HYDRAULIC RESEARCH NEEDS

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With greater utilization of water resources, the importance of hydraulics and related subject matter becomes increasingly apparent for technical and economic reasons. Better methods are needed for coping with the hydraulic problems of supplying water for municipalities, industry, agriculture and recreation.

New provisions must be made for a more dynamic approach to hydraulic design and development of water resources if we are to keep up with a growing population's demand for food and an increased industrial demand for new materials synthesised from agricultured products. Already, the population growth coupled with increased mobility, has forced the abandonment of the old concept of system design for a long term in favor of a more flexible short term system that can be modified periodically to meet changing need.

Interest generated by present publicity of the space sciences and engineering science has diverted a disproportionately large number of today's outstanding students into their fields. To regain our share of these students, we must publicize the importance of hydraulic concepts and theories and actively encourage a continued flow of new engineers and scientists into the vital area of hydraulics.

Historically, the concepts of hydraulics, fluid mechanics and related fields have improved with time and with the need for improved knowledge. However, most of our practical theories and concepts give approximate solutions that are experimental or semi-theoretical. With the necessity to more completely and economically develop our water resources, refinements of these concepts are urgently required.

During the past decade a number of reports have delineated research needs in the various sub-areas of hydraulic and irrigation engineering. In some cases, the deficiencies of existing knowledge have been pin-pointed and general agreement has been evident on the primary items suggested for immediate study. Other deficiencies related to the problem of hydraulic research are: lack of interchange of ideas, confusing terminology, lack of interdisciplinary cooperation and absence of coordination and utilization of knowledge resulting from world-wide basic and applied research.

Some of these deficiencies were discussed at a recent research conference (1) by several participants including the writer. A brief discussion follows.

COMMUNICATION AND INTERCHANGE OF INFORMATION

There is need for better communication and information interchange between the researcher, the design engineers and operations and management personnel. Development of avenues of contact including common terminology, common publication outlets, discussions and cross association between basic and applied efforts need attention. In the case of fluvial hydraulics the design engineer seldom has a chance to discuss problems with the operating engineer. There is even less opportunity for these engineers to communicate with research personnel. The flow of knowledge is inhibited by the natural reluctance of people to disclose their mistakes and unsolved problems. Diversity of responsibilities within organizations has brought about an extension of this practice.

Too often, the research engineer is involved in the analysis of a highly idealized system that bears slight resemblance to the real situation and his results are often in the form of complicated graphs and equations generally incomprehensible to the practicing engineer. In this regard, there has been severe criticism of many of the recently published technical papers. The practicing engineer faced with the realities of design operation and maintenance of systems, must make many decisions. Seldom is there time to thoroughly ponder the pros and cons of complicated (and in many instances non relevant) concepts.

A more direct line of communication must be established if we are to alleviate these obstacles. Information uncovered by fundamental and applied research must be immediately made available in an intelligible language to design and operating engineers if time lag is to be reduced. Too often, under the present system, there is a ten year interval between the development of a new concept and its application.

TERMINOLOGY

There is considerable divergence and many inconsistencies in terminology and definitions related to certain phases of hydraulics. This deficiency exists internationally and nationally. Within the field of fluvial hydraulics and sedimentology it has been stated (1) that:

> "Clarification and establishment of acceptable terminology and definitions, such as bed load, applicable to all disciplines dealing with the broad field of sedimentation must be accomplished to remove this restraint on general progress."

INTERDISCIPLINARY APPROACHES

In many facets of hydraulic engineering the final solution is not likely to result from consideration of hydraulic principles alone. Much of the required research in engineering and in hydraulic engineering is interdisciplinary in nature. Hence, an effort is required to provide the atmosphere and the scientists and engineers necessary to conduct a multi-disciplined attack on such problems. This suggests a joint effort by various combinations of hydraulic engineers, hydrologists, geologists, geomorphologists, soil physicist, chemists, micro-biologists, watershed management staff, instrumentation experts, electronics specialists, mathematicians, and others depending upon the problem. Currently, certain funding agencies are beginning to recognize this need as evidenced by their increased research programs.

FUNDAMENTAL AND APPLIED RESEARCH

Many complex problems in hydraulic engineering and related fields are so urgent that it is impractical to wait for time consuming laboratory solutions resulting from basic research. To help meet the current needs, research of an applied nature must be encouraged. Often research is conducted in an unrealistic laboratory environment with little emphasis on attempting to correlate research discoveries with actual field phenomena. This frequently limits the usefulness of new findings in practical engineering. It is suggested that wider use be made of field cites. This is particularly true when dealing with canals and rivers. In the laboratory we have varied the magnitude of significant parameters by changing slope, while in the field the variation in parameters may be largely due to changes in depth and discharge. In reality, we know very little of the effect of depth on bed forms, bed material transport and channel geometry. However, it is more difficult and more expensive to conduct field research because of various limitations. Panel 3 (1) stated:

> "At present, inadequacies in instrumentation and techniques are limiting the field investigations on boundary shear, sediment and velocity distribution in the vertical, shear strength of in-situ bank materials with degree of saturation, water surface gradient instataneously and with time; determination of total transport and bed and suspended particle size distribution instantaneously and with time; and the identification of bed forms with changing hydrograph."

