DATA SYSTEMS FOR WATER RESOURCES MANAGEMENT

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ABSTRACT

Water resources management decisions are facilitated by the use of well organized and readily available data. For the data to be converted to useful information, it must be analyzed and reviewed with the specific data needs of the users in mind, a task which is greatly aided by an appropriate data structure. Efficient water resources management is best achieved by using, as a foundation, data which are organized by hydrologic relationships. Easy access to current data is equally as important as appropriate structure. Thus, data storage and retrieval methods need to be capable of rapid update with sufficient flexibility to organize current knowledge in a usable format and response to availability of new data and changing data needs. Recently developed computer based water data systems are discussed. At the center is a hydrologic data base for the major surface waters of the contiguous 48 states. It contains unique identifiers and hydrologic connections for over 68,000 reaches. In addition to the river network, the data base contains the digitized traces of streams, lakes, coastlines and basin boundaries. The data base can be used as a framework for organizing water data and routing streamflow and pollutants through the nation's river systems. Linked to the file are a series of data modules including: ambient conditions, point source discharges and drinking water intakes. As the system is utilized, it is anticipated that new modules will be added. It is recommended that all the data modules be linked to one system to assure better data accessibility.

INTRODUCTION

The development of water data systems has been an on-going endeavor by water resources managers for at least 20 years. The impetus for the development of these systems comes from the growing concern for the quality of the aquatic environment and the concomitant increase in the demand for water resources, which have occurred in the past two decades. It has been realized that detailed, accurate and up-to-date information is a prerequisite for accomplishing any goal related to water resources management. The mandate to maintain and improve the quality of the nation's water, accompanied by the ever increasing demand for competing uses of that water has created a tremendous demand for data by those charged with managing water resources. The processing and analysis of such large amounts of data have inexorably demanded the use of automated information systems. Recent developments in computer technology, most notably the development of powerful data base management systems and the significant reduction in computer storage costs have created the potential for the development of very powerful national level water data systems. Some recently developed and developing water data bases, which take advantage of the new computer technology are described here.

It is easiest to define an information system in terms of its functions. Simply stated, a system performs the tasks of data storage and retrieval. The value of a system can be judged by how well it meets the information needs of its users, so a successful water information system design must reflect the unique nature of water data.

There are some general criteria which can be used to evaluate a system. One of the most important is the ease with which data can be stored and accessed. A water information system becomes more useful as more data is contained in it, but unless the addition and retrieval of data is made very easy not many groups will want to add their data to the system. Flexibility is also of prime importance in a water data system. Not only should the system be able to accept and output many different forms of information, but it should also be capable of change when it is required.

Another aspect of system quality, which is often overlooked is the quality of the data contained in the system. No matter how easy it is to access data or how flexible the outputs, if steps have not been taken to insure the quality of the data, the system will ultimately fail. An important part of any successful system is the quality assurance subsystem, which should at least include input standards, range checks, source codes and security measures to prevent accidental or unauthorized changes to data.

Steps can be taken at all phases of system development to ensure that a water data system will be useful. The system design must include data structures which are appropriate for the kinds of data to be stored and for the kinds of questions that will be asked. The data base structure should maintain key relationships between data types. Some of the most important relationships needed in a water data system are:

- Type of observation;
- Location of observation; and
- Time of observation.

With the data related in these ways, users can access data of specified types for a given area and time period. In a water data system, location should be specified in relation to geographic, political and perhaps most importantly to hydrologic frames of reference. Relating data to its location in the hydrologic system is important because it allows water data to be stored, retrieved and analyzed in the same framework from which it was originally taken. If all data is keyed to its location in a hydrologic frame of reference, where the links between the features are maintained, then the system can provide the ability to link observations hydrologically and to route information through the hydrologic network. For example, if water intakes were coded to the network, those facilities with intakes downstream of a toxic chemical spill could be quickly and easily found.

The key to maintaining hydrologic relationships is the existence of an appropriate river network, which facilitates coding data and permits simple upstream and downstream traversals of the network. For geographic and political location, there exist many suitable frames of reference which can be applied to an automated system. For river systems, there has not been a widely accepted framework developed for the entire nation. Recently SCS Engineers, under contract to the U.S. Environmental Protection Agency has developed what we believe can become the standard frame of reference for hydrologic data in the United States.

