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16. ABSTRACT

Introduction:

Alteration of water quality typically occurs as a result of its usage or by substances added to the water from external sources as the water journeys on its way downstream. whenever these alterations interfere with subsequent use of the water, they are regarded as pollution.

In this manual, potential ways in which alteration of existing water systems can occur from public works activities are discussed. Methods for performing a water quality survey, analyzing data, and interpreting results are outlined. An assessment of probable impact can then be determined.

Enhancement actions and remedial measures can be employed early in the design stage to reduce probable impacts (both short range and long) that have been identified in the course of the water quality study. Submission of an erosion control plan by the contractor provides further implementation. In addition, specifications or special provisions requiring certain remedial works to prevent water pollution can also be provided.

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"Analysis of Water Quality For Highway Projects"

Page	Correction
I-4	Figure 23 should read Figure 2.
IV-5	Second para. should read one-pint bottles.
IV-11	Last para., word should be "weighted", not weighed.
IV-19	First sentence, should be "electrode", not selectrode.
IV-22	Second para., third sentence should read "The largest space . . ."
IV-26	Heading should read "References Section IV"
V-10	Third para., last sentence should read ". . . lowering the sampler to the streambed . . ."
V-25	Fourth para., should read ". . . an uncapped bottle tied . . ."
V-26	First para., last sentence should read ". . . those obtained with regular . . ."
V-30	First para., first sentence word should be "concentration".
V-33	Fourth para., last sentence word should be "orifice".
V-34	Second para., fifth sentence should read "The stream velocity at any point . . ."
V-40	Fourth sentence should read ". . . the recorder to activate an electromagnet . . ."
VI-4	Under A. Reagents, item 2 should read "ALKali- . . ."
VI-6	Under B. Procedure, colorimetric is misspelled.

Under D. Test Procedure, step 2 should read "... "W" - weigh each dish to 0.0001 gm. ..."

Fourth sentence should read, "... to algae and other growth."

Sixth para., last sentence should refer to (13), not (14).

In table of irrigation water, reference to chloride should be "meq/l", not ppm.

Under "Septic Zone", Lesch is misspelled.

Last para., second sentence should read "For very ...."

Last para. should read "... in Manual 4 of this water quality series."

WATER QUALITY MANUAL

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Special acknowledgment is given to John Wark, Edward Jones and Leroy Gamble of the U.S. Geological Survey for information on sedimentation analysis and equipment, George Gaston of the California Department of Water Resources for information on chemical analysis of water, and to Fred Kopperdahl of the California Department of Fish and Game for assistance on toxicity tests. Information from the U.S. Environmental Protection Agency course entitled "Water Quality Studies" conducted by Donald May of Corvallis, Oregon, is especially appreciated.

The assistance of others who contributed to this manual is greatly appreciated.

TABLE OF CONTENTS

TABLE OF CONTENTS (con't.)

TABLE OF CONTENTS (con't.)

FIGURES

TABLES

FORMS

INTRODUCTION

Alteration of water quality typically occurs as a result of its usage or by substances added to the water from external sources as the water journeys on its way downstream. Whenever these alterations interfere with subsequent use of the water, they are regarded as pollution.

In this manual, potential ways in which alteration of existing water systems can occur from public works activities are discussed. Methods for performing a water quality survey, analyzing data, and interpreting results are outlined. An assessment of probable impact can then be determined.

Enhancement actions and remedial measures can be employed early in the design stage to reduce probable impacts (both short range and long) that have been identified in the course of the water quality study. Submission of an erosion control plan by the contractor provides further implementation. In addition, specifications or special provisions requiring certain remedial works to prevent water pollution can also be provided.

In some cases, contingency plans may be necessary for accidental chemical spills on major roadways located near domestic water supplies. The use of pesticides near water systems must be exercised with extreme care. Long-term effect on the quality of water must be assessed as well as short term effects. Long-term effects such as slope erosion over the service life of the pavement, mineral leachates, and usage of chemicals in the highway environs during maintenance operations, are commonly overlooked in the evaluation of environmental impact.

This manual is not meant to be a complete document in which all areas of water pollution are discussed. Rather, subjects were selected which will enable highway personnel to obtain information on water quality and to properly perform an analysis which will provide input to an environmental impact statement for the particular project.

Water quality surveillance equipment has been rapidly changing. New equipment for analysis of water samples is continually coming on the market. Criteria for water quality as established by regulatory agencies is also subject to change. For these reasons, this manual will be updated when necessary.

Detailed analyses on specific areas of water quality studies are available in much of the literature. Specific references have been cited at the end of each Section in this manual and the reader is encouraged to utilize these materials as much as possible.

Likewise, certain phases of water analyses require persons trained in areas of specialization such as water chemistry, bacteriology, aquatic biology, and sanitary engineering. Specialists should be consulted for cases requiring specialized knowledge.

SECTION I

ENVIRONMENTAL IMPACT

SECTION I
ENVIRONMENTAL IMPACT

Possible pollution of water by public works activities is classified principally into three categories: 1) Physical, 2) Chemical, and 3) Biological. Each of these types of water pollution represents a potential impact on the environment. Understanding the nature of the "changed" environment resulting, for instance, from a highway activity assists in determining the probable water quality impact.

In the study of water quality, the watershed is taken as the unit of study. Within the watershed, many working systems exist, such as soil-plant-animal and water-atmosphere. The highway activity commonly traverses a watershed in some defined manner. It may affect conditions both above and below the crossing. Thus, it is desirable to study conditions throughout the watershed in order to understand system relationships. Once the "system" is defined, the impact caused by the "changed" environment can be ascertained. Water quality criteria help determine whether the impact is negative or positive. The criteria also point to the proper remedial measures required either to enhance the environment or decrease the adverse effects.

Physical Pollution

The major impact resulting from highway facilities generally is erosion and subsequent sedimentation. This impact is classified as physical pollution. Investigations have revealed erosion of highway slopes to be a significant contributor of sediment in streams and lakes.

Adverse effects of erosion and sedimentation include the addition of nutrient particles to streams and lakes. In some cases, the addition of nutrients can help to accelerate eutrophication (the natural aging process) of the water system. The principal nutrients leached from the eroded soil are nitrogen, phosphorus and carbon compounds (1).*

Sediment deposits on the streambed are detrimental to the propagation of fish which rely on the clean gravel beds for spawning. Fish foods which thrive on the streambeds are also adversely affected by increased sediment deposits.

Deposits of eroded material in drainage systems also decrease the flow capacity of the facility. During periods of high flow, over-bank flooding could occur from the decreased conveyance

*Numbers refer to references at end of each section.

capacity. Sediment bearing waters increase in "bulkiness" which means a larger volume per unit time is required versus that for relatively clean water.

Sediment build-up at down-slope areas periodically suppresses emerging vegetation. In some cases, it has also covered the aeration zone (located within the drip-line of trees) required for vigorous growth of larger vegetation species.

Maintenance costs required to remove sediment from drainage facilities and "repair" badly eroded slopes can be sharply reduced through a comprehensive erosion and sedimentation control plan.

Accelerated erosion of highway slopes occurs principally as one of three types: sheet, gully, and rill erosion. The degree or extent of the erosion process depends upon many factors. Soil type, vegetative cover, topography, climatic and meteorological conditions, etc., all play an important role in the erosion process (2).

Figure 1 depicts some of the common agents at work in erosion of slope particles (3). There are other factors again which are not detailed. Generally, raindrop impact and surface flows play significant roles in eroding particles from barren slope faces. This is one reason why revegetated slopes generally produce less sediment than a correspondingly denuded slope. Raindrop impact energy is absorbed by the vegetation, the root structure and humus increase the infiltration capacity as well as the hydraulic slope through the circuitous routing of surface flows and allows catchment areas on the slope to withhold sediment.

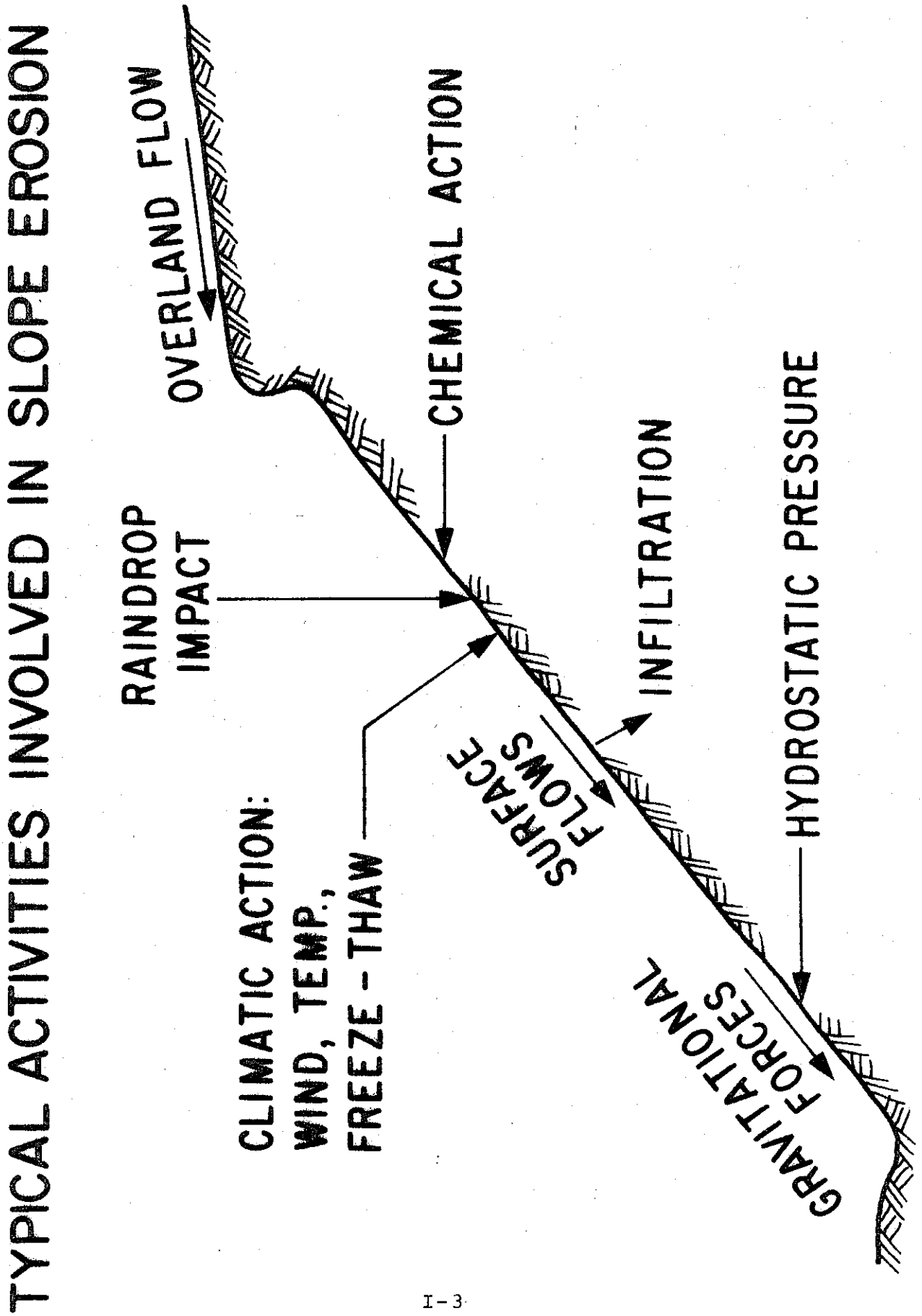
The eroded material from a cut or fill slope is available for sediment transport. The quantity of sediment that is actually transported is dependent upon a number of factors which are discussed more thoroughly under Slope Erosion Transects in Section VI - Laboratory and Field Tests.

Sediment Transport

The following discussion deals with sediment particles as they are transported in streams and rivers. Sediment is generally defined as to its source within a watershed and according to the mode by which it is transported.

Wash load is the finer sediment particles whose source is from the upstream watershed and whose range of particle sizes are not found in appreciable quantities in the streambed.

Figure 1


TYPICAL ACTIVITIES INVOLVED IN SLOPE EROSION
OVERLAND FLOW
CHEMICAL ACTION
RAINDROP IMPACT
INFILTRATION
HYDROSTATIC PRESSURE
CLIMATIC ACTION: WIND, TEMP., FREEZE - THAW
SURFACE FLOWS
GRAVITATIONAL FORCES

The bed material load is composed of sediment in transport whose sizes are found in appreciable quantities in the streambed. However, the origin of the bed material load may be a combination of upstream sources such as sheet erosion, slope erosion from disturbed lands including roads and developments, geologic disturbances, streambank erosion and scour of streambed.

Sediment transport occurs in essentially two modes: 1) suspended sediment and 2) bedload. The interchange between the two modes is dependent upon certain hydraulic and stream characteristics. Figure 2 shows a schematic of sediment transport. The total load is the summation of the suspended sediment load and bedload.

The suspended sediment is kept in suspension by the turbulent forces of the stream. The size distribution of suspended particles is finer than those transported as bedload. It is important to note that the transport capacity of a stream changes with different water temperatures due to changes in the viscosity of the water.

Particles transported as bedload roll, slide and skip (saltate) along the bottom of the stream. Bedload is hard to measure and equipment to measure bedload is not too reliable (4). Traps are commonly employed to gather bedload samples. A sample of the bed material can also be analyzed for use with flow-duration relationships to determine bedload rates. For an accounting of various bedload formulas, the reader is referred to reference 5.

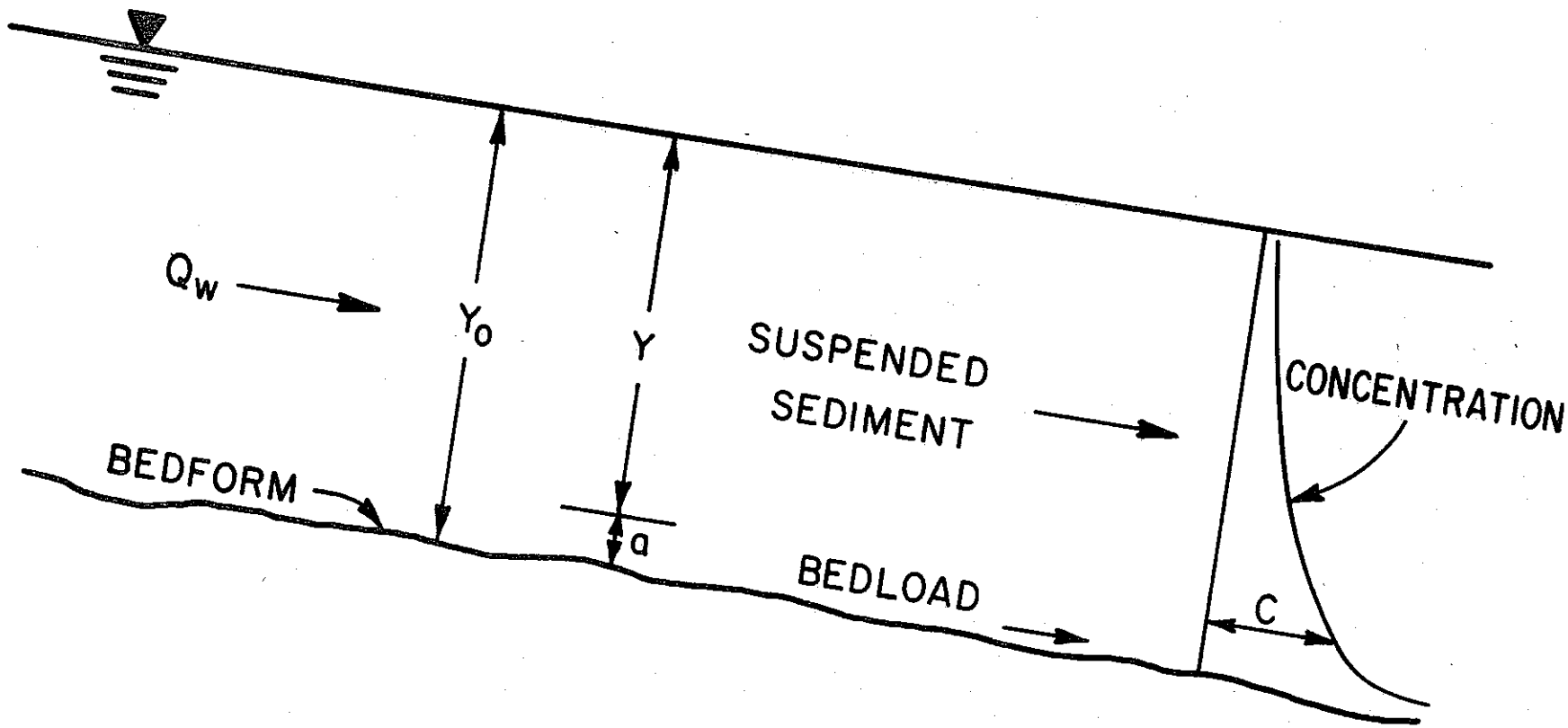
The distance "Y" shown in Figure 23 represents the region in which a suspended sediment sample is obtained when using the depth-integrated samples. The distance "Y_o" is the stream depth. The difference between Y_o-Y is equal to "a". This distance is commonly taken as 0.3 foot which is the unsampled zone, and represents the distance between the heel of the sampler and the intake nozzle. In some bedload relations, "a" is assumed to be the Laminar Sublayer (5), which is the layer of flow near the boundary governed by viscous forces (6).

As shown by the concentration distribution in Figure 2, the highest sediment concentrations occur near this region. Bedload formulas are available which take this into account when computing transport rates. A discussion on calculations of transport phenomena is included in Section VII.

The velocity distribution in a stream is an important factor affecting sediment transport. It does not vary linearly from the stream surface to the stream bottom (6). For measuring stream velocities, refer to Section V.

An important aspect for determining the total sediment transport of a stream or river is streamflow information. At higher stream-

SEDIMENT TRANSPORT



TOTAL LOAD = SUSPENDED SEDIMENT + BEDLOAD

Figure 2

flows, the transport capability of a river increases. At lower flows, some of the suspended sediment may be deposited and transported as bedload or it may not move at all.

Total transport can also be determined from the use of an annual flow-duration curve and an analysis of bed-material samples. The Meyer-Peter, Muller relationship utilizes this concept.

A size analysis of the sediment particles will be useful in identifying the activity of transport. The following table shows a common designation (7):

Table 1

General Classification of Sediment Size

Size	Designation	Remark
$D<0.5\mu$	Colloids	Always flocculated
$0.5\mu<D<5\mu$	Clay	Sometimes or partially flocculated
$5\mu<D<64\mu$	Silt	Nonflocculating-individual crystals
$64\mu<D<2mm$	Sand	Rock fragments
$2mm<D$	Gravel, boulders	Rock fragments

According to Dr. Einstein (7), gravels and boulders may be expected to move predominantly as bedload, while silts and clays move predominantly in suspension. Sand will undergo both types of motion.

An analysis of the particle sizes on the Upper Truckee River one-mile upstream from Lake Tahoe revealed the following size distribution for suspended sediment and bed-material (8):

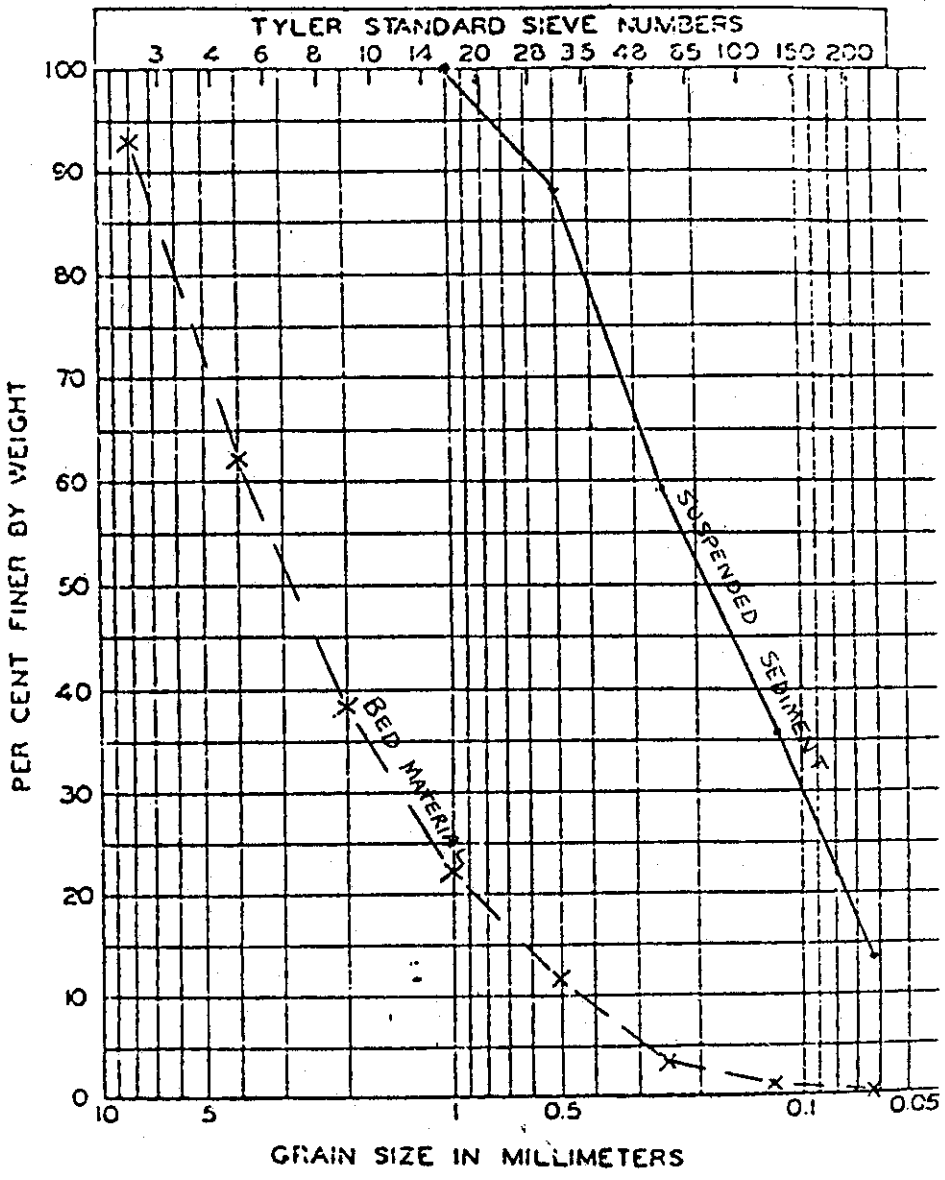


Figure 3

Grain Size Distribution - Upper Truckee River

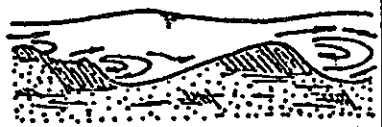
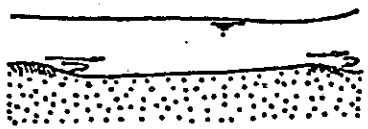
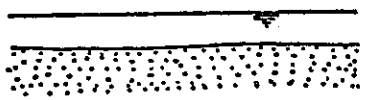
Interpretation of the graph shows 86% of the sampled suspended sediment is designated as sand whereas for the bed-material 38% is sand and 62% is gravel.

As the flow regime changes, the bed form of alluvial channels undergoes a series of changes. Lower regime flow is generally accompanied by ripples or ripples on dunes. A flat bed is only achievable in a laboratory flume and rarely experienced in nature. Between lower and upper regime flow is a transition in which washed-out dunes occur. Upper regime flow starts with a plane bed, progresses to antidunes and at extreme upper regime flow, breaking antidunes occur. Figure 4 shows the various bed forms and the general bed-material concentration (suspended sediment plus bedload).

Methods of collecting sediment samples are described in Section V. Formulas and procedures for calculating sediment transport rates are described in Section VII.

An estimate of the probable amount of erosion on highway slopes for a specified period of time can be performed through a field survey. Information relating to soil type, degree of vegetative cover, topography, potential rain-fall intensities and duration, etc., need to be gathered. Investigation of existing slope erosion through a slope erosion transect survey is a method for predicting annual erosion rates (9).

BED FORMS
Figure 4

FLOW REGIME	BED FORM	BED MATERIAL CONCEN-TRATION	MODE OF TRANSPORT	WATER SURFACE BED PHASE RELATION	RESISTANCE TO FLOW.
LOWER	 Ripples	0 - 200 ppm	Discrete Steps 	Out of Phase	Form roughness predominates-spacing and amplitude of roughness elements vary with the fall diameter of bed - material, $C/\sqrt{g}$ varies from 7.75 to 13.90
	 Dunes	100-1200ppm			
TRAN-SITION	 Washed out Dunes	1,000 - 1200 ppm			Variable
UPPER	 Plane	1,200 - 2000 ppm	Continuous 	In Phase	Grain roughness predominates-for Plane bed $C/\sqrt{g}$ varies from 14.0 to 21.0
	 Antidunes	1,800 - 6,000 ppm	Continuous 		
	 Breaking Antidunes	1800 —	Discontinuous 		

Chemical Pollution

Chemical pollution of water from highway sources occurs primarily through use of products for de-icing, and weed, rodent, and insect control. Runoff from the highway facility may carry residue from these products into nearby streams or lakes. A constant build-up of chemicals in a defined aquatic life system may lead to adverse effects.

Certain species of vegetation may be sensitive to de-icing salt whereas others may have a high salt tolerance. Biostimulation of undesirable phytoplankton or algae by trace elements in salt can occur (10).

Toxic materials are particularly of concern when they pollute unintended receptors. Most of these materials are used during the operation and maintenance phases of the highway program. The chemical composition of roadway drainage water may contain toxic substances, heavy metals, and oil and grease.

Biological Pollution

Biological pollution of water systems is primarily a bacteriological concern. Development of water supply systems for human consumption or watering ponds must be safe from the health stand-point. The same is true for waste disposal areas at roadside reststops. Disposal of solid waste products procured during the maintenance operation requires safe techniques.

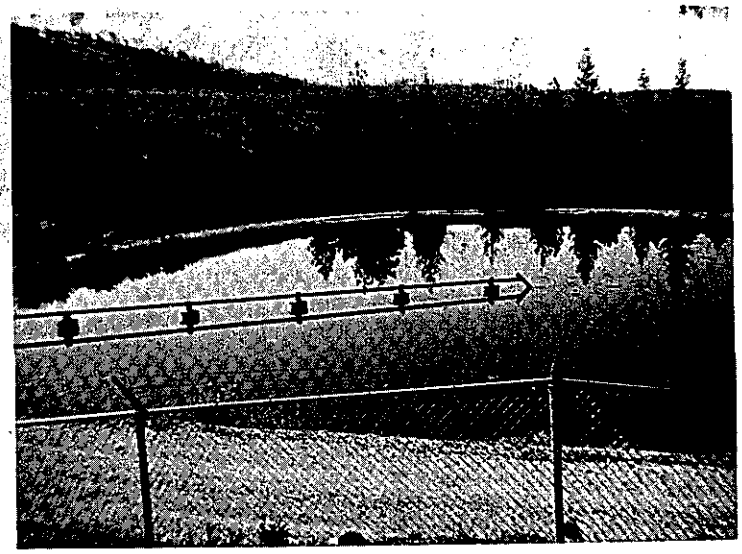


Figure 5

Waste water disposal at roadside reststop.

Dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, and coliform count are types of tests performed for biological pollution analysis.

Summary

The principal categories of water pollution are 1) physical, 2) chemical, and 3) biological. Understanding the "system" in which the highway facility or activity will intrude is necessary to formulate an impact assessment.

A program should be developed for a particular project that is fitted to the needs or conditions of the anticipated problem. Insufficient data or inadequate sampling can be eliminated by properly formulating the water quality survey in the early stages of a project study. Coordination of activities with affected agencies will assist in developing a comprehensive and acceptable plan.

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6. "A New Look at Sedimentation in Turbulent Streams", Arthur Ippen, Journal of Boston Society of Civil Engineer, July 1971.

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10. Environmental Impact of Highway Deicing", Environmental Protection Agency, Water Quality Research, June 1971.

SECTION II

BIOGEOCHEMICAL CYCLES

SECTION II
BIOGEOCHEMICAL CYCLES

Aquatic eco-systems are significantly affected by the quality of water in their environment. The make-up of streams and lakes are influenced by biogeochemical cycles that exist in nature. Changes to components of the cycles result in an alteration to the complete system. In some cases this may result in an enhancement to aquatic eco-systems or it may serve to degrade the water in some manner that subsequently renders it unfit for a particular use.

The need for monitoring certain substances becomes clearer when and examination of cycles or schemes is undertaken. The following four diagrams indicate the relationships for: 1) eutrophications, 2) nitrogen, 3) oxygen addition, and 4) eco-systems.

1. Eutrophication - This is the process in which nutrients are added to a water system, resulting in an increase in productivity, i.e., growth of algae and other organisms (1). Under most circumstances, the aging process of a lake is a natural condition, which takes place over several hundred and even thousands of years.

Some lakes have become eutrophic much faster because nutrients were readily available in the system. Oligotrophic lakes are defined as pristine, clear water and low in nutrients. These lakes are fairly deep and contain cool water. Examples are Crater Lake in Oregon and Lake Tahoe in California. Mesotrophic lakes are starting to collect silt and have some shoreline vegetation. Fish are starting to proliferate. Eutrophic lakes have extensive algae growth and are nutrient rich. The lake is starting to become extinct. Klamath Lake in Oregon is an example.

The nutrients limiting eutrophication include carbon, nitrogen and phosphorus. There may be other micro-nutrients limiting the process in specific cases, but in general these three elements are considered to be the most influential.

The following diagram shows the eutrophication scheme and identifies essentially five factors prevalent in the process.

The first source of eutrophic elements is the atmosphere. The exchange of many elements takes place at the water surface and is dependent upon climatic factors such as exchange of air in contact with the water surface, i.e., wind, temperature, pressure, etc.; elements in the air volume; and characteristics of the water surface and the viable organisms in the fluid that are capable of utilizing the elements in the atmospheric sink.

EUTROPHICATION SCHEME

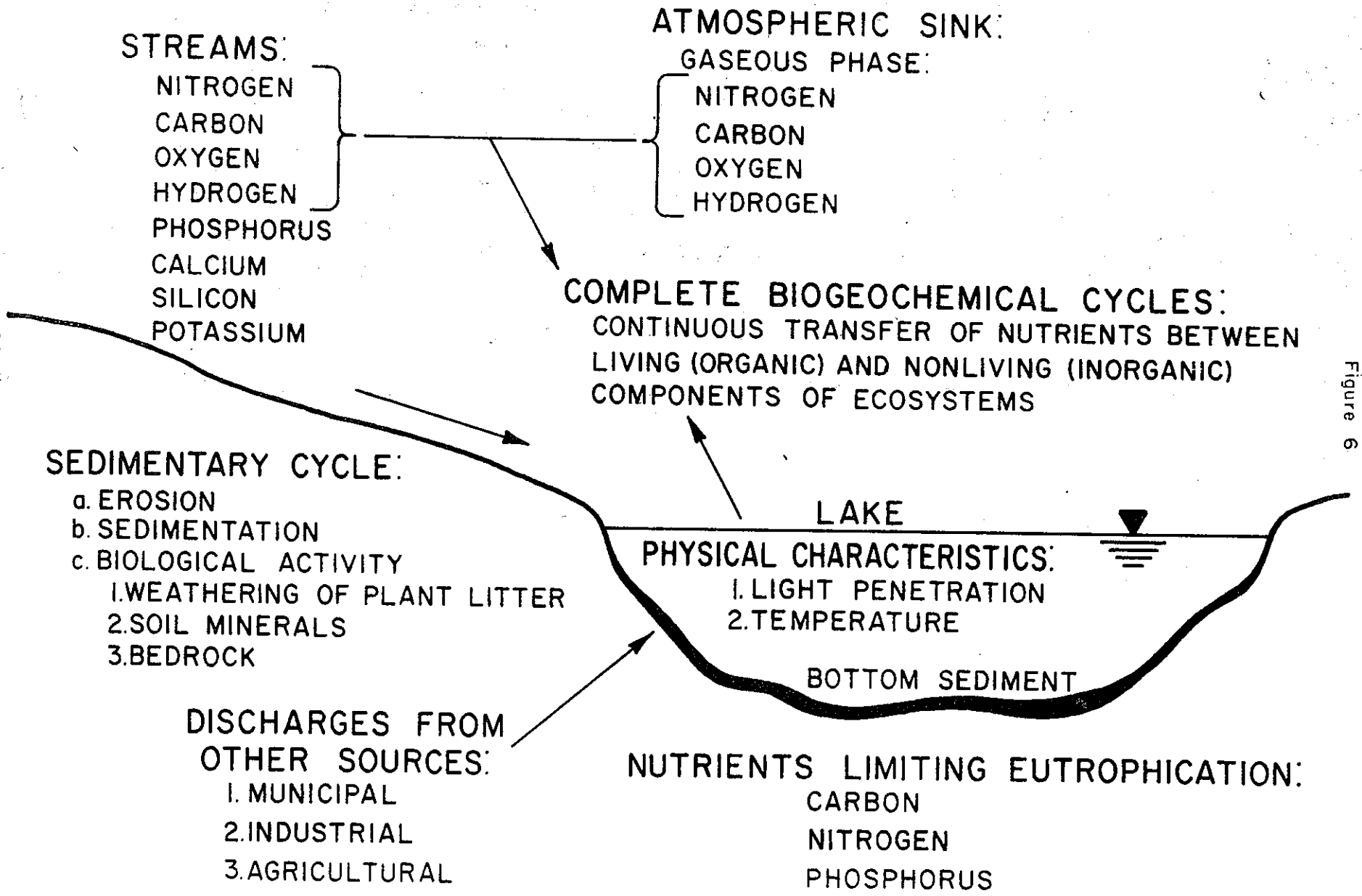


Figure 6

Another source is streams that are tributary to a water system. The chemical, physical and biological composition of the stream water may be such that elements such as nitrogen, carbon, oxygen, hydrogen, phosphorus, calcium, silicon, and potassium may be carried to the water system. In addition, various bacteria may be a characteristic of the water.

The Sedimentary Cycle describes a third possible parameter in the eutrophication scheme. Here, erosion of land surfaces, sediment transport, and biological activity such as weathering of plant litter, soil minerals and bedrock provide a source of eutrophic elements to the water system.

In lakes and other bodies of water located near urbanized areas, a major source of nutrients are derived from municipal, industrial and agricultural dischargers. Most municipal and industrial waste discharges have been treated to some extent.

Finally, the water system itself plays an important role in determining the rate at which eutrophication occurs. Large volumes of water with a rapid flushing action are able to withstand a greater increase in nutrients per unit time than smaller bodies of water. Light penetration and water temperature are major factors in this determination. A warm, shallow lake is subject to a more rapid increase in productivity than a deep, cold lake.

