RESEARCH NEEDS AS RELATED TO THE DEVELOPMENT OF SEDIMENT STANDARDS IN RIVERS

by

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RESEARCH NEEDS AS RELATED TO THE DEVELOPMENT OF SEDIMENT STANDARDS IN RIVERS

Part I

Position Paper

By Johannes Gessler

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Introduction

There is increasing pressure from society at large to protect our environment from man's interference. This has already led to numerous restrictive regulations largely in the area of pollution. The demand for tighter controls on water pollution has certainly resulted in considerable improvements in the quality of our rivers and streams. Yet one area of water quality remains, at this time, without explicit regulation: the amount of sediment carried by rivers and streams. Considering the complexity of the problem this cannot be surprising. Most rivers carried a considerable amount of sediment even before human interference occurred. The river environment is well adjusted to this continuous flow of sediment. Not only this: the environment may actually require the maintenance of this flow of sediment. The aquatic life is adjusted to it; the life outside of the water along the banks depends, at least indirectly, on it; the general behavior of the stream in terms of its morphology is greatly influenced by the amount of sediment moved by the water.

A change in the natural load of sediment can then result in a dramatic chain reaction. Short term effects will possibly include drastic disturbances of the equilibrium among the various species of aquatic life. Though certainly not all species are sensitive to changes in the suspended and/or bed load, it may be sufficient to drastically change the population of one in order to offset the equilibrium. If this is called a short term effect, this is to be understood as a relative statement. Since all rivers naturally show considerable changes in concentration of suspended load, the aquatic life is adapted to such changes within certain limits. It will then require a systematic shift in the concentration distribution over considerable time to lead to significant effects. The larger the shift the shorter, of course, the response time. A rough estimate for the order of magnitude of the response time may be one to three years.

Animal life along the river banks may be effected with a considerably longer response time. Their food source may change only slowly. And it might take several years until the balance among the species starts to change. About the same time scale may apply to changes in the vegetation.

Long term effects relate to the morphologic stability of the river or stream beds. Due to changes in their sediment load, aggregation or degradation of the river bed occurs and in turn may lead to drastic changes in the cross-sectional characteristics of the river. The order of magnitude of the time scale of these changes may be decades.

Changes in the bio-sphere of the stream may go unnoticed to the casual observer for quite some time. Adjustments in the morphology will eventually become very obvious, yet the response is very slow. The setting of sediment standards then becomes something of great difficulty. A misjudgement cannot be easily corrected since only after years it may become apparent. By that time the damage done to the stream environment may be almost irreversible. Before sediment standards can be set we must understand perfectly well the importance of sediment loads in rivers and streams. It is the purpose of this paper to develop a framework of thinking in order to analyze characteristics of past and future research as it will be required for the setting of sediment standards.

The Need for Sediment Standards

Concern about pollution of our rivers developed in regard to pollutants which were truly foreign to the river environment. When their effect on the environment became unfavorable it was a relatively simple matter to limit the amount of pollutant which could be discharged into the river. The regulation may specify that the concentration of pollutant in the river could not exceed a set standard. Control of such a regulation again is relatively straight forward since the pollutant was truly foreign to the river.

The situation became more difficult when pollutants were identified which are naturally present in the river. Yet due to human interference the concentration levels were significantly changed. To mention just two examples: salinety and heat pollution. Setting standards and controlling them becomes difficult for two reasons: (a) the river environment is adjusted to the pollutant. Its total elimination does not necessarily lead to an improvement. If the system can tolerate (or needs a certain amount), can it adjust to higher (man induced) concentrations? (b) the natural pollution level is likely to be a stochastic variable. The situation with man induced pollutant cannot be directly compared with a situation as it would exist if human interference would not have taken place. If, at some given point, a regulation would permit the increase of the water temperature by a set number of degrees (e.g. due to a series of nuclear power plants upstream), control of such a regulation would be difficult, since the temperature under conditions without power plants (but all other parameters the same) would be known. It would be possible to set absolute limits for the pollutant. The amount of pollutant which then can be released into the river becomes the stochastic variable, from an operational point of view a highly undesirable aspect.

Sediment as a pollutant (and of course like salinety and heat, the term pollutant is strictly relative) certainly falls into this category: rivers and streams do have a natural load of sediment which varies significantly with time at a given point. The river environment is not only well adjusted to the load and its variation, but actually depends upon maintenance of it.

But human activities tend to drastically change the sediment load. Sediment erosion from land is significantly controlled by the type of vegetation. An area highly developed for agricultural use is likely to have a significantly different erosion rate than the same area had before agricultural development took place. Furthermore, changes in crop patterns will lead again to changes in erosion rate. Large construction sites, including the continuous belt around the sprawling urban areas, have their vegetation ground cover largely removed (and the same is true for surface mining areas) which again leads to drastic changes in erosion patterns. Depending upon the specific circumstances, such a change may well be short term. Its effect on the river environment is then more pronounced in those areas with short term response times (i.e., the biota). After an urban area is developed, houses built, streets and parking lots paved, backyards well established and attended a significant reduction of soil erosion over a considerable area has occurred which, at least locally, could result in significant new adjustments in the river environment.

It is, then, the purpose of setting standards to make sure that changes in the sediment load of streams and rivers due to human activity will not result in adjustments in the river environment which are more significant than those adjustments and variations which would occur naturally.

Classification into Areas of Concern

Based upon the statement of purpose for setting sediment standards, one can easily identify three problem areas:

(1) what is the range of adjustment and variations which occur naturally in a river without human interference;

(2) how much in sediment load will result from various types of human interference; and

(3) what will be the effect on the river environment due to such a change in sediment load.

People interested in studying item (1) are the biologists and the fluvial-morphologists. Both groups need to carefully distinguish between adjustments (trends, in the stochastic terminology) and random fluctuations around the mean. The problem, like in so many geophysical and biological time series, is that frequently the standard deviation of the fluctuations is of the same order of magnitude as is the mean. This makes the detection of trends very difficult. Nevertheless, one must realize that these trends are present. The biological world in and around the river is in an evolutionary process. And no river is truly in an equilibrium stage if viewed from a geomorphic point of view and if sufficiently large time periods (say a decade or more) are considered. Item (1) provides the base information for two undertakings: setting the standards as well as the base for monitoring the conditions after standards have been set. Therefore, the agencies charged with the task of enforcing the standards have also a direct interest in this area.