A COMPUTERIZED HYDROLOGIC DATA BASE

The Reach file contains the hydrologic structure for approximately 32,000 hydrologic features in the contiguous United States. These features are uniquely identified and divided into approximately 68,000 reaches. Features included in the file are rivers, lakes, coastlines and international borders. The Reach file was designed to be as simple as possible while maintaining unique identifiers and the linkages between features. Reaches in the file are identified by the USGS-WRC Cataloging Unit and a three digit reach number. For each reach, linkages are provided to adjacent upstream and downstream connecting reaches. During the original coding of the Reach file, the segment names were also codified and associated with reaches. This information forms the basic structure of the Reach file and it provides a very simple framework for locating and routing data. Updates are also easy to accomplish because linkages only affect adjacent connecting reaches. When a reach is added, only the linkages in the connecting adjacent reaches need to be updated.

The reaches were derived from the NOAA 1:500,000 Aeronautical Charts. The base maps were chosen to provide a file of minimum size that would nevertheless include most streams which receive direct discharges from pollutant sources and most streams which provide water supply for industrial, domestic and agricultural purposes.

In addition to the names and linkages and associated data contained in the hydrologic structure portion of the system, this system also contains traces of the reaches known as "trace data". Digitization of stream traces was accomplished using optical scanning techniques and automated line following procedures to transform the raster data generated by the scanning process into vectors which could be plotted to represent streams and lakes. Scanning was selected rather than digitizing for this effort because it was believed it would provide a more uniform and higher quality representation of surface hydrologic features. The resolution of this approach was about 150 meters.

This trace data enables users to obtain display of hydrologic data overlaying on the reaches in any area. It also permits the calculation of three types of reach length data. The first type is the length of each individual reach. The second type is the total length of all reaches upstream from the bottom of each reach. The third type is the length from the bottom of each reach to the mouth of the river through which it discharges to the ocean. The resulting mileage data may be used in a number of applications.

INFORMATION DISSEMINATION

In order to document the river network contained in this hydrologic file, a draft directory has been produced. This directory contains two basic types of information: first, tabular listings and second, plots of the stream traces. A sample listing of reaches in hydrologic order is shown in Figure 1.

Plots of the stream traces have been produced at 1:500,000 scale (see Figure 2). They include representation of the hydrologic features, labeling of each segment number, cataloging, unit boundary and cataloging unit numbers. Due to the scale of map used, it is expected that changes and corrections will be made. In addition, reaches are expected to be added gradually over time as specific needs arise for more detailed coverage in specific areas. Thus, frequent reprinting of the directory will likely be necessary (perhaps on annual or bi-annual cycles). Because of this frequent reprinting, maps were produced in single color only to save printing costs. The capability of the system and the equipment would readily permit the production of multi-color maps for specific limited applications.

The combination of listings and hydrologic feature plots will provide users with the ability to link their data to a common hydrologic framework such as is compatible with an automated storage and retrieval system.

AUXILIARY DATA

The universe of data for which hydrologic structure is appropriate is very large. Examples of the type of data linked to the Reach file include:

- Industrial wastewater discharge data, especially type of discharge and discharge quantity and quality;
- Municipal wastewater dischargers;
- Indirect wastewater discharge, that is, dischargers from industrial processes to municipal wastewater treatment plants;
- Surface water supply intakes;
- State reported fish kill events;

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==BRANCHING PATTERN LEVEL== =TYP= ======SEGMENT NAME======  SEGMENT NUMBER   PATH   ARBLAT
    0    1    2    3    4                                                    MILE    MILE

