LAND ORIENTED WATER RESOURCES DATA SYSTEM IN NEW JERSEY

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INTRODUCTION

In choosing New Jersey for developing an environmentally oriented data bank system and for evaluating extreme surface flows in smaller areas, there were several considerations. It was felt that efficient environmental resources planning needs interdisciplinary data gathering concentrated in water interaction on the natural environment. To succeed in developing a model for a land-oriented water resources data bank, a region with a variety such as New Jersey seemed to be appropriate.

New Jersey is a State of contrasts in many respects. Not only is it one of the most densely populated regions of the world (400 persons per km^2 with an area of 20,295 km^2), sandwiched between two overpopulated metropolitan areas (New York City and Philadelphia), but 45% of its territory is still forest. The highly urbanized area has only two cities with a population over 100,000 inhabitants and accounts for 19% of the land. Some 27% of the region is agricultural with one of the highest per hectare dollar value for crops produced in the U.S. The transportation network, both highway and railroad, has the greatest traffic density in America. The chemical industry of New Jersey is one of the most developed in the U.S., however, its largest industry is still recreation related to the Atlantic Coast bathing beaches. The mineral industry, especially in dollar value of minerals produced per km^2 is within the top 16% of the U.S. Artificial and natural lakes, including swamps, occupy 9% of its surface and the territory of the State is bordered by fresh or salt water except in the north.[1/]

Geologically, 60% of the region is underlain by cretaceous or later sediments, which are primarily unconsolidated sands and gravels, including the area of the famous Pine Barrens Natural Park. Twenty percent of the State, the most densely populated part (over 10,000 persons per km^2) consists of triassic shale and sandstone with basalt flows or diabase intrusions. The remaining 20% of the region is underlain by precambrian crystallines and early or middle paleozoic limestones and shales.

Editor's Note: In this paper the author updates his article, "Water Resources Data Bank in New Jersey and Computations of Extreme Flows" which appeared in G. C. Vansteenkiste, Modeling and Simulation of Water Resources Systems, North Holland Publishing Company, 1975.

The climate of the area is moderate with an average rainfall of 1200 mm/year. Periodically, severe droughts occur such as in the years 1961-1966 with an average rainfall of 800 mm/year. The extreme point rainfall intensity for 24 hours reaches 250 mm value in many parts of the State with a 2-5 years frequency. The northern half is characteristic for moderately high mountains (up to 600 m). On the other hand, the southern half is flat with less than 70 m above sea level. The whole area can be characterized as one of smaller rivers with a watershed less than 250 km^2 (except Delaware, Passaic and Raritan Rivers) and with many natural and artificial lakes. The evapo-transpiration and interception average 450-55- mm from the annual precipitation. The ground water availability indicator has a value from 0 to 450 mm yearly, depending on the permeability and storage capacity of the geological formations in accordance with the yearly precipitation.[2/]

Finally, the last but never the least reason in selecting the area for developing the data bank was the fine cooperation of the N.J. Bureau of Geology and Topography with the Columbia University Seminars on Water Resources by making available over 90,000 well records and other valuable land use, demographic, geologic and surface-flow data, and by materially supporting the whole project. Furthermore, the N.J. Department of Community Affairs helped to develop the program as it will be described in "The Technique of the Data Bank."

BASIC PHILOSOPHY IN DATA COLLECTING

Environmental data collecting reflects the interaction of water on the natural environment. The inventory of natural resources is gathered from the viewpoint of their utilization by man. Since water and its quantity and quality are of utmost importance to life, the data bank is water resources oriented. It should give basic information about water quantity and quality in connection with surface streams including extreme values and ground water storage capacity based on permeability of the geologic subsurface. A climatic description of the area as primary source for water is also needed. Inasmuch as land use development is the source of demand for water, both for consumption and for treatment, it is necessary to identify current water distribution, sewage systems, treatment and polluting activities (point and area pollution). As additional information, an inventory of other natural resources -- including geologic survey, land use, geographic description, together with areas utilized for transportation, historic sites and public spaces -- is essential.

Man being in the center of any evaluation of the environment, updated demographic data are also an important part of the data bank. Demographic information, based on the latest census, gives area density, concentration of the population within each community, and each community boundary.

Finally, data collecting and its importance is governed not only by demographic and water resources information, but also by real estate values in land use. Taxation is an excellent indicator for defining the grade of importance of the area in question. Therefore, data from tax maps and locally maintained information, after being evaluated and computerized, should also be incorporated as part of the data bank.[3/] Tax considerations lead to the conclusion that the smallest land use unit for the data bank may cover 3 hectares in settled areas and 12 hectares outside the community. Later, it was decided that 4 hectares (10 acres) should be the smallest cell of information, using 1:63 360 scale basic topographic maps for graphical consideration.

The itemized information of the data bank may be stored by computer, by MTST (magnetic tape/selectric typewriter), or by whichever method best fits the character of the gathered data. The advantages and disadvantages in the case of the New Jersey data bank will be discussed later.

AVAILABLE WATER AND EXTREME SURFACE FLOW VALUES

The most important part of an environmentally oriented data bank is the water resources inventory and the computation of the available water with its average and extreme values, including the ground water capacity of the area.

The various sophisticated methods such as those of unit hydrographs, flood frequency, log Pearson Type III curves, etc., give excellent values for larger areas. It is generally accepted that the available data can be interpreted with a workable accuracy only for a time no longer than twice that of the period of observation. This means that for computation of 100 year extreme flow it is necessary to have at least 50 year observations, which may be available for larger rivers in many regions but almost non-existent for smaller streams. The need for data on peak and lowest flow occurs at random and in emergency conditions; therefore, there are no collected data nor is there time to collect data for longer periods.[4/] Since these methods are based on probability, the curves at their lowest and peak value are less reliable. Extending the curves and forecast extreme values for periods twice as long as the observation can give already a ±20-30% error. Further extension of any forecast makes the computations highly unreliable as estimates in regional planning. On the other hand, regardless of the size of the watershed, these methods give excellent average flow values for streams for which there is a shorter observation period or no data, but where conditions are similar to those of known and recorded watersheds. Analogous difficulties can occur with surface flow formulas using too many parameters. In general, they are based on probability computations and so the errors and deviations accumulate.

