Hydraulics Research
Wallingford

HYDRAULIC STRUCTURES: RESEARCH NEEDS

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The DoE nominated officer is Dr R P Thorogood. This report is published with the permission of the Department of the Environment, but any opinions expressed are not necessarily those of the Department.

ABSTRACT

The aim of Hydraulics Research is to continue its policy of carrying out research that meets the most urgent needs of the civil engineering industry. In order to discover how the industry sees its needs at the present time, a questionnaire was circulated to organisations representing consultants, water and local authorities. Fifty-one replies to the questionnaire were received and have been analysed.

On the basis of the replies that were received, six topics justifying further research have been identified and outline research proposals have been put forward. The six topics are:

(i) preparation of a design guide for non-standard flow measuring structures;

(ii) preparation of an illustrated manual of roughness values for UK rivers;

(iii) preparation of a design guide for energy dissipators for small structures and research on protection measures downstream from the dissipators;

(iv) research on tide flaps for circular pipes;

(v) research on drowned venturi sluices;

(vi) research on various aspects of sediment removal devices.

CONTENTS

1 INTRODUCTION

Hydraulics Research Limited has a history of research on hydraulic structures, output from which has provided important and reliable information for all branches of the civil engineering industry.

In order to ensure that future research continues to meet the needs of the civil engineering industry, it was decided to seek suggestions from consultants, regional water authorities and other organisations with hydraulic interests

It was decided that the survey should take the form of a questionnaire, which would be sent to all prospective HR Associate Members; proposals for future research would be based on the recommendations that were made in response to the questionnaire.

2 QUESTIONNAIRE

The questionnaire, a copy of which is included as Appendix 1, was sent together with a covering letter to all prospective Associate Members of HR (Appendix 2). The aim was to identify areas where research was required to fill in the gaps in knowledge on hydraulic structures and associated phenomena. The emphasis was to be on topics that had river engineering applications rather than coastal or maritime.

The letter accompanying the questionnaire suggested that, initially, respondents should spend only a relatively short time on the reply; further time might be involved in follow-up discussions with HR, if this was necessary in order to draw up detailed research proposals.

There were two main topics of enquiry:

(a) Hydraulic structures/devices

(b) Hydraulic phenomena

The respondents were asked to indicate which of the listed structures they or their organisation had had experience of; also the type of hydraulic phenomena they had encountered. They were also asked to comment on aspects of either (a) or (b) which they felt would benefit from research and development.

3 ANALYSIS OF REPLIES

3.1 Structures/devices/phenomena encountered

Questionnaires were sent to 75 organisations including consultants, water authorities, local authorities and others. Replies were received from 51.

Table 1 shows the ranking order for answers to question A(1), firstly for all replies and then grouped together according to types of organisation.

It can be seen that the structure/device most commonly encountered by all organisations was the culvert mentioned by 84% of the replies. This was followed by valves (67%), pumps (61%) and tunnels (59%). Different types of organisation work in different fields and therefore individual priorities vary. For instance, the Water Authority returns displayed culverts, flumes and weirs in joint top place (83% of the replies).

Table 2 is a similar indication of replies to question B(1) on hydraulic phenomena, with sedimentation and flow measurement being the overall leaders, followed closely by roughness values.

Again individual priorities varied, with modelling being top of the consultants returns (91%) and flow measurement well down the list (64%).

3.2 Research suggestions

All suggestions for future research and development were listed by organisation type and are presented as Appendix 3. A second listing grouped by subject area is included as Appendix 4. Each topic listed is associated with its originating organisation.

Subject areas include:

Stilling basins/tailworks, flow measurement (open channel), intakes, spillway flow, tunnels and closed conduits, pipe flow, pumps valves and gates, rivers/channels.

In order to get a clearer idea of the data that are available for the various types of hydraulic structures, a brief literature search was carried out on the material held in the HR library. From this it became obvious that there were certain areas which although listed as requiring further research and development were already well documented and reasonably up-to-date.

