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VARIABLE SELECTION IN WATER QUALITY MONITORING NETWORKS

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Up-to-date investigations regarding variable selection in water quality monitoring network have not arrived at a definite procedure to be followed within the design process. An attempt is made in this study to cover the topic thoroughly and to develop clear-cut guidelines for selection of variables. The complicated nature of the problem required extensive efforts and patience to realize the basic objectives of the study.

I am indebted to Assoc. Prof. Dr. Necdet ALPASLAN, my supervisor, for his motivation and support during many months of difficulties I encountered throughout the study.

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ABSTRACT

With respect to utilization and development of water resources, the quality of water is as important as its quantity, and it plays an increasingly significant role in the development of almost all sectors of the society. Water quality has previously been overlooked in assessing water demand, basically with the belief that natural water resources would remain unlimited with respect to water use. However it is recently recognized that water quality is particularly significant in terms of pollution control, and that it is one of the basic factors to determine the amount of available water that can be used to meet a specific water demand. Due to increases in population densities, societal developments and pollution of surface waters man has begun to experience limitations in the utilization of available water resources. Societies have also become more interested in water quality as surface waters become the major sources of diseases.

When water quality is of concern, its definition becomes the first issue. Water quality is mostly related to water uses and is generally defined by chemical, physical, and biological variables. Information on water quality can only be achieved by monitoring these variables in a river basin. However, the main question is how to select from among hundreds of variables and how to decide on what quality variables to monitor within a basin. Investigations up-to-date have not yet reached a definite solution for this problem. This study attempts the development of a method to determine the quality variables to be involved in a water quality monitoring network.

In the study presented, it is proposed that objectives of monitoring must be specified as a priority so that relevant quality variables can be selected to satisfy the objectives. Although many different objectives have been defined in literature, two gross objectives can be outlined as "water uses" and "impact assessment". Water uses include various beneficial uses of water by public and each beneficial use requires information on different quality

variables. Impact assessment aims at determining the quality characteristics of point and nonpoint source discharges in a basin. The study presented foresees the selection of quality variables with respect to these two objectives.

When such objectives are taken into consideration and variables are selected depending upon these objectives, selected variables will inevitably become dependent on the individual monitoring stations and show difference from station to station. On the other hand, network-based monitoring may require homogenous conditions. Homogeneity in selected variables can be obtained by monitoring the same variables at all stations within the basin. Serving this purpose, variables to be monitored in all stations in addition to the station-based variables are determined by taking into consideration basic properties of the variables to be monitored. Finally, it is foreseen in the study that correlation analyses between quality variables may be useful in reducing the number of selected variables.

It is expected that the approach proposed in the study will serve to provide a systematic framework of guideliness to select variables to be sampled in a water quality monitoring network. The problem still retains its difficulty; however, the prevailing confusion in the selection process is deemed to be reduced by applying the systematic approach proposed.

ÖZET

Su kaynaklarının gelişimi neticesinde su kalitesinin su miktarı kadar öneme haiz olduğu görülmüştür. Geçmişte su kaynaklarının sınırsız olduğu düşüncesiyle kaliteye gereken hassasiyet verilmemişti. Ancak yakın zamanda kirlilik kontrolünde ve kullanılabilecek su miktarının tayininde kalitenin önemli olduğu görüşüne varılmıştır. Nufüstaki artış ve toplumsal ve teknik gelişmelerle yüzeysel suyun kirlenmesi neticesinde kullanılabilecek su miktarında sınırlamalar ortaya çıkmıştır. Ayrıca kirlenmiş yüzeysel suların bulaşıcı hastalık kaynağı oluşturmaları nedeniyle de kalite degerleri önem kazanmıştır.

Kalite söz konusu olunca yapılması gereken ilk iş bu terimin tanımlanmasıdır. Kalite çoğunlukla su kullanımları ile ilişkillendirilmekte ve genellikle fiziksel, kimyasal ve biyolojik değişkenler yardımıyla tanımlanmaya çalışılmaktadır. Bu değişkenler hakkında bilgi edinilmesi de ancak ilgili havzada kalite gözlemeleri yapılması suretiyle mümkün olabilmektedir. Burada esas soru yüzlerce kalite değişkenleri arasından hangilerinin gözlem programı için seçileceğidir. Bugüne kadar yapılan çalışmalar belli bir sonuca ulaşamamıştır. Bu noktadan hareketle sunulan çalışmada bir metod geliştirmek suretiyle bu konudaki eksikliğe bir çözüm getirilmesini amaçlamaktadır.

Bu çalışmada önce amaçların tanımlanması gerektiği ve daha sonra amaçlara bağlı olarak değişkenlerin belirlenmesi gerektiği önerilmekterdir. Literatürde araştırmacılar tarafından pekçok amacın tanımlanması yanısıra, etki degerlendirmesi ve su kullanımları olmak üzere iki genel amaç belirlenmiştir. Su kullanımları suyun çeşitli faydalar için kullanımı demektir ve her bir faydaya hizmet edecek su kullanımı bir ölçüye kadar farklı kalite değişkenlerinin dikkate alınmasını gerektirir. Etki değerlendirilmesi ise noktasal ve/veya yayılı kirlilik deşarjlarının su kalite karakteristiklerini nasıl etkileyip değiştirdiğinin belirlenmesidir. Dolayısıyla ölçülecek değişkenlerin belirlenmesinde deşarjlar etkindir.

Bu amaçlar dikkate alınarak kurulacak bir gözlem ağında değişkenler amaçlara bağlı olarak belirleneceği için, değişkenler istasyona bağlı olacak ve istasyondan istasyona da farklılık gösterecektir. Öte yandan gözlem ağı, bir havzadaki istasyonlarda ölçümü yapılacak değişken gruplarının homojen bir durum arzetmesini gerektirebileceği düşüncesinden hareketle değişkenlerin bazı özellikleri dikkate alınarak bütün istasyonlarda ölçülmesi gereken değişkenlerin belirlenmesi yoluna gidilmiştir.

Son olarak kalite değişken değerleri arasında korelasyon katsayısının değişken sayısının azaltılmasında yardımcı olabileceği önerilmiştir.

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1.1 The Nature and Significance of Water Quality

Water is a required element in the maintenance of life, and living organisms can not survive for long periods without water. This fact has resulted in the development of a direct relationship between the quality, as well as the abundance of water, and the quality of life.

Water quality is defined in terms of specific characteristics. Throughout history, the most important characteristic has been the concentration of salts because of the strict relationship between salt content and land productivity. Existence of pathogenic organisms (disease-causing organisms) has become more important as the population densities increased. Owing to industrial developments, some other characteristics, such as temperature and specific ion content, became significant. Recently the discharge of newly manufactured chemical compounds into surface waters, even in trace amounts, has gained importance.

When water quality is concerned, its definition is probably the first issue to be considered. In the design of a monitoring program, quality aspects need to be clearly defined. Even though many attempts have been made, the term "water quality" has not been fully defined yet. Its definition can not simply be contributed to protecting public health and the complete ecosystem, nor can it be defined by only one variable. Several variables are needed to identify water quality, and this fact makes its description rather complicated. Chemical, physical, biological, and radioactive substances specify the quality of water. Water quality is also described by classifying its constituents as "gross variables" and "specific variables" (Tchobanoglous and Schroeder, 1985). In this classification, no distinction is made between individual chemical, physical, and biological variables. "Gross variables" are the most easily measured and interpreted variables for the description of water quality, such as Ph, electrical conductivity, color, turbidity, temperature, dissolved oxygen, hardness etc. "Specific variables" are variables of concern with respect to a particular water use objective.

Identification of water quality may be related to beneficial uses of a particular water body (Lee et al, 1982). Beneficial uses include domestic water consumption, industrial purposes, agricultural use, maintenance of fisheries, recreation, aesthetic appreciation, and conservation of natural ecosystems. Since all these purposes require water at various quality levels, a general description serving all purposes can not be implemented (Connell and Miller, 1984; Lee et al., 1982).

Up to present, water quality criteria and water quality standards have been the widely approved measures of water quality. Existing water quality conditions have been defined in some cases by comparing the chemical concentrations in a water sample with relevant prescribed quality criteria and standards (Lee et al., 1982).

1.2 The Role of Water Quality Monitoring

Water quality monitoring activities date back to almost 100 years. However, systematic measurements within what may be called a "network" cover a much shorter period of about twenty years. Despite all developments, the design of water quality monitoring network is still a controversial issue receiving considerable attention from researchers and practitioners.

In the water environment, water quality monitoring includes the measurement of certain quality variables with a frequency at selected locations for a period of time. Various types of definitions of monitoring may be found in literature, such as factor monitoring and target monitoring (Connell and Miller,1984), compliance monitoring and ecological monitoring (Magnien and Christopher, 1986).

Monitoring at problem or project-oriented levels differs from actual monitoring from the point of view of actual definition of network. Actual monitoring network design requires homogenous, as well as systematic, conditions which in turn supply the demanded information. Accuracy in the determination of water quality can not be provided unless existing monitoring activities are evolved into a "network" which follows the well-defined objectives of monitoring (Alpaslan and Harmancıoğlu, 1991).

Another factor concerning water quality monitoring includes the regular observation of variables over both space and time (Cotter, 1985). Transformation of data into information requires data observed continuously or with a particular time. These systematically observed data are convenient to handle, and such data can be used in practice by environmental managers and engineers. Systematically observed data would also help to review the present and future monitoring networks for revision purposes (Alpaslan and Harmancıoğlu, 1991). Past water quality observations have been carried out randomly and now the evolution is unavoidable from random to systematic monitoring. Various institutions in developed countries gathered plenty of data, but these data can not be used efficiently to evaluate into information. This situation has been called the "data rich-information poor syndrome" in water quality monitoring (Alpaslan and Harmancıoğlu, 1991; Ward and Loftis 1986).

1.3 Objective of the Study

In order to obtain quantitative information on surface waters, it is obvious that quality, as well as quantity, must be known. Quality is mainly defined by the amount of impurities present in water. Impurities are subject to variation over space and time, hence they are called "quality variables". Occurrence of variation with space and time is caused by the activities of society and natural hydrological cycle. Since these two mechanisms, man-made and natural causes, are assumed to be stochastic, information on water quality can only be obtained by monitoring in the area of interest. This stochastic prospect has made the design of monitoring sites unavoidable, where one of the problems is the selection of variables to be sampled.

Variable selection, to a large extent, is dependent on the monitoring objectives and objectives determine what variables to be monitored at a monitoring site. Therefore significant efforts are spent to specify the objectives. Following objective specification, selection of variables to be monitored becomes relatively clear. However, the number of variables to be monitored may be still too high to be included in a monitoring program. Therefore, variables are put in order of significance with respect to objectives and a cut off point is selected in the number of variables.

Although variables may be selected by an objective-based approach, water quality monitoring network may stipulate the measurement of same variables at every monitoring site in the scope of a network. This prospect brought the further selection of variables in use which have been considered as important in various water uses. These variables are those that need to be observed at every monitoring site, and objective-based variables are observed depending on the specific monitoring site. Variables to be monitored at every monitoring site may be determined by taking into consideration the cost and ease of measurement, statistical behavior and frequency of appearance.

As a case study, Sakarya riverbasin is assessed with respect to variable selection in a monitoring program. Sakarya river and its tributaries are utilized for various beneficial uses of the society, and each activity of the society requires water with different levels of quality. On the other hand, natural and man-made activities have resulted in discharge of impurities into the river and its tributaries. Hence, both monitoring objectives, water uses and impact assessment, have been proposed to apply in the basin. Water uses are proposed to apply wherever need is a water use, and impact assessment is proposed to apply wherever pollution loads are discharged into the river. In addition to objective-based selected variables, variables to be monitored at every monitoring site have been determined by taking into consideration the variables, which have been proposed as significant in water uses, from the scope of ease and cost of measurement, statistical behavior and frequency of appearance. Finally a correlation analysis has been done in the study to reduce the number of variables.

2. PREVAILING APPROACHES TO VARIABLE SELECTION

2.1 Review of The Current Approaches

2.1.1 Monitoring Objectives

Objective definition plays a key role in water quality monitoring network design. Up-to-date many different objectives have been proposed by researchers but these have not been readily accepted by environmental managers and engineers. Because of the difficulties in determining objectives, water quality monitoring network design becomes complex. A clear statement of objectives can ensure the collection of only the necessary data and can avoid needless and wasteful expenditures in time, money, and cost. Many different objectives have been proposed including the following (Ward, 1971; Ward et al., 1973; Sherwani and Moreau, 1975; EPA, 1977; Langbein, 1979; Trisch and Male, 1984);

- to establish a data base for the planning and development of water resources;
- to delineate prevailing water quality conditions and predict possible trends in water quality with respect to time and space;
- to provide a basis for the enforcement and development of pollution regulation;
- to supply data for the evaluation of control and abatement measures;
- to provide a data base for the development, calibration and verification of mathematical models of water quality to be used in support of other activities;
- to collect data required for research purposes;
- to assure a publically credible basis for controversial decisions.

It was agreed by the U.S. Federal, State, interstate, and local agencies that the overall objectives of the water pollution control program should include (California State Water Resources Control, 1974):

> "a.long term information on changes in water quality at key points in a river system, as such quality may be affected by change in water use and development.
> b.continuous information on the nature and extent of pollutants affecting water quality".

Steele (1971) suggested that three general functions of networks, survelliance, areal synthesis and basin accounting are in question when the concern is limited to data collected specifically for management and control of streamflow quality.

Steele (1971) stated that surveillance basically deals with temporal changes in quality and focuses on "the needs for verifying compliance or violation of stream standards". On the other hand, in areal synthesis, the emphasis is on identification of spatial variability of water quality. According to Steele (1971) "..regionalization techniques become extremely useful in generalizing water quality conditions from a fixed configuration of stations functioning in an areal synthesis network. Emphasis would be placed upon the following:(1) transferring information to streamflow sites with little or no information at a flowpoint located between sampling stations or located between sampling stations or located in drainage basins with similar lithology and other environmental factors affecting water quality, and (2) extrapolating from short-term records gathered by the areal synthesis network to obtain network to obtain water-quality average and extreme characteristics over a variety of flow conditions". Basin accounting procedures combine the evaluation of both spatial and temporal variations in water quality.

Schilperoot and Groot (1983) stress that monitoring network should be based on the water system to be monitored and the monitoring objectives. They stated that definition of objectives is required to make monitoring efficiently.

Schilperoot and Groot (1983) refer to the complicated nature of such a definition due to the presence of numerous different objectives which include the estimation of the present quality state, the detection of long term trends, the detection of standard violations, and model studies.

Tirsch and Male (1984) also refer to the same difficulty and state that "surface water quality monitoring network design is no easy matter, and difficulties arise in clearly defining the objectives of monitoring".

Depending upon objectives, some researchers have defined specific types of monitoring. For example, Connell and Miller (1984) consider that monitoring the pollutant in different parts of the environment can be described as "factor monitoring", and monitoring the effects of the pollutants on the natural ecosystem and associated biota as "target monitoring". Magnien and Christopher (1986) state that the objectives of a monitoring process dictate the complexity of the practice, and similar to Connell (1984) they mention nearly the same monitoring types under different titles such as:

> "..compliance monitoring studies typically have rather straightforward objectives: water quality parameters are examined relative to standard criteria often associated with a given discharge permit."

> "..."ecological" monitoring studies go beyond an assessment of conditions in an attempt to develop a better understanding of the factors and interactions that characterize the biological, chemical, and physical processes occurring in a body of water. These types of monitoring programs are by necessity more complex to design and implement than compliance studies. Indeed, the "ecolocigal" studies are often used to develop the cause-and-effect relationships between a pollutant discharged and its ecological consequences."