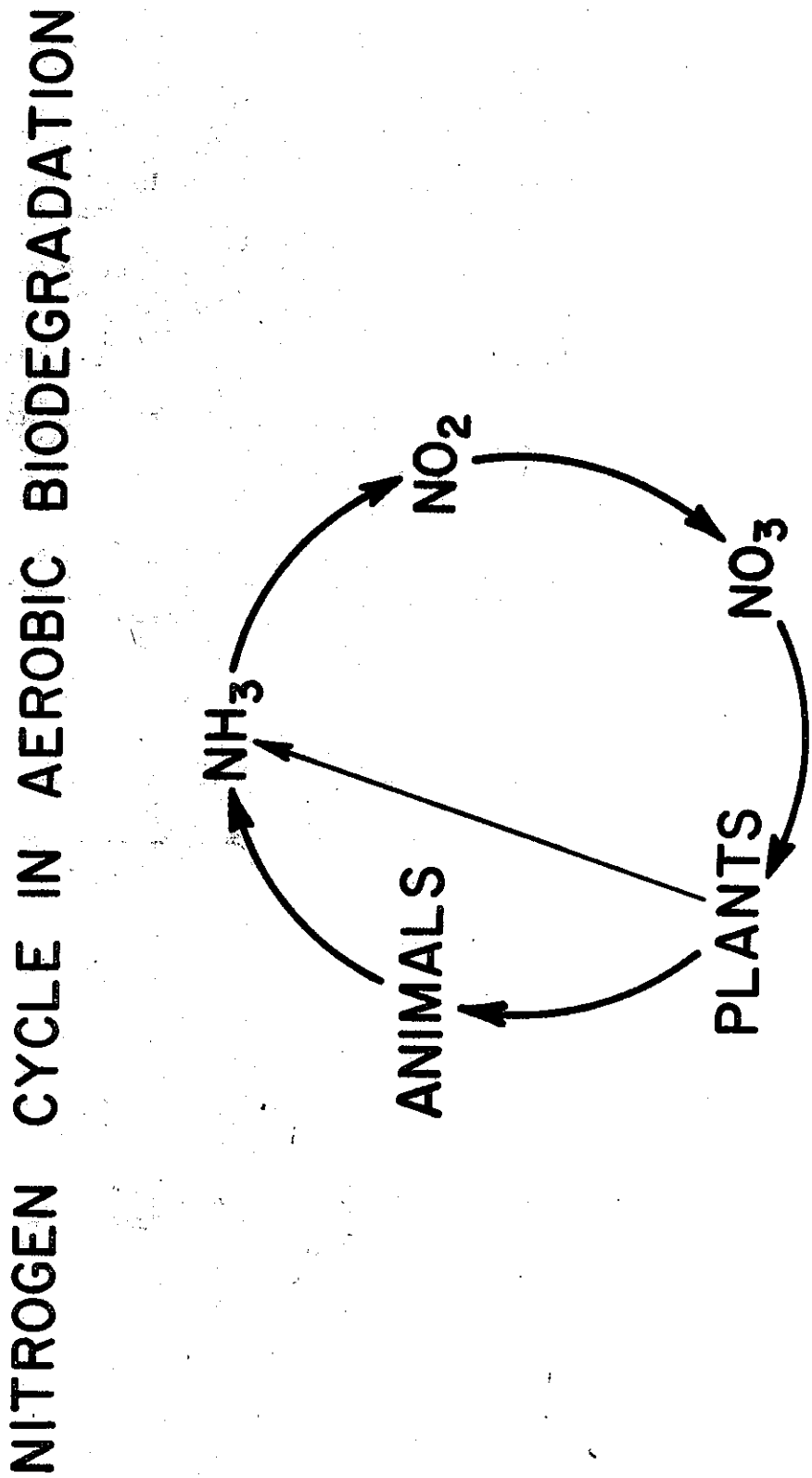
Rivers are described as 1) Youth, 2) Old Age, and 3) Mature. Generally, a river described as "Youth" has a steep gradient, cold water, not much nutrients unless leached from the ground, small in size and has an eroding bottom. An "Old Age" river is meandering, has floodplains, and more nutrients. A "Mature" river is very old, cut down to base level, very wide and has a large amount of nutrients.

2. Nitrogen Cycle - The following diagram shows the nitrogen cycle under aerobic conditions. Four forms of nitrogen are observed as follows: Biological processes in plants and animals produce ammonia (NH_3). In some cases, they consume the vegetation and the waste product results in the formation of ammonia. Decaying animal matter and vegetation also result in the formation of ammonia.

The ammonia is converted into the compound, nitrite (NO_2^-). This unstable compound is changed to nitrate ($NO_3^=$). In this form, plants are able to again utilize the nitrogen.

Organic nitrogen content of water is developed in various degrees by biologic processes through amino acids, polypeptides and proteins.

Figure 7


NITROGEN CYCLE IN AEROBIC BIODEGRADATION
NH_3
NO_2
NO_3
PLANTS
ANIMALS

As an example of the relative proportions of the various nitrogen forms, a recent study (2)of the South San Francisco Bay found the following average amounts:

Ammonia	270 mg/kg
Nitrites	0.2 mg/kg
Nitrates	1 mg/kg
Organic Nitrogen	1500 mg/kg

Other studies have revealed other proportionate amounts, but this serves as an indicator as to relative amounts that may be found when conducting water quality tests.

Under anaerobic condition (absence of oxygen) the decay of plant and animal matter produces ammonia through the action of anaerobic bacteria which must unlock from chemical compounds the oxygen needed to obtain energy for the oxidation of carbon (1).

3. Oxygen Addition - Viability of water systems for major uses is dependent upon a proper oxygen content. Oxygen can be depleted or reduced to such a level by the addition of waste or toxic discharges that undesirable effects begin to take place. Such a body of water is then termed polluted and in some cases contaminated where a threat to the health and safety of the public is involved.

The following diagram shows three processes through which a water system naturally receives the required oxygen. Inflow from tributary streams supply a water system with oxygen. Splashing action traps oxygen and in turn a percentage of the oxygen is dissolved into the water.

Wave action produces the same effect although certain conditions must occur to allow wave action to occur.

Photosynthetic processes by the flora of the aquatic system produce oxygen much the same as vegetation on the land masses.

Dissolved oxygen levels in water are dependent upon water temperature, pressure and salinity. "Standard Methods for the Examination of Water and Waste Water"(3) contains tables to determine the saturation level for the dissolved oxygen content of water under varying conditions.

Figure 9 shows the effects of changes in dissolved oxygen content of a stream (4). Physical changes in the appearance of water as well as changes in the types of fish, invertebrates and plankton that reside under varying stream conditions are illustrated.

OXYGEN ADDITION THROUGH AERATION AND PHOTOSYNTHESIS

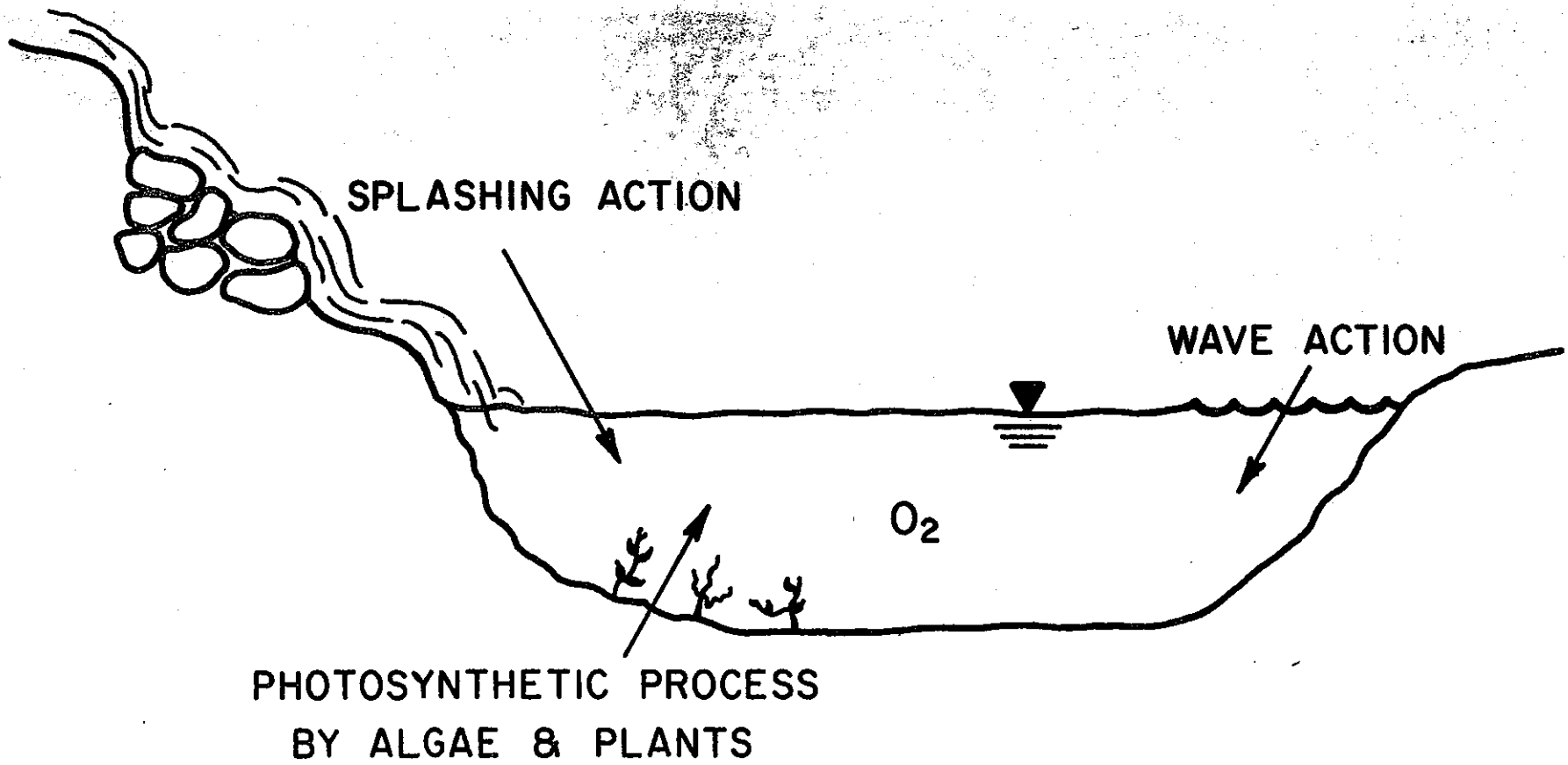
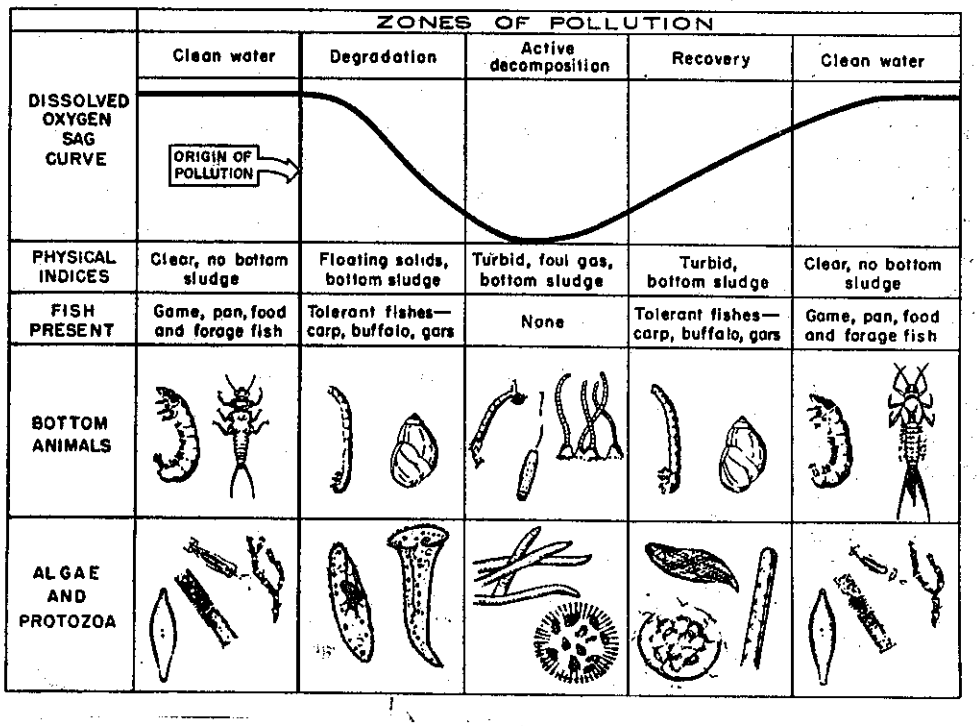


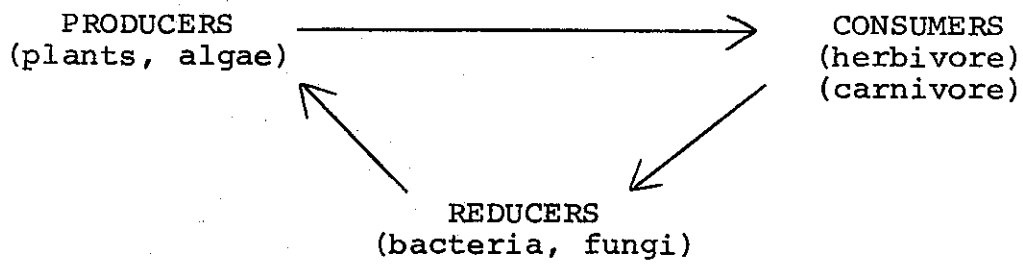
Figure 8

Figure 9



Pictorial diagram showing some examples of life associated with clean water and water polluted by organic wastes.

4. Eco-system - The eco-system consists basically of the following types:



Nutrients and chemical compounds allow the growth of plants and different forms of algae. Enriched waters are generally abundant with vegetation. Consumers feed on the algae and plants. Higher animal forms feed on lesser forms and constitute the food chain. As the insects and other aquatic organisms die, the remains are reduced by the bacteria and fungi in the water. Complex forms are reduced to component chemical parts which serve as food for the plants and algae. Some compounds are precipitated and become a part of the bottom sediment while other substances, such as mercury, become concentrated in higher life forms in the food chain.

The relationship in the dynamic eco-system between plants, carnivores and bacteria can be seen. Introduction of nutrients, toxic substances or some other change in the aquatic environment may result in a significant change to the system.

There are other "systems" and cycles that are not described in the foregoing discussion. It is hoped that the material presented will afford an opportunity to appreciate the various aspects and dependencies of eco-systems and natural cycles.

References Section II

1. "Engineering Management of Water Quality", by P. H. McGauhey, University of California at Berkeley, p. 8, 1968.

2. "Water Quality Study - Dumbarton Bridge Replacement", Quint, Howell, Shirley, Materials and Research Department Report No. M&R 667099-1, March 1972.

3. "Standard Methods for the Examination of Water and Waste Water", Thirteenth Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation.

4. "Graphic Expression of Biological Data in Water Pollution Reports", Ingram and Bartsch, Journal Water Pollution Control Federation, March 1960.

SECTION III

WATER QUALITY SURVEY

SECTION III
WATER QUALITY SURVEY

In the establishment of a water monitoring program, sites must be selected for collecting water samples that will adequately represent the characteristics of stream quality from which an assessment of environmental impacts can be made. This section reviews the essential elements and procedures for determining sample site locations and the water quality parameters that will be monitored during a water quality survey.

Reconnaissance

Before selecting the sites, a reconnaissance of the affected area is in order. Topographic maps delineating areas in sufficient detail to identify land features, tributaries, and upstream watersheds will be useful for this survey. The watersheds should be boldly outlined on the map, stream courses marked, important topographic features checked such as landslides or water barriers, and vegetation and soil type (erosion potential) boundaries delineated.

Upstream water discharges should be noted as well as water users along the stream course. The water rights and uses should be fully explored. Typical water uses may include recreation, domestic and municipal, power, irrigation, navigation, and wildlife management. The downstream water uses generally determine the water quality criteria for the stream and also help establish the parameters which should be monitored for the environmental study.

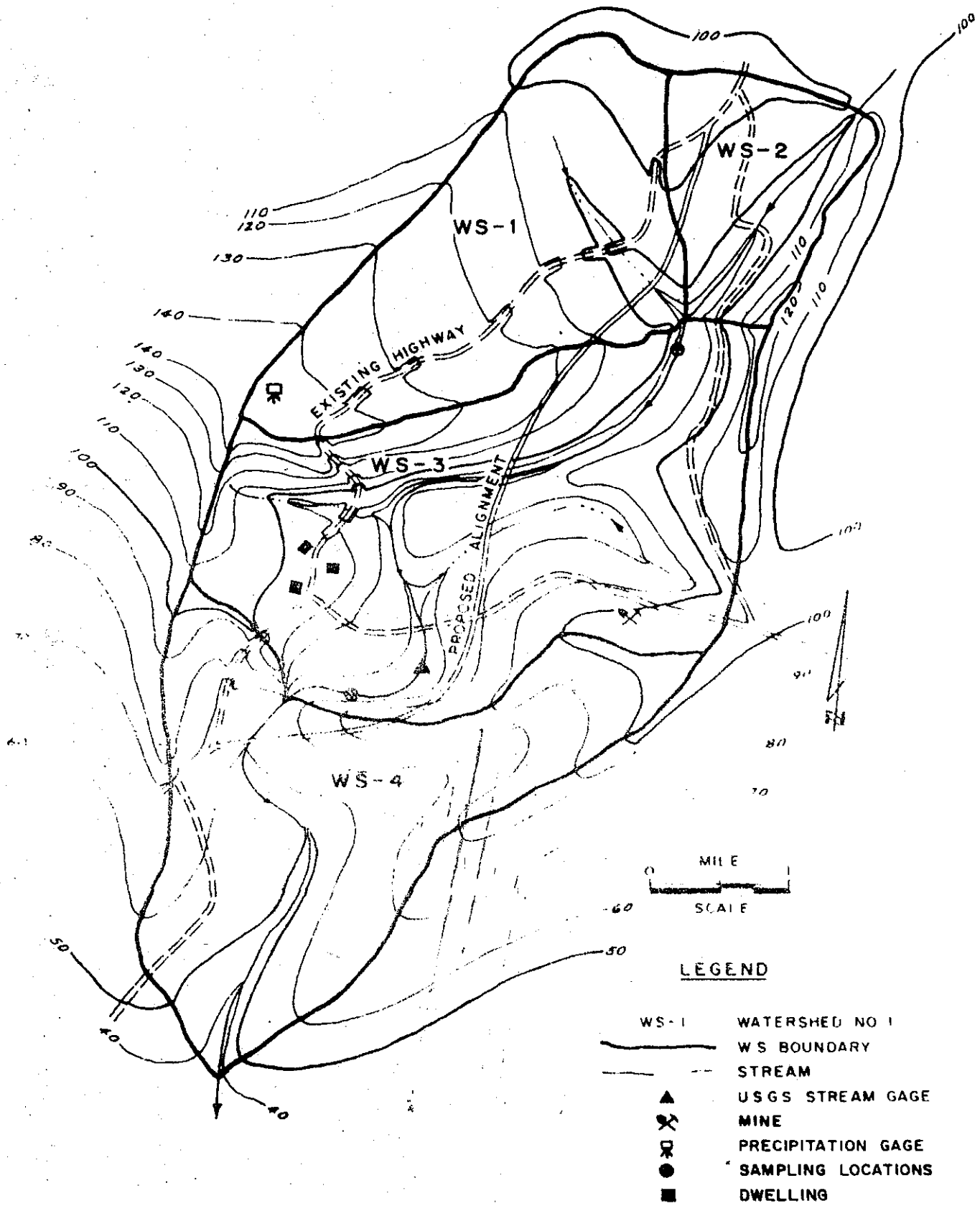
The existing highway system should be drawn on the map as well as significant local roads. The new alignments should also be placed in the proper location. These facilities obviously pinpoint the maximum upstream sampling point for water quality monitoring purposes. Figure 10 indicates a typical watershed layout with important features displayed.

It was mentioned earlier that vegetative extent and type should be noted. This information is useful for determining potential erosion rates in the watershed and for estimating climatic conditions (freeze-thaw, zonal regions, precipitation, temperature).

Slope erosion depends on soil type and use, topographical features, precipitation, vegetative cover and climatic elements. Erosion potentials should be determined as a part of each project.

Hydrologic information will be very useful in the reconnaissance phase for determining the characteristics of streamflow (intermittent, perennial, ephemeral); the maximum, minimum, and mean discharges; potential watershed yield; precipitation and intensities; and floodplain information.

Figure 10



EXAMPLE RECONNAISSANCE MAP WATER POLLUTION SURVEY

If known water discharges exist in the upper watershed, an attempt to determine the discharge characteristics or information as to the type of discharge should be made. This information may be available from regulatory agencies (either state or local public health departments) or Federal agencies. In some cases, upstream water samples may be needed on a regularly scheduled basis to determine this information if it is not readily available from other sources. Permits from regulatory agencies sometimes define the effluent characteristics and can reasonably be used as an indication of discharge characteristics.

Activities in the upper watershed also need to be identified. Such activities may be material or man-related. They would include logging, mining (both land and in-stream operations), land development activity, road-building or other construction operations, agricultural practices, etc.

Future land-use may also govern the significance of the potential highway impact on the environment within the service life of the project. For instance, a future domestic water use downstream of the proposed highway that will be built within the service-life of the project may affect the parameters that will be monitored.

Land use information in the watershed is also useful to "ecologists" and other resource conservationists and managers for their evaluation of the proposed study and subsequent analysis for impact determination.

There may be existing hydrologic instrumentation established in the watersheds or adjacent watersheds that are maintained by other agencies which can be used for data input. Stream gages operated by the U.S. Geological Survey or the California Department of Water Resources are located throughout the state on major tributary streams (1). Precipitation gages are also interspersed throughout the water basins and records are generally available from the maintaining agencies. These records may be used to develop needed streamflow data for long-term periods during the project study or the records can be analyzed to ascertain the limits of streamflow for various watersheds.

In some cases, chemical (mineral) analysis of the water are taken at various points by resource agencies. This information is utilized by other agencies in planning the resource programs and establishing "needs" within the state (2).

Sampling Site

A sampling location should be established downstream of the proposed facility in such a manner that data collected can be used to characterize pre-construction water quality. The site should be selected such that it can be used for both low and high flows and can be used for a long-term period including post-construction if necessary.

Changing sampling sites is not recommended during the course of a study because this will typically yield varying results due to the different channel characteristics that may exist (pools versus ripples, turbulence, etc.).

If it is anticipated that a sampling location will change during a study period, an attempt should be made to locate the new site in an area that has similar physical characteristics to the original site. In addition, the data should be supplemented with periodic samples from other locations on the stream system.

The site characteristics should be amply identified. Typical information would include a cross-section of the channel (include all the area within the floodplain or historical high water mark), stream gradient, Manning's roughness coefficient (refer to Supplement B-Hydraulics of the Soil Conservation Service Engineering Handbook), streamflow, biota, velocity distribution, etc.

Criteria for selecting a site for monitoring streamflow information includes the following (3):

1. The section should be straight and uniform for a distance upstream equal at least to five times the width of the stream and for a distance downstream equal to twice the stream width.

2. The bed of the stream should be fairly smooth. It should not contain vegetal growth, boulders or other obstructions. Bridge piers can give erroneous results in metering streamflow.

3. The streambed and banks should preferably be firm and stable.

4. The current should be normal to the metering section.

5. Velocities should be between one and four feet per second.

6. Large overflow sections at high stages will pose problems in estimating discharges.

7. Accessibility to the site is required.

Criteria for determination of a site location for sediment transport include:

1. Locate near metering section or stream gage.

2. Avoid bends or curves.

3. Establish site below inflow from tributary (if tributary data is to be included) in such a manner that "mixing" is assured.

4. Reservoir or deep pools will pose difficulties in measuring sediment transport.

5. Avoid areas with upstream blockages.

6. Accessibility is a must for all stages of streamflow.

7. Select stable channel reaches if available. Shifting stream bottoms could decrease accuracy of data.

Other physical parameters such as turbidity and temperature only require that the streamflow be thoroughly mixed at the sampling site. Stratified flows can be sampled but they must be identified in the process. Turbidity factors such as organics are generally well mixed in a stream section.

There are three types of mixing in streams. These include longitudinal, vertical, and lateral mixing. Stratification is established by the degree of vertical mixing, longitudinal mixing fixes the rate at which a portion of water moves downstream in advance of the average longitudinal velocity, and lateral mixing sets the rate at which pollution spreads from one bank to another.

Lateral mixing is a function of turbulence and velocity gradients in a stream. Laminar flow reduces the amount of lateral mixing. Pollutants tend to be concentrated at various points in the stream where mixing is incomplete. Sampling at several points across a stream will verify this condition.

For a more complete discussion of mixing, the reader is referred to "Water Quality Criteria" (4).

Dispersion of chemical constitutents likewise is generally characteristic of the stream section as long as the sampling site is located sufficiently below the point of entry of the waste discharge.

A stream survey consisting of a series of sites, may have to be taken in order to identify chemical or biological differences over a channel reach. In some cases, this can locate the source of the pollutant.

The location of water samples taken in the stream play an important role in intepreting the various aspects of pollutional effects on aquatic eco-systems.

Depending upon the sampling sites selected for the study, comparison of samples taken at various points on a stream or lake must be made. For example, if samples are taken at a riffle downstream, then the results of a water quality analysis must be compared with a sample taken at a riffle section upstream. Likewise, a sample from a pool section downstream must be compared to a pool section upstream. Because aquatic organisms vary according to habitat, i.e., depth, velocity of flow, and type of substrate that forms the stream bed, it is important to select similar sections.

After the above procedures have been examined, the site is chosen and amply referenced for future monitoring. Pictures should be maintained of the general site environment. An accounting of stream characteristics and installation of necessary stream gaging equipment should be initiated as soon as possible. Periods of low flow are generally the most opportune time to record these data.

Measured Parameters

The following is a list of potential pollutants that may be monitored in the water quality survey in order to assess the environmental impact. The list is not meant to be complete, but it does provide an indication of the areas that should be considered when establishing a monitoring program.

1. Physical Pollution
   a. Sediment (suspended and bedload).
   b. Turbidity.
   c. Solid particles, i.e., rubber from tires, etc.
   d. Litter from traveling public.

2. Chemical Pollution
   a. Pesticides, herbicides, etc., and other toxic substances.
   b. Oil, grease, fuels, lead, etc.
   c. Mineral leachates from newly exposed slopes.
   d. Accidental chemical spills on highway.
   e. Leachates from disposal or storage areas.
   f. Residue (ash) from fires within right-of-way.
   g. Residue from deicing chemicals.
   h. Nutrients from erosion of slopes.
   i. Fertilizer washoff.

3. Biological Pollution
   a. Organics from diseased or destroyed vegetation.
   b. Contaminants from sewage facilities at reststops.

4. Groundwater
   a. Leachates.
   b. Recharge and ponds.
   c. Wells.

At the sampling site, monitoring of required physical, chemical and biological pollutants will be maintained for a specified period of time. This information will be utilized in the data bank from which an assessment of the environmental impact from the proposed facility can be determined.

Information on sediment transport, chemical characteristics and biological aspects of a stream system should extend over a minimum of one year (one hydrologic cycle). Periods of maximum runoff or discharge generally characterize the time of maximum sediment transport and minimum chemical or biological pollution impact. Periods of low flow reverse the situations and generally reflect minimum sediment transport and maximum chemical and biological effects from upstream discharges.

The following table identifies the typical monitoring parameters which may be included in a testing program.

Table 2

Water Quality Characteristics

Turbidity	Conductivity
Suspended Sediment	Biochemical Oxygen Demand
Bed Material Analysis	Chemical Oxygen Demand
Streamflow	Dissolved Oxygen
Temperature	Coliform Count (MPN)
Toxicity	Total Hardness
Pesticides	Total Dissolved Solids
Metal Ion Content	Nutrients (Biostimulation)
Chloride Ion	Phenols
Sulfate	Flouride Ion
Nitrate	pH
Phosphate	Lead
Biological Organisms	Alkalinity

The items selected for monitoring will be dependent upon the potential changes in the environment due to a new highway project. Obviously, a project that will not disturb the environmental aspects of water will not require a detailed examination of water quality factors.

A means of judging the potential impact is to delineate the paths of highway drainage water to a receiving stream, estimate the quality of discharge water, and relate this information to the

stream system. If the nature of the stream system is delicate, i.e., public water system, etc., and significant drainage quantities from the highway are expected and the flow is unimpeded, then a sufficient number of monitoring parameters should be selected such that a valid data bank is developed from which an assessment of the environmental impact can be estimated. In some cases, it may be necessary to consult with other state and local authorities to specifically agree upon selected monitoring parameters.

It should be kept in mind that minimal sampling will allow only minimal interpretation and assessment of environmental impact. It is important to collect enough information to properly convey a picture of the water quality characteristics of the stream system. If all the water samples were collected during periods of high runoff, then the data are necessarily qualified in those terms. An adequate water quality analysis will include information for a variety of flow conditions and extend over a sufficient time period to insure that the most probable conditions were included in the study.

For the water quality staffs to avail themselves of as much opportunity for measuring various conditions, studies must be initiated with as much lead time before construction as possible. A short lead time will result in limited data which may be difficult to analyze (see Section VII).

For monitoring water supply or wastewater discharges from highway roadside rest stop areas, refer to the "Drinking Water Standards" of the Public Health Service (5). The testing and sampling criteria for these special cases are defined in more detail by Public Health regulations.

Water quality testing and analysis are described in Section VI and VII of this manual.

Sampling Frequency

A typical sampling schedule will include the collection of a sufficient number of samples over a range of streamflows that will enable one to present a valid discussion of the water quality characteristics for a given stream.

Each watershed is unique and sampling frequency will be dependent upon:

1. Available personnel
2. Streamflow
3. Precipitation
4. Monitoring parameters
5. Lead time before construction
6. Availability of resources for testing

A rigorous and comprehensive sampling program may entail a need for several men to collect and analyze the required samples. If personnel is a limiting factor, outside assistance may be desirable to complete the study as planned. Collection of data from other sources may also diminish the need for extensive sampling.

Low streamflow or intermittent streams will not require a rigorous sampling program. Likewise, semi-arid climatic conditions may only require a comprehensive sampling program during storm periods. In mountainous terrain where streams are frozen or covered with snow during the winter season, samples may be difficult to obtain.

For various reasons as cited above, the sampling schedule will be dictated by the conditions of the project and locale.

Table 3 below delineates a sampling schedule for a river in a typical central valley region of Northern California. Modifications to the schedule are required for other projects which may need more or less intensive sampling. Notice that biological and toxicity testing is not included which may be necessary for a particular project as determined by water quality criteria and other factors.

TABLE 3

SAMPLING SCHEDULE

Sampling Program	Location	Before Construction		During Construction		After Construction	
		Low Flow	High Flow	Low Flow	High Flow	Low Flow	High Flow
Suspended Sediment	Upstream	-		2 per wk.	Daily	2 per mo.	2 per wk.
	Downstream	2 per mo.	2 per wk.	"	"	"	"
	Settling Basin Outlets	-		Daily during flow		Daily during flow	
Turbidity	Upstream	2 per mo.	2 per wk.	Daily	Daily	2 per mo.	2 per wk.
	Downstream	2 per mo.	2 per wk.	Daily	Daily	2 per mo.	2 per wk.
	Settling Basin Outlets	-		-		-	
Chemical Analysis	Upstream	Monthly		Monthly		Monthly	
	Downstream	"		"		"	
	Settling Basin Outlets	-		Monthly, or daily during and after chemical usage in the construction operation.		Monthly	
Aquatic Organisms	Upstream	Seasonally		Seasonally		Seasonally	
	Downstream	"		"		"	

References Section III

1. "Index of Stream Gaging Stations in the Adjacent to California", Bulletin 157, Department of Water Resources, June 1971.

2. "Water Resources Data for California - Water Quality Records", U.S. Geological Survey, 1969.

3. "Hydrology", Wisler and Brater, John Wiley, 1965.

4. "Water Quality Criteria" by McKee and Wolf, Water Resources Control Board, April 1971.

5. "Drinking Water Standards", Public Health Service, 1962.

SECTION IV

EQUIPMENT

SECTION IV
EQUIPMENT

Standard equipment for water quality surveys includes items for field work and laboratory analysis. Sediment samplers and hydrologic instruments are used exclusively in the field to obtain data. Chemical and biological testing equipment is available for both field and laboratory usage. However, field analyses are generally performed through the use of "field kits" whereas laboratory instruments give capability for more refined analysis as prescribed in "Standard Methods" (2).

Physical

Sediment samplers (1) consist of those that can measure suspended sediment and bed material samples.

1) Suspended Sediment

The suspended sediment sample is obtained with a US-DH-48 depth integrating sampler if the stream is shallow and can be waded. This is a light-weight sampler for collection of suspended-sediment samples where a wading rod-suspended sediment sampler is used.

The sampler consists of a streamlined aluminum casting, 13 inches long, which partially encloses a round pint bottle sample container. The sampler weighs 4 1/2 pounds including sample container. A brass intake nozzle extends horizontally from the nose of the sampler body. A streamlined projection, pointing toward the rear on the side of the sampler head, accommodates the air exhaust port from which air may escape from the bottle as the sample is being collected. A 1/2-inch diameter steel rod is threaded into the top of the sampler body for suspending the sampler. The sample container is held in place and sealed against a rubber gasket in the sampler head, by a hand-operated spring-tensioned clamp at the rear of the sampler. The instrument can sample to within 3 1/2 inches of the stream bed. The sampler is calibrated with a 1/4-inch inside diameter nozzle. A nozzle having a 3/16-inch bore may also be used.

In the sampling operation, the intake nozzle is oriented into the current and held in a horizontal position while the sampler is lowered into the stream. The sampler is lowered at a uniform rate from the water surface to the bottom of the stream, instantly reversed, and then raised again to the water surface at a uniform rate. At least one suspended-sediment sample should be taken at each vertical (vertical sampling line) selected in the stream cross section. A clean bottle is used for each sample.

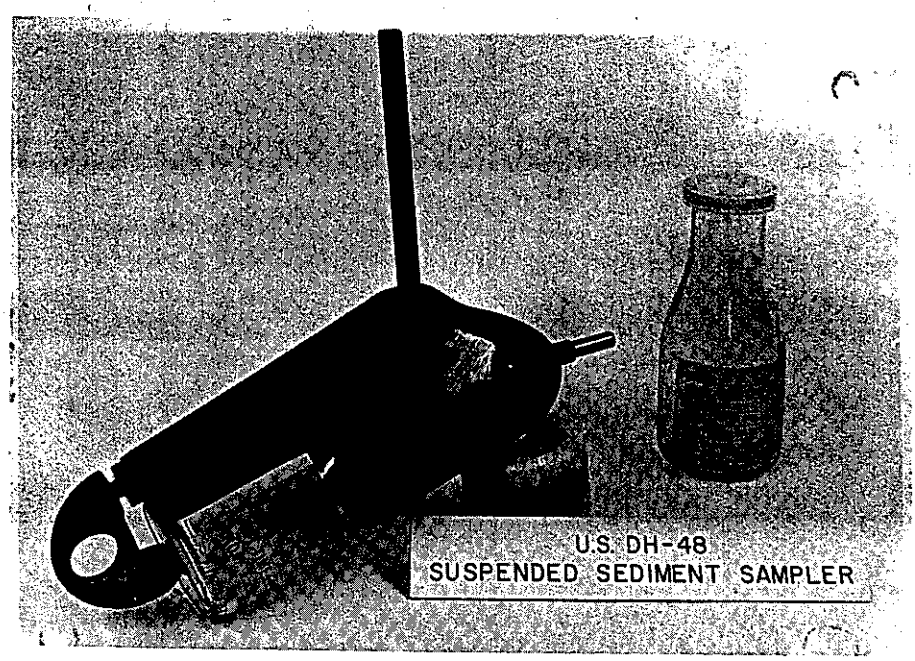


Figure 11

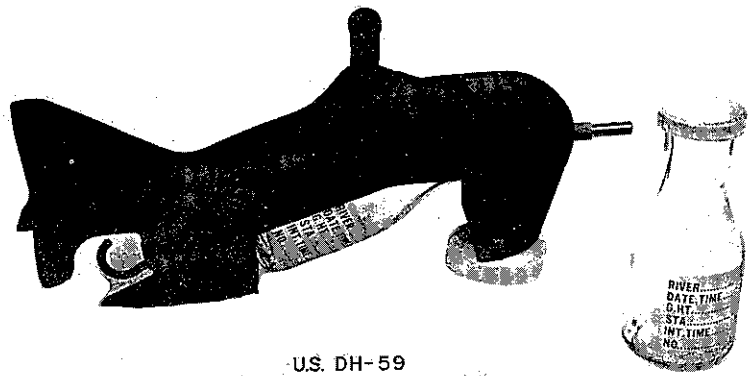
US-DH-48 Depth-Integrating Suspended Sediment Sampler.