Despite these shortcomings, it can be efficiently evaluated and utilized with the help of local geologic survey and meteorologic conditions data, establishing correlation and similarities between permeability of the geologic subsurface and extreme values of the meteorologic records on one side, and the extreme flows from smaller watersheds with an area of less than 250 km^2 on the other side. For watersheds over 250 km^2 in area, the geologic and meteorologic conditions have less effect on extreme flows except in regions, such as certain areas of Australia, Midwestern United States, Soviet Union, etc., where greater uniformity of these factors prevail.

The approach in New Jersey utilized over 90,000 well records and 101 selected stream gaging station statistics gathered in the period 1945-1974 for the wells and 1882-1974 for the streams. Furthermore, historical flood data and point rainfall intensity observations for the period 1825-1882 were also taken into consideration.

The developed formula of peak runoff has the following pattern:[6/]

$$Q = (P_1.P_2).(i_1.i_2).A^{-e}.(C_v.C_e)$$

where

Q = peak runoff in m^3/sec. km^2
C = coefficient which varies from 0.5 to 147 according to geologic and climatologic conditions (coefficients for vegetative cover and concentration of the watershed not included)
A = area of watershed in km^2
C = configuration of terrain (geographic region and slope characteristic): 0.32 for plains up to 0.5 for Alpine type mountains
P_1 = permeability factor of the soil and of the geologic subsurface with a value from 1.0 to 18.5
P_2 = urbanization factor, from 1.0 to 14.0, in accordance with the impervious land use and permeability of the geologic subsurface
i_1 = 24 hrs. point rainfall intensity, from 0.5 to 2.0 (0.5 for 35 mm/day; 1.0 for 125 mm/day; 2.0 for 250 mm/day)
i_2 = storm characteristics, from 1.0 to 4.1 (depending on the size and pattern of the extreme storms and on the wind velocity)
C_v = coefficient of vegetative cover, from 0.95 to 1.05 (from 40% to 70% watershed area covered by forest)
C_c = concentration coefficient, from 0.90 to 1.05 (0.90 for elongated shape or at least 1.5; 0.95 for horseshoe-shaped and 1.05 for fan-shaped watersheds)

For lowest runoff (50 years?) a similar formula based on the 1961-1966 drought in New Jersey was developed as follows:

$$Q = C.A^{-e}$$

where

Q = lowest runoff (50 years?) value in 1/sec. km^2
C = coefficient depending on the geological subsurface from 0 to 5.75
e = 0.065 [7/]

The validity of this approach was confirmed by observation for watersheds up to 100 km^2 in area. If the catch basins have an area of over 100 km^2, this computation method is not recommended because of a complexity of factors influencing the lowest flow.[8/]

Based on the above principles, the surface runoff extreme values were computed and the results, organized by hydrogeologic regions, were put in the data bank with a value of an area of one square mile. As a by-product of this method, the ground water capacity of the various hydrogeologic areas was also established.

TECHNIQUE OF THE DATA BANK

Based on the outlined principles, the Bureau of the Statewide Planning of the N.J. Department of Community Affairs, and the Bureau of Geology and Topography of the N.J. Department of Environmental Protection, with the help of the Columbia University Seminars on Pollution and Water Resources, developed a data bank system in two general parts; data were recorded from many sources and files.

The information system was originally conceived for the purpose of developing a system capable of continuous revision which would permit the quick assembly of data relative to land use planning. With the cooperation and assistance of the Department of Community Affairs and the Bureau of Geology and Topography, there has been developed a system of land use, regional, geologic, geographic, and environmental maps and fact sheets covering the entire State of New Jersey. The aspects of the system consist of four group items:

The first part:

- Computerized land use data based on real estate values (because of insufficient funds not yet available)

The second part:
(in operation)

- Atlas Sheet Descriptions - Bulletin #74, Geologic and Geographic Factors and References - N.J. Information System
- Block Descriptions - An MTST (magnetic tape/selectric typewriter) printout of 16 environmental factors specifically identified with the above maps
- Block Maps - A series of maps covering about 88 km^2 (34 square miles) each or 6' latitude and longitude based on the rectangular coordinates in use by many agencies for filing purposes since 1890
- Geodetic monuments, aerial photo coverage, map collection since 1855, and publications of the Bureau of Geology and Topography

Real estate values, detailed land use and similar data are assembled from tax maps and from information maintained locally or by the appropriate County Board of Taxation assisted by the Bureau of Local Property Tax, Department of Treasury. This information is computerized by the Bureau of Statewide Planning, Department of Community Affairs, which uses the State Plane Coordinate System for the location of the centroid of properties. The Plane Coordinate System is a legally accepted system for designating property corners with $\underline{x}$ and $\underline{y}$ values in feet. The origin is a point ESE of Cape May at 74° 40 min. West Longitude and 38° 50 min. North Latitude with $\underline{x}$ = 1 000 000 and $\underline{y}$ = 0.

This coordinate system is shown on the Federal USGS 7.5 min., Quadrangle Maps. Origin was selected for easy handling and to always have positive values.

The part of the system covering physical parameters of the environment such as geology, topography, drainage basins, water and other resources, together with the specific types of land use such as historic sites or sanitary landfills, is based on the long standing Rectangular Coordinate System. The (17) State Atlas Sheets are the base for the system with the map number being the first two digits of a seven-digit number. There is a uniform rectangular grid for each Atlas Sheet consisting of (25) blocks, most of which are 6 min. of latitude by 6 min. of longitude. Each full block (designated by the third and fourth digits) covers an area of approximately 88.0 km^2 (34 square miles) and only 228 maps, based on the block, are required to cover the entire State. Each block is divided into (9) rectangles of 2 min. of latitude and longitude (the fifth digit) which can then be again divided in a similar manner into (9) squares (6th digit); and finally into (9) units each of which is 30 acres or 0.12 km^2 (7th digit).

A computer program successfully developed which will permit the regional data of the Rectangular Coordinate System to be further subdivided, by using additional digits, into a unit of approximately 0.013 km^2 (3.3 acres), or by further subdivision to 0.0014 km^2 (0.36 acres). The Department of Community Affairs found it most convenient when using tax data to determine the <u>x</u> and <u>y</u> coordinates of the centroid of the tax units for use in a computer program. Conversion from <u>x</u> and <u>y</u> coordinates to the appropriate block number under the Rectangular Coordinate System, or vice versa, is easily done on the computer. Thus the two systems of data presentation are compatible.