RESEARCH NEEDS

Many groups and organizations have been and are recognizing the urgency for planned research in engineering. University staff are looking ahead and planning their work with greater continuity. The state and federal agencies are developing well-organized research teams and programs oriented toward achieving specific goals. Most technical societies are emphasizing the need for a greater research effort.

The Water Ways and Harbors Division of American Society of Civil Engineers is preparing a proposed ten-year research program in coastal engineering. In 1961 (2) a group of leading engineers and scientists from related fields of civil engineering were assembled at Colorado State University by a planning committee consisting of staff from the American Society of Civil Engineers, the U.S. Bureau of Reclamation, and Colorado State University to investigate means of promoting and streamlining research in civil engineering. The interests considered were primarily water resources oriented. The topics selected for discussion included:

1. Static and dynamic behavior of soils
2. Static and dynamic behavior of rock
3. Static and dynamic behavior of concrete
4. Fluvial hydraulics
5. Hydraulics of water conveyance
6. Flow in porous media
7. Conservation and utilization of water

In March of 1964 an Irrigation and Drainage Research Conference (1) was conducted at Utah State University. Sponsors of the conference were the American Society of Civil Engineers, Utah State University, the U.S. Bureau of Reclamation and the National Science Foundation. The purpose of the conference was to assemble authorities in certain fields of irrigation and drainage and related fields to delineate and stimulate research needs in selected subject fields. The fields were:

1. Evaporation from water and soil
2. Salinity and alkali problems
3. Stable channels
4. Small low-cost hydraulic structures for conveyance and distribution systems
5. Weather modification
6. Ground water management

The writer participated in the foregoing conferences and has drawn freely from the valuable suggestions of these panels.

There is a need to evaluate proposed research programs and extract and report those problems which have to do with hydraulics and hydraulic research. The field of hydraulic engineering is very broad and encompasses many specialties. Hence, it is impossible for special groups or any one individual to be knowledgeable of all existing and potential research problems. Nevertheless, until a more thorough study of research needs in hydraulics is conducted it may serve a useful purpose to cite some of the hydraulic research needs that the writer is aware of as a result of his research, teaching, and participation with various panels that have reported on research needs.

FUNDAMENTAL HYDRAULIC PHENOMENA

Some of the fundamental hydraulic phenomena that requires study include:

1. Turbulence as it pertains to energy losses, entrance and exit loss coefficients, and air entrainment.
2. Separation as it occurs when the streamlines are forced to change direction by the boundary configuration. Separation causes reduced flow areas, increased head loss, pressure reduction, cavitation, and variation in the flow that may cause vibration and shock in hydraulic structures.
3. Cavitation which can cause serious damage to hydraulic structures and hydraulic machinery. A panel on the hydraulics of water conveyance (2) stated that:

   > "Intensive laboratory study of this phenomena is needed. It is probable that large scale, high-velocity apparatus will be required to simulate the proper boundary layer conditions. Control of dissolved air and foreign matter may be necessary as the cavity forms more readily around such nuclei."

4. Boundary layer phenomena development and application.
5. Instabilities such as the formation of vortices, division of flow, and Taylor type instabilities. The vortex instability affects performance of culverts, weirs, locks, bridge piers, and may play a significant role in the mechanics of flow in sand bed channels with large form roughness.

Problems that are of an applied nature include:

6. Dividing flow into two or more streams such as into multiple penstocks and sprinkler pipes.

7. Combining flows from pipes and open channels. These problems are particularly difficult and unresolved for joining supercritical flows or subcritical and supercritical flows in open channels.

8. Wave motion involving both gravity and pressure waves.

9. Flow stratification such as occurs in reservoirs caused by variations in temperature, sediment concentration, and chemical content.

10. Energy dissipation.

11. Pressure and velocity distribution.

12. Forces on hydraulic structures.

A much broader and more detailed discussion of these and related research needs were reported and discussed in the Symposium on Basic Research in Civil Engineering (2).

FLUVIAL HYDRAULICS

The problems of fluvial hydraulics are complex, interesting and very important. Their complexity is primarily caused by the involvement of many interrelated variables such as free surface flow, variations of turbulence, and secondary circulations, and boundary layer phenomena.

