327

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RESEARCH PROBLEM STATEMENTS: HYDROLOGY, HYDRAULICS AND WATER QUALITY

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modes
1 highway transportation
3 rail transportation

subject area
22 hydrology and hydraulics

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INTRODUCTION

This circular contains forty-eight research problem statements developed by the Committee on Hydrology, Hydraulics and Water Quality. The statements were screened by subcommittees and the ordering of statements by subject represents the best concensus of priority research in that subject.

R E S E A R C H P R O B L E M S T A T E M E N T S

PRIORITY STATEMENTS BY SUBJECT

HYDROLOGY

HYDRAULICS

HYDRAULICS (Continued)

WATER QUALITY

HYDROLOGY

PROBLEM NO. 1

I. NAME OF PROBLEM - MODELS FOR FLOOD FREQUENCY PREDICTIONS FOR BRIDGE AND CULVERT DESIGN

II. THE PROBLEM - Highway drainage structures are designed for runoff events calculated to recur on the average of once in a certain number of years. As a basis for design, recurrence intervals of 10, 25, and 50 or more years are assigned, depending upon the relative importance of the highway and the degree of risk that can be accepted. In order to determine the design capacity needed for a structure for a give recurrence interval, the engineer must usually resort to some information transfer mechanism since observed flood data are usually nonexistent for the site of interest.

Information transfer techniques consist of regional regression equations relating peak discharge to climatic and/or watershed characteristics, rainfall runoff models based on design or historical rainfall values, or simply the transfer of a flood-frequency curve from a nearby gaging station to the ungaged site. These various information transfer techniques can give quite different design discharges. With the exception of the rainfall runoff model based on a design rainfall event, these techniques are based on flood-frequency analysis of observed peaks at gaging stations. Flood-frequency analysis is a mathematical procedure for estimating the probability of future floods on the basis of past flood events. The solution is obtained by fitting the observed peak discharges to a theoretical probability distribution.

A pilot test comparing the performance of ten frequently used transfer techniques for estimating peak discharges for ungaged watersheds was completed several years ago. This test, which was sponsored by the Hydrology Committee of the Water Resources Council (WRC), indicated that regression models tended to be more unbiased and reproducible than the rainfall-runoff models. The test further indicated that the variability among the various transfer techniques (models) was greater than the variability associated with different theoretical probability distributions for the gaging station data.

Due to the high costs of a nationwide test, it is not feasible to consider so extensive a test at this time. However, it would be of value to re-examine commonly used transfer techniques and identify their capabilities and limitations, including geographic constraints. Opportunities for calibration and verification of transfer techniques should also be a criteria for selection.

Transfer techniques or models selected for study should not be limited to those used in the WRC Hydrology Committee pilot test. Emphasis should be on transfer techniques applicable to small watersheds (less than 100 square miles). Recognition of mixed population floods as discussed in problem statement number five will be necessary in studying the transfer techniques or models.

III. OBJECTIVES

A. To select for study those transfer techniques or models commonly accepted by professional hydrologists, and also new promising techniques.

B. To assess the capabilities, limitations, geographic constraints, and any measures of errors and accuracy of selected models.

C. To assemble and highlight essential guidelines for application of models giving consideration to factors such as watershed size, physiographic province, climatic regime, and statistical parameters.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA Contract Research Studies at Utah State University (1977); WRC Committee on Hydrology sponsored research at the Center for Research in Water Resources, University of Texas; WRC pilot test of comparison of transfer techniques documented in a (1981) WRC report. Approximately 30 small watershed studies in various states most of which are complete or in the final stages.

B. Suggested key words: Flood-frequency analysis, recurrence interval.

V. URGENCY - Flood-frequency predictions are basic elements in the design of highway drainage structures. The success or failure of a design is often dependent on the accuracy of such predictions. Engineers have frequently been misled into underdesign, or else have

applied factors of safety resulting in overdesign. The consequences have been expensive in either case. For the past 10 to 15 years the U.S. Geological Survey, in cooperation with many state highway departments, has collected runoff data from a larger number of small rural watersheds. These data provide a real opportunity for a study and comparison of flood-frequency techniques. The results of such a study would reduce the risk element in the hydraulic design of bridges and culverts and lead to more uniform practice in the prediction of design discharges for such structures.

PROBLEM NO. 2

I. NAME OF THE PROBLEM - FLOOD HYDROGRAPHS FOR URBAN AND RURAL BASINS FOR USE IN DESIGN OF DRAINAGE STRUCTURES WITH RISK ANALYSIS

II. THE PROBLEM - Knowledge of the magnitude and frequency of storm runoff from rural and urban streams is required for safe and economic design of highway drainage structures. Most urban and many rural drainage systems are so complex that flood routing is often needed to generate the necessary flood hydrographs (peaks, volumes, and duration of flooding) for design purposes. However, considerable data and resources such as manpower, time, expertise, and computers are required to route flows and account for storage conditions that usually exist in urban watersheds. An expedient method of generating flood hydrographs is needed which can account for the temporary in-channel storage resulting from highway embankments and runoff detention structures. Previous research by Harley and the U.S. Geological Survey (in the "Interim Analysis of Urban Flood Data") has developed methods of estimating flood peaks, flood volumes, flood hydrographs and basin lagtime for urban watersheds which do not exhibit significant temporary in-channel storage. This research needs to be extended to watersheds with significant storage. Simplified methods of quantifying this temporary in-channel storage need to be developed.

III. OBJECTIVES - Develop a simplified and widely applicable technique for reliably estimating flood hydrographs, flood peaks, and flood volumes for urban and rural streams which have significant temporary in-channel storage. Develop a simplified technique for estimating the duration of flooding above a specified discharge.

IV. CURRENT ACTIVITIES

A. Related research activities: A recently completed project of FHWA and USGS demonstrated that a dimensionless unit hydrograph can be used to estimate flood hydrographs for ungaged urban watersheds. This approach used the Clark Method for linear storage routing and regression equations for estimated peak discharge and basin lagtime. These regression equations were only applicable to urban watersheds without significant in-channel storage.

FHWA sponsored a study at Utah State University in 1976 on urban storm runoff inlet hydrographs for typical highway

right-of-way sections. That study resulted in a relatively complex computer model to compute hydrographs, but it was not pursued to the next step of using the model to generate simplified design parameters. That study, however, was limited to runoff from the highway right-of-way.

The "Interim Analysis of Urban Flood Data" conducted by the Federal Highway Administration (FHWA) and the U.S. Geological Survey (USGS) identified approximately 70 watersheds with significant temporary in-channel storage and these data could form the basis for a more comprehensive data base for defining the estimation technique.

FHWA sponsored a project with Camp Dresser and McKee, Inc. to develop an Urban Highway Drainage Model. This model includes a hydrograph module along with a number of other modules including an input rainfall module, a pumping module, a cost module and a quality module. FHWA has had difficulty converting the model from CDC to the Amdahl system, but it does have some good features.

B. Suggested key words: design floods, urban watersheds, frequency analysis, flood hydrographs, flood volumes, detention storage, storm drainage.

V. URGENCY - Designs of culverts, bridges, and other drainage facilities will be improved significantly through more realistic and more easily coordinated design criteria. Significant economic benefits will accrue to both highway and non-highway users.

PROBLEM NO. 3

I. NAME OF PROBLEM - THE ECONOMICS OF FLOOD DATA COLLECTION AND CULVERT DESIGN

II. THE PROBLEM - Most culverts must be located on streams where flood data are nonexistent. The design flood must be estimated on the basis of data from other gaged streams in the vicinity by using best available hydrologic models as the information transfer mechanism. If the procedure used for the hydrologic design is economically valid, as more data are collected in the area, the new or replaced culverts in that area will be better designed. However, the procedure for specifying an optimum program of flood data for the design of culverts does not currently exist.

III. OBJECTIVES - Develop techniques for estimating the regional requirements for flood data to be used in designing highway culverts.

IV. CURRENT ACTIVITIES

A. Related research activities: several studies have addressed this problem in the past, but useful conclusions have yet to be reached.

B. Suggested key words: culvert design, flood-frequency analysis, data collection networks.

V. URGENCY - The collection of flood data requires time, and this study is a prerequisite to the initiation of optimum data programs. Thus, delays in initiating this study perpetuate the current paucity of understanding concerning the sizing of highway culverts.

PROBLEM NO. 4

I. NAME OF PROBLEM - LONG RANGE WEATHER FORECASTING TO AID IN PREDICTING SNOW REMOVAL BUDGETS BY TRANSPORTATION AGENCIES

II. THE PROBLEM - The annual snow removal budgets prepared by transportation agencies are often inaccurate. This is due in part to the budgets being prepared six to 12 months prior to the ensuing snow season. Reliable procedures for transportation agencies to forecast snow removal costs are not available. Often the budget is only a reflection of the previous year's snow removal costs or some type of floating average of such costs from prior years.

This type of guess work or simple arithmetic approach to budgeting snow removal costs often results in a poor use of transportation funds. Excessive overestimates of expected snow removal costs results in the denial or delay of funds for other essential transportation projects; underestimates result in either deficit funding or the deletion of important projects as the snow season progresses.

III. OBJECTIVE - The objective of this research is to develop statistical, hydrological and meteorological procedures for use in projecting snow removal costs in a timely manner and within known limits of certainty. These costs would be made for inclusion in a transportation agency's annual budget call as well as for midcourse corrections.

IV. CURRENT ACTIVITIES - This program requires a two-fold effort: (1) Relating annual snow accumulation to snow removal costs; and (2) Developing long range predictions of snowfall in relation to predicted precipitation and temperature regimes. The former requires routine analysis of snow removal costs in relation to the frequency of occurrence of seasonal snowfall. Activity in long range predictions includes the following:

A. There has been considerable activity in attempting to devise global and regional physical predictive models. The National Climatic Program Office in Rockville, Maryland has been a focal point for this work on the North American Continent.

The National Science Foundation (NSF) supported research has produced encouraging prediction results. Florida State University has used monthly wind analyses from the National Oceanic and Atmospheric Administration (NOAA) to update a simple, coupled ocean-atmosphere procedure that predicts thickness of the warm water layer in the equatorial Pacific.

Incorporation of this wind analysis in near real-time will allow crude forecasts of El Nino onsets and the resultant effects of weather on the American Continent. A good relationship between forecast and observed temperature over a five-year time interval encourages further development of this model.

The NSF supported research has also demonstrated a relationship between rainfall in northeast Brazil and several Atlantic Ocean ocean-atmosphere variables. Efforts are now being made to acquire these data in a near real-time framework in order to utilize them for predicting rainfall in drought-prone regions of Brazil.

NOAA has statistically evaluated the influence of the fall Southern Oscillation Index on tropical East Pacific warming situations. Another NOAA study has used satellite data to confirm inverse relationships between Eurasian mean winter snow cover extent and the following warm season Indian Monsoon rainfall. Other studies have shown how large amplitude atmospheric anomalies are driving sea surface temperature anomalies in the Southern Hemisphere. These foregoing kinds of global research may prove useful in the development of long range forecasting procedures for the American Continent.

Improvements have also been made in the statistical-dynamical forecast techniques. NSF supported research has resulted in a refined statistical analog prediction technique for the East Coast of the United States that predicts monthly temperatures. Further work with the statistical-dynamical climate prediction technique indicates the excludability of certain nonlinear terms; if true, this would greatly simplify the use of certain prediction techniques.

Monthly forecast experiments by NOAA indicate the feasibility of monthly forecasts. Refinement of selected small-scale physics has improved the experimental monthly forecasts by better simulating blocking pressure ridges and better placing the geographic locations of planetary-scale waves in the westerlies.

NOAA monthly and seasonal predictive operations entered their third year in a probabilistic format. Fifty-four monthly predictions for North America and Eurasia have been completed on a semi-monthly schedule and twenty-seven three-month predictions for the United States, on a monthly schedule.

The experimental climate forecast center at the University of Washington will concentrate on the implications for long-range prediction based on studies of the EL Nino and Southern Oscillation and other very large scale, definable phenomena.

The annual reports of the National Climate Program, compiled by the National Climate Program Office, National Oceanic and Atmospheric Administration, 6010 Executive Boulevard, Rockville, Maryland 20852 provide additional, detailed comments on current activities.

B. Another alternative that should not be overlooked is that of employing probabilistic methods. No activity is known to have

occurred on attempting long range forecasting of snow removal requirements using this alternative. Similar to the flood-frequency analysis of stream gage records, this approach would make use of climatological records to arrive at a statistical relationship regarding the probability of realizing snowfall amounts each year.