For rivers or streams that cannot be waded, the suspended sediment samples are obtained with heavier samplers that are suspended by cable from an overhead structure such as a bridge or walkway. A US-DH-59 depth-integrating suspended-sediment sampler is commonly used for this purpose.

This is a medium-weight suspended-sediment sampler for attachment to a hand-line type of suspension. The sampler can be lowered and raised by hand with a flexible suspension line and hand over hand operation.

The US-DH-59 comprises a stream-lined bronze casting 15 inches long, which partially encloses a round pint-size glass bottle. The sampler weighs approximately 22-pounds and is equipped with a tail vane assembly to orient the intake nozzle of the sampler into the flow streamlines. The glass-bottle container is sealed against a gasket in the head cavity of the casting by the pressure

applied to the base of the bottle by the hand-operated, spring-tensioned, pull-rod assembly. Suspended-sediment samples, collected by the intake nozzle projecting horizontally upstream from the head of the casting, are discharged into the pint bottle containers. The air in the bottle which is being displaced by the accumulated sample is ejected downstream through an exhaust port cast integrally with the body. The sampler is calibrated and supplied with nozzles having 1/4-inch, 3/16-inch and 1/8-inch bore.



U.S. DH-59
SUSPENDED SEDIMENT SAMPLER
(22 lbs)

Figure 12

US-DH-59 Depth-Integrating Suspended Sediment Sampler.

In operation, a clean bottle is securely sealed within the body of the sampler. The appropriate nozzle is selected and seated in the threaded recess of the sampler head, and the sampler is lowered and raised at a uniform rate between the water surface and the bottom of the stream. On contacting the stream bed the direction of travel is reversed instantly and the sampler raised at a uniform rate. The sampler continues to collect the sample throughout the period of submergence and must be removed from the stream before the bottle has completely filled. Bottled samples are carefully removed from the sampler, properly capped and marked, and shipped to the laboratory for analysis.

For very large discharges, a heavier depth-integrating suspended-sediment sampler must be used.

The US-D-49 is a 62-pound sampler designed for use with a cable, reel, and crane. The sampler can normally be used in streams not greater than 18 feet in depth.

The HD-49 has a cast bronze streamlined body 24-inches long, in which a round pint bottle container can be enclosed. The head of the sampler is hinged to permit access to the sample container. Tail vanes are provided to orient the instrument into the stream flow. The head of the sampler is drilled and tapped to receive a 1/4-inch, 3/16-inch, or 1/8-inch intake nozzle. An exhaust port is provided to allow the air to escape as it is being displaced by the water.

The instrument is suspended from a hanger bar attached to a 1/8-inch steel cable and is lowered and raised by means of crane mounted reel. This instrument is generally operated from a bridge or cableway.

To obtain a sample, a bottle is inserted in the sampler and the instrument is lowered at a uniform rate from the water surface to the bottom of the stream, instantly reversed, and then raised again to the water surface at a uniform rate. The sampler continues to take its sample throughout the time of submergence. At least one sample should be taken at each vertical selected in the stream cross section. A clean bottle is used for each sample.

In some instances, it is desirable to obtain a suspended-sediment sample at a particular point in a stream. The P-61 Point-Integrating sampler is used for these cases.

This is a 100-pound electrically operated sampler for collection of suspended-sediment samples at any point beneath the surface of a stream, or for taking a sample continuously over a range of depths.

The sampler is cast bronze, 2 feet 4 inches long, is streamlined, and equipped with tail fins for streamflow orientation. The sampler head is hinged to provide access to the pint bottle container. A nozzle for collecting the sample projects into the current from the sampler head. An exhaust port is provided to permit escape of air from the container as it is filled. An electrically acutated valve mechanism to start and stop the sampling process is located in the sampler head. The valve has two positions, (1) the equalizing position for balancing the pressure in the sample container with the hydrostatic pressure, and (2) the sampling position. The valve is held in the equalizing position by a spring. A solenoid, when electrically energized, holds the valve in the sampling position. The compression chamber in the body of the sampler permits operation to depths of 150 feet.

Suspended sediment samples are collected and transported to the laboratory in one-pine bottles as shown in Figure 13.

2) Bed Material

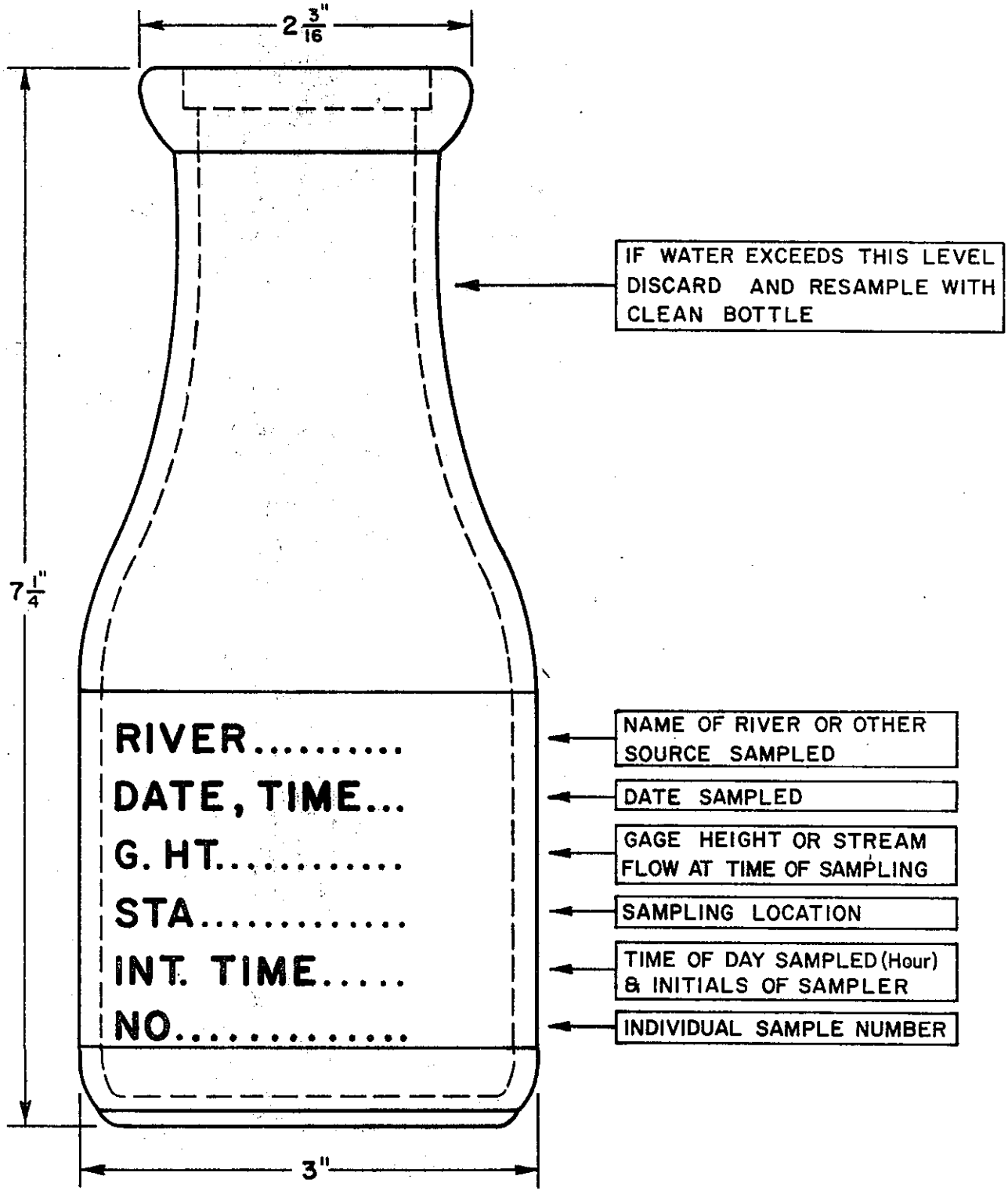
Bed material samples are taken from the stream bottom. These samples are analyzed in the laboratory and the results are used for estimating the bed material load.

For a shallow stream that can be waded, a US BMH-53 Piston-Type Bed-Material Hand Sampler is used.

The sampler contains a cylinder 2 inches in diameter and 8 inches in length which is pressed into the stream bed to collect the sample. A piston is located inside the cylinder. The overall length of the sampler is 46 inches. A handle for pressing the cylinder into the bed is located at the top of the sampler frame. The piston rod with a handle on its upper end passes through the sampler frame. The piston is retracted when the cylinder is pressed into the bed material. The suction created by the piston holds the sample in the cylinder. After retrieval the sample is pushed out of the cylinder by the piston.

For shallow streams and waterways, the drag bucket bed material sampler may be used to obtain a bed-material sample. A cable attached to the inner core of the cylindrical sampler allows it to be "thrown" downstream. The sampler is then dragged in the upstream direction. The sampler is not effective for stream bottoms composed of coarse material.

Figure 13



NOTE: NORMAL WATER-SEDIMENT SAMPLE IS 350-400 GRAMS.

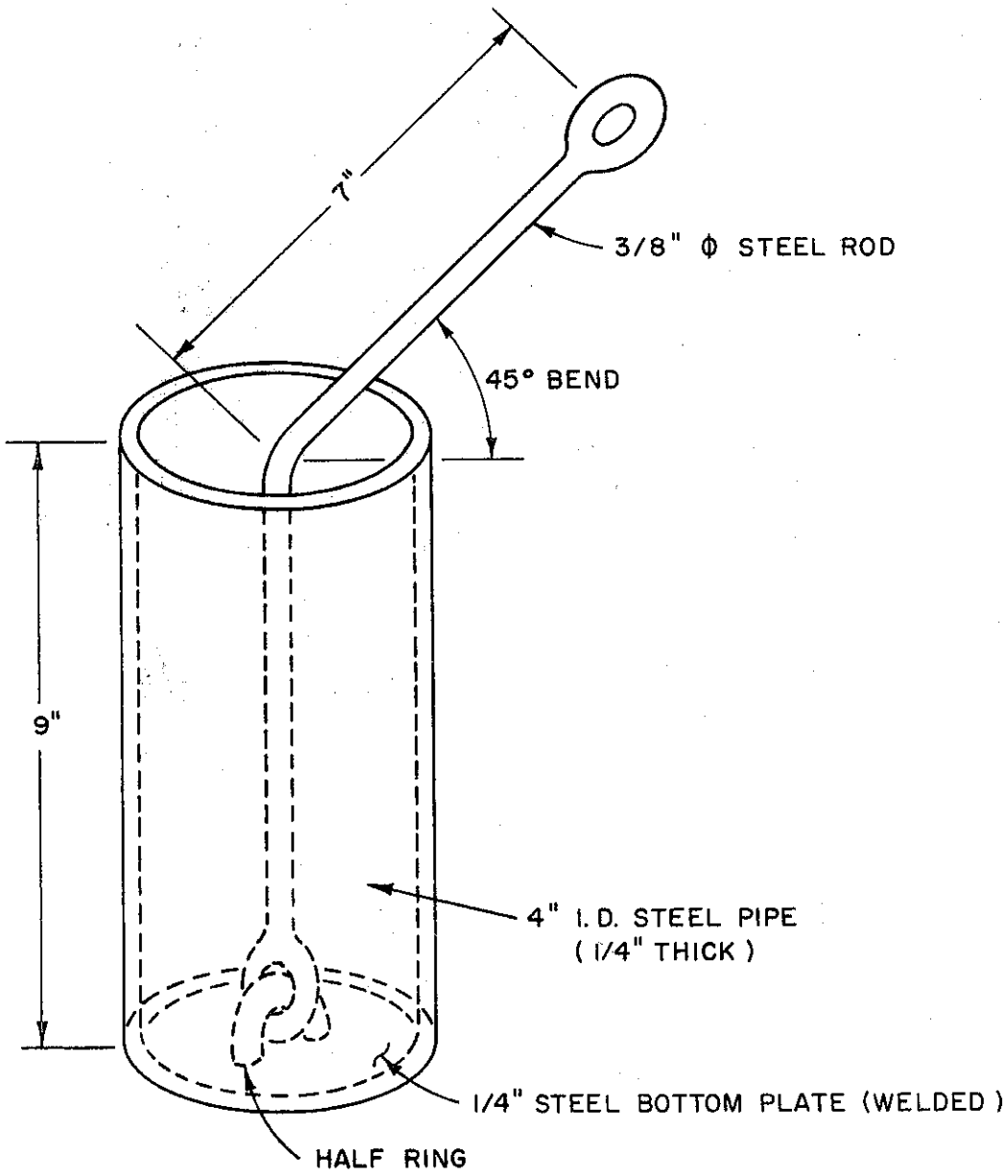
STATE OF CALIFORNIA
DIVISION OF HIGHWAYS
MATERIALS & RESEARCH DEPARTMENT
ENVIRONMENTAL IMPROVEMENT SECTION

SUSPENDED SEDIMENT SAMPLE BOTTLE

4-72

Figure 14

DRAG-BUCKET BED MATERIAL SAMPLER



For water courses that cannot be waded, a US BMH-60 Hand-Line Bed-Material Sampler is used. This is a 30-pound sampler used to collect samples from the bed of a stream, lake, or reservoir. Penetration of the bed material is approximately 1.75-inches. The sampler can be suspended from a flexible line and lowered and raised by hand.

The body of the sampler is made of aluminum, is equipped with tail vanes and is approximately 22-inches long. Ballast has been placed in the body of the sampler to control its weight. The sampling bucket accommodates about 175 cubic centimeters of material and is spring loaded. When the sampler is supported by the hand suspension line or whenever the safety yoke is in place on the grooved hanger, the bucket may be cocked to the open position, i.e. the bucket is fully retracted within the body shell of the sampler and ready to take a sample when released. As long as the safety yoke is in place on the hanger, the bucket mechanism cannot be released. However, with the safety yoke removed and the sampler supported by the hand line, the spring loaded cocking device will release the bucket mechanism when the tension on the supporting hand line is released, as when the sampler rests on the bottom of the stream. The bucket in closing, penetrates the stream bed and completely encloses a sample of the bed material. Gaskets prevent loss or contamination of the trapped sample. When the sampler has been recovered from the stream, the bed material sample can be removed, transferred, and packaged for shipment.

The weight of this sampler limits its use to tranquil streams and moderate or slightly compacted bed materials.

For very deep or rivers that are difficult to sample, a US BM-54 Bed-Material Sampler is utilized. This is a 100-pound sampler used to collect samples from the bed of a stream or reservoir of any depth.

The sampler is made of cast steel, is equipped with tail fins, and is 22 inches long. When the sampler is supported by a steel cable the bucket may be cocked, that is, set in the open position, for taking a bed sample. When tension on the cable is released by resting the sampler on the stream bed, the bucket snaps shut taking a sample. The sample is collected from the top 2-inches of a stream bed, in a single scoop-type bucket which swings out of the bottom of the sampler body. The bucket encloses the sample in such a way that it is not washed out when the sampler is raised to the water surface.

3) Bedload Samplers

Recently developed equipment does not appear to be completely adequate for measuring bedload discharge accurately. New methods and equipment are being investigated by various agencies which hopefully may yield more accurate results. They include a portable pit sampler; photography; tracking of dune movement, particularly by ultrasonic sounding; pressure transducers; and ultrasonic sounding of large particles (2).

One of the most accurate of all the retaining-type bedload samplers is the slot or pit sampler. The sampler can only be used in streams that have predominately sand beds and low velocities, unless stay lines are used.

4) Turbidity

For measuring the optical property of water, a turbidity measurement is generally made. Turbidity in water is caused by the presence of suspended mater, such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms (3). Turbidity is an expression of the optical property of a sample which causes light to be scattered and absorbed rather than transmitted in a straight lines through the sample (see "Standard Methods").

Two methods of measuring turbidity include the nephelometric and visual (candle turbidimeter). Some colorimeter or color comparison kits are available commercially.

A standard measuring instrument is the Hach 2100A Turbidimeter. This device is capable of reading up to 1,000 Jackson Turbidity Units (JTU) and makes direct reading measurements of suspended particles in a liquid by means of "light scattering" of the nephelometric principle of operation.

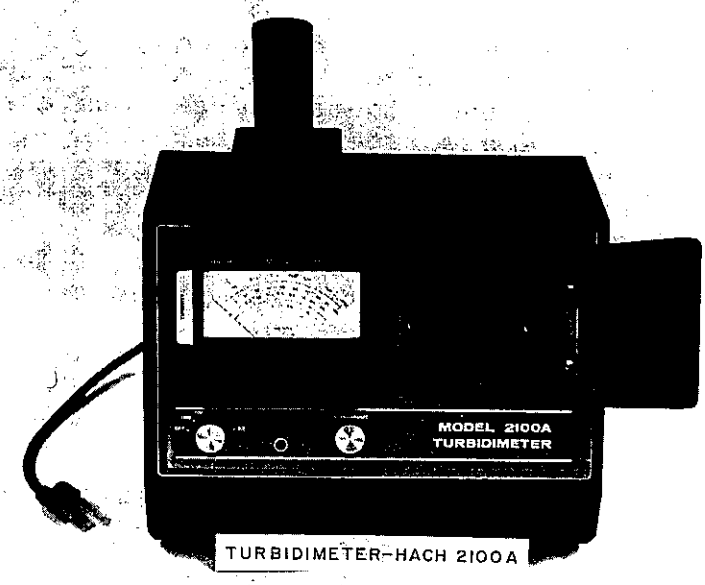


Figure 15

Turbidimeter

Specifications for the instrument include:

Accuracy: ± 2% full scale (FS)

Repeatability: ± 2% FS

Sensitivity: ± 0.5% FS

Calibration: Formazin

Dark Current: 1.0% FS

Ranges: 0-0.2, 0-1.0, 0-10, 0-100, and 0-1000 JTU

Response Time: 1 second

Power Requirements: 95-135 VAC 50-60 Hz 35 watts

Construction: electronics; Solid State Case; Heavy gauge steel with corrosion-resistant painted finish

Hydrologic

1. Current Meter

For determining stream discharge information, a water velocity meter (Price's Type) can be used. This instrument measures velocity at various points in a stream cross-section by counting the number of rotations of the cups per unit of time.

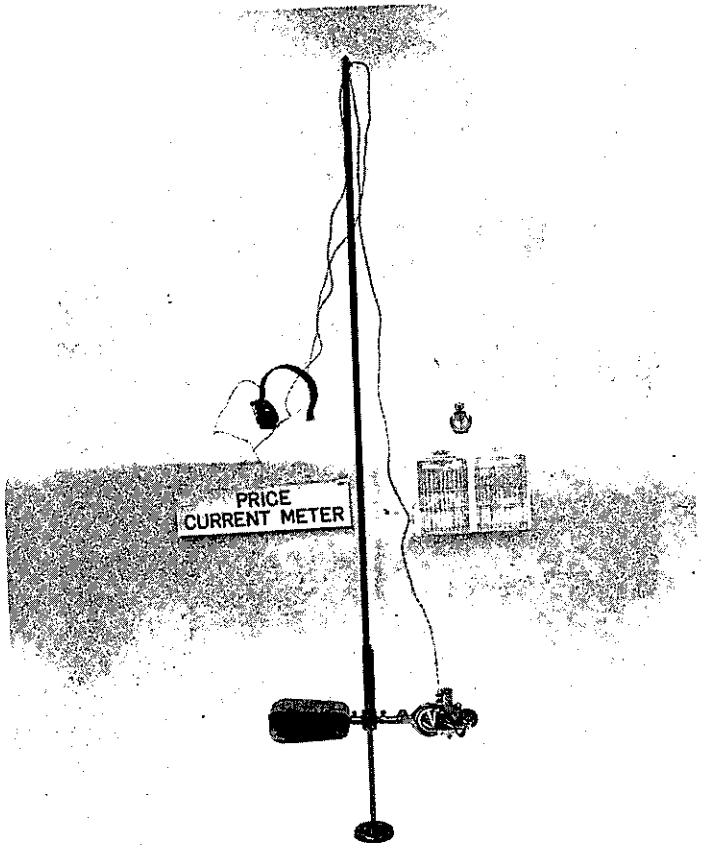


Figure 16

Price-Current Meter and Assembly Rod

A velocity rating table is used to convert the known revolutions to velocity. The instrument can be attached to a vertical rod for wading streams or it can be weighed and suspended by cable.

2. Stage Gages

Stage gages may be used to correlate known discharges to a gage height reading. Visual observation of the water level on the gage can then be converted to a water discharge.

Figure 17

Stream Gage

This method is used where minimum hydrologic information is desired.

For more complete water discharge information, a permanent recording stream gage can be installed. Stream-flow is continuously recorded on standard chart paper for given time intervals. For detailed hydrologic information, this is the preferred method (4).

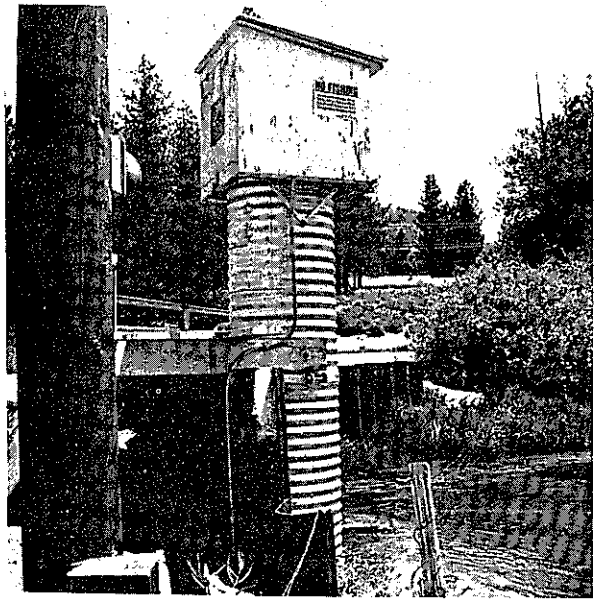


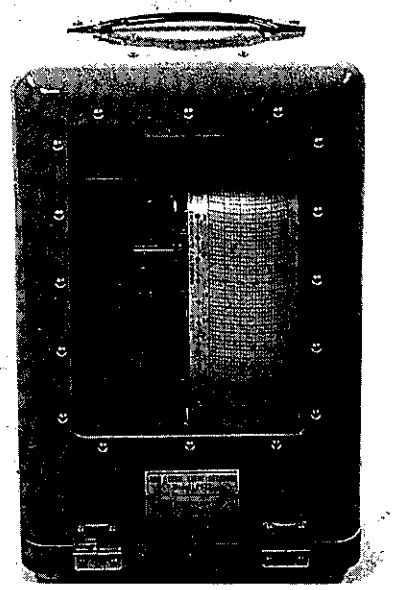
Figure 18

Automatic Water Level Recorder.

3. Precipitation

Other hydrologic data, such as precipitation, can be recorded with automatic precipitation gages.

The tipping-bucket assembly records each 0.01 inch of precipitation by sending an electrical signal to a clock driven recorder which activates a pen and ink trace on chart. The Weather-Measure P511 also contains a heating element which allows recording of data during freezing weather.



PRECIPITATION RECORDER
WEATHER MEASURE MODEL P522

The recorder will trace 3-months of data before replacement of the chart paper is required. The unit is battery-powered but may be connected to a telemetry system.

4. Thermograph

To measure temperature variances, a thermograph with a bi-metallic strip sensor is commonly used. The recorder provides a continuous temperature record in either degrees Fahrenheit or Centigrade. The instrument must be housed in a protected shelter to prevent direct solar radiation coming in contact with the sensor.

Chemical

Field test kits give the capability of making rapid tests on water samples while at the stream. Results of these preliminary tests frequently will indicate the chemical constituents that should be monitored in the laboratory. Numerous field test kits are available.

To examine water samples in the field, a test kit is normally used that is capable of measuring the following:

ALKALINITY
Titration with phenolphthalein for total alkalinity. Enough of each indicator for 100 tests. Enough titrant for 100 average (125 ppm) tests.

CARBON DIOXIDE
Standard Titration procedure -- Enough reagent for approximately 100 tests.

CHLORIDE
Mercuric Nitrate Titration -- Enough reagent for approximately 100 tests.

CHLORINE
Improved Orthotolidine Method
Colorimetric Range: 0-1 ppm
Enough reagent for 60 tests

CHROMATE
Diphenylcarbohydrazide Method
Colorimetric Range: 0-1.5 ppm
Enough reagent for approximately 100 tests

COLOR
Colorimetric Range: 0-500 APHA platinum-cobalt units. No reagents required

COPPER
Cuprethol Method
Colorimetric Range: 0-3 ppm
Enough reagent for approximately 100 tests

FLUORIDE
SPADNS Method
Colorimetric Range: 0-2 ppm
Enough reagent for approximately 10 tests

HARDNESS, CALCIUM
EDTA Titration Method
Enough reagent for approximately 100 tests

HARDNESS, TOTAL
EDTA Titration Method
Enough reagent for approximately 100 tests

HYDROGEN SULFIDE
Screen test color chart comparison...0.1-5 ppm
Enough test paper for 100 tests

IRON
Simplified Phenanthroline Method
Colorimetric Range: 0-3 ppm
Enough reagent for approximately 100 tests

MANGANESE
Cold Periodate Oxidation Method
Colorimetric Range: 1-10 ppm
Enough reagent for approximately 100 tests

NITRATE, NITROGEN
Cadmium Reduction-Diazotization Method
Colorimetric Ranges: 0-1.5 ppm, 0-15 ppm, 0-150 ppm
Enough reagent for approximately 100 tests

NITRATE, NITROGEN
Diazotization Method
Colorimetric Range: 0-0.2 ppm
Enough reagent for approximately 100 tests

PHOSPHATE, ORTHO & META
Stannous Reduction Method
Colorimetric Range: 0-2 ppm and 0-8 ppm
Enough reagent for approximately 100 tests

SILICA
Heteropoly Blue Method
Colorimetric Range: 0-3 ppm
Enough reagent for approximately 100 tests

SULFATE
Turbidimetric Method
Range: 0-300 ppm
Enough reagent for approximately 100 tests

A typical kit is the Direct Reading Engineers Laboratory (DREL) produced by Hach Chemical Corporation.

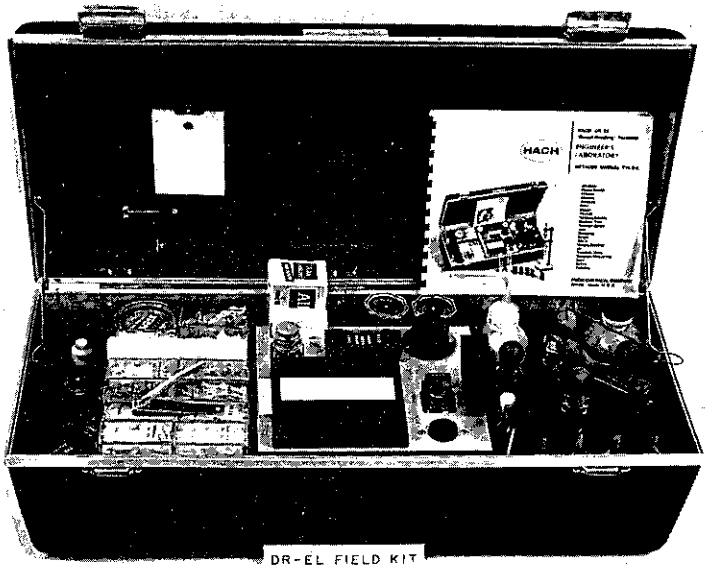


Figure 20

Chemical Testing Field Kit

2. pH Meter

A pocket pH meter capable of reading 2 to 12 pH is desirable when examining the hydrogen or hydroxide ion content of water. A Beckman instrument is shown below.

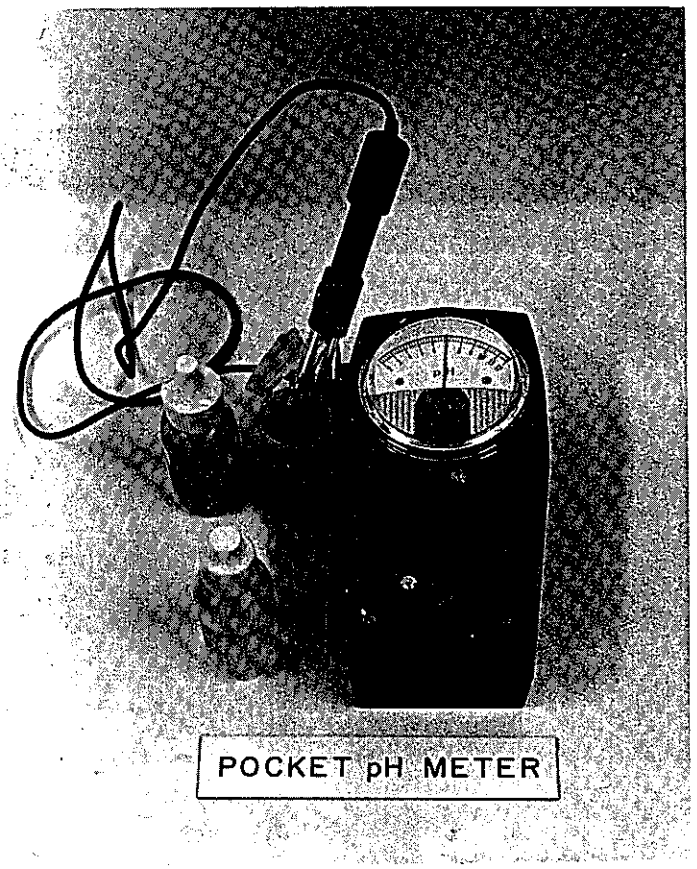


Figure 21

Pocket pH Meter

The instrument is battery-powered and includes a membrane sensing electrode.

3. Specific Ion Electrode

To measure Halide Ions (CL^-, F^-, Br^-, I^-), a specific ion selectrode may be used. The instrument provides a digital display on ion concentration (ppm).

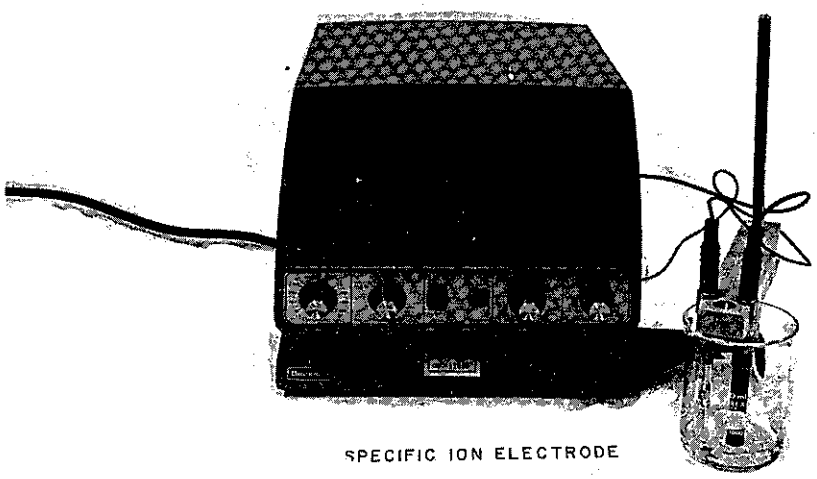


Figure 22

Specific Ion Electrode with Digital Display

The electrodes may be purchased separately from the digital display instrument. Interfering ions may be present in the test solution and must be accounted for.

Biological

1. Dissolved Oxygen

Dissolved oxygen is necessary for the viability of aquatic organisms. "Standard Methods" (3) recommends the azide modification of the iodometric method for unpolluted waters. Membrane electrodes may be used for field tests. Dissolved oxygen test kits are available which include the sampler. The test method utilizes the Winkler titration theory.

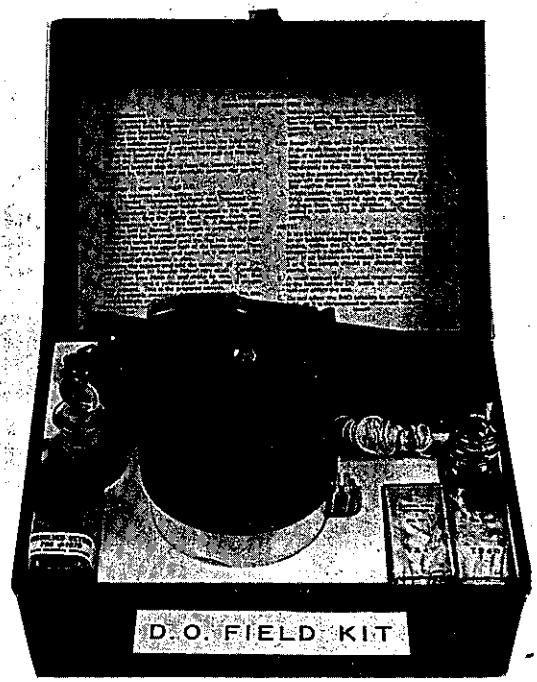


Figure 23

Dissolved Oxygen Field Kit (Titration Method)

An in-situ dissolved oxygen monitor may also be used for measurements of dissolved oxygen at various depths in a body of water. The instrument includes a submersible sampling tube with an integral stirring mechanism that insures a constant sample flow past the sensor. Temperature effects are generally automatically compensated for in most instruments. Specification for the instrument include the following:

Ranges: 0-20, 0-10, and 0-2 mg/l

Accuracy: $\pm$ 0.2 ppm

Sensor: Polarographic gold/silver electrode system; automatic temperature compensation and in-situ stirrer. 10-second time sensor.

2. Aquatic Organisms

Bottom organisms in a stream cross-section can be evaluated by counting the types and numbers within a representative area of the stream bottom. The Surber square foot sampler is a good device for quantitative evaluation in riffles. It consists of a frame one foot square with a conical net attached. It is usable only in moving water. In use it is firmly planted on the bottom. The bottom stones and gravel within the square frame are then carefully gone over by hand to ensure that all organisms have been dislodged and carried by the current into the net. A stiff vegetable brush is often useful in this regard. From three to five square-foot samples should be taken at each station to insure that a reasonable percentage of the species present will be represented.

The Ekman dredge (Model 196) is most useful on soft bottoms. This is a completely closing clamshell type grab with spring operated jaws. Size of the grab is usually 6"x6" or 9"x9". For shallow water, it is convenient to rig an Ekman with a handle and a hand operated jaw-release mechanism. The Petersen type grab may be used in deep swift riffles or where the Surber is unsuitable. It is planted by hand on the bottom and worked down into the bottom with the feet. It is then closed and lifted by pulling on the rope in the usual manner.

The riffle is one of the most satisfactory habitats for comparing stream conditions at different points. The hand screen is the simplest and easiest device to use in this situation. In use the screen is firmly planted in the stream bed. The upstream bottom is thoroughly disturbed with the feet, or worked over by hand by another person. Organisms dislodged are carried down into the screen. The screen is then lifted and the organisms dumped into a sorting tray or collecting jar.

Equipment Summary

A typical District's initial equipment needs are listed on the following page. Two laboratory balances are needed: one capable of reading to the nearest gram and one to the nearest 0.1 milligram. An oven is required to dry the sediment samples in the concentration analysis.

A schematic of a typical laboratory is also shown. Existing space in District laboratories should be utilized. The larges space requirement for water quality testing will be for sediment concentration analyses.

