated that, for the required operating conditions, the pipeline would not run full and that some modifications to the proposed relief and pressure control valves were needed.

Victoria Dam, Sri Lanka

Victoria Dam on the Mahaweli Ganga in Sri Lanka is an integral part of a comprehensive scheme of power generation and irrigation. The dam is a double curvature concrete arch structure 100m high, spanning a narrow gorge 450m wide at the crest level of the dam. The design maximum flood discharge of 8500m^3/s is transmitted by an overspill crest in the centre of the dam and controlled by eight radial gates. These are 12.5m wide and lift to clear a head of 11m. Energy is dissipated by a system of flow splitters on the crest and a concrete apron extending 110m from the toe of the dam. In addition, twin low level pipe outlets controlled by lifting gates, discharge onto the apron through high trajectory flip-buckets. A low level intake near the dam supplies a 210MW power station through a 5km long tunnel that bypasses a steep rapid close to the dam, thereby augmenting the operating head. Three models were built: (1) A 1:80 scale model of the whole dam and of a stretch of the river either side of the dam was used to investigate flow conditions in the river during and after construction of the dam and to study approach conditions to the tunnel intake. (2) A 1:40 scale sectional model was used to investigate the performance of the crest gates and the efficiency of the energy dissipation system. (3) A 1:25 model was used to develop the design of the low level outlet flip-buckets (Report EX 1006). In order to allow the site engineers to investigate unforeseen problems during the four year construction period of the dam a replica of the 1:80 model has been built at the site under the supervision of the Station. The Victoria Dam project is being funded by the Overseas Development Administration. The consulting engineers are Sir Alexander Gibb and Partners and the contractors are Balfour Beatty Nuttall Joint Venture. Construction began during 1980.

Chisumbanje Intake, Sabi River, Zimbabwe

The Sabi river has a catchment area of 43 400km^2 to the Sabi gorge and forms the largest internal river system in Zimbabwe. The mean annual runoff to this location is 2390 x 10^{6}m^3 based on 21 years of records. The highest observed flow was 4600m^3/s in 1962/63. The combination of good water supplies in the upper part of the Sabi catchment, where rainfall is plentiful, and large areas of irrigable land in the more arid lower parts of the catchment makes the development of large scale irrigation projects attractive, assuming adequate storage reservoirs can be provided. One proposal is to increase the irrigation area at Chisumbanje from 2400ha to 13 500ha for an ethanol/sugar project. The present model study is concerned with the new intake required for such an expansion. A mobile bed non-Froudian river model is being used to choose the optimum siting for the intake and to evaluate the need for river training works. Model scales are horizontal 1:120, vertical 1:20 and discharge scale 1:5000. A separate fixed bed model will be used to optimise the design of the intake itself (Report EX 991). The study which is financed by the Overseas Development Administration is being carried out for the Ministry of Water Development, Salisbury, Zimbabwe.

Sproughton intake, River Gipping

A short series of tests has been commissioned by the Anglian Water Authority to provide data to assist with the redesign of a gated structure used to control water level at the intake. If the bed level was raised locally at the structure,

the replacement gates could be smaller and forces would be reduced. The tests, to be made in an existing physical model of the Gipping, will indicate the hydraulic effects of the raised bed.

Degradation on the River Nile

During the first half of this century a series of barrages were constructed across the River Nile to maintain water levels in order that irrigation water could be abstracted from the river. The barrage at Esna, 167km downstream of Aswan, was constructed in 1908 and subsequently raised in 1948. The closure of the High Aswan Dam in 1963 has had a significant effect on the movement of sediment in the Nile and has resulted in increased erosion downstream of Esna barrage. The age of the barrage and the increased load placed upon it by the erosion downstream has led to fears about the integrity of the structure and there has been a proposal that the barrage be replaced. HRS is currently involved in a study for the Overseas Development Administration of the movement of sediment associated with the barrage and the effect of replacing the barrage with a new, higher structure.

Crest tapping on Crump weirs

Crump weirs that are to be used for measuring discharge in the drowned flow range are provided with crest tappings to enable measurement of the pressure in the separation pocket just downstream of the crest. These crest tappings are susceptible to blockage in two ways. When river flows are sufficient to carry bed load over the weir, the particles gravitate through the tappings. When the stage is rising, water passes through the tappings to raise the stilling well level and suspended load settles out throughout the system. The Station has been experimenting with a siphon system that feeds water continuously into the crest tapping well from the upstream gauged head well to create a constant outflow from the tappings, thereby excluding suspended sediment and a proportion of the bed load. The system was fitted to a prototype weir whose crest tapping trap had been cleared of one year's accumulation of sediment. The aim of the system was to establish a rate of flow that would exclude a worthwhile proportion of moving sediment without creating a driving head on the crest tapping well that would introduce an unacceptably high error in the crest tapping head reading at any stage. The system was monitored and developed over a period of one year and was found to be completely successful in maintaining sediment free crest tappings.

Chatra main canal intake, Nepal

The headworks of the Sunsari Morang Irrigation Scheme are located on the east bank of the Sapt Kosi River at Chatra in Nepal. In this region the bed slope of the river flattens markedly, causing heavy sediment deposits. These deposits have diverted the active river channel westwards, so that insufficient water is obtainable for irrigation. Tests to develop suitable control structures were carried out on a model (horizontal scale 1:190, vertical scale 1:76) first using a rigid bed then a mobile bed (Report EX 955). The work was done in association with Messrs Coode and Partners, consulting civil engineers to HM Government in Nepal, and was financed by the Overseas Development Administration.

Performance of petrol and oil interceptors

Tests have been carried out for the Property Services Agency of the Department of the Environment to determine the efficiency of separation of the small, 3-chamber petrol interceptor (GLC type) commonly fitted to surface water drains. Shortcomings of the traditional design have become apparent during the tests — in particular the provision of dip-pipes between chambers leads to high surface velocities in the chambers, which re-entrain the already separated petrol layers. Testing has continued with a modified design incorporating a drowned inlet and submerged full-width slots between chambers. The interceptor has been converted to a standard 2-chamber oil interceptor and its efficiency of separation has been determined using lubricating oils and diesel fuels as the contaminants.

Capacity of road gullies

An experimental study of the hydraulic efficiency of four types of gully grating used in roads has been carried out by Oxford Polytechnic under an extramural contract. Data from the study will be used to produce a general design method for determining the spacing of gullies.

Motorway drainage trial

Field measurements have been made of the performance of a new system of motorway drainage that uses surface channels instead of underground pipes. The section of hardshoulder along a 1.6 km length of carriageway was used to convey run-off to a discharge point at the downstream end. Over a period of 18 months automatic measurements were made of the rate of rainfall, the depth of flow along the hardshoulder and the discharge at the downstream end. Data from the trial will be used to check a design method for long surface channels that has been developed at HRS. The study is being carried out for the Department of Transport.

Electromagnetic gauging in sewers

Recently the Station has completed calibration tests on behalf of the Water Data Unit of commercially manufactured equipment for measuring flow in rectangular open channels. One aspect of the tests was to establish the minimum length of insulated lining which was necessary in the channel (Report IT 212). The technique might now be used for measuring flow in circular sewers. The equipment has been calibrated by the National Engineering Laboratory as part of an extra-mural contract, and the results are being assessed by the Station. A similar design of meter has been installed by the Thames Water Authority at the Riverside works, Rainham, Essexfor field performance trials. The equipment is supplied by Redland Automation Ltd.

Trials of urban drainage programs

A package of new computer programs for the design and analysis of urban storm drainage networks has been developed at the Station. The programs were made available to selected design offices for practical working trials. The groups involved represented water authorities, local authorities and consulting firms. Results from the trials provided valuable information on various aspects of the pre-release versions of the programs and accompanying reports. Some software faults were corrected and other improvements made to the concepts incorporated in the programs and to the input/output information. The HRS involvement in these trials was financed by the Water Research Centre.

Drainage of flat low-lying catchments

The Station is co-operating with the Institute of Hydrology in developing complementary design and simulation models for channel systems draining flat, low-lying catchments. The models, which will incorporate results of experimental studies of rainfall-runoff relationships as well as hydraulic calculations of flow in the drainage channel system, should enable pumping stations to be designed more accurately and to be operated more efficiently. Optimal channel dimensions can be generated by the design model for prescribed layout, outfall water level, and discharge and design rainfall to minimise the cost of construction of the system. Steady flow is assumed. The simulation model may be used to assess the performance of the designed or existing systems under unsteady flow. The models will be tested with field data (Report EX 987).

Dilution gauging in storm sewers

A project to develop equipment for automatic dilution gauging in storm sewers has been completed by the Institute of Hydrology working under contract to the Station. The equipment consists of easily portable dosing apparatus and a pump sampler, which are triggered at a preselected water level. The feasibility of the system was demonstrated during field trials over a three-year period.

Flood magnitudes in mixed urban/rural catchments

Flood flows in urban catchments are generally produced by short duration, high intensity rainstorms, whereas floods on rural catchments are more likely to result from longer lower intensity rainfall. On catchments with roughly equal proportions of rural and urban area, it is not clear which storm condition will give rise to the higher flows, and therefore how design flows should be determined. Existing approaches to the determination of flows in mixed catchments in the United Kingdom. An alternative approach has been developed, which gives a good representation of the data over a wide range of catchment sizes. The effect of differing distributions of rainfall and catchment characteristics has also been examined (Report IT 211).

Flow reduction in urban drainage systems

In a project sponsored by the Water Research Centre, alternative means of restricting the entry of storm flows into drainage networks, or of attenuating discharges within networks, have been examined. Methods of reducing inflows include the reduction of contributing impermeable area, the use of semi-permeable paved surfaces and increased use of natural percolation through grasses areas. Among the methods of attenuating discharges are a reduction in the number of entry points to the drainage system, the use of larger or throttled gulley pots, and the provision of storage tanks within the pipe network. The work has included: computer simulations of alternative design assumptions; the development of equations describing the attenuation process; extended sensitivity testing using the new Wallingford procedure for storm drainage analysis; and a review of relevant literature.

Wallingford procedure — application in the UK

The Wallingford procedure for urban drainage design and analysis (developed by HRS, the Institute of Hydrology and the Meteorological Office) was released for general use in October 1981. Before that date HRS undertook several investigations at the request of drainage authorities with urgent problems.

Worthing, Sussex

A large urban catchment was analysed for the Southern Water Authority using the surcharging program in the Wallingford procedure. This catchment had recently experienced serious flooding and one purpose of the tests was to investigate the capacity of the system under once-in-two year flow conditions. The study also investigated the significance of runoff from an area of possible development within the catchment, and the effect of high river levels at the system outfall.

Hadlow, Kent

A culvert through the village of Hadlow, Kent, carried both the storm runoff from the developed area and the natural drainage from a rural area further upstream. The capacity of the culvert has been affected by structural changes including the internal re-lining of the pipe line and partial constriction by cross pipes. The capacity of the culvert up to pipe full flow condition, and the associated flow return periods, were examined for the Southern Water Authority using the Hydrograph Method in the Wallingford procedure. The contributions to runoff from the rural area, the road areas and other paved areas were also identified (Report EX 979).

Barton-upon-Humber, Humberside

A new length of trunk sewer in a very flat area of Barton-upon-Humber was designed for Glanford Borough Council using the Hydrograph Method. Some economies were possible by recommending small changes to some of the pipe gradients.

Storm sewer design and simulation methods

Development of the Wallingford procedure for the Design and Analysis of Storm Sewers has been completed and the package of computer programs has been tested by potential users. A five-volume manual has been prepared at the Station and was published by the National Water Council in October 1981. The computer programs were made available to UK users at the same time. Four methods are included in the package: (1) a Modified Rational Method, (2) a general purpose hydrograph method, (3) a method which in-

corporates the design of both the pipe diameters and pipe depths and (4) a simulation method in which surcharging and surface flooding can be accurately assessed. The development of the package has included the results of research by the Meteorological Office into rainfall profiles and by the Institute of Hydrology on overland flow processes in urban catchments. The results of the research on urban drainage in this and other related projects are being reported to the National Water Council/Department of the Environment Studying Technical Committee on Sewers and Water Mains.