These were excluded from the list of likely topics and attention was focussed on the other items. Some of these involved topics that were outside HR's expertise and were thus eliminated, others are in the current HR research programme. Of the topics remaining after this weeding-out process, many were of a one-off nature and it was difficult to judge the extent of the need for further research; others were broadly in line with an HR assessment of research needs, based on queries that had been received over a number of years.

4 SELECTION OF RESEARCH TOPICS

Following the review of suggestions and taking into account the brief literature search, a short list of six subject areas/topics was chosen for further investigation, from the original list of ten (see Appendix IV). Limitations of time and money available for this search, restricted the number of areas that could be chosen for more detailed appraisal.

Because so many of the replies were of a very general nature, they served only to outline possible research topics. These were fleshed out into more detailed proposals as a result of subsequent discussions with some of the respondents, backed up by HR's assessment of need based on past discussions with other engineers.

The six topics considered were as follows:

1. Flow measuring structures
2. Roughness values for UK rivers
3. Stilling basins/energy dissipators
4. Tide flaps
5. Venturi sluices
6. Settling basins/sediment exclusion

5 PROPOSALS FOR FURTHER RESEARCH

5.1 Flow measuring structures

There was considerable general interest shown in various aspects of flow measurement using weirs, sluices, etc. Much work has already been carried out on standard flow measuring structures such as Crump weirs, flat vee weirs, thin plate weirs, broad crested weirs and critical depth flumes. this is all well documented in the BS and ISO series. Design information is thus readily available, which allows stage-discharge relationships to be calculated for modular and non-modular flow conditions.

There are, however, numerous other types of non-standard structure in use both in the UK and overseas which are used for flow control and which operate under drowned and modular conditions. For some of these structures data on performance characteristics are available, but scattered throughout the literature. For other structures, no performance data are available.

The proposed research has as its objective the publication of a manual on non-standard flow measuring structures, to serve as a companion volume to that already published on standard structures [1].

The proposed research would be split into two parts. The first would comprise a comprehensive literature review gathering together all the published performance data for non-standard structures. The second part would comprise experimental research on structures in fairly common use but for which no information was available (e.g. short crested weirs, drowned radial gates), or on new types of structure to meet specific needs e.g. Crump weirs with intermediate piers. The ultimate purpose would be to publish a design manual containing both the old and the new data.

The results of the research would be of great value for water authorities wishing to use new or existing non-standard structures for flow measuring. It would also be invaluable for any engineer wanting to build a numerical model of a river that contains such hydraulic structures: he would then be able to model the performance of the structure in a realistic rather than an empirical fashion.

Much of the work on this project would involve working with water authorities, even if only collecting data for existing structures. However, there is scope for some deeper involvement and there is reason to think that some financial support might be forthcoming from some of the authorities.

5.2 Roughness values for UK rivers

All hydraulic computations involving flow in rivers require an estimation to be made of the roughness of the river. At present the only means of doing this is either by carrying out slope-discharge measurements in the river or by analogy with other rivers of similar characteristics and known roughness. The first method is not straightforward to execute there are little data available to permit the second method to be generally applied. In the United States, the Geological Survey has produced a handbook [2] containing coloured photographs of a large number of streams and rivers, together with recommendations on the appropriate roughness values.

Experience in the United States has shown that trained engineers can predict the roughness coefficients with an accuracy of plus or minus 15%.

There would be much value in a similar publication describing British rivers: interest in such a project has been expressed on a number of occasions.

To provide data for the UK, comparable with that in the USGS document (which itself took fifteen years to formulate) would be a major task for any individual organisation. However, if this were to be a joint venture by water authorities, each considering sites in its own area with HR acting as central co-ordinator, with responsibility for the final publication, then considerable information could be assembled in a relatively short period.