Table 4

Tests Performed by Other
State and Federal Agencies

Test	Agency
Toxicity of Bottom Sediments	Department of Fish & Game
Size Analysis of Sediment <0.063mm	U.S. Geological Survey
Atomic Absorption (Metals)	Department of Water Resources
Biochemical Oxygen Demand	" " " "
Chemical Oxygen Demand	" " " "
Coliform Count (MPN)	Department of Public Health
Pesticide Residue	Department of Agriculture or Department of Water Resources

Table 5

Water Quality Equipment
Summary

Physical Pollution

- Depth Integrating Suspended Sediment Sampler DH-48
- Depth Integrating Suspended Sediment Sampler DH-59
- Bed-Material Sampler BMH-53
- One-pint Sediment Bottles & plastic caps
- Price Current Meter (rod & suspension cable)
- Turbidimeter
- Stage Gages (Porcelain enameled)
- Water Level Recorder
- Aspirator device for Concentration Analysis
- Desiccator & Plates (including crucibles)
- Water Thermometer
- Secchi Disc

Chemical Pollution

- Field test kit for testing metals, nitrogen, phosphate, alkalinity, chloride, fluoride, hardness, hydrogen sulfide and sulfate.
- pH and electrical conductivity meters
- Laboratory oven and glassware
- Plastic Water Sample Containers
- Specific Ion Electrode Apparatus

Biological Pollution

- Dissolved Oxygen Meter or test kit
- Surber stream bottom sampler
- Ekman or Petersen Dredge
- Handscreen

Laboratory Space Requirements

The following diagram is an indication of probable laboratory space requirements. A sizable area of the laboratory will be needed for sediment analysis. If several highway projects requiring water quality studies are anticipated, an area large enough to accomodate accomodate processing the one-pint samples will be needed. Generally, the water samples are delivered to the laboratory where they are weighed and a turbidity analysis performed.

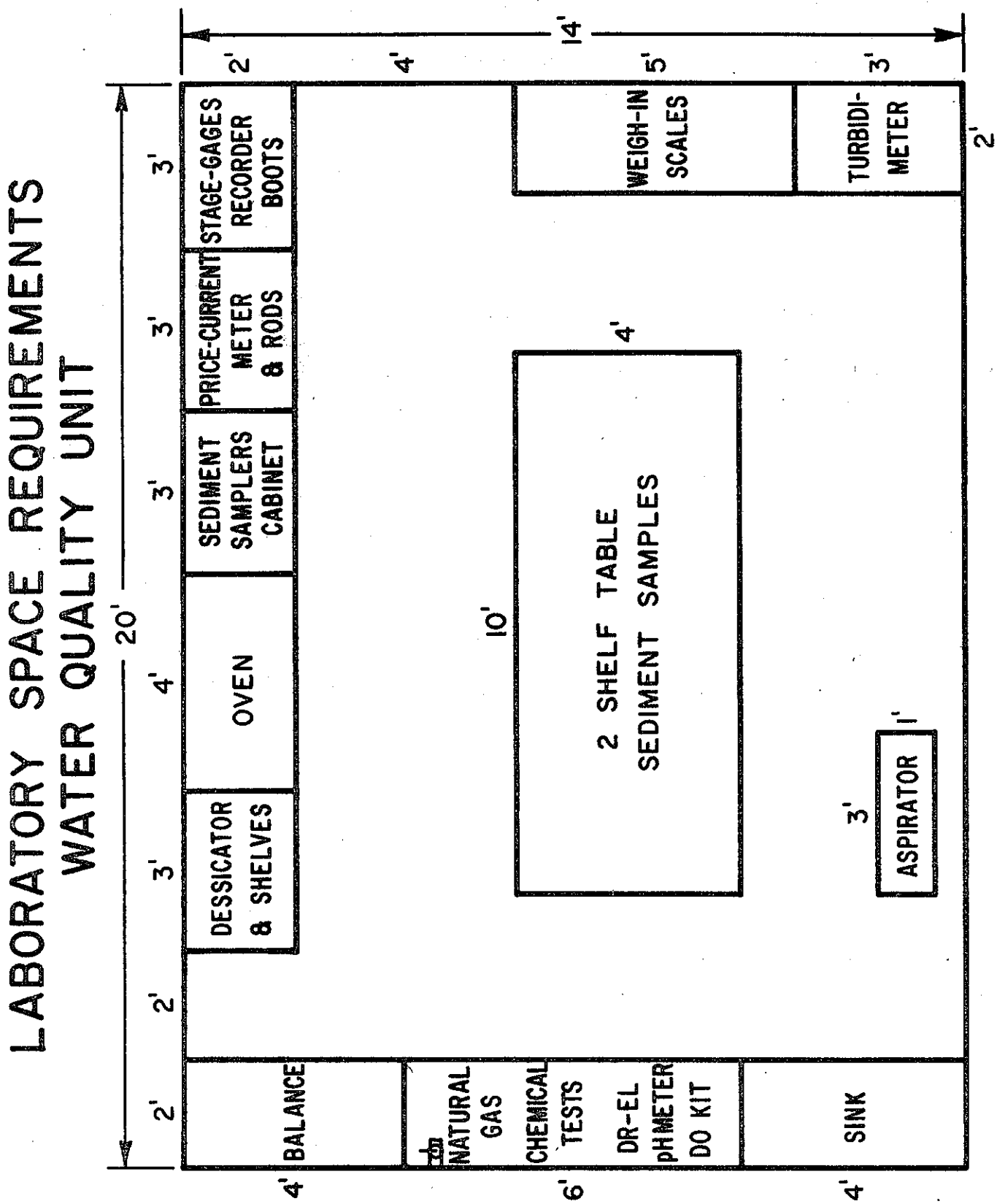
The suspended sediment and bed-material samplers require a bulk-type storage space. Water-level recorders and stage-gages along with charts and weights also need some large cabinet or bin for storage.

The DH-59 suspended sediment samplers can be used with either a cable and reel or with a portable crane. Space should also be provided for this equipment.

The Price-Current Meter is a delicate instrument that should be stored with care. The rotating cups and bearings are subject to damage if handled improperly.

Other field gear such as hip-boots, sample bottles, precipitation gages, thermometers, etc. will require some type of storage space.

Figure 24


LABORATORY SPACE REQUIREMENTS
WATER QUALITY UNIT
20'
14'
2'
4'
5'
3'
2'
3'
3'
3'
4'
3'
2'
2'
4'
6'
4'
10'
4'
3'
1'
STAGE-GAGES RECORDER BOOTS
PRICE-CURRENT METER & RODS
SEDIMENT SAMPLERS CABINET
OVEN
DESSICATOR & SHELVES
WEIGH-IN SCALES
TURBIDI-METER
2 SHELF TABLE SEDIMENT SAMPLES
ASPIRATOR
BALANCE
NATURAL GAS
CHEMICAL TESTS
DR-EL pH METER DO KIT
SINK

References Section II

1. "Instruments and Reports for Fluvial Sediment Investigations", Federal Inter-Agency Sedimentation Project, February 1971.

2. "Apparatus and Techniques for Measuring Bedload", by D. W. Hubbell, Geological Survey Water-Supply Paper 1748, 1964.

3. "Standard Methods for Examination of Water and Wastewater", Thirteenth Edition, American Public Health Association, American Water Works Association, Water Pollution Control Federation.

4. "General Procedure for Gaging Streams", by R. W. Carter and Jacob Davidian, U.S. Geological Survey.

SECTION V

FIELD EQUIPMENT USAGE

SECTION V
FIELD EQUIPMENT USAGE

The usage of various types of standard equipment in sampling and analyzing water for evidence of physical, chemical, and biological pollution is presented in this section. Hydrologic equipment for obtaining streamflow and precipitation data is also discussed.

PHYSICAL POLLUTION

The investigation of physical pollution includes the measurement and analysis of fluvial sediment and the determination of the turbidity of the water. This is done primarily by measurements of suspended sediment and determination of bedload transport and through measurements of the optical properties of water.

A. Fluvial Sediment

The following discussion on fluvial sediment measurement (1) is divided into two main sections. First, the section on "Sediment Sampling Equipment" includes a brief review and summary of the characteristics and limitations of commonly used samplers. (These are described in detail in the "Equipment" section of this manual.) Secondly, the section on "Sediment Sampling Techniques" includes a discussion of "where, when, and how" to obtain fluvial sediment samples.

1. Sediment Sampling Equipment

Field methods for measurement of fluvial sediment require the use of suspended-sediment samplers to obtain water samples for suspended-sediment analysis, and bed-material samplers to obtain samples of the stream bed for bedload analysis.

Most of the sediment samplers carry the following coded designation:

CODE	DESIGNATION
US	United States Standard Sampler
D	Depth Integrating
P	Point Integrating
H	Hand held by rod or rope - for cable-and-reel suspension the H is omitted.
BM	Bed Material
Year	Last two digits indicate the year in which the sampler was developed.

a. Suspended-Sediment Samplers

The purpose of the suspended-sediment sampler is to obtain a sample that is representative of the water-sediment mixture moving in the stream in the vicinity of the sampler.

There are several models of suspended sediment samplers of various sizes, weights and shapes. The controlling factor in selecting the model for a specific location is the depth and velocity of the water in the stream. A summary of some of the samplers and their applications is presented in Table 6. The two basic types of suspended-sediment samplers are depth-integrating samplers and point-integrating samplers.

The depth-integrating sampler is designed to accumulate a water-sediment sample from a stream vertical at such a rate that the velocity in the nozzle at point of intake is always as nearly as possible identical with the immediate stream velocity, while running the vertical at a uniform speed. The depth-integrating sampler collects and accumulates the sample as it is lowered to the bottom of the stream and raised back to the surface.

The point-integrating sampler, on the other hand, can be operated to obtain a depth-integrated sample from deep or swift streams by holding the valve open while integrating the steam depth in parts. For streams less than 30 feet deep, either the full depth can be sampled by integrating from the surface to the bottom only, or vice versa; or if the stream is deeper than about 30 feet, the limiting distance through which the sampler can adequately integrate is one direction, then the vertical can be integrated in parts.

Because each of the sampler nozzles is calibrated for its particular sampler or series of samplers, a nozzle from one series of samplers cannot be properly used in another series of samplers. The only exceptions are the recent P-61 and P-63 series which use the same nozzles.

Except for the DH-48, three different size nozzles, 1/4-inch, 3/16-inch, and 1/8-inch, may be used to take samples with the depth-integrating samplers. The DH-48 was designed for use in slow wadable streams, and therefore, a 1/8-inch nozzle has never been calibrated for this instrument. Table 7 may help determine to which instrument a specific nozzle belongs. Remember that just because a nozzle may physically fit a sampler, it is not necessarily the correct one.

The reason for different size nozzles is that stream velocities and depths occur which will cause the sample bottle to overfill for a specific transit rate when using the largest nozzle. More specifically, the maximum theoretical sampling depths for round

TABLE 6
SUSPENDED SEDIMENT SAMPLERS

MODEL	WEIGHT (Pounds)	TYPE	USAGE (Stream conditions noted are approximate and may require trial and error experience)
US DH-48	4	Depth Integrating	Used in wadable streams where the depth x velocity < 10 , or suspended from a boat or low level bridge.
US DH-59	22	Depth Integrating	Used in streams up to about 15 feet in depth and 6 fps velocity. Sampler is suspended by a flexible line and raised and lowered by hand over hand operation or with a light reel, from a bridge or boat or cableway.
US D-49	62	Depth Integrating	Used in streams up to about 15 feet in depth and 8 fps velocity. Sampler is suspended by a flexible cable and raised and lowered with a crane and winch from a bridge or boat or cableway.
US P-61	100	Point Integrating	Used in streams or reservoirs up to about 150 feet in depth and 8 fps velocity. Sampler suspended by a flexible cable and raised and lowered with a crane and winch from a bridge or boat or cableway.
US P-63	200	Point Integrating	Used in streams or reservoirs of any depth and about 10 fps velocity. Sampler suspended by a flexible cable and raised and lowered with a crane and winch from a bridge or boat or cableway.

trip integration are about 8, 14, and 15 feet for the 1/4-, 3/16-, and 1/8-inch nozzles, respectively, when the ordinary pint sample bottle is used. The larger the nozzle, the smaller the chance of excluding large sand particles which may be in suspension.

Point-integrating samplers are supplied only with a 3/16-inch nozzle because the opening through the valve mechanism is only three-sixteenths of an inch.

Table 7

Guide for comparing suspended-sediment sampler nozzles.

	Pertinent Nozzle Characteristics		
Sampler US-	Length (in.)	Exhaust end tapered 1/4 inch per foot; approx 1 inch deep	Other
DH-48	4 1/8	No	No flat part on knurled collar.
DH-59	4 1/8	Yes	"
D-49	3 7/8	Yes	Flat part has no number.
P-61	4	No	Interchangeable between both sampler series.
P-63	4	No	"

Of equal importance to the correct nozzle in the instrument is the necessity to use the proper gasket to seal the bottle mouth sufficiently. The gasket for this purpose is usually made of a spongelike neoprene material which deteriorates somewhat with use and time. Thus, to avoid leakage around the mouth of the sample bottle which will yield bad samples, it is best to check the gaskets occasionally. It is possible that gaskets can be misaligned or even lost during transportation, or while changing bottles when taking samples.

To check the gasket for adequate seal, insert a bottle in the proper position in the sampler, then while the air-exhaust port is closed with a finger, blow through the sampler nozzle. If air escapes around the bottle mouth, the gasket needs replacing, or perhaps the spring loaded foot holding the bottle in place is not working properly. Each sampler series uses a different size or shaped gasket, so it is necessary to have spares of each series on hand.

Sampler bottles are usually stored and transported in wire or wooden cases holding 20 or 30 bottles each. However, in the field, it is

desirable to use a small bottle carrier which holds about 10 bottles. This eliminates the need to handle the heavier 20- or 30-bottle cases while making a measurement and provides a convenient and relatively safe place to set the bottles. In making wading measurements both hands can be freed to operate the sampler if the bottle carrier is suspended from the shoulder with a strap or rope.

b. Bed-Material Samplers

The purpose of the bed-material sampler is to obtain a sample of the top inch or so of the stream bed. The samplers are only capable of collecting particles finer than about 30 or 40 mm in diameter. Standard equipment is not available for sampling larger particle sizes. There are several models and types of bed-material samplers of various sizes, shapes and weights. The controlling factor in selecting the type for a particular location is the depth and velocity of the water in the stream. A summary of some of the available samplers and their application is presented in Table 8.

c. Miscellaneous

The various types of specialized equipment necessary in the field measurement of fluvial sediment are outlined in this section.

Crane and Winch:

There are several models of cranes available for maneuvering the heavier sediment samplers. It is important that the winch have a variable speed clutch and a counter so that the operator can control the transit rate of the sampler.

Boats, Rafts:

Commercial models of boats and rafts can be easily modified to accomodate a crane and winch for handling the heavier samplers.

Other miscellaneous equipment includes water temperature thermometers (°C) and hip waders.

2. Sediment Sampling Techniques

This section deals with the decisions that need to be made and the instructions necessary to obtain the quantity and quality of samples required for computation and compilation of the desired sediment records.

The requirements for knowledge of suspended sediment in streams make it necessary to obtain a sufficient number of depth-integrated samples to define the concentration on either a periodic or a

TABLE 8
BED MATERIAL SAMPLERS

MODEL	WEIGHT (Pounds)	TYPE	USAGE (Stream conditions noted are approximate and may require trial and error experience)
US BMH-53	10	Vertical Piston	Used in wadable streams where the depth x velocity <10 , or suspended from a boat or low level bridge.
Drag-Bucket Sampler	10	Drag Bucket	Used in streams up to about 10 feet in depth and 6 fps velocity. Sampler is suspended by a flexible line and raised and lowered by hand over hand operation from a bridge or cableway.
US BMH-60	30	Spring-Loaded Bucket	Used in streams up to about 10 feet in depth and 6 fps velocity. Sampler is suspended by a flexible line and raised and lowered by hand over hand operation or with a light reel, from a bridge or boat or cableway.
US BM-54	100	Spring-Loaded Bucket	Used in streams or reservoirs of any depth. Sampler suspended by a flexible cable and raised an lowered with a crane and winch from a bridge, boat or cableway.

continuous basis, depending on the nature of the stream and the accuracy required. At locations for which a daily or continuous concentration record is desired, much of the routine sampling is accomplished by local observers who collect samples at one or more verticals in the stream cross section.

It is necessary to maintain a periodic program to obtain additional samples for use in conjunction with the observer's samples. These additional samples are used to insure that the observer's samples can be adjusted to the real cross-sectional concentration. Such a program requires that a technically trained person visit the site on a periodic basis to make a complete sediment-discharge measurement. Such a measurement must include two or more sets of sediment samples to define the sediment concentration across the stream section, two or more bottles at the routine sampling vertical collected in the same manner as used by the observer, and a water-discharge measurement either from an established rating or from an actual current meter measurement. The person making such measurements would also have the responsbility for obtaining timely suspended- and bedload samples suitable for particle-size analysis.

a. Suspended-Sediment Sampling

Suspended-sediment sampling involves the procurement of a representative sample of the water-sediment mixture of a stream or body of water. To obtain a good sample the methods and guidelines presented in this section should be followed.

(1) Site Selection

The site should be located at or near a gaging station because of the relation of sediment movement to the flow of the stream. If the sediment-measuring site is more than a few hundred feet from the water-stage recorder, then it may be desirable to install a simple nonrecording stage indicator at the site so that a correlation of the flow conditions between the sediment and the distant water-measuring sites can be developed. The difficulties with inflow between the sites from small tributaries should also be avoided.

The normal stage-discharge relation at a gaging station upstream from the confluence with another stream may be disturbed at times because of unusual water-surface slope conditions resulting from partial backwater effects. The unusual slope condition will likewise affect the normal movement of sediment and thereby require many additional sediment measurements.

A sediment-measuring site downstream from the confluence of two streams may also require extra sediment measurements. Sites in areas of active erosion should be avoided. Also the bed of the stream should be smooth and free from vegetal growth, boulders and other obstructions.

Because sediment samples must be obtained more frequently during floods, it is imperative that a site be selected where it is feasible to obtain data during times of flooding. That is, particular attention should be given to the ease of access to the water-stage recorder and a usable bridge or cable during a flood.

In choosing a sediment-measurement site, it should be emphasized that samples should be collected at the same cross section throughout the period of record. Also, photographs of the proposed or selected sediment-measuring sites are necessary to help document such features as channel alignment, water surface conditions at various stages, composition of bed and bank material (at low flow), and natural or man-made features which could affect the water discharge and (or) sediment-discharge relations. Such pictures are particularly useful when deciding on alternatives among sites and in later consideration of environmental changes at the site(s).

(2) Equipment Selection and Maintenance

Before the sampling team departs on a sediment-data collection trip, they should know what specific information is desired in order to assemble the proper equipment which will enable them to collect representative samples of the actual stream conditions.

The streamflow conditions and sampling structures (bridge, cableway, or other) determine specifically which sampler or samplers should be used at a station. Stream depth determines whether hand samplers such as the DH-48 or the BMH-53 or cable-suspended samplers such as the D-49 or the P-61 should be used. Depths over 15 feet should theoretically require the use of point samplers as one-way depth-integrating samplers to avoid overfilling or using too fast a transit rate. Stream velocity and depth are factors in determining whether or not a stream can be waded. When the product of depth in feet and velocity in feet per second equals ten or greater, the stream's wadability is questionable. Application of this rule will vary considerably among individuals according to weight and stature and to the condition of the streambed.

The depth-velocity product also affects the action of each sampler. The larger the product, the heavier and more stable the sampler required to collect a good sample. At a new station or for inexperienced persons, considerable trial may be necessary to determine which sampler is best for a given stream condition.

Before departing on the field trip or even before using equipment at the site, it is desirable to check several items, such as nozzles, gaskets, and air exhausts on samplers as well as the other necessary equipment. One needs to be certain that the nozzle in the instrument belongs to that instrument or series. The correct size of

nozzle to use for a given situation must often be determined by trial. It is best to use the largest nozzle that will permit depth integration without over filling the sample bottle or without exceeding the maximum transit rate (about 0.4 the mean stream velocity).

If a sample bottle does not fill in the expected time, the nozzle or air-exhaust passages may be partly blocked by such things as bug nests, organic material, or ice. The flow system can be checked by blowing through the nozzle with a bottle in the sampler. If air does not circulate easily, or not at all, check the nozzle first to see if it is clear. If not, remove and clean as necessary. If the air exhaust is closed for reasons other than being damaged or frozen, it can generally be cleared by using a flexible piece of multistrand wire. In checking the flow system of a point sampler, always be certain the valve mechanism is in the sampling position.

Power equipment used with the heavier samplers and point sampler needs a periodic operational check and battery charge. The point sampler should also be checked on the shore immediately before use to determine, among other things, if the valve is opening and closing properly. Such precautions will avoid unnecessary exposure to traffic if on a bridge, and will avoid lost time if repairs and adjustments are necessary.

(3) Routine Sampling Methods

Some of the details of equipment selection and maintenance may depend on the required location and number of suspended-sediment sampling verticals at a measuring site, which in turn, may depend on the kind of information needed in relation to the physical aspects of the river. The number of verticals depends on the accuracy being sought and on the variation of sediment movement across the stream.

Suspended-sediment samplers are designed to accumulate a sample that is directly proportional to the stream velocity. The accumulated sample may be from a vertical line between the surface and the stream bed, or several such vertical lines across the entire stream section. Such a sample can then be considered to be representative of some element of cross-sectional flow whether it be a few square feet adjacent to both sides of a vertical line, or the area of the entire flow summed by several vertical lines. Samples of sediment concentration obtained by integration with the flow can then be used with the flow rate in the given cross section to compute the sediment discharge.

In addition to the need to determine the quantity of suspended sediment in transport, it is also necessary to determine some of its other characteristics, such as particle-size gradation. For

determination of the particle-size distribution, the suspended-sediment sample must contain enough sediment for the laboratory analysis. Also, a number of verticals must be sampled to adequately represent the cross section in the sample.

Streamflow and channel conditions may change considerably with time, and therefore, adjustments in any prearranged program must be made as necessary. . It should be easy to assess the nature of the stream changes because nearly all sediment measuring stations will be located near water-discharge measuring stations.

(a) Single Vertical

For streams with a stable cross section and a rather uniform lateral suspended-sediment distribution, sampling at a single vertical usually will be adequate. If the sampling site is at a highway bridge, the sampler may be housed at a fixed installation extending from the bridge rail. When a cableway site is used, the fixed vertical at which the sample is to be taken can be painted on the tram cable.

Fixed vertical installations (sampler housings) can be used to take samples during almost all conditions of flow. After opening the box or sampler housing, the observer inserts a clean sample bottle into the sampler and checks to see that there are no obstructions in the air and exhaust tubes. The sampler is then lowered to the water surface so that the nozzle is above the water and the tail vane is in the water for proper upstream-downstream orientation of the sampler. After orientation of the sampler, depth integration is accomplished by lowering the sampler ot the streambed at a constant or uniform transit rate.

When the bottom of the sampler touches the streambed, the operator immediately reverses the sampler direction and raises the sampler to clear the surface of the flow at a constant transit rate. The transit rate used in raising the sampler need not be the same as the one used in lowering, but in order to obtain a velocity or discharge-weighted sample, both rates must be constant. The rates should be such that the bottle fills to near its optimum level (approximately 3 inches below the top or 350-400 grams for the pint milk bottle). When a stream is shallow or the velocity is low, it is generally easier and more accurate to make the round trip from the surface to the bed and return more than once to obtain the desired quantity of sample. Figures 25 and 26 illustrate a sampling operation with a DH-48 sampler.

For streams that transport heavy loads of sand and perhaps in some other streams, the observer should take at least two bottles or complete depth integrations as close together in time as possible.

Figure 25

Wading into the stream
with the DH-48 sampler.

Figure 26

Sampling with DH-48 depth-integrating
suspend sediment sampler.

Each bottle constitutes a sample, but for the purposes of the record, two or more bottles are sometimes composited in the laboratory, or otherwise averaged, whereby they are called a set. This set is then a sample in time with respect to the record. Individual bottle analyses that yield two or more samples for a given observation are useful to indicate the variation between bottles - an obvious advantage in the event that one bottle is in error with respect to concentration. Every bottle or sample should be inspected visually immediately after collection by swirling the water in the bottle and observing the quantity of sand particles collected at the bottom. If there is an unusually large quantity or a difference in the quantity of sands between bottles, then another sample from the same vertical should be taken immediately. The sample suspected of having too much sand should not be discarded; but instead, an explanation such as "too much sand" should be clearly written on the bottle. If by chance a bottle is overfilled, that is closer than 2 inches from the top or if a spurt of water is seen coming out of the nozzle when the sampler is raised past the water surface, then the sample should be discarded. A clean bottle is to be used for each sample.

To help avoid the problem of striking the nozzle into a dune or settling the sampler too deeply into a soft bed, it is recommended that a slow downward integration be used after which a more rapid upward integration can then be used. Because most of the sand is transported near the bed, it is essential that the sampler transit be immediately reversed after it has touched the bed.

During high flows when the depth exceeds the theoretical 15-foot limit, the observer should try to obtain a sample even though the recommended transit rate may be somewhat exceeded. The practical sampling depth limit can be more than the theoretical limit if the stream velocity is not too high and especially if the suspended sediment is mostly silt and clay.

The best location in the cross section for a single-vertical sediment sample is determined by trial. Generally each new sediment-record site is carefully investigated by means of several detailed sediment-discharge measurements to determine the concentration of sediment across the stream at different times. The sediment-discharge measurement to determine the cross-sectional distribution of concentration can be made using the equal-transit-rate (ETR) method. The ETR method utilizes a constant up and down rate for the sampler at all vertical stations in the cross-section.

The sample concentrations from the sediment-discharge measurement are plotted, and a vertical, or stationing point that yields a concentration most nearly equal to the average is determined. The routine sampling vertical should be located at or near this point, but at least 10 feet from any supporting pier. For the first several months of sampling at a station, the results from the fixed vertical should be compared to frequent cross-sectional sampling by technical or professional field personnel.

The number of verticals required in the cross section for the sediment-discharge measurement depends on the width and discharge of the river as well as the concentration variation across the width at the time of sampling. Additional samples are collected at the single vertical, both before and after each cross-section sample. These samples then form the basis of a coefficient that may be needed to adjust the concentration of the fixed vertical samples. This adjustment coefficient, or comparison of the routine single vertical with the cross section, is determined by computing the ratio of the average concentration of cross-section samples to the daily samples taken between sediment-discharge measurements. If the coefficient is consistently above or below unity, it may be desirable to change the position of the fixed routine sampling installation to a location where the coefficient would be at or near unity.

After the initial trial period, detailed sediment-discharge measurements by ETR method are made once a month. More frequent measurements are necessary during high water periods and other events like flood flow that may cause channel changes when a major change in the coefficient may occur and when additional samples are needed for particle-size analysis.

(b) Multivertical

The distribution of sediment concentration and bed roughness across sand-bed streams can vary markedly with distance across the stream and with time because of changes in the bed form that may vary from a smooth firm surface to a very pronounced dune or antidune form. Thus, it is often unrealistic to try to relate sediment concentration for the entire cross section to concentration at a single vertical in a sand-bed stream.

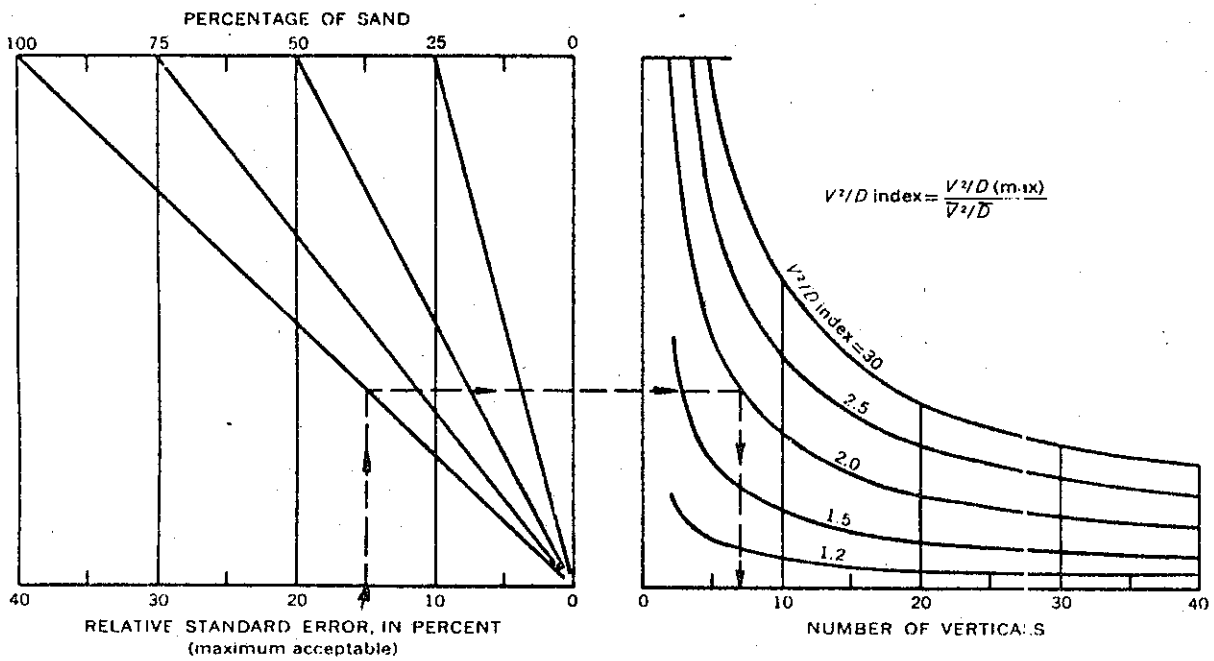
A realistic "daily" sampling program for a wide sand-bed stream may require sampling at two to five or more verticals. Locations of the routine multi-sampling verticals can be determined in the same manner as already described for the single-vertical locations. As the stream changes with flow rate or with season, it may be necessary to move the sampling stations from time to time. For some streams, the ETR method should be used routinely if a high level of accuracy is required for the sediment record.

(4) Sediment-Discharge Measurements by the ETR Method

A cross-sectional suspended-sediment sample obtained by the ETR method requires a sample volume proportional to the amount of flow at each of several equally spaced verticals in the cross section. This equal spacing between verticals across the stream and an equal transit rate (ETR) both up and down in all verticals,

FIGURE 27

Nomograph to determine the number of sampling verticals required to obtain results within an acceptable relative standard error based on the percentage of sand in the sample and the V^2/D index.



(V^2/D) Max is the ratio from the vertical having the maximum V^2/D

$(\overline{V}^2/\overline{D})$ is the ratio of the mean velocity squared to the mean depth of the whole stream. The mean velocity and mean depth are computed and available from water discharge measurements.

Note: When the discharge of sand-sized particles is of primary interest, the 100 percent line should be used regardless of the amount of fines in the sample.

Use 15% as maximum acceptable standard error unless otherwise noted.

in water and sediment at the immediate stream velocity. If the sampling vertical represents a specific width of flow, the sample is considered to be discharge weighted because the uniform transit rate allows each increment of velocity or discharge in the vertical to be given the same amount of time to enter the sampler. This is the reason that the point was made to keep the transit rate of the samplers constant throughout at least a single direction of travel.

Also, if the sampler were held in a stationary position in the stream, then the lines of flow entering the nozzle would make a zero angle to the nozzle. However, because a sampler is in vertical motion during sampling, the line of flow must enter at an angle greater than zero whereby the effective velocity of the water entering the nozzle is reduced. This reduction in velocity affects the concentration of the sample and becomes important when the transit rate exceeds four-tenths the mean velocity ($0.4V_m$) in the vertical. In addition to the limit by the angle, the downward transit rate is also theoretically limited by the rate of air compression in the bottle. If the air compresses at a rate faster than the bottle is filled on a downward trip, hydrostatic pressure will force an increase in the intake velocity, or perhaps entry of water through the air exhaust. Thus, the maximum transit rate should not exceed $0.4V_m$. The minimum transit rate is controlled by the time that it takes to fill the sample bottle with about 400 cc of water. The minimum transit rate equals the length of the depth integration (usually twice the depth of the stream) divided by the filling time illustrated on Figure 28.

(6) Sample Timing

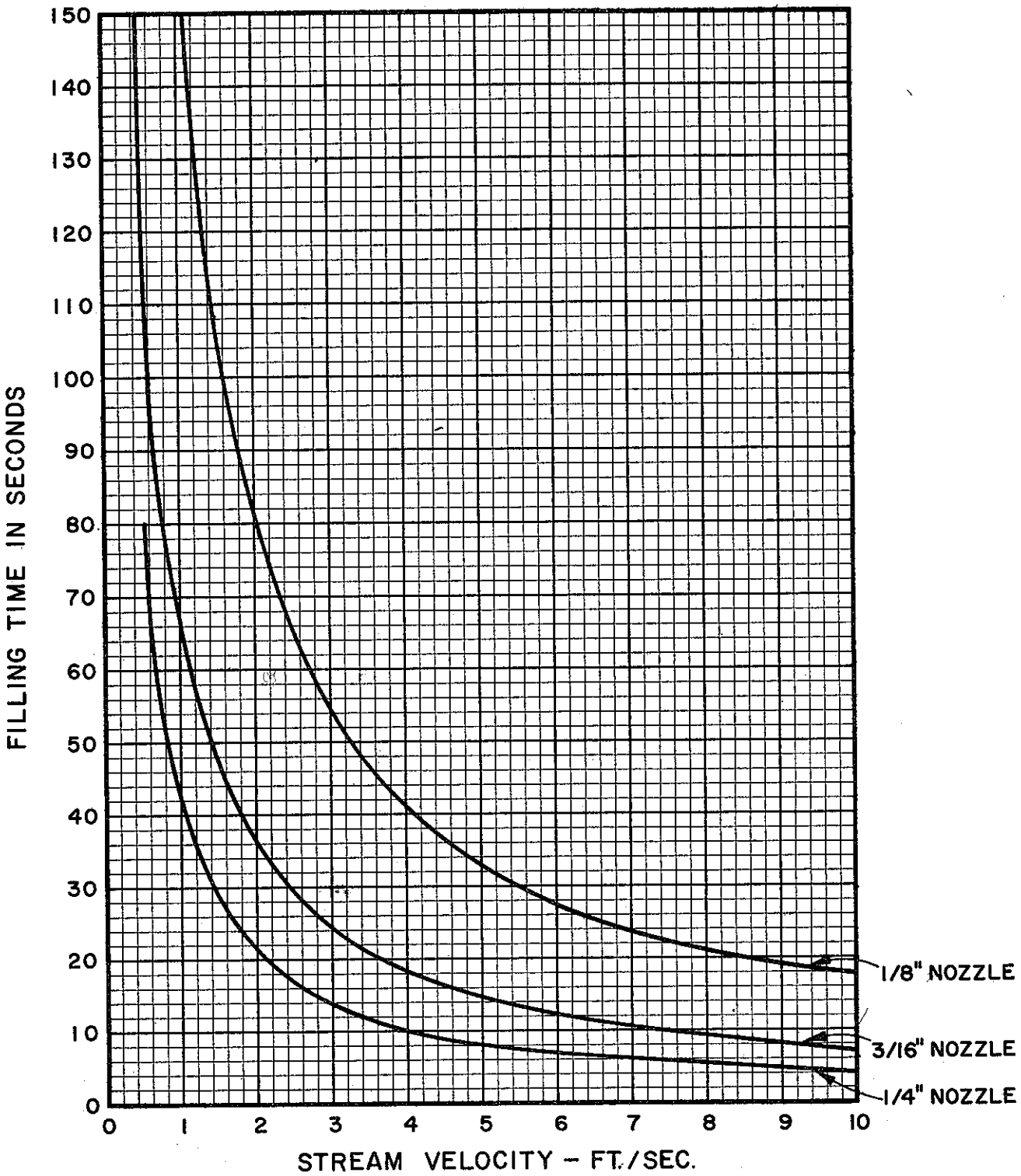
The desirable time distribution for samples depends on many factors such as the season of the year, the runoff characteristics of the basin, the adequacy of coverage of previous events, and the accuracy of information desired or dictated by the purpose for collecting the data.