    008                       S   LOYALNANNA CR              05010008-008  2176.8     8.2
     |
     |   009                  S   ROLLING ROCK CR            05010008-009  2175.7     7.2
     |/
    007                       R   LOYALNANNA CR              05010008-007  2168.6    21.8
     |
     |   006                  S   FOURMILE RUN               05010008-006  2177.4    15.2
     |/
    005                       R   LOYALNANNA CR              05010008-005  2162.2    67.7
     |
     |   005                  S   QUEMAHONING CR             05010007-005  2217.7    19.7
     |    |
     |    |   006             S   STONY CR                   05010007-006  2223.9    25.9
     |    |/
     |   004                  R   CONEMAUCH R                05010007-004  2197.9    48.0
     |    |
     |    |   008             S   SHADE CR                   05010007-008  2211.5     7.5
     |    |    |
     |    |    |   009        S   CLEAR SHADE CR             05010007-009  2214.2    10.3
     |    |    |/
     |    |   007             R   SHADE CR                   05010007-007  2204.0    26.1
     |    |/
     |   003                  R   CONEMAUCH R                05010007-003  2195.6    86.9
     |    |
     |    |   010             S   LITTLE CONEMAUGH R, N BR   05010007-010  2208.9    26.1
     |    |/
     |   002                  R   CONEMAUGH R                05010007-002  2182.8   149.2
     |    |
     |    |   013             S   BLACKLICK CR, S BR         05010007-013  2190.7    15.6
     |    |    |
     |    |    |   014        S   BLACKLICK CR, N BR         05010007-014  2190.7    15.6
     |    |    |/
     |    |   012             R   BLACKLICK CR               05010007-012  2175.1    51.6
     |    |    |
     |    |    |        016   S   YELLOW CR                  05010007-016  2183.4    21.8
     |    |    |       /
     |    |    |   015        R   TWO LICK CR                05010007-015  2161.6    28.6
     |    |    |/
     |    |   011             R   BLACKLICK CR               05010007-011  2154.7    88.3
     |    |/
     |   001                  R   CONEMAUGH R                05010007-001  2146.6   252.6
     |/
    011                       R   KISKIMINETAS R             05010008-011  2131.5   321.8
     |
     |   010                  S   BLACKLEGS CR               05010008-010  2143.7    13.7
     |/
    004                       R   KISKIMINETAS R             05010008-004  2130.0   347.4
     |
     |   003                  L   BEAVER RUN RES             05010008-003      .0      .0
     |    L
     |   002                  S   BEAVER RUN                 05010008-002  2124.3     6.3
     |/
    001                       R   KISKIMINETAS R             05010008-001  2118.1   368.3
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HYDROLOGIC SEGMENT PLOT LEGEND FOR FIGURE 2

CATALOGING UNIT ------------ 05010007

REACH SEGMENT -------------- 012

SURFACE HYDROLOGIC FEATURE -

CATALOGING UNIT BOUNDARY ---

Figure 1. 1) Hydrologic segment directory -- hydrologic listing for cataloging units 05010007 and 05010008; and 2) legend for Figure 2.