Item (2) has been and still is extensively studied as part of the soil conservation problem. It is the farming community which changes the soil surface conditions on a large scale by farming land in the first place, and secondly by changing crop patterns. And accordingly, agronomists took the lead in research and field studies on soil loss. But people in forestry and water shed management have also accumulated information of great value. Sediment sources which areawise may be much more limited but because of their very high strength are of great significance are mining areas, especially trailings and surface mining. Finally, any construction site is a high strength source. Even though it is a short term interference and will, therefore, have little effect on the river geomorphology, it may significantly affect the aquatic biota. In this last category two cases are of importance: river improvement projects and housing construction in urban areas. The first because the source is directly at and in the river. The second because it must be considered a long term activity. The individual construction site is only an active source over a few months, or at the most, a year. But an urban area is continuously growing and therefore surrounded by an ever moving and increasing belt of construction activity. In addition to agronomy and forestry, the mining and construction industry must have prime interest in the problem of soil losses.

Item (3) is closely related to item (1). If the adjustments and variations in an undisturbed river environment are understood, one should have a great deal of information in order to predict long term effects due to man induced changes. Therefore, it is again the biologist and river-morphologist who will provide the necessary information for item (3).

An Alternate Approach to Classification

In the previous paragraph classification of areas of concerns was according to professional interest spheres. Such a classification was logical in the early phases of the investigative process. Especially in a process as complex as the sediment movement in the environment it is to be expected that various parts of the interested community, frequently parts which are professionally unrelated, will attack certain aspects of the problem independently.

The agronomist developed interests because excessive soil erosion generally decreases the potential productivity of cropland. His initial concern was not that partial denudation or changing crop patterns could significantly increase erosion rates, possibly leading to the elimination of certain species in the stream biota and/or significant changes in the morphologic structure of a stream. And he did not necessarily see that such changes could result in heavy increase in bank erosion (farmland losses) and/or increased flooding problems endangering the crop.

At the other extreme we may consider the civil engineer's interest. He is concerned with structures along the river (bridge piers, defense structures, etc.). The foundations of such structures should never be exposed. Therefore, the concern centers around problems of variations in bed level as well as slow but systematic adjustments or trends in bed level. The civil engineer did really not care where the sediment came from. He accepted the fact that there appeared to be an "unlimited" source of sediment.

For any group of people concerned with the movement of sediment through the environment one could show that its interest is initially related to a particular fraction of the overall process. The group studied this component of direct concern. It developed its own methodology and terminology, and frequently this methodology is strongly related to the group's educational background. An example illustrating this point is the geologist's interest in fluvial morphology versus the civil engineer's interest. The geologist's background in mathematics and fluid mechanics is frequently much weaker than the engineer's background. And the geologist naturally tended to use empirical analyses of his data. The engineer with his extensive background in mechanics attempted to solve the problems more by means of analytic analysis of the process. Both approaches can have their very distinct pitfalls: empirical analyses may overlook the significance of certain parameters, and therefore it is dangerous to extrapolate the results beyond the limits of the data used in deriving the empirical relationships; analytic analysis may have to use oversimplistic assumptions leading to incomplete, less than general results.

The increasing understanding of the individual components of the total process leads to attempts to link these components together. Furthermore, if society demands control of the sediment movement at one point in its path through the environment, this will necessarily result in changes along the entire path. And if it should become essential to have control at two points, yet possibly for different reasons, only an understanding of the total process will provide the information required to avoid contradictions. Quite clearly in the case of sediment movement we are quickly approaching a situation of multiple point control: farm production requires minimizing soil losses, recreational groups demand elimination of suspended sediment, considered to be a pollutant, biologists realize the significant effect of suspended and bed load on the stream biota but have at this time apparently insufficient data to enter their demands for sediment control, yet are convinced of its necessity, and the morphologists (geologists and engineers) are just about to understand the extreme complexity of morphologic equilibrium and the devastating changes which can occur if the equilibrium is changed at some point in space and time.

If we need control (and it was shown above what the purpose of such control is) all interested parties have to join. They must learn to understand each other in terms of terminology and value systems. They must jointly understand the process of the sediment moving through the environment. And then they must learn to adjust the individual interests. This will be possible only if in the process of mutual understanding we change our values to a common level: a river or stream with clear water is not necessarily "more beautiful", and is certainly less natural than one which carries a significant suspended load. After we have reached this level of common values we then may be able to set standards acceptable to all parties involved and not contradicting each other. But any process which requires the reestablishing of value systems (which is really an educational process) is, unfortunately, painfully slow.

With the total understanding of the process as the final goal it becomes logical to follow the sediment along its path through the environment, and to ignore, initially, the professional groups who historically had prime interest in certain fractions. The specific physical concepts at any stage of the process need to be identified. And persons with the best possible background in regard to this concept should work on it. In doing so they may find it convenient to fall back on work previously done, and certainly on data previously collected. Having new people involved may lead to a host of new ideas in attacking certain problem areas. In their analysis the researcher must consider significant changes in the input as a function of time and must be able to identify the output accordingly, since it will serve as input in the next step.

If every step is understood in this manner, it will become possible to route the sediment along its path. Preferably such routing would be done in the form of a large computer simulation. Stochastic input variables should be simulated using Monte Carlo Techniques. The most interesting part of such a simulation would be the possibility to observe the time response of the system. And when the point is reached where such simulations give verifiable results, such a simulation program may well be used as a management tool. This could permit the establishment of absolute standards. If it would become a necessity to allow temporarily higher concentrations, one would know the short term effect and by proper management of other input variables it could be possible to minimize damage.

The Various Steps of Sediment Movement

In the following paragraphs an attempt is made to follow the sediment along its path through the environment, as it was suggested in the previous pages. An attempt will be made to enumerate the various steps and to identify the physical concepts involved. The steps involved include: (1) the detachment processes, (2) the transport processes in the watershed, (3) the transport processes in the stream and river, and (4) the direct or indirect effects of the moving sediment on the biota along the entire transport path.

The detachment process. The traditional literature on this subject concentrates on the detachment due to rainfall. The erosion process begins when raindrops strike the soil surface and detach soil particles as a result of the drastic momentum change. The potential for actually detaching particles depends on the raindrop velocity, direction of this velocity, the drop size distribution, but also on the geometry of the boundary (the soil) at the impact point. But an additional detachment process can occur if there is sufficient surface runoff. The flowing water exerts a shear on the boundary. This shear may be sufficient to break small particles out of the boundary. The actual process, of course, is likely to be a combination of the two processes mentioned: raindrops impact and break through a thin layer of surface flow.