Karpuzcu et al., (1986) refer to short and long-term goals defined previously by Sherwani and Moreau (1975). These can be summarized as follows:

Short-term goals:

- monitoring and investigation of complaints;
- identification of gross pollution and nuisance conditions;
- prevention of water pollution emergencies or episodes; e.g., fish kills;
- set, amend, or repeal water quality standards;
- development of effluent standards;
- issuance of discharge permits for significant waste sources;
- enforcement of existing standards; investigation of the degree of compliance and frequency of violation;
- establishement of priorities for the control of souurces of pollution;
- authorize and approve water pollution control and abatement plans for drainage basins.

Long-term goals:

- long-range program planning, policy, and land-use planning;
- determination of origin and distribution of pollutants;
- tracing of pathways and fate of pollutants;
- understanding of the physical, chemical, and biological response of streams;
- evaluation of variouus control strategies;
- response of water quality to standards, permits, regulation, and enforcement;
- prediction of water quality;
- evaluation of trends; determination of the background levels of pollution.

Sanders et al.,(1988) consider that monitoring objectives involve detecting of trends, checking compliance with stream standards, and measuring ambient water quality conditions.

Reinelt et al., (1988) state that monitoring objectives may be general or specific and they design a model to meet the objectives for three different types of monitoring: reconnaissance monitoring, ambient monitoring, and enforcement monitoring.

Watering and Groot (1985) recognize two main objectives of water quality monitoring; determination of the present water quality and testing for water quality standards, determination of long-term water quality changes in time and in space.

Smith and McBride (1990) explain that New Zealand initiated a nationwide network in 1989 for the long-term monitoring of water quality in rivers. Detecting significant trends in water quality and developing better understanding of the nature of the water resources and hence better management of these resources are taken into consideration as the major monitoring objectives.

Trujillo-Ventura and Ellis (1990) states that many monitoring objectives have been reported in literature and there does not exist any methodology so far which can accomplish the duty of designing a network capable of satisfying all the objectives referred to in literature.

Alpaslan and Harmancıoğlu (1991) state that water quality monitoring is required for the following purposes:

- to detect rapid and continuous changes in quality;
- to identify the natural and man-made impacts that cause quality changes;
- to determine the effectiveness of water pollution control measures;
- to assess compliance with standards;
- to assess the impacts of development plans;
- to delineate present water quality conditions.

2.1.2 Water Uses and Monitoring Objectives

Steele (1971) stated that in many states water quality standards, consideration has been given to dominant uses of stream, and the initial water uses designation class changes, data networks are subject to periodic modification displaying a dynamic process. He also claims that under limited conditions on money and manpower, the problem arises as how to allocate these limited sources to supply a workable information system.

Skogerboe (1973) states that whenever water is diverted from the stream its quality gets worse in return, and diversions from river occur many times along the downstream to satisfy the needs of the inhabitants.

Skogerboe (1973) states that

> "..if the quantity of the pollutants in the return flow is large in relation to river flow, then it is very likely that the water is not suitable for the next user unless the water is treated to remove objectionable constituents. Since water is diverted many times from the major rivers, the river flows show a continutial degradation of quality in the downstream direction. As the water resources become more fully developed and utilized, without controls, the quality in the lower reaches of the river will likely be degraded to such a point that the remaining flows will be unsuitable for many uses, or previous uses of the waters arriving at the lower river basin no longer will be possible."

Nemerow (1974) stated that there exist two fundemental water quality standards in the U.S. as known stream standards and effluent standards. He says it was common to set stream standards for each benificial use of the stream such as drinking, swimming, fishing, irrigation etc, and since 1968 a new understanding began to influence which considered establishing one set of criteria for all waters, based on the most beneficial use.

Nemerow (1974) stated that

"..a regional rather than local or separate control system has great merit. A major characteristic of the regional system is that a region is often composed of many different kinds of waste discharges and water uses."

Chapman et al.,(1982) states that

"..the development of any monitoring program ultimately requires answers to two basic questions-what samples should be collected and what should they be analyzed for? The answers to these questions are naturally linked together and to the specifc objectives. If, for example, one is concerned with knowing the concentration of apollutant in a source of drinking water, the answers too sampling and analysis are fairly obvious. However, when the concerns of a monitoring program are expanded to include a list of 129 toxic chemicals and all aspects of water usage (including the swimmabble, fishable, and drinkable concerns of EPA) it becomes far more difficult to establish realistic sampling and analytical needs. Also the high cost associated with measuring organic pollutants (114 of the 129) creates additional financial constrains that further dictate the need to set priorities in sampling and analytical activities."

Lee et al., (1982) stated that

"..the first step in developing a plan for pollution control is to define the desired characteristics of water quality. According to PL 92-500, these are "chemical,physical, and biological integrity", and, intermittently, "the protection and propogation of fish, shellfish, and wildlife" and provision for "recreation in and on the water" (fishable, swimmable), wherever attainable. Because of the close tie made between these goals and water quality standards and criteria, water quality unfortunately and inappropriately come to be defined in some States by the comparision of chemical concentrationsin a water sample to equivalent Red Book water quality criteria and standards. As alluded in the law (which requires inclusion of the designated uses of the waters as part of quality standards), and as classically defined, "water quality" should be tied directlty to the beneficial uses of a paticular water body by man. Beneficial uses include domestic, industrial, and agricultural water supplies, sport and commercial fishing, recreation, and aesthetic quality as perceived by someone sitting on the bank or boating on water.

Connell and Miller (1984) states that a judegement is required involving the use to which a part of the environment is put. The uses of a particular water segment is manifold and the quality requirements for the different uses change accordingly. Therefore, the quality requirements of a monitoring program should be defined prior to initiating network.

Connell and Miller (1984) stated that

> "..environmental standards and criteria give an indication of the acceptable levels of occurence of a pollutant for the maintenance of water quality. In the recent past, acceptable water quality was related to use in domestic supply, industry, and agriculture."

> "..in recent years the objectives of environmental management and of water quality management, in particular, have expanded. Water quality management is now also concerned with recreation, aesthetic appeal, and conservation of natural systems. With these new aspects of water quality it is more difficult to define criteria and standards."

2.1.3 Practical Aspects of Monitoring Networks

Historically sanitary engineers were involved in water quantity and ambient water quality (Sanders et al, 1983). As the need has been increasing on water resources, and man's deteriorating effect on surface water quality has become obvious, emphasis on environmental pollution control has increased substantially (Sanders et al, 1983). Pollutants in surface waters reflect the strength the deteriorating effects caused by population growth, industrial activities and natural causes. Increased concern on water quality has been caused by the need to comprehend hydrologic cycle and antropogenic pollution potentials in relation with water quality deterioration. For industrial and domestic water supplies, treatment facilities have been designed to obtain water of a desired quality. However man primarily desired to know the available characteristics of water rather than design treatment facilities to arrive at the desired quality. Finally, monitoring activities turned out to be essential to serve human beings or towards to any other special purposes.

Steele (1971) stated that interplay between cost function and information expectations should provide the basis to arrive at a design citeria, and the cost function might be considered an economic model which includes as major components: costs of field visitations, constituent analysis, and data processing.

Steele (1971) stated that

> "..a sampling program may advocate continuing coverage of several constituents measured over a historical period which provides additional information with few benefits. In extreme cases, perhaps the water quality variables measured historically do not provide any information on current water quality problems. For example, continued data-collection programs for many ionic constituents in surface waters may tie up funds that might more justifiably be used for measuring biologically related variables, trace elements, and other important characteristics of water quality.

Nemerow (1979) stated that

> "..the operating cost function deals with various changes associated with operating stations in a given type of network. Charges generally reflect certain everhead items (administrative, office supplies, etc.) and depreciation write-offs or capitalized items (equipment, laboratory supplies, instruments, analytical methods, etc.) as well as the direct cost items, such as field personnel, laboratory operating costs, and data processing."

> "..interplay between these two options (cost-benefit) should hopefully provide the basis for arriving at design for station operation agreeable to both the water resourcer manager who must use the resultant data and the network planner who must provide the data."

Watering and Groot (1985) stated that the monitoring networks in The Netherlands in 1981 has reached 400 sampling stations and at some stations approximately 100 quality variables have been monitored. Further in the light of these developments, a method for the optimization of the monitoring effort has been developed and monitoring sampling locations reduced 400 to 260 in 1983.

Reinelt (1988) states that

> "..past monitoring programs have been overly broad and poorly directed (Rago et al., 1983; Horner et al.,1986). Controlling the diagnostic capability and cost of monitoring requires systematic analysis of the potential causes ecological change, culminating in the definition of specific, achievable objectives for monitoring (States et al.,1978; Mar et al., 1986a)."

Sanders et al.,(1988) claims that monitoring is expensive and many efforts are necessiated for minimizing cost while maximizing the benefit.

Steele (1971) stated that

> "..from a system viewpoint it should be stressed that the network-data-network should be initiated by objectives specified from the planning level and not by the capacity of data loadings. Traditionally, among massive data collection programs, setting of objectives in sufficiently quantiative terms prior to implementation and subsequent expansion rather than the rule."

Connell and Miller (1984) states that the effective management program requires knowledge about the detrimental effects of pollution loads and factors causing these loads. It has been suggested that knowledge about the quantities, sources, and distribution of pollutants, effects of these substances, effects and causes of trends in concentration of pollutants, and the modification extent of these inputs, concentrations, are needed for an effective management program. In addition, legal, engineering, administrative, social, economic aspects should be taken into cosideration (Connell 1984; Holdgate,1979).

Bell (1984) stated that

> "..many management and monitoring goals are the direct consequences of a legal decision (regulations) as water quality may be related to the standards."

Tirsch and Male (1984) hesitates about whether local, regional, and national water quality goals are being reached or not, and qualititative information regarding these questions can only be obtained from water quality networks.

Reinelt (1988) claims that knowlodge about physical area, parameters of interest, personel experience, and expert judgement have been the major influencing factors on water quality monitoring programs, and more recently statistical analyses (the estimation of the mean and variance of variable(s) of interest; the detection of a change in the variable(s) over space and time) and optimizasyon techniques have become more significant.

Ward et al., (1988) stated that

> "..for many years hydrologists have recognized and treated qantities, such as runoff and streamflow, as statistical estimates."

> "..hydrologists and environmental managers have generally recognized water qauntity variability. Only recently, however, have some recognized that water qality observations are also variable, subject to uncertainity."

> "..admittedly, water qality behaviour is extremly complex and difficult to characrterize. Water quality behaviour can be characterized by using a stochastic modelling approach, but a completely acceptable one may not be forthcoming for many years."

Chapman et al.,(1982) states that

> "..the development of any monitoring program ultimately requires answers to two basic questions-what samples should be collected and what should they be analyzed for? The answers to these questions are naturally linked together and to the specifc objectives. If, for example, one is concerned with knowing the concentration of apollutant in a source of drinking water, the answers to sampling and analysis are fairly obvious. However, when the concerns of a monitoring program are expanded to include a list of 129 toxic chemicals and all aspects of water usage (including the swimmabble, fishable, and drinkable concerns of EPA) it becomes far more difficult to establish realistic sampling and analytical

needs. Also the high cost associated with measuring organic pollutants (114 of the 129) creates additional financial constrains that further dictate the need to set priorities in sampling and analytical activities."

In Turkey, DSI (State Hydralic Works) started monitoring activities in 1979, and had 489 monitoring sites in 1986 and have been monitoring approximately 40 variables. Variables observed in DSI monitoring programme are assembled in two groups; variables to be monitored at every monitoring site and variables to be observed depending on the monitoring site. Variables to observed at every monitoring site constitute the first group and variables to be observed depending on the monitoring site constitute the second group (DSI, 1986). First group variables are the most commonly known and traditionally measured variables. The second group variables are determined by considering the present and future use of water, receiving media properties, present pollution-bearing sources, field-logistics and available laboratory techniques.

EIE (Electrical Works Planning Department) began to perform water quality observations since 1970 and now it has 75 monitoring sites. EIE proposes water use, pollution control, and water resources development as monitoring objectives and major water use of EIE is the hydroelectrical power generation.

2.1.4 Choice of Monitoring Location and Quality Variables

A definite rule for variable selection for the design of water quality monitoring networks has not been developed yet. Institutional constrains, as well as expectations, dominantly affected variable selection. Laws, standards, expectations of users of network were taken into consideration in evaluating variable selection. Statistical analysis and optimization techniques might also have significant roles in the issue (Sanders et al, 1983). Some other aspects, including high expenses of measurement and excessive time-consuming analyses methods, have also been important in variable selection. Many researchers advise the measurement of "easy variables" as an undertaking to variable selection. This includes the measurement of variables which have been monitored traditionally.

Watering and Groot (1985) stated that in the set up of present water quality monitoring programme in the State-managed waters of The Netherlands, the main in-and-outflows (rivers entering The Netherlands and running to the North Sea and Wadden Sea), representativity (a relatively large are with the same hydrological characteristics), hydrological transition areas (river entering and leaving an area with the same hydrological characteristics), and gradients (present, and possibly future, main quality changes as a function of location) played an important role in the choice of sampling locations and the classification of locations.

Sanders et al.,(1988) states that

> "..both sampling location and sampling frequency can be developed independently of the water quality variable. However both criteria are affected by the water quality variables being monitored. Therefore, before a water quality monitoring network can be designed in a systematic fashion, the variables to be monitored should be specified so that their natural and/or man-made variation in time and space can be considered. In reality the specification of water quality to be monitored prior to initiating network would be ideal. In practice, however, network design is specified and one must know or determine what water quuality variables can be acurrately monitored with the existing network."

Smith and McBride (1990) stated that

> "...there are two types of stations in the network: (1)"Baseline", where there is likely to be no or little effect of diffuse or point source pollution and which will account for natural or near-natural effects and trends; and (2)"Impact", which are downstream of present, and possible future, areas of agriculture, afforestation, industry, and urbanization. Both types are required to properly adress trends but in some instances only baseline or impact stations are possible."

Steele (1971) stated that

> "..the premise of design flexibility in constituent determination is based on a philosophy that, if water quality variable A can be shown directly or by inference to be highly correlated with variable B at some flowpoint in a stream system, the additional information on one of the variables provided by continued concurrent measurements of A and B quickly becomes reduntant."

Watering and Groot (1985) stated that in the set up of present water quality monitoring programme in the State-managed waters of The Netherlands, directives (so-called Drinking Water Directives), basic water quality (all variables listed under the so-called "Basic Water Quality"), international agreements (agreed set of water quality variables), type of water (a specific set of quality variables), and wastewater discharges (specific set of variables with respect to wastewater discharges) played an important role in the choice of water quality variables.

Tchnobaglous and Schroeder (1985) stated that water quality can be defined by physical,chemical, and biological variables. Other than these measures, two other categories are also present:gross and specific measures. In these measures no distinction is made between individual physical, chemical, and biological variables. Gross measures are the most commonly known and easily measured, while the specific measures are determined with respect to some specific conditions.

Watering and Groot (1985) stated that

> "...for the choice of water quality variables a distinction has been made between four groups of quality variables to be analysed at the different sampling locations."

Alpaslan and Harmancıoglu (1991) stated that variable selection depends on the monitoring objectives and economics of monitoring. Beside some references propose that water use should be taken into consideration for variable selection, some advise that problem or project-oriented programmes are important for classification of variables to be observed.

2.2 Problem Statement

Monitoring activities were carried out on relatively polluted and pollution-bearing districts. As the information expectation on water quality increased, the number of variables, sampling frequency, and monitoring sites have been multiplied with respect to economical developments. This increase also could not answer the expectations since systematic monitoring has not been applied to get the demanded information (Alpaslan, and Harmancıoğlu, 1991). Subsequently there has been an increasing consideration in recent years to view the selection of sampling locations, determination of sampling frequencies, selection of variables, and duration of monitoring in a more comprehensive context (Sanders, 1983).