V. URGENCY - Annual transportation related snow costs for highway and streets at all levels of government were found to be in excess of one billion dollars. (Reference: Minsk, L. David, "Chemical Control of Snow and Ice on Highways", Strategic Transportation Research Study - Technical Design, AASHTO, Washington, D.C. May 1984)

A realistic annual allocation of funds between snow removal and construction would allow many essential transportation projects to be constructed in a more timely manner.

PROBLEM NO. 5

I. NAME OF PROBLEM - MIXED POPULATION FLOOD-FREQUENCY ANALYSIS

II. THE PROBLEM - Knowledge of the magnitude and frequency of flood is required for safe and economic design of highway drainage structures. General guidelines for estimating the magnitude and frequency of future flooding from gaging records have been provided by the Water Resources Council. Existing guidelines only weakly cover the analyses applicable for sites where flooding results from two or more distinct causes such as snowmelt, thunderstorms, hurricanes and cyclonic storms. Highway drainage engineers need additional guidance and/or better techniques for estimating the magnitude and frequency of floods in areas where multiple flood causes are experienced.

Some aspects of Problem I (Models for Flood Frequency Predictions for Bridge and Culvert Design) may pertain to this problem as well.

III. OBJECTIVES - Develop more detailed and/or alternate guidelines for estimating magnitude and frequency of flooding in mixed population areas. Develop procedures for discrimination of regions significantly impacted by mixed population phenomena.

IV. CURRENT ACTIVITIES

A. Related research activities: In a pilot study the U.S. Geological Survey has identified gaging stations in Colorado, Montana, and Idaho where mixed population flooding occurs. Recent regional flood-frequency reports in Montana and Idaho were based on gaging station data for combined rainfall-snowmelt frequency curves. The U.S. Corps of Engineers has used the concept of mixed population frequency curves in the North Atlantic States and the Pacific Northwest.

B. Suggested key words: floods, design floods, frequency analysis.

V. URGENCY - More reliable estimates of design floods should provide more effective and safe designs for bridges and culverts with substantial economic benefits to non-highway as well as highway users.

PROBLEM NO. 6

I. NAME OF PROBLEM - TECHNIQUES FOR ESTIMATING HISTORIC EXTREME FLOODS

II. THE PROBLEM - Considerable breakthroughs have been achieved in developing accurate methods to estimate flood-frequency relationships from stream-gage records. The small watershed studies undertaken by most states in cooperation with the U.S. Geological Survey (USGS) are one of the major sources of data and information. The accuracy of flood-frequency predicting methods based on stream-gage data is largely a function of the record length, except where major hydrologic changes have occurred during the period of record. Stream-gage data of short duration can be influenced by climate and physiographic factors, some of which are as yet unknown or are little understood. Whereas there are some continuous stream-gage data for periods in excess of 50 years; most are relatively short term, 25 years and often much less. Simple and cost-effective methods have recently become available for adding one or more pre-gage flood events and their dates of occurrence.

These methods are a previously untapped resource for extending stream-gage records in time. Either separately or in combination, analyses of channel and floodplain morphology, measurement and interpretation of historic channel changes, carbon dating of flood remnants and alluvial stratigraphy, analysis of lichen growth and tree rings and other similar botanical changes can be used with conventional hydraulic methods to estimate ungaged streamflow. Their application moderates the influence of other high outliers that distort the higher recurrence interval range of the station record.

A need exists to systematically examine the stream channels to which these methods apply and to satisfactorily sample in space these large events which are rare in time on any one river. It is not expected that the methods mentioned can be used equally well in all geographic regions and care must be taken to use the most appropriate method or methods. For regions where these methods do apply sets of extreme floods will thus be documented on rivers which also have systematic streamflow records.

III. OBJECTIVES

A. To extend the existing stream-gage records in time by establishing the appropriate time and magnitude of ungaged extreme floods located in gaged watersheds.

B. To estimate the magnitude and approximate date of occurrence of catastrophic floods.

C. To shed some light on the historical climate and physiographic changes that influence stream-gage records, annual peak floods in particular.

IV. CURRENT ACTIVITIES

A. Related research activities: research has been completed by universities and the USGS to use carbon-dating analysis to quantify early flood evidence. Also, Geomorphic and botanical evidence is being used by the USGS and others to extend knowledge of flood frequency.

Statistical techniques are presently being developed to satisfactorily insert such large historical floods into flood-frequency analysis. This will provide the mechanism for using the above data for better defining the upper end of the frequency curve.

B. Suggested key words: extreme flood, paleoflood, botanical evidence, flood-frequency analysis, water-surface profiles, slack water deposits.

V. URGENCY - With the rapidly escalating cost of construction, application of this technology promises to provide an immediate return by significantly moderating rising construction costs. This is because an accurate flood-frequency relationship is the basic element in most transportation drainage design. Much basic research for estimating ungaged extreme events has been done. In addition, unlike many hydrology studies, the availability of flood data is not dependent upon the future occurrence of events but rather upon past events. Because the data already exist in the field, they can be collected and analyzed for a particular state in a year or two for relatively little cost. These methods provide an excellent potential to improve the accuracy of existing flood-frequency estimating methods that are derived from stream-gage records by moderating the costly impact of high outliers on station records.

PROBLEM NO. 7

I. NAME OF PROBLEM - CRITERIA FOR THE ANALYSIS OF EXTREME FLOODS IN THE ANNUAL FLOOD PEAK SERIES

II. THE PROBLEM - Highway bridges and culverts are designed to pass a flood event of a magnitude that is expected to be exceeded about once in a specified number of years. Statistical probability analysis of annual flood observations commonly is used to establish a relation between flood magnitude and frequency for gaged sites. Techniques have been developed for estimating flood magnitude frequency relations at ungaged sites where bridge and culvert design criteria are needed, but these estimating techniques usually are based upon transfer of frequency relations defined for gaged sites. Flood-frequency relations for gaged sites therefore are basic elements of highway drainage structure design.

The reliability of any flood magnitude-frequency relations, whether defined by a Log-Pearson Type III probability analysis as currently recommended by the Water Resources Council or by some other probability analysis, is dependent upon the observed flood record being a representative sample of the floods that can be expected to occur over a very long time period. Records of observed floods are generally of a short duration, yet some contain an observation of one or more very unusual floods. These unusual floods, sometimes called "outliers", may seriously influenced the definition of a flood-frequency relation.

III. OBJECTIVES

A. To test procedures of using historic extreme floods in a flood-frequency analysis by comparing fitted flood-frequency curves with the empirical at-station probability plots and identifying, describing, and classifying inconsistencies in the results.

B. To propose guidelines for defining a flood-frequency relation from a gaging record that contains one or more unusual events.

IV. CURRENT ACTIVITIES

A. New techniques have been published for inserting historic extreme floods into a statistical time-series analysis. The topic has been the subject of several recent symposia, and interest has been encouraged by improved methods to estimate historic extreme floods. The research has been conducted by a number of universities and the U.S. Geological Survey.

B. Suggested key words: outliers, unusual floods, flood-frequency analysis, non-stationarity testing.

V. URGENCY - Flood-frequency relations are a basic element of highway drainage structure design. The success of a design is dependent upon accurate frequency information. The proposed study would lead to improved accuracy of frequency definition and more uniform practices in the hydrologic analysis for design sites.

PROBLEM NO. 8

I. NAME OF PROBLEM - HYDROLOGY OF VERY FLAT TERRAIN

II. THE PROBLEM - Some parts of the United States, especially southern Florida and southern Louisiana, have extremely flat topography that complicates hydrologic predictions and presents unique problems with hydraulic design of bridges and culverts. This terrain is characterized by indefinite watershed divides and watershed areas that vary with distribution and intensity of rainfall. Often there is extensive pumping and cross channel flow from one watershed to another. Discharge and sometimes even the direction of flow are unknown at highway crossings.

Hydraulic design of bridge approach roads is more often dictated by elevation above the water table to avoid subbase saturation than hydrologic considerations. Hydraulic design of culverts and bridge openings and channels and ditches is technically very uncertain.

III. OBJECTIVES - Determine what studies have been conducted and what information is available. Identify alternate methods of estimating discharge, e.g., the applicability of channel geometry techniques. Determine the researchability of the problem and identify reasonable goals of a gaging program. Determine the flood regulation patterns used to operate pumping stations in these areas.

IV. CURRENT ACTIVITIES

A. Related research activities: No research is known to be under way on this specific topic although Louisiana is attempting to set up a special gaging program.

B. Suggested key words: hydrology, flat terrain hydrology, culvert design, bridge design, flood control.

V. URGENCY - Although the area for this problem was purposely limited to very flat terrain, the problem exists in varying degrees over a much broader area in the coastal plain of the eastern and southern parts of the United States. Any information that is developed for very flat terrain will have application to other flatland areas. Results of this study could lead to a more economical design of bridges and culverts.

HYDRAULICS

PROBLEM NO. 1

I. NAME OF PROBLEM - IMPLEMENTATION OF IMPROVED TECHNOLOGY FOR HIGHWAY DRAINAGE DESIGN

II. THE PROBLEM - In spite of considerable efforts to publicize, disseminate and provide training, there has been limited success in implementing new technology in the design of highway drainage structures. It is believed this reluctance is based in part on a natural resistance to change and in part on perceived consequences which may or may not result from the implementation of new technology.

Examples of available technology which are not being fully utilized might include design procedures for improved inlets on culverts; use of storage at culvert inlets and in storm-drainage and pumping-station systems; depressed curb and gutter sections and curb-opening inlets; river-training works; energy dissipators for culverts, and improved designs for bridge-deck drainage.

III. OBJECTIVES - The objectives are to fully identify the reasons for delays in implementing completed research and identify corrective measures to overcome the deficiencies in implementation. In general, this is anticipated to consist of:

A. Conducting a national in-depth inventory of problems encountered implementing completed highway drainage research and determine reasons why implementation was not attempted. Identify and evaluate existing systems for implementation.

B. Developing effective methods for improving hydraulics technology transfer; drainage design implementation.

IV. CURRENT ACTIVITIES

A. No other research in this field of interest has been identified.

B. Suggested key words: technology transfer, hydraulics, drainage design, standard, systems, computer.

V. URGENCY - The potential benefits of full utilization of the extensive research completed to date continue to be unrealized. This research effort could be accomplished quickly and at a relatively modest cost, thereby placing it in the immediate need category.

PROBLEM NO. 2

I. NAME OF PROBLEM - SCOUR AT BRIDGES

II. THE PROBLEM - Considerable effort in personnel resources and money has been spent on the problem of scour at bridges. The problems have been studied using fluid-flow theory, laboratory model studies, field data-collection programs, empirical correlation of laboratory and field data, and field observations resulting in rules of thumb. Scour and the effects of scour can still not be quantified with any degree of certainty. This uncertainty is costly not only in bridges lost to scour, but in those needlessly (but unknowingly) overdesigned. The location and design of river-training works and countermeasures to protect bridge piers and abutments is an empirical process. Furthermore, laboratory model studies have been conducted using sand-bed channels only. As a result, knowledge of scour in other soils or in mixed bed materials is lacking.

This research has been beneficial, however, for much has been learned about scour. For example, local scour depth increases as pier size increases for a given flow; local scour increases with velocity up to a point; and contraction scour depth increases as the width of the constriction decreases. There are four types of scour: local, contraction, lateral channel migration and streambed degradation. These scour types interact even though they have most often been isolated for study. Their net effect is often considered to be additive.

Recent research has focused on the collection of field data to validate the available formulas. However, these effects have met with major logistical problems, costly instrumentation packages, and difficult data interpretation problems. Much has been learned from these efforts about collecting field scour data, but little usable data have been obtained.

The design of a bridge footing supported by piles which lies within a flood plain is further complicated by the uncertainty of the elevation as to where the bottom of the footing should be located. If, for example, the long-term scour is shown to be 27 feet deep, the conservative design procedure would be to excavate to this depth, drive piles and pour the footing at a depth of 27 feet below the flood line of the channel. This would require expensive dewatering activities and substantial excavation. As an alternative, the pile could be driven to bearing without excavation and the footing be founded at an elevation so the top of the footing is just slightly below the bottom of the channel. This would eliminate the expensive excavation and dewatering activities; however, it is unknown what effect this footing, which is supported on piles some distance above the long-term scour depth, would have on the long-term serviceability of the footing and the rate of scour.