Resisting these removing forces is the gravity of the grain and possibly the cohesion of the soil. While the gravity would appear to be a well defined factor, the exact geometry of the boundaries will greatly effect its possible effect. This is a first reason why cropland tillage has significant effects on the erosion process. The resisting effect due to cohesion is very complicated. The cohesion is a chemical-physical characteristic of soil. It is significantly affected by certain chemicals which could be present due to fertilizing. Furthermore, the continuous wetting-drying cycle which occurs at the surface changes cohesion as well.

But there is a second detachment process. In arid and semi-arid areas wind becomes a major component in moving soil. The detachment process, or better, removal process becomes then very similar to the one of sediment grains going from a state of rest to one of motion on a riverbed. This process, known in the fluvial morphology as incipient motion, has been extensively studied in water, yet the recent literature clearly indicates that no generally accepted model is available. Understood to an even lesser degree is the process in air. It has been pointed out that in air the impact of previously removed grains is probably of great significance in the detachment of new grains, which apparently is not true in water. Also, the much larger density difference between fluid and grain makes the two processes quite different.

Finally, human interference, beyond land management techniques, can be a major compontent in the detachment process. Wherever soil is moved, like on construction sites or in mining operations, soil particles are detached and remain highly susceptible to removal by water or wind.

<u>The transport process in the watershed</u>. To be considered in this section are the transport mechanisms between the point of detachment and the point where the grain reaches a permanently established water course. This is a somewhat arbitrary definition. The transport process in some good sized temporary channels which run only during periods of intensive rainfall may be very similar to the processes in streams. Yet it is frequently pointed out that the mobility of grains is apparently much higher where the flow is intermittant. This may justify the above definition.

In the very first stages of soil erosion by rain the impacts of raindrops may result in a transport process due to the splashes, even though there might be no surface runoff. Due to the drop impacts, loose grains are thrown up. If the soil surface has sufficient slope, there is an increased chance for the grain to come to rest at a location a short distance further downhill. The process may not move significant amounts of sediment, but it could be important indirectly: the sequence of small steps of the grains at the surface may lead to a very loose grain arrangement. When the point is reached where surface runoff occurs, these loose grains would appear to be very susceptible to removal.

However, most soil is normally moved by surface runoff. After the surface storage capacity has been filled and the infiltration rate of the soil is less than the rainfall intensity, runoff will occur. Prediction of soil erosion at this stage becomes very difficult since surface storage capacity and infiltration rate are parameters which vary in a very wide range. By various land management techniques they can be dramatically changed. Soil with very good permeability characteristics may rapidly develop soil surface seals which quickly decrease the intake rate. Such characteristics depend on the grain size distribution of the soil as well as the clay minerals. The prediction of the point where surface runoff will occur is of utmost importance in the prediction of soil erosion. After surface runoff occurs, the process of sediment transport becomes somewhat similar to what happens in small streams. Close observations show many of the typical features of streams in semi-arid areas: very high sediment concentrations, dunes, standing waves, antidunes, but all at a scale of possibly less than an inch. The rate of sediment transport, then, depends on the runoff velocity (or slope, flow depth and roughness characteristics) and the susceptibility of the soil to erosion. Land management techniques again will effect roughness and local geometry and therefore general predicitons become difficult.

Like in the case of the detachment process, water may not be the only cause for soil erosion. Wind blown soil may become a major problem in semi-arid areas and could well be of more importance than erosion due to water. But very little research has focused on sediment transport by air. The little information available is not verified by other independent studies and/or field data. A reason why this aspect of erosion remained largely uninvestigated may be found in the arguement that soil and dust suspended in the air will eventually be deposited and most likely again on the same field. Yet typically enough, this fine material will be deposited in some small depression or an embankment. Considerable accumulations will occur at these locations, which also are locations where the runoff from rain storms will be collected. This fine sediment will then find its way to the river very directly in case of some rainfall.

<u>The sediment transport in the river</u>. The transport process in streams and rivers may be divided, somewhat arbitrarily, into two phases: suspended transport and bed load transport. Both phases are

of great importance to the morphologic and biotic environment, but people concerned with the recreational qualities of the river have interest only in the suspended sediment. Despite the fact that such a division is frequently convenient, the two transport processes are mutually dependent.

The loose boundary of a river bed continuously changes its shape. This shape, ranging from flat beds to dunes and possibly anti-dunes, greatly controls the turbulence level in the river which in turn determines the concentration profiles of the suspended sediment. At the same time the flow characteristic and bed forms determine the bed load transport which is again an important boundary condition for the suspended load. It is this very complex feedback mechanism which makes the understanding of the total process so difficult. Furthermore, it may very well be possible that more than one parameter set represents an equilibrium condition for a given discharge. Temporary fluctuations in one parameter may be compensated for by changes in other parameters, without affecting the overall equilibrium. And because the time response is extremely slow, systematic shifts in parameters may well remain undetected for a long time. But even with very slow responses considerable damage may occur due to minor, yet systematic, shifts in parameters. The reason why the proper cause of such damage may remain undetected is that rivers behave somewhat erratically in a wide range of parameters. Differentiation between temporary fluctuation and systematic shifts becomes then quite difficult.

Sediment and Biota in the river. It is in a great variety of ways that sediment affects the stream biota. Accumulation of silt and fine sand on gravel and rubble stream beds may eliminate the spawning grounds of fish and the habitat of many aquatic insects which form the food supply for the fish. Of similar importance are the river bed characteristics like dunes and ripples since again they form preferred spawning grounds. Changes in the overall concentration may well eliminate or create dunes. Suspended sediment causes turbidity which reduces light penetration into the water and, therefore, reduces photosynthesis again significantly effecting the entire biota. Fish can tolerate high turbidities for short periods of time. But since fish productivity ultimately depends upon plant life and bottom fauna, any effects on those will eventually affect the fish habitat.

Characteristics of Prior Research

It cannot be the purpose of this general discussion on the movement of sediment through the environment to give a complete and critical review of all research done in relation to this topic. Rather, an attempt is made to show certain characteristics of some research. It is the writer's feeling that the examples given are fairly typical. Yet this does not exclude considerable efforts outside of the framework to be set.