The major part of the task involved would not be the photography although good representative clear photographs will be essential; the principal task would be measurements of the channel dimensions, discharge, bed forms, channel slope and water surface slope, in the selected reaches of the rivers. Flood plain flow would only be considered where it was practicable to measure channel and overbank flows separately. By repeating the surveys at different times of year, seasonal variation of roughness could be measured.

It is understood from contact with one water authority that they have already instituted a survey programme, collecting the necessary data and photographs from 8 rivers within their region. It is not known whether any other authorities are engaged in a similar exercise, but the authority that is already active, would welcome a joint venture with other organisations.

5.3 Energy dissipators

The questionnaire revealed several different problems associated with this topic. All parties concerned were aware of the considerable amount of research carried out in the USA by the USBR and of other relevant work. The general opinion however was that much of the available design information was for larger structures than those that would be appropriate for the UK. The need in the UK is for relatively small structures to be built with limited resources. Unfortunately, at present the designer of these small structures has to resort to first principles, there being no standard manual available to enable him to produce a design quickly and cheaply. Need for such a manual was expressed, and it could be seen as an extension to the research by CIRIA on the flow over grass spillways, complementing it with guidelines for energy dissipation.

A survey has been carried out [3] on 370 prototype energy dissipators on dams in 61 countries, and this establishes (within broad limits) the ranges of head and flow over which certain types are used and identifies where major problem areas occur. Only existing structures are considered and only those for which reliable data were available. The results of this survey reflect what has been past practice and it was felt that this information, perhaps expanded to include up-to-date and unusual designs, could be incorporated in the manual referred to above.

A secondary problem that was identified, arises when designing protection measures downstream from energy dissipation structures. Problems have occurred due to undetected scour undermining and causing failure of existing basins. In some circumstances, unstable, high velocity jets persist downstream from the energy dissipating structure and attack the banks. Guidelines on the type of channel protection and its extent, are evidently needed.

In some cases stilling basins of small structures serve as means of removing entrained air from the flow prior to it entering tunnels; guidance on the efficiency of air entrainment and its subsequent release from stilling basins would be of considerable benefit.

Experimental research on both these aspects will be essential. Although there is clearly need for further work on energy dissipators, on the lines set out above, it was not possible to define the study as clearly as was possible for proposals 5.1 and 5.2. Further discussions with the industry are necessary before this can be done.

5.4 Tide flaps

Tide flaps are used to prevent the reversal of flow in drainage conduits discharging into rivers or tidal waters. Although a certain amount of research has previously been carried out on these structures (4,6,7), it has consisted mainly of theoretical relationships derived for rectangular gates under free and drowned flow conditions, and usually with lateral expansion of the flow suppressed.

The early work by Anwar (4) involved the pressure distribution along the face of the gate. Coefficients of contraction were confirmed with reference to experimental data obtained by Gentilini (5). Harrison (6) produced a design chart relating discharge to the mass of the gate and the upstream head on it, again for the rectangular and free flow situation only. Pethick and Harrison (7) extended the previous work to include drowned flow and considered two approaches to derive non-dimensional head discharge relationships: (a) the integration of the pressure distribution along the face of the gate and (b) momentum flux.

The principal shortcoming is that all the work-to-date has concentrated on rectangular flaps (which are simpler to analyse theoretically) whereas those in most common use are circular. At present there is no method of predicting how such gates will perform in practice and arbitrary assumptions about their stage - discharge characteristics have to be made. The problem is similar to that experienced with non-standard structures (see 5.1).

An experimental study of the hydraulic characteristics of circular tide flaps would be relatively inexpensive and straightforward to carry out and would quickly produce a useful amount of data.

5.5 Venturi sluices

The increasing interest in tidal power has focussed attention on the hydraulic structures that will form part of the barrage. The sluices, by means of which the reservoir on the up-river side of the barrage is filled on the flood tide, are of particular interest. The more efficient the sluices are in discharging flow under small differential heads, the smaller (or, alternatively, the fewer) the sluices need to be. The system that has been proposed for the Severn and the Mersey Barrages is a venturi sluice i.e. a short culvert that tapers in cross-section from both the up- and downstream faces to the centre. These structures are relatively new and there are little data about their characteristics. As a result of their particular geometry and their manner of application, there can be a pronounced asymmetry in the flow through them and this can lead to flow separation and areas of low pressure. Careful design is necessary.