Storm sewer data

Recording of storm rainfall intensities and the consequent flows in the storm sewer system have continued on catchments in Bracknell, Derby and Stevenage. The data have been checked and analysed for use in the development and testing of mathematical models of storm sewer networks.

Storage in storm sewer systems

Drainage engineers are showing increasing interest in the use of online and offline storage tanks to attenuate the flood peaks in surface water drainage systems and to reduce the frequency of operation of storm overflows. Earlier work on the relationship between storm duration, peak discharge and storage volume for offline tanks has now been extended to online tanks. A paper (contained in Report IT 211) summerising the results of the whole investigation has been presented and a detailed report is in preparation. Recommendations relating the volume of storage at storm overflows to a reduced frequency of spill have also been prepared.

Wallingford procedure — overseas version

The recently completed Wallingford procedure for the design and analysis of urban storm drainage is restricted in its application overseas because of its reliance upon data obtained in the United Kingdom. This restriction affects not only the rainfall intensities used but also features such as surface runoff and the contributions from paved and unpaved areas, which are dependent on engineering practice and urban design. The Hydraulics Research Station is hoping to develop the procedure for use in other countries in order to help British consulting engineers to compete for design and analysis work. A major requirement is rainfall-runoff measurements to assist the appropriate adjustment of the existing procedure. Exploratory discussions about joint research with institutions in appropriate overseas countries have been held and a prototype overseas version of the Wallingford procedure has been prepared.

Design of roof drainage

An experimental study of the capacity of gutter outlets was carried out under an extramural contract by the British Hydromechanics Research Association, and covered a wide range of outlet conditions. The results were analysed at HRS and were combined with recent theoretical work at the Station on flow in gutters to produce new design methods for a British Standard Code of Practice on the drainage of roofs and paved surfaces. The background to these design methods is described in a recently-prepared Station report IT 205. HRS operates an advisory service on roof and road drainage, and enquiries have ranged from the analysis of existing gutter systems on large industrial buildings to the design of a novel drainage system for a new housing development.

Hydraulic roughness of slimed sewers

The experiments on slime growth in sewer pipes, which began in 1976 at Lit tlemore pumping station, Oxford, were completed at the end og 1980 with a third and final test of 190 days duration at a slope of 1 in 100 and a maximum velocity of approximately 1.2m/s. The results of all three prolonged tests haved been analysed to determine hydraulic roughness in terms of k in the Colebrook-White resistance equation, which can be used by the engineer designing a foul sewer system. It has been found that the amount of slime

growth and the roughness of the pipe depend on flow velocity: pipe material is also an important factor in determining the amount of slime. A full report on the tests, the analysis of the results and the roughness values has been prepared (IT 220). The results from these experiments form the basis for the recommendations of slimed sewer roughness made in the 1982 editions of the HRS Charts and the HRS Tables.

Deposition of grit in sewers

Experiments have been carried out to determine the flow conditions that are needed to prevent the deposition of grit and sediment in storm sewers. Tests were made using a 150mm diameter uPVC pipe and a 75mm diameter perspex pipe with sediment ranging in size from 0.5mm to 6mm. The results are being analysed and compared with a theoretical model that describes the movement of sediment in pipes at low concentrations.

Engineering, field services and computing

Automatic processing of Rapid-drop Profiler data

The Station is developing programs which automatically set up a data bank using results from the HRS Rapid-Drop Profiler. The RDP is a surveying instrument which measures vertical profiles of temperature, salinity and turbidity and can produce many hundreds of profiles from an area under investigation. The instrument has been fitted with an automatic logger. The purpose of the data processing programs is to store this data automatically to form a data bank. It is proposed that the data stored in the bank, which will describe conditions in the reach in three dimensions and as a function of time, can be plotted in any form required by the user.

Data logging for the HRS silt/salinity/depth profiler

The silt/salinity/depth profiling system has been in use for several years now to produce real-time graphical records of variables against water depth. Subsequent interpretation often calls for the digitisation and file storage of several hundred plots arising from any one survey. In order to avoid the tedious manual handling a magnetic tape logging system has been designed to store the readings for subsequent computer analysis. Depth, salinity, silt and temperature are recorded on a 4-channel fm cassette tape recorder, each cassette storing 16 profiles. The control unit for the recorder inserts identification codes on the tape. It also serves to trigger a cluster of samplers attached to the profiler for the recovery of calibration water samples. The samplers are fired automatically at preset depths, and the graphical plots are marked at the instant of sampling. It is intended to replay and digitise the data at 4 x real time (each profile takes about 30 secs).

Spate diversion model

The new tidal model control equipment, described in last year's report, has been applied for the first time to the control of a hydrograph in this model. The system employed controls the water level over a bank of fixed vee-notch weirs, and hence the discharge into the model, by diverting excess water over a tilting weir which is controlled by a servo to produce the required hydrograph. Wet sediment is injected into the model by a special device, the sediment injection rate being dependent on the rotation speed of a leadscrew. The leadscrew is driven by the control equipment which was designed to drive the axial flow pumps for current generation in tidal models. Thus with little modification of the control equipment, it has proved possible to syndronously control the discharge of both water and sediment into a model to conform with a pre-ordained time history.

Vibration measurement

Equipment has been purchased and commissioned for the measurement of vibrations and small displacements of hydro-elastic models. It consists essentially of a Michelson Interferometer, in which adequate light intensity is assured by the use of the highly collimated light from a laser source. The use of a laser, which also produces very coherent light, ensures that the interferometer will operate over a wide range of displacements. Signal processing is possible in any of the ways normally associated with laser anemometers. For instance, a frequency tracker will yield an output proportional to the instantaneous axial speed of the measuring point; and modulation and heterodyne techniques can be used to determine the direction.

Temperature module

A new instrument module has been designed and manufactured for temperature measurements. It conforms to the HRS modular standard and is thus interchangeable and compatible with other instruments in the range. It is a 10-channel module, enabling 10 temperature sensors to be interfaced to a magnetic tape or microprocessor data logger, or to an on-line computer, in a quick and effective way. Any number of the new modules can be used together to interface any required number of sensors. The module incorporates electronic prediction which has the effect of speeding up the apparent response of the sensor. This provision provides effective time constants of the order of 0.1 second using fairly rugged sensors, and is based upon the assumption of a fairly crude 'model' for the probe. The use of finite element modelling of the probe is being considered as a possible extension of the compensating technique to achieve faster response times.

Multi-channel timer for field current meters

Most field current meters produce output pulses or contact closures at a rate which is dependent on the angular speed of their rotor. When the pulse rate is low it is necessary to count over a long time interval in order to obtain sufficient velocity resolution. For low velocity flows, or where the current meter has a very long pitch, it is therefore common practice to time the interval over which a preset number of counts is accumulated, thereby minimising the time taken for a measurement to achieve sufficient resolution. A multi-channel timer able to operate with arrays of current meters has been developed for the gauging of large, slow flowing rivers or canals.

Wideband conductivity meter

A new conductivity probe has been designed and constructed. It has two principal differences from any existing equipment: (1) Electrolytic effects, such as polarisation, at the electrodes are cancelled by a differential measuring technique. This eliminates the previous requirement for electrodes to be constructed from graphite or platinised metal. The new device can operate satisfactorily with any metal electrode which is chemically compatible with water (eg stainless steel) and is therefore cheap and robust. (2) The frequency bandwidth of the device is very high. It can detect conductivity fluctuations over a bandwidth of several kilohertz. The intention is to use this device to investigate the possibility of developing a stochastic measuring system in which the random variability would be used (by correlation techniques) to obtain velocity information or (by spectral techniques) information about transported properties within turbulent flow. If viable, such methods may offer a very attractive way of obtaining data from some of the more hostile field situations with which the Station deals.

Power saving modifications for field siltmeters

The increasing requirement to establish recording siltmeters in remote overseas sites has highlighted the need to improve the equipment's battery life and recording capacity. The commercial, optical occlusion sensor in regular use by the Station is continuously powered and records continuously on chart paper and consequently is a heavy consumer of power. The equipment has now been modified so that the internal light source is powered only at intervals, typically less than 15 seconds every 15 or 30 minutes. The reading is retained during the interval by a very low power store. The stored value is made

available either to a portable chart recorder or, in the frequent case where the silt station is established at a flow gauging structure, the addition of a second pen to the conventional clockwork-powered float recorder will allow the superposition of the silt trace to the water level record. The modification also makes the sensor compatible with it being controlled and its output recorded by most field data loggers.

Set-down generator

A new device for subtracting set-down from the random signal input to shallow water wave machines has been developed. The device is placed between the wave spectrum synthesizer and the wave machine, and consists of a special purpose microprocessor which performs the necessary signal processing digitally in real time, and also performs the necessary analogue-digital and digital-analogue conversions of input and output. The use of recursive digital filters, which can be simulated before construction, has permitted evaluation of a very large number of options before finalising the design so that the performance of the new set-down generator — particularly in terms of its frequency band width — is considerably improved over that of previous designs.

Non-reflecting wave machines

Work has started on the conversion of existing piston wave machines on shallow flumes and wave basins to provide them with the ability to partially absorb waves which have been reflected back towards the generator by the structures being model tested. Particular problems being studied are concerned with the reversion of the system to normal position control outside the frequency bandwidth over which absorption is effective, and dealing with lateral instabilities of the water surface across the face of the paddle. Reversion to position control is necessary to prevent the wave machine driving, or drifting, to its mechanical limits of movement, and the lateral instabilities have a serious de-stabilising effect on the absorption feedback loop, especially if the paddle is wide. A new sensor, capable of spatially averaging the water level across the width of the wave generator, has been specially designed for use in converted wave machines. The work will be extended in the near future to the wedge machines which are used on the deeper wave channels. These have an additional problem in that the motion of the paddle has both horizontal and vertical components, unlike the piston, which only moves horizontally.

Circular mud flume

A flume capable of producing specified shear gradients in water heavily loaded with fine-grained sediments has been designed and constructed. The flume is annular and has a floating roof, which can if necessary be raised clear of the flume. The roof is rotated by a speed-controlled servo-system to produce the required shear in the water on which it floats. Work still in progress includes the design of attached equipment to measure the shear stress being produced, and the development of a commercial precision density meter as an on-line sampling and measuring device.

Overseas development unit

Design methods for vortex tube sediment extractors

A design manual for vortex tube sediment extractors has been produced, using the HRS design method. The manual is intended to enable local engineers to follow through the design, in a logical step-by-step manner. The method has been simplified by the production of design graphs, and the com-

puter program which predicts trapping efficiency has been adapted to check all design figures. The production of the manual was initiated by a request from Indonesia, where field trials on a vortex tube designed according to HRS method have already been carried out.

Symposium on soil erosion and sedimentation, Bangkok, Thailand

The Overseas Development Administration, through its subvention to the HRS Overseas Development Unit, gave the necessary financial support for the organisation of a highly successful symposium on the complementary problems of erosion and sedimentation. The symposium concentrated upon the experience of these problems in the south-east Asian region, because this is at present one of the worst affected parts of the world. It was held at the Asian Institute of Technology, Bangkok, in January 1981. The symposium sought to bring together specialists in soil conservation, land use, agriculture, forestry, and other disciplines concerned with the sources of erosion; as well as engineers and others concerned with the downstream sedimentation problems that are the consequence of erosion. The success of this approach was shown by the large response to the invitation for papers. In the end forty-two papers, relating experiences in sixteen countries, were accepted. Copies of the symposium proceedings are available from the Hydraulics Research Station.