Detachment and transport in the watershed. It is felt that the research which led to the Universal Soil-Loss Equation is very typical for the efforts in relation to soil losses. The soil loss per unit area is expressed as the product of six factors: a rainfall factor, a soil erodibility factor, a slope-length factor, a slope steepness factor, a cropping-management factor, and an erosion control practice factor. Each of these factors has its own peculiar background.

For instance, the rainfall factor represents a statistical average of a quantity which is the product of the total kinetic energy of a raindrop and its maximum 30-minute intensity. Though such a product may appear intuitively to be meaningful, the main justification for using it is based on proven high correlation with soil erosion. It remains essentially an empirically established parameter. Maps are available which show mean annual rainfall factors. These maps may have justification in analyzing the morphologic characteristics of rivers with large drainage areas. Such characteristics show a slow response and therefore the mean may carry sufficient information. In terms of problems with short response time, especially as related to the biota of streams, the statistical distribution of this factor becomes of dominant importance. Such information for smaller watersheds is, in general, not available.

Many of the other factors are the ratios of mean soil loss from a given slope to that of some standard slope. Their introduction in the equation as a multiplier is therefore necessarily correct. The great difficulty remains how these ratios are determined and what is the statistical distribution and reliability. Even though they represent ratios, they may be evaluated using an empirical equation, like the one used for the slope-steepness factor.

The Universal Soil-Loss Equation is backed by a very large amount of data. But its reliability for a given drainage area, especially smaller ones, is hard to evaluate. It intends to give a mean value, yet the soil loss is certainly a stochastic variable with a very wide distribution. And it only considers soil losses due to rainfall and not snow melt or wind.

Transport in the river. Two schools of thought have developed and both have reached a stage where considerable insight is gained into the complex interaction among the many parameters. One approach is essentially empirical and based upon the analysis of a great amount of field and laboratory data. The other approach attempts to understand the basic physical mechanism of transport, largely based upon analytical analysis and laboratory experiments.

It is the strength of the empirical approach that it is extensively based upon field data. But like any empirical concept it cannot be applied outside of the range of data and parameters used to establish the relationships. Furthermore, no insight is gained into the stochastic component of the process. The strength of the analytical approach is, that results may be extrapolated, with care, into parameter ranges and combinations which were never tested in the laboratory. Yet it appears that we are still short at least one basic relationship relating mean width of stream or river to the other parameters. But even in relation to the other aspects, there is no general agreement what is right and what is incorrect or oversimplified.

It seems that in the past there was not very much interaction between the two schools. But clearly both could only benefit from a closer cooperation. One discussion brought up extensively by both groups has to do with the question which parameters are dependent and which ones are independent. Though there might be a few truly independent or at least essentially independent parameters, the question does not seem appropriate in a system which is a stochastic feedback process.

And finally, too many of the parameters have been entered as mean values where really the statistical distributions are of great importance, or at least the distributions of the extremes is the controlling factor.

Biota in the river. Considerable research has been done on investigating the relationship between substrate composition and stream biota, at least in a general fashion. But the question of the actual physical mechanism for elimination or enhancement of certain species has not received much attention. When it is reported that turbidity of water is endangering a species, it is not clear whether this is because of respiratory or behavioral problems, or because the food supply of the species under consideration is effected etc. Effects of suspended sediment on the biota appears to be an area where even less information is available. There are very obvious correlations between sediment and quality of biota. But it is not clear whether these are direct or indirect correlations. Such information is essential for the optimum management of the sediment.

Research Needs

The introductory statement to the previous paragraph again applies here. The writer's own specialty is only a narrow aspect of the total problem of sediment movement in the environment. Yet from reviewing some of the literature and discussing with people who are involved in the various areas of specialties, the writer has, rightly or wrongly, developed some ideas on research needs.

Even though the Universal Soil-Loss Equation is backed with considerable data and is widely used, it appears that it tries to incorporate too much information into one equation. Soil-loss is the result of two distinctly different processes: detachment and transport. They should be studied separately. Furthermore, it might be possible to develop analytical models for the processes which could be calibrated against the large amount of available data. These analytical models would also have to include the time response. The transport process by surface runoff should be studied much like the transport process in rivers, again using analytic models rather than empirical data correlation.

An area which needs major consideration is the sediment transport by wind. Incipient motion, surface creep, and suspended load should be studied, much like the corresponding studies for these processes in water.

Despite the large amount or research done on sediment transport in rivers, the process does not appear to be physically understood to the point where adequate predictions or morphologic behavior can be made. Areas which were definitely neglected include the effect of grain size distribution and the time response of the bed deformations as the discharge changes. While most analytic models consider the width to be an independent variable, it clearly must be effected by the difference of sediment transport capability and sediment supply. The time response of this dependence is obviously slow, but for the overall equilibrium of a stream or river it is important.

Research on the stream biota needs to become much more specific. It should include investigations of the micro-distribution of various species, the effect of substrate composition and geometry as well as suspended load on community structure, and especially of the actual causes of enhancement or elimination. Special attention should focus on sediment size distribution as well as the time response of community structure after changing essential parameters.

Together with the sediment motion through the environment there is likely to be a parallel motion of organic matter. This organic matter may more or less move independently. More likely it is moving with the sediment where the grains act as the carrier. If it is true that the transport of sediment and organic matter are strongly correlated, it would be necessary to learn the combined transport mechanism. Obviously such organic matter would have a great deal of significance in the response of the stream biota.

In all areas of concern mentioned above the knowledge of the time response was emphasized. The reason is a need for computer simulations of the sediment movement through the environment. Verified simulations could then become a valuable tool in the management of the sediment behavior.

RESEARCH NEEDS AS RELATED TO THE DEVELOPMENT OF SEDIMENT STANDARDS IN RIVERS

Part II

Summary of the Workshop

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Part II

Summary of the Workshop

Introduction

On August 13 and 14, 1974 a workshop was held at Colorado State University on the same subject as the position paper which forms Part I of this report. By inviting people to participate in the workshop, the attempt was made to cover as wide a cross section of people with interest in the subject as possible. People from outside Colorado State University should be matched with people from Colorado State University with similar background. The following people participated from outside C.S.U.:

K. Bovey,	Student, University of Montana
E.J. Carlson,	U.S. Bureau of Reclamation
G. Clausman,	Kansas University
J.K. Culbertson,	U.S. Geological Survey
K.W. Cummins,	Michigan State University
R.R. Curry,	Sierra Club - University of Montana
R. Doyle,	Environmental Protection Agency
E.M. Flaxman,	Soil Conservation Service
H.P. Guy,	U.S. Geological Survey
H.P. Johnson,	Iowa State University
T. Lisle,	Student, University of California
A. Mercer,	Consulting Engineer
D. Rosgen,	U.S. Forestry Service

The participants from C.S.U. included:

N.A. Evans,	Director, Environmental Resource Center
R.D. Heil,	Agronomy
S.A. Schumm,	Earth Resources
H.W. Shen,	Civil Engineering
D.B. Simons,	Dean of Research, Engineering
W.D. Striffler,	Earth Resources
J.V. Ward,	Zoology and Entomology
J. Gessler,	Civil Engineering, and Chairman of the Workshop.