Most researchers have recognized the scour mechanisms, that is, the vortex system at piers and abutments and the contracted streamlines in the constrictions. Both mechanisms result in shear stresses at the bed sufficient to erode the bed material. The mechanisms have been studied separately (for example, Liu, Bradley and Plate, 1957; Shen, et.al., 1968; Schneider, 1968) to simplify the problem, but this previous work is not conclusive. Since flow in the vicinity of the bridge is three-dimensional, further investigations making one-dimensional or two-dimensional, approximations may not be productive.

III. OBJECTIVES

A. Reduce risk and cost in designing new bridges by making available more knowledge about scour.

B. Provide for more efficient countermeasures.

C. Evaluate current design practices to reduce backwater and increase capacity.

D. Determine the optimum depth of pier footings and arrangements of piling supports for piers within the channel banks and on flood plains.

The specific objective is to quantify the mechanics of scour in order to learn how the four types of scour interact and how to extrapolate laboratory data to the field. This research could be conducted two ways. Measurements of velocity distribution, bed shear stress, strengths and transport capabilities of the vortex systems, and other data as required, should be related to constriction ratio, as well as the abutment and pier geometries. The measured stress can then be related to the erodibility of soil other than sand. The shedding characteristics of the vortex systems may be related to the design of riprap as a countermeasure. Shen and Schneider (1970) found that the horseshoe vortex system at a pier could be

contained harmlessly at the pier by attaching a through-like structure to the pier.

In addition, a mathematical model which considers the three-dimensional nature of the flow through the constriction should be developed. The laboratory data would be valuable in this effort. Because of the complexity of the problem and the potential computer storage requirements, certain cross sections or locations of maximum shear may have to be identified in lieu of a model of the complete flow field.

IV. CURRENT ACTIVITIES

A. References:

1. Liu, H.K., Bradley, J.N., and Plate, E.J., "Backwater Effects of Piers and Abutments", Colorado State University, Civil Engineering Section, Report No. CER57HKLO, p. 364, 1957.

2. Schneider, V.R., "Mechanics of Local Scour", Ph.D Dissertation, Colorado State University, Fort Collins, Colorado, 1968.

3. Shen, H.W., Schneider, V.R., and Karaki, S., "Local Scour Around Bridge Piers", American Society Civil Engineers Proc., Journal of Hydraulics Division, V. 95, No. HY6, pp. 1919-1940, 1969.

4. Shen, H.W., and Schneider, V.R., "Effect of Bridge Pier Shape on Local Scour", Preprint Paper No. 12388, Presented to the ASCE National Meeting on Transportation Engineers, Boston, Massachusetts, July 15-17, 1970, p. 10, 1970.

5. Hopkins, G.R., Vance, R.W., and Kasraie, B., "Scour Around Bridge Piers", FHWA Report RD-79-103, February 1980.

6. Chang, F.F. M., "Scour at Bridge Piers - Field Data from Louisiana Files", FHWA Report RD-79-105, January 1970.

7. Jain, S.C. and Fischer, E.E., "Scour Around Circular Bridge Piers at High Froude Numbers" FHWA Report RD-79-104, April 1979.

V. URGENCY - This study of scour should result in quantifying the mechanisms of scour. The resulting mathematical model could be used not only to develop design criteria to predict scour but to devise rational methods to reduce and prevent scour and to increase bridge capacity.

PROBLEM NO. 3

I. NAME OF PROBLEM - DRAINAGE SURVEY ACCURACY REQUIREMENTS

II. THE PROBLEM - It has been found that considerable savings in cost can be realized in obtaining drainage surveys using photogrametric practices as opposed to conventional field surveys. There is also a growing need to obtain survey data on floods in progress, often under adverse weather conditions. Field control is a major cost factor in obtaining drainage surveys using aerial photography, as is the accuracy required for the survey. Depending on the required accuracy, it may be possible to eliminate or limit the amount of ground control using remote-sensing practices. Remote-sensing practices are also evolving to where satellites may provide valuable drainage survey data in the near future. With satellite sensing, the accuracy required for drainage survey data becomes of paramount importance.

Transportation hydraulic engineers have become accustomed to an existing level of survey accuracy. This accuracy has derived largely from the accuracy used in the roadway embankment design. Because of sensitivity of remote sensing and photogrammetry costs to accuracy, there is a need to determine what survey data accuracy or accuracies are required for drainage design.

III. OBJECTIVES - The objectives are:

A. Review drainage design practices to determine what design accuraces are being obtained.

B. Review published rules, regulations, laws, ordinances, policies and similar regulatory requirements to determine what design accuracies are expected.

C. Conduct research to determine what survey accuracies are required in light of the findings in III A and B.

IV. CURRENT ACTIVITIES - No other research in this field of interest has been identified.

V. URGENCY - The photogrametric and remote sensing potential is expanding at a rapid rate. To influence the photogrametric and remote-sensing development, it is imperative that required drainage survey accuracy be defined immediately.

PROBLEM NO. 4

I. NAME OF PROBLEM - HYDRAULICS OF BRIDGE WATERWAYS

II. THE PROBLEM - Where highways cross waterways, water is conveyed through bridges and culverts. For larger floods, it may flow over the embankment. Present procedures for sizing the structures involve estimating the flow for each structure as an isolated unit. The resulting discharges are summed and adjusted to make sure that the total is equal to the assumed design flow. Scour caused by a constriction is computed when the estimated flow is known. Sustained high flows will result in an enlarged section and a possible change in the flow distribution. In all of these computations,

one-dimensional or empirical approximations are used. In reality, flow may be through any or all of several bridges and culverts, or over the road simultaneously, while the channel may be degrading or aggrading. Often the flow may be more nearly two-dimensional or three-dimensional.

Significant lateral velocities and significant lateral variations in stage are observed in wide flood plains characterized by rapid expansions or contractions, highly variable roughness, or variable topography. Two-dimensional models can provide information about transverse, as well as longitudinal, water-surface profiles; local velocities near bridge approach embankments; and the lateral flow distribution at a proposed bridge site. Application of existing two-dimensional finite-element models which were developed as research, not operational tools to such bridge crossings (for example, the application of the model RMA-2 developed by Resource Management Associates to the Congaree River), have revealed numerous deficiencies in these models.

III. OBJECTIVES - The objective is to develop improved one-dimensional and two-dimensional computational procedures to describe this dynamic interactive process. Field or laboratory research could provide insight into the physics of this problem, as well as data to calibrate and verify models. Computerized models using modern graphics would help to standardize and streamline the design process. Guidelines should be developed for selecting the most appropriate (one-dimensional or two-dimensional) design method. The following components of two-dimensional finite-element models need to be tested in a variety of hypothetical and field situations and compared on the basis of stability, accuracy and economy:

(1) automatic grid-renumbering techniques;
(2) element types;
(3) methods of numerical integration;
(4) methods for solving large, sparse, banded-matric equations;
(5) boundary conditions;
(6) roughness coefficients and eddy viscosities.

These components of finite-element models need to be tested in situations that incorporate the particular difficulties arising in floodplain modeling, such as large ground-surface gradients and discontinuties in roughness.

IV. CURRENT ACTIVITIES

A. Related research activities: An FHWA study being conducted by USGS (Shearman and Schnieder) includes a task for computerizing multiple-opening analysis along with other features of bridge-waterways hydraulics. The study will also include updated procedures for handling wide, wooded flood plains, road overtopping, and constriction scour. An NCHRP study by Dames and Moore used existing models like the Corps of Engineers HEC-2 to generate data for regression equations that should suffice for planning needs. The NCHRP study does not consider multiple

openings or road overtopping, but it does include constriction-scour relations. Additional work that may be needed to meet the above problem statement objectives will be converting programs to an interactive mode and developing graphics enhancements.

B. A current study is underway to develop a two-dimensional finite-element model well suited to the particular problems of modeling river floodplain systems. The study is being conducted for FHWA by the USGS.

C. Suggested key words: bridge and culvert hydraulics, bridge waterways, scour, finite-element model, bridge site, floodplain model.

V. URGENCY - The results of this study will assist in reducing the size and cost of hydraulic structures by improving the designer's capability to study alternative drainage schemes. Since attention would be focused on the composite model, research needs would be easily identified as the weak lines in the model. Approximately $3 billion is spent nationwide on bridges each year for replacement, rehabilitation, or new construction. Consequently, there is a potential for significant savings in public funds through use of improved design procedures, since the majority (87%) of the nation's bridges are waterway bridges.

Several current bridge site studies of wide, complex flood plains using the two-dimensional model RMA-2 indicated the need for a two-dimensional model that can be applied by the design engineer to analyze proposed crossings. These studies have also revealed deficiencies in currently available models. The proposed research will develop tools better suited for such modeling efforts.

PROBLEM NO. 5

I. NAME OF THE PROBLEM - EFFECTS OF INSTREAM MINING ON CHANNEL STABILITY

II. THE PROBLEM - Instream activities frequently cause unstable channel conditions and related damage to highway embankments and bridges. The analysis of hydraulic, geologic, and water-quality factors associated with instream mining and resultant channel instability are lacking, as related to specific channels. Problems associated with instream mining are considered continuous in time, since the channel has little opportunity to reach stable conditions.

Conversely, there is some evidence that a controlled level of instream mining in the immediate vicinity of some bridges or culverts may produce a beneficial effect by preventing aggradation that might otherwise reduce the hydraulic capacity of such structures.

III. OBJECTIVES - The objective is to document a variety of streams affected by instream mining as a means of determining the significant hydraulic and geologic factors associated with unstable channel conditions. Specific objectives include a survey to determine the extent of the problem, evaluation of factors associated with channel

instability, and recommended methods to prevent or control channel instability.

IV. CURRENT ACTIVITIES

A. Related research activities: Completed research on degradation and aggradation (FHWA/RD-80/159) documents the results of numerous instream mining operations. In addition this report provides much of the information posed in the objectives section of the subject problem statement. An evaluation of countermeasures for hydraulic problems at bridges (FHWA/RD-78/162 & 163) provides documentation of 12 case histories specifically on instream mining (reference report 162, p. 108.).

B. Suggested key words: instream mining, channel stability.

V. URGENCY - Many stream channels are excellent and renewable sources of aggregate. As other sources of aggregate diminish, instream mining has increased, often with a resultant increase in damage to highway crossings. Methods are urgently needed to identify when such damage can be expected, when there will be a beneficial effect from instream mining; and, if appropriate, how to reduce or avoid the damage to highway structures from this activity. The result would be a considerable savings and increased safety to the traveling public. Since instream mining is legal in many states, the total impact of this activity needs to be recognized to determine if legislative controls on such activities are warranted.

PROBLEM NO. 6

I. NAME OF PROBLEM - CONTROL OF STREAM INSTABILITY AT BRIDGE CROSSINGS

II. THE PROBLEM - Stream instability must be considered in design to provide for the most cost-effective crossing. For existing crossings, it has been demonstrated that application of appropriate countermeasures for stream hazards substantially extends design life. Numerous references on stream instability at highway crossings and the use of countermeasures are available from the FHWA and from other sources; however, much of this information is not readily available and is scattered throughout many publications. There is a need for a synthesis of existing research information and development of a document especially aimed at moderately-sized streams (10 to 100 meters wide). The synthesis should include aspects of vertical control of streambeds (aggradation/degradation) and horizontal control of stream banks (bank erosion and meander migration).

III. OBJECTIVES - The objectives are:

A. Review existing technology to determine the most effective stream-instability control methods.

B. Provide a synthesis report useful to bridge and hydraulic engineers.

IV. CURRENT ACTIVITIES - A synthesis of this type has not been done, although numerous publications are available to serve as source material.

IV. URGENCY - Proper consideration of stream instability is only one concern for bridge engineers; but by decreasing the number of bridges lost to hydraulic hazards, the total number needing replacement for any reason is lessened. Guidance on practical cost-effective measures to control scour and erosion problems is needed in the design, as well as maintenance of stream crossings. A synthesis of the valuable information would greatly facilitate implementation of proven methods to reduce potential bridge losses due to channel instability.

PROBLEM NO. 7

I. NAME OF PROBLEM - RIVER-TRAINING WORKS AS RELATED TO HIGHWAYS

II. THE PROBLEM - The highway engineer is often confronted with the problem of stabilizing channels at highway stream crossings. The task may involve training works associated with either a channel relocation or control of channel shifting and bank erosion. Most river-training installations are expensive, and many have failed to accomplish desired results. A need exists for information on this subject, compiled for ready use by highway engineers. Case histories, design methods and details, costs and materials related to prediction and control of river meanders, and undesirable channel shifting should be studied and presented in a form useful to the highway designer.