Sedimentation of reservoirs in the Brantas river basin, Indonesia

Sedimentation studies in the basins of two reservoirs in East Java were commenced in 1977 in co-operation with the Brantas River Multipurpose Development Project in Malang. The research work has involved the accurate survey of the two reservoirs, Selorejo and Karangkates, so as to calculate the volume of sediment deposits. Equipment to measure the variation of suspended sediment load has been installed in the tributary rivers of the reservoirs. Reports detailing the surveys and experience of using the turbidity monitors have been published. In the past year certain aspects of this study have been presented as papers in two international symposia. Investigations have continued with attempts to identify and quantify areas of high sediment yield within these mountainous drainage basins. Work is continuing with the development of equipment appropriate to tropical conditions to improve the retrieval of suspended sediment data. Further surveys of the reservoirs are planned for 1982 so as to determine the distribution and quantity of sediment deposited over the last 5 years. This will be compared with the data collected from the tributaries to obtain some idea of the trap efficiency of the reservoirs. Considerable interest has been aroused by this project in Indonesia. Efforts are now being made by the Indonesian authorities to promote soil and water conservation projects within the drainage basins. Help in the form of drafting project proposals is to be given to the Indonesian authorities by the Overseas Development Unit.

Sediment movement on the middle reach of the Brantas River, Indonesia

The middle reach of the River Brantas, E. Java has been particularly prone to annual flooding especially since the last eruption of Gn. Kelud in 1966. Excessive deposits of volcanic sand have caused bed levels to rise with consequent rises in flood levels and loss of river flood capacity. Regular monitoring of river flows and suspended sediment loads was proposed in 1979 and the first intensive survey was undertaken at Jongbiru in the Wet season of 1980 in co-operation with the Brantas Multipurpose Project. The information so gained has already been used to provide quantitative evidence on bed level changes in the river and major irrigation canals. It is intended to continue the intensive measurements at Jongbiru and other sites so as to provide information on the effectiveness of the 10 year river dredging and improvement scheme on the Brantas middle reach.

Sedimentation of reservoirs on the Tana River, Kenya

The Tana River is the largest river in Kenya and the country's major surface water resource. The potential for development of the river for hydropower and irrigation is high and several schemes are already in existence or planned

for the near future. However, although attention has been given to the study of siltation in the Tana River, there is still a large amount of work required in an understanding of erosion, sediment transport and deposition is to be obtained. The Overseas Development Unit has undertaken a research project in collaboration with the Tana River Development Authority (TRDA), the Ministry of Water Development (MOWD) and the East Africa Power and Lighting Co. Ltd (EAPL) to investigate these phenomena. The first phase of this research programme is expected to last three years and will be concerned primarily with the establishment of sampling methods, installation of field equipment, data analysis and reservoir surveys. During a six week period in June/July 1981, hydrographic surveys were carried out of Kindaruma and Kamburu reservoirs. A topographic survey of the new Masinga reservoir (commissioned by TRDA) was interrupted by the 1981 "long rains"; this survey was completed using hydrographic techniques. Preparations have been made for the installation of "Partech" turbidity monitors and "ALS" vacuum samplers ready for a full programme of data collection to be stored early in 1982. Help has also been given to the MOWD laboratory by providing both equipment and advice in preparation for the receipt of about 140 sediment samples per week.

Evaluation of soil conservation practices, Bvumbe, Malawi

In Malawi, as in many other developing countries, soil erosion is a serious threat to long term agricultural productivity. Recommendations for good land husbandry have been published in Malawi, but at present there is no quantitative data to relate erosion control effect to the benefits obtained. A collaborative research project is being undertaken with the Ministry of Agriculture and Natural Resources, Government of Malawi in order to quantify soil and nutrient losses from catchments under different land uses. It is proposed that field measurements be carried out on small catchments designated as having (a) natural, indigenous vegetation, (b) intensive 'uncontrolled' land use, (c) a complete array of physical conservation works but without a planned system of land use, (d) a complete physical conservation and land use plan in accordance with land husbandry recommendations. To quantify the effect of different land use patterns field measurements will be made of rainfall, surface runoff, total sediment load, soil moisture, nutrients, and crop cover. In the initial phase of the study catchment type (b) and (d) are to be monitored and two suitable areas were identified on the Blantyre encampment in southern Malawi. These two catchments were instrumented in the period May to September 1981 in readiness for the 1981/82 rainy season beginning October/November 1981.

Water management on a smallholder rice irrigation system, Kaudulla, Sri Lanka

Traditional methods used in South East Asia for smallholder rice irrigation systems are being studied. Efficiencies of these schemes are low with the volume of water issued at headworks often much greater than the requirements. Better management of existing systems, to extend the areas under cultivation or to increase cropping intensities, should be cheaper than constructing new works. The rice growing areas of Sri Lanka are typical of South East Asia. Two monsoon seasons give rise to the Wet Zone over the mountainous south western quarter of the island and to the Dry Zone elsewhere. Irrigated rice is the main crop in the Dry Zone, using water stored in ancient tanks (reservoirs) during the NE monsoon. Tank issues are used to supplement rainfall in the wet season and the principal paddy crop is grown between October and March. If stored water is sufficient a secondary crop is grown between April and September, the dry season in this part of Sri Lanka. Since 1978 a study has been undertaken at Kaudulla scheme, in the Dry Zone, to monitor this traditional system and to identify potential improvements in existing water management practices. Over the irrigated area of 4250 ha, irrigation and drainage flows, climatological data, groundwater levels and cropping data have been recorded. Water budgets for each season have been derived from these observations and actual tank issues have been compared with potential minimum releases obtained from a mathematical model of the

scheme. Interim reports covering the first four seasons concluded that water use during the dry Yala season was relatively efficient because of considerable drainage refuse, rain falling on the paddy during the wet Maha season was not being used effectively, the prescribed schedule of rotational issues had not been maintained and that land preparation periods should be shortened. During the 1980/81 Maha season improvements in the last two items resulted in a significant reduction in issues. Future plans include development of the mathematical model, a more detailed field investigation of part of the scheme and extension of the studies to other areas of South East Asia.

Irrigation water management at ten tanks, Sri Lanka

A water balance study is being carried out on ten tanks (reservoirs) throughout Sri Lanka. These are: Murutha Wela in the Wet Zone; Hakwatuna Oya and Nagadeepa Manawewa in the Intermediate Zone; Iranamadu, Vavunikulam, Padiviya, Pavatkulam, Wahalkada, Mahawilachchiya and Mahakandarawa tanks in the Dry Zone. The objectives of the study are 1) to examine the individual water balances on each of the tanks for common patterns of water loss in the dry Yala season; 2) to compare the computed seepage loss using the Penman predictions for open water evaporation with that calculated using Class A evaporation pan data; 3) to compare runoff coefficients required to close the water balance equation in the wet Maha season; 4) to establish methods of data collection and analysis suitable for use by local Irrigation Engineers throughout Sri Lanka. The project is being conducted with the co-operation of the Sri Lankan Irrigation Department who are providing records of issues from 1978 together with tank area and capacity curves. Meteorological data from eight stations in Sri Lanka, namely: Thirunelveli, Kantalai, Vanativillu, Maha Illuppallama, Bathalogoda, Mahiyangana, Kundasale, Angunukolapelessa are being provided by Colombo Observatory.

Irrigation water management, Philippines

A reconnaissance visit to the Philippines was undertaken in October 1981 to determine whether a research project on irrigation water management could be established there in collaboration with the National Irrigation Administration (NIA). Discussions with NIA and site tours in Luzon showed that there are a number of topics on which staff of the Overseas Development Unit (ODU) are currently working that are relevant to problems faced by NIA. Report ODV 90 identified potential collaborative studies in the fields of irrigation water management and soil erosion/reservoir sedimentation and suggested that advice could be given on problems of sedimentation at irrigation intakes. The report also concluded that there is much of mutual interest in the work being carried out by the Irrigation Water Management Division at the International Rice Research Institute in the Philippines and present ODU studies in this field at Sri Lanka. Continuing contacts between IRRI and ODU are envisaged which may well lead to more formal collaboration. ODU staff will visit the Philippines early in 1982 in order to prepare specific proposals, for collaborative research.

Bhola irrigation scheme, Bangladesh

In September 1981, a member of HRS staff was contracted by the United Nations Food and Agriculture Organisation (FAO) to make an assessment of salinity intrusion and abstraction problems for the proposed Bhola Irrigation Scheme in Bangladesh (EX 1027). The total area to be irrigated in this scheme is about 38 000 hectares and it is proposed to use about 1800 pumps of $0.06 m^3/s$ capacity. The irrigation scheme will be operated, if possible, by pumping directly from the existing system of tidal creeks within Bhola Island. The main problems likely to be encountered are the intrusion of saline water from the Tetulia Channel into the system of creeks during low fluvial flows and the lack of sufficient depths of water to allow pumping from the creeks. An analysis was carried out at HRS on field observations made in the Tetulia Channel in the years 1976-81. This showed that the period during which

saline water intrudes into the project area during the irrigation season is strongly correlated to the mean monthly fluvial flow entering in the delta in March. One-dimensional mathematical model techniques were used to create a schematic model of the Meghna Delta which showed that there was a net residual discharge of about 1400m³/s down the Tetulia Channel in the dry season, a finding which is supported by discharge observations in the channel north of Bhola Island. The maximum rate of abstraction for the project is about 100m³/s or about 7% of the average net residual flow in the Tetulia Channel. Numerical model techniques were also used to simulate tidal flows and pumped abstractions in two creek systems within Bhola Island with a total length of about 260 kilometres of channel.

Reservoir operation studies on the Brantas Dam, Indonesia

The construction of several dams on the Brantas River has increased the need for a planning model so that various water resource strategies can be tested. The objective is to arrive at an optimum strategy for hydro power, irrigation and flood control in the river basin. As a first stage to this planning model a mathematical river flow simulation model is being developed at HRS so that flow hydrographs at selected points along the main channel can be predicted. This model, of the drainage basin response, will then be used in the optimisation model of reservoir operations. This work is being undertaken at HRS for the Brantas Multipurpose Project. It is intended that the computer models will be run on available computers in Indonesia.

Scale model of a Wadi water diversion structure, Tihama, Yemen Arab Republic

A mobile bed model with a scale of 1:32 is being used to evolve the design for a spate Wadi diversion structure. The model has been designed to simulate the spate floods and large variations in sediment load that are a feature of Tihama Wadis. A sophisticated but flexible control system allows any required sequence of floods to be simulated. Peak discharges and flood durations can be varied independently. Saturated sediment is supplied at the model inlet using a specially developed sand injector at control rates varying with model discharge. Any required relationship between water and sediment discharges can be achieved. Initially a section of the Wadi Zabid has been modelled to allow the comparison between model and prototype results that is necessary to evaluate scale effects. When this phase of the work has been completed a Wadi diversion structure proposed by the Land Resources Development Centre (ODA) will be tested. This work is being part funded by the Mediterranean and Near East Department of the ODA.

Freshwater flow measurement in the tidal reach of the Berbice River, Guyana

In common with many coastal plain estuaries the Berbice River is affected by tides over an extensive length. A knowledge of freshwater flow is necessary for planning the use of water within the estuary and balancing the demands of competing users. A tidal gauging system has been installed on the Berbice River by American consultants, and this uses stage measurements at two locations and a program to compute instantaneous discharge. The residual freshwater flow is found by integrating over one or more tidal cycles. The Overseas Unit is assessing the accuracy of this method with regard to low freshwater flows. The program produces unsatisfactory results and so an existing HRS one-dimensional tidal model has been adapted to compute discharges. Preliminary results show excellent agreement with observed discharges. In order to further calibrate the HRS model and determine its region of applicability a field survey was conducted in October 1981 to collect data at a period of low flow.

Monitoring of water control structures, Wadi Zabid, Yemen Arab Republic

Wadi Zabid is the first of seven major Yemen Tihama wadis to be developed. Five conventionally designed diversion structures have been built to replace a larger number of existing traditional irrigation intakes. The Overseas Development Unit, in collaboration with the Tihama Development Authority, are engaged in a data collection programme, to quantify the performance

of these structures by determination of (a) the overall water abstraction efficiency of the scheme, (b) the division of total abstraction between individual offtakes, (c) the volume of sediment entering the supply canals and (d) the feasibility of reducing sediment input by changing operational procedure at canal headworks. Measurements of canal and wadi discharges, suspended sediment concentrations and the patterns of accretion/scour in the group one canals are being made, and a continuous record of gate operations is being maintained.