For many streams, the largest concentrations and certainly the largest sediment loads occur during spring runoff; on other streams, the most important part of the sediment record may occur during the period of the summer thunderstorm or during winter storms. The frequency of suspended-sediment sampling should be much greater during these periods than during the low flow periods. Streams usually carry between 70 and 90 percent of the annual sediment load during these peak runoff periods.

During some parts of this period, bihourly sampling may be required to define the sediment concentration accurately. During the remainder of the year, the sampling frequency can be stretched out to daily or even weekly sampling for adequate definition of concentration.

Figure 28

FILLING TIME FOR SAMPLE OF 400 C.C.



Most streams, during long periods of rather constant or gradually varying flow, have concentrations and quantities of sediment that vary slowly and may therefore be adequately sampled every two or three days; or in some streams, one sampling a week may be adequate. For some streams, several samplings a day may occasionally be needed to define the diurnal fluctuation in sediment concentration.

The temporal shape of the hydrograph is an indicator of how a stream should be sampled. Sampling twice a day may be sufficient on the rising stage if it takes a day or more for a stream to reach a peak rate of discharge. During the peak, samples every few hours may be needed. During the recession, sampling can be reduced gradually until normal sampling intervals are sufficient.

Intermittent and ephemeral streams usually have hydrograph traces where the stage goes from a base flow or zero flow to the maximum stage in a matter of a few minutes or hours, and the person responsible for obtaining the samples frequently does not know when such an event is to occur. Ideally, samples should be obtained as follows: during the rising stage, sample small streams every few minutes and large streams every half hour or hour. After the peak rate of flow passes, if this can be determined, the sampling frequency may be reduced somewhat. During the recession, the sampling rate should gradually be reduced to the normal daily schedule as the preceding base flow is reached, or as the flow stops. Generally, adequate coverage of such a peak is obtained if samples on the rising limb are four times as frequent as are the samples needed to define the recession limb.

Elaborate and intensive sampling schedules are not required for each and all events from small streams with drainage basins of rather uniform soil and geologic conditions because similar runoff conditions will yield similar concentrations of sediment for the different runoff events. Once a concentration pattern is established, then samples collected once or twice daily may suffice even during a storm period.

Streams which drain basins having a wide variety of soils and geologic conditions and receiving uneven distributions of precipitation cannot be adequately sampled by a rigid predetermined schedule. Sediment concentration in the stream depends not only on the time of year but also on the source of the runoff in the basin. Thus, each storm or changing flow event should be covered as thoroughly as possible, in a manner similar to that described for intermittent and ephemeral streams.

In summary, sample timing depends on:

1. season of the year
2. stage of the hydrograph
3. runoff characteristics of the basin
4. adequacy of coverage of previous events
5. required accuracy of information

Table 9 can be used as a guide for sample timing.

Table 9: Sample Timing

Condition	Sample Timing
Low flow*	One per week
Average flow*	Two per week
High flow or during storms	One or more per hour, especially during the rising portion of the hydrograph

*Several samplings per day may be needed occasionally to define the diurnal fluctuation in sediment concentration.

(7) Sample Quantity Requirements

The requirements in terms of quantity of sediment for use in the laboratory to determine particle-size gradation may at times exceed the other requirements for sediment concentration.

The minimum number of bottles of sample required to provide sufficient sediment for size analysis may be determined from the curves in Figure 29 as developed by the U. S. Geological Survey. (In general, about 1/4 inch of sediment on the bottom of a pint bottle should be sufficient.) The range of concentration values and percent finer than 0.062 mm needed to use Figure 29 should be available in the station records for the preceding year.

The procedure used for analysis will be selected by laboratory personnel unless specified by the project chief or by responsible field personnel.

About 10 size analyses per year at various stages should be adequate.

Sample bottles for particle-size analysis should be plainly labeled as they are separate from sediment concentration analysis samples.

(8) Sample Labeling

Most of the information needed on sample bottles is indicated on Figure 7. Other information may be helpful in the laboratory and in record processing. Field personnel will need to keep the requirements for such processing in mind so that other explanatory notes can be recorded on the sample bottle or on the inspection sheet Form HMR T-709.

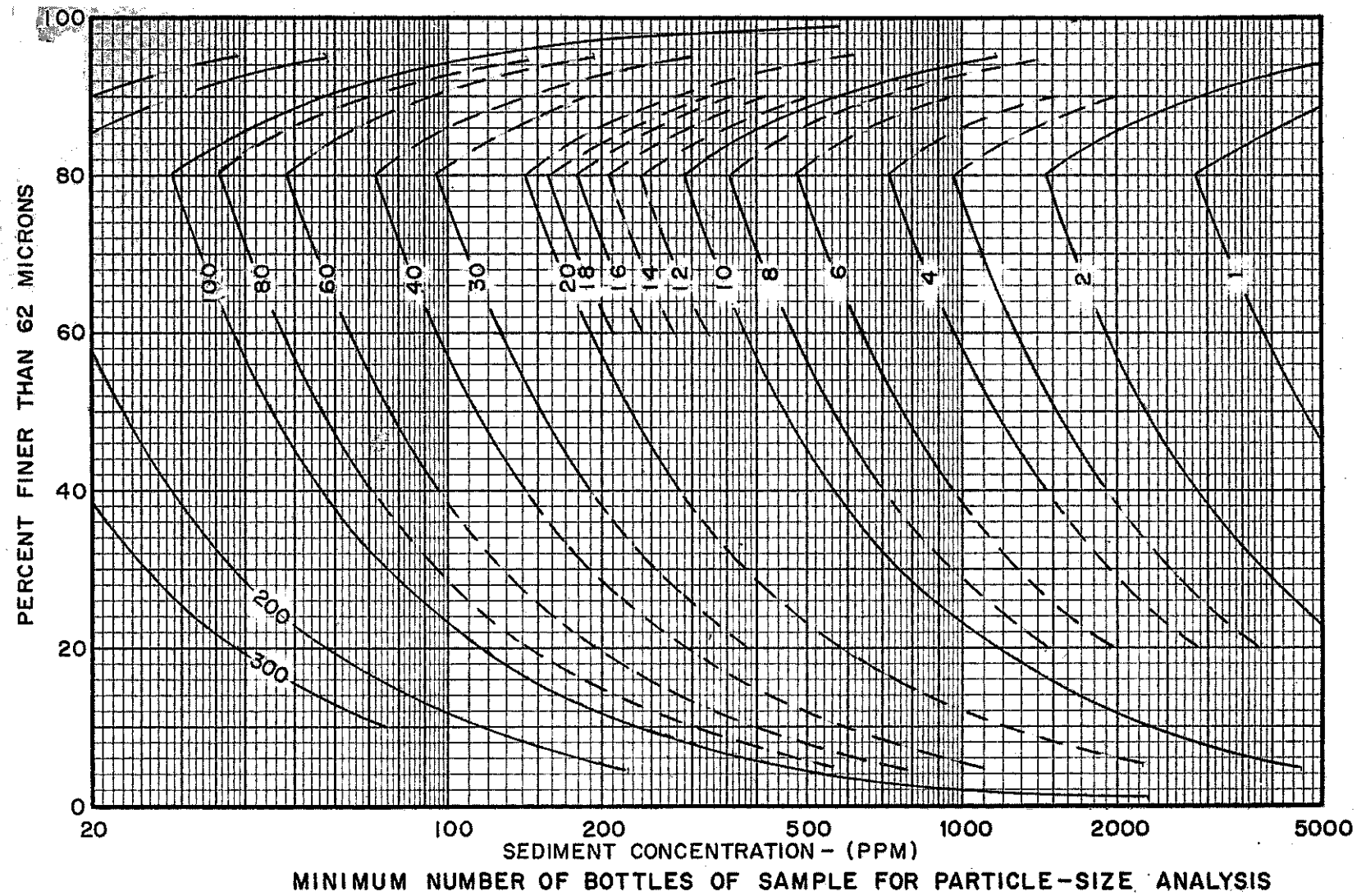


Figure 29

Instructions: Estimate concentration and percent finer than 62 microns based on knowledge of stream and (or) examination of first bottle. The number of bottles required is the value of the line left of the intersection of concentration and percent finer. Interpolation of number of bottles may be made along abcissa. This figure is based on 350 grams of sample per bottle, and yield a minimum of 0.2 grams of sand for sieve or visual-accumulation-tube analysis and 0.8 grams of silt and clay for pipet analysis in 400 milliliter suspension. For analysis by the bottom-withdrawal-tube method the number of bottles needed for less than 80 percent finer is five-eighths of the indicated number.

STATE OF CALIFORNIA
DIVISION OF HIGHWAYS
MATERIALS & RESEARCH DEPARTMENT
ENVIRONMENTAL IMPROVEMENT SECTION

SEDIMENT SAMPLING INSPECTION SHEET

Sta. No. _____ Date _____, 19____

Station _____

Party _____ Disch. _____

Width _____ Area _____ Vel. _____ Time _____ G.H. _____

SUSPENDED SEDIMENT SAMPLES: Wading, cable, ice, boat, upstr., downstr., side bridge _____ feet, mile above, below gage and _____

Sampler: DH-48, DH-59, D-49, P-61, P-63

Method	Time	G.H.	No. of Vert.	No. of Bottes	Stations

Nozzle size _____ in.
Air: ____ °C at ____
Water: ____ °C at ____
Weather _____
Flow _____
Turbidity _____

BED MATERIAL SAMPLES: Time _____ G.H. _____ No. samples _____

Sampler _____ Wading, cable, ice, boat, upstr., downstr., side bridge _____ feet, mile above, below gage and _____

Stations _____

Stage: Rising, falling, steady, peak Peak G.H. _____

REMARKS: _____

HMR T-709 (Orig. 6-72)

(9) Field Inspection

Every sample taken by field personnel should be the best possible considering the stream conditions, the available equipment, and time. Also, sampling errors frequently occur on sand-bed streams in the dune regime where the nozzle of the sampler will accidentally pick up sand from the downstream side of a dune. Therefore, each sample bottle must be inspected in the field immediately after removing it from the sampler.

After the first bottle is taken, it can be checked by swirling the contents of the bottle, then holding the bottle where the sand on the bottom can be seen moving. A mental note is made of the quality of sand contained in the bottle. The second and remaining bottles can then be examined and compared with the previous bottles. Any vertical or verticals should be carefully resampled where a bottle or bottles contain a significantly different quantity of medium and coarse sand than in the remainder of the set. If the "check" sample also contains a noticeably different amount of sand in comparison to others in the set, retain both bottles and note that the high or low concentration of sand is consistent at the vertical or verticals in question. If the check sample contains a smaller or more representative amount of sand, or if the quantity of sand is different from the first but still not "normal," it may be desirable to wait several minutes to take a third bottle on the assumption that the dune face would move beyond the sampling vertical.

A more subtle error in sample concentration may occur when a bottle is overfilled. This error also results in too high a concentration. The error caused by overfill may occur wherever the bottle is filled to less than 2 inches from the top. Such a sample should be discarded and another sample obtained by use of an increased transit rate. If the transit rate or the nozzle must be changed to avoid overfilling during an ETR measurement, then it is best to discard any previous samples and resample in clean bottles.

(10) Point-Sampler Techniques

Point samplers are used in streams where depth exceeds the recommended 15 feet for a round trip with depth integrating samplers and where the combination of depth and velocity cause the bottle to overfill at the maximum allowable transit rate. Somtimes the velocity is too high for the lighter samplers to be stable. Stream depths as much as 30 feet can be handled with point samplers by integrating the depth in only one direction at a time. Generally, the sampler is first lowered to the streambed (with the intake closed) at which time the depth is determined. This then makes it possible to estimate a transit rate to yield the desired sample quantity. Upward integration from the bottom is maintained at a given transit rate immediately upon opening the intake nozzle.

At least two bottles should be obtained at a given vertical. If the first is from bottom to top, then the other should be taken on a descending trip.

Depths between 30 and 60 feet are sampled in four steps by using four bottles instead of two. The first step is accomplished by lowering the closed sampler to the bottom and noting the depth. After opening the nozzle, the sampler is raised at a predetermined transit rate to an even foot at about one-half the depth, at which point the nozzle is immediately closed. The remaining trip to the surface can be made at any desired speed. The bottle is then removed and labeled. For the second step, a clean bottle is inserted and the sampler is again lowered, but only to that depth where the nozzle was closed on the ascending trip. At this point, the nozzle is again opened, and the upper part of the flow is sampled while ascending at the identical transit rate used in the lower part. The third and fourth steps are to sample the upper then the lower parts of flow in descending trips at a transit rate dictated by the method being used. For depths of over 60 feet, more steps must be used, as needed.

In addition to the usual information the label on each bottle should indicate the segment or range of depth sampled and whether it was taken on a descending or ascending trip.

The use of point-sampler to obtain sample concentration at one or more points in the stream is reserved for special research studies as this method of computing the sediment discharge is rather time consuming and complicated.

(11) Sediment Related Data

(a) Water Temperature

Water temperature data may seem unimportant in comparison with the sediment data. However, it has a growing list of uses besides the need to help evaluate the sediment-transport characteristics of the stream. The temperature or viscosity of the flow affects sediment suspension and deposition and may affect the roughness of a sand-bed stream.

The best or preferred method to obtain the correct water temperature is to submerge the thermometer while wading some distance out in the stream. The thermometer is held beneath the water until sufficient time (about one-half minute) has passed to allow the temperature of the thermometer to equalize with the water temperature. The stem or the scale of the thermometer is raised out of the water and held so that the etched scale on the stem is at right angles to the line of sight and then the temperature should be read to the nearest one-half degree. The bulb of the thermometer should always remain in the water until after the reading is obtained.

Be certain that the location in the stream where the temperature is taken is not affected by the inflow from a spring or tributary.

When it is not possible to wade out into a stream, the water temperature may be taken from a sample bottle. The thermometer should be inserted into a bottle from near midstream to let the thermometer adjust to the approximate temperature. Then, immediately after removing the next bottle from the sampler, transfer the thermometer from the previous bottle and allow about 15 seconds for the temperature to stabilize. The thermometer should be read while the bulb of the thermometer is submerged.

(b) Stream Stage

As with temperature, stream-stage data may seem insignificant but in reality can be very important. The data at times may be used to construct missing gage-height records for periods of recorder failure and to verify time of sampling or who collected the sample. Gage heights may also serve to indicate whether the observer actually obtained a sample at the time and in the manner indicated by available notes.

Remember that the gage height is defined as the water surface elevation referred to some arbitrary gage datum. In order for the gage height to be considered correct, the observer should always note which gage is read. The streamflow and sediment records are computed on the basis of the inside or recording gage. The observer usually is instructed to read only the outside or reference gage. Because of differences in location and the effect of velocity head, it is not expected that both gages will read the same at a given time, though some relationship may exist between them as the stage changes. Under turbulent flow conditions the outside gages should be read by noting the average of several "high" and "low" readings that may occur within a period of 10 or 15 seconds.

The fieldman should record the inside gage reading at least once each visit to the station to insure that the gage is working properly.

(12) Cold Weather Sampling

Subfreezing temperatures can cause ice to form on or in a stream and can create many difficulties in regard to suspended-sediment sampling. Suspended-sediment samplers should never be used to break through seemingly thin ice by dropping the sampler more than 3 or 4 inches. The sampler and nozzle can be damaged by such forces. If the ice will not break by the sheer weight or very gentle drop of the sample, then a hole must be opened by some other means.

If the ice is too thin to safely support a person's weight, it is best not to obtain a sample for a few days, because winter samples are generally low in sediment concentration, and therefore, most certainly are not worth taking chances. When the spring breakup occurs, the large slabs of floating ice can easily cause damage to the sampler, the support equipment, or the operator. In this case, a surface sample may be all that can be obtained between cakes of floating ice. Every effort should be made to obtain such a surface sample because the sediment concentration can and usually does change considerably under such conditions.

(13) Surface and Dip Sampling

Circumstances are sometimes such that surface or dip sampling is necessary. These may include: (1) stream velocity too high for the sampler to integrate, (2) large floating and moving submerged debris, (3) when a regular sampler is not available, and (4) very shallow depths.

A surface sample is one taken on or near the surface of the water, with or without a standard sampler. At some locations, stream velocities are so great that even 100-pound samplers cannot penetrate the water more than a short distance before they are dragged downstream and out of the water into an erratic movement. Under such conditions, it can be expected that all except the largest particles of sediment will be thoroughly mixed with the flow and therefore a sample near the surface is very worthwhile. Extreme care should be used, however, because often such high velocities occur during floods when much large debris is moving, especially on the rising part of the hydrograph. These materials may strike or become entangled with the sampler and thereby damage the sampler, break the sampler cable, or injure field personnel. A full explanation of sampling conditions should be noted on the bottle and in the field notes in order that special handling may be given the samples in the laboratory and in computing the records.

If, for some reason, a sampler is lost or equipment is not available, a sample obtained by lowering an uncapped bottled tied to a rope into the water is better than no sample at all.

In wadable water when no sampler is at hand, a "depth-integrated sample" can sometimes be taken by holding the bottle in one hand with one or two fingers of that hand placed in the bottle opening to form an elongated hole for the water to enter below the fingers and another such hole above the fingers to allow the air to escape. The remaining fingers should be extended below the bottle to avoid getting the mouth of the bottle too close to the streambed and thereby collecting some particles directly from the streambed. The fingers in the opening keep the water from entering too quickly and thus prevent circulation of the water and sediment in the bottle if overfilled.

There are many bad features about surface and dip sampling that should be avoided, especially for flows with a velocity insufficient to mix the sands in the flow. If possible, any dip sampling of such moderate or low flows should be followed and correlated, if possible, with standard sampling equipment and techniques. Because the quality of the surface and dip samples is likely to be inferior to those obtained w-th regular samplers, they should always be appropriately identified.

(b) Bed-Material Sampling

Bed material sampling involves the procurement of a sample of the top inch of the stream bed.

(1) Equipment Selection and Operation

The selection of a suitable bed-material sampler is primarily dependent on stream depth and velocity. When a stream can be waded, the most practical of the standard samplers is the BMH-53. Its use can be extended to streams about 4 feet in depth by the use of a boat.

To use the BMH-53, it is placed in a vertical position on the streambed with the piston extended to the open end of the cylinder. The cylinder is then pushed the full 8 inches into the bed while the piston is held at the bed surface. Complete filling of the cylinder will help insure a minimum of disturbance of the top 1 or 2 inches when the sampler is raised through the flow. When coarse sand or gravel material is being sampled, it is often necessary to pull on the piston rod while pushing on the cylinder. By pulling on the piston, a partial vacuum is created above the sample which helps draw the sample into the cylinder and may also reduce some of the required cutting pressure. The sampler is then withdrawn from the bed and held in an inclined position above the water with the cylinder end highest. For most purposes only the upper inch of material nearest the surface of the streambed is desired or needed in an analysis. This is obtained by pushing on the piston while the sampler is still inclined until only 1 inch of material remains in the tube. Any excess material is removed by smoothing off the end of the cylinder with a spatula or a straight pencil. The material left in the sampler is ejected into a container (usually a 1 pint paper or plastic carton). A separate container is used for each vertical.

The drag-bucket sampler, consisting of a cylindrical bucket and handle, can be used in streams up to about 10 feet in depth and 6 fps. velocity. See Figure 14.

To obtain a bed material sample the sampler is suspended by a flexible line and lowered by hand over hand operation from a bridge or cableway. The sampler is lowered to within a few inches

of the water surface. Then it is alternately swung under the bridge and out away from the bridge so as to form an arch parallel to the stream. When the sampler reaches the furthermost point of the arch (from the bridge) the line is released and the sampler drops into the water down to the streambed. The sampler is then dragged back toward the bridge. As the bucket is dragged along the streambed, it scoops up a layer of bed-material about 1 inch thick (2).

If the stream is too deep or swift for either of the samplers discussed above then the BMH-60 or the BM-54 should be used. The 30-pound BMH-60 is easiest to use when stream velocities are under 2 or 3 feet per second and depths are less than about 10 feet. To use the BMH-60, suspend the entire weight of the sampler by the hanger rod and cock the bucket in the open position with the allen wrench provided. The energy thus imparted to the spring and the sharp edge of the bucket makes it obvious that one must keep his hands away from the bucket opening at all times. If necessary, the safety yoke may be fastened around the hanger bar while opening and cocking the bucket. After the safety yoke is removed and fastened to the tail, the sampler can then be lowered by hand or by cable and reel to the surface of the streambed. Any jerking motions made while lowering the sampler that would cause the cable to slack may release the catch and allow the bucket to close prematurely. This can happen if the water surface is struck too hard. After the cocked sampler touches the streambed and tension is released on the line, the sampler should be lifted slowly from the bed so the bucket will scoop a sample even if the spring tension is not sufficient to force the bucket through the bed upon contact.

To remove the sample from the bucket, the sampler is positioned above a carton or container and the bucket opened with the allen wrench. The sampler need not be held by the hanger bar during sample removal unless considerable material is clinging to the flat plate within the bucket cavity. If removal of such material is required, the bucket should be cocked in the open position and the sample brushed into the container with a stick or small brush. When moving the sampler between verticals and when storing it in the trunk, the bucket should be in the closed position to avoid an accidental closing and to reduce the tension on the spring.

The 100-pound BM-54 is needed for faster velocities and depths that are greater than about 10 feet. The BM-54 action is similar to the BMH-60 except that the bucket opens front to back. It is used only with crane-and-winch suspension and is rather awkward to handle when removing the sample. The techniques for taking a sample with the BM-54 are essentially the same as for the BMH-60. One important difference in operation involves the use of a safety bar on the BM-54 to hold the bucket in an open position instead of

the safety yoke on the BMH-60. The sampler should be stored with the bucket in a closed position and if extended storage is anticipated, the tension on the spring should be further reduced.

When extremely high velocities are encountered and samples are unobtainable with the BM-54, an additional C-type weight can be placed on the hanger bar above the BM-54. If additional weights are required with the BM-54, extreme care should be taken to avoid bending and possible breaking of the hanger bar between the sampler and the C-type weight.

(2) Location and Number of Verticals

Bed-material samples are often needed in conjunction with a water-discharge measurement and (or) a set of suspended-sediment samples. If the discharge measurement and (or) the suspended samples are taken first, then the bed-material samples should be collected at the same stations, but not necessarily the same number of stations. By taking them at the same stationing points, any change in bed-material or radical change in discharge across the stream that would affect the sediment-discharge computations can be accounted for by subdividing the stream section at one or between two of the common verticals.

For wadable streams, it is often best to obtain the bed-material samples prior to the water- or suspended-sediment measurements to avoid excess disturbance of the bed. Also by taking the bed-material first, radical changes across the section in bed-material size and water discharge can be used as a basis for choosing desirable verticals for the other measurements. One pint of sample from each vertical should be sufficient for bed-material sampling. Samples should be taken about every two months unless a total load analysis is being conducted, in which case more frequent sampling may be required.

B. Turbidity

Turbidity samples can be obtained with a suspended sediment sampler or by any other means that would insure the securing of a representative sample of the stream water.

Turbidity can be measured in the field with a colorimeter field kit or the samples can be shipped to the laboratory where the turbidity is measured with a laboratory turbidimeter.

CHEMICAL POLLUTION

1. Chemicals and Metals

A chemistry field kit can be used in the field to detect the presence of various chemicals and metals in the water. The concentrations of chloride, chlorine, chromium, copper, fluoride, hardness, hydrogen sulfide, iron, manganese, nitrate nitrogen, nitrite nitrogen, phosphate, silica and sulfate can be approximated by following the procedures outlined in the "Methods Manual" which is included with the kit. If an unusually high concentration of one or more of these ingredients is detected, another water sample should be obtained and submitted to a chemical laboratory for a formal chemical analysis. It must be emphasized that the purpose of the field kit is to detect rather than to precisely measure the concentrations of chemicals and metals in the water. For test procedures, preservation of water samples and maximum holding time, see Section VI.

The results of the chemical analyses are recorded on Form HMR T-705.

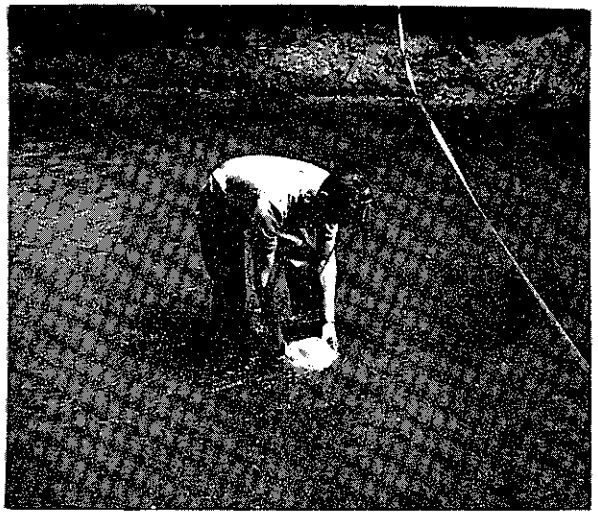


Figure 30

Field sampling and testing with chemical kit.

2. pH

The pH of a water sample is a measure of the hydrogen ion concentraion in the water. The pH scale reads from 0 to 14 with 7 (the pH of distilled water) the neutral point. Numbers greater than 7 indicate degrees of alkalinity while those less than 7 indicate degrees of acidity.

The pocket pH meter is a compact and portable instrument used to measure the pH of water samples in the field. Rather rapid field measurements can be made by the following procedure:

1. Slide switch to "on" position and remove cap from electrode tip.
2. Slide electrode sleeve down below the filling hole. Check the KCI - AgCI level and refill if necessary.
3. Rinse electrode in distilled water, wipe with tissue, and insert in buffer vial.
4. Turn adjusting knob until meter reads pH of buffer you are using.
5. Hold down check "button" and set "Memory" dial to the meter reading observed. Release "check" button.
6. Remove electrode from the buffer vial, rinse distilled water, dry with tissue and place it in the sample.
7. Read the pH of the sample on the meter dial.

To insure accuracy, the "check" button should be depressed before each measurement to check the meter reading against the "Memory Dial" setting. To correct the meter reading use the "adjust" knob while holding the "check" button down.

The pH of a solution changes with its temperature and thus a temperature correction should be applied for precise measurements. Each instrument kit should contain a table listing the correction factors for the various temperatures.

The pH of a water sample can also be determined in the field with a chemistry field kit. Briefly, the procedure involves the mixing of an indicator solution with the water sample, placing the mixture in the colorimeter and reading the pH on the meter scale. The procedure is detailed in the "Methods Manual" included with the kit.

BIOLOGICAL POLLUTION

Investigation of biological pollution factors includes an assessment of dissolved oxygen content, aquatic organisms, and bacteriological organisms. Dissolved oxygen determinations are discussed below. More information on biological monitoring will be presented in Manual 5 of this series.

One method of determining the dissolved oxygen content is by analyzing a water sample with a chemistry field kit, following the procedure outlined in the "Methods Manual." Dissolved oxygen normally is determined in the field due to the low holding time of the sample. Field kits are available which use the modified Winkler method. Some field kits include a water sampler for sampling water at any desired depth in the stream or reservoir. The sampling operation includes the following steps:

1. Place the 60 ml. DO sampler bottle into the sampler.

2. Attach the lid on the sampler with the sample inlet tube extending into the sampler bottle.

3. Wet the rubber stopper and insert it into the tube which extends approximately one inch above the top of the lid.

4. Lower the sampler into the stream by the chain; then pull out the stopper at the desired depth.

5. When air bubbles stop rising from the sampler raise the sampler by the chain and carefully remove the sample bottle.

The determination of the DO of the water in the sample bottle involves the addition of some chemicals in accordance with the procedure presented with the kit.

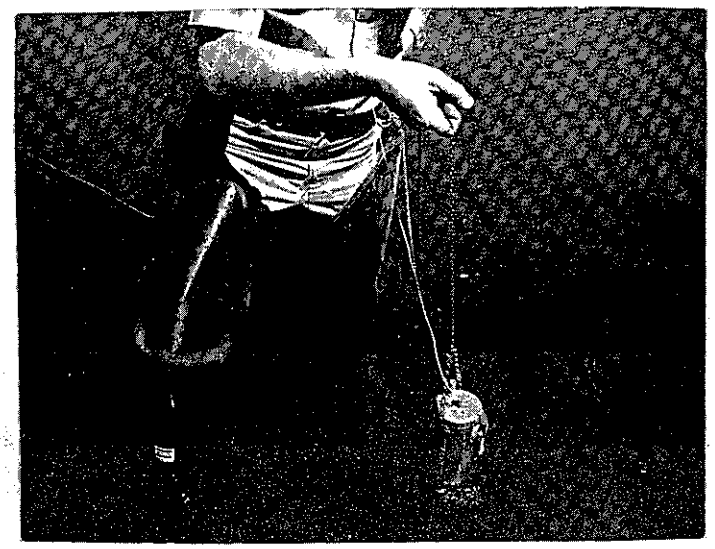


Figure 31

Sampling water for a "D.O." analysis.

In situ dissolved oxygen monitoring instruments may also be used to measure the dissolved oxygen content of the water. This type of instrument consists of a sensor probe that is lowered into the water by an electrical cable which is connected to a monitoring instrument. The observer can lower the probe to various depths and read the D.O. and temperature directly on the monitoring instrument.

For sampling biological organisms, see Section VI.

HYDROLOGIC INFORMATION

This section describes the usage of various types of equipment to obtain hydrologic information such as stream discharge and precipitation data. Stream discharge is determined by measuring the velocity and cross sectional area of a stream (Q = VA). The discharges measured at several stages are correlated to a stream gage and a stage-discharge curve is developed. Subsequent discharges can be determined by simply reading the stream gage and referring to the stage-discharge curve.

1. Stream Gaging

(a) Site Selection - When selecting a gage site, geologic and topographic maps of the area should be examined and probable sites selected for review in the field. After a field investigation of the tentative sites, the gage site is selected. The following items should be considered when selecting a site:

1. Stable stream channels are preferable to changing bed configurations.

2. Avoid areas where backwater is possible from downstream sources such as constricted channels, culverts, bridges, etc.

3. Availability and ease of a cross section for discharge measurements.

4. Selection of a representative channel section; generally a straight reach. Avoid bends if possible.

5. Placement of gage with respect to stage-discharge control.

6. Availability of structures or their possible installation for high stage-discharge measurements.

7. Avoid areas where there is a possibility of flow bypassing the gaging site.

8. Availability of power for electrical instruments if contemplated.

9. Accessibility to the site, especially during high stages.

b. Method and Equipment - The stage of a stream is the height of water surface relative to an established datum. A stream discharge measurement can be correlated to the gage height, thus enabling a stage-discharge curve to be developed. The stage is used to determine future discharges. Stream stage can be determined by observations of a non-recording gage (stage gage) or by the installation of an automatic recording gage. The gage should be located so it is easily accessible and capable of recording at all expected stream stages.

The non-recording gage is a calibrated rod or tape used to measure the height of water above a datum. It has a low initial cost and is generally easily installed. The main disadvantage is that discharges are only recorded periodically by an observer, thus discharge fluctuations are relatively unknown.

The recording gage has many advantages where long term operations are contemplated. Continuous data is stored on a strip-chart or digital tape by the water-level recorder. The continuous data eliminates errors in water stage records that would occur with a non-recording gage. Therefore, the accuracy and reliability of the data are improved.

Stage may be sensed by two methods: 1) a gas-purge (bubble gage) system or 2) a float in a stilling well. For the gas-purge system, gas (nitrogen) is fed through a tube and bubbled freely through an orfice mounted on the stream bottom. Pressure in the tube is measured and recorded by a mercury manometer on a stage recorder. The bubbling gas tends to keep sand from covering the orfice in sand-channel streams and the gas tube is easily extended to follow shifting channels.

Stage may also be sensed by a float in a stilling well connected to the stream by intake pipes. Stilling wells can be installed on streambanks, in the streams, or attached to abutments or other structures. The bottom and top of the stilling wells extend beyond the expected stage limits. The stream stage is recorded by the elevation of the float.

2. Discharge Measurements

a. Site Selection

Discharge measurements consisting of velocity and cross sectional area measurements are made at or near stage gages to determine a stage-discharge relationship for the site. The reliability of these measurements depends largely upon the proper site selection. See Section III for site selection criteria.

b. Method

When the metering site has been selected, the station is cross-sectioned to accurately define its contour. The section should be extended to include all areas that might be inundated during peak flood stage. The cross section is plotted and depth shown at all metering locations (a vertical). If the stream bed is stable and not subject to erosion or sedimentation, the depths can be computed at any stage knowing the gage height and original cross section. The cross section should be checked periodically to determine that the stream bed has not shifted.

The cross section is examined and subdivided into partial sections that will yield a representative velocity. Care should be exercised in selecting partial sections and verticals so that the adjacent sections do not differ greatly in depth or velocity because velocity does not vary linearly with depth. For larger streams the cross-section should be divided into a minimum of 20 partial sections and any partial section should not measure more than about 5% of the total discharge. Velocity is measured at the horizontal midpoint ($^b/2$) and either 0.2 and 0.8 depth or 0.6 depth points of the partial section. The stream velocity or any point varies from the surface down. Velocity is usually measured by the two point (0.2d and 0.8d) or one-point (0.6d) methods (see Figure 32).

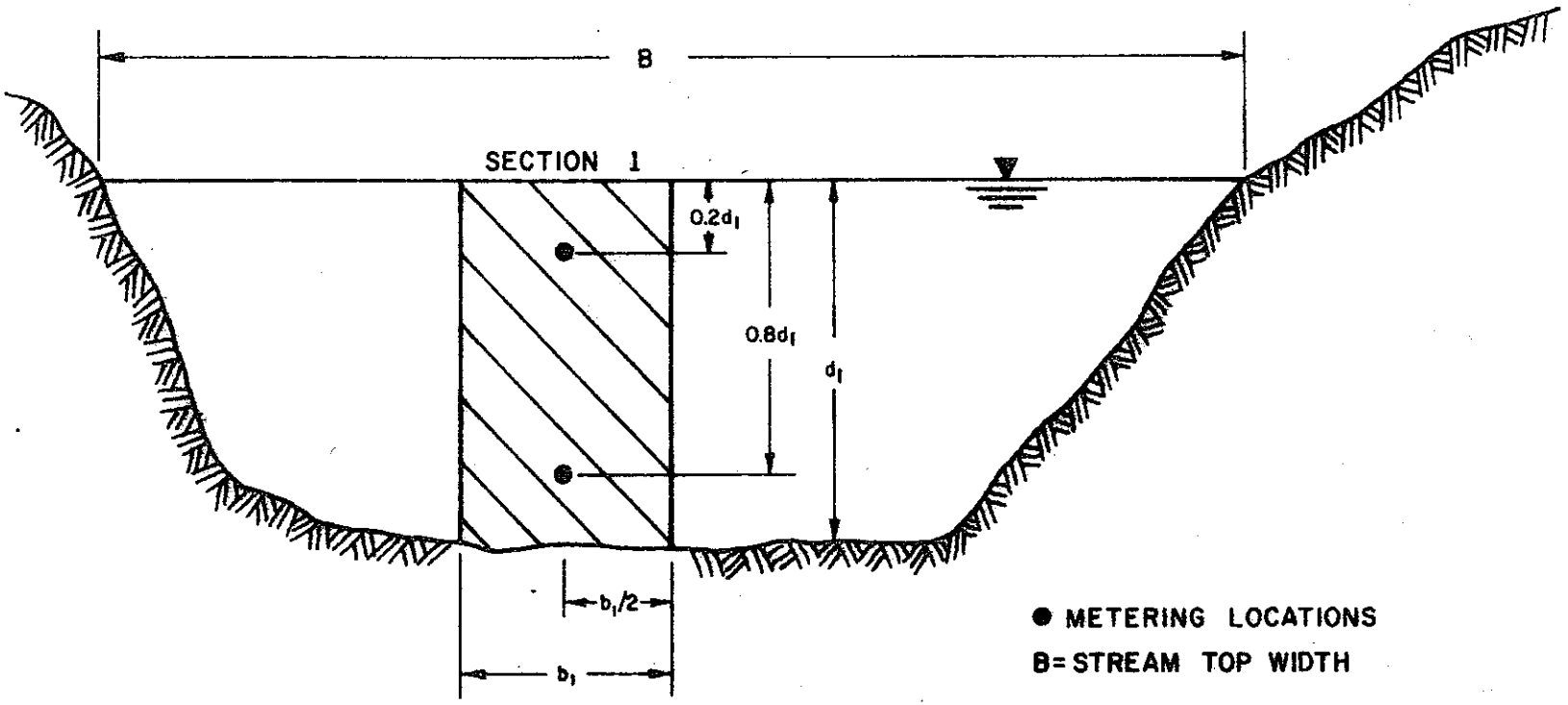
In the two point method, observations are made two-tenths of the depth and again at eight-tenths of the depth as measured from the water surface. The average of these two values is considered the mean velocity of the partial section. In cases where the stream depth is less than one foot but greater than 0.3 foot, a single measurement (one-point method) is made at six-tenths of the depth as measured from the water surface. This is considered the average velocity of the partial section. When the velocity has been established, the discharge can be computed by multiplying velocity times partial area. The total discharge is the sum of partial section discharges.