III. OBJECTIVES - To prepare a state-of-the-art report on river-training works, with specific applications to the highway river-crossing problem. The study should employ state-of-the-art knowledge of river mechanics and the behavior of alluvial streams.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA has completed research in the following areas:

1. Channel Changes
2. Flow-Control Measures
3. Riprap

B. Suggested key words: river-training, channel stabilization, river meanders, alluvial streams.

V. URGENCY - The Federal Highway Administration has conservatively estimated annual costs of flood damage to highways to be on the order of $140 million per year. Improved procedures for protecting highway embankments and drainage structures utilizing river-training works can be used by the state highway agencies to reduce such costs by a significant degree.

PROBLEM NO. 8

I. NAME OF PROBLEM - HEAD LOSS IN STORM-DRAIN MANHOLES AND JUNCTION CHAMBERS

II. THE PROBLEM - Extensive highway storm-drainage systems have a multitude of manholes and junction chambers which are significant components of the system. An important element of storm-drainage design is computing the head loss at these structures. Adequate structure drop must be provided at manholes to offset energy loss; however, since total fall available in the storm-drain system is usually limited, it is important that head losses be kept to a minimum to produce cost-effective designs.

Some municipalities have investigated the problem and developed design procedures. The City of Los Angeles has developed a procedure and tested it in the city's research facility. This method along with others could be studied and incorporated into a general design procedure. The University of Missouri completed comprehensive research, but only on full flow systems. The American Public Works Association completed a comprehensive design manual on junction losses in 1986. Nevertheless, work is still needed on partially full systems.

III. OBJECTIVES - The objective is to develop computational procedures to estimate head loss at storm-drain manholes and junction chambers. Partially full systems are of particular interest. Field and laboratory research may be necessary to verify the design procedures. Geometric layout of manholes and junction chambers must be studied to identify cost-effective designs.

IV. CURRENT ACTIVITIES

A. Related research activities: City of Los Angeles research and University of Missouri research on full-flow systems, and APWA.

B. Suggested key words: head loss in manholes and junctions.

V. URGENCY - Much of the future highway work will be upgrading urban freeway systems which will contain large expensive storm-drain systems. It is imperative that accurate design procedures be used to estimate the manhole and junction-chamber losses so that cost-effective designs will be produced.

PROBLEM NO. 9

I. NAME OF PROBLEM - EFFECT OF VERY LARGE SEDIMENT CONCENTRATIONS ON FLOW CHARACTERISTICS

II. THE PROBLEM - Intense storms in arid regions can cause floods in watersheds that are normally dry. Many of these watersheds have soil deposits composed of silt, sand, and rocks that are readily transported by the flowing water. This creates large concentrations of sediments in the water course. Calculations of velocity,

discharge, sediment transport, scour, Froude number, etc., may not be valid when the fluid properties (density and viscosity) and flow characteristics (turbulence) are modified by large concentrations of fine sediments.

III. OBJECTIVES - The objectives of this research study are to first predict the amount of sediment that will be carried by a stream for a given discharge, and then to determine the effect of heavy sediment concentrations on flow characteristics. Estimates of scour potential, slope-protection needs, channel capacity, conveyance and hydraulic-jump potential are all common hydraulic design problems that are complicated when the fluid no longer acts as clear water.

IV. CURRENT ACTIVITIES

A. No other research in this field of interest has been identified.

B. Suggested key words: sedimentation, flash floods, arid-region hydraulics.

V. URGENCY - The problem of insufficient knowledge of how to design for water that may have significantly different characteristics has been known for some time. Development of more knowledge in this area is needed to achieve improved cost-effective designs for transportation facilities located in flood plains which carry large sediment loads.

PROBLEM NO. 10

I. NAME OF PROBLEM - PROTECTING BRIDGE PIERS WITH EXPOSED PILING CAUSED BY SCOUR

II. THE PROBLEM - Scour at bridge piers is a dynamic phenomenon which varies with discharge , depth of flow, and other factors. Maximum scour depths occur during flood stages, and accurate measurements have been difficult to obtain. The problem of measuring scour is currently being addressed through research. Scour measurements made as a result of bridge inspections, or other means, and observations after flood events have indicated that, in some cases, scour has progressed to the point where the bridge-pier piling has been exposed.

When scour of this nature is encountered, the problem is: what action, if any, should be taken to protect the pier from further scour? Because methods of underwater protection can be very expensive, it is important that the countermeasure chosen be cost effective and correctly designed for the particular set of circumstances.

III. OBJECTIVES - The objectives are:

A. Review state-of-the-art practices to determine what reliable protection measures are available.

B. Establish guidelines as to when piers need to be protected. Factors to be considered include, but are not limited to, the following:

1. Extent of piling exposed.
2. Sediment transport within the river system.
3. Stream velocity, discharge, and depth of flow at the time of measurement. (i.e., the regime of the flow).
4. The ratio of measured scour to potential maximum scour.
5. Soil type of river bottom and its susceptibility to scour.
6. Determination as to what caused the scour (general scour, contraction scour, local scour).
7. Probability and magnitude of future scouring events.

C. Recommendations as to lateral extent and depth of protection measures.

D. Methods to determine riprap sizing and thickness, where appropriate, or other means for protection. (Concrete shelves, gabion mattresses, grade-control structures, etc.)

IV. CURRENT ACTIVITIES - Improved methods of measuring scour are being studied by the Federal Highway Administration, U.S. Geological Survey, the State of Arkansas, and others.

V. URGENCY - Underwater protection of piers against scour is expensive: however, failure to provide adequate protection may be much more costly if failure of the bridge results. More bridges fail because of scour than from any other cause. The Federal Highway Administration and the State Highway Agencies have assigned a high priority to their program for bridge inspection, repair, and rehabilitation.

PROBLEM NO. 11

I. NAME OF PROBLEM - LONG-SPAN CULVERT HYDRAULICS

II. THE PROBLEM - National emphasis of highway safety, bridge replacement, environmental protection, and economics has generated an increasing interest in the use of long-span structural-plate corrugated-metal and precast-concrete arch structures for highway drainage at stream crossings. Industry has responded to these needs, and is actively promoting the use of a wide range of sizes and shapes of "long-span" structures, which are often an alternative to special designs and standard bridges.

The size, shape, treatment, and corrugation configuration available from various suppliers offer the designer an array of alternatives; however, only a limited effort has been expended to develop hydraulic analyses and design techniques similar to that available for conventional culvert and bridge design. Adequate procedures are not presently available for estimating the extent of scour which will occur in long-span culverts with natural bottoms.

III. OBJECTIVES

A. To expand and/or develop criteria and procedures with design aids to be used for the hydraulic analysis and design of long-span structures. This development will include appropriate entrance losses and inlet-control characteristics of the various structures. Confirmation of friction losses within the barrel, where arch structures are utilized with the natural stream bottom, should be included in the development.

The use of step-backwater computations appears to be the best approach for establishing the tailwater-headwater relationship for structures of this type; however, present methods of evaluating the various entrance, friction, and exit losses are not readily adaptable to the water-surface profile computational process.

B. To develop criteria and procedures with design aids for use in estimating scour in long-span culverts with natural bottoms.

IV. CURRENT ACTIVITIES

A. Related research activities: In January 1974 the Federal Highway Administration's Office of Engineering, Bridge Division, Hydraulics Branch developed a preliminary draft of a publication titled "Hydraulic Design of Large Structural Plate Corrugated Metal Culverts." The FHWA has issued a design manual (Calculator Design Series No. 4) which included procedures for hydraulic design and analysis of some long-span culverts. The information utilized to develop this manual is largely empirical, and based on knowledge and experience gained from research for conventional culvert design.

B. Suggested key words: long-span culverts, hydraulic design, culvert hydraulics.

V. URGENCY - Present emphasis on bridge replacement, economics, and hydraulic efficiency relative to floods, and on management and flood risk require a thorough investigation and documentation of the design for stream crossings.

The analysis and design techniques being utilized should be confirmed and/or improved, as necessary, in order to assure that the long-span culvert will function hydraulically as designed.

PROBLEM NO. 12

I. NAME OF PROBLEM - HYDRAULIC DESIGN OF SOIL-CEMENT BANK PROTECTION

II. THE PROBLEM - There has been increased use of soil cement as a material for bank protection during the past 10 years, particularly in the semi-arid southwest. In areas where ephemeral streams flow through sandy soils, soil cement has the advantages of economy, ease of construction, and a natural earth appearance. Currently, construction practices dictate the thickness of soil cement banks

protection. Hydraulic criteria on the thickness of the bank protection needs to be determined in order to optimize construction costs while maintaining the structural integrity of the soil cement installation. In addition, the resistivity of soil cement to erosion from high velocity streamflow needs to be determined based upon percent of cement content, by weight, in order to minimize materials cost associated with bank protection installation.

III. OBJECTIVES - The objectives are:

A. Develop hydraulic design criteria that address the thickness required of soil cement to maintain structural integrity.

B. Develop design criteria that identify the minimum cement content, by weight, necessary to produce soil cement which resists erosion from high velocity streamflow.

IV. CURRENT ACTIVITIES - A design manual for soil cement applications is currently being developed by the American Concrete Institute. The Pima County Flood Control District (Arizona) has conducted several studies on soil cement, and has extensive field data. The Corps of Engineers is currently investigating soil cement applications for flood control purpose.

V. URGENCY - This research will result in a significant savings in the construction cost of soil cement bank protection, while maintaining the structural integrity and design effectiveness of such installations.

PROBLEM NO. 13

I. NAME OF PROBLEM - TEST AND EVALUATION OF MAJOR STORMWATER DRAINAGE SYSTEMS

II. THE PROBLEM - A number of major expressways and urban arterials have experienced highway pavement flooding during relatively minor storms. Traffic delays during the flooding have produced a level of service that is undesirable. A new generation of computer drainage models has provided the highway drainage engineer with sophisticated tools for investigating the problem and for devising cost-effective solutions to existing problems. Various cities, such as Chicago, Denver, Los Angeles, El Paso, etc., have constructed storm-drainage systems based on locally developed design procedures and techniques. At the time these expressways were designed, such design procedures were considered to be the best methods available; however, new methods, such as the EPA SWMM computer program and the FHWA highway drainage computer program, as well as proprietary models such as MITCAT and HYDRA, are now coming into existence to provide highway engineers with improved computer models to aid drainage design. An evaluation should be made of the new design models by comparing computed runoff values with field-measured values.

III. OBJECTIVES

A. To measure the performance of the surface drainage system in urban areas on selected portions of expressways and/or arterials under actual storm conditions. Measurements should include (1) continuous recording of rainfall over the entire drainage area and (2) continuous recording of runoff from sub-units of storm-drainage systems for which rates of flow had been computed in the design process.

B. To compare runoff based on measured rainfall in accordance with the various design procedures.

C. To analyze the computed vs. observed runoff from the test areas.

D. To evaluate the validity of the various design procedures.

E. To identify design procedures that produce the closest results to the measured runoff.

F. To make recommendations for improving design procedures.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA sponsored research on inlet hydrographs at Utah State University and local-storm research at the University of Illinois. Information on a real rainfall and runoff in the storm-drain system is available for selected urban-highway projects.

B. Suggested key words: inlet hydrographs, Chicago Method, roadway drainage, SWMM, FHWA highway drainage computer program.

V. URGENCY - Engineers working with urban drainage problems are in urgent need of an accurate means of designing roadway drainage and storm drains. Evaluation and verification of design procedures that accurately model field conditions would be a major advance in roadway drainage design.

PROBLEM NO. 14

I. NAME OF PROBLEM - METHODS FOR ACCOMMODATING FLOATING DEBRIS AT BRIDGES

II. THE PROBLEM - Lodging of debris at bridges is one of the primary causes of bridge failure or the need for high maintenance efforts. The types of floating debris causing bridge damage are drift, such as brush, log, etc., and ice.

Presence of floating debris at a bridge may cause a flow constriction with increased potential for high flow velocities and subsequent scour, impact damage, and lateral displacement of the structure.

Present methods for controlling floating debris include the

design of streamlined pier shape, increased bridge clearance, physical removal of debris, and drift arrestors placed in the stream near the bridge.

III. OBJECTIVES - The objective is to determine the best methods for preventing bridge damage caused by floating debris. The various methods may be categorized as debris prevention, passage improvement, and physical removal of debris at the bridge site. Specific objectives include:

A. The classification of streams, or areas, to determine the problem severity and probable type of floating debris.

B. Survey of methods presently used to prevent damage by debris.

C. Effectiveness of methods now in use.

D. Recommendations for new techniques to prevent drift problems.

IV. CURRENT ACTIVITIES

A. Related research activities: National Research Council of Canada and Corps of Engineers (CRREL) Research on Ice Loads on Bridges.

