HYDROLOGIC MONITORING SYSTEMS FOR THE U.S. NATIONAL PARK SERVICE

Vujica Yevjevich
Research Professor and
Director of International Water Research Institute
George Washington University
Washington, D.C. 20052

Hydrology and National Parks

The hydrologic aspects of the national parks, national forests and wilderness areas (controlled areas within the continuously changing land-use surfaces around them)may be classified in two broad groups:

(1) Hydrologic aspects related to water resources problems specific for the development, maintenance and operation of parks, forests and wilderness areas. These are related to the following problems: minimal damage or survival of various facilities during intensive floods, extensive droughts (by duration and severity), erosion control from intensive rains, water quality protection, building of recreational areas with proper water supply and pollution control, general water supply, improving (without making them man-made or artificial looking) all bodies of water within the areas, improving wildlife and fishing conditions, and hydrologic aspects of other similar water resources problems.

(2) Hydrologic aspects of national parks, forests and wilderness areas, transcend the specific interests and objectives of these areas. Although they are related to them, they are intended to solve the broad national, regional, state and local water resources problems. Such problems are: the stabilization or increase of

water yields from these areas; decrease of fluctuations of water flows by the proper management of lands, lakes, ponds, swamps, and other bodies of water, of forests and grazing and of snow; control of areal sources of pollutions, especially by the use of fertilizers, herbicides, insecticides, and fire fighting materials; monitoring the long-range hydrologic characteristics, and effects of land use on water regime, through the use of the representative or controlled river basins within the parks, forests and wilderness areas.

In this paper it should be understood that any discussion about national parks will frequently also apply for the state and local parks, national and state forests, wilderness areas, and similar surfaces.

Water Resources and National Parks

The conflict of interests between the objectives for developing preserved areas in the form of national parks, forests and wilderness areas, and the development of natural resources (minerals, timber, water, and grazing) should be resovable in most cases involving water resources. Surface reservoirs may be conceived and built so that they meet the objectives of national parks, but also contribute to general recreation, flood control, and emergency drought alleviation. Subsurface water resources of a national park can be utilized in such a way that no one could identify their use. The objectives of National Parks include the enhancement of natural beauty and the appeal to human needs to enjoy nature. These objectives often parallel to water resources needs. Examples are the control of erosion and sediment, insurance of clean water, obtaining ecological balance in bodies of water, and flood and drought control. Therefore, there are many justifications and mutual benefits for joint work by the National Parks' authorities, various hydrology oriented governmental and state agencies, universities, and other water resources and hydrology oriented organizations. These organizations should work solutions of water resources problems through an advanced hydrologic system within the national parks.

No solutions of water resources problems will be better than the information available on various hydrologic aspects of the national parks.

One can ask a pertinent question, namely whether the hydrology of national parks, with the observations (and measurements) of hydrologic quantities (variables) of river basins within the park areas, and the general monitoring of various hydrologic impacts, is any different than in any other area. One may argue that the techniques of hydrologic services are generally valid for any area, provided these are properly adjusted to it. These adjustments represent the crucial factors, which produce specificities in the case of national parks. When commonalities of hydrologic services among the various areas predominate, one could be inclined to consider that these services are general and should be uniformly applied. This point of view may be defended by leaders of some standard hydrologic services. However, when hydrologic specificities of such areas are important (and are of the same order of magnitude as commonalities), as seems to be the case for the national parks, the hydrologic monitoring services may need special attention. Adjustment of the general hydrologic observational techniques needs to be made for these specificities.

This paper starts with the hypothesis that the hydrologic aspects of national parks have specificities that deserve a particular approach in the design of monitoring hydrologic activities. The information produced should allow the identification of current and potential water problems, which affect each park. These specificities will be called the external specificities, because they result from a comparison between the national park areas and the various surrounding types of area.

Parks are located in different geographic areas, with differences in topography, geology, soils, climate, and vegetation. Therefore, the water resources problems of parks will depend on two basic sets of variables: (1) those that result from natural geographic conditions of each particular park area; and (2) those that result from the specific objectives and man-made facilities of each park. Differences among the parks may be as great, or even greater, than their common hydrologic and water resources factors. Therefore, each park has to be considered as a particular entity from both perspectives.

Both external and internal specificities of water resources problems and hydrologic monitoring of park areas should be compared with the general approaches to solutions of water resources problems, and with the general hydrologic monitoring services, to provide feasible solutions to problems and optional hydrologic information for these solutions.

Current Monitoring Services, Oriented to Hydrology, as Related to Hydrologic Monitoring in National Parks

Federal and state governments in the United States have general and particular services oriented to general geographic and specific hydrologic monitoring services. Among the general services one should first mention the cartographic and geologic services of the U.S. Geological Survey.