Some work has been done at Bristol University [8] on a half-model of one sluice, but there is need for further research on a complete sluice operating both singly and in a multiple unit. Any improvement in the efficiency of these structures that can be achieved, could have a significant effect on the construction costs of a barrage scheme.

5.6 Settling basins/ sediment exclusion

From various discussions with respondents following the initial analysis of the replies, it was evident that there was concern about the performance of sediment exclusion devices, on both power generation and irrigation schemes.

A considerable amount of work has been done on sediment exclusion from irrigation and power supply canals and there are a number of reviews/papers containing useful information. The three references (9,10,11) quoted contain over 300 further references.

Complete exclusion of sediment from a system is usually impossible. The usual procedure is to locate channel off-take works in such a position that will minimise, as far as possible, the amount of sediment taken into the channel. Some (but usually not all) of the sediment that does enter the canal is subsequently removed by means of one of the standard removal devices that are installed on canals. It is on some aspects of these sediment removal devices that further work appears to be necessary. In particular the following suggestions have been put forward.

1. Extension of Camp's sediment removal function [12] to aid design of settling basins for fine sediment (< 0.1mm).

2. Further work required on flushing and sluicing systems to improve designs so that less water is lost in carrying out these operations.

3. Determination of optimum width of under sluice pocket and length of upstream wall to ensure minimum sediment entry into channel offtake from barrage.

4. Evaluation of flushing velocities in the conduits as a function of sediment concentration, particle size, conduit size and slope.

5. Evolution of self cleansing sediment exclusion devices for power intakes.

6 SUMMARY OF RECOMMENDATIONS

1. Following a detailed literature review and model testing of some common, but non-standard structures, to produce a manual of the discharge characteristics of such structures covering both modular and non-modular modes of operation. This would be of particular use to all hydraulic engineers, both consultants and water authorities. It is possible that some financial support from water authorities would be forthcoming.

2. To produce a publication containing photographs of UK rivers and streams and their associated roughness values. The data in the publication would be based on survey information obtained by various water authorities. The role of HR would be to analyse and collate the field data from the various sources and to be responsible for the

final publication, which would be extremely useful to UK river engineers.

3. To produce a standard design manual for small energy dissipating structures suitable for use in the UK: this would also include guidance on the types of energy dissipators that are suitable for particular conditions. Preparation of the manual would need to be done in collaboration with a firm of consulting engineers. Some research is required on protection measures downstream from stilling basins and on the efficiency of stilling basins/weirs as air entraining/de-entraining devices.

4. Experimental research of the hydraulic characteristics of circular tide flaps under free and drowned flow conditions.

5. To carry out research on the flow characteristics of venturi-type sluices, both singly and in multiple units.

6. Further research on aspects of sediment removal devices.

   (a) to improve removal efficiency of < 0.1mm;

   (b) to improve the effectiveness of flushing systems;

   (c) to improve the design of canal entrances so as to minimise the quantity of sediment entering the canal;

   (d) to determine the required flushing velocities as a function of sediment concentration, particle size, conduit size and slope;

(e) to develop the design of self cleansing sediment exclusion devices.

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TABLES.