Furthermore, there have been prepared from the tax data base so-called "Quick-maps" of land use with a 7-acre unit. This is the smallest area that can be shown with a distinct symbol under the present program developed for Passaic Township, which covers 32.4 km^2 (12.5 sq. mi.) and has some 6,000 tax parcels. Identification of locations using the Plane Coordinate System is, of course, easy because it is a Cartesian Coordinate System referenced on the USGS Maps of New Jersey. The development of larger grids is easily accomplished.

The Rectangular Coordinate System, used for the State Atlas Sheets, is confusing at first but, as indicated above, can be used to locate a specific area by extending the normal 7-digit reference number to the 8th and 9th digits. For the purpose of the data bank, however, only 4 digits are required to produce maps covering the 88 km^2 (34 square mile) area of the block. To assist in converting to other coordinate systems, each block map has the latitude and longitude and the <u>x</u> and <u>y</u> coordinates given for the lower left-hand corner of the block. Since the New Jersey State Atlas Sheets are based on a scale of 1 mile to the inch (1:63360), a mechanic's rule can be used to measure distances in feet to within about 61 m (200 feet) of the actual location on the ground.

The data bank, based on the State Atlas Sheets, has developed into four parts:

- General information about the Atlas Sheet area given as a descriptive tabulation with a uniform format (printed in book form) containing such information as extreme surface flow, ground water capacity and recommended lot size for domestic well and septic tank, etc.

- Block descriptive material including some of the specific items from the Atlas Sheet summary, but giving data which apply specifically to the 88 km^2 (34 square mile) area of the block (stored on tape, each block individually)
- Block maps (the series, which is to be expanded to between ten and twenty multi-parameter maps as data becomes available, consists of six maps: population, water supply, sewage and sanitary landfills, drainage basins, land use, and geology with well records -- on microfilm)
- Geodetic monuments' description, aerial photo coverage 1:24 000 from 1961 and 1972, together with map collections covering the entire State from 1855 to 1975 (in easily reproducible form on polyester film, photo, overlay map or map form)

The system is supplemented by base maps and Atlas Sheet overlays. It is possible to revise or enlarge the amount of material provided for the Atlas Sheet or blocks by transferring the existing tape information and the additions or corrections to a new tape. Map changes for each block can readily be accomplished by changing the microfilm in the appropriate Atlas Sheet microfilm jacket. Given the 4-digit reference of the system, maps and descriptions can normally be recovered within minutes.

There were many changes as the work progressed from the initial concept. The general information about the Atlas Sheets was originally planned for issuance through the MTST (magnetic tape/selectric typewriter) as needed. The information contained on these Atlas Sheet descriptive summaries has proved to be of such general interest that it is now proposed to print a source book of environmental parameters which will include the Atlas Sheet descriptions for all 17 sheets with key maps to show counties and municipalities described within the Atlas and the block references needed for more detailed information.

There was much discussion as to whether the block maps should show only a single environmental factor. Experimentation suggests that it would be desirable to go ahead with the four basic maps with multiple parameters on some and complete the coverage in these four areas for the entire State before going on to other equally desirable block maps.

The population map at present shows not only the municipal boundaries, the average population density for the municipality, and the percentage of the municipality in the block being considered, but also shows the main highways and urbanized areas where the population density is over 1,000 inhabitants per square mile (or 2.59 km^2).

The water supply map shows service areas for water by company with the political boundaries of the municipalities. Also indicated are the major water supply lines and surface water intake points. Because of clutter on this map, the major water wells have been placed on the geologic map.

Sewage maps indicate the public and semi-public sewage systems and sanitary landfills and show the areas served by each sewage company, their main trunk lines, sewage treatment plants including capacity, and used or abandoned sanitary landfill areas.

The drainage basin maps show the actual streams as shown on the Atlas Sheets or the so-called County Stream Maps. The drainage divides, as shown on the Drainage Basin Map of New Jersey overlay, are also indicated. Flood-plain delineation, stream flow information, points of diversion, and points of potential pollution may be indicated on these maps in the future.

Land use maps are based on 1972 aerial photo (1:24 000) and 1973 EROS Image Space Photos (altitude 250 miles) evaluation, and their classification complies with USGS Circular 671 (1972): B. Anderson, "A Land Use Classification System for Use with Remote-Sensor Data" and with USGS Land Use Data Analysis (LUDA).

The geologic map has been assembled from the most recent data and may, from time to time, be modified to give additional information. The characteristic industrial public supply and other wells from 90,000 well records assembled in 1945-1973, are shown; from these logs geologic cross-sections may be constructed.

The State Archaeological Society is ready for the preparation of maps showing archaeological and historical sites, including for the former, sites which have not yet been published. A method of flagging the block map, so that such an unpublished archaeological site will not be endangered by construction, has been developed. It may be that this map will include other items connected with the general interest in our heritage and history.

A transportation routes block map has been investigated and samples prepared. Other areas would include public utilities, airport locations, and Federal, State, county and municipally owned lands for recreation or other purposes. A map series prepared for any particular activity will require only 228 block maps. Where there is only a limited number of blocks needed to show sites for a particular activity, reference to the appropriate special block maps could be included within the Atlas Sheet descriptive material or prepared as a special listing.

It is believed that the work completed so far indicates that the data bank is compatible with other land use or water resources data systems, makes the maximum use of available files in various State agencies, is flexible enough to permit retrieval from many different points of view, and is capable of quick and easy expansion whenever the need arises. The material prepared for the data bank is a necessary first step for any computer program which may be developed for this type of information especially when it includes a larger than 20,000 sq. mi. (or 50,000 km^2) area. Similar considerations must be given in case that a wealth of point-type information is available.

DESCRIPTION OF THE LAND ORIENTED RESOURCES DATA SYSTEM IN NEW JERSEY (LOIS-LAND ORIENTED INFORMATION SYSTEM AND LORD-LAND ORIENTED REFERENCE DATA)

The material presented here is mainly part of the Water Resources and Land Oriented Information System which is based on the New Jersey Bureau of Geology and Topography Topographic Atlas Sheet Rectangular Coordinated System. A diagram showing the use of the system is included. The maps and narrative data are filed by the Atlas Sheet and block number, or the first four digits of the Rectangular Coordinate (the first two steps in the diagram). The total area of an Atlas Sheet is about 800 square miles (2,072 km^2); of the reference block about 34 square miles (88 km^2); of a unit (7th digit designation) about 1/4 x 3/16 of a mile or about 30 acres (0.12 km^2). Each full block covers six minutes of latitude and longitude as compares to the 7.5 minute USGS Topographic Quadrangle Map. For convenience, the two minute wide strip, the right edge of each Atlas Sheet (05, 15, etc.), is included with the blocks immediately to the left (04, 14, etc.).