Development of seepage measurement techniques

Development of the new MK III seepage meter system and testing in laboratory facilities have continued. The work has concentrated on checking design principles and evolving an efficient and reliable mode of operation for routine use in the field. The system comprises three units — an underwater measuring unit integral with the 1m diameter seepage 'bell', a control unit incorporating power supplies, recorders and switchgear and a priming unit with a variable speed electrical pump to remove air and check the calibration of the metering devices. In addition to this, the design features are being examined of a seepage probe that could perhaps be inserted into a canal bed more easily; this probe might be suitable for long reaches of canal where a system of higher efficiency but perhaps lower absolute accuracy could be tolerated. Finally, experience has indicated the need to study and define the probable errors in 'measuring' seepage by gauging canal discharges at different points. A report has been prepared that includes a thorough statistical analysis of these errors and comments on their implications. It concludes that for all canals except those of the smallest capacity, gauging of higher accuracy than normally achieved is needed. The results of this work will be applied to HRS development work on gauging techniques in India.

Comparison of alternative drainage methods for salt leaching, Zawia, Egypt

This recently started experiment is aimed at identifying the most appropriate form of field drainage for inducing effective leaching of saline soils in the Zawia area; this includes comparing cost-effectiveness as well as determining the drainage efficiency. Six trials are being carried out with specially developed drain discharge measuring systems being used for five of them. The trials are: (1) Shallow ditches, (2) Subsurface tile pipes, (3) Gravel filled, material wrapped tubes, (4) Mole drains, (5) Wellpoints and (6) Control, comprising open ditches to the pattern used extensively in the area. The National College of Agricultural Engineering are collaborating in the model drain trial through an extramural contract and in the wellpoint trial through an ODA/NIAE student sponsorship scheme.

Evaluation of design and operation of a smallholder irrigation system, Nyanyadzi, Zimbabwe

The potential for irrigation in Zimbabwe has not been fully developed, especially on smallholder schemes, where farm holdings are usually only a few hectares in size. The Government of Zimbabwe intends to expand the area of land under smallholder irrigation so as to promote rural development and to give more employment to the rural population. A visit to Zimbabwe has been made by personnel of the Overseas Development Unit to identify the technical and social problems associated with the management of the Nyanyadzi scheme in Manicaland. Research proposals have been prepared so as to set up a joint investigation on this scheme in co-operation with the Department of Agricultural Development. The objective of the investigation will be to provide information on the use of water at field level within this scheme. Aspects of the socio-economic problems will also be studied. The information to be gained from this study may be used to improve the management of existing schemes and to provide for the design of smallholder schemes in the future.

Soil salinisation and reclamation, Zawia, Egypt

The slow progress achieved in reclaiming saline clayey soils in Zawia, Egypt is being investigated. Evaporation, drainage capacity, level and the salinity of groundwater influence reclamation strongly. The complex nature of water

and salt movement through swelling clays is another relevant parameter. The leaching trials in a 72 ha. area in the Northern Nile Delta are being used to quantify the different influences. A mathematical model to map the ground water table with intermediate drains has been developed. Work aimed at understanding water and salt movement through clays is planned. A comparison of different drainage methods is in hand. The work is being carried out in collaboration with the Delta Sugar Company (Cairo) and the Authority for Reclamation and Agricultural Development, Egypt.

Salt intrusion in the Rio Guayas estuary, Ecuador

Recent work was aimed at identifying the reasons for the worsening salt intrusion problem at the La Toma intake. The increasing competition for water in the Western parts of the Guayas basin has resulted in shortage of water in the dry seasons. Low rainfall has contributed to the reduction in residual flows experienced recently. The saline intrusion model was re-run with freshwater flows modified to take account of the increased abstractions and satisfactory agreement with observations was obtained.

Salt intrusion in estuary of Nilwala Ganga, Sri Lanka

The water supply for the town of Matara, Sri Lanka is abstracted from the Nilwala Ganga within the tidal reach and is frequently affected by salt water intrusion. The Overseas Development Administration are financing the improvement of the existing intake and treatment works and the provision of new works sited upstream of anticipated salt water penetration. A one-dimensional mathematical model, developed by the Station to predict long term intrusion in tropical estuaries, was used to study the present situation in the Nilwala Ganga and to predict likely salinity levels for higher abstraction rates. The information was also used to check the location of the new intake and calculate storage requirements needed to safeguard supplies during periods of intake shut down due to excessive salinity. A report on the model findings was published in March 1981. The work was carried out in collaboration with the National Water Supply and Drainage Board, Colombo and Halcrow-Balfour Ltd.

Evaluation of small solar powered irrigation pumps, Pakistan

The Overseas Unit was invited by Intermediate Technology Industrial Services of Rugby to assist in their field trials of solar powered irrigation in Pakistan. Twenty units, consisting of pump and solar photovoltaic panels, have been located throughout Pakistan; 14 were made available to the Agricultural Development Bank of Pakistan (ADBP) for deployment on individual farms, and the remainder going to the Pakistan Agricultural Research Council, (PARC), to be installed on a number of research farms. The trials are being conducted over a one year period, which is due to end in March 1982. An evaluation of the pumps' performance and suitability to the conditions of smallholder irrigation over the one year trial period, will be made. The novel feature of these trials is that most of the pumps are being used for practical irrigation by small farmers. Interim findings suggest that; a) the price of this technology is still a little high, but it is now approaching economically competitive levels; b) the units used, of 250W nominal panel capacity, are rather small to satisfy Pakistani farmer's needs; c) maintenance problems have not been severe; d) the efficient utilisation of the small but continuous flows produced is not easy.

Research collaboration with Irrigation and Power Research Institute, Amritsar India

In May the Director of the Punjab State Irrigation and Power Research Institute (IPRI), Amritsar signed a Research Collaboration Agreement between the Institute and HRS. This agreement, which will be for four years, is governed by a Memorandum of Understanding between the Government of India and the UK on "twinning" of Indian and British research establishments. The general objective of the research programme is to enhance the physical and technical capabilities of the Institute in solving problems of particular interest and difficulty. Four main research themes will be pursued: (1) Seepage from canals — its measurement and control by lining

and other practices; (2) Discharge of hill torrents — their measurement during major floods, including mobile materials; (3) Sediment control structures — with special reference to the design and efficiency of vortex type ejectors and (4) Salinity of irrigated soils — tracing and finding the causes of variations with time.

Development of mathematical modelling techniques for large deltas

The ODA Unit commissioned the Estuary Division at HRS to adapt the type of mathematical model techniques which are commonly used to solve problems in estuaries to do the same for large deltas in tropical climates. The development work was done at the same time as a major ad hoc field and mathematical model study of the Irrawaddy Delta in the years 1978-81. A series of standard types of one-dimensional models have now been developed and tested by simulating conditions in the Irrawaddy Delta. The same basic fully implicit, time-centred, six-point, finite-difference scheme using a double-sweep method with a sparse matrix solution of the junction equations is employed in all the versions of the model. This means that the models can be used to simulate very large networks of channels, with thousands of kilometres of channels and hundreds of junctions, without incurring unduly high computing costs. The main problems requiring further research are the representation of intertidal storage from networks of tidal creeks connected to the main channels, the representation of longitudinal mixing processes, the varying roughness of sandy channels and the transport of sediment in deltas.

Numerical model studies of the Irrawaddy Delta, Burma

The Station has just completed a three year mathematical model study commissioned by the Burma Irrigation Department and funded by the British Overseas Development Administration. The main objective of the study was the development of mathematical models to simulate and predict the interaction of fluvial and tidal flows in the Irrawaddy Delta. The work was done in collaboration with Sir William Halcrow and Partners, Consultants to the Irrigation Department, who were carrying out a World Bank Study into the rehabilitation of paddylands in the delta. The data for the models was collected by a specially formed Irrawaddy Delta Survey Team with 230 personnel from the Irrigation Department. HRS developed a one-dimensional channel system model capable of simulating the evacuation of upland floods in the range 20 000—50 000m^3/s together with local rainfall in the delta. The same technique was used to simulate conditions in the dry season when the flows are contained within the river channels except during tidal surges. This version of the model was used to calculate the distribution of residual fluvial flows during the dry season which in turn supplied data for a model used to simulate saline intrusion. The salinity model calculated the movement of the high water spring tide slack salinity distribution throughout the dry season taking into account varying upland flows. HRS also constructed a two-dimensional model of the whole of the Bay of Bengal which was used to simulate the growth of storm surges along the coast generated by the windfields from moving cyclones. The one-dimensional delta model was used to simulate the propagation of the resulting surge tide within the delta. The flow models were used to predict the effect of building flood protection embankments around a large number of islands (EX 927 and EX 1025). The saline intrusion model was used to predict conditions during a 1 in 10 year drought. In conclusion HRS now consider that the models are capable of predicting the incremental effects of large-scale engineering works in the delta with an accuracy necessary for planning purposes.

Jetty for inter-island vessels, Praslin, Seychelles

Advice has been requested on the orientation of a small jetty extension in Bai Ste Anne, Praslin, Seychelles. This involves carrying out a series of wave refraction calculations using an existing suite of computer programs. These programs use a representation of the sea bed levels on a triangular grid for their calculations and also require information on the offshore wave climate. Results are given in the form of wave climate at the required inshore position,

in this instance the proposed jetty extension. The work is being carried out for the National Consultancy Services Ltd, a Government company of the Republic of Seychelles.

Field trials of low level gabion structures, Wadi Rima, Yemen Arab Republic

Two experimental gabion bed stabilizers were constructed during 1979/80 dry season, in the Wadi Rima, Yemen Arab Republic. ODA requested the Overseas Development Unit to monitor the performance of these structures under the extreme flow and bed load conditions of a steep silt laden river. The objective of the trials is to assess the suitability of gabions as an alternative low cost construction material for building spate irrigation diversion works. Data has been collected during the 1980 and 1981 wet seasons by the Tihama Development Authority following the monitoring programme specified by HRS.

Technical assistance, Egypt

Technical assistance in the form of advice, training and equipment has been given to the Hydraulics and Sediment Research Institute, Delta Barrage, Egypt as part of a three-year co-operative programme funded by the Overseas Development Administration. The period of the agreement ended in April 1981 and discussions have been held with a view to extending the programme for a further period.

Port Qasim, Pakistan

The Station is providing a continuing advisory service to the Port Qasim Authority. The work is funded by the Overseas Development Administration. Topics under this heading include: (1) advice on the acquisition of a position fixing system for hydrographic survey and pilotage purposes; (2) prediction and analysis of siltation in the dredged approach channel (Report EX 1003); advice on proposals for developing Bakran Creek, provision of shallow-water berths, reclamation of local catchments, alignment of the creek and preventing siltation in the canalised channel (Report EX 844); development of a computer program for calculating under keel clearance of a 25 000dwt vessel entering Port Qasim during the south-west monsoon period (Reports EX 916 and EX 1005).

Papers and reports

January — June 1982

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Papers and reports
January — June 1982

The following is a list of all published papers, technical memoranda and reports produced by the Hydraulics Research Station Limited.

The items often relate to work undertaken on a fee-paying basis for clients and the full report cannot be released without the agreement of the client. However the techniques used in an investigation may be applicable in other circumstances, and readers may have problems similar to those described on which they would like advice. In such cases readers are invited to write to the Managing Director, stating clearly their needs and giving as much information as possible.

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Published papers

*** AN EXPERIMENTAL STUDY OF THE STRUCTURE OF A FRESHWATER-SALTWATER INTERFACIAL MIXING**

H O Anwar Dr Ing and J A Weller

La Houille Blanche, No 6, 1981

This paper describes the results of an experimental study of freshwater flowing two-dimensionally over a still pool of saltwater.

*** ENVIRONMENTAL LOADING AND RESPONSE**

E C Bowers BSc, PhD, DIC and R G Standing PhD

ICE Conference Offshore moorings, London, March 1982

Environmental forces on offshore structures are caused by winds, waves and currents. Their separate effects are discussed as well as coupling between waves and currents and the combined effect of all three.