Past monitoring programs have been overly broad and poorly directed (Reinelt,1986). Some researchers state that monitoring goals are directly related to the regulations. Shortly monitoring has become a complex issue due to many factors and the most important of which is the clear and strict definition of objectives. Objective definition strongly affects the technical design of monitoring, and hence objectives should be agreed prior to determination of variable selection. Objectives of monitoring were not well-defined and based on personally decision-making. A strict and accurate definition of objectives will ensure the collection of required data and will prevent unnecessary expenditure in money, effort, and time (Mckee and Wolf, 1978).

As in the objective definition, there does not exist any strict and valuable criteria for variable selection as well. In practice water quality monitoring network is designed and consequently variables are determined. Technical attainability, economic attainability (cost of analysis and field visitations), field logistics, and legal enforceability have been taken into consideration to some extent in varşiable selection.

Sanders (1983) proposed that determining what water quality variables to measure is, to an extent, based on knowledge about physical-bio-geochemical processes affecting each variable in the hydrologic cycle. Physical-bio-geochemical processes indicate that some variables may not be found in detectible concentrations in dissolved form; they are found with greater probabilities in suspended or bottom sediment. Certain variables may be greately diluted by higher streamflows; hence, measurements should be taken during low flows. Conversly, higher amounts may be measured corresponding to higher flows. Seasonal changes in water quality (originating from domestic, municipal and industrial etc. processes) help to explain temporal changes and will influence the naturally occuring fluctuations. Specifically, information on industrial processes, irrigation schedules, or seasonal patterns of domestic water use may assist in sketching times, locations, and quality variables of concern.

Newly synthesized chemicals with the development of industry are being discharged into the surface waters. This fact has also increased the quality variables to be monitored. In order to totally describe the water quality behaviour for any user of interest, hundreds of variables may be needed to observe. Because such an effort is not possible economically to fulfill, some approaches for variable reduction turned out be unavoidable.

Water in the environment is affected by the activities of society and the natural hydrological cycle (Sanders et al., 1983). These two mechanisms are directed by the laws of chance. Surface water characteristics are subject to variation over space and time since the impurity concentrations may show an increase or decrease with space and time. To provide a perspective for quality characteristics it would be instructive to consider these two stochastic processes and their relationships to these characteristics. Wastes are the main origins of impurity and have the most deleterious impact on water quality due to the disposal to surface waters.

Variables to be observed in a monitoring program reach quite excessive levels, therefore some methodologies must be determined for selection. This determination will supply advantages from the scope of time and money.

Objective definition will provide a valuable basis for variable selection. Each objective itself determines the variables to be monitored, but the number of variables may become still too much to observe economically. Hence, some methods taking into consideration the resources of the society, including ease and cost of measurement, are proposed. Other than ease and cost of measurement, significance of variables and statistical characteristics of variables are also proposed as being important in variable selection.

3. PROPOSED APPROACH

3.1 Selection With Respect To Objectives

3.1.1 General

Water quality in rivers is affected by natural and man-made causes and subsequently quality characteristics show variations depending upon these two processes. Information on water quality under natural and man-made processes can only be achieved by monitoring the streamflow in the basin.

It has been proposed in this study that objectives of monitoring network play an important role in water quality monitoring network design and variables are selected depending upon objectives. Although many different objectives have been proposed in the literature by many researchers and objective definition is quite a complicated issue in the network design, two overall objective has been proposed as being essential and common in water quality monitoring network design. After deciding on objectives, technical aspects of networks are evaluated. Technical aspects include the selection of variables, sites, sampling frequency and duration of monitoring (Figure 3.1).

Some methodologies which were proposed to select the locations of sampling stations sed drainage area or flow characteristics. Scheidegger (1965) proposed using stream order numbers while Sharp (1971) proposed foreseeing a hierarchical order in establishing sampling sites (Alpaslan and Harmancıoglu, 1991).

Statistical methods have been proposed as quantiative criteria in selection of sampling intervals. Sanders et al., (1983) mention about some of the methods as the determination of statistical properties of water quality series, ratios of maximum flows to minimum flows, determination of confidence intervals of the mean values. Whitfield (1988) proposes that different sampling frequencies are to be selected for different monitoring goals (Alpaslan and Harmancıoğlu, 1991).

Alpaslan and Harmancıoğlu, (1991) states that duration of sampling is basically treated with the temporal design.

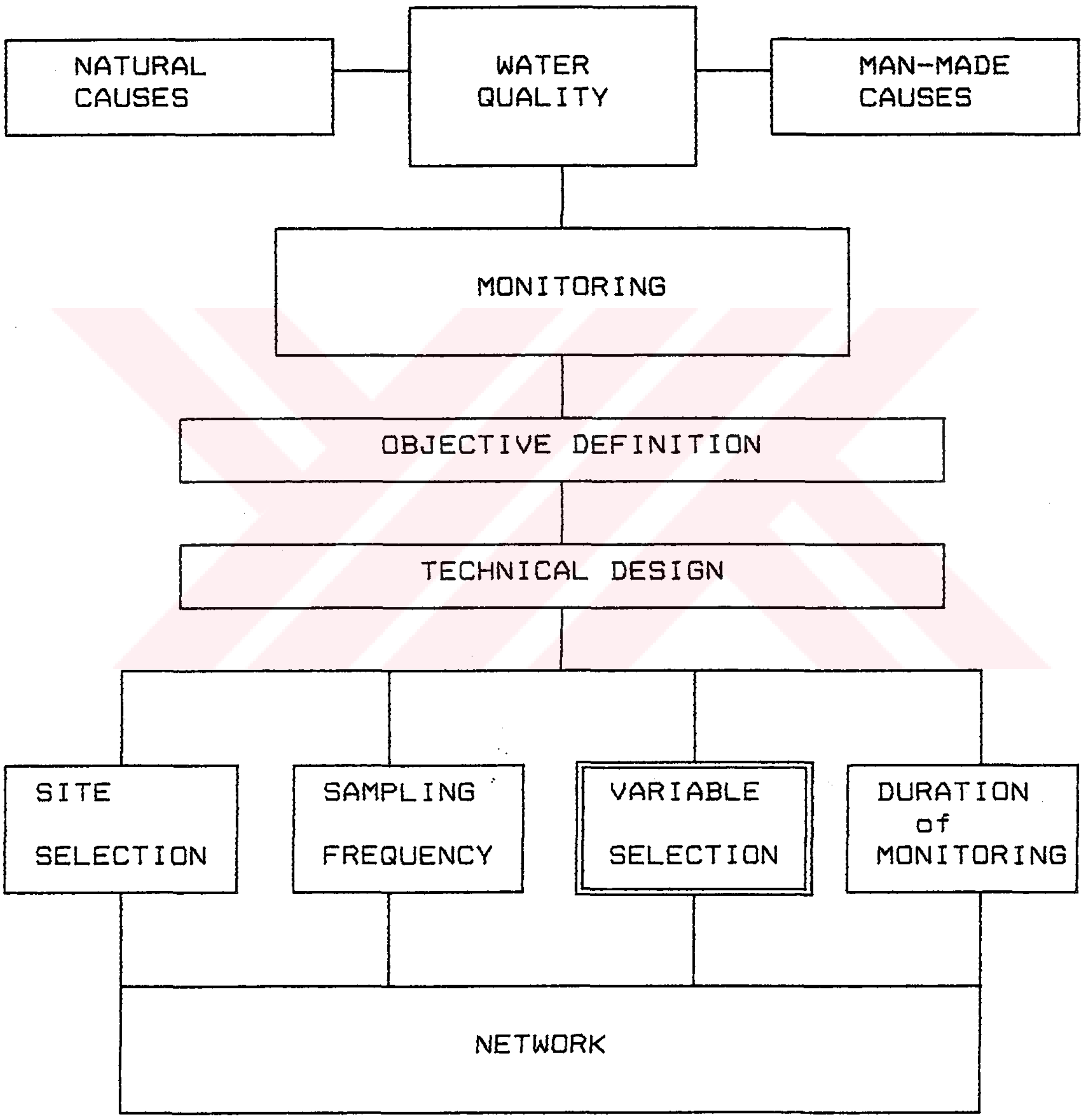


Figure 3.1 Schematic representation of water quality monitoring network

Streamflow serve towards to beneficial uses of man. These usages are misscallenous, and quality expectations of waters with respect to each usage change in a certain extent. Monitoring the streamflow waters for the convenience of any beneficial use has been called "water uses" in this study.

At the same time streamflow waters are polluted by the discharges of point and nonpoint sources lying in a river-basin area, and it becomes necessary to monitor and assess the quality characteristics of these pollution loads. Monitoring in a river-basin for the identification of discharge characteristics has been called "impact assessment" in this study.

To summarize, water uses aims the beneficial uses of water by man and impact assessment aims identifying point and nonpoint source discharge characteristics in a river basin area. Variable selection, subsequently, has been proposed to be highly correlated with these objectives (Figure 3.2). As shown in the figure, group A point out the variables to be monitored in all stations, group B refer to variables to be monitored with respect to water use, and group C are determined by considering discharges.

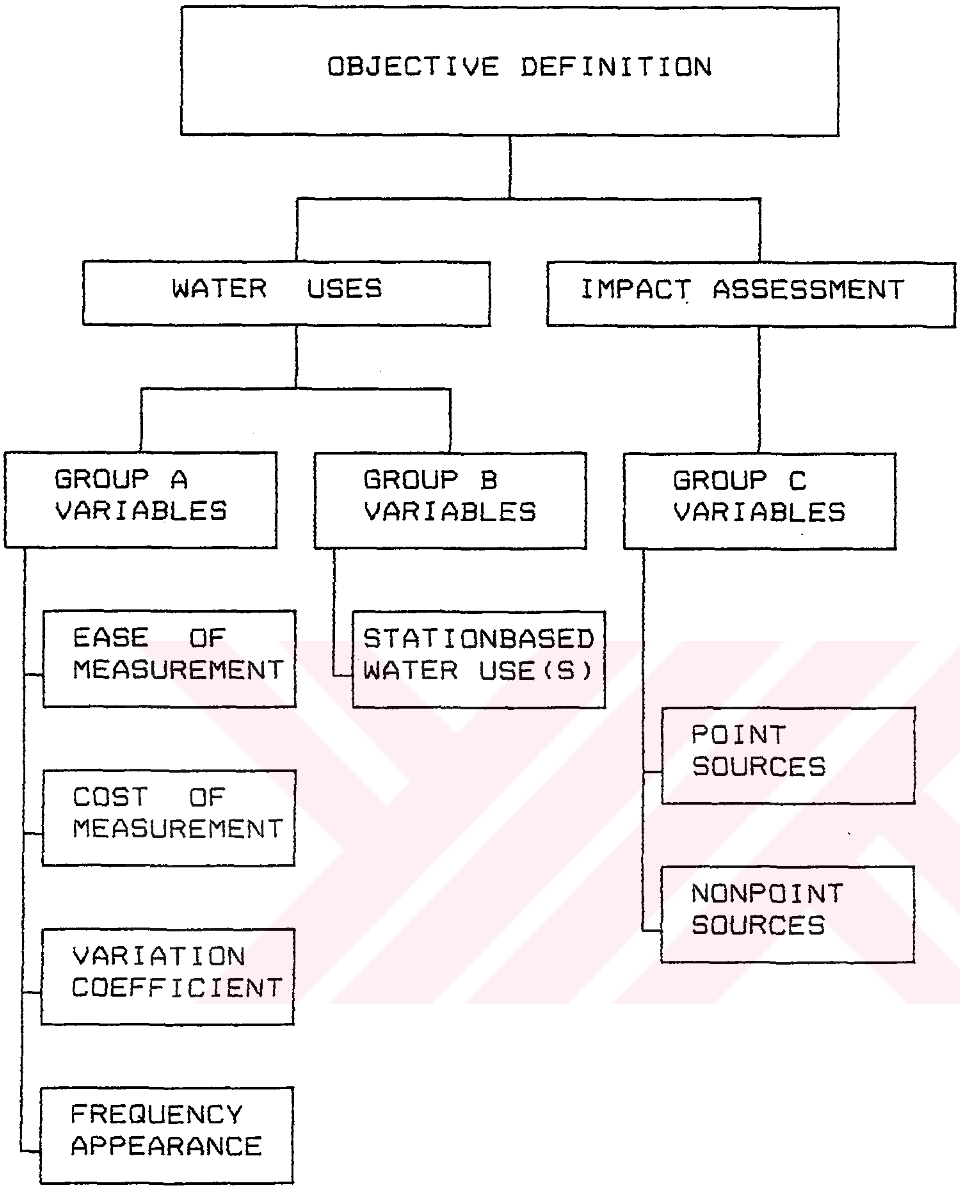


Figure 3.2 Components of variable selection procedure

3.1.2 Water Uses and Proposed Variables

The use, development, and management of water resources is one of the most important factors affeting the socio-economic structure of communities. As the most abundant compound on the face of the earth, water is required to serve many purposes ranging from internal consumption by living organisms, through agricultural and industrial uses, to the exploitation of its remerkable powers to transport and assimilate the wastes of civilization. As the demand for a limited water resources intensifies, rational use of water is becoming more essential and complex. The many purposes that water serves in promoting quality of life of a society are known as beneficial uses. As a dynamic and multiple-use resource, beneficial uses of water are listed in Table 3.1. A ranking of these beneficial uses is impossible in terms of economy or importance of water quality. Specific needs of communities determine the degree of priority.

Table 3.1 Water uses in a river-basin

a. Domestic water supply
b. Industrial water supply
c. Agricultural water supply
d. Stock and wildlife watering
e. Propagation of fish and other aquatic life
f. Shellfish culture
g. Swimming, bathing, and other water-contact sports
h. Boating and aesthetic enjoyment
i. Water power and navigation
j. Transport, dispersion and assimilation of wastes

Many of these uses, such as domestic water supply and industrial water supply, may be compatible. The effect of thermal discharges may be insignificant or even beneficial to domestic and agricultural users, but catastrophic with respect to the aquatic community. Hard waters may be perfectly satisfactory for drinking, but very unsatisfactory for use in boilers. For fisheries and aquatic life the parameters considered are dissolved oxygen, pH, and ammonia nitrogen. On the other hand, for irrigation water supply, one of the most important parameters is "sodium absoption" which can be calculated from sodium, calcium, and magnesium concentrations. So the definition of water quality is, to some extent, related to the intended use of the water.

a. Domestic Water Supply

Water consumed by human beings for drinking or other domestic purposes is considered to have primary, highest priority. On the contrary, other water uses may require water of higher quality from the scope of some quality variables.

Raw water supplies are being harmed by developments in society life. On the other hand, man requires water of higher quality with the developments in human life. Groundwater supplies are relatively better to use, but disinfection, softening, carbonate equilibrium may be necessary. Proposed variables for domestic water use are listed in Table 3.2 in order of significance.

Table 3.2 Proposed variables in order of significance for domestic water use

Variable	*Abbreviation*
Coliform	-
Turbidity	-
Color	-
Dissolved Oxygen	*DO*
Dissolved Solids	*TDS*
Hardness	-
pH	*pH*
Oil	-
Ammonia	*NH3*
Biological Oxygen Demand	*BOD5*
Odor	-
Nitrogen-nitrate	*NO3*
Nitrogen-Nitrite	*NO2*
Hydrogen Nitrate	*HNO3*
Selenium	*Se*
Cadmium	*Ca*
Barium	*Ba*
Arsenic	*As*
Phenol	-
Fluoride	*F*
Cyanide	*CN*
Beryllium	*Be*
Iron	*Fe*
Lead	*Pb*
Mercuric Chloride	*HgCl2*

Table 3.2 (continued)

Mercury	*Hg*
Hydrogen Sulphide	$H2S$
Hydrogen Cyanide	*HCN*
Phosphate	$PO4$
Electrical Conductivity	*EC*
Carbonates	$CO3$
Bicarbonates	$HCO3$
Alkalinity	-
Sodium	*Na*
Carbon Dioxide	$CO2$
Manganese	*Mn*
Chlorides	*Cl*
Potassium	*K*
Sodium Chloride	*NaCl*
Suspended Solids	*SS*
Temperature	*T*
Magnesium Chloride	$MgCl2$
Aluminum	*Al*
Silver	*Ag*
Magnesium	*Mg*
Chromium	*Cr*

b. Industrial Water Supply

In industrially developed countries, industrial water demand is much higher than municipal or irrigation requirements. Water serves many purposes in industry (e.g. as an ingredient in the finished product, as a cleansing agent, as a coolant, as a source of steam in heating and power production).