The workshop was broken up into three sessions with the three themes: I. Work in Progress; II. Specific Research Needs; III. How Do We Link the Systems Together. It is not surprising that the discussions of such a diverse group is unlikely to follow the lines sketched by one person - the author of the position paper and chairman of the workshop - nor should it. The very topic of the workshop suggests that there is insufficient knowledge and it was the purpose of the discussions to explore the various areas related to the development of sediment standards. The group as a whole had to find a way through the immensely broad subject area.

With the agreement of all the participants, the three sessions were recorded on tape. After the workshop these tapes were transcribed (in form of a rough draft) into a volume of approximately 150 pages. The author was then faced with the problem of compiling these at times extremely lively discussions, which drifted within minutes from one end of the spectrum of interests to the other, into a report representing the discussions and restating the conclusions.

As soon as the transcripts became available it was evident that the only truly objective report, the literal transcript, was totally unacceptable. It appeared even unfeasible to follow the discussions in a fairly loose way, if the report should remain a concise and readable document. The material needed to be grouped again much like in the position paper. Yet order and importance will be according to the way the author sensed the agreement among the participants (if such an agreement really existed). And it must be said again like it was said in the position paper: this results in a highly subjective report, even if every effort is made to be as objective as possible.

Considerable time was spent on providing the group with reports on "Work in Progress." The purpose was to acquaint the group well with each other. Only then one can expect a good interaction among the participants. Even if the provided information may not have appeared at all times to be of immediate relevance to the theme of the workshop. It appears then to be of little importance to go through the background of each participant, one by one. Their affiliations as listed above already give a great deal of information. Nevertheless a short summary of the general background will follow.

The Present Interests of the Group

The group included people who are actively involved in developing means of setting standards, and even setting standards; in part through the regular legislative procedure, in part through court cases. There were representatives who very carefully monitor the field conditions on a continuous basis, though in a relatively small area, who trace excessive sediment concentrations to specific sources and develop means to reduce sediment production at the source, no matter whether the source may be a "true" point source, a point source in its legal definition or a "true" non-point source. And then there were people who are working within the agencies charged with monitoring the conditions relative to sediment transport through the environment, be it at the source or in the rivers, be it at a specific locality or at the grand scale of nation-wide management. This first group includes people who are actively involved in the activity of working with the status quo out in the field.

A second interest group, largely consisted of the people with university affiliations, is heavily involved in all aspects of the movement of sediment through the environment because such movement is at present poorly understood and a prime research area. Furthermore, such movement significantly affects parts of the environment especially the biota in and along streams and rivers in ways which are at best partly, but in many cases not at all explored.

And finally the students, though certainly part of the second group, in some more philosophical way, represented the generation who has the most immediate interest in an improved environment. Because no matter what is done to improve present conditions, because of the time scales involved the benefits to be derived are not necessarily ours but those of generations to come.

The Purpose of Sediment Standards

It needs little explanation why the discussions continuously drifted back to this subject. Only if we know the purpose of setting standards can we indicate what kind of standards. And only if we know the kind of standards can we actually discuss the information necessary, yet unavailable, to set and enforce standards. It may well be one of the more significant conclusions of this workshop that there remains a considerable research need on the level of the purpose of sediment standards. In the position paper it was taken for granted that there is need for sediment standards, and in the paragraph, accordingly entitled (pages 2-4), more effort was spent on the questions of how sediment standards would differ significantly from other pollutant standards. The final question on what the purpose of such standards must be was answered only in a very philosophical manner: "... to make sure that changes in the sediment load of streams and rivers due to human activity will not result in adjustments in the river environment which are more significant than those adjustments and variations which would occur naturally."

The workshop participants were more interested in very specific questions.

They did accept the concept of needs for such standards for three reasons:

a) Water resources are already in many instances imposing limits on human activities. And the quality of such resources are of prime concern to the user, no matter on which level of use - industrial, domestic, recreation, irrigation, etc.

b) An environment can only be considered healthy as a whole if each component is healthy. The river biota is undoubtedly a significant part of the environment and must not suffer from man induced changes in the sediment load of the river.

c) Rivers should stay within certain boundaries. The sediment transport and erosion characteristics directly influence these boundaries.

But is it then the purpose of standards to maintain the status quo or do we need to make good for some of the damage done in the past?

Legal considerations strongly favor standards which are based on the status quo, simply because in most instances any previous status is unknown, or at least not sufficiently documented and defined. And if the status quo should not be known a concentrated effort could produce the necessary information at least at specific localities in order to set standards, monitor the controlled parameters and if necessary identify the violators.

Yet a glance at some of our streams and rivers immediately convince us that maintaining the status quo is not enough. We do need to back up; if not to pristine conditions (for economical reasons) at least to a point somewhere in between pristine and present. Now we talk not only about a condition to be maintained, we talk of back stepping into an interval of which we do not even know one of the limits: the pristine condition. One is obviously faced with a difficult question: How much do we need to make good?

Setting sediment standards to insure water quality for industrial, or domestic use is relatively straightforward. We specify the desired quality, we know the efficiency of the filter plants, and we can set the standards in the river. Setting standards for recreational use is much more difficult and highly subjective. The only reasonable assumption seems to be that if we meet the quality requirements for water use and those for maintaining a healthy biota in the streams the standards for recreational use are met as well. If this means accepting a river or stream which at times is very muddy then we may be faced with the problem of developing a new value system as discussed in the position paper.