TABLE 1: Replies to Question A(1)

Associate members were asked to indicate which hydraulic structures or devices they or their organisation have used or worked on. The results are:

All	%	Consultants	%	WA's	%	LA's	%
Culverts	84	Culverts	92	Culverts	83	Culverts	79
Valves	67	Valves	83	Flumes	83	Pumps	58
Pumps	61	Flumes	71	Weirs	83	Valves	53
Tunnels	59	Tunnels	71	Channel transitions	67	Bridges	42
Flumes	57	Dams	67	Gates	67	Weirs	37
Weirs	53	Intakes	67	Pumps	67	Cascades	32
Bridges	53	Bridges	62	Bridges	50	Flumes	26
Stilling basins	49	Stilling basins	62	Cascades	50	Dams	26
Dams	49	Temporary works	62	Dams	50	Siphons	26
Temporary works	49	Pumps	62	Intakes	50		
				Siphons	50		
				Spillways	50		
				Valves	50		
No of Replies	51		24		6		19
						Others 2	

TABLE 2: Replies to Question B(1)

They were then asked to indicate which flow related phenomena they or their organisation had encountered.

All	%	Consultants	%	WA's	%	LA's	%
Sedimentation	61	Modelling	91	Flow measurement	100	Flow measurement	53
Flow measurement	61	Sedimentation	82	Head loss	83	Sedimentation	47
Roughness values	59	Head loss	68	Roughness values	83	Roughness values	47
Design	57	Roughness values	68	Erosion	67	Design	47
Head loss	53	Design	68	Super-critical flow	67	Erosion	42
Modelling	53	Water Hammer	64	Design	67	Water hammer	32
Erosion	47	Flow measurement	64	Sedimentation	50	Head loss	32
Water Hammer	45	Surges	54	Cavitation	50	Calibration	31
Surges	41	Cavitation	50	Aeration	50	Pressures	26
Cavitation	35	Erosion	50	Modelling	50	Surges	26
				Turbulence	50		
No of replies	49		22		6		19
						Others 2	

APPENDICES.

APPENDIX I

QUESTIONNAIRE
HYDRAULIC STRUCTURES/PHENOMENA

Name: ....

Position: ....

Organisation: ....

A. Hydraulic structures/devices

1. The following is a list of structures and devices, some directly relevant to water flow (e.g. weirs) annd some indirectly (e.g. bridges). Please put a mark against those which you know you or your organisation have used or worked on.

Tick

- Baffle blocks
- Barrages
- Bridges
- Cascades
- Channel transitions
- Chutes
- Culverts
- Dams:
  - Abutment
  - Arch
  - Earth
  - Gravity
  - Rock-fill
- Drop structures
- Flume:
  - Venturi
  - Long throated:
    - Rectangular
    - Trapezoidal
    - U-shape
    - Others (please name)
  - Short throated:
    - Parshall
    - Cut throat
    - Others (please name)

Tick

- Gates:
  - Barrel
  - Drum
  - Overflow
  - Radial
  - Tainter
- Intakes:
  - Irrigation
  - Power
- Lower level outlets
- Piers
- Pumps
  - Axial
  - Centrifugal
  - Mixed
- Sills
- Siphons
  - Air regulated
  - Bellmouth
- Sluices
- Spillways:
  - Bellmouth
  - Bucket
  - Lateral
  - Morning Glory
  - Orifice
  - Overflow
  - Side
  - Ski-jump

Tick

- Steep channels
- Stilling basins
- Temporary works
- Tunnels
- Turbines
  - Francis
  - Pelton Wheel
- Valves
  - Air
  - Butterfly
  - Gate
  - Iris
  - Needle
- Weirs
  - Compound
  - Flat-v
  - Rectangular profile
  - Round-nosed
  - Thin plate
  - Triangular profile
  - Others (please name)

2. Comment on any problems which you have experienced when using any of these structures/devices and identify any problems which might be resolved by research and development.

B. Hydraulic phenomena

1. The following is a list of phenomena relevant to hydraulic flow. Please put a mark against any which you or your organisation have encountered.