B. Suggested key words: floating debris, bridges, damage prevention, ice.

PROBLEM NO. 15

I. NAME OF PROBLEM - A COST-EFFECTIVE APPROACH TO HYDRAULIC DESIGN OF HIGHWAY DRAINAGE STRUCTURES

II. THE PROBLEM - Conventional practice in the hydraulic design of highway drainage is to provide for conveyance of the peak discharge for a flood with a pre-selected recurrence interval. Usually consideration is only given to initial capital costs, and the probability or chance of property damage and traffic delays due to other (larger and smaller) flood events are seldom quantified in economics terms. A cost-effective approach is needed to define the optimum design hydraulic load, considering not only capital costs but also potential economic losses due to the flood hazards represented by a range of flood events.

III. OBJECTIVES - To develop criteria and procedures for incremental cost analysis for use by decision makers in the selection of designs for highway drainage facilities. The procedure would recognize the probability that various floods will be exceeded during the life of the highway; include techniques for arriving at an optimum design, considering capital costs and potential economic losses; and provide guidance for decision making in view of limiting constraints, initial capital investments, and potential damage costs.

The scope of the effort should include design procedures considering individual as well as drainage facilities on a route or

route segment. Included should be consideration of the availability of alternative routes, the importance of the route or route segment to commerce and national defense, traffic volumes and desired level of traffic service, and the need for the route for emergency supply or evacuation in case of a natural disaster and other factors.

The procedures for the design of each drainage feature would include an economic analysis of the hazards of life and property, including both the risk of damage to the highway and other property affected by the presence of the highway; total cost of the highway encroachment, including capital costs for construction, costs for maintenance, costs for repair and reconstruction, costs for liability due to damage caused by the highway, costs of traffic interruption, and other factors. It should also provide guidance for decision making in recognition of budgetary constraints for capital investment, as well as potential damage costs and consideration of a preferred level of traffic service. Inherent in this are methods for evaluating the present worth of probable future costs and techniques to minimize or mitigate damages.

The procedure would include consideration of flow duration as well as flood peaks in assessing flood losses.

IV. CURRENT ACTIVITIES

A. FHWA has published hydraulic engineering Circular No. 17. Design of Encroachments on Flood Plains Using Risk Analysis.

B. Suggested key words: design flood, floodplain, encroachments, hydraulic designs.

V. URGENCY - The Federal Highway Administration's annual budget for emergency repair and reconstruction of damage to highways on the Federal-aid system from natural disasters is on the order of $100 million. The states and local jurisdictions undoubtedly spend a like amount for the repair and reconstruction of roads damaged by events which are not widespread enough to be declared an emergency. An additional $40 million is expended annually by the Federal Emergency Management Agency (FEMA) for repair and reconstruction of off-system (non-Federal-aid) roads and streets. Much of the costs incurred by local governments for emergency repairs are disallowed by FEMA, so the actual costs are much higher than $40 million annually. In addition to these costs, courts have held highway agencies liable for flood damages and these costs are not accounted for in the above recital. The bulk of the FHWA $100 million ER funds is expended for flood-damage repairs.

In view of an annual expenditure nationally on the order of $200 million for flood-damage repairs, it is appropriate to reassess present design criteria and procedures; and to develop and utilize, where appropriate, techniques for optimizing the design of drainage structures on the basis of total costs, initial capital costs, and potential economic losses assigned to the structures.

PROBLEM NO. 16

I. NAME OF PROBLEM - ENERGY DISSIPATION AT CULVERT OUTLETS AND STORM-DRAIN OUTLETS

II. THE PROBLEM - There is an urgent need to develop criteria for the design and use of simple, practical, economical stilling devices for dissipating the energy of the flow from culverts and storm-drain outlets up to 144-inch diameter, or equivalent size. Damaging erosion of drainage channels often results from discharge of high-velocity flow from the outlets of culverts and storm drains. Energy dissipators can be effective in reducing the velocity of flow from culverts to a degree that damage to the channel and channel bank will not undermine the culvert or endanger the highway embankment.

III. OBJECTIVES

A. To develop criteria which will provide the designer with a basis for selecting the type of energy dissipator most suited to the conditions.

B. There are several complex types of energy dissipators suitable for the more costly applications, such as for reclamation, flood control, or the larger highway drainage structures. For most highway drainage systems, consisting of commercial culverts or storm drainings; simpler and more effective/economical devices, and, in particular, prefabricated modular types, are urgently needed.

C. Designs should be applicable to pipe or box culverts of all shapes operating over a wide range of discharge rates and relationships of velocity head to depth of flow at the outlet.

IV. CURRENT ACTIVITIES

A. Related research activities: Colorado State University is conducting known ongoing research in this area. The FHWA has published HEC No. 14, Hydraulic Design of Energy Dissipators for Culverts and Channels.

B. Suggested key words: energy dissipators, stilling basins.

V. URGENCY - Inadequate outlet designs results in added maintenance or need for subsequent drainage and erosion-control facility replacements and improvements. There is also recurring loss due to overdesigns, where the design principles are not clearly established for erosion-control structures. Erosion at culvert and storm-design outlets is a perennial problem. Better guidance and design will help to reduce construction and maintenance costs and enhance safety and aesthetics in accord with good engineering practice. Prefabricated modular devices that can be made commercially available will do much to encourage the use of such devices.

PROBLEM NO. 17

I. NAME OF PROBLEM - ESTIMATING EMBANKMENT DAMAGE DUE TO FLOOD OVERTOPPING

II. THE PROBLEM - Highway stream crossings are frequently built so that the embankments are overtopped under some flood conditions. An economic analysis model has been developed to determine the design alternative with the optimum crossing conditions. One of the weak links in the model, however, is in estimating embankment damage that results from scour when overtopping of the roadway by flood waters occurs.

III. OBJECTIVES

A. Document field experience after floods to record amount of pavement and embankment damage for various depths and duration of overtopping floods. Records should reflect embankment soil types, vegetation cover, embankment heights, estimate of water-surface drop over the roadway, and estimated flow velocity over the downstream shoulder.

B. Establish prediction methods for estimating embankment damage based on field experience and controlled experimental data.

C. Establish guidelines for use of protection such as riprap, filter cloth, nylon matting, and fiberglass roving on embankments.

IV. CURRENT ACTIVITIES

A. Related research activities

1. A recent research study of flood-risk analysis for design of bridge waterways included a thorough literature review of embankment erosion, but the literature review did not reveal satisfactory methods for predicting highway embankment erosion during overtopping.

2. The Federal Highway Administration has a research contract underway to study overtopping of highways through the use of physical models.

3. An effort to assemble field observations from maintenance records for recent flood events is underway. This information will be very useful in providing direction to the research effort. The FHWA is developing an administrative research effort to study the effects of overtopping under controlled conditions.

B. Suggested key words: embankment erosion, embankment protection, scour, spillway protection, spillway design, flooding, flood-risk analysis, flood-hazard analysis.

V. URGENCY - During the period of 1953 to 1973, an average of more than 1000 bridges were built over water per year on the Federal-aid system alone. During approximately the same period, 43.2 percent of the bridge failures were characterized by washed-out approach embankments, according to a very limited analysis of FHWA emergency relief files. The large number of bridges that have been built (many of which will be replaced under the bridge-replacement program) and the frequency of embankment failure represent evidence in support of the urgency for the search to better define an optimum stream-crossing design.

PROBLEM NO. 18

I. NAME OF THE PROBLEM - DESIGN OF LARGE DETENTION BASINS AND APPURTENANCES

II. THE PROBLEM - Large detention basins, both permanent and temporary, are increasingly being specified for entrapment of buoyant and settleable constituents of runoff from highway and non-highway right-of-way prior to discharge into lakes and streams. There is no rational method available to the designer to estimate efficiency of constituent removal relative to the size of a basin. Additional information is needed regarding estimating frequency of clean-out, design of outlet structures, provisions for maintenance draw-down, design of overflow sections, aesthetic and multiple-use considerations, methods of predicting quantity and nature of inflow constituents, and skimming methods.

III. OBJECTIVES - To develop a design manual on permanent and temporary detention basin design for transportation facilities. The manual would provide comprehensive guidelines, criteria, and recommendations regarding all facets of detention basin design, as well as construction and maintenance considerations. A nationwide review of experience with use of basins should be conducted.

IV. CURRENT ACTIVITIES

A. Related research activities: NCHRP study on erosion-control features; USGS study of North Carolina; HPR studies, Pennsylvania, Milwaukee, Florida; Research studies by FHWA.

B. Suggested key words: sediment basins, design manual, water quality, detention basins, spillway design, outlet structures, skimming.

V. URGENCY - Federal and State laws, rules and regulations have been promulgated that mandate measures to mitigate environmental damage caused by stormwater runoff. Detention of runoff appears at this time to be the most cost-effective method available. A design manual is urgently needed in order that use of basins proceeds on a rational basis.

PROBLEM NO. 19

I. NAME OF PROBLEM - EROSION RESISTANCE OF GRASSES USED IN HIGHWAY DRAINAGE CHANNELS

II. THE PROBLEM - The U.S. Department of Agriculture has performed tests on various grass covers to determine their hydraulic retardance and resistance to erosion, and has published the results, mainly during the 1950's.

Since that time, various types of vegetation such as Crown Vetch, Crested Wheat, and Bahia have come into general use as ground covers and erosion-control measures. Hydraulic and erosion-control data are needed on these types of vegetative covers.

III. OBJECTIVES

A. To determine the hydraulic retardance and erosion resistance of grasses and vegetal cover being used along the highway right-of-way. Perform tests similar to those used by the Agriculture Research Station at Stillwater, Oklahoma, using both permissible-velocity and tractive-force theory. Quality of cover, as influenced by climate and agronomic considerations, should be an important variable in this study.

B. To determine design criteria for various commercial materials and mats that provide a permanent, nondeteriorating and noneroding cover on bare earth for supporting vegetal growth.

IV. CURRENT ACTIVITIES

A. Related research activities: SCS publication, "Handbook of Channel Design for Soil and Water Conservation"; Mississippi State University tests on sodded channels; FHWA Publication Hydraulic Engineering Circular No. 15, "Design of Stable Channels with Flexible Linings."

B. Suggested key words: vegetation, erosion control, flow resistance.

V. URGENCY - Channel design methods presently in use utilize vegetation as one type of lining. In many instances, vegetation is the best lining choice since it retards flow, is self healing, and allows infiltration. However, design information is not available for many of the grasses being widely used on highways. Proper design and construction of such grass-lined channels has the potential of saving maintenance dollars, and serious safety hazards and aesthetic problems may be avoided.

PROBLEM NO. 20

I. NAME OF PROBLEM - SEDIMENT DEPOSITION IN CULVERT INSTALLATIONS WITH MULTIPLE BARRELS

II. THE PROBLEM - Deposition of sediment in one or more barrels is a common problem affecting multiple-barrel culvert installations.

Partial or complete blockage of a barrel, or barrels,, can occur during peak runoff events, with a resulting significant adverse effect on the culvert's performance. Growth of bushes and trees in the sediment at the culvert entrance add to the maintenance problem for such installations.

III. OBJECTIVES

A. Develop design procedures for estimating the effect of the changed conditions due to a culvert installations on a stream's capacity to maintain its sediment load.

B. Develop guidance and criteria for the design and maintenance of multiple-barrel culvert installations so as to minimize the problem of sediment deposition.

IV. CURRENT ACTIVITIES - No current research on this topic has been identified.

V. URGENCY - Improved design and maintenance guidance and criteria for minimizing deposition of sediment in multiple-barrel culverts will help to resolve a major disadvantage of this type of culvert installation.

This may achieve significant cost savings by making multiple-barrel installations more attractive, and serve to reduce the flooding hazard to roads and properties caused by clogged culvert barrels.

PROBLEM NO. 21

I. NAME OF PROBLEM - SPUR DIKES AT BRIDGE ABUTMENTS

II. THE PROBLEM - Many highway crossings of major streams have long approach fills on the flood plain to reduce structure costs. These fills block the passage of overbank flow and divert floodplain flow to a bridge opening. Eddies, formed when lateral flow from the flood plain mixes with main channel flow, cause scour at bridge abutments and at adjacent piers, and reduce the effectiveness of part of the bridge opening. Spur dikes projecting upstream from bridge abutments have been effective in preventing serious problems at these locations, but research data are needed to develop criteria for the design of the spur dikes. Downstream dikes or trailing dikes are sometimes needed to prevent scour by redistribution of flow in the floodplain.