As of September 1975 there are six available maps for blocks of sheets 21 through 37 microfilm printouts.

The six maps provided are Geology, Drainage, Water Supply, Sewage and Sanitary Landfills, Land Use and Population. On the Geologic Map the location of major industrial water wells is indicated. On the lower right of the Drainage Maps you will find the name of the 7.5 minute USGS Quadrangle Map or maps which cover the area of the block. The Water Supply Map shows municipal boundaries for orientation, the service area for water supply, water intakes, major water distribution mains, reservoirs. The Sewage and Sanitary Landfill Map indicates the sewage service areas, sewage treatment plants, main trunk lines and sanitary landfills. The Land Use Map gives classifications for various land uses. The Population Map shows the average population density of the municipality and the percent of the municipality shown within the block with urbanized areas (1,000 inhabitants per square mile) and main highways.

Narrative data on the MTST printouts are provided: a) for items which pertain to or explain conditions within the entire Atlas Sheet, and b) information about items which are found on a particular rectangular coordinate block.

A legend sheet indicating the symbols and significance of terms used on the six maps is available. For the Geologic Map, depending on the complexity of the geology of the area, there are one or two pages of legend explaining the geologic symbols and rock formation designation letters.

A complete sample of the data bank pertaining to Phillipsburg Town (block #24-21) is provided below. The following pages show examples of the six maps, as well as a map of atlas sheets of New Jersey, a diagram showing the use of the rectangular coordinate system, and community boundries of Atlas Sheet #24.

BLOCK #24-21

A. Bloomsbury, Easton

B. Delaware River-Lopatcong Creek, Musconetcong, Pohatcong

C. 1. Phillipsburg - Non-recording temperature and precipitation gauges

2.

Map No.	Location	Period of Record
153	Delaware River at Easton, Pa.	1967-
155	Lopatcong Creek at Lower Harmony	7/9/45
156	Lopatcong Creek near Stewartsville	7/9/45
157	Merrill Brook at Ingersoll-Rand Dam, Phillipsburg	7/9/45

3.	153	Delaware River at Easton, Pa.	1947-1951,1957-1960, 1963-1964, 1967-
	346	Delaware River, Phillipsburg-Easton Bridge (free bridge)	1965-
	351	Lopatcong Creek at Phillipsburg (Alt. 22 Bridge)	1964-

Water Quality Standards: (explained in Atlas Sheet description) FW2

D. Kittatinny Limestone (Єok), Jacksonburg Limestone-"Cement Rock" member (Ojr), Epler Formation (Oe), Rickenback Limestone (Or), Allentown Formation (Єa), Leithsville Formation (Єl)

E. 1. Physiographic Province: Appalachian Valley and Ridge
Subdivision: Kittatinny Valley
Major Topographic Features: Kittatinny Valley
Elevations (ft. above sea level): ridges 400, valleys 150
Relief (ft.): 250

Physiographic Province: New England (Reading Prong)
Subdivision: N.J. Highlands
Major Topographic Features: Scotts Mountain, Pohatcong Valley
Elevations (ft. above sea level): ridges 1100, valleys 150
Relief (ft.): 950

2. a. Normal Year: 47"
Dry Year: 35"
Wet Year: 61"

b. January: 30° F
July: 74° F

c. 226 days. Last killing frost: 4/25; first killing frost: 10/15

3. Not available as of 12/74.

F. State, County Owned Land and Major Semi-public Areas
Div. of Parks and Forestry - Delaware River Recreation and Access Areas
Lopatcong Water Company - Private Watershed
Peoples Water Company - Private Watershed

G. Water Well Records

Location	Owner	Year Drilled	Screen Setting or Depth of Casing	Total Depth	g/m Yield	Formation
24-21-172	Peoples Water Company	1966	23	65	3,000	Qed
24-21-172	"	1967	58	82	3,500	"
24-21-172	"	1967	46	66	3,000	"
24-21-173	Steckle Concrete Company	1967	128	188	75	"

. . . .