Most difficult appears the question of how much back stepping is needed in order to restore or maintain a viable biota. The question is one of equilibrium. If present conditions are in equilibrium or if such an equilibrium could be reached within short terms, maintaining of the status quo might be sufficient, even if the biota does not represent the pristine biota. After all a pristine biota is dynamic and develops into new stages too. On the other hand, if the present conditions in the river or stream are such that the equilibrium is destroyed and maintenance of the status quo would result in a rapid and significant drift away from present conditions obviously drastic steps would be necessary to achieve an acceptable equilibrium. It may be an advantage that the response time of the biota is relatively fast and that restoring past conditions may not take an excessive amount of time.

Setting standards relative to the geomorphic conditions of a river is again an easier matter. If one assumes that the sediment transport-erosion-system is understood, it amounts to a quite straightforward cost-benefit analysis. Response times are long. We have lived with the status quo for some time and standards which would maintain this status quo would be acceptable. Yet again it is a question of equilibrium. And if the equilibrium is significantly off-set, drastic standards may be required to maintain the status quo.

Interestingly enough the following discussions seem to be quite independent of the purpose of the standards, i.e., to maintain the present or to move back toward more pristine conditions. Either way we need to understand the ways in which the system works: in regard to the strictly physical aspects of sediment motion and in regard to the interaction between this physical process with the biota.

Conclusion: Maintenance of a viable river biota and of geomorphic equilibrium are the main purpose of sediment standards. If standards oriented toward these purposes do not suffice for sufficient water quality for industrial and domestic use, more vigorous standards (smaller sediment concentrations) can only be implemented if this does not upset the biota and geomorphic equilibrium. Recreational aspects of sediment standards have a low priority.

The Dichotomy: Sediment Source - Measuring Point

Standards have value only if they can be enforced. Which implies that (1) we can measure how much sediment is moved by the rivers and streams, (2) we can pin point the source of excessive sediment, and (3) we can control the production of moveable sediment at the source. An ideal situation would be where we can measure the sediment production at the source itself. Yet in many instances this is impossible because the source is physically speaking a non-point source. A typical example is sediment erosion due to rain and/or wind from cultivated land. There is no feasible way of directly measuring such loss. The detachment process is intermittent (stochastic), the initial transport phase is intermittent; there is temporary storage in the intermittently running creeks before the sediment reaches the streams which continuously carry water and sediment. The only feasible point of measuring the sediment flux is not until the sediment has reached such streams. There is then a dichotomy which poses extreme difficulties in the enforcement of sediment standards: the locality of the source and the measuring point are far apart. In between is a very complex intermittent transport process which has a time scale heavily influenced by the general characteristics of the local climate: in wet areas, (e.g., coastal regions,) this scale is certainly much less than in very dry areas, (e.g., on the east side of the continental divide,) where the time scale may well exceed one year.

This spacial separation naturally leads to the fact that the measured sediment flux (assuming it can in fact be reliably measured) is the integration of sediment production and transport from all sources upstream of the measuring point. If excessive sediment flux occurs it is not immediately clear where the sediment comes from. And not only is it a multitude of possible sources, but the excessive transport could be due to geomorphic changes within the river or stream system, totally unrelated to the instantaneous sediment production of the land. Typical examples are changes and adjustments in the meander pattern of a stream where large amounts of sediments may be transported over relatively short distances.

The chances of pin pointing excessive sediment sources are better the smaller the possible number of sources, i.e., the smaller the watershed. An effective control system would need numerous measuring points at small streams. Such a requirement is in clear contradiction to the demand of an economical surveillance system.

Conclusion: The necessary spacial separation of sediment source and measuring point makes it excessively difficult to pin point heavy sediment sources. In order to be still effective, measuring points need to be at small streams. Yet the economical consequences then exclude the possibility of a wide spread, systematic measuring program.

Control at the Source

If it is in general impossible to trace excessive sediment flux at the measuring point to a specific source, the only way to locate the source is by evaluating the practices of the people using the land. If a user is located who employs methods known from past experience to produce large amounts of sediment, he may be causing the excessive sediment flux. But if this indirect way of locating the source is the only feasible means, one might as well reduce the effort in measuring sediment transport in the stream (as we will see in itself a very difficult task) and spend more effort on the surveillance of the practices employed by the land users. This applies for any source which is not clearly a point source.

Following this line of thought a point source then would be one where it is possible to directly measure the sediment production. For instance a construction site at a river crossing would be such a source. By measurements immediately upstream and downstream of the site it is possible to give a direct measure for the strength of that source. Even a site with strong wind erosion (e.g., a surface mine) may fall into the category of point source, according to this definition.

It was pointed out already in the position paper that various land management techniques will greatly affect the erosion rates. Considering that society at large has a clear interest in the movement of sediments in the environment, it does not appear as an undue interference with the land users if such land use management techniques are regulated. Especially not since the land user has himself the same immediate interest as does society at large: to minimize soil losses.

Conclusion: It appears more reasonable to develop standards for land management techniques which are enforceable, than to develop sediment standards in rivers which are very difficult to enforce.

How to Derive Standards for a River

Even if a rigorous program on land management techniques is developed and standards enforced, a need for sediment standards in rivers continues. Human interference with the environment has in the past and will in the future influence the sediment transport in rivers, no matter how well the management techniques are developed. The best conditions for the river are unlikely the most economical conditions for the land user. And the question of whether one can afford a deviation in one or the other direction from present conditions will continuously be posed.

Whether it ever will be possible to define generally applicable standards appears unlikely. Even if we move away from the small stream and conduct a surveillance system only at the larger rivers we need to appreciate the fact that under pristine conditions some rivers carried a very heavy sediment concentration while others carried extremely clear water. Whatever the conditions, the biotic equilibrium and the geomorphic equilibrium adjusted accordingly. And if the same standard is used for both rivers, and land use is managed in a way such that the sediment transport is right at the limit, one river may badly erode and the biota may suffer from insufficient food supply while the other one shows heavy aggregation and the biota is endangered because of the high, unusual amount of sediment.

In the discussion of the workshop the concept kept developing of classifying and mapping rivers according to at least two concepts: a mapping according to (1) the geomorphic characteristics and (2) the biotic conditions. A superposition of the two maps would then determine the applicable sediment standards. The concept is based upon the assumption that streams in a certain area show a high degree of similarities in their geomorphic structure. The climate is very similar, the ground cover, the geology, as are parameters like slope, or sediment size which directly influence the geomorphology. At the same time the biota is frequently quite similar as one moves from one stream to the next, since the stream biotas are directly or indirectly interconnected. Yet whether the geomorphic characteristics are heavily correlated with the biotic ones appear questionable. It is quite possible that two "clear mountain streams" may show significantly different biotas and therefore require different standards in regard to tolerable sediment concentrations.