Although existing research data and field observation of existing dikes have been very helpful in the design of spur dikes, additional research information is needed to improve designs and to give engineers more confidence in their performance. Needed research on these structures consists of two parts which can be programmed concurrently. Part one includes extensive laboratory testing of various types and shapes of dikes in both fixed-bed and movable-bed models. Part two consists of field observations and measurements of flood conditions at existing dikes.

III. OBJECTIVES

A. To expand present data so that adequate criteria can be developed for the design of spur dikes taking into account various types, shapes and orientation, flow distribution, bridge opening and vegetal cover.

B. To analyze and evaluate performance of prototype installations in the field during and following flood flow.

C. To define where trailing dikes are needed to inhibit scour at the downstream toe of the abutment fill.

IV. CURRENT ACTIVITIES

A. Related research activities: The FHWA has conducted limited flume studies of the effect of spur dikes on bridge backwater.

B. Suggested key words: spur dikes, bridge abutments.

V. URGENCY - Good design criteria and additional field observations of existing dikes will encourage a wider and better use of these structures. It is estimated that the use of spur dikes in conjunction with both new bridge construction and remedial work on existing bridges could approach savings of three million dollars annually.

PROBLEM NO. 22

I. NAME OF PROBLEM - DEBRIS CONTROL AT HIGHWAY CULVERTS

II. THE PROBLEM - Highway culverts are often the primary outlet structures of much larger and more fragile floodplain drainage systems. The increased ponding, associated loss of capacity, and increased occurrence of overtopping resulting from a debris-clogged culvert, particularly with low roadway fills or where there is little storage capacity available for ponding, results in significant damage to the highway as well as to the entire floodplain community.

III. OBJECTIVES - The objectives are:

A. To develop a procedure to identify and classify watersheds which have the likelihood to generate significant debris loads.

B. To categorize highway culverts with regard to susceptibility to debris obstruction.

C. To review the efficiency of present debris-control measures and procedures.

D. To develop improved debris-control methods, thereby improving operating performance of highway culverts and related drainage facilities.

E. To develop methods of analysis for determining the most cost-effective approaches to the debris problem.

IV. CURRENT ACTIVITIES - Guidance on this subject is set forth in the FHWA Hydraulic Engineering Circular No. 9, Debris-Control Structures and in the California Culvert Practice manual of the California Department of Transportation.

A. No current research is known to be underway on this specific topic.

B. Suggested key words: debris, culvert design, clogging, hydraulic uplift, overtopping, ponding, pooling, rocks, standing water, trash rocks, undermining washout.

V. URGENCY - Culvert design and overall performance of much larger drainage systems will be improved with a corresponding reduction in highway drainage lawsuits. Flood-damage costs will be reduced, resulting in significant economic and safety benefits to both highway users and adjacent property owners.

PROBLEM NO. 23

I. NAME OF PROBLEM - COST-EFFECTIVE STORM-DRAIN DESIGN USING ECONOMIC (RISK) ANALYSIS TECHNIQUES

II. THE PROBLEM - Cost-effective roadway drainage and storm-drain design is based on a difficult trade-off of highway safety, hydraulics, and storm-frequency factors. There are a number of goals that are at cross purposes. For example, since design storms are relatively infrequent, economics dictates that drainage costs be kept low; however, traffic safety considerations require that pavement flooding be kept within tolerable limits.

The flow of stormwater on a pavement is quite sensitive to any change in design parameters, particularly cross slope, storm frequency and longitudinal slope. Changes in these parameters could adversely affect the width of spread and conflict with traffic safety considerations. With the cost of automotive energy rising each year, traffic delays caused by minor storms are matters of serious concern. Energy cost and time lost may be important factors that should be considered in the economic balance.

The principles established in the economic (risk) analysis approach for designing encroachments on flood plains are excellent tools for evaluating the roadway (surface) drainage problem. Development of an economic analysis approach for roadway drainage and storm drain-design may provide for cost-effective improvements in existing highway drainage design procedures.

III. OBJECTIVES - To develop economic (risk) analysis procedures for roadway drainage and storm-drain design considering traffic safety, hydraulic, storm frequency, energy and time losses, damage and economics.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA sponsored research on highway drainage.

B. Reference: FHWA's HEC No. 17, The Design of Encroachments of Flood Plains Using Risk Analysis.

C. Suggested key words: risk analysis, highway drainage computer program, pavement drainage.

V. URGENCY - Highway drainage engineers are in urgent need of an improved approach for selecting cost-effective drainage design parameters, since drainage costs on urban highways are a significant portion of overall project costs.

PROBLEM NO. 24

I. NAME OF PROBLEM - STREAM DEGRADATION AT BRIDGES

II. THE PROBLEM - Many bridges have experienced foundation problems as a result of stream degradation caused by river mining of aggregates, reduced sediment loads due to urbanization, downstream changes to the channel, or for other reasons. This streambed lowering not only endangers bridge foundations; but also other public investments in utility crossings, such as gas, water, communication and sanitary sewer lines.

More information is needed on how to design economical drop structures of small height to stop the degradation and stabilize the stream channel, since highway agencies are regularly using drop structures as a countermeasure for channel degradation.

III. OBJECTIVE - The objective is to develop various drop-structure designs for different ratios of drop heights to flow depths, especially those less than 0.67, and to establish dimensionless parameters necessary to determine actual design.

IV. CURRENT ACTIVITIES - Model Study of Low-Drop Grade-Control Structure, W.C. Little and J.B. Murphy, ASCE Journal of the Hydraulics Division, October, 1982; Studies by Pima County (Arizona) Flood-Control District using physical models to identify design parameters for grade-control structures. The Iowa and Wyoming DOT have successfully used drop structures within a bridge opening; all state DOT's should be surveyed for their present practices.

V. URGENCY - Designs from this procedure can be used as soon as they are available and distributed.

PROBLEM NO. 25

I. NAME OF PROBLEM - BEHAVIOR OF SUPERCRITICAL SEDIMENT-TRANSPORTING FLOW

II. THE PROBLEM - Streams in which the flow is supercritical can become extremely unstable and can behave entirely differently than the more common subcritical rivers. Culverts can become completely clogged, and deposition can occur at bridges.

III. OBJECTIVE - The objective is to achieve a better understanding of the mechanisms of sediment transport under conditions of supercritical flow, and to develop design procedures which take into consideration the sediment load and the hydraulic forces under these conditions. Preliminary analysis of the problem indicates that little or no obstruction to the flow can be tolerated, and that a different kind of design may be necessary for highway crossings of such streams.

IV. CURRENT ACTIVITIES

A. While the problem has been recognized, there have been no formal studies undertaken to establish a design approach for such conditions.

B. Suggested key words: drainage structures, river behavior, supercritical flow, deposition and scour.

PROBLEM NO. 26

I. NAME OF PROBLEM - FREEBOARD REQUIREMENTS AT BRIDGE WATERWAYS

II. THE PROBLEM - Significant hydrostatic and hydrodynamic loads may be imposed upon bridge superstructures if adequate freeboard is not provided. These forces may be large enough to displace the superstructure from its supporting foundation, with resulting failure of the bridge. Present methods for estimating freeboard at bridges vary from simple "rules-of-thumb" to complex probabilistic approaches. Many areas of the nation have unique hydraulic conditions which merit special attention. For example, the impact of "ice debris" upon freeboard requirements needs to be considered in cold regions, while heavily forested/vegetated regions may present a problem with trees. In locations where high-velocity flows (i.e., near critical, critical, or supercritical) occur there is a need to consider the impacts of unstable water-surfaced profiles, such as encountered with standing waves and anti-dunes, upon freeboard requirements. It is likely that combinations of one or more of the above-noted conditions may occur during a flood event at some locations.

III. OBJECTIVES - The objectives are:

A. Review present state-of-the-art practices and criteria for establishing freeboard requirements at bridges.

B. Identify the various factors that should be considered when establishing freeboard requirements at bridges.

C. Develop practical approaches toward quantifying the identified freeboard components from Step B.

D. Provide guidelines as to the application of procedures developed for establishing freeboard requirements at bridges. Such guidelines would include, but not be limited to: (1) regional applicability, (2) design-flood applicability (alternative analysis) and (3) techniques for estimating the probability of occurrence of significant amounts of debris during flood events.

IV. CURRENT ACTIVITIES - No other research in this field of interest has been identified.

V. URGENCY - Eighty-seven percent of our Nation's bridges cross waterways. Thousands of bridges, for various reasons, are being replaced annually. An improved approach toward establishing freeboard requirements at bridges could lead to a substantial long-term savings in future bridge replacement costs, especially in regions where high debris loads and/or conditions of highly unstable flow are predominant during the larger flood events.

PROBLEM NO. 27

I. NAME OF PROBLEM - FLOW CONTROL IN CULVERTS AND STORM DRAINS

II. THE PROBLEM - Numerous types of flow may occur in culverts and storm drains required for surface drainage of the Nation's transportation systems. Among those are weir, orifice or inlet-flow control, open channel, partial conduit, full conduit, and/or outlet transition flow control. The latter is particularly common with height to width or aspect ratios equal to or greater than 1.5. Median and/or intersecting adjoining drainings may induce throttling and an additional intermediate type of flow control somewhat similar to orifice flow control. Manholes and changes in alignment, grade or size of conduit may induce similar sources of flow control. Intermittent or permanent vortices, separation or flow, and debris and/or tailwater conditions can induce additional types of flow control, as well as flow instability. The shifting of flow control from one regime to another normally induces instability of flow, and may result in gulping, burping, noisy and adverse pressure-flow conditions that may induce infiltration, exfiltration, embankment settlement, piping, and misalignment of the barrel, as well as severe cavitation and structural fatigue or rupture. To prevent these undesirable consequences, guidance is needed to assist designers in ready identification and/or analysis of the types of flow permissible in a given culvert or storm-drain system. Means of assuring stable flow conditions in a drainage system are also desired.

III. OBJECTIVES - Develop improved numerical computational procedures or physical models to describe this dynamic interactive process. Computerized models using modern graphics would help to standardize and streamline the design process. Develop guidelines for selecting the most appropriate one-dimensional or multi-dimensional numerical physical model.

IV. CURRENT ACTIVITIES - No current research in this field of interest has been identified.

V. URGENCY - Development of more knowledge in this area is needed to achieve improved cost-effective drainage facilities for transportation facilities.

PROBLEM NO. 28

I. NAME OF PROBLEM - LOCATING AND DESIGNING HIGHWAYS ON ALLUVIAL FANS

II. THE PROBLEM - The location and design of highway crossings of alluvial fans presents a number of problems because of the unstable flow conditions that exist on their formations. The flow pattern on the fan during peak flood events is not predictable, and may occur in one or in several channels. This makes it difficult to determine the effect of the highway on the alluvial fan, the effect of the fan's flow conditions on the highway, and the size of highway structures necessary to convey flood flows. These conditions become even more complex if significant development has occurred and/or if the highway project is subject to floodplain regulations for the alluvial fan.

III. OBJECTIVES

A. Identify the relationship between water and sediment routing and how such a relationship affects the geometry of the fan.
B. Develop guidelines and procedures for locating and sizing drainage structures on an alluvial fan.

IV. CURRENT ACTIVITIES - No other research in this field of interest has been identified.

V. URGENCY - The results of this study should assist in reducing the size, the number, and cost of hydraulic structures for highways located on alluvial fans.

PROBLEM NO. 29

I. NAME OF PROBLEM - ACTUAL BACKWATER ON STREAMS WITH ERODIBLE BEDS

II. THE PROBLEM - The backwater which occurs at bridges when the stream is in flood is important not only in the design of the bridge but in evaluating the increased potential flood damage to floodplain property. Most predictions of bridge backwater assume rigid boundaries, and a flow pattern upstream of flow toward an orifice (or slot) and downstream a flow pattern of a free, turbulent jet. The predicted backwater is largely due to the excess kinetic energy of the jet which is dissipated through the generation of turbulence.

During the last ten years, advances have been made in understanding the backwater in wide, heavily vegetated valleys through field observatiosn and analytic techniques. The flow pattern is quite different from the turbulent jet, and the flow returns to the flood plain because of a lateral hydraulic gradient, not through

the mechanism of turbulent mixing. In general the backwater is found to be larger than would be predicted by the older methods, and there is backwater downstream from the bridge as well as upstream.