Quality requirements of water for industrial use change depending upon the purposes to which water is put. Since each industrial process requires water of different quality, it becomes impossible to constitute a single set of standards. Even in a single industrial organization, water may serve different purposes, in each of which quality expectations vary markedly.

In general, industries may accept water that satisfies quality requirements of drinking water although some reqires higher qality.

Though water is an essential element in industry, it may also cause some problems either (e.g. effect on products, deterioration of equipment, reduction of efficiency or capacity). Proposed variables for industrial water use are listed in Table 3.3 in order of significance.

Table 3.3 Proposed variables in order of significance for industrial water supply

Variables	*Abbreviation*
Alkalinity	–
Hardness	–
Chlorides	*Cl*
Dissolved Solids	*TDS*
Oil	–
pH	*pH*
Phenol	–
Temperature	*T*
Turbidity	–
Settlable Solids	–
Suspended Solids	*SS*
Sulfates	*SO4*
Cadmium	*Cd*
Copper	*Cu*
Fluorides	*F*
Hydrogen Sulphide	*H2S*
Lead	*Pb*
Nitrogen-Nitrate	*NO3*
Nitrogen-Nitrite	*NO2*
Manganese	*Mn*
Carbonates	*CO3*
Bicarbonates	*HCO3*
Iron	*Fe*
Magnesim Chloride	*MgCl2*
Sodium	*Na*
Zinc	*Zn*
Phosphate	*PO4*
Aluminium	*Al*
Potassium	*K*
Odor	–
Color	–
Chlorine	*Cl2*
Magnesium	*Mg*

c. Agricultural Water Supply

Natural irrigation waters don't contain so high salt concentrations that cause immediate hazard to plants. But the concentration increases with succesive irrigations and salt content reaches its solubility limit value in the root zone. Salts such as borates, chlorides, and sulfates of sodium and magnesium become dangerous to crops.

Salts affect the permeability and indirectly aeration of soil. Direct physical effects of salts prevent water uptake of plants (osmotic effects). Total salt content, which is stated in terms of specific electrical conductance, causes osmotic effect. Direct chemical effects of salts are important for metabolic reactions of plants (toxic effects).

Boron, silicon, fluorine, sulfur, phosphorus, and iron compounds; nitrite and ammonium ions; hydrogen ion concentration; and organic matter contribute to the total osmotic effect, and they are often toxic above certain concentrations.

The anions: carbonate, bicarbonate, sulfate, chloride, and nitrate, and the cations: calcium, magnesium, sodium, potassium contribute to the total osmotic effect. They may be toxic above certain limits.

Chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, and zinc are the trace elements which cause toxic effects. Proposed variables for agricultural water use are listed in Table 3.4 in order of significance.

Table 3.4 Proposed variables in order of significance for agricultural water supply

Variables	*Abbreviation*
Boron	*B*
Electrical Conductivity	*EC*
Alkalinity	-
Potassium	*K*
Sodium	*Na*
Magnesium	*Mg*
Chlorides	*Cl*
pH	*pH*
Sulfates	*SO4*
Molybdenum	*Mo*
Nickel	*Ni*
Lead	*Pb*
Selenium	*Se*
Zinc	*Zn*
Dissolved Solids	*TDS*
Sodium Chloride	*NaCl*
Arsenic	*As*
Barium	*Ba*
Fluorine	*F*
Beryllium	*Be*
Cadmium	*Cd*
Aluminum	*Al*
Mercury	*Hg*
Copper	*Cu*
Cobalt	*Co*
Chromium	*Cr*
Carbonate	*CO3*
Bicarbonate	*HCO3*
Iron	*Fe*
Nitrogen-Nitrite	*NO2*
Nitrogen-Nitrate	*NO3*

d. Propogation of Fish and Other Aquatic Life

As many physiolgical and environmental factors can change the responses of fish to specific constituents of the water, it is difficult to establish rigid quality standards. For example, species, size, age of fishes play an important role against the effects of harmful substances. Chemical composition of water supply becomes important, such that in hard water. The damaging effects of poisons are generally lower than that of in soft water. Decreased oxygen concentration and increased temperature become susceptible to fish.

Fluctuating water levels, especially in impoundments may change the tolerance of fishes to the effects of pollutants in their natural habitats.

Dissolved oxygen, pH, specific conductance, free carbon dioxide, ammonia, and suspended solids have been proposed as being important for fish life (Mckee and Wolf, 1963). Proposed variables for fishing are listed in Table 3.5 in order of significance.

Table 3.5 Proposed variables in order of significance for propagation of fish

Variables	***Abbreviation***
Dissolved Oxygen	*DO*
Suspended Solids	*SS*
Carbon Dioxide	*CO2*
pH	*pH*
Hydrogen Cyanide	*HCN*
Color	–
Mercury	*Hg*
Zinc	*Zn*
Temperature	*T*
Electrical Conductivity	*EC*
Ammonia	*NH3*
Aluminum	*Al*
Chloride	*Cl*
Mercuric Chloride	*HgCl2*
Potassium	*K*
Turbidity	–
Arsenic	*As*
Cyanide	*CN*
Hardness	–
Phenol	–
Phosphate	*PO4*
Oil	–
Dissolved Solids	*TDS*
Barium	*Ba*
Boron	*B*
Cadmium	*Cd*

Table 3.5 (continued)

Chlorides	*Cl*
Nickel	*Ni*
Hydrogen Nitrate	*HNO3*
Nitrogen-Nitrite	*NO2*
Sodium Chloride	*NaCl*
Hydrogen Sulphide	*H2S*
Alkalinity	-
Copper	*Cu*
Iron	*Fe*
Lead	*Pb*
Manganese	*Mn*

e. Swimming Waters

Waters that are employed for swimming purposes should be in compliance with the some well-known general conditions. These conditions include nonexistence of disagreeable floating and suspended materials, offensive odors and color, harmful substances to skin, pathogenic organisms. If the main conditions cited above are provided, such water may be accepted as favorable.

pH, color, and turbidity are also proposed to include as they are easy to determine (Mckee and Wolf,1963). Proposed variables for swimming purposes are listed in Table 3.6 in order of significance.

Table 3.6 Proposed variables in order of significance for swimming purposes

Variables	*Abbreviation*
Coliform Bacteria	-
Suspended Solids	*SS*
Turbidity	-
Odor	-
pH	*pH*
Oil	-
Taste	-
Color	-
Dissolved Oxygen	*DO*
Aluminum	*Al*

f. Stock and Wildlife Watering

The water which is safe for human consumption may be suitable for consumption by stock. But animals can tolerate higher limits of salinity and some specific substances.

Animals would not, undoubtedly, prefer to drink saline water if better is available, but they can adjust themselves. The permissible level of salinity to animals will change with the species, age, and physiological conditions.

The total salts include the chlorides, sulfates, and bicarbonates of sodium, calcium and magnesium. Sulfates are more hazardous than chlorides, and magnesium chloride is more hazardous than calcium or sodium chloride.

Nitrates, fluorides, salts of selenium and molybdenum are important for animal consumption.

It is essential that water including bacterial contamination should be treated completely for use by cattle although pathogenic bacteria are more critical to remove.

Oily substances are detrimental to livestock. Taste and odor hinder the use of water by livestock. Proposed variables for wildlife and livestock watering are listed in Table 3.7 in order of significance.

Table 3.7 Proposed variables in order of significance for wildlife and livestock watering

Variables	*Abbreviation*
Chlorides	*Cl*
Selenium	*Se*
Oil	–
Dissolved Solids	*TDS*

Table 3.7 (continued)

Hydrogen Cyanide	*HCN*
Coliform	-
Sodium	*Na*
Fluorides	*F*
Taste	-
Odor	-
Sulfates	*SO4*
Bicarbonates	*HCO3*
Nitrates	*NO3*
Acidity	-
Dissolved Oxygen	*DO*
Turbidity	-
Dissolved Solids	*TDS*
Electrical Conductivity	*EC*
Calcium	*Ca*
Magnesium	*Mg*
Molybdenum	*Mo*
Alkalinity	-
Arsenic	*As*
Setleable Solids	-
Cadmium	*Cd*
Chromium	*Cr*
Lead	*Pb*
Iron	*Fe*
Mercuric Chloride	*HgCl2*
Sodium Chloride	*NaCl*
Temperature	*T*
Ammonia	*NH3*
Aluminum	*Al*
Boron	*B*
Magnesium Chloride	*MgCL2*

g. Shellfish Culture

Quality requirements for shellfish culture are, to some extent, different from the that of fish culture. Shellfishes are the non-motile benthic organisms, and they are not able to move when there exists an unfavorable conditions.

Quality variables for shellfish production include salinity, temperature, pH, oxygen concentration, and copper content. Proposed variables for shellfish culture are listed in Table 3.8 in order of significiance.

Table 3.8 Proposed variables in order of significance for shellfish culture

Variables	*Abbreviation*
Copper	*Cu*
Zinc	*Zn*
Dissolved Oxygen	*DO*
pH	*pH*
Dissolved Solids	*TDS*
Salinity	-
Hydrogen Sulphide	*H2S*
Temperature	*T*
Magnesium	*Mg*
Turbidity	-

h. Boating and Aesthetic Enjoyment

Requirements of water for boating and aesthetic enjoyment purposes don't much differ from the that of swimming, bathing, and water-contact sports, fishing and wildlife purposes. Expectations for these three group of water are nearly similar in quality.

Settled, suspended, and floating solids, sludge masses, plankton blooms, wastes from industrial origins and natural sources, oil and grease, surfactants causing foam on water surface, and excessive water temperature are considered the factors causing the quality deterioration of boating and aesthetic enjoyment waters.

Excessive nitrates, phosphates, carbonates, and silicates cause rapid eutrophication which result in production of heavy plankton blooms. Proposed variables for boating and aesthetic enjoyment are listed in Table 3.9 in order of significance.

Table 3.9 Proposed variables in order of significance for boating and aesthetic enjoyment

Variables	*Abbreviation*
Oil	-
Color	-
Turbidity	-
Suspended Solids	*SS*
Phosphates	*PO4*
Nitrogen-Nitrate	*NO3*
Carbonates	*CO3*
Silicates	*SiO2, SiO3*
Temperature	*T*

i. Water Power and Navigation

Some materials hinder the use of water for water power and navigation. These are mainly acid and alkali substances, silt and other suspended solids, organic matter, algae, and floating oil.

Acid and alkali substances cause corrosion; debris and silt are responsible for clogging problems; organic matter produces offensive odors and hydrogen sulfide gas; and floating oil is potential for fire hazard.

Dissolved oxygen, hydrogen ions, chlorides, sulfides, free carbon dioxide, high temperature and algae are the substances that accelerate the corrosion. Proposed variables for water power and navigation are listed in Table 3.10 in order of significance.

Table 3.10 Proposed variables in order of signifcance for water power and navigation

Variables	*Abbreviation*
Acidity	-
Alkalinity	-
pH	*pH*
Oil	-
Phosphate	*PO4*
Hydrogen-Nitrate	*HNO3*

Table 3.10 (continued)

Nitrogen-Nitrite	*HNO2*
Sulfate	*SO4*
Dissolved Oxygen	*DO*
Chlorides	*Cl*
Temperature	*T*

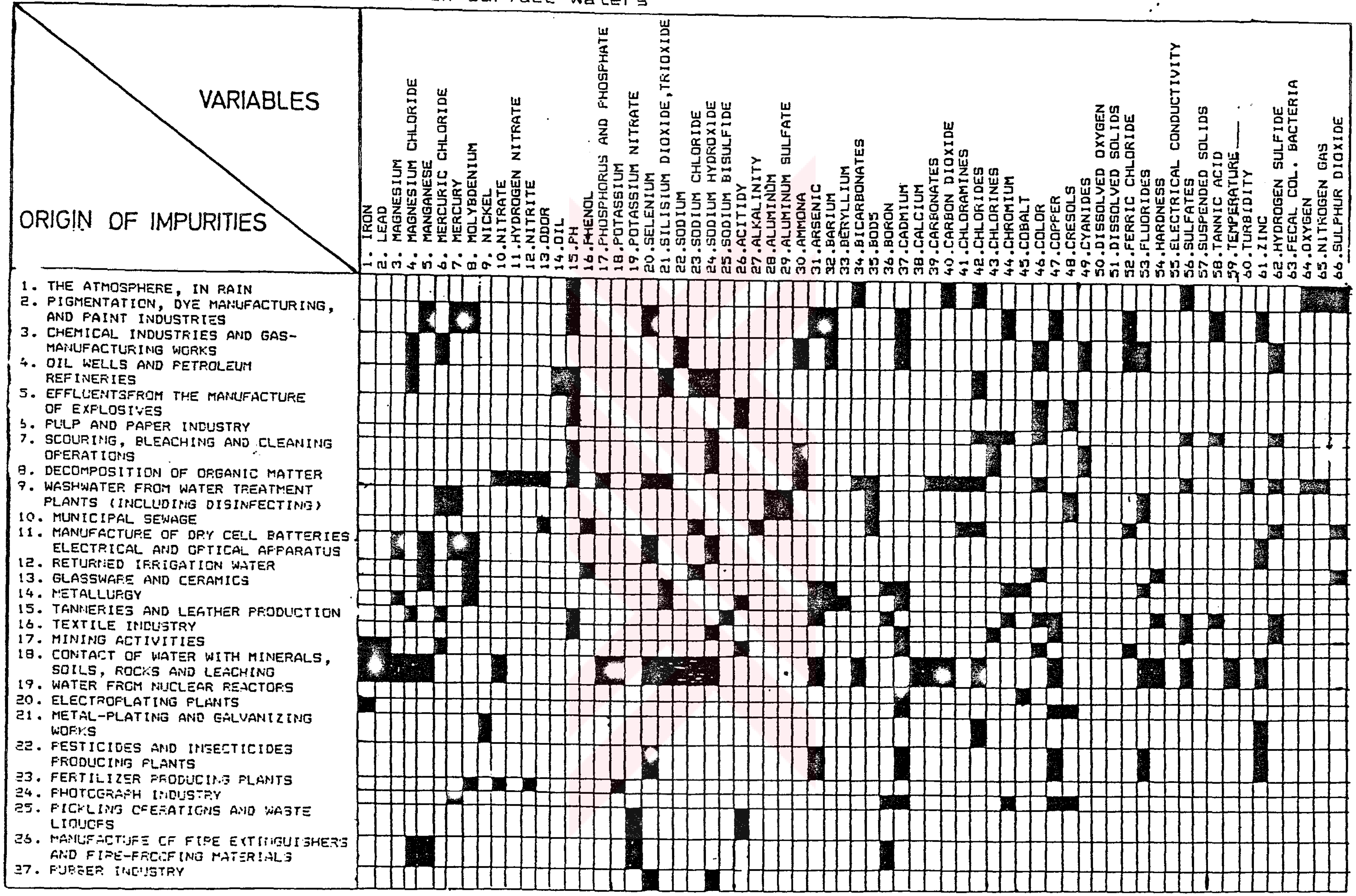
3.1.3 Impact Assessment and Proposed Variables

A surface water is affected by many natural and man-made impurity sources lying on the river-basin area. These are classified as point and nonpoint sources and they make a vast contribution to surface water pollution either by the discharge of new compounds or an addition to the available concentrations. And impact assessment is proposed to be implemented with regard to revealing the pollution characteristics of theses sources.