For planning any hydrologic monitoring service in national parks and for interpretation of the accumulated hydrologic data, proper topographic information (scales and details), appropriate geologic maps, and data from monitoring of various evolutions, especially in the biological cover, are indispensable. The changes in biological cover of the land and the evolution in land uses are very much related to topographic and geologic background information and monitoring. Therefore, the design of hydrologic monitoring, for given current and potential future water resources problems, will greatly depend on topographic, geologic, biologic cover, and land use information. The evolution by the adjustment of any hydrologic monitoring service in national parks will then depend, from time to time, on various geographic changes.

Particular hydrology related services usually cover the following areas:

(1) Hydrometeorological monitoring, includes all the major climatic variables and variables needed for meteorological forecast and supply of general information. This includes those that affect not only the park services and park environment in general, but the hydrologic environments and processes in particular. Especially valuable information for hydrologic purposes are data on precipitation and warning of flood peaks. The observational stations of the U.S. Weather Service supplemented by similar services in each national park, supply most of the information on climate and atmos-

pheric processes needed for hydrologic purposes.

(2) Hydrologic monitoring of surface water (of river levels, discharges, floods, lake levels, and reservoir levels) is basically the domain of the U.S. Geological Survey, Water Resources Division, which maintains the general national monitoring network of river gauging stations. It is a very reputable and dependable source of river runoff information. Many state agencies and water users often maintain their own specific monitoring stations for surface water runoff, dictated by particular objectives of each user. Such a system of specific stations in national parks, integrated with the general surface water monitoring networks, may be an attractive solution to the authorities of many national parks. They may be of general benefit, beyond the specific needs of each park.

(3) Forecast of river flows for middle-size and large-size rivers either for flood warning or for water and water course uses, and forecast of flood peaks of small rivers for flood warning purposes, are carried out by the U.S. Weather Bureau, River Forecasting Service. Significant potential exists for the cooperation between the National Park Service and the Weather Bureau for mutual benefit, for purposes of flood forecast and general forecast of states of river flows and lake levels, which are of importance to the fulfillment of objectives of the National Park Service.

(4) Sediment transport along rivers is observed at river flow gauging stations by the U.S. Geological Survey. Monitoring sedimentation of lakes and reservoirs is made by many agencies, public and private, that build and operate the reservoirs. The National Park Service may be interested how rapidly some of their lakes, as well as man-made reservoirs, are filled by sediments. Monitoring of these processes by the Park Services may be of mutual benefit not only to the National Park Service, but also to the upstream and downstream water resource interests.

(5) Subsurface water resources are mainly monitored through water wells. The U.S. Geological Survey is the main organization for such monitoring, though many states and local water resources districts have supplemental services for ground water monitoring purposes. The ground water resources in the parks of the National

Park Service may be of interest for monitoring the specific problems of individual parks, either for the internal water supply needs, or for their use and supply to the areas around the parks. In that way it can be shown that the uses of lands for the parks, forests and wilderness areas do not represent a total decrease in the use of natural resources.

(6) Soil erosion is basically observed by the agriculture and forestry oriented agencies, federal and state, particularly by the U.S. Soil Conservation Service and the U.S. Forest Service. The problems related to soil erosion in national parks, and the monitoring of areal and time evolution of all the important processes related to soil erosion can be best accomplished by the park authorities by applying the technology already available in these federal and state agencies.

(7) River erosion and stabilization problems are oriented to users of river channels and to water users with riparian interests. The navigational rivers are under the control of the U.S. Corps of Engineers. Monitoring river problems (meandering, erosion, undercutting, degradation, agradation, scour at bridges and the other river structures) are specific problems in many national parks, with the proper techniques to be used for protection of banks, and local river stabilization and training works. Here, also, the transfer and proper use of the existing technology is crucial for the National Park Service.

(8) Monitoring snow on the ground is a subject of increasing importance, basically for the forecast of spring and summer water yields from the national parks for downstream water users, for the purposes of flood warning and control, and for managing various aspects of water resources for the National Park Service domains. The U.S. Soil Conservation Service is one of the most experienced agencies for snow monitoring and forecast of its melt and water yield. This particular service, combined with the meteorological and forecast service, is essential in singling out the most likely avalanche areas at any given time during the winter park uses. In some national parks the avalanches present a potential danger to communications and various facilities, beyond the damages to trees and shrubs. The accumulating snow, its physical state and the

oncoming weather conditions can be used to forecast potential avalanche areas.