For flows of less than one cubic foot per second, other methods must be used to determine discharge such as collecting a known volume per time interval. A calibrated weir flume can also be used.

When a group of discharge measurements have been made, the data are plotted on semi-log paper with stages as the ordinate and discharge as the log scale abscissa. This curve is referred to as the Stage-Discharge curve.

To accurately graph the results, it is necessary to plot data for the range of normal flows. A straight line should connect most of the plotted points.

STREAM CROSS-SECTION



FOR SECTION 1:

$$\text{Velocity (fps)} = V_1 = \frac{V_{0.2d} + V_{0.8d}}{2} \text{ (for } d \geq 1 \text{ foot) or } V_1 = V_{0.6d} \text{ (for } 1 > d > 0.3)$$

d_1 = average depth of section

b_1 = width of section

Area (sq. ft.) = $a_1 = b_1 \times d_1$

Flow (cfs) = $q_1 = v_1 \times a_1$

FOR TOTAL STREAM:

$$\text{Area} = A = \sum_{n=1}^{n} a_n$$

$$\text{Flow} = Qw = \sum_{n=1}^{n} q_n$$

$$\text{Velocity} = \frac{Qw}{A}$$

STATE OF CALIFORNIA
DIVISION OF HIGHWAYS
MATERIALS & RESEARCH DEPARTMENT
ENVIRONMENTAL IMPROVEMENT SECTION

VELOCITY MEASUREMENT

4-72 Figure 1

Figure 32

c. Equipment Usage

The Price current-meter is the instrument commonly used to measure stream velocity. It is an electric differential meter whose rotor consists of six cone shaped cups that rotate on a vertical axis. The differential pressure, caused by the current, on the concave portion of the cups causes the rotor to revolve. The number of revolutions the rotor makes is signalled through a headset worn by the observer. The telephone circuit is energized by a small battery (1.5V). The meter can produce a signal at each revolution or every fifth revolution. When velocities are very high the fifth count circuit is used.

The meter can be mounted on a hand held graduated rod for measuring flow in streams less than 4 feet deep. (A rule of thumb is to consider the stream wadable if the product of velocity in fps times depth in ft. is less than 10.) For larger streams or rivers, the meter can be suspended by a cable. In these cases, there must be a supporting structure such as a bridge, cable way or boat over the

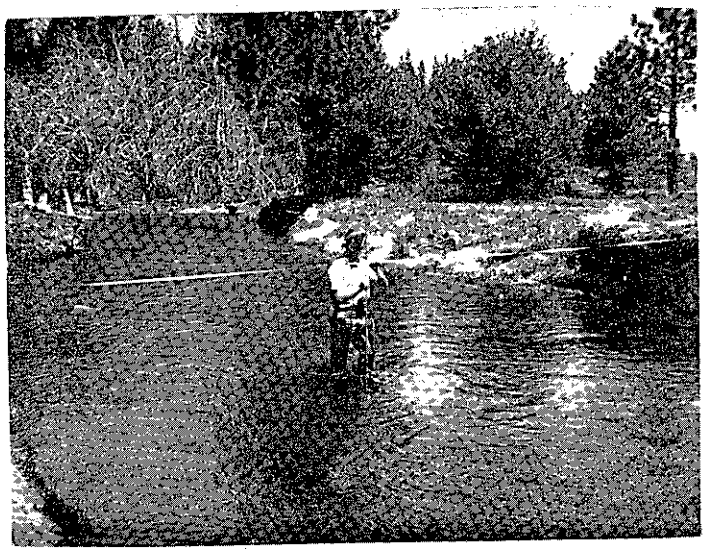


Figure 33

Measuring stream velocity with Current Meter.

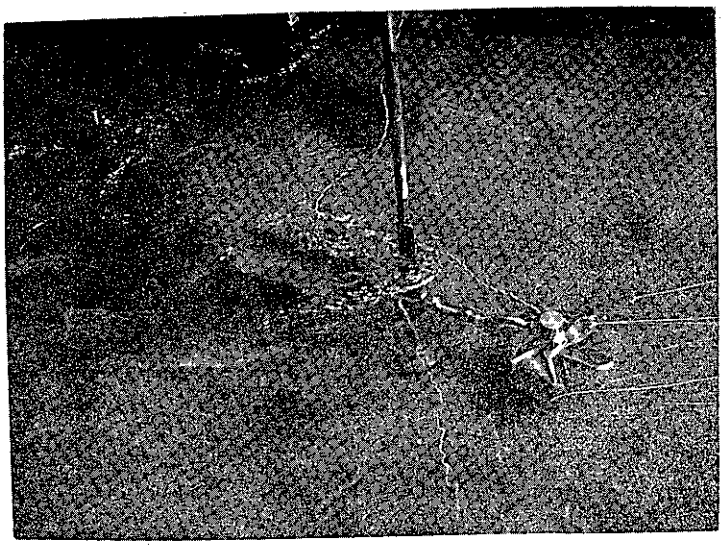


Figure 34

Closeup of Current Meter in stream.

water way. To measure velocity, the observer sets the meter at the desired depth as determined from known cross-section information and starts a stop watch on an initial signal (click) by the rotor. The next signal, after a complete rotor revolution, is counted as one. The observer continues counting revolutions until a minimum of 40 seconds has elapsed. When the next multiple of 10 revolutions is counted, the observer stops the watch and records the total elapsed time and number of revolutions counted. Knowing the elapsed time and number of revolutions, the current meter rating table (see Table 11) is consulted to determine velocity. A rating table is supplied with each current meter. Stream flow measurements are tabulated and calculated on Form HMR T-707.

In order to obtain consistent and correct results, care should be taken to avoid any damage to the meter that may alter its operating characteristics. Never allow the rotor cups to come in contact with rock or gravel in the streambed.

3. Precipitation Data

a. Site Selection

Precipitation measurements are usually intended to be representative of a relatively large area. Important factors which influence the representativeness of the gage catch are adequate protection from strong winds and an exposure free of large obstructions.

Site the gage on level ground and, if possible, high enough to be above the normal snow pack for the year. In any case, do not install a gage where the ground falls away steeply in the direction from which the wind blows during precipitation (usually southeast through southwest in the Northern Hemisphere). Terrain features such as depressions can sometimes be used to protect the gage from strong winds. If no protection from wind is possible, a wind screen should be used.

While obstructions are desirable to diminish the effects of strong winds, they should be from 2 to 4 times their height away from the gage. Otherwise, the obstructions might tend to shield the precipitation from reaching the gage.

b. Equipment

Precipitation data can be obtained with a precipitation gage and recorder, or a visual accumulation tube rain gage.

A common precipitation gage consists of an insulated conical cover which houses a tipping bucket precipitation gage. Precipitation falling into the orifice at the top of the gage is funneled into one of the two small buckets which are calibrated to tip when 0.01

RATING TABLE FOR TYPE AA CURRENT METER

Table 10

EQUATIONS: V=2.180R + .020 (2.200) 2.170R + .030 — Std Rating No. 1

Time in Seconds	VELOCITY IN FEET PER SECOND — Revolutions									Time in Seconds
	3	5	7	10	15	20	25	30	40	
40	.183	.292	.401	.565	.837	1.11	1.38	1.65	2.20	40
41	.180	.286	.392	.552	.818	1.08	1.35	1.62	2.15	41
42	.176	.280	.383	.539	.799	1.06	1.32	1.58	2.10	42
43	.172	.273	.375	.527	.780	1.03	1.29	1.54	2.05	43
44	.169	.268	.367	.515	.763	1.01	1.26	1.51	2.00	44
45	.165	.262	.359	.504	.747	.989	1.23	1.47	1.96	45
46	.162	.257	.352	.494	.731	.968	1.20	1.44	1.92	46
47	.159	.252	.345	.484	.716	.948	1.18	1.41	1.88	47
48	.156	.247	.338	.474	.701	.928	1.16	1.38	1.84	48
49	.153	.242	.331	.465	.687	.910	1.13	1.35	1.80	49
50	.151	.238	.325	.456	.674	.892	1.11	1.33	1.76	50
51	.148	.234	.319	.447	.661	.875	1.09	1.30	1.73	51
52	.146	.230	.313	.439	.649	.858	1.07	1.28	1.70	52
53	.143	.226	.308	.431	.637	.843	1.05	1.25	1.67	53
54	.141	.222	.303	.424	.626	.827	1.03	1.23	1.63	54
55	.139	.218	.297	.416	.615	.813	1.01	1.21	1.61	55
56	.137	.215	.292	.409	.604	.799	.993	1.19	1.58	56
57	.135	.211	.288	.402	.594	.785	.976	1.17	1.55	57
58	.133	.208	.283	.396	.584	.772	.960	1.15	1.52	58
59	.131	.205	.279	.389	.574	.759	.944	1.13	1.50	59
60	.129	.202	.274	.383	.565	.747	.928	1.11	1.47	60
61	.127	.199	.270	.377	.556	.735	.913	1.09	1.45	61
62	.125	.196	.266	.372	.547	.723	.899	1.07	1.43	62
63	.124	.193	.262	.366	.539	.712	.885	1.06	1.40	63
64	.122	.190	.258	.361	.531	.701	.872	1.04	1.38	64
65	.121	.188	.255	.355	.523	.691	.858	1.03	1.36	65
66	.119	.185	.251	.350	.515	.681	.846	1.01	1.34	66
67	.118	.183	.248	.345	.508	.671	.833	.996	1.32	67
68	.116	.180	.244	.341	.501	.661	.821	.982	1.30	68
69	.115	.178	.241	.336	.494	.652	.810	.968	1.28	69
70	.113	.176	.238	.331	.487	.643	.799	.954	1.27	70
	3	5	7	10	15	20	25	30	40	

Actual Rating Limits: 0.25 to 8.0 feet per second — Date: 03-05-70

Time in Seconds	VELOCITY IN FEET PER SECOND — Revolutions									Time in Seconds
	50	60	80	100	150	200	250	300	350	
40	2.74	3.28	4.37	5.45	8.17	10.88	13.59	16.30	19.02	40
41	2.68	3.21	4.26	5.32	7.97	10.62	13.26	15.91	18.55	41
42	2.61	3.13	4.16	5.20	7.78	10.36	12.95	15.53	18.11	42
43	2.55	3.06	4.07	5.08	7.60	10.12	12.65	15.17	17.69	43
44	2.50	2.99	3.98	4.96	7.43	9.89	12.36	14.83	17.29	44
45	2.44	2.92	3.89	4.85	7.26	9.67	12.09	14.50	16.91	45
46	2.39	2.86	3.80	4.75	7.11	9.46	11.82	14.18	16.54	46
47	2.34	2.80	3.72	4.65	6.96	9.26	11.57	13.88	16.19	47
48	2.29	2.74	3.65	4.55	6.81	9.07	11.33	13.59	15.85	48
49	2.24	2.69	3.57	4.46	6.67	8.89	11.10	13.32	15.53	49
50	2.20	2.63	3.50	4.37	6.54	8.71	10.88	13.05	15.22	50
51	2.16	2.58	3.43	4.28	6.41	8.54	10.67	12.79	14.92	51
52	2.12	2.53	3.37	4.20	6.29	8.38	10.46	12.55	14.64	52
53	2.08	2.49	3.31	4.12	6.17	8.22	10.27	12.31	14.36	53
54	2.04	2.44	3.24	4.05	6.06	8.07	10.08	12.09	14.09	54
55	2.00	2.40	3.19	3.98	5.95	7.92	9.89	11.87	13.84	55
56	1.97	2.35	3.13	3.90	5.84	7.78	9.72	11.65	13.59	56
57	1.93	2.31	3.08	3.84	5.74	7.64	9.55	11.45	13.35	57
58	1.90	2.27	3.02	3.77	5.64	7.51	9.38	11.25	13.12	58
59	1.87	2.24	2.97	3.71	5.55	7.39	9.22	11.06	12.90	59
60	1.84	2.20	2.92	3.65	5.45	7.26	9.07	10.88	12.69	60
61	1.81	2.16	2.88	3.59	5.37	7.14	8.92	10.70	12.48	61
62	1.78	2.13	2.83	3.53	5.28	7.03	8.78	10.53	12.28	62
63	1.75	2.10	2.79	3.47	5.20	6.92	8.64	10.36	12.09	63
64	1.72	2.06	2.74	3.42	5.12	6.81	8.51	10.20	11.90	64
65	1.70	2.03	2.70	3.37	5.04	6.71	8.38	10.05	11.71	65
66	1.67	2.00	2.66	3.32	4.96	6.61	8.25	9.89	11.54	66
67	1.65	1.97	2.62	3.27	4.89	6.51	8.13	9.75	11.37	67
68	1.62	1.94	2.58	3.22	4.82	6.41	8.01	9.60	11.20	68
69	1.60	1.92	2.55	3.17	4.75	6.32	7.89	9.46	11.04	69
70	1.58	1.89	2.51	3.13	4.68	6.23	7.78	9.33	10.88	70
	50	60	80	100	150	200	250	300	350	

STREAM FLOW MEASUREMENTS

CALIFORNIA DIVISION OF HIGHWAYS

MATERIALS & RESEARCH DEPARTMENT - ENVIRONMENTAL IMPROVEMENT SECTION

DIST. CO. RTE. P.M.
PROJECT ____________________
DRAINAGE BASIN ____________________
LOCATION ____________________
SAMPLING STATION ____________________ GAGE HT. ________ ft.

DATE ________ / ________
TIME ________
BY ________
TEMP. ________

(1) TAPE DISTANCE	(2) ___ BANK DISTANCE	(3) DEPTH	(4) 0.2 DEPTH / 0.8 DEPTH	(5) REV. / TIME	(6) VEL.	(7) AVG. VEL.	(8) AVG. d	(9) AREA (2) x (8)	(10) q (7) x (9)

TOTAL

$\bar{V} = \frac{(10)}{(9)}$

$\bar{D} = \frac{(9)}{W_T}$

CALCS

HMR T-707 (Orig. 6-72)

inch of water has been collected. As one bucket tips the other is brought into position to catch the precipitation. If the precipitation is in the form of snow, the heat generated by a propane flame located at the base of the instrument is channeled up between the inner and outer cases to heat the collecting funnel and melt the snow. With each tip of the bucket, a mercury switch closes momentarily in the precipitation gage. The switch permits current from a battery in the recorder to activate on electro-magnet which advances the recorder pen one division on the chart. The chart is mounted on drums and driven by battery operated clock mechanism.

The precipitation information from the chart is recorded on a precipitation data sheet (Form HMR T-704). Figure 35 illustrates a daily precipitation record sheet.

The visual accumulation tube rain gage is a rather simple device for obtaining accumulated precipitation measurements. These gages come in various sizes and shapes, but basically consist of a graduated plastic tube which accumulates the rainfall. The amount of rainfall is periodically read by observing the liquid level in the graduated tube. These gages are not suitable for measuring snowfall as they are not equiped with heaters.

PRECIPITATION DATA

ENVIRONMENTAL IMPROVEMENT SECTION, MATERIALS & RESEARCH DEPT.
DIVISION OF HIGHWAYS

Dist. ______ Co. ______ Rte. ______ P.M. ______ Location ______

Job No. ______ Prec. Gage No. ______ Recorder No. ______ Date Installed ______

Calc. By ______ Chkd. By ______

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DATE	T (Hours)	P (Inches)	Type	ΔP (Inches)	ΔT (Hours)	I (in./hr.)	REMARKS

COL.(2) T = Time
COL.(3) P = Precipitation
COL.(4) TYPE: R = Rain, S = Snow, O = Other
COL.(7) = $\frac{\text{COL.(5)}}{\text{COL.(6)}}$ I = Intensity

HMR T-704 (Orig. 4/72)

ENVIRONMENTAL ENVIRONMENT SECTION
MATERIALS AND RESEARCH DEPARTMENT
DIVISION OF HIGHWAYS

Daily Precipitation Record (inches)

W.O. 657078S Gage Location Luther Highway District 03 County ED Route 89 Post Mile 2.4

Year 1972

Day of Month	January	February	March	April	May	June	July	August	September	October	November	December
1	0	0	0	0	0							
2	0	0	0.44 R	0	0							
3	0	0	0.50 R	0	0							
4	0	0.12 S	0	0.06 R	0							
5	0	0.18 S	0	0.50 R,S	0							
6	0	0	0	0.53 R	0							
7	0	0	0	0.01 R	0							
8	0	0	0	0.02 R	0.01 R							
9	0	0	0	0	0							
10	0	0	0.02 R,S	0	0							
11	0	0	0	0	0							
12	0	0	0	0	0							
13	0	0	0	0.34 S	0							
14	0	0	0	0.56 S	0							
15	0	0	0	0	0							
16	0	0	0	0	0							
17	0	0	0	0	0							
18	0	0	0	0.01 S	0							
19	0.08 S	0	0	0	0.44 S							
20	0	0	0	0	0.17 S							
21	0.07 R	0.17 S	0	0	0.05 R,S							
22	0.14 S	0.39 S	0.64 S	0	0							
23	0.33 S	0	0.01 S	0								
24	0	0.40 S	0.07 R	0.14 S								
25	0.45 S	0.33 S	0.16 R	0								
26	0.16 S	0.02 S	0	0								
27	1.01 S	0	0	0								
28	0.02 S	0.15 R	0	0								
29	0	0.20 S	0	0								
30	0		0	0								
31	0		0									
Total	2.26	1.96	1.84	2.17	0.67							

Figure 35: Daily Precipitation Record

REFERENCES
(Section V)

1. Field Methods for Measurement of Fluvial Sediment, Guy and Norman, U. S. Geological Survey, 1971.

2. Determination of Fluvial Sediment Discharge, Report No. 14., U. S. Inter-Agency Committee on Water Resources, December 1963.

3 General Procedure for Gaging Streams, Carter and Davidian, U. S. Geological Survey, 1968.

SECTION VI

LABORATORY AND FIELD TESTS

METHODS FOR THE CHEMICAL ANALYSIS OF WATER

Scope

This method describes the procedure for determining the chemical constituents in a water sample.

Procedure

Record the test data on Form T-705. Determine the following properties and constituents of water using the procedures that are specified in the accompanying references.

A. Reagents

Unless otherwise indicated, all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

B. Hardness (Calcium, Magnesium, and Total)

Refer to Test Method No. Calif. 405-B, "Methods for Chemical Analysis of Water" and to "Standard Methods for the Examination of Water and Wastewater" (1).

C. Alkalinity (Carbonates, Bicarbonates Hydroxide, Free CO_2, and pH)

Refer to Test Method No. Calif. 405-B, "Methods for the Chemical Analysis of Water," and to "Standard Methods for the Examination of Water and Wastewater" (1).

D. Turbidity

Refer to "Standard Methods for the Examination of Water and Wastewater" (1).

E. Dissolved Solids

Refer to Test Method No. Calif. 405-B, "Methods for the Chemical Analysis of Water," and to "Standard Methods for the Examination of Water and Wastewater" (1).

F. Suspended Solids

Refer to "Standard Methods for the Examination of Water and Wastewater" (1).

G. Specific Conductance

Refer to "Standard Methods for the Examination of Water and Wastewater" (1).

H. Chloride

Refer to Test Method No. Calif. 422-A, "Method of Testing Soils and Waters for Chloride Content," and to "Standard Methods for the examination of Water and Wastewaters" (1).

I. Nitrate

Refer to Test Method No. Calif. 405-B, "Methods for the Chemical Analysis of Water," and to "Standard Methods for the Chemical Analysis of Water and Wastewater" (1).

J. Sulfate

Refer to Test Method No. Calif. 417-A, "Methods of Testing Soils and Waters for Sulfate Content," and to Standard Methods for Chemical Analysis of Water and Wastewater" (1).

K. Silica

Refer to Test Method No. Calif. 405-B, "Methods for the Chemical Analysis of Water." and to "Standard Methods for the Chemical Analysis of Water and Wastewater" (1).

L. Nitrogen (Nitrate, Nitrite, Organic, Ammonia, Total)

Refer to "Standard Methods for the Chemical Analysis of Water and Wastewater" (1).

M. Sodium

Refer to Test Method No. Calif. 405-B, "Methods for the Chemical Analysis of Water" and to "Standard Methods for the Chemical Analysis of Water and Wastewater" (1).

N. Potassium

Refer to Test Method No. Calif. 405-B "Methods for the Chemical Analysis of Water" and to "Standard Methods for the Chemical Analysis of Water and Wastewater" (1).

WATER QUALITY ANALYSIS

ENVIRONMENTAL IMPROVEMENT SECTION - MATERIALS & RESEARCH DEPARTMENT
DIVISION OF HIGHWAYS

DIST. CO. RTE. P. M. _____ Work Order _____

Drainage Basin _____

Location _____

Type of Analysis:

Date Sampled _____ /

Sampled By _____

Sample No. _____

Date to Lab. _____ /

Date Started _____ /

Date Completed _____ /

Chemist

(1) Hardness _____ ml 1 ml _____ mg F ☐ L ☐ $CaCO_3$ T.H. mg/L	(2) Calcium _____ ml 1 ml _____ mg F ☐ L ☐ Ca Ca mg/L	(3) Magnesium _____ meq/L T.H. _____ F ☐ meq/L Ca _____ meq/L Mg _____ L ☐ Mg mg/L	(4) Alkalinity _____ ml 1 ml _____ mg F ☐ L ☐ HCO_3 HCO_3 mg/L	CO_3 mg/L pH
(5) Turbidity F ☐ L ☐ Turb.	(6) Dissolved Solids 180° C T.D.S. mg/L	(7) Suspended Solids _____ ml S.S. mg/L V.S.S. mg/L	(8) Dissolved Oxygen Temp _____ °C Sat. Level F ☐ L ☐ D.O. mg/L	(9) Specific Conductance 25° C R (Std) _____ R (Sam) _____ Micromhos/cm
(10) Chloride _____ ml 1 ml _____ mg F ☐ L ☐ Cl Cl mg/L	(11) Nitrate _____ ml NO_3 F ☐ L ☐ NO_3 mg/L	(12) Sulfate _____ ml SO_4 F ☐ L ☐ SO_4 mg/L	(13) Silica _____ ml SiO_2 F ☐ L ☐ SiO_2 mg/L	(14) Chlorine _____ ml Cl_2 F ☐ L ☐ Cl_2 mg/L
(15) Nitrate _____ ml F ☐ L ☐ as (N) mg/L	(16) Nitrite _____ ml F ☐ L ☐ as (N) mg/L	(17) Organic Nitrogen ___ ml as (N) mg/L	(18) Ammonia _____ ml as (N) mg/L	(19) Total Nitrogen T.N. mg/L
(20) Filterable Orthophosphate _____ ml, C _____ A _____ Factor _____ A (Sam) _____ F ☐ as (P) mg/L L ☐	(21) Filterable Hydrolyzable Phosphate _____ ml A _____ C _____ A (Sam) _____ F _____ as (P) mg/L	(22) Total Phosphorus _____ ml, C _____ A _____ Factor A (Sam) _____ F ☐ as (P) mg/L L ☐	(23) Sodium _____ dil % T _____ Curve _____ Na mg/L	(24) Potassium _____ dil % T _____ K mg/L

HMR T-705 (Orig. 5-72)

F - Field Analysis
L - Laboratory Analysis

METHOD OF TESTING FOR DISSOLVED OXYGEN IN WATER

Scope

This method discribes the test procedure for determination of the Dissolved oxygen content of water.

Procedure

A. Reagents

1. Manganese Sulfate Solution
2. Alhali-iodide-ozide reagent
3. Sulfuric Acid
4. Starch
5. Sodium thiosulfate stock solution
6. Standard sodium thiosulfate titrant
7. Standard Potassium Biniodate solution

B. Test Procedure

Refer to "Standard Methods for the Examination of Water and Wastewater" (1) (Iodometric Method - Azide Modification).

C. Calculation

$$DO\ (mg/l) = \frac{(ml's\ Thiosulfate) \times Normal \times 1000}{(ml\ of\ sample) \times 40}$$

D. Reporting of Results

Report the test results on Form T-705.

METHOD OF TESTING WATER FOR CHLORINE RESIDUAL

Scope

This method describes the procedure used to determine the residual chlorine in water.

Procedure

A. Reagents

1. Acetic Acid
2. Potassium iodide
3. Standard Sodium thiosulfate
4. Standard Sodium thiosulfate titrant
5. Starch indicator solution
6. Standard iodine

B. Test Procedure

Refer to "Standard Methods for the Examination of Water and Wastewater" (1) (Iodometric Method).

C. Calculations

$$\text{mg/l Cl} = \frac{(A \pm B)(N)(35{,}450)}{\text{ml sample}}$$

A = ml titration for sample
B = ml titration for blank
N = Normality of $Na_2S_2O_3$

D. Reporting of Results

Report the test results on Form T-705.

METHOD OF TESTING WATER FOR PHOSPHATES

Scope

This method describes the procedure used to determine the concentration of phosphates in water.

A. Materials

1. Autoclave, 15-20 psig
2. Hot plate
3. Conical Flasks, 125 ml
4. Porcelain evaporating dishes
5. Spectrophotometer

B. Procedure

Refer to "Standard Methods for the Examination of Water and Wastewater" (1) (Vanadomolybdophosphoric Acid Colormetric Method).

C. Calculations

$$\text{mg/l P} = \frac{\text{mg P} \times 1{,}000}{\text{ml sample}}$$

D. Reporting of Results

Report test results on Form T-705.

In addition to the more common parameters outlined in the preceeding test methods, it may be necessary under certain conditions to conduct a more detailed chemical analysis. "Standard Methods for the Examination of Water and Wastewater" describes the following additional tests which can be performed on waters in the absence of gross pollution.

a. Copper
b. Lead
c. Aluminum
d. Iron
e. Chromium
f. Manganese
g. Zinc
h. Arsenic
i. Pesticides (Chorinated Hydrocarbon)
j. Boron
k. Cyanide
l. Alkyl Benzene Sulfonate
m. Phenols
n. Tannin and Lignin
o. Biochemical Oxygen Demand
p. Chemical Oxygen Demand
q. Oil and Grease

It is recommended that water samples requiring detailed chemical analysis be sent to a standard testing laboratory. Chemical field test kits will provide "ball park" estimates of the actual chemical composition of water.

MATERIALS AND RESEARCH DEPARTMENT

State of California
Department of Public Works
Division of Highways

Test Method No. Calif.

METHOD OF TESTING WATER FOR TURBIDITY

Scope

This method describes the procedure used to determine the turbidity of a water sample.

Procedure

A. Materials

1. Turbidimeter consisting of a nephelometer with a light source for illuminating the sample and one or more photoelectric detectors with a readout device to indicate the intensity of light scattered at right angles to the path of incident light. Sensitivity of 0.02 units or less for readings under 1 unit. The instrument must measure from 0 to 40 units of turbidity.

B. Test Procedure

Refer to "Standard Methods for the Examination of Water and Wastewater" (1) (Nephelometric Method).

C. Reporting of Results

Report the test results on Form T-705.

SUSPENDED SEDIMENT CONCENTRATION ANALYSIS

Scope

This method describes the procedure for determining the relative amount of suspended sediment mixture as obtained from a suspended sediment sample of a river or lake.

Procedure

A. Apparatus

1. Platform Scale. A scale with a minimum capacity of 500 grams and sensitive to 1 gram.
2. Semi-micro analytical balance. A balance with 160 gram capacity and an accuracy of ± 0.1 mg.
3. An oven or other suitable thermostatically controlled heat-device capable of maintaining a temperature of 110°C (± 5° C).
4. Dessicator - 250 mm inside diameter constructed of heavy glass.
5. Aspirator System.

B. Materials

1. Crucibles, Size 4, 35 ml capacity, 25 mm bottom diameter and 0.6 mm diameter perforations.
2. Filter papers, grade GFA, glass fiber, 2.4 cm in diameter and .25 mm thickness.
3. Distilled water.

C. Test Record Form

Record test results on Form T-706.

D. Test Procedure (2):

1. Inspect the general condition of the samples as they are received. Loose caps should be replaced and bottles with dirty exteriors should be cleaned.
2. Store bottles in cool dark room.
3. Arrange samples from a given location in chronological order.
4. Record the sample identification from the bottle labels on the concentration form.
5. Each sample bottle should be weighed prior to use, by selecting a standard tare bottle and etching the weight difference as ± "X" grams on each sample bottle.
6. Using the standard tare, weigh the bottle and sediment mixture to the nearest gram. Apply the correction factor etched on the bottle and record the net weight on Form T-706.

7. Store the sediment samples overnight to assure that the sediment settles from suspension.
8. Decant most of the sediment free water using care not to disturb the sediment. An aspirator with a vacuum line is the preferred method for removing the sediment free water.
9. Prepare the proper number of crucible with filters. Seat each filter by placing the crucible in the aspirator system. Run a small amount of distilled water through the crucible and filter.
10. Place the crucibles in an oven at 110° C for 1 hour.
11. Remove the crucibles and place in a dessicator to cool to room temperature.
12. Weigh the crucibles to the nearest 0.1 mg on the balance and record as the tare weight of the sediment.
13. Use distilled water to wash the sediment from each bottle into the previously weighed crucible.
14. Dry the crucibles after all visible loss of water at 100° C for 1 hour. The crucibles must be dried at a temperature low enough to prevent "spattering" of the sediment from the crucible by boiling action.
15. Cool the crucibles to room temperature in a dessicator.
16. Weigh the crucibles to the nearest 0.0001 gram on an analytic balance and record as the gross weight of sediment.
17. Compute the net weight of the sample.
18. Compute the concentration of the sample in parts per million determined on the basis of one million times the ratio of the net weight of the sediment to the net weight of the water-sediment mixture.

E. Calculations

$$\text{Conc.} = C \frac{\text{net wt. of dry sediment}}{\text{net wt. of water sediment mixture}} \times 10^6$$

F. Reporting of Results

The results are reported in mg/l which is equivalent to ppm for concentrations under 15,900 ppm. For values over 15,900 ppm a correction factor "C" must be applied as shown in the table below.

Table 11
Sediment Concentration Correction Factors

Factors C for computation of sediment concentration in milligrams per liter when used with parts per million or the ratio (times 10^6) of the weight of sediment to the weight of the water-sediment mixture

[The factors are based on the assumption that the density of water is 1.000, plus or minus 0.005, the range of temperature is 0°-29°C, the specific gravity of sediment is 2.65, and the dissolved solids concentration is less than 10,000 parts per million]

Ratio	C	Ratio	C	Ratio	C
0- 15, 900	1. 00	234, 000-256, 000	1. 18	417, 000-434, 000	1. 36
16, 000- 47, 000	1. 02	257, 000-279, 000	1. 20	435, 000-451, 000	1. 38
47, 000- 76, 000	1. 04	280, 000-300, 000	1. 22	452, 000-467, 000	1. 40
77, 000-105, 000	1. 06	301, 000-321, 000	1. 24	468, 000-483, 000	1. 42
106, 000-132, 000	1. 08	322, 000-341, 000	1. 26	484, 000-498, 000	1. 44
133, 000-159, 000	1. 10	342, 000-361, 000	1. 28	499, 000-513, 000	1. 46
160, 000-184, 000	1. 12	362, 000-380, 000	1. 30	514, 000-528, 000	1. 48
185, 000-209, 000	1. 14	381, 000-398, 000	1. 32	529, 000-542, 000	1. 50
210, 000-233, 000	1. 16	399, 000-416, 000	1. 34		

If several samples are collected per stream cross-section, the weighted concentration is found by

$$(\text{Conc.}_1)\ (q_1) = \text{wt. Conc.}_1$$
$$(\text{Conc.}_2)\ (q_2) = \text{wt. Conc.}_2$$
$$(\text{Conc.}_n)\ (q_n) = \text{wt. Conc.}_n$$

Conc. for cross-section

$$C_s = \frac{\sum_{i=1}^{n} (\text{wt,Conc.}_i)}{Q_w}$$

C_s = Weighted mean concentration of sediment in mg/l

Q_w = Streamflow in cfs

The concentration from this test is used in various sediment transport formulas to compute the instantaneous sediment discharge rate of the stream. See "Data Analysis, Section VII" for sample computations.

CALIFORNIA DIVISION OF HIGHWAYS-MATERIALS & RESEARCH DEPARTMENT-ENVIRONMENTAL IMPROVEMENT SECTION

SEDIMENT CONCENTRATION NOTES, DEPTH INTEGRATED SAMPLES

Project _____ (DIST) _____ (CO.) _____ (RTE.) _____ (P.M.) Location _____ Calc. By _____ Chkd. By _____ Date _____

Date											
Time											
Gage height											
Sampling Sta.											
Sampled By											
Temp. & Spec. Cond.	/	/	/	/	/	/	/	/	/	/	
Remarks											
WEIGHT OF SAMPLE	Gross										
	Tare										
	Net										
Container no.											
WEIGHT OF SEDIMENT	Gross										
	Tare										
	Net										
	D.S. corr.										
	Net										
Conc. (ppm)											

Date											
Time											
Gage height											
Sampling Sta.											
Sampled By											
Temp. & Spec. Cond.	/	/	/	/	/	/	/	/	/	/	
Remarks											
WEIGHT OF SAMPLE	Gross										
	Tare										
	Net										
Container no.											
WEIGHT OF SEDIMENT	Gross										
	Tare										
	Net										
	D.S. corr.										
	Net										
Conc (ppm)											

HMRT-706 (Orig. 6-72)

METHODS FOR SIZE ANALYSIS OF SEDIMENT

Scope

This method describes the test procedure for determining the size distribution of a suspended sediment sample.

Procedure

A. Apparatus

1. Hand vibrator.
2. Semi-micro analytical balance of ± 0.1 mg accuracy.
3. 3 inch or 8 inch (for bed material) U.S. Standard Sieve Series.
4. An oven or other suitable thermostatically controlled heating device capable of maintaining a temperature of 110°C (± 5°C).
5. Dessicator - Minimum 250 mm inside diameter constructed of glass.

B. Materials

1. Evaporating dishes.
2. Distilled water.

C. Test Record Form

Record Test Results on Form T-708.

D. Test Procedure

1. Assemble 9 clean, dry evaporating dishes and label each with a corresponding sieve size including the pan. Also label each of the dishes with the appropriate test number.
2. After labeling, weigh each dish to .001 gm on an analytic balance and record its weight on Form T-708 as the sample tare weight.
3. Select the 4 mm sieve. Carefully wash the sediment from the previously decanted bottle (or bottles). Collect the water sediment mixture with particles smaller than 4 mm in a clean dry beaker.
4. After the sample bottle has been thoroughly washed of all sediment particles, vibrate the sieve while gently adding distilled water until the water flowing from the sieve is completely clear to the eye.
5. Carefully wash with distilled water the material retained on the 4 mm screen into the evaporating dish marked 4 mm.
6. Using the beaker of collected sediment and water with particles sizes less than 4 mm, repeat steps 4 and 5 with the 2 mm size. Follow this procedure for each sieve size placing the material that passes the .062 mm sieve in the dish marked "pan".