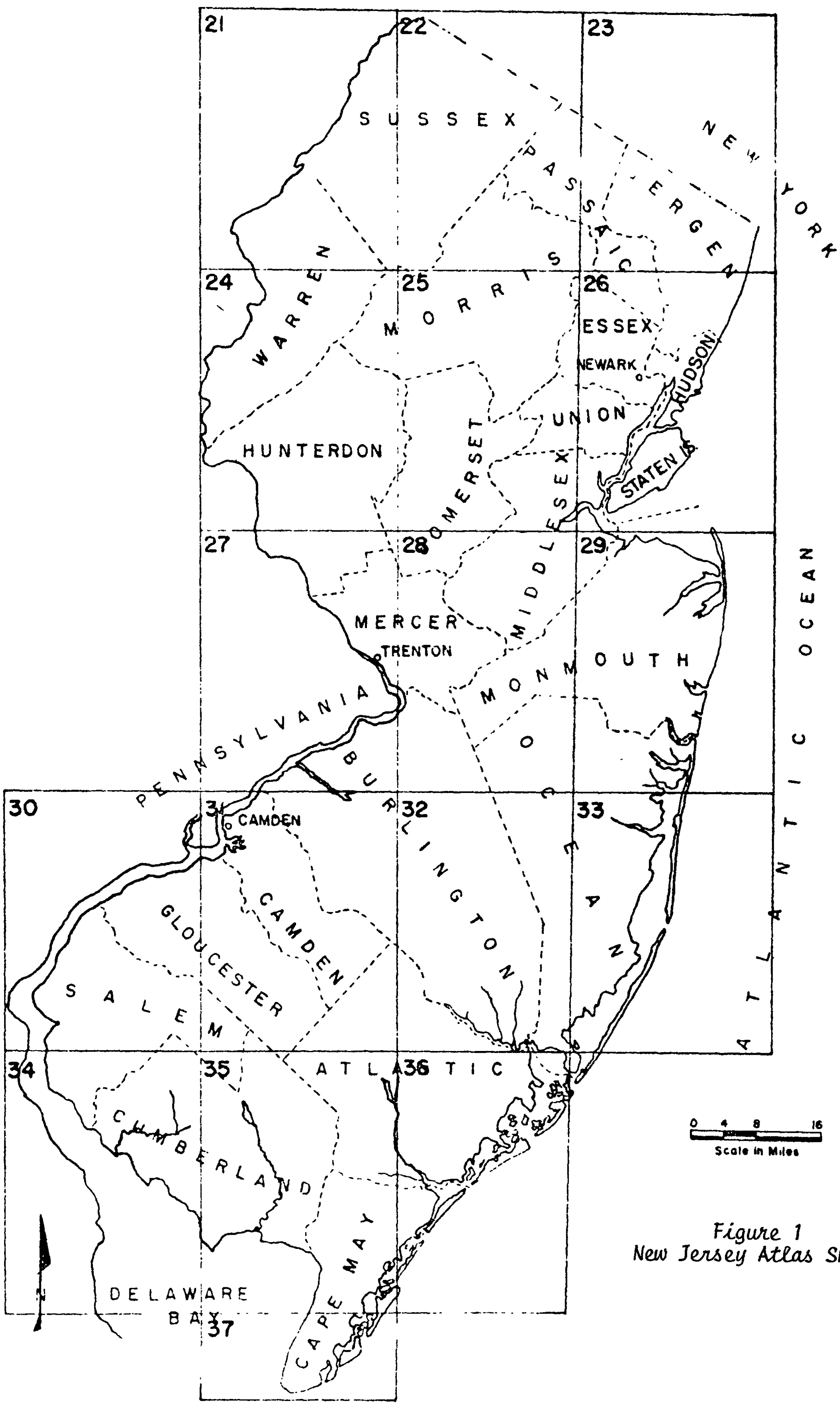


Figure 1
New Jersey Atlas Sheets

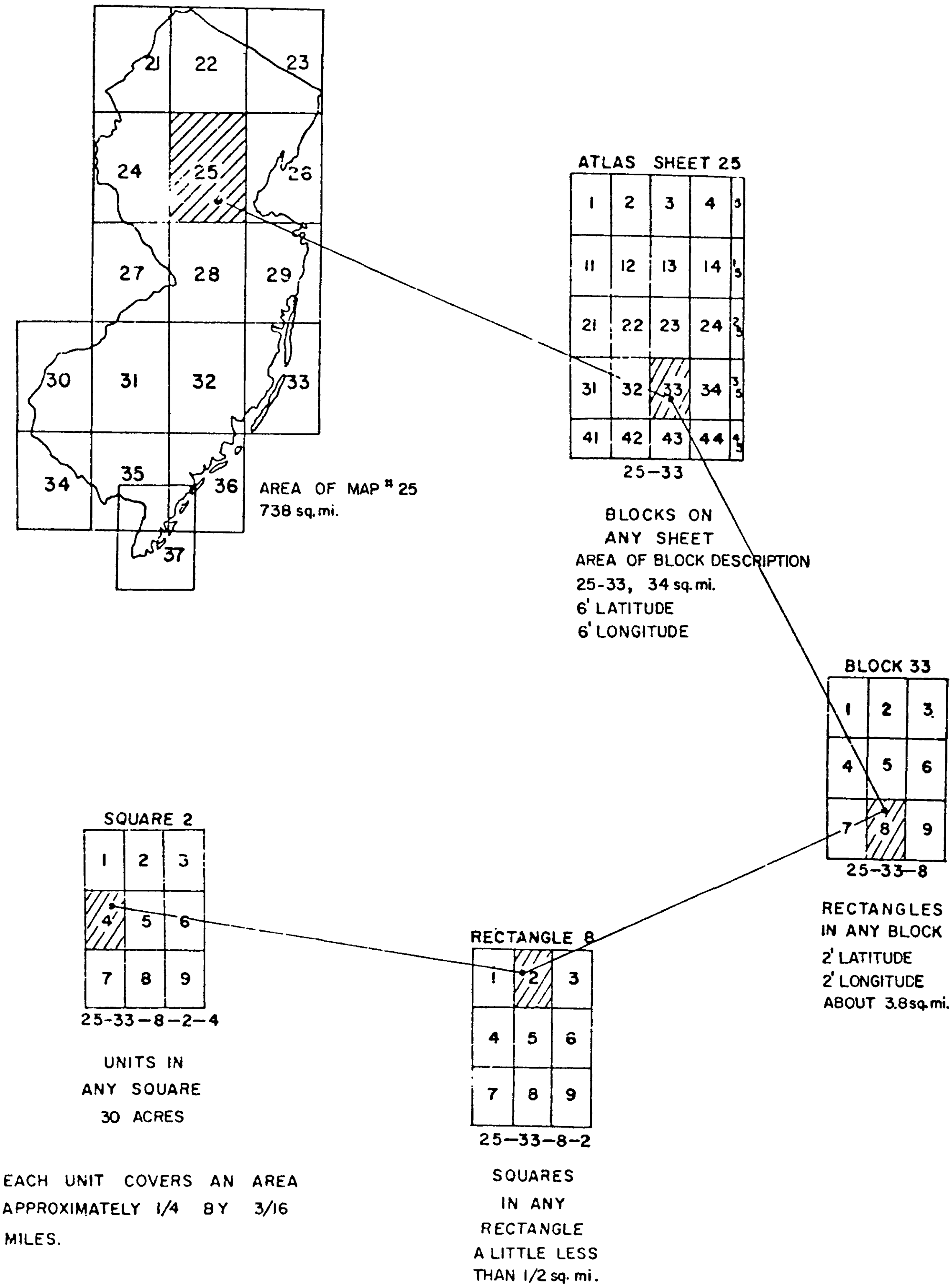


Figure 2. Diagram showing use of New Jersey rectangular coordinate system. To locate a facility at 25-33-8-2-4