(9) Monitoring water quality variables has become a growing problem in many areas. Several parks (or parts of each park) have become the sources of increased water pollution from point, line and area sources of water pollutants. Some variables determining the water quality of rivers and lakes are observed by the U.S. Geological Survey. Several monitoring stations are in the domain of the U.S. Environmental Protection Agency or are of interest to the U.S. Public Health Service, as well as the other federal and state agencies, municipalities, rural water supply and water disposal districts, industrial complexes, and mining outfits. The National Park Service should be interested in monitoring the water qualtiy variables within their areas from two points of view: (1) to insure the environmental quality and ecological balance, and the supply of good quality water within the parks for park objectives, and (2) to insure that the waters leaving the park areas are of the best quality, or at least of acceptable quality, for various downstream users. Identification of all potential sources of water pollution within the parks, as well as upstream of the parks, and finding the proper solutions for these problems requires the corresponding water quality monitoring networks. It is necessary to single out those water quality variables that may be specific to each park, especially if they are not part of the 5-7 standard water quality variables that belong to the general water quality monitored quantities (T^o, conductivity, pH, BOD, DO, turbidity, etc.). Examples are heavy metals in water, both of park origin and air-borne.

In principle, any hydrologic monitoring service for any important area of a national park, should properly integrate the general geographic monitoring and information services, with the standard and specific park hydrologic monitoring activities. In this regard, commonalities in general geographic (especially topographic), geologic, biologic and other monitorings, as well as the external and internal specificities of water resources and hydrologic monitoring services of national parks, should be blended together for each park, so that the most economical way be found to procure the optimal hydrologic information for the solution of water resources problems within the parks, as well as those problems that are related to the national park areas.

Approaches to Hydrologic Monitoring for the National Park Service

Hydrologic monitoring is envisioned in this paper as the development of a long-range monitoring service. It can only be reasonably accomplished if it properly blends the following factors:

(1) The existing monitoring services related to factors of geography, geology, ecology and hydrology in the areas under the jurisdiction of the National Park Service.

(2) The properly identified water related problems, namely those experienced in the past, those identified through an assessment of the current problems, and those that represent the projection of potential water resources problems, both within the parks, and around and downstream of them when their solutions depend on the various operations and improvements within the park areas.

(3) A proper use of all the existing park services for monitoring and observation of hydrology oriented quantities, that may be properly balanced and integrated with capabilities of the National Park Service, namely the capability within each park for monitoring those hydrology related quantities that are not monitored at present, and/or that are not apt to be in the future.

It is assumed that the individual parks have various ongoing services, personnel, and logistics, that can be used-- without a disruption or slowdown of the present functions-- for the additional hydrologic monitoring. This is important, because other monitoring activities within the park might be easily extended, at a small additional cost, to hydrology oriented monitoring.

For an action-oriented planning approach to future hydrologic monitoring, the National Park Service may consider undertaking action in the following phases:

(A) Identification of Water Resources Problems of Park Areas. This activity would require a systematic inventory of problems by using the experience accumulated during the history of the park and the experience of the present and retired park personnel, particularly types of water disasters. Such events include floods, droughts, landslides, avalanches, water supply deficits, outbreak of water related diseases, water related accidents, transportation breakdowns, river-related problems of regulation or defense and ice buildups and breakdowns.

For each park a roster of future water resources problems both within the park and areas outside the park but related to it may then be established. These three types of identification of water related problems; those demonstrated in the past, those assessed to be the problems of today, and those identified by an extrapolation should be separated. They in turn may be classified as the short-range, middle-range and long-range problems.

If these water resources problems are identified for all the parks, based on a well prepared manual of how to identify the various problems, they could be classified, as the problems common to most or common to a majority of parks, or as the problems very specific to a park or a small number of parks. Those problems that involve legal aspects, or have a particularly sensitive political, social or economic implication, should also be identified.

The problem identification will be important for three types of planning:

(1) How to procure the necessary (optimal) hydrologic information for the solution of problems along with the design of the appropriate hydrologic monitoring networks, such as networks for precipitation, surface runoff, sediment transport, ground water levels, lake levels, and water quality variables.

(2) How to plan the solutions of water resources problems related to the National Park Service.

(3) How to transfer the experience and technology between parks in both the hydrologic monitoring services and the solutions of park-related water resources problems.

(B) <u>Design of Services for Monitoring Various Hydrologic Variables Within National Parks</u>. No meaningful planning of monitoring services will be feasible without a proper identification of water resources problems in national parks and the corresponding hydrologic variables for which the information will be crucial in the future solutions of water resources problems. Without the identification of what should be monitored in water quantity and water quality variables, the comprehensive, meaningful and long lasting monitoring services can not be designed.

The results of hydrologic network design should be threefold: (1) Proper information should be collected; (2) Cost of efforts should be optimal (for given funds, a maximum information of a given quality is produced); and (3) The extension or contraction of the monitoring services should be easily implemented as the needs for information change with the change and the emphasis in water resources problems.