7. Place the evaporating dishes into an oven and dry for 1 hour at 110°C after all visible water has evaporated. The dishes must be dried at a temperature low enough to prevent "spattering" of the sediment from the dish by boiling action.
8. Cool the dishes to room temperature in a dessicator.
9. Weigh each dish to the nearest 0.0001 gm and record as the gross weight of the sample.
10. Calculate the net weight for each size, compute the percent of the total retained on each sieve, and compute the percent finer for each size.

E. Calculations

$$\% \text{ total} = \frac{\text{Net wt. retained on sieve}}{\text{Total sample wt.}}$$

Total sample wt. = Sum of the net weights retained on each sieve.

% Finer = 100% - % retained on sieve.

F. Reporting Results

The results calculated as shown are plotted on the particle size analysis graph on Form T-708. This information can then be used with various formulas to calculate the suspended sediment load of a stream. See "Analysis of Results Section" of the Water Quality Manual for sample computations.

SIEVE ANALYSIS

CALIFORNIA DIVISION OF HIGHWAYS

MATERIALS & RESEARCH DEPARTMENT – ENVIRONMENTAL IMPROVEMENT SECTION

DIST. CO. RTE. P.M. Work Order

Drainage Basin

Location

Remarks:

Date

Mean Vel.

Discharge

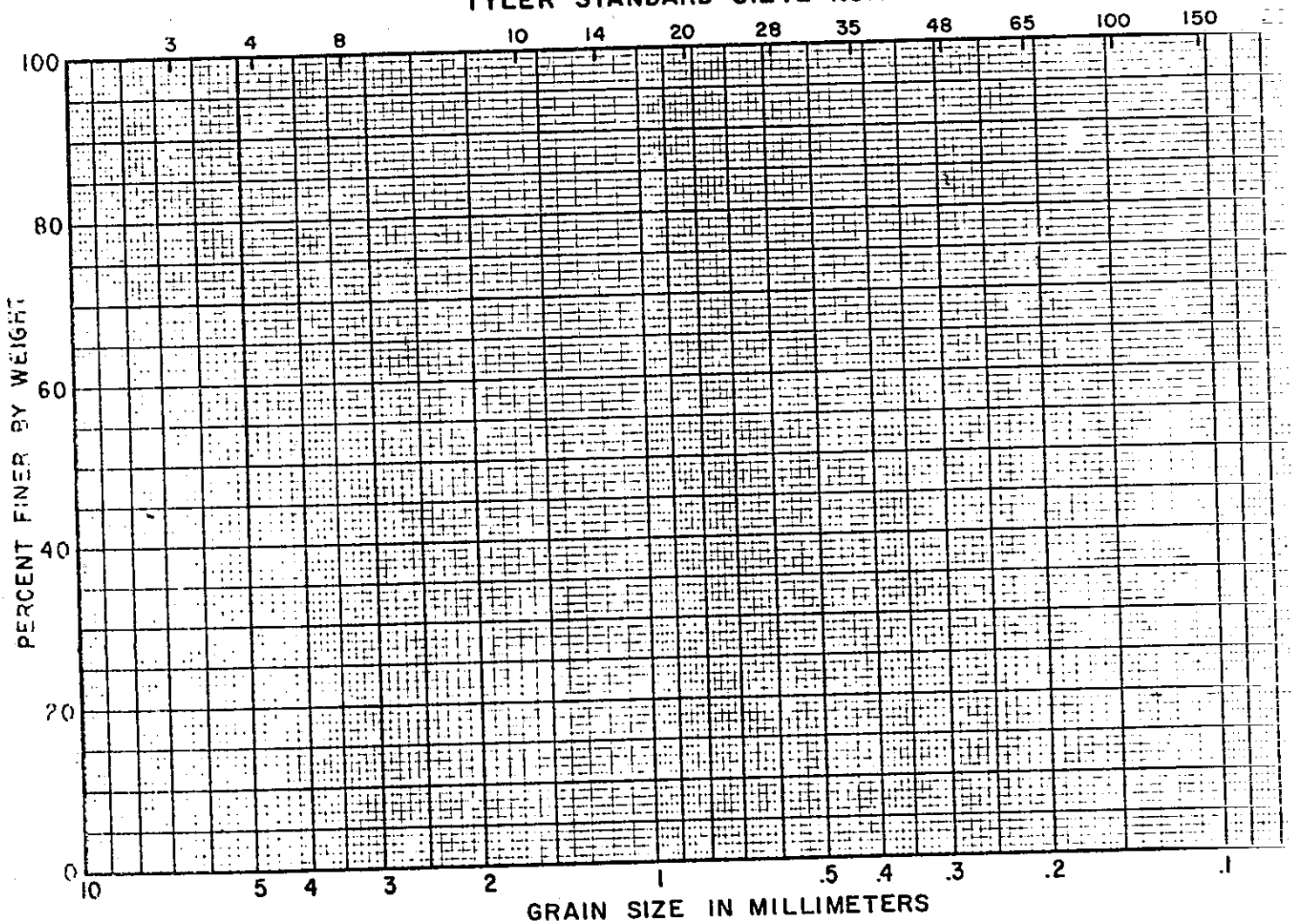
Sample No.

SIEVE ANALYSIS

Size, mm.		8	4	2	1	.5	.25	.125	.062	PAN
Weight, gm.	Gross									
	Tare									
	Net									
% of total										
% finer than										
% in class										
Container no.										

GRAIN SIZE DISTRIBUTION

TYLER STANDARD SIEVE NUMBERS



HMR T-708 (Orig 6-72)

Field Tests for Water Quality Analysis

The selection of specific tests for the analysis of water quality depends primarily on engineering judgment. Each drainage basin is unique and the objective of field testing is to develop sufficient data to describe adequately the existing conditions and to locate potential problem areas. The tests should be conducted with care, following the manufacturer's instructions and performing the indicated checks for ion interference, etc.

The following list contains those parameters generally considered as the most common indicators of water quality in the absence of gross pollution:

Parameter	Comments
1. Temperature	An important field test. Daily and Seasonal variations should be established.
2. Turbidity	Test monthly under uniform conditions plus additional samples for periods of changing streamflow.
3. pH	Test monthly under normal conditions. However, perform a pH test each time the sampling location is visited.
4. Alkalinity	Test monthly unless problems are anticipated (water used for drinking).
5. Hardness	Test monthly unless problems are anticipated (water used for drinking).
6. Chloride ion	Test monthly unless stream has an unusually high chloride level.
7. Dissolved oxygen	In fishable waters test for D.O. frequently. Since D.O. levels vary considerable during a 24 hr. period in polluted waters, daily as well as seasonal variations must be established.
8. Silica	Test monthly under normal conditions.
9. Nitrogen (Nitrate and Nitrite)	In sensitive areas such as Lake Tahoe test for Nitrogen frequently to determine seasonal variation. For other streams monthly tests should be sufficient.

10.	Phospate (Ortho, Meta and Total)	In sensitive areas such as Lake Tahoe, test for Phosphates frequently to establish seasonal variations.
11.	Sulfate	Test monthly under normal conditions.
12.	Coliform Group	" " " " "
13.	Biochemical Oxygen Demand	" " " " "
14.	Aquatic Organisms	Survey seasonally as a minimum.

It should be noted as a reminder that tests conducted with portable field kits serve only as indicators of problem areas. If documented data is required, water samples should be sent to a qualified laboratory for analysis.

The following tables indicate the type of preservative to use and maximum holding time before analyzing the water sample (3):

Table 12

PRESERVATIVE

Preservative	Action	Applicable to:
$HgCl_2$	Bacterial Inhibitor	Nitrogen forms, Phosphorus forms
Acid (HNO_3)	Metals solvent, prevents precipitation	Metals
Acid (H_2SO_4)	Bacterial Inhibitor	Organic samples (COD, oil & grease, organic carbon, etc.)
Alkali (NaOH)	Salt formation with organic bases	Ammonia, amines
	Salt formation with volatile compounds	Cyanides, organic acids
Refrigeration or freezing	Bacterial Inhibitor	Acidity - alkalinity, organic materials, BOD, color, odor, organic P, organic N, carbon, etc., biological organisms (coliform, etc.)

In summary, refrigeration at temperatures near freezing or below is the best preservation technique available, but is not applicable to all types of samples.

Table 13

MAXIMUM HOLDING PERIOD

Parameter	Preservative	Maximum Holding Period
Acidity-Alkalinity	Refrigeration at 4°C	24 hours
Biochemical Oxygen Demand	Refrigeration at 4°C	6 hours
Calcium	None required	7 days
Chemical Oxygen Demand	2 ml H_2SO_4 per liter	7 days
Chloride	None required	7 days
Color	Refrigeration at 4°C	24 hours
Cyanide	NaOH to pH 10	24 hours
Dissolved Oxygen	Determine on site	No holding
Fluoride	None required	7 days
Hardness	None required	7 days
Metals, Total	25 ml conc. HNO_3 per liter	6 months
Metals, Dissolved	Filtrate: 25 ml conc. HNO_3 per liter	6 months
Oil and Grease	2 ml H_2SO_4 per liter - 4°C	24 hours
pH	Determine on site	No holding
Phenolics	1.0 g $CuSO_4$/l + H_3PO_4 to pH 4.0 - 4°C	24 hours
Solids	None available	7 days
Specific Conductance	None required	7 days
Sulfate	Refrigeration at 4°C	7 days
Sulfide	2 ml Zn acetate per liter	7 days
Threshold Odor	Refrigeration at 4°C	24 hours
Turbidity	None available	7 days

The evaluation of an aquatic environment involves a comparison of the living community at one location with that in another (4). Procedures for collecting organisms are contained in Standard Methods (1) and Limnological Methods (Welch, 1948). The sample should be representative of the area sampled. Specialized sampling gear such as the Surber square foot sampler, Ekman and Petersen Dredge should be used. Normally, for a stream 50 feet wide, five locations across the stream should be selected with three samples obtained at each location. The following form can be used to record the organisms.

Biological Data - Bottom Forms
(Benthos and Periphyton)

Station: _____ Date: _____ Time: _____

Sample No.	Unit	No. Spp.	No. Ind.

1. Insects		2. Other Invertebrates	
Kinds	No. or Rel. Abundance*	Kinds	No. or Rel. Abundance*

How collected: _____

Nature of bottom: _____

*+ = present a = abundant

c = common d = dominating

Presence of plants and algae should also be recorded if observed. Diatoms normally appear in the spring, green algae in the summer and blue-green algae in the fall. This can be used as a rule of thumb. Nutrients contribute to algae and plan growth. Identification of biologic species, algae, and bacteria require specialists trained in each respective area.

References Section VI

1. "Standard Methods for the Examination of Water and Waste Water", American Public Health Association, American Water Works Association, Water Pollution Control Federation, 13th Edition, 1971.

2. "Laboratory Theory and Method for Sediment Analysis", U.S. Geological Survey, 1969.

3. "Collection and Preservation of Samples for Analysis by Consolidated Laboratory Services", U.S. Environmental Protection Agency.

4. "A Guide to the Study of Fresh-Water Biology", by Needham and Needham, 5th Edition, Holden-Day, 1966.

SECTION VII

DATA ANALYSIS

SECTION VII
DATA ANALYSIS

Water quality data from the field and laboratory is analyzed to determine quantitative information for use in the environmental impact statement. Section VII discusses some of the methods used to compute sediment transport rates, results of chemical and biological analyses, computer programs, and a brief introduction to methods of conducting slope erosion transect surveys.

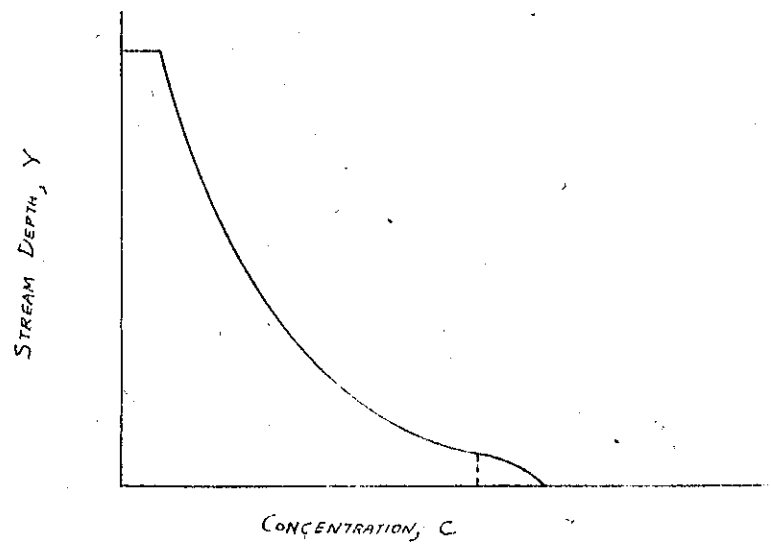
Suspended Sediment Transport

Suspended sediment samples obtained from streams are analyzed in the laboratory for concentration of suspended particles. The following formula indicates the relationship (1):

$$\text{Concentration (mg/l)} = C\text{(ppm)} = C \left[\frac{\text{Weight of Sediment} \times 10^6}{\text{Weight of Water-Sediment Mixture}}\right]$$

The factors for "C" in the computation of sediment concentration are given in Table 12 (1).

There are several relationships that have been developed which can be used to determine sediment transport rates. Each method, however, was developed for certain conditions and hence it is important to know the limits with which the various formulas can be used. The general relationship for analyzing sediment concentrations in a moving fluid is expressed by (2):



$$\frac{C}{C_a} = \left[\frac{d-y}{y}\,\frac{a}{d-a}\right]^z$$

where $Z = \frac{W}{BKU^*}$

The terms in the above equation are defined as follows:

C = Concentration

C_a = Concentration at depth "a"

d = Water depth

y = Distance from bottom

a = Level at which y=a

W = Settling velocity of a particle

B = Numerical constant equal to the diffusion coefficient divided by the momentum coefficient $\varepsilon_s/\varepsilon_n$

K = Von Karman universal constant

U^* = Shear velocity

The suspended particles are kept in suspension by the turbulent forces of the water.

Many factors enter into the determination of sediment transport phenomena. For the practical estimation of suspended sediment transport, the following procedure is recommended.

Instantaneous sediment discharge can be determined from the following relation (3):

$$Q_s = Q_w\, C_s\, K$$

where Q_s = Sediment discharge in English short tons per day

Q_w = Water discharge in cubic feet per second

C_s = Discharge-weighted mean concentration in mg/l

K = 0.0027 (for concentration in mg/l)

The computation of instananeous suspended sediment transport for a given stream flow is performed over a range of flows for a given watershed. A sufficient range of flows are included in order to provide enough sediment information to develop a relationship between streamflow and sediment discharge.

This procedure is normally referred to as the sediment-rating curve, flow-duration curve method of estimating sediment yield (4). Experience with the field use of this method appears to be sufficiently accurate for practical application.

One important requirement in addition to obtaining adequate sediment samples for this procedure, is to obtain sufficient streamflow information from which an analysis of sediment discharge can be based. Inadequate knowledge of streamflow will reduce the reliability of the data upon which the results are reported.

For most sampling sites in highway environmental impact studies, methods have been established for estimating flows in conjunction with sediment monitoring programs. In cases where a staff gage has been placed in the stream or a float stage gage has been installed, a Stage-Discharge curve will be developed to determine streamflows. A Stage-Discharge Curve is shown in Figure 36.

Generally, the curve is developed by using semi-logarithmic paper with the discharge plotted as the abscissa (Log) and stage as the ordinate. The use of a semi-log plot will result in a linear curve. For a more complete discussion of developing Stage-Discharge Curves, refer to texts on the subject (5).

For automatic recording streamflow gages, a continuous water height record will be recorded on tape. However, for staff gages that must be read manually and the data recorded, all streamflow flucuations may not be recorded thus reducing the accuracy of the data.

It is recommended that for staff gages a diurnal flow measurement be performed periodically throughout the course of a study. Measurements taken at set time intervals such, as every hour, will produce the daily discharge changes versus time (6). Analysis of diurnal flow fluctuations will assist in determining the actual discharge from recorded data.

A sediment rating curve can be developed from the instantaneous sediment discharges and known streamflows (7). This curve, shown in Figure 37, is a relationship between suspended-sediment load (in tons/day) and the stream discharge (in cfs). The relationship is a log-log plot.

Figure 36

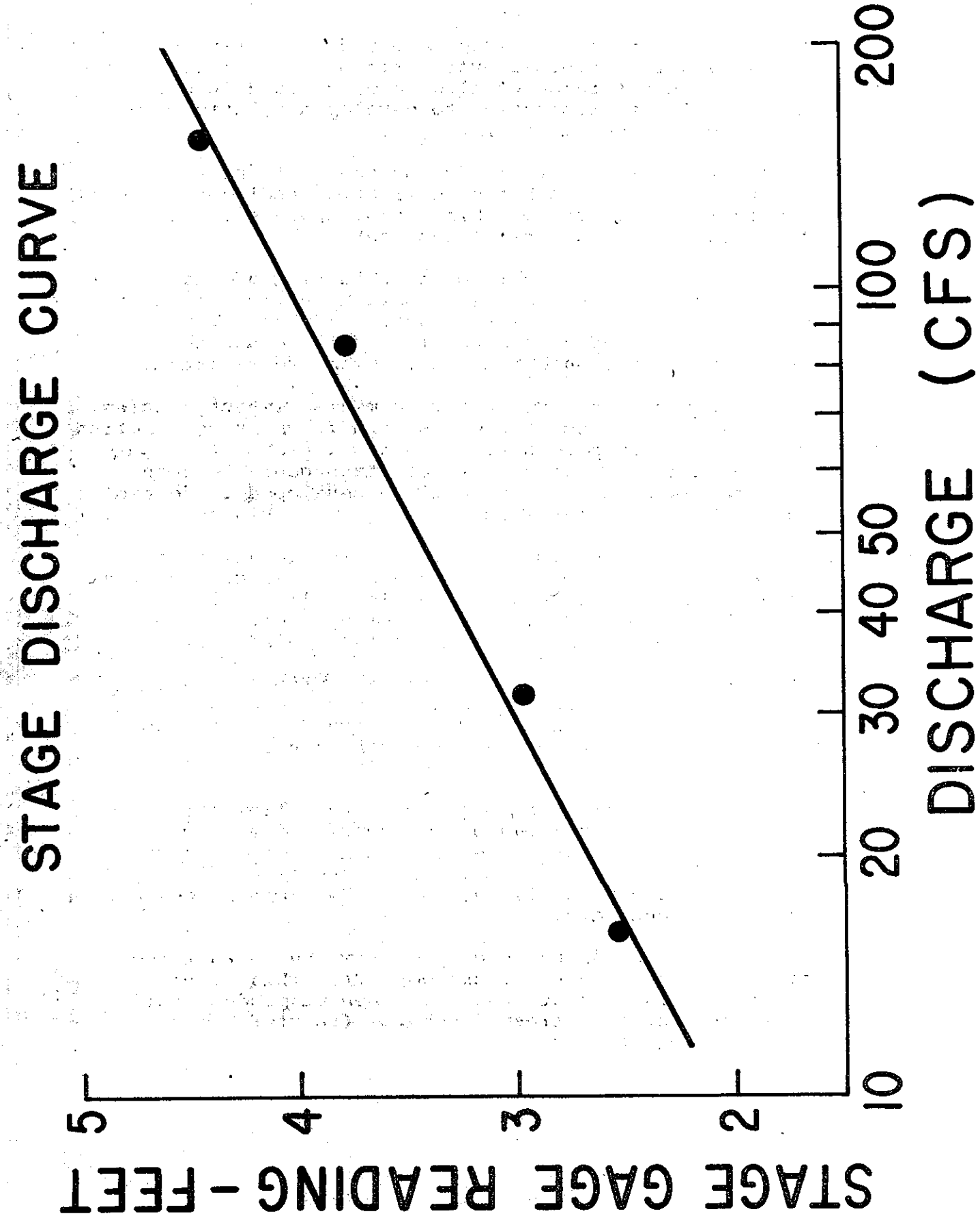
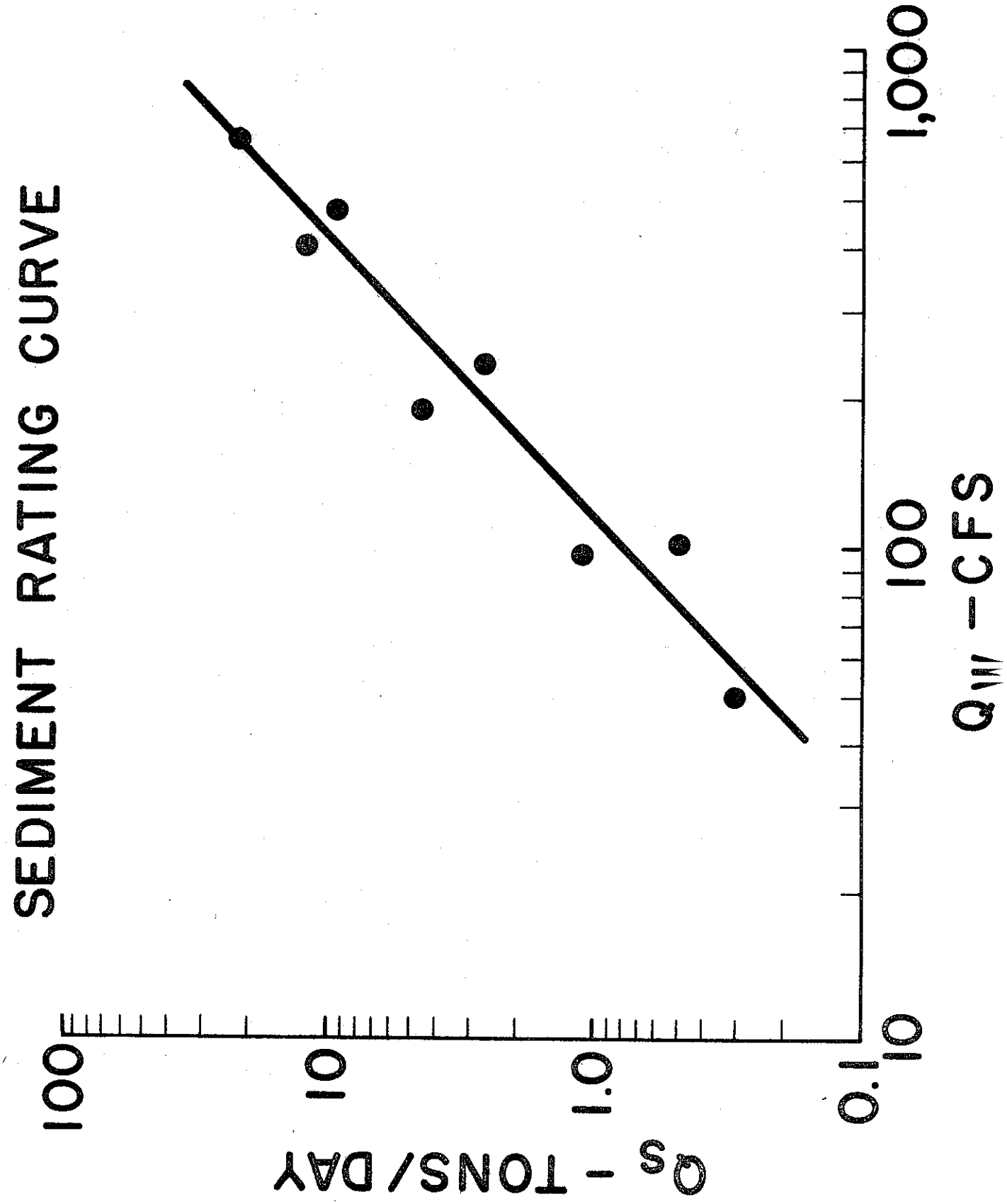

STAGE DISCHARGE CURVE
STAGE GAGE READING - FEET
5
4
3
2
10
20
30
40
50
100
200
DISCHARGE (CFS)

Figure 37


SEDIMENT RATING CURVE
100
10
1.0
0.1
Q_s - TONS/DAY
10
100
1,000
Q_w - CFS

Generally, the plotted data have quite a scattering affect. This can be attributed to discharges that are caused by varied hydrologic events including snowmelt, shape and size of watershed, and rainfall intensities.

Thus for a given discharge, there may be several suspended-sediment rates determined. Utilizing a mean monthly flow rate or daily rate will tend to balance-out these varying rates.

It has been found that the sediment concentration is greater for a dry year than it is in a wet year. Any one year of less than 90% of mean discharge may present a problem in computing a reliable mean sediment load (4).

To calculate the sediment transport rating curve, a linear-regression analysis is performed on the data (6). The data that is needed includes the instantaneous sediment load (Q_s) as "y" values and streamflow discharge (Q_w) as "X" values.

Two computer programs can be used on the Tenet state time-share system: LINREG and CURFIT. If the LINREG is used, the "y" and "X" values must be converted to logarithims first. For the CURFIT program, actual values may be used and the logarithim equation designated. In both cases, the correlation coefficient and the index of determination should be computed also.

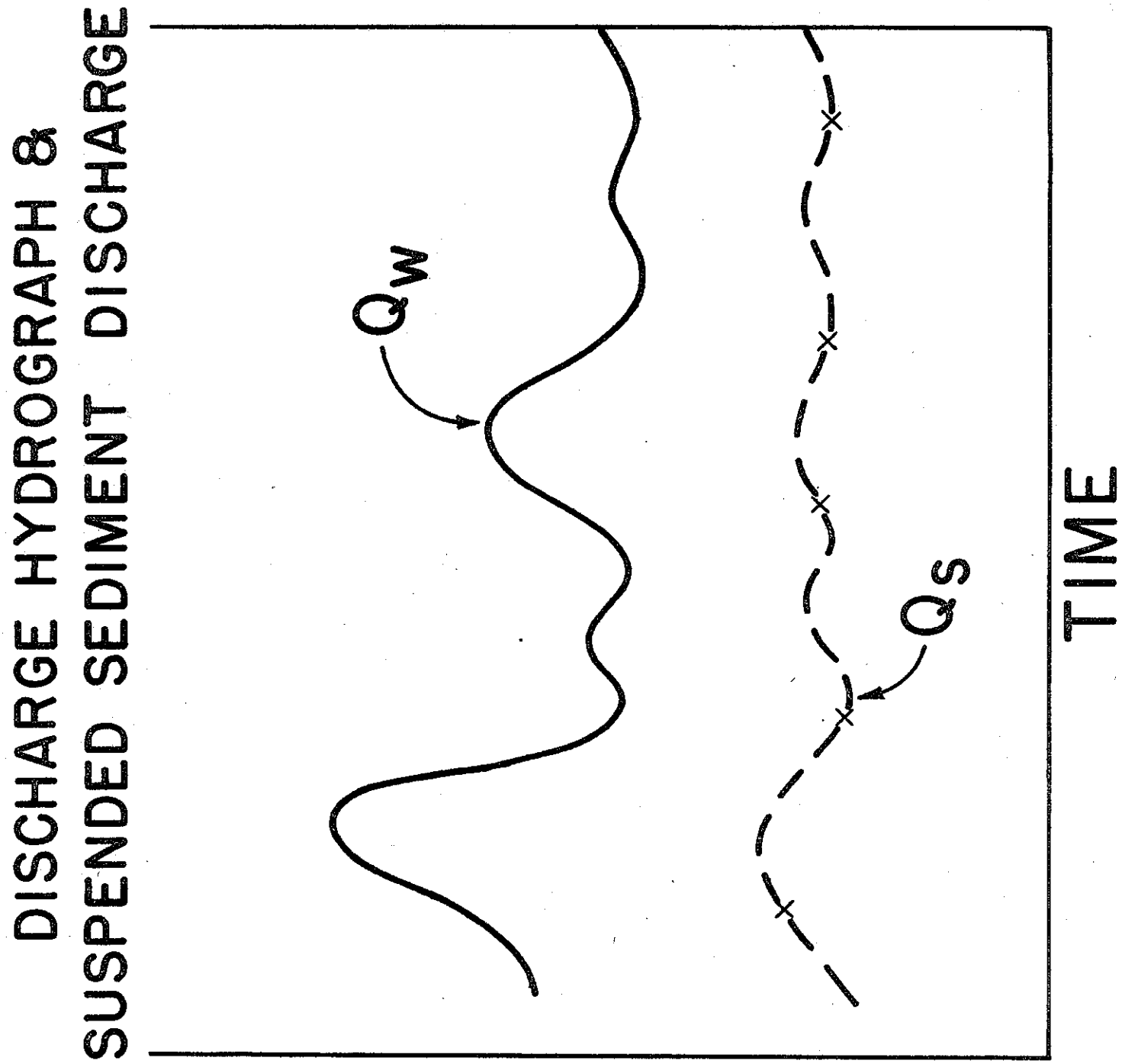
The equation developed by the computer is then plotted on the sediment transport rating curve as shown in Figure 37.

The streamflow data is compiled either on a continuous, daily or mean monthly basis. For each flow, enter the sediment rating curve and find the Q_s value. This value represents the sediment transport for that flow period in tons/day.

A plot of the streamflow versus time is now made as shown in Figure 38. The discharge (Q_w) is plotted as the ordinate and time as the abscissa. On the same graph, values of sediment transport rates, as determined from the sediment rating curve, are also plotted versus time. These values are shown on Figure 38 as "X" marks. To complete the curve, experience indicates that the curve shape will closely follow the "Q_w" curve. In other words, a rise in streamflow may be accompanied by a rise in Qs and vice-versa. Specific values of sediment transport can also be selected from the sediment rating curve. The method used will depend upon the frequency of actual data points and experience (4).

To obtain total suspended sediment load, the area under the sediment transport curve is determined for a given period of time. Normally, the reporting period is for a water year which

Figure 38


DISCHARGE HYDROGRAPH &
SUSPENDED SEDIMENT DISCHARGE
Q_W
Q_S
TIME

runs from October 1 to September 30. For intermittent flowing streams, the time period may include only that interval for which discharges occur.

From the foregoing discussion on sediment transport determinations, it can be seen how important it is to obtain sufficient data points and also how important the need to obtain field data over a wide range of flows. The frequency and type of sampling along with installation of staff gages or permanent recording stream gages will be governed at the beginning of a study by the estimated impact the proposed facility will have on the environment. In regions where the impact may be significant, it is recommended permanent recording gages be installed if there are no existing gages that can be used.

A sample calculation will assist in understanding the recommended procedure for determining suspended sediment transport.

Example: A small stream may be impacted during the course of constructing a new highway facility. For this reason, the project engineer has selected a sampling site and installed a staff gage downstream from the proposed site to obtain streamflow and suspended sediment data. The intermittent stream flowed only during the months of May, June, July and August.

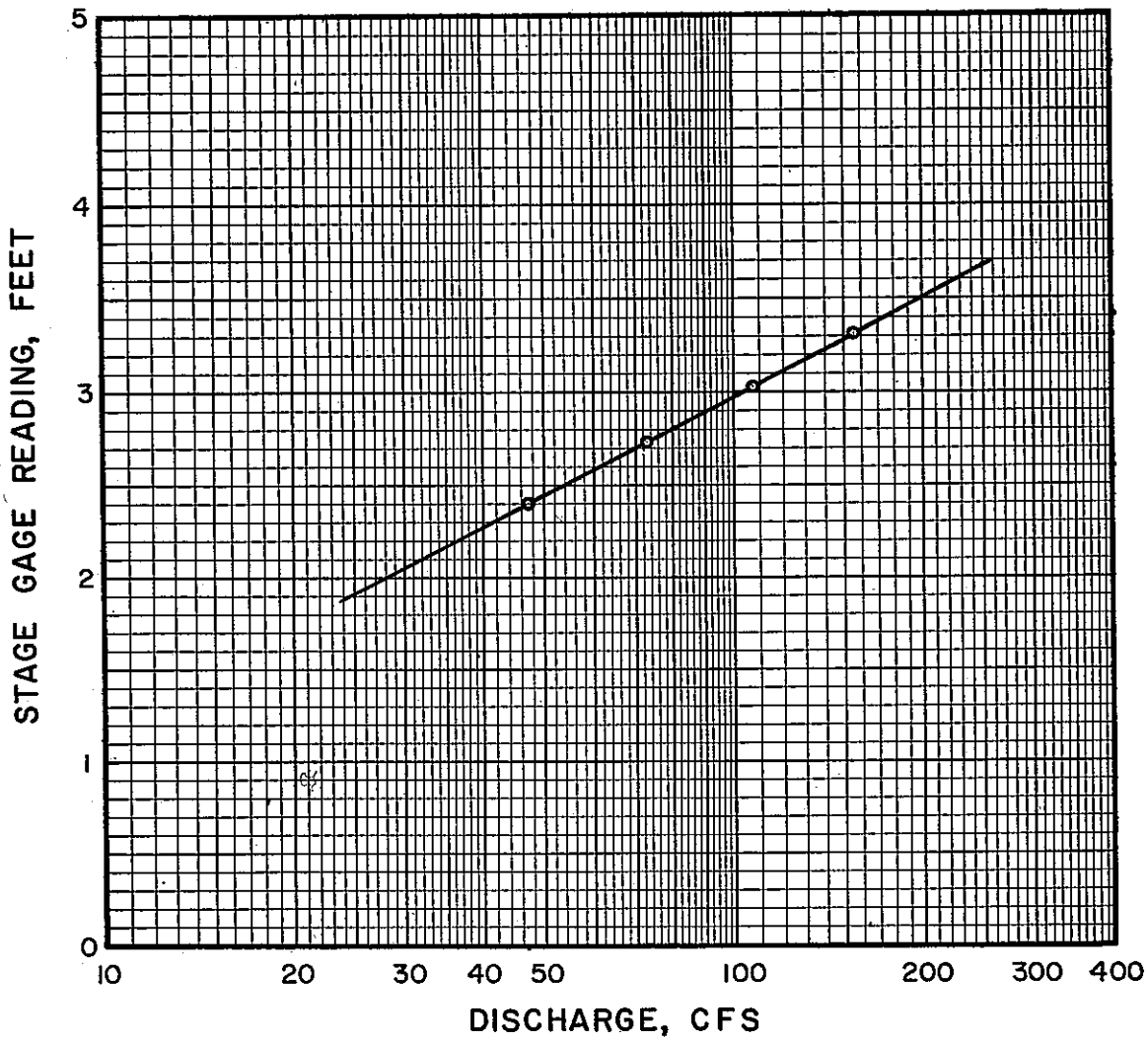
The following data was obtained from the staff gage:

Date	Gage Height	Measured Flow
May 24, 1970	2.3 feet	
30	2.4	47 cfs
June 6, 1970	2.5	
7	2.5	
9	2.5	
12	2.5	
20	2.6	
21	2.5	
22	2.4	
23	2.4	
26	2.4	
27	2.4	
28	2.4	
29	2.6	
30	2.7	
July 3, 1970	2.8	
4	2.7	
5	2.73	72
6	2.7	
7	2.7	

Date	Gage Height	Measured Flow
July 8, 1970	2.81	
9	2.81	
10	3.3	
11	3.1	
12	3.03	
13	3.3	
14	3.1	
17	3.1	
18	3.02	105
19	3.3	
July 20, 1970	3.4	
21	3.1	
24	3.6	
25	3.3	152
26	3.4	
August 3, 1970	2.78	
7	3.15	
16	3.6	
20	3.35	
23	3.25	

A stage-discharge curve for the above recorded data is shown in the following graph:

STAGE - DISCHARGE CURVE



The streamflow values for the other dates can be determined from the stage-discharge curve.