*** WAVE INDUCED SILTATION OF DEEP NAVIGATION CHANNELS**

A H Brampton BSc, PhD

Oceanology Conference, Brighton, March 1982

To maintain the capacity of approach channels, ports often support a continuous programme of dredging. This paper discusses the consequences of dredging a deep channel in an area of high wave activity and describes various mathematical methods which can help to predict siltation and propose dredging programmes.

*** MONEY DOWN THE DRAIN**

P J Colyer MA

Water, Jan 1982

This paper describes how the new Wallingford Procedure is used to design urban storm sewer networks.

*** A WATER MANAGEMENT STUDY AT KAUDULLA IRRIGATION SCHEME, SRI LANKA**

D W Holmes BSc (Eng), ACGI and H Gunston BSc (Ag Eng)

In collaboration with the Irrigation Department, Sri Lanka

Workshop modernisation of tank irrigation: problems and issues, Madras, Feb 1982, Section C, Paper 11

A water management study has been set up to investigate the efficiency of the Kaudulla irrigation scheme. The benefits of applying different management practices have been analysed using desk studies and numerical models.

*** APPLICATION AND EXPERIENCE OF PHOTOVOLTAIC PUMPS FOR IRRIGATION IN PAKISTAN**

R G Pallet BSc (Eng), MSc and T E Brabben BA

4th EC Photovoltaic solar energy conference, Stresa, May 1982

Sun pumps were installed in Pakistan to evaluate their suitability for irrigating small holdings.

Technical memoranda

**** SIX CHANNEL CURRENT METER READOUT**

For measuring velocity in canals, or similar flows

F H Bond BSc (Ag Eng)

Technical Memorandum 1/1982, March 1982

The HRS six channel current meter readout, designed for field use with a variety of power supplies, will greatly improve the accuracy of discharge measurement in canals.

**** A HYDROGRAPHIC FLOW CONTROL SYSTEM**

P L Baber

Technical Memorandum 2/1982, April 1982

This memorandum describes equipment used for reproducing flood hydrographs in physical models at HRS. The control system uses standard HRS instrument modules as the "building blocks".

Reports of the Overseas Development Unit

*** DESIGN MANUAL FOR VORTEX TUBE SILT EXTRACTORS**

S M White BEng, MSc

OD 37, December 1981

Vortex tube extractors are efficient, convenient and simple, but their design is complicated. A method has been developed at Hydraulics Research to enable engineers to design vortex tubes and to predict their performance quickly and reliably.

****URBAN DRAINAGE DATA COLLECTION NETWORKS**

EX 1048, March 1982

The report identifies factors to be considered when planning collection of rainfall-runoff data from urban sewered catchments. Recommendations are made on selection of catchments, measurement of rainfall and sewer flows, siting of instruments, analysis of catchment surfaces and digital preparation of data. The report also includes recommendations for data collection in Mexico City.

****REDUCTION OF FLOW IN URBAN DRAINAGE SYSTEMS**

EX 1049, March 1982

Hydraulics Research investigated means of reducing flows in storm drainage systems by reducing flows entering a system or attenuating flows within it. Results were obtained using the Wallingford Procedure for storm drainage analysis, from new work using kinematic wave equations and by analysis of other data.

****ALDERNEY HARBOUR**

Physical model study

EX 1051, May 1982

A physical model was used by Hydraulics Research to investigate the long term effects of the wave climate in Alderney Harbour if maintenance costs on the main breakwater are reduced.

****THE MONOBAR BREAKWATER UNIT**

Preliminary wave flume tests at HRS

EX 1052, April 1982

Preliminary flume tests on a range of breakwaters built up from Monobar units indicate good absorbing characteristics giving low transmission and reflection coefficients.

****LOCATION OF LEAKAGE SOURCES FROM RESERVOIR HEADWORKS DOHA CITY, QATAR**

Pilot field surveys and review of methods

EX 1053, May 1982

HRS advised on detection and location of serious leaks from large underground concrete reservoirs in Doha. A detailed inspection of the works and pilot resistivity surveys were made by a member of HRS. These have formed the basis for a review of practical methods of leak location.

*****THE MERSEY ESTUARY**

Observations of tidal currents salinities and suspended solids concentrations

WRC pilot study, March 1982

EX 1054, April 1982

Hydrographic observations and rapid drop profiling were carried out in the Mersey "narrows" as part of a WRC investigation into the flux of heavy metals in the Mersey.

*****THAILAND COASTAL PORTS PROJECT**

Navigation channel improvements at the port of Ban Don

Radioactive tracer experiments to examine the disposal of dredged spoil

EX 1055, June 1982

This report describes an investigation into the dispersion of dredged spoil close to the line of the proposed access channel to Ban Don.

*****WAVE FORCES ON PIPELINES**

EX 1056, March 1982

Field experiments were carried out by Hydraulics Research to measure wave forces on submarine pipelines. The results compared favourably with earlier data obtained in a pulsating water tunnel.

*****WAVE FORCES ON PIPELINES**

Addendum — Effects of surface roughness

EX 1059, June 1982

Field experiments were carried out by Hydraulics Research to examine the effects of surface roughness on wave forces on pipelines. The results compared favourably with earlier data obtained in a pulsating water tunnel.

*****ROCK-ARMOURED BREAKWATERS AT LONGUE HOUGUE BAY, GUERNSEY**

EX 1060, May 1982

A desk study was undertaken to check the performance of a number of rubble-mound breakwaters to be built on the east coast of Guernsey to form protection for reclamations.

*****CORK HARBOUR**

Effects of proposed crossing between Haulbowline and Spike Islands

EX 1061, December 1980

Hydraulics Research has carried out a desk study to define the flow regime in Cork Harbour and to assess the consequences of a bridge or causeway crossing.

*****STUDY OF WAVE SPECTRA TRANSFORMATION**

EX 1063, June 1982

This is the final report on work carried out on wave spectra transformation for the Department of Energy.

*****THAILAND PORTS DEVELOPMENT**

Navigation channel improvements at the ports of Ban Don and Pattani

Desk studies to determine locations of disposal of dredged spoil

EX 1070, June 1982

Capital dredging is proposed in the approaches to Ban Don and Pattani. This study considers earlier reports and data together with more recent field information, and recommends locations for dumping dredged spoil at each port.

Reports of background research

* WATER MANAGEMENT STUDY AT KAUDULLA IRRIGATION SCHEME, SRI LANKA

III — Interim report covering seasons Yala 1978 to Maha 1980/81

D W Holmes, R Wooldridge, J A Weller, H Gunston and C H Batchelor

In collaboration with the Irrigation Department, Sri Lanka

OD 38, December 1981

A water management study has been set up to investigate the efficiency of the Kaudulla irrigation scheme. The benefits of applying different management practices have been analysed using desk studies and numerical models.

* A RESISTIVITY TECHNIQUE FOR DETECTING LEAKS IN LINED CHANNELS

Preliminary investigation

N G Deacon BSc (Ag Eng), MSc

OD 39, April 1982

A resistivity technique has been used to detect leaks in a lined channel by identifying localised saturated areas of soil. Measurements were made on a concrete and polythene lined channel in sand. A number of resistivity surveys were carried out under various leak conditions enabling comparisons to be made.

* WARUJAYENG-KERTOSONO CANAL SURVEY

IR D Kadiro and IR T Santoso

In collaboration with the East Java Irrigation Service, Indonesia

OD 42, June 1982

The Warujayeng-Kertosono canal has had siltation problems since 1951. The canal is to be rehabilitated and quantitative estimates of the sediment problem are needed. This report analyses data gathered from surveys in 1975 and 1981. The results highlight the need for sediment exclusion or extraction.

* ESTIMATION OF FRESH WATER FLOW IN THE TIDAL REACH OF THE BERBICE RIVER, GUYANA

M B Amphlett BSc and I W Makin MSc

In collaboration with Ministry of Works, Hydrometeorological Service, Kingston, Guyana

OD 43, June 1982

A numerical model has been developed to estimate flows in the Berbice River. The model was adapted from an existing one-dimensional model developed at Hydraulics Research for analysis of tidal propagation in narrow partially mixed single channel estuaries. Instantaneous tidal discharge results from the model compared well with observed discharges obtained from field surveys.

**DESIGN OF GUTTERS AND GUTTER OUTLETS

Theory and experiment

R W P May MA, MSc, C Eng, MICE

IT 205, April 1982

This report describes the theoretical and experimental background to the design methods for roof gutters and gutter outlets that are contained in a revised version of British Standard Code of Practice CP 308.

**PROPOSED DREDGING OFF LAVERNOCK POINT, BRISTOL CHANNEL

J M Motyka BSc

IT 215, January 1981

Hydraulics Research advised the Crown Estate Commissioners of the effects on the adjacent coastline if coal outwashings are dredged off Lavernock Point.

**SEDIMENT TRANSPORT IN SEWERS

R W May MA, MSc, C Eng, MICE

IT 222, February 1982

An important factor in sewer design is the gradient required to produce a self-cleansing velocity. An experimental investigation, supplemented by field measurements was made into the limit of deposition. A new theoretical model of sediment transport in pipes was developed and used to analyse the results. The study showed that the self-cleansing velocity depends upon sediment concentration, pipe size and sediment size.

**CRUMP WEIR CREST TAPPINGS

The evaluation of a novel device for minimising the ingress of sediment

E Whitehead BSc (Eng)

IT 223, February 1982

A triangular profile weir measuring discharge in the drowned flow range requires a crest tapping. This tends to entrain sediment and blockage is a recurring problem. This report describes the successful trial of a modification to the tapping system to reduce sediment intrusion.

****BHOLA IRRIGATION SCHEME, BANGLADESH**

An assessment of salinity intrusion and abstraction problems

EX 1027, October 1981

A one-dimensional mathematical model was used to calculate flows and saline intrusion in the Meghna delta and the effect of abstracting irrigation water.

****RIVER BIRKET DIVERSION STUDY**

EX 1028, April 1982

Hydraulics Research has predicted the effects of diverting the River Birket through Birkenhead Docks on siltation, water circulation and salinity. A field survey and desk study were carried out.

****RIVER TRENT INLAND PORT**

Preliminary hydraulic study of the effects of proposals to improve the tidal reach for navigation

EX 1030, October 1981

This study examined the effects of channel improvements on low water levels and the effect of incorporating a tidal barrage on siltation.

****DAMMAN SHIP REPAIR YARD**

A random wave model investigation

EX 1036, December 1981

Physical model tests of a proposed extension to the Port of Dammam have been conducted at a scale of 1:100 to obtain estimates of mooring forces and vertical movements for two floating dry docks in the shelter of a breakwater. An optimum position for this breakwater was also established.

****FERRY BRIDGE, WEYMOUTH-PORTLAND ROAD A354**

Effects on hydraulic regime of resiting the bridge

EX 1039, January 1982

The results of hydrographic surveys were used to investigate the channel regime around Ferry Bridge. Recommendations were made on the orientation and dredging required for a new bridge and channel.

*****DEGRADATION OF THE RIVER NILE**

A preliminary assessment of flow conditions downstream of Esna Barrage

EX 1040, January 1982

Esna barrage was built in 1908. However, since construction of the Aswan High Dam, upstream of Esna, the flow and sediment regime in the Nile has changed. Two numerical models have been used to simulate conditions from Aswan to below Esna and to study the effects of replacing Esna barrage by a new, higher barrage.

*****A55 NORTH WALES COAST ROAD — TUNNEL CROSSING OF CONWY ESTUARY**

Short and long term bed changes

EX 1041, February 1982

A field survey was undertaken to investigate past and present variations in bed levels. Numerical model tests were run to forecast changes that could occur as a consequence of reclaiming areas at either end of the immersed tube tunnel.

*****MORECAMBE BAY GAS FIELD**

Model investigation of the scour potential of a complex of offshore structures

EX 1042, January 1982

A physical model investigation was undertaken to determine scour around offshore gas platforms sited in shallow water. The tests established the extent of scour for various designs and combinations of structures.