There is another important class of bridge backwater which has not received sufficient attention; bridges in which scour holes develop around the piers and abutment so that a high velocity jet is not formed, and the backwater is a fraction of the approach velocity head. In the Southwest where the stream velocity can be 16 feet per second, the approach velocity head can be four feet, and the nominal, reference, (nonexistent) velocity head through the bridge opening would be even higher. It is readily apparent that it makes a difference whether the backwater due to a bridge is something like one foot or something more than four feet.

III. OBJECTIVE - To develop a method for determining backwater on streams with erodible beds. The topic needs to be studied in the laboratory with a physical model, and, even more importantly, in the field.

IV. CURRENT ACTIVITIES

A. Related research activities: Two research studies have been conducted by USGS for FHWA on bridge backwater analyses. The first developed a one-dimensional model which is described in FHWA Report RD-86/108. The second resulted in refinements to a two-dimensional finite element model for water surface profile computations. Both of these studies are for non-erodible beds.

B. A current NCHRP study (15-11) "Computer Aided Analysis of Highway Encroachments on Mobile Boundary Streams" is closely related to this topic.

C. Suggested key words: bridge backwater, movable stream bed, bridge hydraulics.

V. URGENCY - Priority for this study will be based on the success and results of NCHRP 15-11 and on completion of that study should be re-evaluated.

PROBLEM NO. 30

I. NAME OF PROBLEM - HYDRAULIC DESIGN OF CULVERTS ON WATERWAYS WITH HIGH APPROACH VELOCITES OF FLOW

II. THE PROBLEM - Current techniques for evaluating the flow capacities of culverts on waterways do not explicitly provide for a solution to the sometimes common occurrence of high approach velocities of flow in regions where steeper bed slopes are prevalent. As a consequence, flow immediately upstream of the culvert face is assumed to be in a "pooled" condition (i.e., negligible approach velocity such that the velocity head can be ignored), often resulting in an underestimation of flow capacity which can lead to significant oversizing of these structures and increased construction costs associated with such

improvements. Recent publications have suggested merely adding the velocity head to flow depth to establish the energy grade line to be used in conjunction with existing design nomographs for sizing culverts in lieu of a"pooled" condition. However, such an application does not do justice to the true flow dynamics, especially in those instances when approach flow is supercritical.

III. OBJECTIVES - The objectives are:

A. Through the application of either physical modeling or mathematical techniques, creation of a data base for flow capacities of culverts on waterways with high approach velocities of flow.

B. Using the data base generated from Step A, develop an explicit relationship or relationships, either in graphical or mathematical form (or both), for evaluating the flow capacities of culverts on waterways with high approach velocities of flow. The relationship(s) should be in a format that can be easily understood and used by practicing hydraulic/transportation engineers.

IV. CURRENT ACTIVITIES - No other research in this field of interest has been identified.

V. URGENCY - Many thousands of culverts are built across our nation's waterways each decade. A number of these structures may be oversized due to the lack of consideration of high approach velocities of flow during the design phase of the project. Considerable cost savings could be realized, in the long-term, if an explicit procedure were developed for evaluating the flow capacities of culverts on waterways with high approach velocities of flow.

PROBLEM NO. 31

I. NAME OF PROBLEM - BENEFITS OF PROPER INSTREAM MINING ON CHANNEL STABILITY

II. THE PROBLEM - Many cobble-bed streams in the western states can be classified as aggrading. The aggradation requires periodical removal of material in order to maintain bridge openings and to reduce severe bank erosion adjacent to highways. Many of the present methods of removing stream deposited material are costly, inefficient, may damage fish habitat, and cause environmental problems.

Secondly, the mining of sand and gravel from streams as a basic resource material to meet construction needs is becoming increasingly common. Such mining is typically done at some single, convenient location, with adverse effect on both upstream and downstream stability.

A concept of planned, selective, gravel harvesting over an extended reach of aggrading stream can simultaneously yield large quantities of sand and gravel and maintain stream alignment as well

as protect fish habitat, riparian vegetation, and wetland areas. Such a procedure would avoid unexpected emergency operations and attendant legal ramifications, provide long term stream stability, allow for more efficient use of limited fiscal resources, and enhance the surface water environment. Additionally, such procedures would make effective use of a renewable resource as opposed to unsightly mining of terrestrial deposits of sand and gravel from river terraces and the destruction of valuable wet land zones.

III. OBJECTIVES - Feasibility, implementation on a trial basis, and development of guidelines for general use are the necessary phases for the project. A minimum of three (3) years would be required. Feasibility involves the identification of the extent of the problem, contact and discussion with potential contractors and stream fisheries experts about practical operation problems and solutions, economic analyses, and coordination with transportation agency operations and management. Several sites need to be identified where selective gravel harvesting techniques can be initiated and evaluated. The development of engineering guidelines founded on fundamental principles, experience, and good judgment would necessarily have to evolve from a beginning of general published directives to more detailed, site-specific removal and monitoring procedures.

IV. CURRENT ACTIVITIES - The feasibility of selective gravel harvesting from certain streams in the Jackson, Wyoming area was performed in 1980 jointly for the Wyoming Game & Fish Department, the Wyoming State Highway Department, Teton County, and the U.S. Forest Service. The work is documented as "Evaluation of Selected Gravel Removal of Nine River Locations in Teton County for the Improvement of Aquatic Habitate and Stabilization of Stream Channel," by M. M. Skinner, February 1980.

The USGS, Cheyenne, Wyoming, is presently doing an investigation on removing material from a point bar at a site on the Wind River in Wyoming.

Other pertinent publications are listed below:

"Identification of Instreams Hazards to Trout Habitat Quality in Wyoming", by M. M. Skinner and Michael D. Stone, March 1983. Prepared for U.S. Fish and Wildlife Service, Washington, D.C.

"Sedimentation Problems of the Buffalo Fork River, Gros Ventre River, Spread Creek, and Pilgrim Creek", by M. M. Skinner, prepared for Teton County 208 Planning Agency, Jackson, Wyoming, November 1976.

"Methods for Assessment of Stream-Related Hazards to Highways and Bridges, by M. M. Skinner et.al., prepared for Federal Highway Administration, 1981.

Publications related to the identification of the aggradation problem are listed below:

"Air Photo Interpretation of River System Behaviour" by M. M. Skinner, Proceedings of American Congress on Surveying and Mapping, American Society of Photogrammetry, Denver, Colorado, 1982.

"Stream Pattern in Relation to Highway Design", by M. M. Skinner, presented at 1973 ASCE National Transportation Engineering Meeting, Tulsa, Oklahoma, July 1973.

"The Use of Color Infrared and Color Aerial Photograph for River Studies", by M. M. Skinner, presented at the 13th American Congress on Surveying and Mapping - Symposium and Workshop, Denver, Colorado, January 1978.

V. URGENCY - Decreasing sources of sand and gravel for all construction activities coupled with the need to protect instream/riparian structures and fisheries habitat make this a most urgent problem. The sand and gravel industry need dependable, long-term supplies that can be obtained and marketed in a cost-efficient way. Increasing legal problems associated with present methods of mining sand and gravel from the stream environment are the direct indication of the need to develop improved methods. However, any new method must be based on environmental considerations and sound engineering fundamentals and judgment, evaluated in the field, and have economic benefit. Techniques must be developed to minimize any turbidity increase or other water quality problems that might be associated with the process. Considerable time and effort will be required to develop proper guidelines and work needs to start immediately.

PROBLEM NO. 32

I. NAME OF PROBLEM - CURVATURE EFFECTS UPON STREAMBED TOPOGRAPHY

II. THE PROBLEM - Bank protection is generally designed and constructed so as to contain the so-called "design flood" within the channel. However, in order to preclude its failure due to undermining from streambed scour, its toe elevation must extend below the maximum potential scour depth. In many instances, current practice is to use a uniform toe depth; but there is strong evidence that streambed scour is highly non-uniform in nature -- especially along channels of non-linear alignment. For example, in channel bends the greater scour normally occurs near the concave banks. In certain cases, the differential scour between concave and convex banks may exceed 20 feet. Such an asymetric scour development, and its longitudinal variation along the channel, requires careful evaluation so that proper toe elevations will be designed that insure the structural integrity of the bank protection, up to and including the "design flood" event.

III. OBJECTIVES - The objectives are:

A. Develop methods for predicting the changes in streambed topography induced by curvature effects, including streamwise variations.

B. Combine the effects of curvature upon streambed topography with scour and fill due to longitudinal imbalance in sediment movement so that adequate toe elevations for bank protection installations may be determined.

IV. CURRENT ACTIVITIES - Research on streambed scour is currently being performed at San Diego State University (Howard Chang). Certain preliminary results have been obtained as documented in the publication "Water and Sediment Routing, Through Curved Channels," in Journal of Hydraulic Engineering, ASCE, Vol. III, April 1985.

V. URGENCY - This research will result in the increased knowledge of changes in streambed topography induced by curvature effects, and will serve as a useful design aid in the design of many types of channel bank linings, such as riprap and gabions.

WATER QUALITY

PROBLEM NO. 1

I. NAME OF PROBLEM - WATER QUALITY MONITORING PROGRAM OBJECTIVES AND REQUIREMENTS FOR TRANSPORTATION PROJECTS

II. THE PROBLEM - Water quality of highway runoff or of water bodies crossed by roadways may be monitored for any of a number of reasons. These include (1) scientific research on quality levels or quality change mechanisms, (2) problem identification, (3) preliminary design of controls, (4) final design corroboration, (5) regulatory compliance monitoring and (6) operational performance monitoring.

Numbers of samples and laboratory analyses to satisfy each of these example objectives range from less than 100 to over 50,000. Comparable sampling, laboratory and analyses costs range from several thousand dollars to many millions of dollars. These findings have resulted from recent (1981) research on the monitoring of general urban runoff including watershed, street surface, storm and combined sewage and receiving water flows.

Analysis of the statistical reliability and costs of quality monitoring programs directed specifically at the unique roadway runoff problem has never been made. Still, highway and other road surface runoff is often singled out as being a significant source of water pollution. Monitoring to prove that allegation, to support controls of the pollutants identified and to predict or demonstrate their adverse effects should be reliably planned and implemented.

III. OBJECTIVES - To relate water quality monitoring objectives for studying road surface runoff to the sample and station number requirements and to the costs of sample programs thus indicated. Guidelines will be formulated on development of project study objectives. For example: Why is certain data being collected? How is it to be used?

IV. CURRENT ACTIVITIES

A. Recent Federal Highway Administration research results exist on (1) monitoring of stream and road surface runoff and (2) mathematical modeling of processes of pollutant transport on and near road surfaces. Whether the data base is sufficient for model calibration or verification or for any other purpose remains a question.

B. Sonnen's 1981 research results on monitoring of urban runoff quality, performed by EPA, suggest that monitoring requirements vary tremendously depending on the objective to be satisfied.

C. Most research on sampling sufficiency of any relevance has been on hydrologic parameters, such as rainfall, gage density and the like.

V. URGENCY - New roadway designs and installations and refurbishments of old road surfaces and rights-of-way continue apace. Adequate pollution controls for the runoff from these surfaces are required by state and federal laws. Water quality sampling of runoff to support conclusions about that adequacy is expensive, but sufficient monitoring is required to satisfy reliably any of a number of objectives for such monitoring. Until monitoring guidelines are produced to relate specific objectives to monitoring requirements insufficient or more than sufficient monitoring is highly likely to result. Either result could be catastrophically costly, both economically and intangibly.

PROBLEM NO. 2

I. NAME OF PROBLEM - EFFECTIVENESS OF TEMPORARY EROSION CONTROL METHODS TO REDUCE WATER POLLUTION

II. THE PROBLEM - There has been an increasing emphasis over the past several years on the prevention of water pollution due to highway construction and operation. One of the pollutants of concern is sediment. Probably the greatest emphasis to date has been directed at sediment since the damaging effects of erosion on the highway are readily visible and the concentration of sediment in runoff is higher than that of other pollutants.

The highway system is most vulnerable to erosion damage and sediment runoff during the construction period; thus there have been numerous publications advocating various temporary erosion control measures. In general these measures are to remain in place until vegetation is established or other permanent controls are installed; then they are removed or biodegraded.

While many different temporary erosion control measures have been advocated, few have been evaluated. Most are not designed but are improvised based on field experience. It appears that some measures may not work or may create more problems than they solve. Failures of several of the commonly suggested methods are often observed on highway projects.

III. OBJECTIVES - To evaluate the temporary erosion control methods commonly proposed by means of laboratory or field studies in order to determine their efficiency, practicality, ease of construction and durability; and to develop guidelines for the design, construction and maintenance of those measures proven to be effective.