Such a procedure does not say anything on what constitutes acceptable limits for sediment transport. It merely suggests a possible procedure which does not require surveying each and every stream in the nation, a task which for economical reasons is impossible.

A much less systematic and less sophisticated approach would be to survey certain rivers, which for one reason or another are of considerable importance. These rivers would be studies in great detail and standards would be set for them one by one according to their geomorphic and biotic characteristics and possibly other factors could be included. Other rivers would not have specified standards. The assumption is that such uncontrolled streams eventually discharge into rivers with standards. And if an uncontrolled stream shows excessive sediment transport it would eventually show up in the controlled stream. From a legal point of view such a procedure is not very desirable, even though it may achieve the goal of a generally stable river environment. The fact that individual streams may become highly unstable is not at all so much different from what can occur under pristine conditions. The question is whether legal steps can be taken to correct an unsatisfactory condition if no specific standards are set.

Carrying this procedure one step further, one could think of standards only to be developed and set as the needs on specific rivers and streams develop. This approach is undesirable since the only way to set such standards is by having some record defining the status quo and possibly dating back far enough, such that trends can be observed.

Conclusion: For legal reasons every river or stream should have some sort of standard. It appears most promising to classify regions at least according to the geomorphic and biotic characteristics of their streams and rivers (possibly more criteria could be included). The two classifications together would determine the applicable standards. But even with such an approach the economical consequences are considerable.

What Standards?

The discussion group showed total agreement that turbidity is an unacceptable parameter for setting standards, even though it is the only one presently used beyond special cases. Turbidity is certainly not a good indicator for geomorphic stability. It depends very much on chemical-physical characteristics of the suspended material which may or may not be related to the material close to or on the riverbed, i.e., material which has more immediate influence on geomorphic stability. Furthermore turbidity is, generally speaking, not a good indicator for the food supply for the biota or the biota itself. The only direct information provided is on light penetration which has no direct influence on geomorphic stability and is only one of several parameters which influence the biota.

The ideal standard would certainly be one which relates to the total sediment transport characteristics of the stream, i.e., to the sediment transport of each grain size, as a function of water discharge, or stage. This information is usually not available at present time, even at rivers which are "extensively surveyed." Data collection is now largely oriented toward discharge and suspended sediment concentration. This has a simple explanation: determination of water discharge is easy after a stage-discharge relationship is measured at a stable cross section; and collection of water samples from various depths poses little difficulties beyond the fact that it is time consuming. Of course this latter aspect is the reason why such suspended sediment transport measurements are very limited and concentrated at the larger rivers.

Why is such information insufficient? The development in time of the longitudinal profile of a river or stream is much more affected by the bed load transport than the suspended transport. Many rivers carry many times their bed load as suspended load. Yet significant riverbed changes can only occur if the bed gets highly mobile. Periods of extensive bed load transport are at many rivers very short and limited to flood stages (especially in the smaller rivers). But in larger rivers bed load transport may be almost continuously in process throughout the year. What situation prevails depends largely on the size distribution of the bed forming sediment. If one would like to understand the geomorphic changes in a river, we must understand the influence of grain size distribution on the bed load transport.

Grain size distribution of the bed material also is an important parameter for the biota since it determines the geometric shape of the boundary. It furthermore affects the "renewal" rate of the top few inches or so of the riverbed which for the biota is an important part of the system.

The grain size distribution of the suspended material may be of lesser significance for the geomorphic characteristics of the stream or river. But for the biota it appears to be of great importance. Inorganic suspended sediment transport is likely to be heavily correlated with the organic sediment transport, which forms the food supply for the biota. And finally, as mentioned above, the suspended material (including its grain size distribution) determines turbidity, i.e. light penetration, which directly affects the biota.

Conclusion: The full spectrum of grain sizes in streams and rivers is of significant importance for the biota. At least the grain sizes of the bed material controls the geomorphic equilibrium. Inorganic sediment standards need to be set for that full spectrum of grain sizes. Standards for organic sediment may be set separately to insure appropriate food supply; yet the two may be so heavily correlated that a separation is impossible and one would have to rely on the assumption that maintaining standards for the inorganic matter insures adequate supply of organic matter.

Summary I

If indeed it is the purpose of standards for the sediment transport in rivers and streams to maintain the geomorphic and biotic equilibrium (or to re-establish such an equilibrium), we are faced with an almost insurmountable task.

Standards must be set and enforced at the small streams else it becomes impossible to locate excessive sediment sources. Such standards need to be very sophisticated and must relate to the full grain size distribution of the moving sediment for geomorphic and biotic reasons. Extensive measuring programs in which data is collected on a more or less continuous basis is then economically impossible.

In order to insure the quality of our streams it is suggested that standard land management techniques are developed for the various regions of the nation which insure acceptable soil erosion levels. But this does not eliminate the needs for standards in the streams. Such standards must take into account the highly individual characteristics of each stream. Since it is an impossible task to survey each stream and set its own standards, such standards must be related to a few key parameters: the hydrology, the geomorphology and the biota of the river. Each of these factors may not vary significantly within one region. Furthermore the first two are so highly correlated that a separation may not be necessary. Instead of mapping each stream it then may be sufficient to map regions. Any combination of geomorphic and biotic characteristics of the region would then determine the standards applicable to the region's streams.

In the remainder of the paper we shall summarize these parts of our discussion which related to the specific research needs in the light of the conclusions reached sofar.

Research Needs as Related to Land Management

It is fully appreciated that this is not directly part of the overall discussions as defined by the title of the study. But because of the previously mentioned dichotomy it must be included.

The universal soil loss equation was already discussed in the position paper. Despite some disagreement on certain statements the author does not want to change the statements made. But the discussions certainly centered around at least one additional problem area: the temporary storage of eroded soil between its original location and the point where it reaches the permanently established water course. This storage is important perhaps for two reasons: (1) it controls the time scale of the sediment movement up to the stream's end (2) it may offer a last chance to keep the sediment from reaching the streams and to change such temporary storage into permanent storage. In the overall analysis of the sediment movement in the environment, this storage adds another highly stochastic component. At present this component enters into the calculations in form of a mean "efficiency." Yet its statistical distribution in time and space appears to be of significance.

If we do in fact consider the development of standardized land management techniques to be important, a continuous updating of such techniques will be necessary due to new methods becoming available. There are especially economical aspects which will determine such new methods: How much additional loss can be tolerated for a much more economical technique? This question can only be answered based upon standards in the streams.