Tick		Tick		Tick	
	Aeration		Head losses		Shock waves
	Calibration		Modelling		Super-critical flow
	Cavitation		Pressures:		Surges
	Design		Static		Turbulence
	Erosion		Dynamic:		Vortexing
	Flow measurement		Roughness values		Others (please name)
			Sedimentation		

2. Comment on aspects of any of these which you feel would benefit from research and development.

3. Other comments

C. Please tick if you would be willing to discuss any of the above very briefly. ☐

APPENDIX II

LIST OF PROPOSED ASSOCIATE MEMBERS

Allen, Gordon & Co
Atkins Research & Development
Babtie Shaw & Morton
Binnie & Partners
D V Buck & Partners
Bullen & Partners
Crouch & Hogg
Engineering & Power Dev Consultants Limited
Wallace Evans & Partners
Sir Alexander Gibb & Partners
F W H Gifford & Partners
Grantham, Brundell & Farran
Haiste & Partners
Sir William Halcrow & Partners
Kennedy & Donkin
Lewis & Duvivier
Sir M MacDonald & Partners
Maunsell Consultants Limited
Merz & McLellen
Mott, Hay & Anderson
L G Mouchel & Partners
Rendel, Palmer & Tritton
Rofe, Kennard & Lapworth
Ward, Ashcroft & Parkman
Watson Hawksley
James Williamson & Partners
Anthony D Bates Limited
Travers Morgan & Partners
French Kier Construction Limited
Sir Robert McAlpine & Sons Limited
May, Gurney & Company Limited
Shephard Hill & Co Limited
B P International Limited
CEGB - Generation Dev & Construction Division
CEGB - Technology Planning & Research Division
Boston District Council
Bournemouth District Council
Adur District Council
Allerdale District Council
Canterbury City District Council
Ceredigion District Council
Colwyn District Council
Copeland District Council
Hartlepool District Council
East Yorkshire District Council
Exeter City Council
Llanelli District Council
Holderness District Council
Portsmouth City District Council

Newport District Council
North Devon District Council
Southend-on-Sea District Council
Suffolk Coastal District Council
Vale of Glamorgan District Council
Wansbeck District Council
Waveney District Council
West Dorset District Council
Orkney Islands Council
Shetland Islands Council
Cornwall County Council
Essex County Council
Hampshire County Council
Kent County Council
West Sussex County Council
Anglian Water
Northumbrian Water
North West Water
Severn Trent Water
Southern Water
South West Water
Welsh Water
Clyde River Purification Board
Forth River Purification Board

APPENDIX III

RESEARCH SUGGESTIONS (GROUPED BY TYPE OF ORGANISATION)

Consultants

Settling, scouring, re-entraining cycle for settling basins with large range of sediment loads.

"Hydraulic resonance" (in tailworks of h-e scheme).

Vibration of partially open gates.

Discharge coefficient of submerged venturi sluices.

Vortices at intakes.

Sediment exclusion at intakes.

Avoidance of damage to stilling basins and baffle blocks.

General - develop theory and analysis to avoid need for model testing.

Scour in large rivers/channels - and formation of armour layer.

Release of air from turbine into tailrace (of pumped storage scheme).

Digestible version of Abraham's "Jet diffusion into an ambient fluid".

Optimisation of tunnel diameters.

Estimation of air demand/requirements for cavitation control.

Control of groundwater for excavations in chalk.

Head losses related to marine fouling (efficiency of chlorination).

Vibration and bad wear of electric screw jack actuators to large cast iron penstock valves.

Comprehensive review of weir discharge coefficients for wide range of weirs, including variation with flow depth (for use in reservoir inspection).

Design criteria for aeration cascades.

Friction head losses in fluids carrying e.g. sewerage sludge and dredging spoil.

Contraction/expansion losses at bridges in a flood plain.

Morphology of gravel bed rivers

Water Authorities

Reservoir inlet and draw-off works - conditions and control.

Reservoir draw-off and bottom scour outlets.

Stilling basins and plunges - energy dissipation.

Grass spillways and overtopping of dams (CIRIA 252) in relation to flow depth, dam face slope and terminal velocity.

Flow measurement in open channels - especially sewers.

Roughness values for river discharge formulae.

Unsteady flow performance of reservoir overflow and by-wash channels.

Hydraulic performance of overflow weirs and spillways (especially during flood).