Many natural and man-affected impurity sources discharge many pollutants and affect the existence of pollutants and pollutant concentrations in surface waters, and therefore should be considered a significant value in variable selection in a monitoring program. Most of the natural and man-made impurity sources which add pollution to surface waters were given in the Table 3.11. In addition to these tabulated sources sanitary landfills, erosion, volcanos, groundwater aquifers, flow regulation (dams), climate, streamflow patterns (low or high), livestock, culture of society and some other minor industrial activities also give rise to an increase in both pollutant concentration or add new pollutants into the water.

Natural and man-made impurity sources discharge their loads as point or nonpoint sources into the water media, and discharges by these two sources require systematic supervision. Point source pollution originates from industrial and municipal establishments and is responsible for major pollutional loads in surface waters.

Table 3.11 Origin of impurities in surface waters



Nonpoint source water pollution can be defined as a diffuse input of substances into a receiving water that negatively impacts the beneficial uses of water (Reinelt, 1986; Chapman, 1982). Nonpoint source pollution is generally carried over or through soils by runoff from rainfall/snowmelt or by in irrigation return flows. Major categories of pollution result from the agricultural, silvicultural, mining, construction, and urban sources (US Environmental Protection Agency,1984; Reinelt, 1986). Determination of major pollutional parameters which belong to nonpoint sources depending on the land-use were given in Table 3.12 as a literature value (Gönenc et al., 1985; Hopstaken et al, 1986; Burak, 1990).

Table 3.12 Major pollutant values from nonpoint sources.

Areas	BOD(kg/ha.day)	N(kg/ha.day)	P(kg/ha.day)
Residential	0.1600	0.0120	0.0030
Agricultural	0.0060	0.0050	0.0003
Others	0.0030	0.0025	0.0002

3.2 Further Selection Criteria

3.2.1 General

Although specification of monitoring objectives provides a relative reduction in the number of variables in comparison with the gross lists, the number of proposed variables is still significantly high for practical purposes. Therefore a further selection for the variable reduction becomes necessary.

With respect to impact assessment, it is not necessary to reduce the number of variables as the number is not too high to be included in a monitoring programme.

3.2.2 Basin-based Selection: Selection of Group A Variables

Group A variables are the variables to be monitored in all stations in a riverbasin monitoring network. Water uses in the riverbasin are taken into consideration and a gross list is prepared (Table 3.13). By the help of this gross list, Group A variables are determined. In other words, Group A variables are selected from the prepared gross list by taking into consideration the cost of measurement, ease of measurement, variation coefficient, and finally frequency of appearence of variables in water uses.

Table 3.13 Gross table of proposed water quality variables to be monitored in a riverbasin for various water uses

	Domestic Water Sup.	Industrial Water Sup.	Agricult. Water Sup	Fish Prop	Swimming &Bathing	Shellfish Culture	Wildlife Watering	Boating & Aesthetic	Water Power& Navigation
Arsenic	*		*	*			*		
Alkalinity	*	*	*	*			*		*
Ammonia	*			*			*		
Aluminum	*	*	*	*	*		*		
Acidity	*	*	*	*			*		*
BOD	*								
Barium	*		*	*					
Beryllium	*		*						
Bicarbonates	*	*	*				*		
Boron			*	*			*		
Color	*	*		*	*			*	
Cadmium	*	*	*	*			*		
Cyanide	*			*					
Carbonates	*	*	*					*	
Chlorides	*	*	*	*			*		*
Chromium	*		*				*		
Copper		*	*	*		*			
Chlorine		*		*					
Cobalt			*						
Diss. Oxygen	*			*	*	*	*		*
Diss. Solids	*	*	*	*		*			
Elec. Conduc	*	*	*	*		*	*		
Fecal Coli.	*				*		*		
Fluoride	*	*	*				*		
Hardness	*	*	*	*		*	*		
Hydrogen Cya.	*			*			*		
Hydrogen Sul.	*	*		*		*			
Hydrogen Nit.	*	*		*					
Iron	*	*	*	*				*	
Lead	*	*	*	*			*		
Magnesium	*		*				*		
Mercury	*		*	*			*		

Table 3.13 (continued)

Mercuric chl	*			*			*		
Manganese	*	*		*				*	
Molybdenum			*	*			*		
Magnesium ch	*	*					*		
Nitrite	*	*	*	*	*	*	*	*	*
Nitrate	*	*	*	*	*	*	*	*	*
Nickel			*	*					
Odor	*	*		*	*		*		
Oil	*	*	*	*	*		*	*	*
pH	*	*	*	*	*	*	*		*
Phenol	*	*		*					
Potassium	*	*	*	*					
Phosphate	*	*		*				*	*
Selenium	*		*				*		
Sodium	*	*	*				*		
Sodium chlor	*		*	*		*	*		
Sulfates		*	*				*		*
Suspend.sol.	*			*	*				
Turbidity	*	*		*	*	*	*	*	
Temperature	*	*		*		*	*	*	*
Taste	*				*		*		
Zinc		*	*	*			*		

a. Cost of Measurement

Cost has a significant role in variable selection since it directly influences the economic considerations in monitoring. Money constitutes a constraint in variable selection and therefore a determination of costs of measurements is definitely required. Cost of measurement as criterion for variable selection includes mainly the expenses of laboratory analyses. Analyses with continuous measuring techniques result in relatively low costs as compared to chemical and other analysis methods. Analysis efforts in the laboratory, also necessitate the transportation and preservation of samples, thereby increasing the cost of measurement. The total cost of measurement includes sampling, transportation, preservation, and field visitation, in addition to laboratory analysis costs.

Variables with the least cost must be given the first priority in a monitoring program and vice versa. Cost of measurement of each variable is calculated and then listed. Finally costs are listed in order of increasing cost. So that selection is made by going down from the top of list until further selection is limited by the available budget.

b. Ease of Measurement

When the variables are dealt with in terms of ease of measurement many factors, ranging from field logistics to analysis methods, may be involved. If the observation is carried out by continuous measurement instrumentation the job will be quite rapid, accurate and easy. For this reason variables for which continuous-measurement instrumentation exist must be given priority for measurement from the scope of ease of measurement. This priority should put these variables at the top levels of ranking. Variables to be analyzed in laboratory result in many difficulties; sampling, transportation, preservation, and analysis efforts. Since almost all variables can be analyzed from the samples taken once, field logistics, sampling, transportation and preservation efforts are equally-troublesome and difficulties in other words ease of measurement, arise in analyzing the sample for each variable.

Different methods of analysis have been used to define the physical and chemical characteristics of water. These are gravimetric, volumetric, physicochemical methods and they are identified in terms of effort spent and kind of work done. Gravimetric analysis is made through a weighing operation, such as suspended solids content determination analysis. Volumetric method is based on the principle of conservation of mass. In physicochemical methods, physical properties other than mass and volume are measured. Instrumental methods of analysis such as turbidimetry, colorimetry, potentiometry, polarography, adsorption spectrometry, fluorometry, spectroscopy, and other nuclear radiation are representative of the physicochemical methods (Tchobanoglous and Schroeder, 1985).

Ease of measurement of each variable depends upon the analysis method employed and variable itself to be analyzed. Analysis of each variable requires various intermittent working periods depending upon the variable of concern and analysis method employed. This fact majorly determines the degree of ease of measurement; most easily measurable variables at the top and most toughly ones at the bottom. In essence, we propose to take into consideration the active working periods for the analysis of each variable and then these values are listed. Consequently it is advised that variable selection begin with the first levels of ranking to the end.

c. Statistical Characteristics

There seems to be a need from the statistical standpoint that some statistical measures are also to be employed in variable selection. Because the variation coefficient (Cv) offers the most desired information about the variation of a variable, we propose that it should be applied as a criterion in variable selection. We are surely on intent of observing variables which display relatively high variations and a ranking list including the mostly varying variables at the top and least varying variables at the bottom is proposed. Consequently these listed values are taken into consideration as a variable selection criteria.

d. Frequency of Appearance

Frequency of appearance "f_a" is determined by the help of the gross list of variables for the river-basin water uses. If, for example, five different water use are in question, and variable "s" seems in all water uses we surely prefer to select this variable in a monitoring program. Finally a list of "f_a" values of all variables is prepared beginning with the highest "f_a" value to the down in the list. We had better undoubtedly select the variables which seem more in the gross list (Table 3.13).

e. Overall Assessment

Each approach has its advantages from the scope of variable selection criteria. An overall approach is necessitated to handle variables in such a way that selection of variables via that method would be thoroughly effective in variable selection.

An overall table is developed by adding cost, ease, variation coefficient and frequency of appearance values belonging to each variable in a total column, and a priority list is obtained beginning with the total highest to the lowest value. Variable selection should preferably begin from the first rows of the hierarchical ranking. As moving downward on the list ease of measurement decreases, cost of measurement increases, variation coefficients and frequency of appearance get less.

3.2.3 Station-based Selection: Selection of Group B and C Variables

Group B variables are determined depending upon the significance of variables with regard to intended water use. If, for example, domestic water use is in question, coliform is the most significant and turbidity is the second significant variable. The list is cut off which has begun with the most significant variable to the down. When more than one water use is in question, group B variables are subcategorized as Group B1, B2,...Bn variables.

If, for example, three different water use is important in a monitoring station, group B1, B2, B3 variables become important. Each usage takes into consideration the significance of variables with respect to each water use. Finally three separate group variables are determined and then the total number is involved in a monitoring site.

Group C variables are the specific variables which are dependent upon the quality characteristics of discharges in the upstream.

3.3 Overall Variable Selection in a River Basin

In the overall selection, a cut off point is selected in the list of Group A variables. These are the variables to be monitored in all stations in a river-basin. Then Group B variables are determined. As in the Group A variable list, a cut off point is selected in Group B variables list. These are station-based variables and they are monitored depending upon the intended water uses in the selected monitoring station. Plus Group A and Group B variables, Group C variables are also included in a riverbasin monitoring network. These are specific variables which are discharged from point and nonpoint sources in the upstream. Consequently, variables to be monitored in a monitoring station are composed of Group A, Group B, and Group C variables.

3.4 Reduction in the number of Variables

Hundreds of variables may be needed for the description of water quality. A huge portion of these variables are chemical and biological while a small number is physical. About 450 quality variables are being known as important in water quality problems (Sanders et al., 1983).With the developments in industrial activities, some new compounds will undoubtedly be synthesized and will migrate into the water environment.

Although an aspect of proposed approach for variable selection has been intended to reduce the number of variables including objective-based and selection and some other criteria, a high correlation between variables may be helpful in reducing the number of variables. If a high relationship is found between quality variables, measurement of both variables will be unnecessary.

Sanders et. al., (1983) stated that a relationship between water quantity and quality or between quality variables may be seen. The amount of information transferred between these two random variables is a function of dependence and correlation coefficient is mostly applied as a measure of dependence. They also claim that measurement of hundreds chemical compounds in water may not be necessary and an economic optimal cut-off point is required on the hierarchical classification list.

Reduction the number of variables will supply benefit from the view of economy. The number of variables to be measured determines the size of monitoring and analysis of a large number variables in a every sample undoubtedly will be rather costly.

If a particular industrial water quality problem is in question, a small number of quality variables may be more important than the information on all the other variables. These specific properties may be less important, or totally unimportant, in irrigation or water supplies (Sanders et al.,1983). Reduction in the number of variables causes the better economic efficiency in operating water quality monitoring network.

4. CASE STUDY

4.1 Selected Basin

Sakarya river basin is located in north-western Anatolia with a surface area of 58.000km^2. The main course of the river originates from the northern part of Afyon city and extends 824 km before discharging into the Blacksea. The average flow of the river is about 200m^3/s with a highly variable flow regime. Sakarya river-basin is divided into three sub-basins as Upper, Middle, and Lower Sakarya. A significant tributary of Sakarya is Porsuk which passes through Kütahya plain and Eskişehir city. The length of Porsuk is 442km up to its confluence with Sakarya river near Polatlı town. Another tributary which contributes to Sakarya flows is Ankara Creek. A number of dams are located in the basin, e.g, Porsuk dam for flood control, Sarıyar and Gökçekaya dams for flood control and energy generation.

River later coalesces Karasu, Göksu, and Göynük tributaries. Karasu tributary with a length of 60km passes near Bilecik city and coalesces Sakarya river. Göynük Creek with a length of 120km originates from Karadağ and passes through İnegol and Yenişehir plains. Catchment area which is supported by many tributaries including Karasu, Göynük, Göksu and others is called the middle part of Sakarya river. Mudurnu Creek with a length of 87km and Çarksuyu Creek with a length of 40km coalesce Sakarya river in the lower part of the Basin. There exists highly productive agricultural areas watered by Sakarya river in Sakarya river catchment area. Seyitgazi, Kütahya, Eskişehir-Alpu, Sapanca-Gölçük, Sakarya-Karasu plains are the major potential agricultural areas on the catchment area. Major residential, agricultural and industrial areas of Sakarya riverbasin are shown Figure 4.1.

The hottest month is july and the coldest is january on that region. Temperature gradient between summer and winter months rises up to 200°C. The least rain is seen in August and the most in December. Rain on that region is lower than that of Turkey with a yearly average of 500mm. Yearly evaporation is about 1200mm for all the area.