Some of the problems that are of interest to the writer and appear to be worthy of study include:

1. Characteristics of alluvial material--Physical and possibly chemical characteristics of alluvial material must be isolated and categorized. Relations must be established between these characteristics and the various modes of bed material transport.
2. Prediction of characteristics of bed material--Characteristics of bed material in alluvial channels must be determinable prior to design and operations of systems.
3. Selection of bed materials for model studies--An improved criteria for selecting bed materials for laboratory model studies is necessary if we are to be able to correlate laboratory findings with field conditions.
4. Stabilization of alluvial channels--Methods of stabilizing the perimeter of alluvial channels using gravel, cobbles, rock and similar material need to be refined and improved. Also, the development of armor from the coarser particles of natural material as a result of removal of finer sizes by scour should be studied.

5. Protection of structures--Improved methods of stabilizing alluvial channels in the vicinity of hydraulic structures must be developed. New synthetic materials may be applicable to this problem.

6. Channel equilibrium--A study of the equilibrium state in alluvial channels is necessary to better explain the delicate balance between channel shape, energy gradient, flow, the various types of sediment being transported, the bed and bank material, and changes in temperature.

7. Temperature--We need a more thorough investigation of the effect of temperature on the mechanics of flow in alluvial channels. For example, it has been established (4) that a change in temperature can radically alter the form of bed roughness and hence may effect other important parameters such as resistance to flow and bed material transport. Temperature probably plays a more significant roll in fluvial hydraulics problems than is realized.

8. Wash-load--A more thorough study of the effect of wash load (clays and silts normally carried in suspension) on alluvial channels is needed. The presence of large concentrations of clays and silts in suspension can alter the bed roughness, affect seepage losses, influence the stability of the channel and radically alter the apparent viscosity of the water sediment liquid from that of water.

9. Bedforms--A detailed study of the bed forms that occur in alluvial channels and their relation to channel stability, resistance to flow, and bed material transport should be carried out.

10. Large alluvial bars--The environment conducive to the development of alternate, point and middle bars and the effect of their movements and physical changes on resistance to flow, channel geometry, stability and bed material transport should be determined.

11. Effect of hydraulic structures--Channel changes induced by construction of the many types of hydraulic structures and their control need further study.

12. Navigation channels--A study of the design and control of alluvial channels for navigation should be conducted. This problem involves not only river mechanics but also methods of changing the channel cross section, the radius of bends, the length of chutes, the characteristics of pools, the forms of bed roughness, the characteristics of bars and methods of utilizing river control structures and bank protection works to help hold the stream in a preferred location and achieve the most desirable channel conditions.

13. Geomorphology--A better knowledge of geologic and geomorphologic implications on stream nets and individual channels in terms of both geologic and engineering time and the effects of geomorphic changes on engineering works must be developed.

14. Unsteady-nonuniform flow-- The mechanics of flow in open channels in terms of nonuniform and unsteady flow conditions should be more thoroughly analyzed. At present, most channel designs are based upon some arbitrary equilibrium discharge and steady flow conditions which may not approximate reality.

15. Channel slope--Precise methods of measuring channel slope, slope of energy gradient and variations in time must

be developed. In some instances, slope is an independent variable, in others it is a dependent variable.

16. Channels with cohesive boundary--Establishment of a more adequate and rational procedure for designing channels formed in cohesive materials should be developed. This requires better methods of defining and measuring the characteristics of cohesive materials and the forces that cause scour.

17. Stochastic processes--Stochastic analysis of bed roughness, channel alignment, shape of channel cross-section and other geomorphic problems are in order.

18. Bed-material discharge--Our bed material discharge relations are still inadequate. At present, we introduce fall velocity in terms of quiescent conditions. Actually, we have not studied the effect of turbulence, know very little of the depth effect and have only touched on the effect of temperature and the concentration of wash load. Above all, it is necessary to investigate how the various size fractions of bed material are transported. Some work has been initiated along these lines by the U. S. Geological Survey (6) at Colorado State University.

19. Turbulence--The roll of turbulence in hydraulics needs to be evaluated. Only recently adequate instruments have been developed for research of this type. Such instruments include the electrokinetic probe, units that utilize the Doppler effect, small differential pressure transducers and specially constructed current meters and recording equipment.

20. Secondary circulation--Secondary circulation is still an unknown entity. This flow phenomenon must be studied in both straight and curved channels. It undoubtedly contributes

to the bed configuration, sediment transport, to velocity and water surface profiles and to channel alignment and geometry.

21. Seepage forces--The effects of ground water on open channels needs further evaluation. The level of the ground water adjacent to open channels controls the inflow or outflow from the channel. This flow causes seepage forces that affect the channel stability, geometry and the adequacy of bank protection works and other hydraulic structures.

22. Other problems--Other important problems include the evaluation of energy losses and shear stresses in bends, the roll and hydraulics of multi-shaped channels, the effect of placing streams in straight jackets by channel stabilization, the development and use of artificial controls, and last but not least more adequate instrumentation for field and laboratory research.