ATLAS SHEET #24

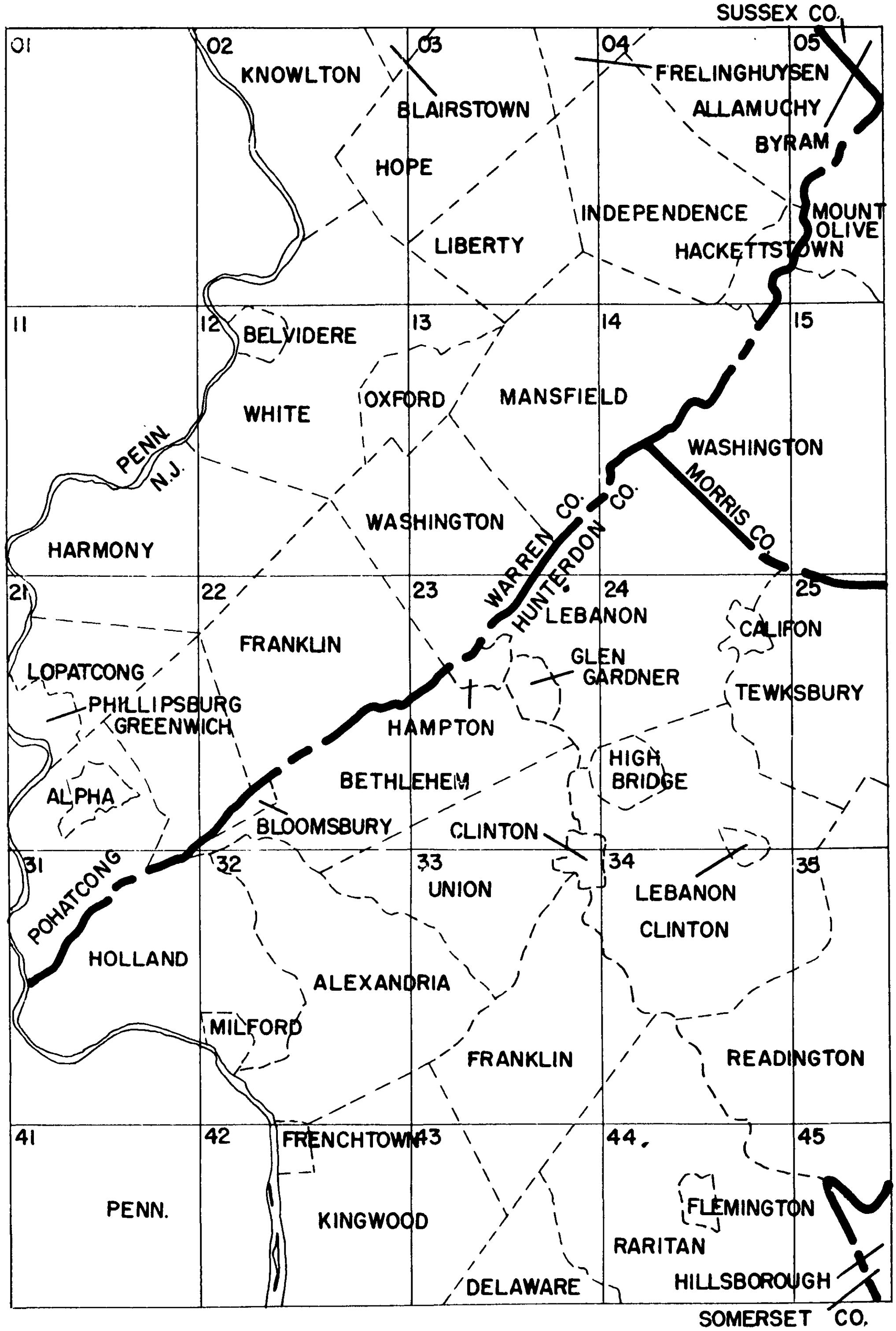
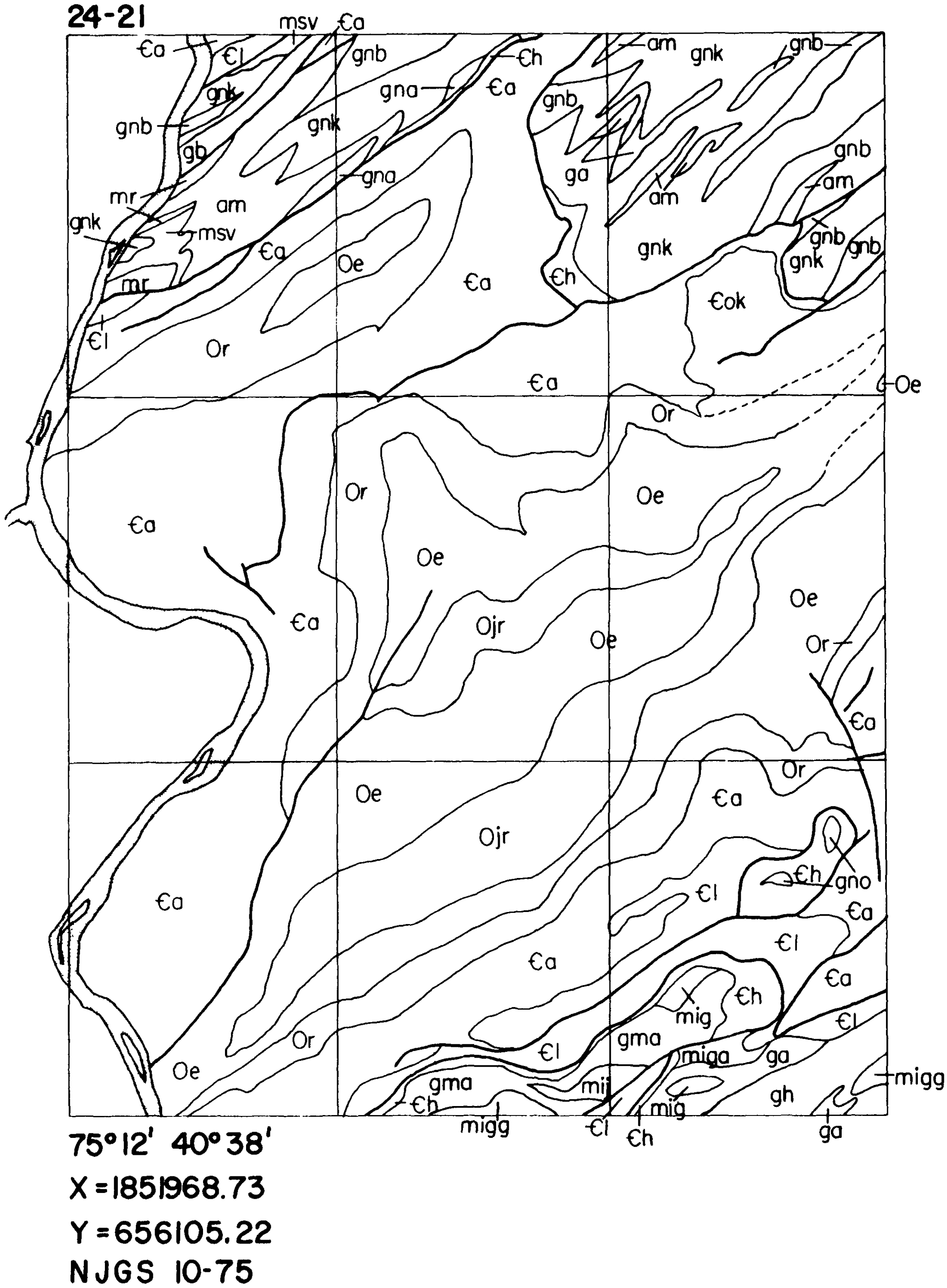