Research Needs as Related to River Morphology

The discussions at the workshop included interesting reports on various measuring techniques used in the field, in specific cases. In the light of the previous discussions the report on bed load measurements was of particular interest. It appeared to be the agreement of the group that such field measurements are an absolute necessity in order to learn more about bed load. Yet it was also agreed that any continuous survey program collecting such data at many locations is not possible because of the financial consequences. Another one of the reports was on the "instantaneous" measurement of suspended sediment load along dozens of miles of a river. In this instance, remote sensing was used and calibrated against a number of actual concentration measurements made at the same time the river's length was flown. Of interest is the fact that with relatively small manpower input, a very substantial and accurate piece of information was obtained. But of equal interest is the concept of instantaneous survey over many miles, where in general we obtain data at one point, and not even continuous in time.

These examples are mentioned because short reports were delivered at the workshop. Equally important is the fact that there are always people who collect "the unusual data." It is hoped that such information is dispersed quickly and widely, not only in a short conference report but in a number of key journals. Because of the multitude of professionals interested in the sediment problem there is acute danger that most of the concerned people will miss a report simply because we don't read and don't publish in each other's journals. A more frequent, and certainly more regular meeting such as the Interagency Sedimentation Conferences could be a logical place for quick and widespread dissimination of information.

It was previously pointed out that two closely related aspects in river morphology need much more attention: bed load and grain size distribution. Bed load research would be of particular interest when related to the corresponding suspended load. Such research cannot be done under laboratory conditions; they must occur in the field. Because of the large effort required only very few sites can be considered and need to be carefully selected, most likely on small streams. After we have gained new insight into the process we must draw the appropriate conclusions for the development of standards and will discontinue to collect more bed load data.

At the same time we need to observe the grain size distribution curves of the moving material. Only one sediment transport equation in wide use predicts grain size distribution. Yet it was developed only for rivers with sandy beds and it never claimed to be accurate in respect to the grain size distribution. It is not at all an overstatement to say that there is no tool predicting the grain size distribution of the sediment transported in a stream or river. Closely related to the problem of grain size distribution is the one of natural sorting processes in rivers including the armoring of riverbeds and its subsequent distruction in the following flood. Again almost no information is available; yet clearly this is directly related to the transition from stable to unstable bed configurations.

Research Needs as Related to the Biota

What we are lacking is a description of the biota and its distribution in the water and riverbed in terms of the geomorphic characteristics of the river. Yet that is what is needed for developing sediment standards. And this is where not only the author but also a number of the workshop participants see the greatest research need. We know a good deal about land management and its affect on soil loss, as well as about river mechanics even though certainly not enough to answer all questions related to setting standards. But about correlation between geomorphology and the biota we seem to be several steps behind.

The group seemed to agree, and this is nothing but perfectly consistent with what was said above, that the efforts should concentrate on the small streams. If we can keep the small streams in order (and of course there are many more miles of small streams than of big rivers), the large rivers will more or less automatically be taken care of.

It may appear tempting to separate these research needs into two groups: one group of concern to the stream ecologist only, the other group to be investigated by a team of biologists and river morphologists. The discussions at the workshop left the non specialist with the distinct feeling that the stream biologists have much less to offer in specific knowledge than the other professional representatives. This should not be surprising; their problem has a multitude more boundary conditions than all the others' problems. Local climatological considerations, the hydrology of the stream, the geomorphology of the stream, etc. all need to be understood before only the boundaries of the biota are defined. The stream biologist's difficulties in advancing then may well be related to this fact. A separation into two groups of research needs appears inappropriate. Any research on the river biota must be done in close cooperation with the other specialists, in particular the river morphologist if we focus on sediment standards.

A number of specific research topics were mentioned which fall into this area. The mentioning of a few may appear arbitrary, especially to the biologist. But since the majority of readers of this report are not biologists it appears of value to do so.

In order to maintain a biota a certain number of "degree days" is necessary. Whether we meet the minimum number by means of a few relatively warms days or an extended period of not so warm days frequently does not matter. When asking what do high sediment concentrations do to the biota it may again not be the absolute value of such concentration but rather the product of concentration and time. This cpens very interesting aspects in regard to sediment standards. Specification of a concentration level never to be exceeded is possibly far from an optimum solution. The process in the pristine river is highly stochastic. Simply limiting the mean appears totally insufficient.

We already mentioned above the fact that an important component of the biota lives in the top few inches or so of the riverbed. This layer may be, geomorphically speaking, very stable over most of the year, particularly in the small stream. But during flood stages it will get completely worked over. What is the significance of this renewal for the biota?

A third aspect of research closely related to sediment and biota is the one on food supply. In terms of transport processes there is considerable similarity between organic particles and sediment (inorganic) particles, despite the different specific weights. If there is a strong correlation between suspended sediment transport at a river cross section and the available food supply this would impose additional limits on the range of possible standards.

One of the major problems in regard to all research of this nature just mentioned is that it cannot be done in the laboratory but must be done in the field. Again of major importance is the site selection.

Research Needs as Related to the Stochastic Aspects

Throughout the discussions so far we pointed to the fact that we deal with a highly stochastic system. Hydrology is largely stochastic; sediment transport is a stochastic process, so is the river eco system. The discussions pointed out again and again that the timing of "major" (i.e., usually rare) events is absolutely crucial for the biota. And not only is the timing important but these rare events, e.g. a 100 year flood are necessary to maintain a healthy biota and possibly necessary to maintain the long term geomorphic equilibrium.

The title of this paragraph is not to imply that we need to develop more and new techniques in the analysis of stochastic processes, but all researchers should keep in mind that we deal with a stochastic system, one in which the distribution of extreme values might be of great importance and that the statisticians have developed a great deal of tools we may be able to use in our studies.

Summary II

In the previous paragraphs we have provided nothing but a summary of research needs, very subjective, as viewed by the author. Let me point to that area which I view as the most neglected area of research activities as related to the setting of standards: the biota as classified by geomorphic characteristics of the river. We need to analyze specific sites to learn more about the effect of geomorphic changes on the biota. We need to classify streams according to some biotic and geomorphic characteristics, and then set standards accordingly.

Standards are to be set to maintain or improve the biotic and geomorphic equilibrium of the streams and rivers and we need to study the very complicated way in which the geomophology affects the biota.