HYDRAULIC STRUCTURES

Some of the current problems of interest as reported by the Irrigation and Drainage Division of ASCE (1, 3) include the following specific problems:

1. Hydraulic Roughness--Basic, imaginative research is needed to better understand and characterize the effect of roughness on flow. The utilization of roughness for energy dissipation and flow control needs further investigation.

2. Flow Measurement--Research is needed for development of entirely new measurement concepts as well as further investigation in modifications of older methods.

3. Energy Dissipation--Dissipation of energy using simple structures needs intensive study. New and unconventional concepts for dissipation and conversion of energy should be investigated.

4. Pipelines--Water hammer, surges, air entrainment, and other hydraulic problems, require that an intensive research program be initiated for improved design of pipeline and pipeline structures.

5. Piping--A better understanding of mechanics of piping and methods of prevention and controls are needed.

6. Canal Linings and Seepage--Better and cheaper canal linings are a continuing need. Improved methods of seepage measurement must be developed.

7. Construction Methods--Development of uses and procedures for construction using prefabricated and modular sections are needed.

8. Materials--The use of new materials which show promise of lower costs and/or more satisfactory structural or hydraulic properties needs more investigation. Standards and specifications for these materials are needed.

9. Codes and Standards for Small Hydraulic Structures--The concept of a "calculated risk" applied to small structures will result in a more economical design. This requires a re-evaluation of allowable stresses and recommended factors on safety.

10. System Design--The entire farm irrigation system design needs intensive study and design improvement. Considerations include labor saving and better application efficiency through automation, better regulation structures, and more efficient methods of water application.

11. Specific Problems--Other specific items that need further study and development include: Turnouts, metergates,

flow measuring devices, trapezoidal structures, side channel weirs, siphons and regulators, stilling basins and wells, transitions, bank erosion control, wave suppressers, seepage measuring devices, canal sealants, sediment control devices, moss and/or weed elimination devices, automatic flow controls, and rescue and safety devices.

COASTAL ENGINEERING

This division of engineering is largely hydraulic engineering in the broad sense of the word and encompasses methods of controlling, improving, and stabilizing inlets, estuaries and shores from waves, tides, storm surges, and normal flow. It also includes problems associated with navigation channels in the tidewater zone and the design of channel and coastal structures including bank protection works, sewer outfalls, cooling water tanks and off-shore drilling platforms.

Some of the suggested problems(7) for immediate consideration include:

1. Instrumentation--Instrumentation must be developed that can measure: wave height, wave direction, wave forces on hydraulic structures, sand transport by waves, sand transport by wind, and current velocity and direction in estuaries.
2. Waves--Wave action in the coastal zone including such problems as generation of waves, bottom effects, wave kinematics and types of waves need further study.
3. Sand transport--Shore processes such as onshore and offshore sand transport, the mechanics of sand transport by waves, the bed configurations generated by waves and growth and stabilization of dunes shoud be investigated.

4. Tides--Tides and surges including the mechanics of tidal flow and the effect of boundary configuration in conjunction with storm surges require additional study.

5. Inlet hydraulics and hydrography--Studies of the effect of different types of storms, degradation, aggradation, bank scour and channel bars should be carried out. Also basic studies of the characteristics of salinity currents and salinity intrusions are needed.

6. Forces--New techniques for evaluating forces that affect structural design such as: wave forces, impact or shock pressures, uplift pressures, mooring stresses and forces on submerged pipelines are needed.

7. Structural life--Knowledge of structure life, structure stability and of filter layers is lacking.

8. Stabilization structures--The effect of various types of coastal structures for stabilization and control is difficult to predict. We specifically need to study the effectiveness of: adjustable groins, seawalls, bulkheads, jetties, breakwaters, methods of transferring sand past inlets, methods of replacing bank sands, maintenance of jetty channels, wave forces on shore structures and improvement of dredging methods.

The panel on coastal engineering research have tenatively suggested that the cost of coastal engineering research should total about $50, 000, 000 in the next ten years to meet the demands for new knowledge and methods.

CONCLUSIONS

It is essential to sell the value and importance of an accelerated and hydraulic engineering research program to funding agencies.

The importance of hydraulic engineering nationality and internationality must be stressed to the academic institutions if we are to be assured of adequate educational facilities in the future. Also, we must strive to catch the interest of a larger precentage of the excellently qualified youth for this field.

An international committee should be assigned the task of evaluating research needs in hydraulic engineering methods of financing these projects must be developed. These problems deserve immediate and detailed attention.

It is essential to devote time and effort to the standardization and adoption of a more universal terminology.

To assure the widest possible dissemination of ideas and concepts, improved outlets of communication must be promoted. This would bring about a more rapid utilization of research findings and minimize duplication of effort among agencies.

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