IV. CURRENT ACTIVITIES

A. Related research activities: EPA has developed, under contract, several recent reports dealing with temporary erosion control methods. Most involve gross estimates of efficiency. A new NCHRP research study has just been initiated on the effectiveness of erosion control methods for roadside development.

B. Suggested key words: water pollution control, erosion, temporary erosion control.

V. URGENCY - There is a pressing need to evaluate the performance of the temporary erosion control methods currently being promulgated. If they do not perform as well as expected their continued use may result in undue sediment pollution of natural waterways and damage to the highway. In fact they may act as placebos curing nothing but providing a false sense of security.

PROBLEM NO. 3

I. NAME OF PROBLEM - NATURAL SYSTEMS TO TREAT HIGHWAY RUNOFF

II. THE PROBLEM - Growing awareness of the potential for environmental damage from the construction and operation of highways and highway drainage systems has resulted in the need to identify and quantify the environmental effects and to develop measures for the protection of the total environment from any adverse effects. Rainfall along highways produces massive amounts of runoff which present significant problems of collection and treatment for contaminant removal by conventional methods. There is a need to develop and evaluate techniques for using the assimilative capacity of natural biological systems that are complementary to highway construction to abate objectionable constituents of highway runoff before discharge into receiving waters. The abatement methodologies must be capable of handling large and variable volumes of runoff in an economical and environmentally compatible manner. Resulting methodologies must be adaptable for application to a variety of site conditions including different soils types, vegetative covers and topographies.

III. OBJECTIVES - The objective is to determine the feasibility of using natural ecological systems to treat highway runoff so as to minimize contaminant loadings to receiving waters. All available information on the potentially feasible systems will be described. Experimentation will be conducted to fill critical information gaps and to develop criteria for establishing reliable abatement systems.

IV. CURRENT ACTIVITIES

A. Highway research in FHWA FCP Project 3E has been scanned in preparing this statement. Many ongoing projects are monitoring, identifying and quantifying highway runoff constituents. The transport mechanisms of certain contaminants are being determined under Project 3E. The next step will be to develop methods of treating objectionable constituents of highway runoff. Results of related research being conducted by the Corps of Engineers and the Environmental Protection Agency on land treatment of wastewater and the management of leachates and runoff from land disposal of dredged and fill material may have potential application to this problem.

B. Suggested key words: abatement/treatment, highway runoff, contaminants.

V. URGENCY - This research will develop state-of-the-art knowledge on the feasibility of utilizing natural biological systems to treat massive amounts of highway runoff and therefore is highly urgent. Discussions at the Federal Highway Administration sponsored annual research review of the Federally Coordinated Program of Research and Development in Highway Transportation at Columbus, Ohio on November 8, 1977, indicated that certain states (New Jersey and California) are currently interested in the potential of wetlands and marshes to treat highway runoff.

PROBLEM NO. 4

I. NAME OF PROBLEM - STRUCTURAL METHODS FOR REMOVAL OF CONSTITUENTS FROM HIGHWAY RUNOFF

II. THE PROBLEM - Much research work is being performed on methods of removing sediment from highway runoff. However, it may become necessary, at least at some sites, to remove other constituents from the runoff. Treatment for one type of constituent may release or enhance the concentration of another constituent.

Research is underway on the quality of highway runoff. If this work and other studies on the effects of the materials on plants and animals show that problems exist it may become necessary to remove certain constituents from the runoff.

Preliminary work indicates that some constituents decay, some are absorbed to sediment and some are lost through ion exchange with soils. These characteristics may lead to some conclusions as to possible removal methods. For example, it appears that sediment ponds may be an excellent method of removing contaminants other than sediment while some oil skimmer designs may be completely unworkable.

III. OBJECTIVES - To derive practical methods of removing problem constituents from highway runoff before such runoff reaches water courses.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA and Washington DOT research on quality of highway runoff. NCHRP study on erosion control methods. Various EPA research studies. Corps of Engineers wash rack and other studies.

B. Suggested key words: highway runoff, pollutants, pollutant removal.

V. URGENCY - If ongoing research defines certain pollutants in highway runoff as being harmful there will be pressure to quickly derive means of treating the runoff. Some preliminary work along this line should be initiated as soon as possible so that rash decisions to utilize unworkable treatment methods will not be made.

PROBLEM NO. 5

I. NAME OF PROBLEM - OPERATIONS AND MAINTENANCE (O&M) OF SANITARY TREATMENT FACILITIES AT ROADSIDE REST AREAS

II. THE PROBLEM - The effluents from many roadside rest area sewage treatment facilities fail to meet state and federal water quality requirements. To some extent these inefficiencies are due to design inadequacies but in many cases the problem results from an under-estimate of O&M needs and a misunderstanding of the peculiar needs of rest area systems. The intermittent nature of the waste loadings and the resulting wide fluctuations in waste strength present major operational problems. The periodic maintenance of the treatment works rather than full time operator assisted systems can also lead to diminished treatment efficiencies. States need guidance in upgrading the effluents through operation and maintenance practices rather than further construction funding.

III. OBJECTIVES

A. To define the operation and maintenance problems that commonly exist at rest area sanitary treatment facilities.

B. To develop O&M methodologies to meet the needs of the facilities. Develop operational guidance for all of the most widely used processes (i.e., lagoons, package plants, oxidation ditches, land treatment systems).

C. To investigate various operational modes and make recommendations based on the manpower and time requirements of each. Delineate equipment and supply limitations for the common treatment trains.

D. To produce a manual or series of manuals that address the above findings.

IV. CURRENT ACTIVITIES

A. Related research activities: The extent of research being conducted by other agencies or organizations is not known. Organizations with similar facilities and needs are:

1. Corps of Engineers Recreational Areas
2. Forest Service Campgrounds
3. State and National Parks Systems
4. Amusement Parks - especially large theme parks in the outskirts of metropolitan areas (Disney World, Busch Gardens, etc.).

B. Suggested key words: intermittent loads, small treatment works, sewage effluents, roadside sanitary facilities.

V. URGENCY - Effluent requirements mandated by federal and state laws will not be relaxed in the coming years. Construction funding will not be available for replacement of processes not currently meeting permit requirements. Therefore, there resides a tremendous need to assess the present technologies and develop methods for existing systems to attain the effluent design standards. Creative O&M activities must be placed into practice to meet the discharge permits while remaining within the funding and manpower limitations of the state governments.

PROBLEM NO. 6

I. NAME OF PROBLEM - RESTORATION OF WETLANDS AS MITIGATION FOR ADVERSE IMPACTS RESULTING FROM THE CONSTRUCTION OF TRANSPORTATION FACILITIES

II. THE PROBLEM - The location and construction of transportation facilities through wetlands areas cannot always be avoided. Certain unavoidable loss of wetlands usually occurs where this situation does exist. Regulatory agencies are requiring replacement or restoration of wetlands as conditions to approval for permits to construct in such areas.

The transportation agency is often required to restore or replace wetlands without having the proper design criteria or technical guidance required to successfully implement restoration programs. Unsuccessful mitigation attempts by various transportation agencies have lent skepticism to the permit review process and have prevented reasonable "trade-offs" from being a legitimate approach to obtaining necessary environmental permits.

III. OBJECTIVES - Synthesis study and development of guidelines and design criteria for the reconstruction of certain typical wetlands such as marshes (both tidal and freshwater), swamps, submerged vegetation meadows, etc., that may be successfully used in wetlands restoration. This would include the gathering of data to understand the physical and chemical requirements of various typical wetlands flora and experimentation in the form of demonstration projects to experimentally produce a variety of wetlands systems.

IV. CURRENT ACTIVITIES

A. Related research activities: U.S. Corps of Engineers restoration experiments with dredge spoil, various university research activities on marsh and seagrass restoration.

B. Suggested key words: wetlands, fish and wildlife habitat, mitigation, marshes, swamp, restoration.

V. URGENCY - The loss of wetlands in the United States has reached critical proportions due to construction and development. There is an urgent need to develop guidelines and criteria for restoration and creation of wetlands lost through construction of transportation facilities.

PROBLEM NO. 7

I. NAME OF PROBLEM - TOLERABLE TEMPORARY VARIANCES IN WATER QUALITY STANDARDS RELATED TO TOTAL SUSPENDED SOLIDS AND TURBIDITY AS CAUSED BY TRANSPORTATION CONSTRUCTION PROJECTS

II. THE PROBLEM - In the course of constructing transportation facilities it becomes necessary to work in and around streams. This work by necessity will cause a temporary increase in the total sediment discharge and turbidity. Many streams provide a water resource of varying values and susceptibility to damage from such modified sediment regimes. Current water quality standards are based on permanent sediment regime changes in water quality with little flexibility for relatively brief and temporary increases due to construction practices. In order to justify efforts to modify existing water quality standards it becomes necessary to quantify the impact on the water resource of these temporary changes into the sediment regime.

III. OBJECTIVES - The objectives of this research would be national in scope and consist of the following objectives. Quantification identified below should attempt to include such details as sediment concentrations, gradations, particle angularity, sediment nature or origin, duration of change in sediment regime, magnitude of changes in sediment regime and the resulting impact on downstream aquatic biota.

A. A case history of common transportation construction projects completed in the past 20 years should be undertaken to determine if:

1. the sediment discharges have returned to normal, and
2. the temporary increase in sediment discharge occurring during construction resulted in a permanent degradation of the nation's water resource.

B. Quantifying the tolerance of key aquatic organisms to temporary increases in sediment discharge and turbidity. Research may be

necessary to complete the work accomplished to date.

C. Quantifying the acceptable limits of temporary changes in the sediment regime on agricultural, municipal, recreational and industrial uses.

D. Determining seasonal effects of temporary changes in the sediment regime.

E. Well documented case history measurements over time are then needed to verify the research finding (before/during/after construction).

F. Research should include suggested draft revisions to existing federal water quality regulations based on the research findings.

IV. CURRENT ACTIVITIES

A. Related research activities: Some completed research regarding the effects of sediment on fisheries, industry, agriculture, recreation and municipal standards for permanent sediment standards are known. However, the permanent environmental effect of temporary increases in the sediment discharge is not well defined.

B. Suggested key words: water quality, sediment, temporary impacts, construction variances, turbidity.

V. URGENCY - There are intensive research efforts that are national in scope being directed at preventing or mitigating temporary increases in sediment discharge arising from construction projects. Additional resources are being directed at designing and constructing facilities to control these temporary increases in the sediment discharges. The foregoing continues to occur without knowledge as to whether temporary increases in sediment discharges from construction projects are permanently degrading the receiving waters.

Regulatory agencies continue to be inflexible about not exceeding water quality standards established for permanent quality levels resulting in delays for needed construction. These delays are costly both in money and loss of life due to untimely replacement of needed transportation facilities.

The foregoing places this research into the immediate need category.

PROBLEM NO. 8

I. NAME OF PROBLEM - PREDICTIVE MODELING OF THE FATE OF HIGHWAY RUNOFF POLLUTANTS

II. THE PROBLEM - Research in recent years has indicated that numerous constituents transported by highway and street surface runoff may be a serious source of pollution to receiving surface waters. Considerable pressure is being applied to transportation departments

by regulatory agencies to provide treatment of storm runoff waters on the transportation facility prior to any discharge into receiving waters. In most cases the treatment practices are required without benefit of design criteria for pollutant removal or the desired results of such treatment in terms of resulting impacts on downstream surface waters.

Considerable data now exist which would indicate the types and concentrations of pollutants that might normally be expected in highway surface runoff. There are no satisfactory mathematical tools available, however, that can predict the fate of these materials (salts, nutrients, heavy metals, etc.) as the ultimate fate and resultant impact of these materials (salts, nutrients, heavy metals, etc.) as they are transported to receiving waters or the ultimate fate and resultant impact of these materials upon receiving waters and associated aquatic biosystems.

III. OBJECTIVES - To develop a practical computerized predictive model to determine the ultimate concentrations of pollutants in highway and surface runoff that would affect receiving waters to be used as a tool to design best treatment practices and determine the effectiveness or need of such practices in project design.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA and various state research on quality of highway runoff. EPA studies on urban runoff and predictive modeling.

B. Suggested key words: highway runoff, pollutants, pollutant removal, storm runoff models.

V. URGENCY - Section 208 of PL 92-500 presently requires regional water quality management plans by the various states. Non-point sources of pollution (storm runoff) are included in the scope of 208 planning. Water pollution abatement practices by regulatory agencies now are being required on transportation projects often at alarming costs without benefit of any analysis of the need or effectiveness of such practices. Modeling tools are sorely needed so that a more responsible approach to project design can be realized.