*****WAVES AND CURRENT FORCES ON PIPELINES IN TRENCHES**

Addendum — Effect of gaps beneath pipe

EX 1043, March 1982

Wave and current forces on a submarine pipeline, installed in an open trench on the sea bed with a gap beneath the pipe, were investigated in an oscillating water tunnel at Hydraulics Research.

*****A55 NORTH WALES COAST ROAD — TUNNEL CROSSING OF CONWY ESTUARY**

Additional model studies

EX 1044, March 1982

Numerical models, developed for an earlier study of alternative tunnel crossings, have been recommissioned to examine some aspects in more detail. The efficiency of stockpiling spoil from the tunnel trench, the consequences of dredging sand from the estuary and the impact of temporary and permanent works have been investigated.

*****TOLO WATER QUALITY MODEL, HONG KONG**

Hydraulic aspects

EX 1045, February 1982

The hydraulic processes causing transport and physical dispersal of biochemical matter and living organisms in Tolo Harbour and Channel were simulated and analysed with the aid of multi-dimensional tidal mathematical models.

*****DESIGN AND ANALYSIS OF URBAN STORM DRAINAGE**

Report on user trials of the Wallingford Procedure

EX 1046, February 1982

The Wallingford Procedure was developed between 1974-79. This report describes user trials undertaken during 1980-81 and major changes introduced as a result.

**THE PROCESSING OF WAVE RECORDS FROM WAVERIDER BUOYS

HRS user manual

R M Shuttler DLC (Hons)

IT 224, March 1982

This report describes methods used at Hydraulics Research for processing and analysing field recorded wave data from Waverider buoys.

**MATHEMATICAL MODELLING OF BUOYANT SURFACE PLUMES

A J Cooper MA, PhD

IT 226, February 1982

Various mathematical models of buoyant surface plumes have been developed by Hydraulics Research to describe the spread and dilution of thermal and sewage discharges. This report gives details of steady and unsteady integral plume models which predict concentrations of pollutants and the bulk flow of water.

**STORAGE TANKS IN STORM DRAINAGE SYSTEMS

G Wooldridge T Eng (CEI), MIPHE, MIMG, Tech E

IT 227, March 1982

A modified version of the TRRL model was used to simulate urban storm drainage networks and storage tanks. A limited comparison for off-line tanks was made using the new Wallingford Procedure. This showed that the better representation of catchment characteristics included in the Procedure produces a significant reduction in required storage volumes.

**URBAN DRAINAGE DATA COLLECTION FROM THREE STORM SEWER CATCHMENTS

E J Forty MIPHE

IT 228, March 1982

The report describes selection, instrumentation and operation of three catchments in the UK. Problems associated with data collection and processing into digital and computer file records are included.

**EXPERIMENTAL STUDY OF DIFFRACTION THROUGH A BREAKWATER GAP

E C Bowers BSc, PhD, DIC and J Welsby T Eng (CEI)

IT 229, April 1982

A physical model was used to investigate effects of differing breakwater configurations on wave diffraction in harbours. A straight breakwater with a central gap and angled breakwaters with central and offset gaps were compared. Tests were also run with angled breakwaters to determine the effect on wave heights of rubble slopes on the front and back faces of the breakwater arms.

**KINEMATIC WAVE CALCULATIONS OF PEAK FLOW REDUCTIONS IN URBAN STORM RUNOFF

R W Pethick BSc

IT 230, February 1982

This report outlines the use of a kinematic wave approach to investigate attenuations occurring over different lengths of overland and gutter flow. Results are presented showing the effect of catchment slope and flow length on attenuations in peak discharges.

**RAINFALL-RUNOFF DATA COLLECTION IN URBAN DRAINAGE CATCHMENTS

P J Colyer MA

IT 232, June 1982

The report identifies factors to be considered when planning collection of rainfall-runoff data from urban sewered catchments. Recommendations are made on selection of catchments, measurement of rainfall and sewer flows, siting of instruments, analysis of catchment surfaces and digital preparation of data.

**INFRA-RED MONITORING OF THERMAL PLUMES

Summary of trials on a hydraulic model

M A Littlewood

IT 233, May 1982

Present methods of monitoring thermal plumes in physical models are time consuming. This report describes a trial of an AGA infra-red scanning system and compares the results with those obtained by thermistor and dyed plume experiments.

**FINANCING OF WATER-BASED RECREATION

IT 236, June 1982

Dartington Amenity Research Trust was commissioned by Hydraulics Research to undertake a comparative study of financing water-based recreation with particular reference to inland navigable waterways and reservoirs.

Project reports for Department of the Environment

* **GROUP CALIBRATION FOR THE BRAYSTOKE TYPE BFM-001 CURRENT METER, WITH 8011 SERIES IMPELLER**

DE 53, January 1982

Calibration of current meters individually is expensive. For a family of physically identical meters a less costly alternative is a group calibration. This is derived from the performance of a sample batch of meters and indicates the average performance of the entire family.

** **SLUDGE DISPOSAL IN LIVERPOOL BAY**

Eighth bed monitoring survey, September 1980 to January 1981

DE 54, August 1981

The report describes the eighth core sampling survey to examine whether changes are occurring in the bed sediment characteristics of Liverpool Bay as a consequence of increases in the rate of sewage sludge dumping.

** **CALIBRATION OF AN ELECTROMAGNETIC METER FOR FLOW MEASUREMENT IN A 0.5M DIAMETER PART-FULL PIPE**

DE 55, March 1982

Measurements were made to define the performance of an electromagnetic meter measuring flow in a pipe. Calibration from experimental observations was necessary because a theoretical rating equation cannot yet be provided.

Project reports for external clients

*** **DYNAMIC INSTABILITIES OF TETHERED BUOYANT PLATFORMS**

EX 989, May 1981

This report describes an investigation by Hydraulics Research and Y-ARD Ltd into the dynamic instabilities of tethered buoyant platforms, using both physical model tests and hybrid computer simulations.

*** **SEDIMENTATION STUDIES, SABI RIVER, ZIMBABWE**

Report on reconnaissance visit, April 1981

EX 991, May 1981

Dr W R White visited the Sabi River to gain first hand knowledge of the sedimentation problems, to formulate an investigation programme to quantify the effects of the Condo and Chitowe Dams, and to specify the data requirements for the study.

*** **WAVE FORCE ON CYLINDERS**

Simulation of high Reynolds numbers

EX 996, May 1981

This report describes experiments carried out by Hydraulics Research to study high Reynolds' number simulation for small scale models.

THE FLUCOMP RIVER MODEL PACKAGE

An engineers guide

EX 999, March 1982

This manual describes how to use the HRS computational river model package, FLUCOMP. It also gives some background information on the way the model treats the physics of river flow.

Price £50 incl p & p.

*** **WAVE HINDCASTING ALONG THE SOMERSET AND AVON COASTLINE**

EX 1024, September 1981

A numerical model of wave hindcasting, previously developed for evaluating wave conditions at the proposed Severn Barrage, has been used to examine wave heights at coastal sites in the Wessex Water Authority area.

Hydraulics Research Station Wallingford Oxon OX10 8BA Telephone 0491 35381

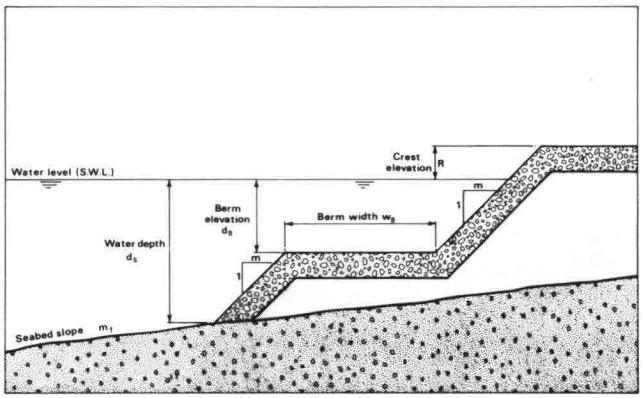
Summary

Design of seawalls allowing for wave overtopping 101

For seawalls with relatively complex geometry, such as stepped promenades or recurved wave return walls, the only way of determining the overtopping discharge for different water levels and wave heights has been by direct measurement either on the seawall or more likely on a scale model. However, work carried out at the Hydraulics Research Station now makes it possible to calculate overtopping for seawalls of the generalised profile shown in Fig 1 without requiring model testing. Under a research contract financed jointly by the Central Electricity Generating Board, Severn Trent Water Authority, Wessex Water Authority and this Station an extensive series of model tests was carried out, measuring overtopping discharges under a wide range of wave climates for a large variety of seawalls having this generalised profile. A simple design manual has been published which can be used by engineers assessing existing seawalls and designing new ones.

Plate 1 Waves overtopping seawall at Porthmellon

Figure 1 Generalised seawall profile



Model tests

Model tests were carried out for the following range of parameters:

Seawall geometry:	Seaward slope, m	1:1 to 1:4
	Crest elevation, R	0.0 to 3.0m above Still Water Level (SWL)
	Berm elevation, d_B	0.0 to 4.0m below SWL
	Berm width, W_B	0 to 80m
Wave climate:	Significant wave height, H_s	0.75 to 4.0m
	Sea steepness, S	0.035 to 0.055
	Angle of wave attack, β	0°(normal attack) to 60°
	JONSWAP wave spectrum (Ref 1)	
	Foreshore slope, m_f	1:20
	Water depth at seawall to toe, d_s	4.0m

Plate 2 Typical seawall for flood defence

The majority of tests were carried out at a scale of 1:25 and for each wave climate and seawall geometry the volume of water and number of waves overtopping the seawall during a period of $100\overline{T}$ were recorded ($\overline{T}$ is the mean zero-crossing wave period of the random wave train). Normally five measurements were taken for each condition and the mean overtopping discharge $\overline{Q}$($m^3/s/m$ run) and the mean number of waves overtopping $\overline{N}$ (%) were obtained by averaging the readings. For the design engineer the value of $\overline{N}$ is somewhat academic: he is more concerned with the value of $\overline{Q}$ since this determines the capacity of his drainage system or the degree of flooding in the hinterland. Attention here is therefore confined to overtopping discharge.

Effect of crest elevation

Previous model studies at the Station have shown that for seawalls having similar underwater geometry the relative effects of different crest elevations under attack by different wave heights are fully taken into account if the overtopping is described by the dimensionless overtopping discharge Q_* and the dimensionless freeboard R_*, defined as:

$$Q_* = \frac{\overline{Q}}{\overline{T}\, g\, H_s}$$

and

$$R_* = \frac{R}{\overline{T}\sqrt{g\, H_s}}$$

where R is the seawall freeboard ie the crest elevation relative to SWL.

Fig 2 shows the values of Q_* plotted on a log scale against R_* for a series of tests for different wave heights, wave periods and seawall crest elevations for a typical seawall. Linear regression shows that these results are linked with a correlation coefficient of 0.97 by an equation of the type:

$$Q_* = Ae^{-BR_*}$$

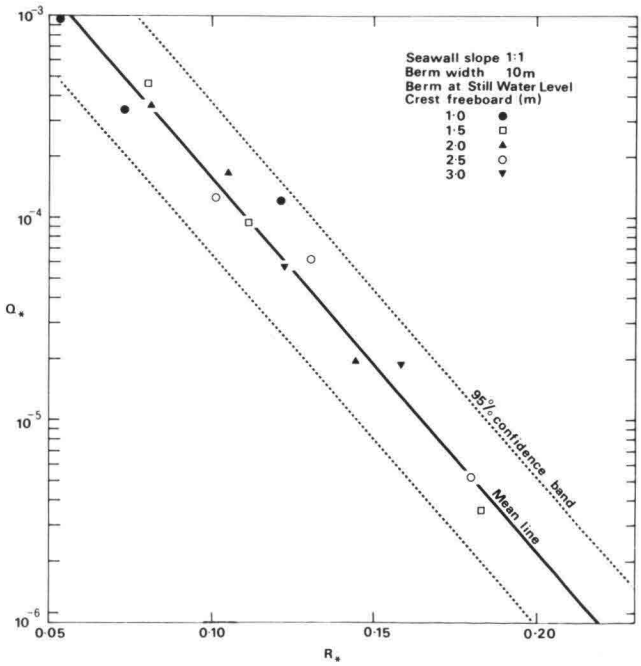
where A and B are dimensionless coefficients having values of 1.08×10^{-2} and 42.2 respectively. Since each plotted point is the mean of five measurements the standard deviation of $\ln Q_*$ can be calculated enabling the 95% confidence limits to be defined. Fig 2 shows that the effect of different crest elevations is fully accounted for by this presentation since the results for each elevation are randomly distributed about the mean line.