The river receives both point and nonpoint sources as domestic, industrial, and agricultural origin. Domestic pollution mainly comes from Ankara, Kütahya, Eskişehir, Bilecik, and Adapazarı cities. Main industrial pollution sources are the industries on Ankara , Karasu, Çarksuyu Creek, and Porsuk river. Agricultural pollution sources are Ağaçköy, Karacaşehir, Şevketiye, Seyitgazi, Çifteler, Upper Sakarya, Yaralı, Kavuncu, Sarıcakaya, Karaağaç, Pamukova, and Lower Sakarya irrigation return flows. Nonpoint sources on that catchment area are: (1)the surface runoff waters from residential areas or outside of the residential areas resulting from rainwater and drainage water, (2)surface and

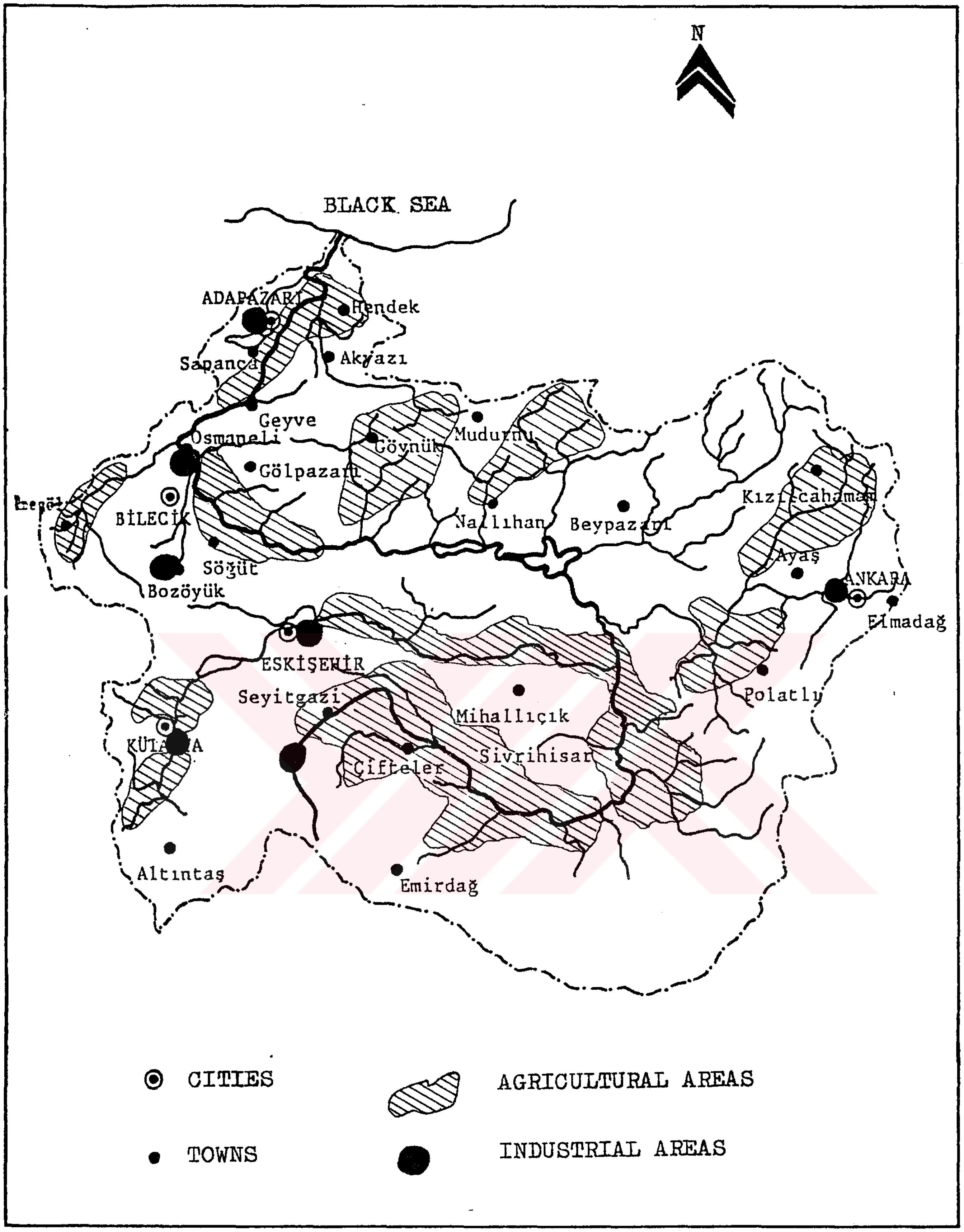


Figure 4.1 Residental, agricultural and industrial areas in Sakarya riverbasin.

drainage waters originating from irrigation, (3)groundwaters.

4.2 Variable Selection in the Basin

4.2.1 Selection with respect to Objectives

4.2.1.1 Water Uses in the Basin and Proposed Variables

a. Agricultural Water Supply

Since the most important livelihood source of that region is agriculture, agricultural water supply constitutes the first hierarchic level of water uses. Because the rainfall is not regular on that region, irrigation schedules becomes more important. Socio-economic observations show that agricultural activities will be also important in the future for inhabitants.

Proposed variables for agricultural water supply in the basin are as in the Table 3.4.

b. Domestic Water Supply

Domestic water supply of Ankara is provided by Çubuk, Kayaş, and Kurtboğazı reservoirs located on the Ankara Creek. Kütahya and Eskişehir cities, which are located on Porsuk-river basin, use mainly waters from wells. Kütahya city reinforces its water supply by Porsuk river. Adapazarı city, which is located in the lower part of Sakarya river-basin, provides its domestic water from Sapanca lake. Bilecik city, which is located in Karasu river-basin, uses groundwater supplies. Porsuk river will be utilized for domestic water supply of Eskisehir city in the future. New reservoirs will be set up on the Ankara river-basin to meet the future water requirements of Ankara city.

Proposed variables for domestic water supply in the basin are as in the Table 3.2.

c. Industrial Water Supply

Industrial water supply satisfies the requirements such as process water, boiler water, and cooling water. Existing industries use waters of tributaries of Sakarya river and ground waters. It is expected that industrialization will show an increase with respect to economic developments in the area.

Proposed variables for industrial water supply in the basin are as in Table 3.3.

d. Power Generation

Sakarya river itself is very rich from the scope of hydroelectrical power generation potential. Gökçekaya and Sakarya dams, which are located in the middle part of Sakarya river-basin, are utilized for flood control and hydroelectrical power generation. More dams for flood control must be built in order to prevent the flood on the productive agricultural fields.

Proposed variables for Power Generation in the basin are as in the Table 3.10.

e. Fishing Purposes

Sakarya river itself, source parts of its tributaries, Sapanca lake, Göynük Creek, Kurtboğazı and Porsuk reservoirs are convenient for fishing. However, some parts of Sakarya river and its tributaries are not convenient for fishing due to the discharge into those waters, and effect of deleterious substances from snowmelt, rainfall and erosion.

Proposed variables for fishing purposes in the basin are as in the Table 3.5.

f. Aesthetic Enjoyment

Economical developments in the region stipulates the presence of recreational activities with the cultural developments. Especially reservoirs near big cities, such as Porsuk and Çubuk dams are suitable places for recreational purposes. Sakarya and Gökçekaya dams may also be utilized for recreational purposes.

Proposed variables for aesthetic enjoyment in the basin are as in the Table 3.9.

To summarize, six different water uses are in question in Sakarya basin as agricultural water supply, domestic water supply, industrial water, supply, power generation, fishing purposes and aesthetic enjoyment. Proposed variables for these uses are given in Table 4.1 which have been taken from Table 3.13. Table 4.1 will be used in the later sections to determine group A and B variables.

Table 4.1 Water uses and proposed variables in Sakarya riverbasin

	Domestic Water Sup.	Industrial Water Sup.	Agricult. Water Sup	Fish Prop	Swimming &Bathing	Shellfish Culture	Wildlife Watering	Boating & Aesthetic	Water Power& Navigation
Arsenic	*		*	*			*		
Alkalinity	*	*	*	*			*		*
Ammonia	*			*			*		
Aluminum	*	*	*	*	*		*		
Acidity	*	*	*	*			*		*
BOD	*								
Barium	*		*	*					
Beryllium	*		*						
Bicarbonates	*	*	*				*		
Boron			*	*			*		
Color	*	*		*	*			*	
Cadmium	*	*	*	*			*		
Cyanide	*			*					
Carbonates	*	*	*					*	

Table 4.1 (continued)

Chlorides	*	*	*	*			*		*
Chromium	*		*				*		
Copper		*	*	*		*			
Chlorine		*		*					
Cobalt			*						
Diss. Oxygen	*			*	*	*	*		*
Diss. Solids	*	*	*	*		*			
Elec. Conduc	*	*	*	*		*	*		
Fecal Coli.	*				*		*		
Fluoride	*	*	*				*		
Hardness	*	*	*	*		*	*		
Hydrogen Cya.	*			*			*		
Hydrogen Sul.	*	*		*		*			
Hydrogen Nit.	*	*		*					
Iron	*	*	*	*				*	
Lead	*	*	*	*			*		
Magnesium	*		*				*		
Mercury	*		*	*			*		
Mercuric chl	*			*			*		
Manganese	*	*		*				*	
Molybdenum			*	*			*		
Magnesium ch	*	*					*		
Nitrite	*	*	*	*	*	*	*	*	*
Nitrate	*	*	*	*	*	*	*	*	*
Nickel			*	*					
Odor	*	*		*	*		*		
Oil	*	*	*	*	*		*	*	*
pH	*	*	*	*	*	*	*		*
Phenol	*	*		*					
Potassium	*	*	*	*					
Phosphate	*	*		*				*	*
Selenium	*		*				*		
Sodium	*	*	*				*		
Sodium chlor	*		*	*		*	*		
Sulfates		*	*				*		*
Suspend.sol.	*			*	*				
Turbidity	*	*		*	*	*	*	*	
Temperature	*	*		*		*	*	*	*
Taste	*				*		*		
Zinc		*	*	*			*		

4.2.1.2 Impact Assessment in the Basin and Proposed Variables

a. Upper Sub-Catchment Area

Upper catchment area is located between the origin of Sakarya river and confluence of Porsuk. The majority of people in this area live in towns and villages which brings rather diffuse pollution to the river. People are involved in agricultural activities and Etibank Boraks plant. Agricultural activities cause point and nonpoint source pollution. The flowrate of Etibank Boraks industry is the magnitude of $70m^3/h$ and causes boron pollution in the river.

Proposed variable for Etibank Boraks exploitation discharge is boron.

b. Middle Sub-Catchment Area

Middle catchment area takes part in between the confluence of Porsuk and Göksu. Although there does not exist any institution discharging directly into the Sakarya river, Ankara Creek and Karasu tributaries discharge domestic and industrial pollution to Sakarya river. Ankara Creek receives the wastewaters of Ankara city and also various types of industries. In fact, this creek deserves special attention with respect to other pollution sources. Söğüt Creek locates in Karasu catchment area. It mixes with Sakarya river near Bilecik city and conveys Söğüt ceramic factory wastewaters and Söğüt town domestic wastewaters. Main industries established on Karasu catchment area are textile, ceramic, soil products, paper and metallurgical industries.

Proposed variables for these discharges can be summarized from Table 3.11 as follows:

Ceramic factory wastewaters	: Mn, Mo, SiO2, SiO3, As, Ba, B, Cd, Cr, Co, F
Metallurgy industry discharges	: Mg, Mo, SiO2, Acidity, As, Ba, Be,Cd
Textile industry discharges	: Ph, NaOH, Cd, Cl, SO4, H2S
Pulp and paper industry	: NaOH, Cl, Cr, Color, SO4, Zn, Tannic acid
Municipal wastewaters	: Odor, Phenol, NaCl, Alkalinity, BOD5, Chloramines, Cl, FeCl3, H2S, SO2

c. **Lower Sub-Catchment Area**

There does not exist any institutions discharging directly into the Sakarya river in that part. Various industrial wastewaters and Adapazarı municipal sewage are discharged into Çarksuyu Creek. Therefore, wastewaters which were brought by Çarksuyu tributary are considered the most important pollution source at that part of Sakarya river. Çarksuyu Creek passes through Adapazarı and İzmit cities and is subject to pollution from both industrial activities and municipal sewage. Main industries along the Çarksuyu Creek are sugar, metallurgy and tannery industries.

Proposed variables for these discharges can be summarized from Table 3.11 as follows:

Metallurgy industry discharges: Mg, Mo, SiO_2, Acidity, As, Ba, Be, Cd
Tannery industry discharges : $MgCl_2$, $HgCl_2$, Ph, As, B, Ch, Color, Copper, Hardness, SO_4, Tannic acid

d. **Porsuk River Sub-Catchment Area**

Porsuk river passes near Kütahya and Eskişehir cities. Kütahya city locates at a distance of 80km from the origin and river keeps its purity until Kutahya city. At that point sugar factory, slaughterhouse, fertilizer factory and other small industries discharge their wastewaters into the river. Porsuk river reaches Porsuk dam at 140km from the source. As a result of sedimentation and some biological activities, in a certain extent, quality of water gets better in that reservoir and keeps it purity until Eskisehir city.

Eskişehir municipal wastewaters, Sümerbank textile factory, sugar factory, slaughterhouse, organized industrial district wastewaters are discharged into Porsuk river respectively. After riverwater leave the vicinity of Eskişehir city, irrigation return flows and wastewaters from small residential areas pollute the river until the confluence to Sakarya river. Industrial activities in Porsuk river catchment area are sugar, slaughterhouse, fertilizer, mineral, metallurgy and textile industries.

Proposed variables for these discharges can be summarized from Table 3.11 as follows:

Irrigation return water : Mn, Mo, PO_4, Na, Color, Hardness, NO_3
Fertilizer producing factory : Mo, Nitrate, Nitrite, K
Textile industry discharges : pH, NaOH, Cd, Cl, SO_4, H_2S
Metallurgy industry discharges: Mg, Mo, SiO_2, Acidity, As, Ba, Be, Cd

4.3 Further Selection

4.3.1 Basin-Based Selection: Selection of Group A Variables

Although objective definition, to an extent, helps to reduce the number of variables to a meaningful level, measurement of all the defined variables for the objectives requires rather excessive time and cost. In fact, time and cost are the main limiting factors which dominantly influence the number and kind of variables. Therefore, a hierarchic ranking which aims at the reduction of variables should also be taken into consideration to monitor less variables in a monitoring site. As the cost and ease are the major limiting factors, ease and cost of measurement should be determined and taken into consideration for further selection. In addition to ease and cost, variation coefficient of variables which can be determined from previously observed data and occurence number of variables should be taken into consideration.

Determination of ease and cost of measurement, and the variation coefficient of variables and frequency of appearance of variables in an overall table helps to nominate the Group A variables to be observed in a monitoring network program, as monitoring network stipulates the observation of same variables in every monitoring site to realize homogeneous conditions.

In this application, statistical characteristics, frequency of appearance, ease of measurement, and cost of measurement of variables have been evaluated in order to give an idea from the scope of further selection of variables.

a. Cost of Measurement

Cost of measurement as a criterion to variable selection includes the cost of analyses of variables of concern. Quality of educated personnel, who are responsible for carrying out experiments and development of laboratory techniques widely affect the cost of analysis, and subsequently cost of measurement. For example continuous measurement instrumentations result in quite low cost in a comparison to laboratory analyses in water quality monitoring networks. In addition to the analysis efforts in laboratory, laboratory analysis methods necessitate the transportation and preservation of samples, and hence in turn contributes to the cost of measurement. Total cost of measurement of variables (including sampling, transportation, preservation and analysis) should be taken into consideration to determine hierarchic levels. Variables whose measurements cost least should be constitute first row and variables whose measurements cost most should constitute the last row.

Cost data in Table 4.2 have been taken from Dokuz Eylül University, Engineering and Architecture Faculty, Environmental Engineering Laboratories and listed in an increasing order. Finally cost values are expressed as percentage values in the last column of the Table 4.2. The least value, 5.000 TL is equaled one hundred percent, and subsequently other values are expressed as percentage values respectively; e.g., 60.000 TL analysis cost equals (5.000*100/60.000) 8.3% percentage value.

Table 4.2. Classification of variables in terms of cost of measurement.

Order	Variables	Measurement Method	Cost of Measurement (TL)	Cost %
1.	T	Thermometer	5.000	100.0
2.	EC	EC meter	10.000	50.0
3.	pH	pH meter	10.000	50.0
4.	Alkalinity	Titration	20.000	25.0
5.	K	Flame fotometer	30.000	16.6
6.	Na	Flame fotometer	30.000	16.6
7.	Cl	Titration	30.000	16.6
8.	Mg	Atomic absorption	30.000	16.6
9.	Ca	Titration	30.000	16.6
10.	DO	DO meter	30.000	16.6
11.	NO2	Colorimetric	40.000	12.5
12.	SS	Gravimetric	40.000	12.5
13.	NO3	Colorimetric	40.000	12.5
14.	NH3	Titration	50.000	10.0
15.	SO4	Gravimetric	50.000	10.0
16.	Fe	Atomic absorption	50.000	10.5
17.	PO4	Colorimetric	50.000	10.5
18.	TH	Titration	60.000	8.3
19.	BOD	Dilution(5 day)	70.000	7.1
20.	B	Colorimetric	75.000	6.6

b. Ease of Measurement

When the variables are dealt with in terms of "ease of measurement" many factors may be involved. However, if the observation is carried out by continuous measurement instrumentation, the job will be quite rapid, accurate and easy. For this reason variables for which continuous measurement instrumentation exists must be inevitably measured and this priority puts them at the top levels of ranking. Variables to be analyzed in the laboratory result in many difficulties; sampling, transportation, preservation and analysis efforts. Since almost all variables can be analyzed from the samples taken once, difficulties arise in analyzing the sample for each variable. Analysis of each variable requires intermittent working periods depending on the of variable of interest. And this fact determines the degree of ease of measurement; most easily measurable variables at the top and most toughly ones at the bottom.