Therefore, the second phase should be developed in two steps: (a) Identification of hydrologic variables to be monitored; and (b) Design of monitoring networks for these water quantity and quality variables. These two basic steps should lead to a proper implementation of designed networks, as well as an optimal procurement of hydrologic information.

(C) <u>Implementation of Designed Networks</u>. Three basic approaches are available to the National Park Service in implementing the designed hydrologic networks for individual parks or groups of parks:

(1) Make agreements with the existing national or state data monitoring service agencies, for networks specific to each agency. This can be done by a transfer to these agencies of funds available for that purpose in the National Park Service.

(2) Establish in each park or a group of parks a hydrologic monitoring service, as a part of all other services of that park or group of parks.

(3) Combine the two above alternatives, in function capabilities, competence, willingness and reliability of: (a) each national or state agency that has a particular hydrologic monitoring service, and (b) each park

or group of parks. Proportional involvement by the outside and inside services would depend on many factors, particularly whether the solution of problems requires the monitoring service of short-range, middle-range or long-range duration, or whether they require monitoring of national, state or only park-related importance.

Without an extensive study, the inclination will be for recommending the third approach as a strategy for the implementation of designed hydrologic networks for national parks, by an appropriate and economically optimal division of work assignments between the general hydrologic service agencies and the National Park Service.

The most important reasons for suggesting the combined strategy approach are:

(a) The national, or state, established services for monitoring hydrologic environments and processes should be involved with the long-range hydrologic information procurement, and the long-range objectives, for example the monitoring at the network stations that will be observed for 30 years or more. This should be the case if the rivers, river basins, and lakes are located within the national parks (national forests, wilderness areas), and are considered as the representative or unique bodies of water, areas of land or aquifers. The objective is then: (i) to procure the basic hydrologic information as a part of the national or state pool of hydrologic data; (ii) to monitor the long-range fluctuations in hydrologic variables unaffected by the parks or parks life and services; (iii) to monitor the effects on hydrologic variables maturing park services and development, including an increase of park facilities, an increase in the number of visitors and visiting days, and changes in park practices; (iv) to monitor the effects of air-borne pollutants, deposited over the parks, on water quality.

(b) The existing or planned hydrologic monitoring services within each park or group of parks, to be implemented and operated by the park services, could be justified for three reasons: (i) water resource problems and the hydrologic data procurement will be of short-range duration, say less than ten years; (ii) problems are specific to a park, and the collected hydrologic data would not add significantly to the general hydrologic monitoring objectives; and (iii) hydrologic information procurements within a park or a group of parks are undertaken concurrently with the collection of other general information required by the park improvements and operations (use of boats, fishing, pollution due to the use of the park and park facilities, and effects on water quantity and quality of park measures or operations).

(c) For the middle-range objectives of hydrologic monitoring and related problem solutions, say for the duration of 10 - 30 years, the monitoring work may be either allocated to general hydrologic service agencies if the objectives fit the general service assignment of procuring the nationally or state needed information, or it may be the task of the National Park Service to monitor these hydrologic processes, if specific park problems are the impulse to establish the monitoring service and the major users of collected data.

<u>Technological, Personnel and Management Constraints</u>

If the third strategy is used having the National Park Service implement the designed hydrologic monitoring network for short-range objectives and park specific problems and monitoring durations, several questions should be posed and answered. For example, would the cost be acceptable for installing and monitoring the proper instrumentation? Could the observational personnel maintain the remote control of monitoring stations? Would there be sufficient management talent within the regular park staff? These constraints are crucial, but not insurmountable.

(A) <u>Technological Constraints</u>. Most of the hydrologic instrumentation and devices are simple and standard, even if they are digital or continuous recording. Telemetry, when needed, may pose some problems, but mastering its installment, maintenance and operation may be simpler than it looks at the first glance. Methods of observation, recording, processing and reporting are also standardized and are often available as manuals with the forms easy to fill in. The problem may be with monitoring the water quality variables. However, samples of water could be sent to the closest laboratories for the analysis on a contractual basis.

The technological cost would be similar for both the monitoring services of the National Park Service in its individual parks, and the general hydrologic monitoring service agencies, provided the personnel in charge of monitoring and maintenance were properly trained.

(B) Personnel Constraints. Personnel should be available in many park services who can be properly trained to perform the monitoring service and maintain the equipment, instruments and other devices. It would be feasible to make the agreement with the hydrologic monitoring service agencies for training the personnel assigned to monitoring within the National Park Service, or the short courses approach might be used, as is currently done for the agencies' field personnel.

(C) Management Constraints. It is quite feasible to consider the park management at various levels as sufficiently educated and trained to be able to master the management problems of hydrologic monitoring networks and operations, just as they manage the other services within the park of the same of even greater order of complexity.