Date	Streamflow	Date	Streamflow
5/24/70	41 cfs	7/8/70	81
30	47	9	81
6/6/70	53	10	152
7	53	11	118
9	53	12	104
12	53	13	152
20	60	14	118
21	53	17	118
22	47	18	105
23	47	19	152
26	47	20	175
27	47	21	118
28	47	24	227
29	60	25	152
30	69	26	175
7/3/70	79	8/3/70	77
4	69	7	125
5	72	16	228
6	69	20	164
7	69	23	144

Mean daily flows are now calculated by averaging streamflow data for the entire month. The following results are obtained:

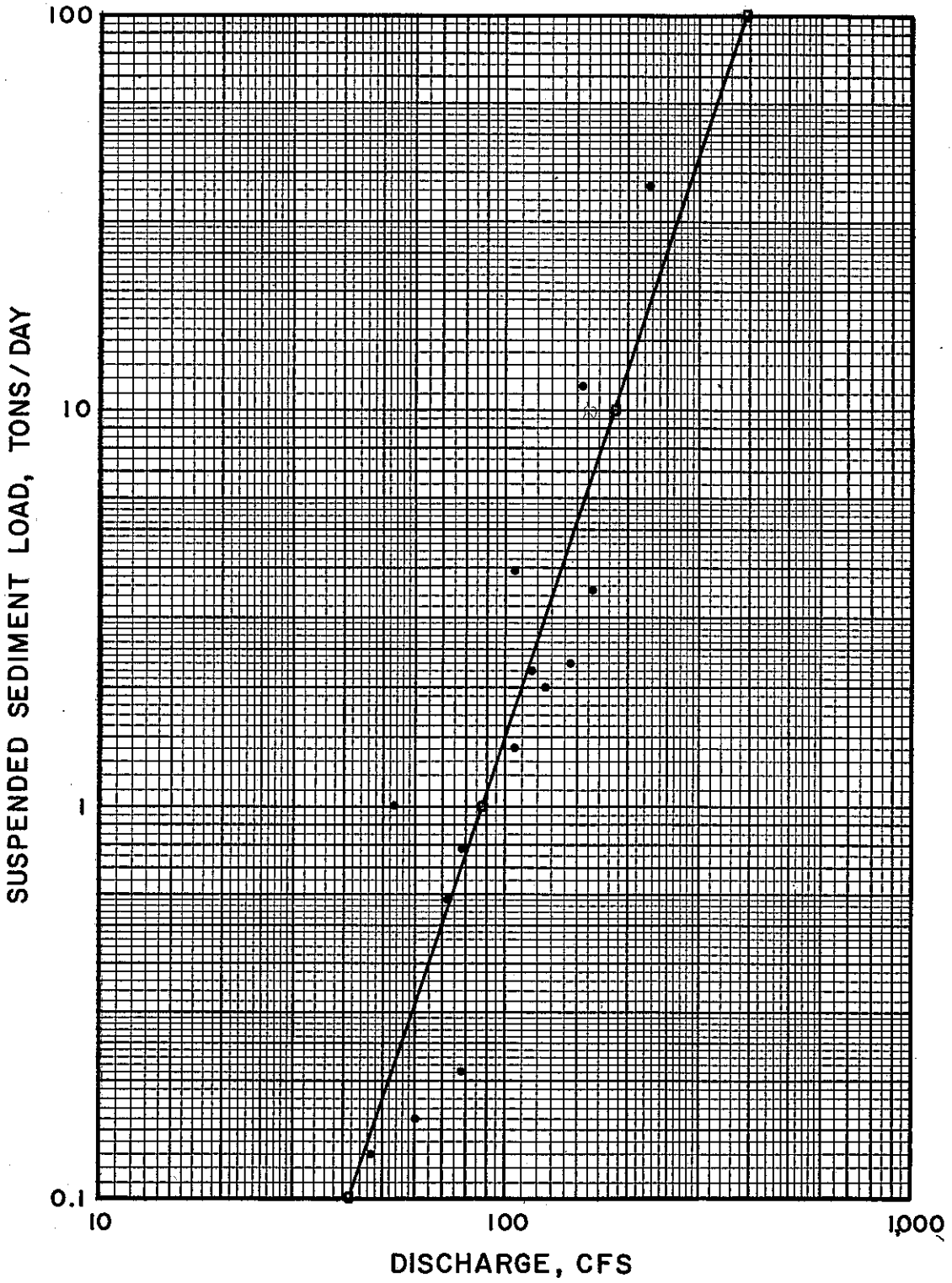
	Mean Daily Flow (cfs)		
May	June	July	August
44	53	119	148

Suspended sediment samples were taken on the following dates and laboratory analysis yields the following concentrations. Use of the instantaneous suspended sediment formula gives the Q_s values.

Date	mg/l Conc.	tons/day Q_s	Date	mg/l Conc.	tons/day Q_s
6/6/70	7.0	1.0	7/25/70	11.5	11.0
20	1.0	.16	8/3/70	1.0	0.21
28	1.0	.13	7	6.0	2.0
7/3/70	4.0	.85	16	60.0	37.0
5	3.0	.58	20	8.0	3.5
12	14.0	3.9	23	3.0	1.2
14	7.0	2.2	9/1/70	3.0	0.55
18	5.0	1.4			

This data combined with stream discharge information is plotted to make a sediment rating curve as shown in the next figure.

SEDIMENT RATING CURVE



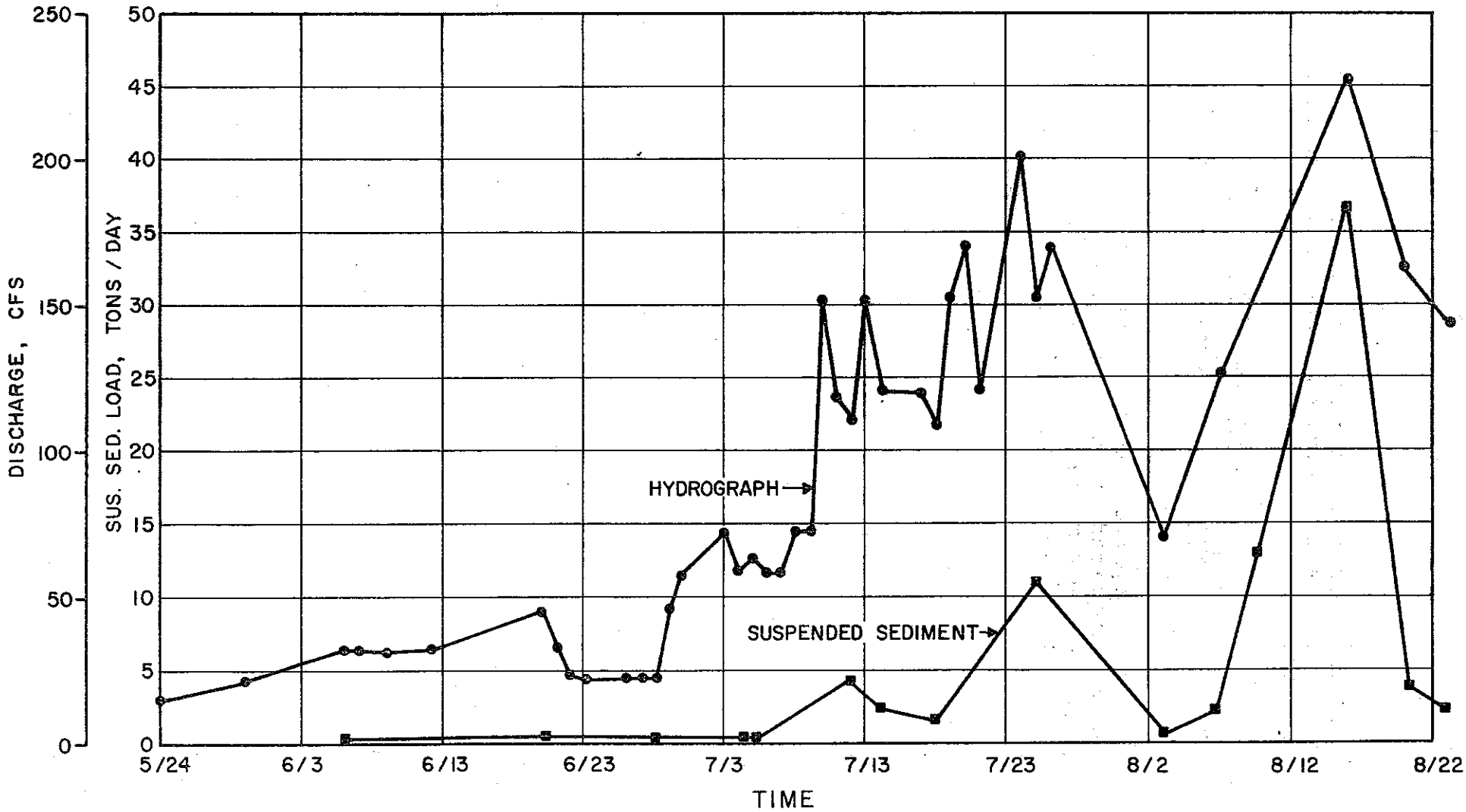
A linear regression analysis using LINREG results in the following equation which is plotted as a straight-line function.

$$Y = -5.94957 + 3.06214\ x$$

The correlation coefficient is 0.89 which represents a good curve fit.

A plot of the streamflow discharge and sediment transport is shown below.

DISCHARGE HYDROGRAPH AND SUSPENDED SEDIMENT DISCHARGE



Using the mean daily discharges and the sediment rating curve results in the following estimate of the monthly sediment discharge:

Suspended Sediment (Tons)				
May	June	July	August	Total
1.1	6.6	77.5	155.0	240.2

The total suspended sediment discharge of 240 tons/year is the quantity reported for the natural state of the stream. This number can be compared with the estimated tons of sediment transported from highway sources.

Bedload

The bedload is the material that rolls, slides and skips along the bottom of the stream. It consists generally of the larger diameter particles although this is not always the case. In laboratory flume studies, particles of the same size were observed to move as both bedload and suspended sediment.

The transport of sediment along the stream bottom occurs when the tractive force (τ) on the particle exceeds or equals the critical tractive force (τ_c) required to initiate motion. This is, of course, true for noncohesive soils (8). Tractive force is defined by the following relationship:

$$\tau = \gamma d\ s$$

where γ = specific weight of water

d = depth of flow of water

s = slope

To explain the relationship of the forces acting on a particle along the bed of a stream, refer to Figure 39 (8).

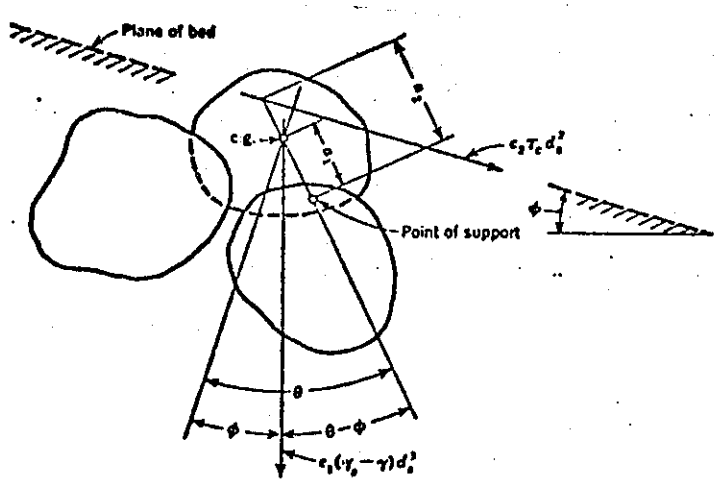


Figure 39

Forces on sediment grain in bed of sloping stream.

From this figure, the following relationship is developed for the critical tractive force:

$$\tau_c = \frac{c_1 a_1}{c_2 a_2} (\gamma_s - \gamma) d_s \cos \phi \ (\tan \theta - \tan \phi)$$

For determining the bedload transport rates in analysis of highway impact studies, the Meyer-Peter, Muller equation may be used.

The basic Meyer-Peter, Muller equation in metric terms is (9):

$$\gamma_w \left(\frac{Q_s}{Q}\right) \left(\frac{k_s}{k_r}\right)^{3/2} dS = A'' \gamma_s'' D_m = B'' \left(\frac{\gamma_w}{g}\right)^{1/3} g_s''^{2/3}$$

where γ_w = specific weight of water (metric tons per cubic meter)

Q_s = water discharge quantity determining the bedload transport (liters per second)

Q = total water discharge quantity (liters per second)

k_s = the bed roughness parameter (meters$^{1/3}$ per second)

k_r = particle roughness = $\frac{C}{D_{80}^{1/6}}$ (meters$^{1/3}$ per second)

where $C = 26$ (meters$^{1/2}$ per second)

d = depth of flow (meters)

S = slope of the energy line

A'' = dimensionless constant 0.047

γ_s'' = specific weight of sediment in water = $\gamma_s - \gamma_w$ (metric tons per cubic meter)

D_m = effective diameter of bed material (meters)

$D_m = \frac{\Sigma D \Delta p}{100}$ where D is average size of particles in a size fraction and p is percent in that size fraction

B'' = dimensionless constant 0.25

g = acceleration due to gravity (meters per second^2)

g_s'' = the specific bedload transport weighed under water (metric tons per meter of width per second)

The U.S. Bureau of Reclamation has developed a form for use in computing the bedload transport for one discharge (9).

Note that the size analysis of the bed material must be known as well as the stream discharge, depth, width, slope, and Mannings roughness coefficients for the total stream and channel sides. The nomograph required to complete the computation are contained in reference 9.

If the flow-duration of a stream is known, the annual bedload transport can be determined using the form established by the U.S. Bureau of Reclamation.

Note that the bedload computation for one discharge will give results in tons/day whereas using the flow-duration relationship will give the yield in tons/year.

Other relationships for calculating bedload transport have been developed by Kalinske, Shields, Schoklitsch, etc., and the reader is referred to the literature for a more complete discussion of their methods (10).

Turbidity

Turbidity in water is caused by the presence of suspended matter, such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms (12). Turbidity is an optical property of the water and is generally measured by the nephelometric method.

Turbidimeters measure the light scattering in a water sample and record the turbidity in Jackson Turbidity Units as standardized against Formazin polymer.

Normally, an excess of 5 units of turbidity is the level at which the turbidity characteristic becomes objectionable to a considerable number of people for drinking water purposes (13).

The California Department of Fish and Game has found that both fishing pressure and catch of Salmon and steelhead drops to essentially zero in the North Coastal area when the turbidity exceeds 30 Jackson Turbidity Units (14).

Other levels may be established by state or local authorities for specific locations.

A sediment study performed at Lake Tahoe during the Spring 1971 snowmelt runoff found no correlation between suspended sediment and turbidity measurements (6). However, a recent study on the Eel River in Northern California by the U.S. Geological Survey, a relation was found between turbidity, density and other fluid properties of a water and sediment mixture and the concentration of suspended sediment (14).

Chemical Composition

In Section VI, laboratory testing, results of chemical analyses of water were reported for various constituents. There are not any specific calculations to perform outside of those listed under each test method.

Various levels or limits for chemical composition of water have been published and are available from local health authorities and regional water boards. The exact criteria is largely dependent upon the specific water useage. For domestic or drinking water, the most restrictive limits are based on protection of the public health.

Other limits are established for irrigation water, agriculture, industrial useage, etc. The following table presents some guidelines for water quality standards.

TABLE 14

CHEMICAL QUALITY STANDARDS

Chemical Substance	PHS Drinking Water Standards Rec. Max. mg/l(1)	PHS Drinking Water Standards Mandatory Max. mg/l(2)	State Bd. Pub. Health Standards Rec. Max. mg/l	State Bd. Pub. Health Standards Temp. Permit Range mg/l(3)	AWWA Quality Goals mg/l	Objections to concentrations beyond permissible limits
ABS Detergent	0.5	-	-	-	<0.20	Foaming, taste, pollution
Aluminum	-	-	-	-	<0.05	Turbidity
Arsenic	0.01	0.05	-	-	-	Toxicity
Barium	-	1.0	-	-	-	Toxicity
Cadmium	-	0.01	-	-	-	Toxicity
Carbon Chloroform Extract	0.2	-	-	-	<0.04	Excess organic matter
Chloride	250	-	250	500-600	-	Taste
Chromium, Hexavalent	-	0.05	-	-	-	Toxicity
Copper	1	-	-	-	<0.2	Taste
Cyanide	0.01	0.2	-	-	-	Toxicity
Fluoride	(See PHS Standards)		(See attached sheets)		-	Dental Fluorosis
Hardness	-	-	-	-	<80	Economic
Iron	0.3	-	-	-	<0.05	Taste, staining, turbidity
Lead	-	0.05	-	-	-	Toxicity
Magnesium	-	-	125	125-150	-	Laxative
Manganese	0.05	-	-	-	<0.01	Taste, staining, turbidity
Nitrate	45	-	(See attached sheet)		-	Toxicity to infants
Phenols	0.001	-	-	-	-	Taste
Selenium	-	0.01	-	-	-	Toxicity
Silver	-	0.05	-	-	-	Toxicity
Sulfate	250	-	250	500-600	-	Taste, laxative
Total Dissolved Solids	500	-	500	1000-1500	<200	Taste
Zinc	5	-	-	-	<1.0	Taste, color

(1) These chemical substances should not be present in a water supply in excess of the listed concentrations where other more suitable supplies are or can be made available.

(2) The presence of these substances in excess of the concentrations listed constitutes grounds for rejection of the supply.

(3) A temporary domestic water permit may be granted by the State Board of Public Health where the concentrations of the substances shown are within the given range. The lower values given are the maximum permissible to be used only where no other more suitable waters are available in sufficient quantity for use in the system. If concentrations of substances exceed the upper values listed, no temporary permit may be issued unless the Board determines after public hearing: (a) The water to be supplied will not endanger the lives or health of human beings; and (b) No other solution to meet the local situation is practicable and feasible; and (c) The applicant is making diligent effort to develop, and has reasonable prospect of developing a supply of water which will warrant a regular permit within an acceptable period of time.

Another indication of possible limits on chemical constituents is shown below for irrigation water. This information was developed from the California Department of Water Resources (16).

"Because of diverse climatological conditions, crops, and soils in California, it has not been possible to establish rigid limits for all conditions involved. Instead, irrigation waters are divided into three broad classes based upon work done at the University of California Laboratory, the Rubidoux Laboratory, and Regional Salinity Laboratories of the United States Department of Agriculture.

"Class 1. Excellent to Good--Regarded as safe and suitable for most plants under any condition of soil and climate.

"Class 2. Good to Injurious--Regarded as possibly harmful for certain crops under certain conditions of soil or climate, particularly in the higher ranges of this class.

"Class 3. Injurious to Unsatisfactory--Regarded as probably harmful to most crops and unsatisfactory for all but the most tolerant.

"Tentative standards for irrigation waters have taken into account four factors or constituents, as listed below:

	Class 1 excellent to good	Class 2 good to injurious	Class 3 injurious to unsatisfactory
Conductance EC x 10^6 at 25°C	Less than 1,000	1,000-3,000	More than 3,000
Chloride, ppm	Less than 5	5-10	More than 10
Per cent sodium	Less than 60	60-75	More than 75
Boron, ppm	Less than 0.5	0.5-2.0	More than 2.0

(End of quotation)

The values shown in the foregoing tabulation should be used as a guide only, since permissible limits vary widely with different crops, soils, and climatic conditions.

Table 15 lists the water quality criteria for grease and floating solids, color, turbidity and toxic materials for various water uses as recommended by the California Board of Public Health Standards for Water Contact Sports.

TABLE 15

WATER QUALITY CRITERIA

Use	Grease and Floating Solids	Color	Turbidity	Toxic Materials
Drinking H_2O	none	none	none	none detrimental to humans: Pb, NO_3, CN, F, Zn, Heavy Metals
Industrial H_2O and Agriculture	low	depends on process	depends on process, usually none	depends on process
Swimming	none	not too important	low	none detrimental to humans.
Recreation	low (protect waterfowl)	not too important	not too important	none damaging to equipment, acids, etc.
Fish	low, may limit oxygen transfer	not too important	low enough to prevent silting or gill obstruction	Cu=.001ppm. H_2S= 0.5 Cr=.05ppm SO_2= 5ppm Cl=0.3ppm Phenol=0.1
Shell Fish	low	not too important	low enough to prevent silitng	very sensitive to organic acids, Cu, Cr high bacterial population.

The chloride ion content of the water is another important parameter for measuring the chemical composition of a stream. Various concentrations of chloride ion may be obtained based on the type of water sampled. The following table presents an indication of the concentration for various water sources (17):

Table 16

Chloride Ion Content of Various Waters

Type of Water	Chlorides (mg/l)
Rainwater	2
Upland Surface Water	12
Unpolluted River Water	<15
Spring Water	25
Deep Well Water	50
Drinking Water	10-20 (but variable)
Weak Sewage	70
Medium Sewage	100
Strong Sewage	up to 500
Urine	4,500-5,000
Sea Water	20,000

An acceptable pH range is from 5 to 9. Outside this range the reproducibility of fish will be affected and growth rates drop off. A rapid shift in pH is very detrimental whereas a gradual change will allow acclimation and probably no detrimental affects. As a rule of thumb, pH>8 will have a lot of plant growth; a pH<8 probably not much plant growth.

Biological Composition

Biological analyses of water samples have been discussed in Section VI, laboratory testing. The most concern with biological pollutants pertains to public health and particularly to drinking water hazards or water contact situations.

Water quality standards for biological tests by California Board of Public Health Standards are listed in the following table:

TABLE 17

Water Quality Standards for Water Resources

Use	Coliform per 100ml	Dissolved O_2 (D.O.)	pH	Biochemical Oxygen Demand
Drinking H_2O	<1.0 org/100 ml <10% of 10 ml portions examined 1 mo.	adequate to prevent odors	6.8 to 7.2 ok up to 8	< 2 - 3 ppm
Industrial H_2O and agriculture	no requirement	-	6.8 to 7.2 depends on process	low- depends on process
Swimming	range: 240-2400 20% not to exceed 1000	adequate to prevent odors	6.5 to 8.5 (some alkali lakes up to 10)	low enough to prevent complete loss of D.O.
Recreation	about 100 - 5000	adequate to prevent odors	6.5 - 8.5	low enough to maintain D.O.
Fish	no requirements but not too high for aesthetic reasons	5 ppm or greater (depends on fish)	6.5 - 8.5 (depends on fish)	low enough to maintain 5 ppm D.O.
Shell Fish	< 70 org/100 ml permissible 70-700 org/100 ml condemn > 700 org/100ml impermissible	never totally absent	depends on species	low enough to maintain D.O.

Saturated dissolved oxygen content of water is dependent upon the water temperature and chloride ion concentrations of the water. The following table from standard methods presents the maximum dissolved oxygen limits for various conditions:

Table 18

SOLUBILITY OF OXYGEN IN WATER EXPOSED TO WATER-SATURATED AIR *

Temperature in °C	Chloride Concentration in Water—*mg/l*					Difference per 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
	Dissolved Oxygen—*mg/l*					
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.016
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008
31	7.5					
32	7.4					
33	7.3					
34	7.2					
35	7.1					
36	7.0					
37	6.9					
38	6.8					
39	6.7					
40	6.6					
41	6.5					
42	6.4					
43	6.3					
44	6.2					
45	6.1					

* At a total pressure of 760 mm Hg. Under any other barometric pressure, P (mm; or P', in.), the solubility, S' (mg/l), can be obtained from the corresponding value in the table by the equation:

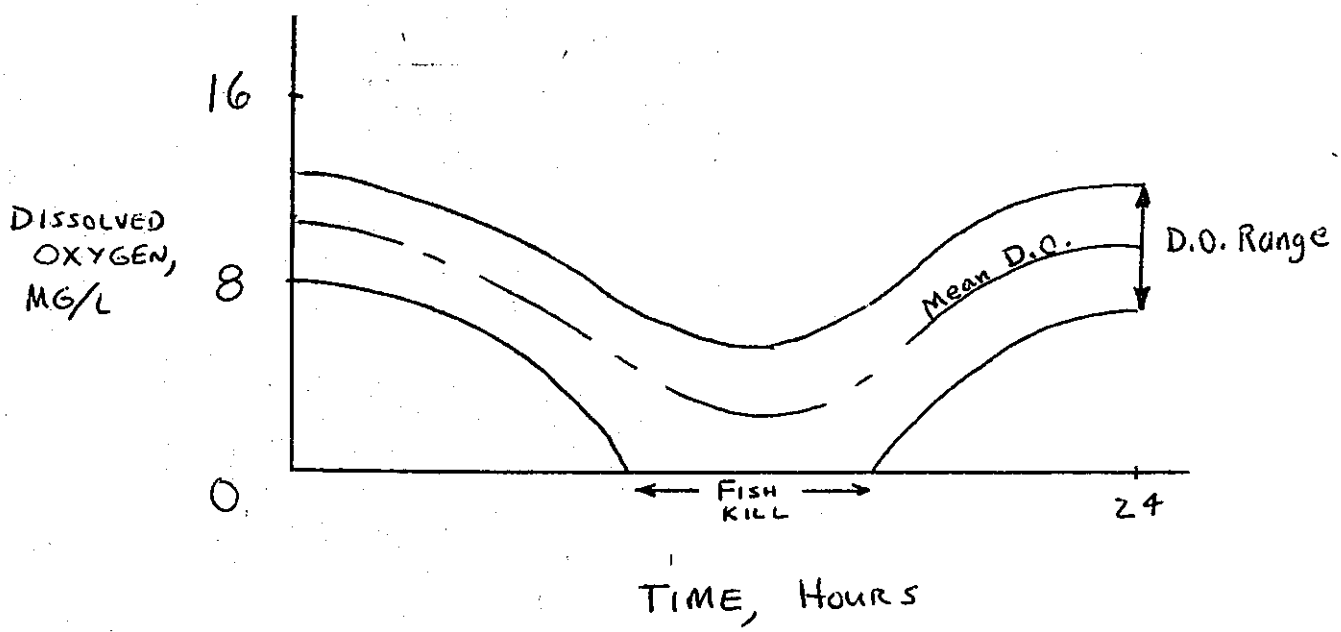
$$S' = S\frac{P-p}{760-p}$$

in which S is the solubility at 760 mm (29.92 in.) and p is the pressure (mm) of saturated water vapor at the temperature of the water. For elevations less than 3,000 ft and temperatures below 25 C, p can be ignored. The equation then becomes:

$$S' = S\frac{P}{760} = S\frac{P'}{29.92}$$

Dry air is assumed to contain 20.90% oxygen. (Calculations made by Whipple and Whipple, 1911. *J. Amer. Chem. Soc.* 33:362.)

Dissolved Oxygen should be reported for a 24-hour period for two or three periods during a water quality survey. Samples taken at 2-hour intervals will be adequate for this purpose. Point samples can be taken at other times during the survey to determine D.O. at a particular time. The minimum dissolved oxygen is the information that will determine if aquatic organisms will be stressed. Fish normally require at least 5 mg/l for survival. The minimum D.O. usually occurs during the night when photosynthesis is at a minimum. A graphic display of the dissolved oxygen content can be used to depict the changes in D.O. concentration as follows:



A more complete discussion of chemical and biological pollutants will be examined in Manual 5 of this five manual series.

Aquatic Organisms

Generally, the following types of organisms will be present for various conditions of water:

Clean water organisms
- Stone fly
- May fly
- Caddis fly
- Dobson fly

Intermediate Zone
- Snail
- Shrimp

Septic Zone
- Blood worm
- Leach

The above list is not meant to be complete and more comprehensive texts should be consulted for further descriptions. Clean water generally exhibits a greater variety of organisms (diversity) than polluted waters. Polluted waters tend to have a higher number of organisms for a particular species but a lesser variety.

The results of an organism count can be reported as a Diversity Index or number of organisms per square foot bottom sample, etc. Species identification is useful in determining water quality conditions. Upstream and downstream stations can be compared, or a station can be assessed for a long-term condition.

Very clear or pristine water may not contain many organisms. This, however, does not indicate degraded water. An evaluation of water quality conditions must include chemical and biological data combined to arrive at conclusive interpretations.

The presence of plants and algae should also be recorded for a sampling location. Nutrients generally contribute to algae and plant growth.

Computer Programs

Computer programs are available to aid in the computation of sediment transport and hydrologic information. Normally, streamflow data of a large magnitude is available in published water supply papers and, therefore, will not be discussed in detail here.

Likewise, precipitation gages located throughout the State are normally digitized for computer analysis of the data and output records are available from agencies responsible for maintaining precipitation information.

Computer programs available for use in the Hydrologic Engineering Center, U.S. Corps of Engineers, are written in FORTRAN and are available to State agencies. Included in their program are:

Number	Title	Date
723-X6-L2010	HEC 2, Water Surface Profiles	Aug. 1971
723-G2-L2240	Suspended Sediment Yield	Mar. 1968

The determination of instantaneous suspended sediment discharges can be determined from the computer program maintained by the U.S. Geological Survey. The output for their program will have the following information:

TABLE 19

Instantaneous Suspended Sediment and Particle Size Table

DATE	TIME	WATER TEMP-PERA-TURE (C)	DISCHARGE (CFS)	CONCEN-TRATION (MG/L)	SUSPENDED SEDIMENT DISCHARGE (TONS/DAY)	PARTICLE SIZE PERCENT FINER THAN THE SIZE (IN MILLIMETERS) INDICATED .002	.004	.008	.016	.031	.062	.125	.250	.500	1.00	2.00	METHOD OF ANALY-SIS
DEC 3, 1967	2030	04	483	193	252	50	64	76	83	88	92	97	99	100	--	--	SCBW
DEC 12.....	1700	08	520	128	180	69	80	86	90	92	93	96	98	100	--	--	SCBW
DEC 29.....	1330	04	482	61	79	62	71	76	79	81	82	87	93	98	100	--	SCBW
JAN 15, 1968	1245	01	1350	129	470	34	36	38	39	40	40	42	53	94	100	--	SCBW
MAY 29.....	2015	15	1050	125	354	44	53	56	57	58	58	62	72	96	100	--	SCBW
JUN 13.....	1305	20	1900	145	744	47	53	55	56	56	57	58	62	95	100	--	SCBW

INSTANTANEOUS SUSPENDED SEDIMENT AND PARTICLE SIZE, WATER YEAR OCTOBER 1967 TO SEPTEMBER 1968
(METHODS OF ANALYSIS: B, BOTTOM WITHDRAWAL TUBE; C, CHEMICALLY DISPERSED; N, IN NATIVE WATER; P, PIPET; S, SIEVE; V, VISUAL ACCUMULATION TUBE; W, IN DISTILLED WATER)

Information pertaining to the coding forms for the input data are available from the Headquarters Materials and Research Department Water Quality Studies Unit. Work is underway to develop in-house computer programs and user's manuals to provide this data.

Previous mention of the CURFIT and LINREG programs for the linear regression analysis was made in the data analysis of suspended sediment transport. The reader is referred to that section for a discussion on the computational procedure.

The U.S. Environmental Protection Agency has a computer program called STORET which is a data bank for water quality conditions of various rivers and streams in the U.S.

Slope Erosion Transects

The purpose for estimating annual highway slope erosion rates is to determine the quantity of sediment that will be discharged into a stream system that is located near the slope. The determined sediment quantities can then be compared with the previously calculated sediment transport capacity of the stream from all sources in the upper watershed. The relative sediment contribution from highway sources can then be analyzed to determine what impact may result from the highway facility.

In regions where the sediment from eroding highway slopes may have a significant impact on the stream ecology, it is suggested that sediment troughs or measurements of sediment transport in road ditches be made to more accurately define sediment quantities from the highway.

Generally, the slope erosion transect method of estimating sediment quantities from highway slopes is a fast, reliable way of determining expected rates from a future highway project (18). A large area can be surveyed utilizing the techniques described in this section in a matter of days whereas measurements of actual transport from the road ditch requires a minimum of one winter storm season.

The slope erosion transect survey can conveniently be performed using the Form HMRT-703. Prior to surveying the eroding slopes, the alignment is defined within a given watershed. This can be done by noting the Post Mile limits or using section designations.

The length of the slope under investigation is recorded in feet. For vary irregular-shaped slopes, it is best to break the slope into portions of equal height or some other obvious delineation scheme.

The aspect of the slope is determined (north, south, east, or west-facing). The slope aspect has importance insofar as exposure to the sun, temperature, time period of extreme climatic conditions such as snow cover, and type of vegetation covering slopes are concerned.

A Brunton-style compass is used to determine the average slope angle. On many slopes, when the configuration is too irregular because of extreme erosion or protrusion of rocks to record an average slope angle, the angle is noted as variable.

Characteristics of the slope should be recorded. These would include amount of rock on the slope, extent and type of vegetation on slope, type of erosion (rill, sheet, gully, sheet), and any other prominent features on or above the slope.

In estimating the quantity of eroded material from a slope, a dual procedure is used. First, an estimate of the amount of erosion occurring over an annual period is made. This involves probing the slope surface for evidence of annual movement of material over the slope. In the alpine environment, a common signature is pine needles. Frequently, pine needles are found burried under fractions of an inch of loose slope material. A change in the color of the needle from bright yellow (first year) to deep black (third or fourth year) gives an indication of the annual rate of sediment deposition. Exposure of fresh plant roots is used to determine annual rates of erosion as is the occurrence of coloration on rocks and boulders in the slope as material is eroded. Curvature of the main stem on woody plant specimens will also give clues as to the movement of material down-slope.

The second procedure followed is to determine the amount of erosion occurring over a long period of time. Such a period might be anywhere from two to 15 years. The longer term periods such as 10 years or more are very difficult to ascertain and much reliance must be made on as-built plans, maintenance records, and memory of personnel working or living in the area. Long term erosion quantities are then reduced to average annual rates for comparison with the annual rates as determined under the first procedure. Sometimes, the two annual quantities are of the same order of magnitude. This indicates a stabilized erosion rate. Other times, the annual rate will be lower than the average annual rate which indicates initial erosion on the slope was extreme. The third case found is where the annual erosion rate is higher than the average annual rate which indicates changing conditions are accelerating the erosion on the slope. In the third case, it is important to look for the factors causing the accelerated erosion and perhaps to instigate remedial action to reduce the erosion.

The over-hang near the top of a cut can frequently be used to predict the long-term erosion quantity. Clumps of rooted vegetation near the top of cuts provide a good indication of former slope profile.

ROAD EROSION TRANSECT SURVEY

BASIN _____

WATERSHED _____

SUBUNIT _____

ROAD DESCRIPTION _____

DATE _____

PARTY _____

LOCATION: T____ R____ S____ B & M _____

START POST MILE _____

END POST MILE _____

ODOMETER READING		EQUIVALENT POST MILES		DISTANCE	CUT FILL / RIGHT LEFT	ASPECT / ANGLE	HEIGHT OF CUT FEET	AREA S.F.	DEPTH EROS-ION	VOLUME - C.Y.		REMARKS
START	END	START	END							YR. DISPL. / TO STR.	YR. DISPL. / TO STR.	

HMRT-703 (Orig 11/71)

In addition to estimating the long term erosion quantitities and the annual erosion rates, the quantities of material reaching drainage systems are also estimated. The normal procedure to determine these quantities is to proceed from the erosion source to the drainage facility and walk the drainage course to its confluence with a tributary stream. Streambank erosion quantities can be estimated as one performs this function.

This procedure can be modified in the determination of sediment quantities reaching streams and available for transport if streambank erosion is not a concern and time is of the essence.

The estimated quantities of erosion are reported as acre-feet/square-mile/year, inches/square-mile/year, or tons/square-mile/year. In some cases, the number of cubic yards or tons per year are reported when comparisons between watersheds are desired.

A more detailed discussion of slope erosion transect surveys will be given in Manual 4 of this quality series.

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