Figure 3. Community boundaries of Atlas sheet #24

Figure 4
Geological Map



<u>EDITOR'S NOTE:</u> *Due to space restrictions, a listing of map legends has not been included.*

Figure 5
Drainage Basin Map

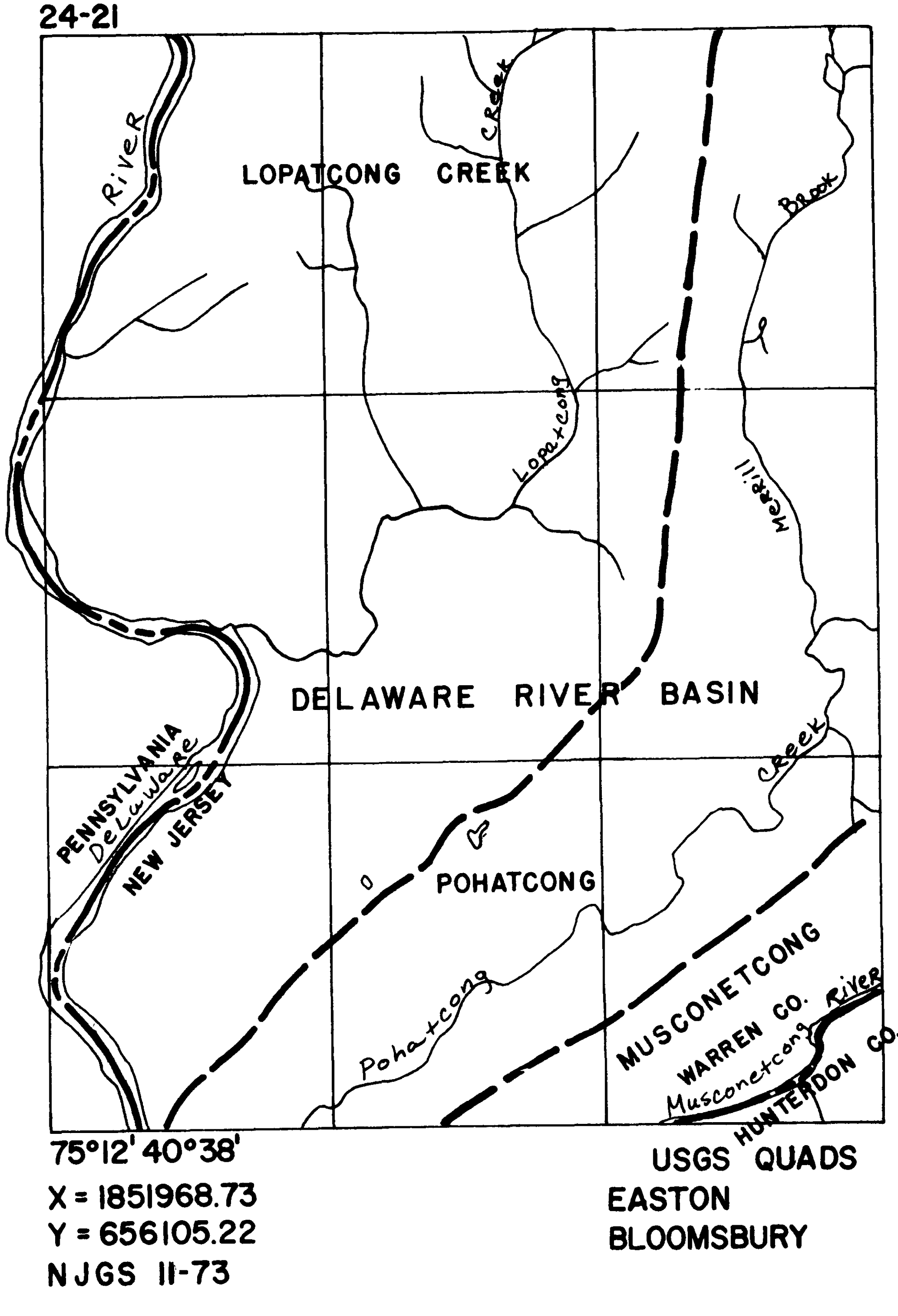


Figure 6
Water Supply Map