Working period indicates the active working time as minutes for analyzing the variable. Working period data in Table 4.3 have been taken from Dokuz Eylül University, Engineering and Architecture Faculty, Environmental Engineering Laboratories and listed in an increasing order. Finally working period values are expressed as percentage values in the last column of the Table 4.3. The least value, 5 minute is equaled one hundred percent, and subsequently other values are expressed as percentage values respectively; e.g., 30 minute working period equals (5*100/30) 16.6% percentage value.

Table 4.3 Classification of variables in terms of ease of measurement.

Order	Variables	Measurement Method	Working Period(min)	W.P. %
1	T	Thermometer	5	100.0
2	Cl	Titration	5	100.0
3	EC	EC meter	5	100.0
4	pH	pH meter	5	100.0
5	SS	Gravimetric	10	50.0
6	NO2-N	Colorimetric	10	50.0
7	NO3-N	Colorimetric	10	50.0
8	DO	DO meter	10	50.0
9	Ca	Titration	10	50.0
10	TH	Titration	10	50.0
11	Alkalinity	Titration	30	16.6
12	Mg	Atomic Absorption	30	16.6
13	Na	Flame fotometer	30	16.6
14	K	Flame fotometer	30	16.6
15	Fe	Atomic Absorption	30	16.6
16	B	Colorimetric	30	16.6
17	NH3-N	Titration	40	12.5
18	PO4	Colorimetric	60	8.3
19	BOD	Dilution(5 day)	60	8.3
20	SO4	Gravimetric	60	8.3

c. Statistical Characteristics

In this study observations which were carried out at "Ağaçköy Monitoring Station" have been used. These observations were done for six years and monthly averages of observations have been published. Data for each variable was in the range of 72 (max. number of data) and 1 (min. number of data). Hence, data for every month during this period was not present. Available data belonging to each variable was treated statistically and mean, standard deviation and variation coefficient of each variable have been calculated. Because variation coefficient (Cv) offers the most desired information about the variation of a variable, Cv has been applied as a measure of statistical behavior of variables. Because the data in this study were scarce, it is better to use this application results as a guide other than a reference. A ranking which includes the mostly varying variables at the top and least varying variable at the bottom has been applied as an approach to variable selection

The data which have been used for calculating Cv values of variables of Table 4.4 is obtained from DSI water quality observations. Calculated Cv values have been put in an decreasing order. This means that we prefer to monitor variables which exhibit more variation with comparision to others. Finally Cv values have been expressed as percentage values in the last column of the Table 4.4. The highest value, 1.983, is equaled one hundred percent and subsequently other values are expressed as percentage values respectively; e.g., 0.117 Cv value equals (0.117*100/1.983) 8.9% percentage value.

Table 4.4. Classification of variables in terms of statistical behaviour (Cv, variation coefficient)

Order	Variables	N (Number of Observations)	Mean	Cv	Cv %
1	SS	59	119.000	1.983	100.0
2	NH3-N	68	0.610	1.803	90.9
3	B	22	0.151	1.615	81.3
4	PO4	65	0.152	1.539	77.6
5	Fe	40	0.549	1.120	56.4
6	NO2-N	68	0.021	0.854	42.9
7	BOD	67	1.387	0.531	26.7

Table 4.4 (continued)

8	K	59	2.220	0.509	25.5
9	T	68	13.500	0.419	21.0
10	Na	59	7.050	0.371	18.5
11	Cl	68	8.540	0.341	17.0
12	NO3-N	65	1.841	0.318	16.0
13	SO4	67	33.070	0.295	14.8
14	Mg	22	22.850	0.192	9.6
15	EC	68	409.500	0.177	8.9
16	DO	65	9.390	0.136	6.8
17	Alkalinity	68	249.500	0.110	5.4
18	Ca	22	69.270	0.104	5.1
19	TH	31	273.500	0.097	4.8
20	pH	68	8.040	0.030	1.5

d. Frequency of Appearance

Frequency of appearance of variables in Table 4.5 have been determined by the help of Table 4.1. If variable "s" seems n times in the columns of Table 4.1, frequency of appearance of that variable becomes s. We preferably chose to monitor the variables which seem more in the Table 3. Finally f_a values are expressed as percentage values in the last column of the Table 4.5. The highest value, 9, is equaled to one hundred percent and subsequently other values are expressed as percentage values respectively; e.g., 5 f_a value equals (5*100/9) 55.5% percentage value.

Table 4.5 Classification of variables in terms of frequency of appearance

Order	Variables	"fa" Frequency of appearance	fa %
1	NO2-N	9	100.0
2	NO3-N	9	100.0
3	pH	8	88.8
4	T	7	77.7
5	SS	7	77.7
6	EC	6	66.6
7	Alkalinity	6	66.6
8	DO	6	66.6
9	TH	6	66.6
10	Fe	5	55.5

Table 4.5 (continued)

11	Ca	5	55.5
12	PO4	5	55.5
13	K	4	44.4
14	Na	4	44.4
15	SO4	4	44.4
16	NH3-N	3	33.3
17	B	3	33.3
18	Mg	3	33.3
19	Cl	2	22.2
20	BOD	1	11.1

e. Overall Assessment

In this part, ease and cost of measurement, and statistical behaviour of variables have been evaluated altogether in terms of total priority (Table 4.6).

Table 4.6 Variable classification in terms of total priority

Priority Order	Variables	(Cost%)*0.25	(W.P.%)*0.25	(Cv%)*0.25	(fa%)*0.25	Total
1	T	25.0	25.0	5.2	19.4	74.6
2	pH	12.5	25.0	0.3	22.2	60.0
3	SS	3.1	12.5	25.0	19.4	60.0
4	EC	12.5	25.0	2.2	16.6	56.3
5	NO2-N	3.1	12.5	10.7	25.0	51.3
6	NO3-N	3.1	12.5	4.0	25.0	44.6
7	Cl	4.1	25.0	4.2	5.5	38.8
8	PO4	2.5	2.0	19.4	13.8	37.7
9	NH3-N	2.5	3.1	22.7	8.3	36.6
10	DO	4.1	12.5	1.7	16.6	34.9
11	Fe	2.5	4.1	14.1	13.8	34.5
12	B	1.6	4.1	20.3	8.3	34.3
13	TH	2.0	12.5	1.2	16.6	32.3
14	Ca	4.1	12.5	1.2	13.8	31.6
15	Alkalinity	6.2	4.1	1.3	16.6	28.2
16	K	4.1	4.1	6.3	11.1	25.6
17	Na	4.1	4.1	4.6	11.1	23.9
18	SO4	2.5	2.0	3.7	11.1	19.3
19	Mg	4.1	4.1	2.4	8.3	18.9
20	BOD5	1.7	2.0	6.6	2.7	13.0

From the Table 4.6, we can decide to select the first ten variables as Group A variables and Proposed group A variables which are the variables to be monitored in all the stations of Sakarya riverbasin are given in Table 4.7.

Table 4.7 Proposed group A variables to be monitored in all stations of Sakarya riverbasin

T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO

4.3.2 Station-Based Selection

i. Group B Variables

Variables to be monitored along the riverbasin area are dependent on the monitoring site. Each monitoring site is set up to serve one of the main objectives; water uses, and impact assessment. "Water uses" monitoring serves towards the beneficial uses of water such as domestic, irrigation, industrial, recreation and other water supplies. "Impact assessment" monitoring aims the observation of variation of variables to be utilized for other purposes.

Main water uses in Sakarya river-basin are irrigation, domestic, industrial water supplies, power generation, fishing and recreation purposes. Main natural and manaffected causes on river water quality are irrigation return flows, municipal sewage, and industrial wastewater discharges. Depending on the objectives, monitoring sites and related quality variables to be observed on Sakarya river basin have been determined in this application.

Quality variables which have been considered as important with respect to water uses were given in Table 4.1. However, these variables are excessively much to include in a monitoring program, and hence a reduction becomes unavoidable. Because of that, first five of quality variables belonging to each water use have been proposed to be included in the monitoring program in Sakarya riverbasin. This has been done personally, and any user of a network may increase or decrease this number depending upon expectations, technical and economic attainability and so on.

Table 4.8 Proposed sub-group B variables depending upon the water uses

B1	*Domestic Water Supply*	*Fecal coliform bacteria, Turbidity, Color, Dissolved Oxygen, Dissolved Solids*
B2	*Industrial Water Supply*	*Alkalinity, Hardness, Chlorides, Dissolved Solids, Oil*
B3	*Agricultural Water Supply*	*Boron, Electrical conductivity, Alkalinity, Potassium, Sodium*
B4	*Fish Propagation*	*Dissolved oxygen, Suspended solids, Carbondioxide, pH, HCN*
B5	*Swimming Purposes*	*Fecal coliform bacteria, Suspended solids, Turbidity, Odor, pH*
B6	*Stock and Wildlife Watering*	*Chlorides, Selenium, Oil, Dissolved solids, HCN*
B7	*Aesthetic Enjoyment*	*Oil, Color, Turbidity, Suspended solids, Phosphate*
B8	*Water Power and Navigation*	*Acidity, Alkalinity, pH, Oil, Phosphate*
B9	*Shellfish Culture*	*Copper, Zinc, Dissolved solids, S linity, Sodium chloride*

As water uses are dependent on individuual monitoring sites, above proposed variables are monitored in the stations where the interested water uses are in question. Proposed variables with respect to monitoring stations in Sakarya riverbasin are given in Table 4.9.

Table 4.9 Proposed group B variables to be monitored in the stations in the Basin established by DSI

Monitoring site	Water Uses	Proposed Group B variables
004 Kümbet Deresi	Industrial Water Supply	(B2) Alkalinity, Hardness, Chlorides, Dissolved Solids,Oil
008 Seydisuyu-Kozyaka	Agricultural Water Supply Industrial Water Supply	(B3) B, EC, Alkalinity, K, Na (B2) Alkalinity, Hardness, Chlorides, Dissolved Solids,Oil

Table 4.9 (continued)

008 Seydisuyu-Kozyaka	Aesthetic Enjoyment Fish Propogation	(B7) Oil, Color, Turbidity, Suspended Solids, Phosphates (B4) Dissolved Oxygen, Suspended Solids, Carbondioixde, pH, HCN
009 Sakarya Nehri-Kavuncu	Agricultural Water Supply	(B3) B, EC, Alkalinity, K, Na
010 Porsuk Çayı-Ağaçköy	Domestic Water Supply Industrial Water Supply	(B1) Fecal coliform, Turbidity, Color, Dissolved Oxygen, Dissolved Solids (B2) Alkalinity, Hardness, Chlorides, Dissolved Solids, Oil
011 Porsuk Çayı-Çalça	Agricultural Water Supply	(B3) B, EC, Alkalinity, K, Na
012 posuk Çayı-Başdeğirmen	Aesthetic Enjoyment Fish Propogation	(B7) Oil, Color, Turbidity, Suspended Solids, Phosphates (B4) Dissolved Oxygen, Suspended Solids, Carbondioixde, pH, HCN
013 Porsuk Çayı-Benzinlik	Domestic Water Supply Industrial Water Supply	(B1) Fecal coliform, Turbidity, Color, Dissolved Oxygen, Dissolved Solids (B2) Alkalinity, Hardness, Chlorides, Dissolved Solids, Oil
015 Porsuk Çayı-Şekerçiftliği	Agricultural Water Supply	(B3) B, EC, Alkalinity, K, Na
018 Porsuk Çayı-Yunus Emre	Agricultural Water Supply	(B3) B, EC, Alkalinity, K, Na
019 Porsuk Çayı-Sazılar	Agricultural Water Supply	(B3) B, EC, Alkalinity, K, Na
030 Sakarya Nehri-Dümrek	Aesthetic Enjoyment Power Generation	(B7) Oil, Color, Turbidity, Suspended Solids, Phosphates (B8) Acidity, Alkalinity, pH, Oil, Phosphates
031 Sakarya Nehri-Yenice	Agricultural Water Supply	(B3) B, EC, Alkalinity, K, Na
034 Sakarya Nehri-Doğançay	Agricultural Water Supply	(B3) B, EC, Alkalinity, K, Na
035 Çarksuyu-Beşköprüler	Domestic Water Supply	(B1) Fecal coliform, Turbidity, Color, Dissolved Oxygen, Dissolved Solids

ii. Group C variables

Various wastewaters are discharged into Sakarya river and its tributaries, of which major ones have been given in chapter 4.2.1.2. These variables are not rather much to include in a monitoring program, and hence we propose the inclusion of all these variables in the monitoring program in Sakarya riverbasin (Table 4.10).

Table 4.10 Proposed sub-group C variables depending upon wastewater discharges

C1	*Etibank Boraks Exploitation discharges*	*Boron*
C2	*Irrigation return water*	*Mn, Mo, Phenol, NaCl, Color, Hardness*
C3	*Fertilizer producing plant discharges*	*Mo, NO3, NO2, K*
C4	*Municipal wastewater*	*Odor, Phenol, NaCl, Alkalinity, BOD5, Cl*
C5	*Textile factory discharges*	*pH, NaOH, Cd, Cl, SO4, H2S*
C6	*Ceramic factory discharges*	*Mn, Mo, SiO2, Ba, B, Cd, Cl, Co, Fe*
C7	*Pulp and paper idustry discharges*	*NaOH, Cl, Ch, Color, EC, SS, Zn*

As impact assessment is dependent upon individual monitoring sites, above proposed variables are monitored in the stations where the interested discharges are in question. Proposed variables with respect to monitoring stations in Sakarya riverbasin are given in Table 4.11.

Table 4.11 Proposed group C variables to be monitored in the stations in the Basin established by DSI

Monitoring Station	Wasterwater discharges	Proposed Group C variables
008 Seydisuyu-Kozyaka	Etibank Boraks Exploitation Irrigation return water	(C1) Boron (C2) Mn, Mo, Phenol, NaCl, Color, Hardness
010 Porsukçayı-Ağaçköy	Irrigation return water Fertilizer producing plant discharges	(C2) Mn, Mo, Phenol, NaCl, Color, Hardness (C3) Mo, NO3, NO2, K
011 Porsukçayı-Çalça	Municipal wastewater	(C4) Odor, Phenol, NaCl, Alkalinity, BOD5, Cl
015 Posukçayı-Şekerçiftliği	Municipal wastewater Textile factory discharges	(C4) Odor, Phenol, NaCl, Alkalinity, BOD5, C (C5) pH, NaOH, Cd, Cl, SO4, H2S

Table 4.11 (continued)

018 Porsukçayı-Yunus Emre	Irrigation return water	(C2) Mn, Mo, Phenol, NaCl, Color, Hardness
020 Sakarya Nehri-Karacaahmet	Irrigation return water Municipal wastewater	(C2) Mn, Mo, Phenol, NaCl, Color, Hardness (C4) Odor, Phenol, NaCl, Alkainity, BOD5, Cl
030 Sakarya Nehri-Dümrek	Municipal wastewater	(C4) Odor Phenol, NaCl, Alkalinity, BOD5, Cl
034 Sakarya Nehri-Doğançay	Irrigation return water Municipal wastewater Textile factory discharges Ceramic factory discharges Pulp and paper idustry discharges	(C2) Mn, Mo, Phenol, NaCl, Color, Hardness (C4) Odor, Phenol, NaCl, Alkalinity, BOD5, Cl (C5) pH, NaOH, Cd, Cl, SO4, (C6) Mn, Mo, SiO2, Ba, B, Cd, Cl, Fe (C7) NaOH Cl, Ch, Color, EC, SS,
044 Sakarya Nehri-Adatepe	Municipal wastewater Irrigation return water	(C4) Odor, Phenol, NaCl, Alkalinity, BOD5, Cl (C2) Mn, Mo, Phenol, NaCl, Color, Hardness

These monitoring sites are also shown in Figure 4.2. Variables to be observed in these monitoring sites, to a large extent, depend upon institutional expectations as well as constrains, Laws, standards, users of network, and so on. Therefore, a definite list for variables can not be constituted. For example, Etibank Boraks exploitation creates boron pollution and boron in excessive amounts harms the plants and other agricultural activities. Therefore, monitoring site numbered-2 above may be intended to monitor only boron. Even though a definite list can not be given for variables to be monitored in "impact assessment" monitoring sites, Table 3.2 and Section 3.3.2 may be utilized for selection.