For all the seawall geometries and wave climates tested Q_* and R_* were always related by $Q_* = Ae^{-BR_*}$ provided that H_s was defined as the significant wave height at the seawall ie post breaking if the seawall is in shallow water.

Effect of seawall slope

For all berm dimensions the tests were repeated with seawall slopes of 1:1, 1:2 and 1:4, and in almost all tests the seaward edge of the berm and the face of the main seawall had identical slopes. One feature of the results was the similarity of the overtopping discharges for 1:1 and 1:2 seawall slopes for almost all berm dimensions. Only for slopes flatter than 1:2 was there a significant reduction in discharge.

Figure 2 Dimensionless discharge against dimensionless freeboard for a typical seawall



Effect of berm elevation

The effect of berm elevation varied slightly depending on seawall slope and berm width, but in all cases the major effect occurred as the berm was raised from 2m to 1m below SWL with only minor further reductions in overtopping discharge when the berm was exactly at SWL.

Effect of berm width

The effect of berm width varied with seawall slope and berm elevation. In each case the overtopping discharge decreased significantly as the berm width increased. For berm elevations 2m or more below SWL the effect of width was less marked than for higher berms. The slope of the seaward edge of the berm had no noticeable effect.

Effect of angle of wave attack

For simple seawalls having no berm or a narrow berm the highest overtopping discharges were recorded not at normal incidence, but when waves struck the seawall 15^0 off normal. Only for angles greater than 30° did the discharge decrease significantly. For seawalls with wide shallow berms the discharge remained nearly constant at angles up to 30^0, and then reduced. Subsequent tests on seawalls with recurved wave return walls have indicated that for that type of seawall the overtopping discharge reduces at all angles off normal attack.

Design information

A published report (Ref 2) gives the result of these and other related model tests in a form suitable for the design engineer. The report consists of a series of graphs presenting the values of A and B for all the different seawall geometries examined, where A and B are the dimensionless coefficients in $Q_* = Ae^{-BR_*}$.

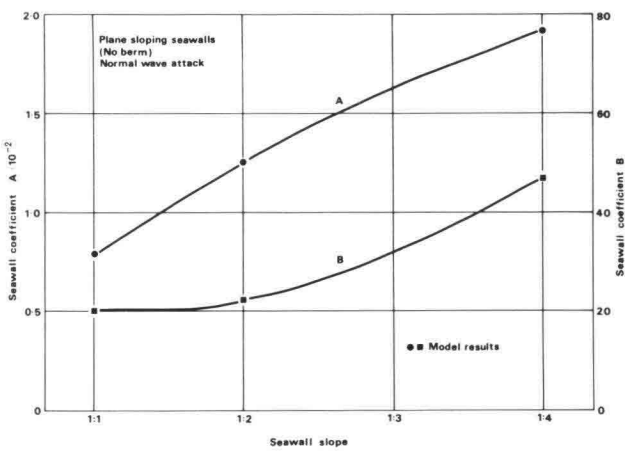
Fig 3 shows the simplest of these graphs, giving the variation of A and B with seawall slope for walls without berms. Using this or similar graphs the engineer can read off the values of A and B for the particular geometry of his seawall. Knowing the crest elevation, and having selected the design values of SWL, H_s and $\overline{T}$ the dimensionless freeboard R_* is determined and the dimensionless discharge Q_* then obtained from $Q_* = Ae^{-BR_*}$ using the particular values of A and B. Since $Q_* = \overline{Q}/(\overline{T}gH_s)$ the mean overtopping discharge $\overline{Q}$ is then readily obtained.

References

1 Hasselman K et al. Measurements of wind wave growth and swell decay during the Joint North Sea Wave Project(JONSWAP), Deutsche Hydrographische Institut, 1973.

2 Hydraulics Research Station. Design of seawalls allowing for wave overtopping. Report No. EX 924, 1980.

Figure 3 Variation of coefficients A and B with slope—simple seawalls



Hydraulics Research Station Wallingford Oxon OX10 8BA Telephone 0491 35381

Summary

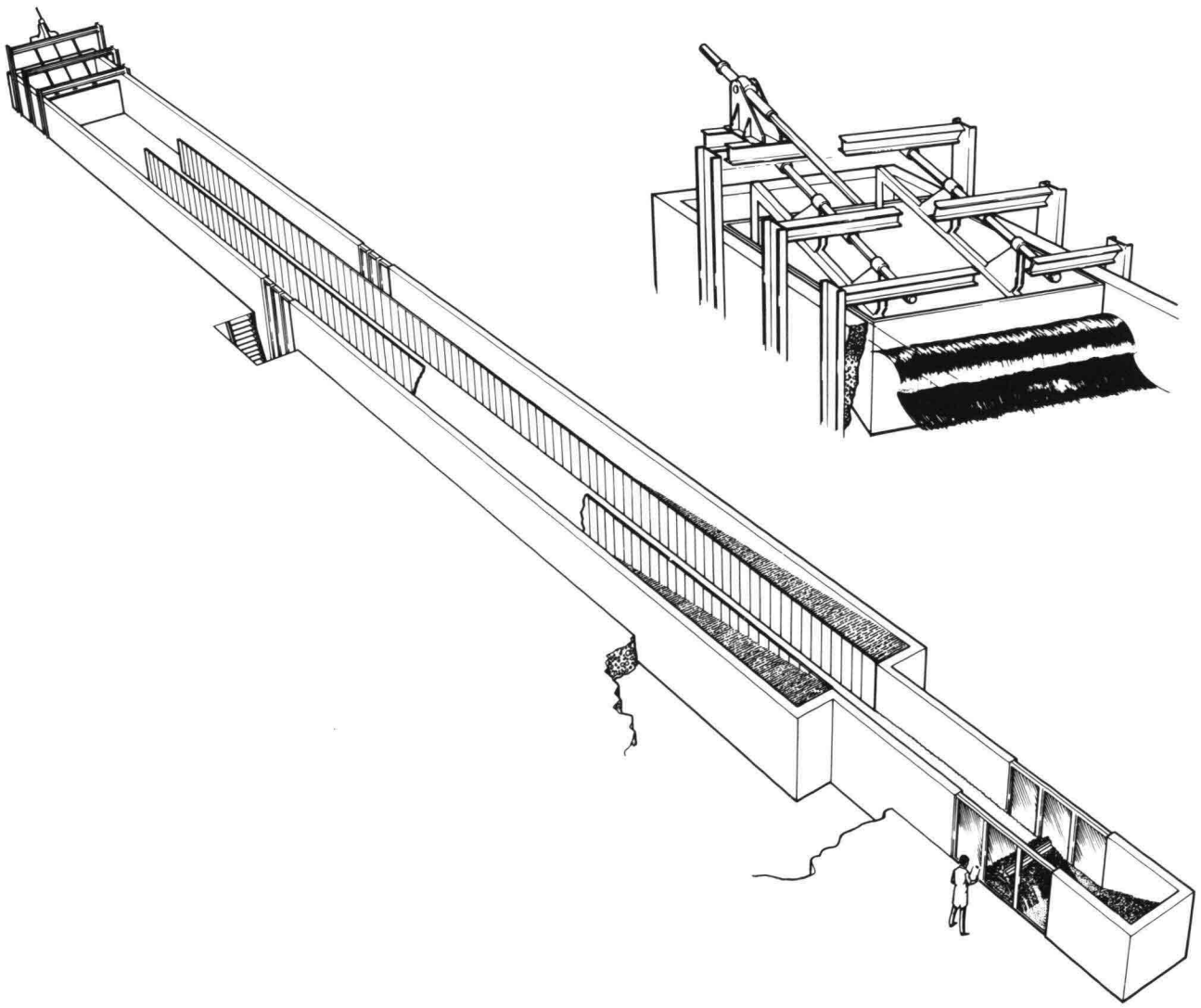
Deep random-wave flume

102

The deep random-wave flume at the Hydraulics Research Station was commissioned in January 1980 and has since been in constant use for testing two-dimensional models of breakwaters, seawalls and offshore structures. A number of studies of the stability of rubble-mound breakwaters are outlined in Summary 103.

Structure

The main section of the flume is 42m long, 3m wide and 2m deep and incorporates a pit 2m square by 1m deep. The pit is used when testing offshore structures to ensure the correct reproduction of the structure foundations or the dynamic response of very tall structures. When not required the pit is covered over. The main flume is extended for 10m by a finger flume 1.2m wide, which can be isolated from the main section by a full depth gate. This permits model construction or damage measurements to take place in the dry. The flume is glazed in certain areas to allow observations of the test structures.



The most frequent investigations are of breakwaters or seawalls when a model is placed in the finger flume. (Most offshore structures are studied in the HRS short-crested sea basin, see Summary 104). The flume is equipped with removable vertical splitter walls of increasing porosity towards the wave paddle, allowing any wave reflections from the modelled section to dissipate gradually, thus reducing re-reflections and inhibiting the formation of cross-waves. To reduce the time required for setting up between projects, the flume has a modular false floor which may be easily altered to model the prototype bathymetry from deep water inshore to the particular site. Wave shoaling and breaking between deepwater and the site are thus correctly reproduced.

Operation

Mean water depths are usually about 1.0 or 1.5m; the wedge-type wave paddle being set to give optimum performance at either of these values. A double-acting hydraulic ram drives the paddle, and is controlled by a signal generated by an HRS wave spectrum synthesiser (Ref 1). This synthesiser produces a pseudo-random (but repeatable) signal having any required spectrum, with a computer program calculating the required filter settings. For the usual JONSWAP or Pierson-Moskowitz spectra the system can produce waves with significant heights up to 0.33m.

The wave sequence can be varied so that very short sequences (typically 2 — 5 minutes) are used for, say, spectral analysis of waves, thus reducing data handling, recording time and computing costs without introducing statistical uncertainty. Very long sequences (typically several hours) can be used when probability distributions and extrema are measured. These long sequences are always used for breakwater stability tests and other studies where the structure's response to the waves may be nonlinear.

Data collection and analysis

Wave heights and periods generated in the flume are measured by wave probes connected to a mini-computer which is part of the HRS data acquisition and analysis system (Ref 2). This computer network allows a number of different analysis techniques to be used. For example during calibration a spectral analysis program is run to calculate the wave energy spectrum from instantaneous water surface elevations. The significant wave height H_s, and the mean zero-crossing wave period, T_z, as well as other spectral parameters can then be calculated. Alternatively, during tests a statistical analysis program is run while data collection proceeds. The program lists the main statistical properties of the wave records collected, and other parameters such as pressure, force or movement can also be fed in and analysed in a similar way.

References

1 Dedow H R A, Thompson D M and Fryer D K. On the generation, measurement and analysis of random seas. HRS Reprint, March 1977.

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Dd 8220552 3M 5/82 88326/3921

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Summary

Seepage meter for large canals

104

The loss of water from large unlined canals due to seepage is a very serious problem in arid countries. Not only is water wasted but a rise in the local water table can cause drainage and soil salinity problems. The total lining of canals is very expensive. However, selective lining of canal reaches where high seepage rates occur is a desirable alternative. The Overseas Unit have developed measuring equipment (the HRS seepage meter) which identifies areas of excessive seepage in large canals.

Introduction

A seepage meter measures water percolating into an area of canal bed which has been sealed off from the surrounding area (Ref 1). The method was first used in small canals. HRS has developed a high accuracy meter for use in large canals.