Performance of drowned vertical sluice gates - estimation of onset of drowning.

Elevation of level in open rivers, in flood conditions, caused by bends.

Weirs - problems of coping with range of flow. Wide crests give poor sensitivity at low flow. Compound weirs with dividing walls (prevent cross-flow) collect debris. Possibility of compound flat-vee weir?

Local Councils

Scour - especially on downstream side of inverts and stilling basins.

Design philosophy for vortex-drop type structures. Usual criteria based on work of Prof Y Peter - Civil Engineering Sept - 1969.

Inflow/infiltration into foul sewers.

Pumping stations - cost effective routine maintenance for foul and storm stations.

Pumps "Which" type report on e.g. impellers and gland packings.

Operation of sewers laid at very flat gradients.

Use of "minimum energy inverts" to prevent deep scour around bridges.

Economic apparatus for storage/attenuation of storm flows for new development in steep catchments.

Good flow measuring instrument for flow in sewers.

Jointing of precast concrete culverts, jointing materials. Winching culverts into place, sealant placement, bedding.

Macerating sewage pumps.

Automatic sluice channel controls.

Air entrainment in pumping mains. Generation of hydrogen sulphide/sulphorous acid in mains.

Flow measurement for flow surveys, accurate surface level measurement, computer data logging. (Arkon dip tubes become dragged).

Roughness values in sewers.

Others

Stilling basin sizing.

Air entrainment/de-entrainment in weirs.

Head loss in needle valves.

Dynamics of open channels under pump trip conditions (cooling tower systems) - simulation programme required.

Dispersion of warm water from outfalls - possibility already covered by HR.

Dynamic pressures from breaking waves.

APPENDIX IV

RESEARCH SUGGESTIONS (GROUPED BY TOPIC)

Stilling Basins/Tailworks

Topic	Originator
Hydraulic resonance (in tailworks of h-e scheme)	James Williamson & Partners
Avoidance of damage to stilling basins and baffle blocks	Engineering & Power Development Consultants
Release of air from turbine into tailrace (of pumped storage system)	James Williamson & Partners
Stilling basins and plunges-energy dissipation	Severn Trent Water
Scour especially on downstream side of inverts and stilling basins	Cornwall County Council
Stilling basin sizing	CEGB GDCD
Proportioning sleeve valve stilling basins	Sir Alexander Gibb & Partners
Ranges of permissible use for energy dissipators	Sir Alexander Gibb & Partners

Flow Measurement (Open Channel)

Comprehensive review of weir discharge coefficients for wide range of weirs, including variation with flow depth (for use in reservoir inspection)	Crough & Hogg
Weirs - problems of coping with range of flow. Wide crests give poor sensitivity at low flow. Compound weirs with dividing walls (to prevent cross-flow) collect debris. Possibility of compound flat-v weir	Clyde River Purification Board
Air entrainment/de-entrainment in weirs	CEGB
Automatic sluice channel controls	Exeter City Council
Performance of drowned vertical sluice gates - estimation of onset of drowning	Forth River Purification Board

Discharge coefficient of submerged venturi sluices	Ward Ashcroft & Parkman
Flow measurement in open channels especially sewers	Severn Trent W A
Discharge characteristics of partially opened flap valves on tide locked outfalls	Travers Morgan & Partners

<u>Intakes</u>

Scaling vortices between models and prototypes	Sir Alexander Gibb & Partners
Reservoir inlet and draw-off works conditions and control	Severn Trent W A
Design philosophy for vortex-drop type structures. Usual criteria based on work of Prof Y Peter - Civil Engineering Sept 1969	Bournemouth Borough Engineers & Surveyors Department
Vortices at intakes	Engineering & Power Development Consultants Limited
Sediment exclusion at intakes	Engineering & Power Development Consultants Limited