4.4 Overall Variable Selection in the Basin

DSI has 44 monitoring sites in Sakarya riverbasin (Figure 4.2). We

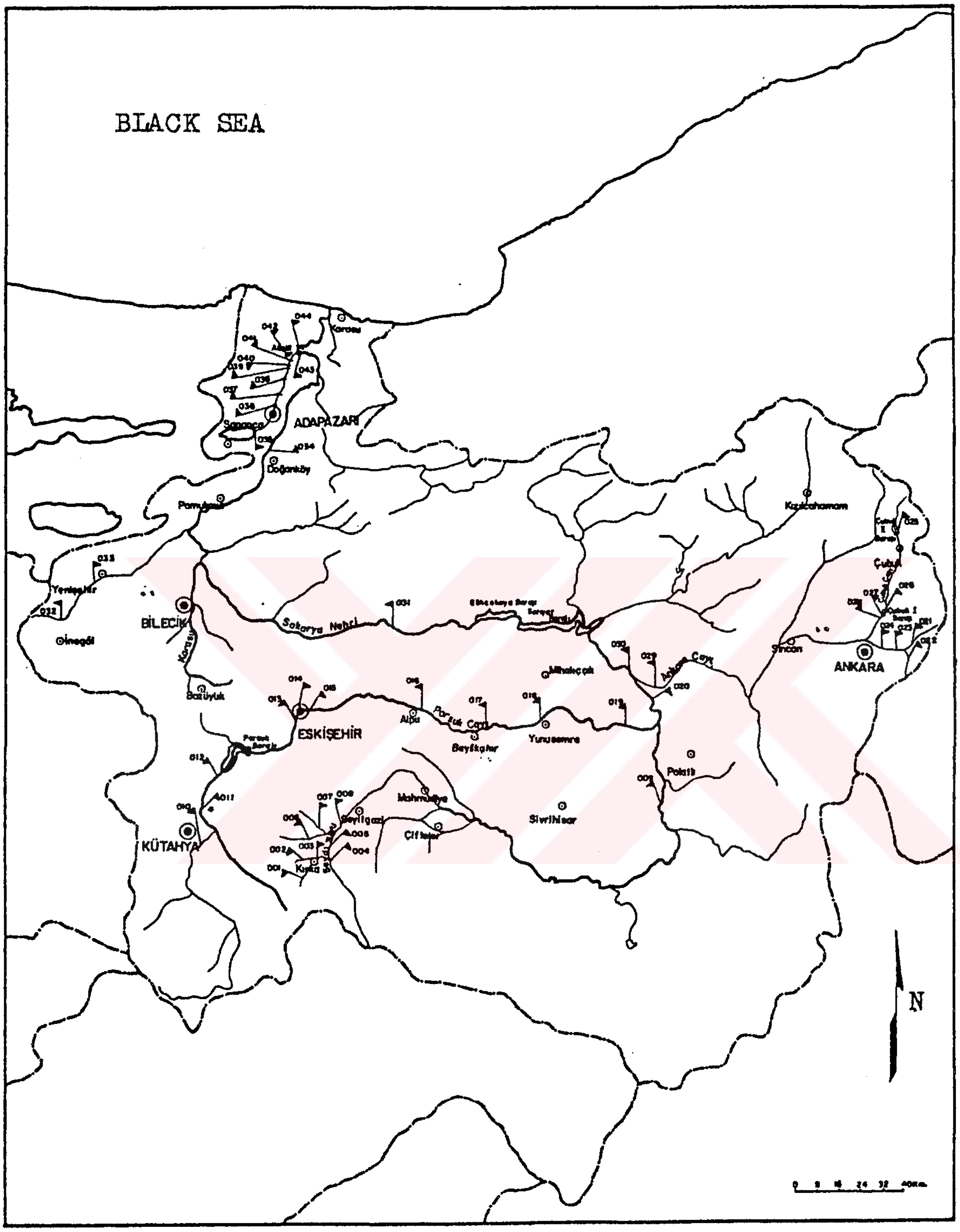


Figure 4.2 Monitoring stations established by DSI in Sakarya riverbasin.

have attempted to make an application in order to determine what variables must be monitored in those stations of the basin. Variables to be monitored with respect to monitoring stations of the basin have been given in Table 4.12.

Table 4.12 Proposed variables in the basin

Monitoring Stations	Proposed Variables (Groups)	Proposed Variables
001 Ağızkara Deresi-Akpınar Kaynağı	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
002 Lepçek Deresi-Köprü	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
003 Haremidere-Kırkaköprüsü	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
004 Kümbet Deresi-Yarbasan	A, B2	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO, Alkalinity, Hardness, Chlorides, Dissolved Solids, Oil
005 Haramidere-Numanoluk	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
006 Akin Deresi-Köprü	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
007 Keçeliözü Deresi	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
008 Seydisuyu-Kozyaka	A, B2, B3, B4, B7, C1, C2	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO Alkalinity, Hardness, Chlorides, Dissolved solids, Oil, Boron, K, Na, CO2, HCN, Color Turbidity, Mn, Mo, Phenol, NaCl
009 Sakarya Nehri-Kavuncu	A, B3	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO B, Alkalinity, K, Na
010 Porsuk Çayı-Ağaçköy	A, B1, B2, C2, C3	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO Fecal coliform bacteria, Color, Dissolved solids, Alkalinity, Hardness, Chlorides, Oil, Mn, Mo, Phenol, NaCl, K
011 Porsuk Çayı-Çalça	A, B3, C4	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO B, Alkalinity, K, Na, Odor, Phenol, NaCl, BOD5, Cl
012 Porsuk Çayı-Başdeğirmen	A, B4, B7	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO CO2, HCN, Oil, Color, Turbidity,
013 Porsuk Çayı-Benzinlik	A, B1, B2	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO Fecal coliform bacteria, Turbidity, Color Dissolved solids, Alkalinity, Hardness, Chlorides, oil

Table 4.12 (continued)

014 Akademi Kuyusu	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
015 Porsuk Çayı-Şekerçiftliği	A, B3, C4, C5	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO B, Alkalinity, K, Na
016 Porsuk Çayı-Yeşildon	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
017 Porsuk çayı-Beylikahır	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
018 Porsuk Çayı-Yunus Emre	A, B3, C2	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO B, Alkalinity, K, Na, Mn, Mo, Phenol, NaCl Color
019 Porsuk Çayı-Sazılar	A, B3	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO B, EC, Alkalinity, K, Na
020 Sakarya Nehri-Karacaahmet	A, C2, C4	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO Mn, Mo, Phenol, NaCl, Color
021 Hatip Çayı-Koçocağı Deresi	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
022 Hatip Çayı-Yazı Deresi	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
023 Hatip Çayı-Lalaham Deresi	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
024 Hatip Çayı-Bayındır Barajı Çıkışı	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
025 Çubuk Çayı-Çubuk II Barajı Çıkışı	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
026 Çubuk Çayı-Çubuk I Barajı Girişi	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
027 Çubuk Çayı-Çubuk I Barajı Kret üst	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
028 Çubuk Çayı-Çubuk I Barajı Çıkışı	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
029 Ankara Çayı-Meşelik	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
030 Sakarya Nehri-Dümrek	A, B7, B8, C4	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO Odor, Color, Turbidity
031 Sakarya Nehri-Yenice	A, B3	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO B, Alkalinity, K, Na
032 Kalbut Çayı-İnegöl Sunta Fabrikası	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO
033 Göksu Çayı-Boğazköy	A	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO

Table 4.12 (continued)

034 Sakarya Nehri-Doğançay	A, B3, C2, C4, C5, C6,C7	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO B, Alkalinity, K, Na, Mn, Mo, Phenol, NaCl Color, Odor, BOD5, Chlorides
035 Göksu-Beşköprüler	A, B1	T, PH, SS, EC, NO2, NO3, Cl, PO4, NH3, DO Fecal coliform bacteria, Turbidity, Color, Dissolved solids
036 Çarksuyu-Yazlık Köprüsü	A	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO
037 Çarksuyu-Karakamış	A	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO
038 Çarksuyu-Karaman	A	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO
039 Çarksuyu-Söğütlü	A	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO
040 Çarksuyu-Ferizli	A	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO
041 Çarksuyu-Seyfiler	A	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO
042 Akgöl	A	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO
043 Sakarya Nehri-Botbaşı	A	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO
044 Sakarya Nehri-Adatepe	A, C2, C4	T, PH, SS, EC, NO2, NO3, CL, PO4, NH3, DO Mn, Mo, Phenol, NaCl, Color, Odor, Alkalinity, BOD5, Cl

4.5 Reduction in the number of variables

Ağaçköy monitoring data with monthly averages for six years have been used. Correlation coefficient between variables have been determined, and a strong relation between variables could not be found to reduce the number of variables to be monitored (Figure 4.13).

Table 4.13 Correlation coefficient between variables

	Q	T	pH	EC	M-Al	Cl	NH3-N	NO2-N	NO3-N	DO	PV	BOD	O-PO4	SO4	Na
T	-.313														
pH	.055	.120													
EC	-.503	.749	.101												
M-Al	-.474	.138	.023	.189											
Cl	-.306	.161	-.105	.274	.122										
NH3-N	.509	-.244	.005	-.256	-.226	.069									
NO2-N	.043	-.152	.309	-.134	.006	.065	.126								
NO3-N	-.108	-.140	-.036	-.077	-.033	.100	-.272	.121							
DO	.247	-.738	-.023	-.561	-.001	-.228	.187	-.032	.048						
PV	.699	-.119	.141	-.289	-.486	-.117	.503	.171	-.011	.094					
BOD	.103	-.446	-.026	-.344	-.035	.027	.223	.264	-.212	.358	.049				
O-PO4	.270	-.203	.186	-.288	-.061	-.127	.373	.427	-.055	.178	.355	.085			
SO4	.146	-.333	.099	-.206	-.088	.157	.476	.513	-.110	.351	.290	.330	.608		
Na	-.299	.416	-.158	.245	.112	.191	-.151	-.175	.218	-.334	-.197	-.443	-.010	-.190	
K	.050	-.220	-.158	-.221	.155	.354	.294	.038	.011	.016	-.046	.120	.204	.110	.088

5. EVALUATION OF THE RESULTS

This study, which aimed the development of a methodology to be applied in variable selection in a water quality monitoring network, required the inclusion of a large range topics to arrive at conclusion. These topics ranged from objective definition of water quality monitoring network to quality variables which are important in various beneficial uses of water and quality variables which exist in large amounts in point or nonpoint source discharges.

Scope of this study does not include the determination of quality variables which is important in various water uses or quality variables which exist in large amounts in discharges. Preparing the tables of quality variables with respect to water uses and discharges have been carried out for the purpose of displaying quantitative results in variable selection. The tables have been prepared by obtaining knowledge about the variables in the literature, and naturally it cannot be expected that these tables are quite reliable. Preparation of such tables is out of the scope of this study and, strictly speaking, more ahead of this study. As it would have been very difficult to realize such a study without these tables, these tables have been attempted to come into being.

Because data for all quality variables does not exist, correlation coefficients could be calculated for only 20 variables. In the same way, ease and cost of measurement for all variables could not be determined because measurement of all variables are not being carried extensively. And a list is prepared for only twenty variable whose ease and cost of measurement, correlation coefficient and occurrence number values could be determined. And Group A variables have been determined by the help of this table. it does not seem conceivable that if ease, cost and Cv values for all variables could have been calculated and involved in this table, variable order in the table would have changed markedly. So it is reliable to determine the Group A variables which are the variables to be monitored in all stations of the basin.

Ease and cost of measurement have been determined by taking into consideration the only one analysis method. When different methods for the analysis of a variable are applied, it is obvious that different values for ease and cost of measurement are found. So tabulated ease and cost values are not rigid, and they change depending upon the analysis methods applied. For example, determination of dissolve oxygen by Winkler method requires reagents, excessive time and equipment, on the hand determination of dissolve oxygen by probe is rapid and cheap.

In the determination of Group A variables ease of measurement, cost of measurement, correlation coefficients and frequency of appearance of variables have been taken into consideration. This does not mean that these criteria are quite strict and some other criteria can not be added for the determination of Group A variables. Other than determination on the criteria, proposed four criteria have been assumed to be equally effective in assessing the Group A variables and may not be assessed equal.

In the overall selection, ten of Group A variables, 5 of Group B variables, 5 of Group C variables have been included in the monitoring network. This has been done because of economic, labor, technical possibility and some other constraints. As these constraints may vary from country to country, and also with the economic developments, more variables may be added to the selected variables by moving down on the lists.

Another problem is that determination of water uses and discharges to the river requires an extensive study and this subject is also out of the scope of the study. Water uses and discharges in the basin have been determined by the help of literature.

In the case study, both all water uses and impact assessment objectives are involved in the network of the basin. It is also possible to establish the network for only impact assessment or water uses. Even a network may be established for only one water use. In this case, selected variables for that water use are involved plus Group A variables.

Finally, an effort has been spent to reduce the number of variables to be observed in a monitoring site. Monthly data for Ağaçköy monitoring site (1978-1984) have been used in this study, and satisfactory results could not obtained. The data were not suitable to treat statistically. Treatment results have showed that there does not exist strong relations between variables, even though a weak relationship between temperature and electrical conductivity (Cv=0.749), flowrate and phenolphthalein alkalinity (Cv=o.699), and a reverse relationship between dissolved oxygen and temperature (Cv=-0.738) have been shown. These results can not be trusted to apply in a real monitoring program. Because the data were short and not suitable to treat statistically.

6. CONCLUSIONS

This study foresees the development of a method in variable selection in water quality monitoring networks. A wide range of topics have been evaluated to realize the basic principles of the study. Finally it has been seen that objective-based approach provides the solution to variable selection. Therefore objectives have been first defined and then variables have been selected depending upon the objectives.

Water uses and impact assessment have been proposed as monitoring objectives, which are applied whenever need is a water use and detecting of discharge in the basin respectively. The defined objectives in this study are gross objectives and may involve the many of pre-defined objectives by many researchers. Therefore they are expected to answer much of the requirements of network users.

Table 3.11 and 3.13 have just been prepared to show quantitative results in variable selection and hence a reader may hesitate about the strictness of proposed variables with respect to water uses and discharges. Because variables and standard values for various water uses and discharges have not yet been established by authorities, even in the world-scale.

Although variables, which have been determined with respect to discharges in the basin, under the heading of impact assessment are relatively low in number, the number of variables under the heading of water uses are rather much to involve in a monitoring program. Therefore a cut off point is selected in the number of proposed variables depending upon the needs of network users, technical possibilities, economical constraints and so on.

Objective-based selected variables are dependent on specific monitoring sites. In addition to objective-based variable selection, some properties of variables have been taken into consideration for selection of variables to be monitored at every monitoring site. These properties have been the ease and cost of measurement, statistical behavior and frequency of appearance of variables. The data to determine these criteria for all variables were not present, and therefore these four criteria could be analyzed for only 20 variables. Moreover, the data for correlation analyses were also short and inadequate to evaluate the reduction of variables.

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