The HRS Marks I and II seepage meters were built for the Ismailia Canal in Egypt (Ref 2). A typical profile from the Mark II meter is shown in Fig 1. Improvements have been made to the meters and the Mark III meter has been evolved which increases efficiency and reliability.

Description

The seepage meter consists of three parts (Fig 2): an underwater measuring unit integral with a 1m diam 'bell', a pump and manometers for priming and testing the underwater unit, and a control and data collection box.

Figure 1 Typical profile from Mark II meter

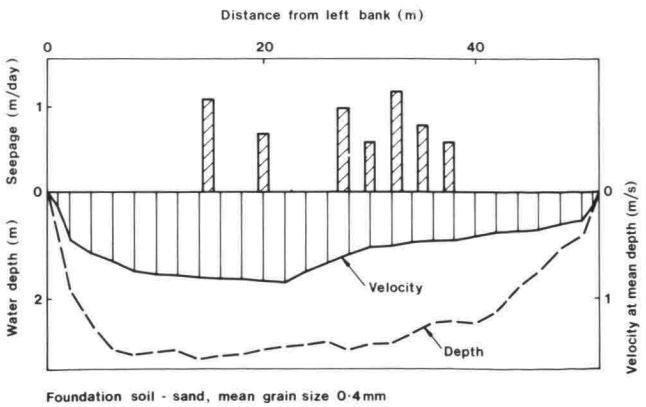
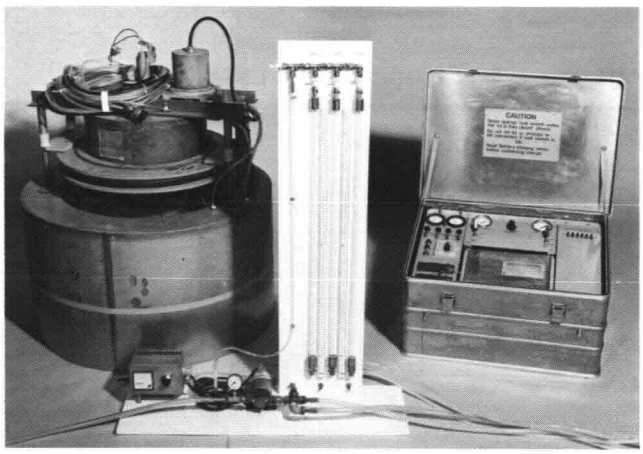


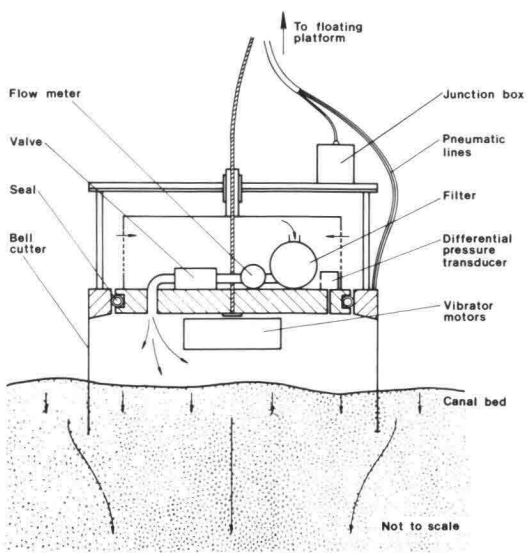
Figure 2 Mark III meter



Operation

The meter is operated from a mobile floating platform. The underwater unit (Fig 3) weighing 150kg is lowered into a canal where the system is primed. The unit is then lowered by winch onto the canal bed. The bell is vibrated into the bed using servo motors and closed off from the canal by a pneumatic seal. By opening a pneumatic valve water enters that part of the bed sealed off by the bell.

Figure 3 Cross-section of underwater unit



Water is filtered and measured by a sensitive flow meter as it passes into the bell. This creates a head loss (Ref 3) which is recorded by a pressure transducer. The head loss hinders the passage of water and distorts the field of flow (Fig 4). A factor to correct the metered flow, previously established only from theory, has been verified from tests at HRS; an example is given in Fig 5.

Trials

HRS has a test facility reproducing seepage in a $16m^2$ area of canal bed. Percolation rates through the bed can be varied and the Mark III meter has measured rates between 0.13 and 2.0 m/day.

Trial surveys are planned on the Sirhind Canal in the Punjab in 1982 as part of the HRS Wallingford — IPRI Amritsar Collaboration Agreement.

For further information please contact Mr C L Abernethy, Head of the Overseas Development Unit at the Hydraulics Research Station.

Figure 4 Characteristic curve of flow measurement system

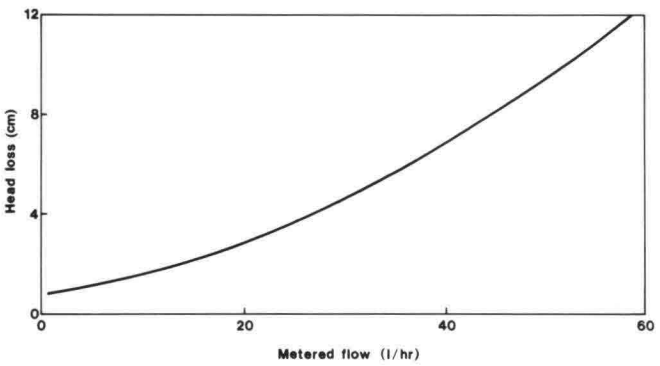
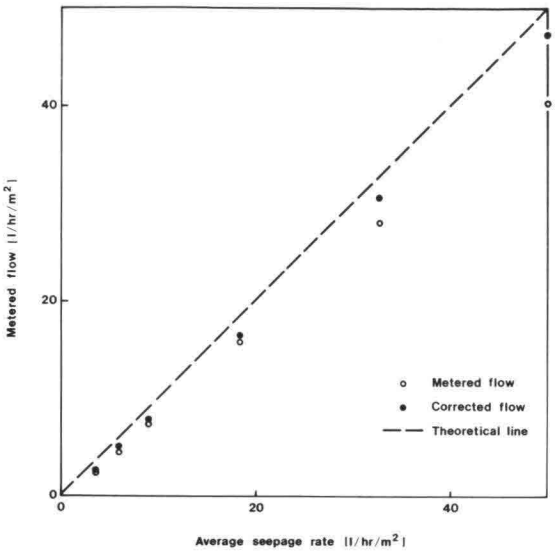


Figure 5 Laboratory test results



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2 Hydraulics Research Station. Measurements of bed seepage from the Ismailia Canal — First report. Report OD 14, 1978.

3 Hydraulics Research Station. A field distortion principle for measuring the rate of seepage from canals. Report OD 32, 1980.

Dd.8220555 3M 7/82 PSG 88749/3921

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Summary

Vortex tube sediment extractor

106

Vortex tubes are used in canals carrying excessive amounts of sediment as cheap and efficient sediment extractors. Although inexpensive to construct, their design is complicated. Until recently designs were based on small scale model tests and field experience. The Overseas Unit at HRS have now developed a new design procedure which requires only one empirically determined constant.

Description

A vortex tube sediment extractor (Fig 1) consists of a pipe, closed at one end, with a longitudinal slot along the top. The pipe is buried in a canal bed so that the slot is flush with the surface of the bed. As water and sediment pass over the tube a forced vortex is set up within it. Water and sediment are extracted from the canal and discharged; the spiralling flow within the tube preventing clogging. Sediment enters the tube from the bottom of the canal where the material is most coarse; a vortex tube is therefore more efficient at removing coarse rather than fine sediments.

Figure 1 Layout of vortex tube sediment extractor

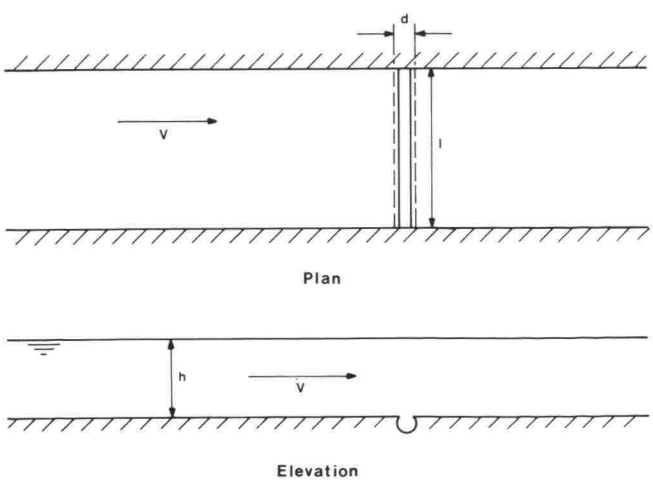

Figure 2 Vortex tube installed in canal in Java showing waste channel discharging into settling basin

The tube can discharge in several ways. In areas of steep topography its contents can be directed back into the parent river. Or a settling basin can be constructed beside the canal (Fig 2) from which sediment is dredged and water run to waste or back into the canal. Alternatively the total flow can be pumped away or run to waste. The discharge arrangements must be carefully planned to prevent siltation in the waste channels which would impair the efficient operation of the vortex tube.

Design

The design procedure (Refs 1 and 2) is in two parts: planning of the tube geometry and operating conditions, and prediction of the sediment trapping efficiency. The tube's performance is affected by many independent parameters and the procedure enables an engineer to isolate these effects.

Tube geometry is influenced by the need to prevent clogging and to allow operation at sensible head differences; this leads to a restriction on the parameters l/d (length/diameter). Tubes are usually constructed normal to the flow although they may be installed at other angles.

Trials

Following development of the design procedure the method was first proved by laboratory tests (Refs 3 and 4). This was followed by field measurements of the tube's performance (Fig 3 and Ref 5). The results confirmed the success of the procedure; for example, differences between predicted and observed trapping efficiencies were usually less than 10%.

Design manual

A design manual for vortex tube sediment extractors (Ref 6) has been prepared. It enables engineers to design vortex tubes easily and to predict their performance with confidence.

Figure 3 Monitoring field performance of vortex tube in Java

References

1 Sanmuganathan K. Design of vortex tube silt extractors. HRS Report OD 6, 1976.

2 Sanmuganathan K and Lawrence P. Design of vortex tube silt extractors. Proc Int Conference on Water resources development, Taipei, 1980.

3 Lawrence P. Laboratory verification of vortex tube design method — Coefficient of discharge. HRS Report OD 40, 1982 (in preparation).

4 Wooldridge R. Laboratory verification of vortex tube design method — Trapping efficiency. HRS Report OD 41, 1982 (in preparation).

5 Lawrence P and Sanmuganathan K. Field verification of vortex tube design method. Proc South-East Asian Regional Symposium on Problems of soil erosion and sedimentation, Bangkok, 1981.

6 White S M. Design manual for vortex tube silt extractors. HRS Report OD 37, 1982.

Dd.16497 3M 7/82 PSG 88749/3921

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Summary

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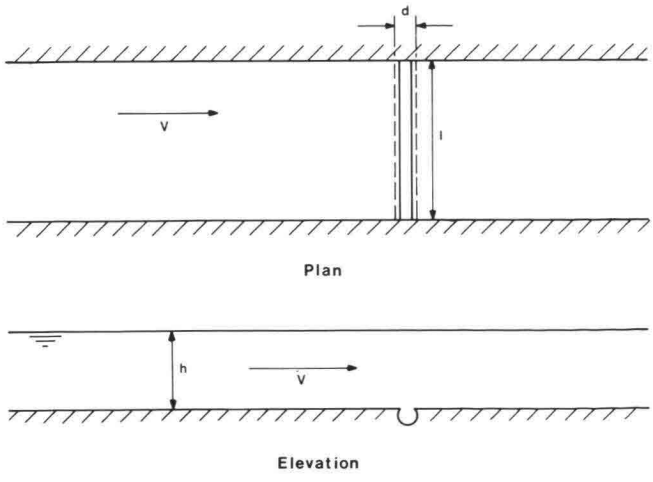

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