<u>Spillway Flow</u>

Hydraulic performance of overflow weirs and spillways (especially during flood)	Severn Trent W A
Unsteady flow performance of overflow and by-wash channels	Severn Trent W A
Durability of steep protected grass slopes under overtopping conditions	Rendel Palmer & Tritton
Design criteria for aeration cascades	Haiste International Limited
Aeration of spillway flow	Sir Alexander Gibb & Partners
Effect of aeration on energy absorption	Sir Alexander Gibb & Partners
Grass spillways and overtopping of dams (CIRIA 252) in relation to flow depth, dam face slope and terminal velocity	Severn Trent W A

Tunnels and Closed Conduits

Temporary works and tunnels, scour and accretion	Travers Morgan & Partners
Air demand characteristics and pressure conditions when valves or gates discharge into closed conduits, e.g. tunnels	Rendel Palmer & Tritton
Optimisation of tunnel diameters	Engineering & Power Development Consultants
Estimation of air demand/requirements for cavitation control	Engineering & Power Development Consultants
Jointing of precast concrete culverts jointing materials. Winching culverts into place, sealant placement and bedding	Exeter City Council

Pipe Flow

Flow measurement for flow surveys accurate surface level measurement, computer data logging	Exeter City Council
Good flow measuring instrument for flow in sewers	Suffolk Coastal D C
Operation of sewers laid at very flat gradients	Newport Borough Council
Roughness values in sewers	Exeter City Council
Friction head losses in fluids carrying e.g. sewage sludge and dredging spoil	Maunsell
Inflow/infiltration into foul sewers	Newport Borough Council
Roughness values for modern generation pipes	Bournemouth Borough Engineers & Surveyors Department
Air entrainment in pumping mains. Generation of hydrogen sulphide/sulphuric acid in mains	Exeter City Council

Pumps, Valves and Gates

Vibration of partially open gates	Ward Ashcroft & Parkman
Vibration and bad wear of electric Screw jack actuators to large cast iron penstock valves	Wallace Evans & Partners
Pumping stations cost effective routine maintenance for foul and storm stations	Newport Borough Council
Pumps - "which" type report on e.g. impellers and glan packings	Newport Borough Council
Head loss in needle valves	CEGB
Macerating sewage pumps	Exeter City Council
Reservoir draw-off and bottom scour outlets	Severn-Trent W A

Rivers/Channels

Scour in large rivers/channels - and formation of armour layer	Sir M MacDonald & Partners
Use of "minimum energy inverts" to prevent deep scour around bridges	West Sussex C C
Economic apparatus for storage/ attenuation of storm flows for new developments in steep catchments	West Dorset D C
Dynamics of open channels under pump trip conditions (cooling tower systems) - simulation program required	CEGB
Contraction/expansion losses at bridges in a flood plain	Maunsell
Morphology of gravel bed rivers	Bullen & Partners
Roughness values for river discharge formulae	Severn-Trent W A
Elevation of level in open rivers, in flood conditions, caused by bends	Forth River Purification Board
Scour around bridge piers	Travers Morgan & Partners

General Topics

Develop theory and analysis to avoid need for model testing	Rofe Kennard & Lapworth
Sediment transport	Travers Morgan & Partners
Causes of erosion	Sir Alexander Gibb & Partners
Aeration and cavitation	Binnie & Partners
Roughness values	Binnie & Partners
Sedimentation	Binnie & Partners

More work required on:

Baffle blocks, ridges, channel transition, gates, irrigation, low level outlets and tunnels	Binnie & Partners
Roll wave formation in near critical and super-critical flow	Binnie & Partners

Others

Settling, scouring, re-entraining cycle for settling basins with large range of sediment loads	Sir M MacDonald & Partners
Digestible version of Abraham's jet diffusion into an ambient fluid	Lewis & Duvivier
Control of groundwater for excavations in chalk	May Gurney Tech Services Limited
Head losses related to marine fouling (efficiency of chlorination)	French Kier
Dynamic pressures from breaking waves	CEGB
Ship impact forces	Travers Morgan & Partners