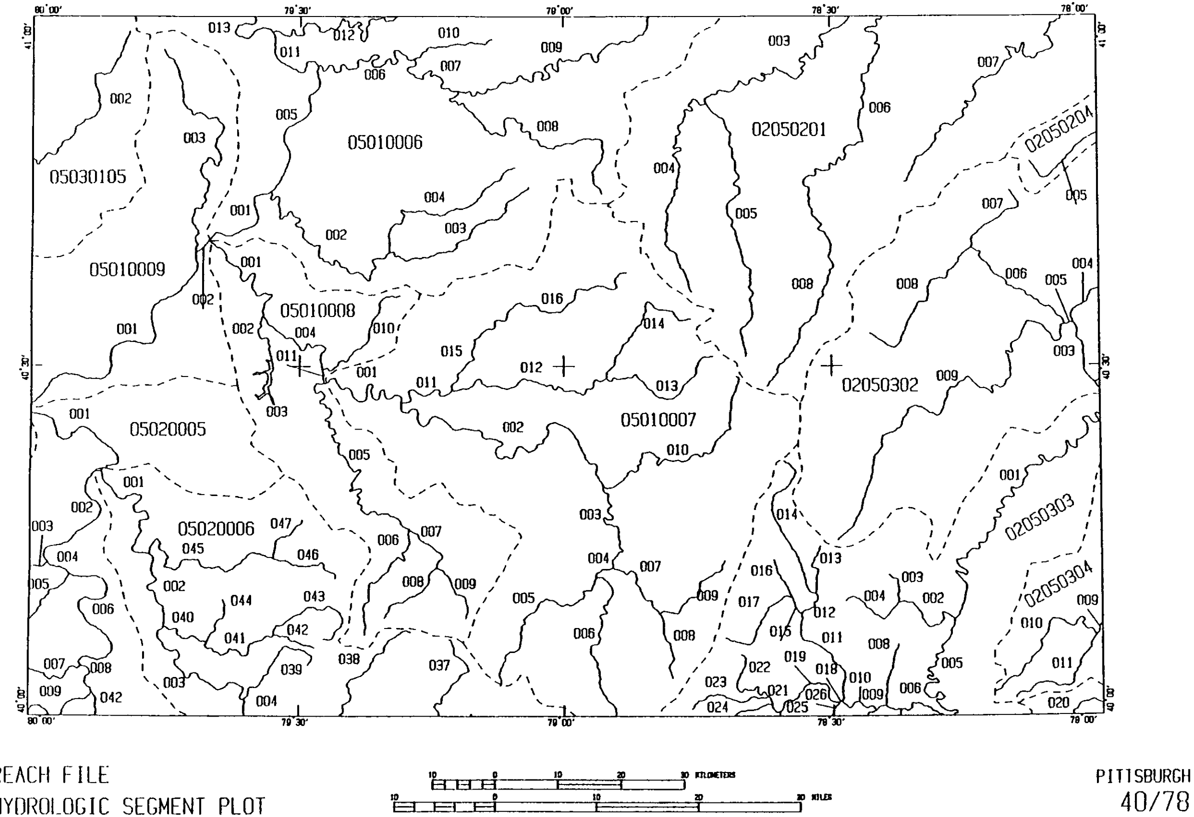

Figure 2. Hydrologic segment plot.

- Water quality monitoring stations and associated data;

- Stream characteristics such as flow, time of travel, bed material, bed slope, etc.;

- Fisheries classifications; and

- Eco-regions, (i.e., the general category of biological environment).

There are of course a wide variety of other types of data which would be appropriate for adding onto the file. Some of these data which are anticipated to be included at least for some selected geographic areas in the reasonably near future are:

- Land use and land cover data (beyond eco-region data);

- Meterological data, especially precipitation;

- Runoff quantity and characteristics data;

- Transportation (water born) data;

- Power generation statistics;

- Socio-economic data, especially population;

- Dam locations and operating rules/records; and

- Land disposal sites for waste.

APPLICATIONS

There are basically two categories of applications of this hydrologic system: those which have been implemented and those which may well be implemented within the next several years. In the first category, specific applications include:

- Strategic planning studies for industrial water supply;

- Inventory of water-related resources, especially fisheries information and water quantity data;

- Assessment of risks associated with pollutant discharges to support the development of controlling regulations;

- Water availability for power plant siting;

- Assessment of benefits derived from pollution control measures;

- Fisheries inventory;

- Studies of drinking water intake quality; and
- Studies of problem areas which may exist or develop (based on generalized input data for areas where detailed ambient monitoring data is not available).

In the area of potential applications, the list could be very long. Applications included below are those which seem to have the most likely potential for being implemented in the reasonably near future.

- Use of the system for storage and retrieval of water transportation data, especially barge traffic, and water-related statistics such as channel depth. In addition, it might be used to store and retrieve data on the types and conditions of various navigation-related structures and channel dredging projects to facilitate management or trade-offs in spending from one project to another as a function of need;
- Planning of water supply allocation and quality analysis, including the possibility for reuse of wastewater and its impact on availability and stream quality;
- Comparative studies of point and nonpoint-source pollution impact;
- Incorporation of ground water information, especially in areas of conjunctive use (with service water supplies);
- Area-specific analysis of land use impacts on water quality;
- Allocation of stream assimilative capacity;
- Analysis of new facilities siting feasibility;
- Tracking of pollutant discharge quantities with respect to applicable regulations to further simplify or maximize enforcement resources; and
- Response to emergency situations such as chemical spills, such that downstream water users could be notified of when they should shut down their intakes.

SUMMARY

Water data is required by many federal, state and local users and the creation and maintenance of a system to allow the sharing of data can improve the efficiency of all their operations by making access to data more convenient and by providing information in a form that facilitates analysis. There are various ways to provide a comprehensive water data system. One way is to establish a centralized data bank, which provides data and analytical capabilities to all users. Another possibility is to have a central core of data and many smaller systems for accessing and analyzing the data. A third possibility is to have a number of large data bases in various locations that can share data. For this to be a workable system, extreme care would have to be taken to ensure that the same data was identified identically in all subsystems. Each of the possibilities has advantages and disadvantages, so a study should be carried out to explore these and to make recommendations. Since the users of any comprehensive water data system would come from many different agencies, a decision on how such a system would be developed and maintained should be agreed to by all participating groups.

The technology now exists to provide a comprehensive national level water data system and recently some of the essential building blocks of such a system have been developed. The next logical step is to take the building blocks and develop a fully integrated water data system.