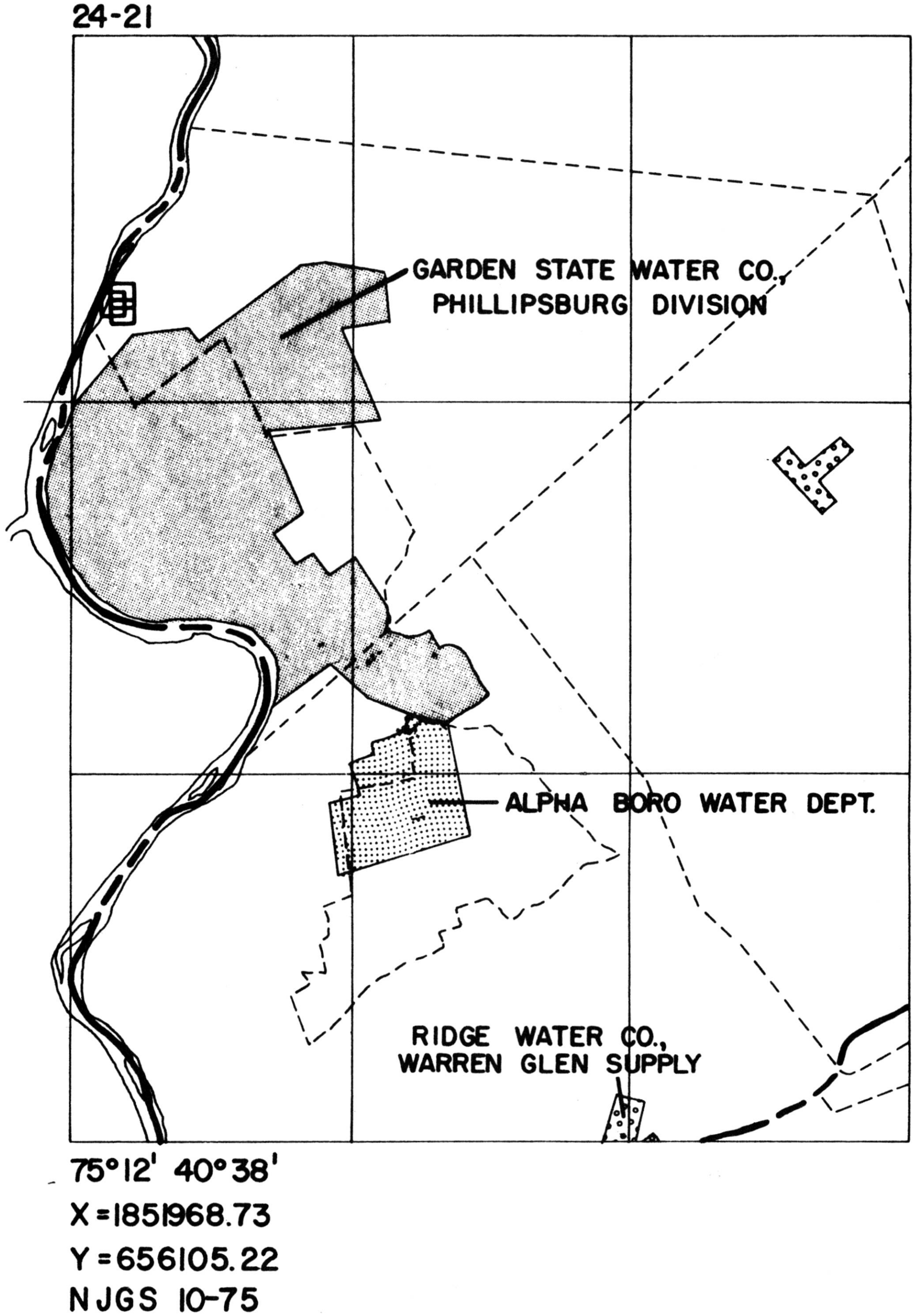
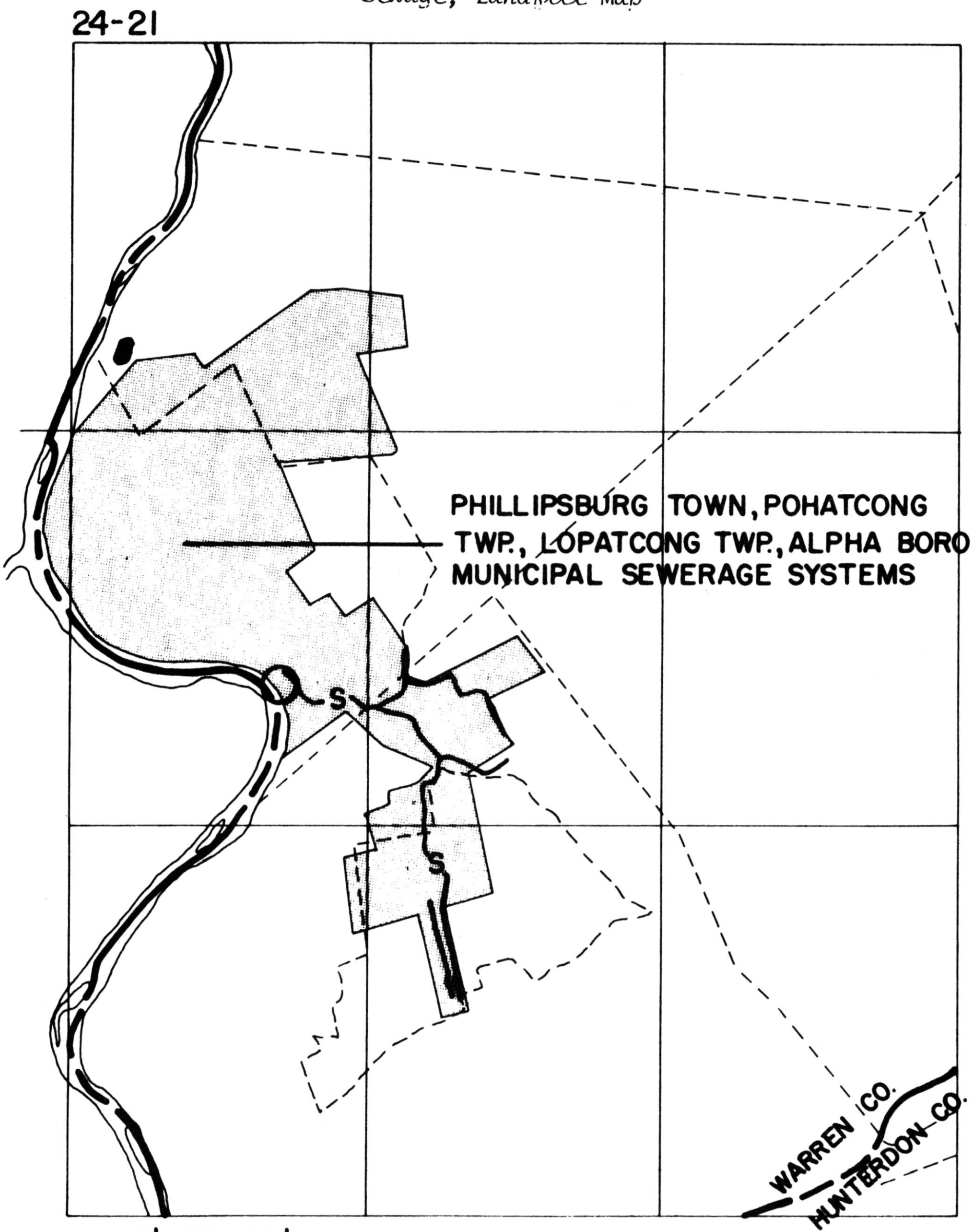


Figure 7
Sewage, Landfill Map



75°12' 40°38'
X = 1851968.73
Y = 656105.22
NJGS 10-75

○ SEWAGE TREATMENT PLANTS
2421467 3.5mgd DOMESTIC

● SANITARY LANDFILL
2421175 BAKER CHEMICAL

Figure 8
Land Use Map

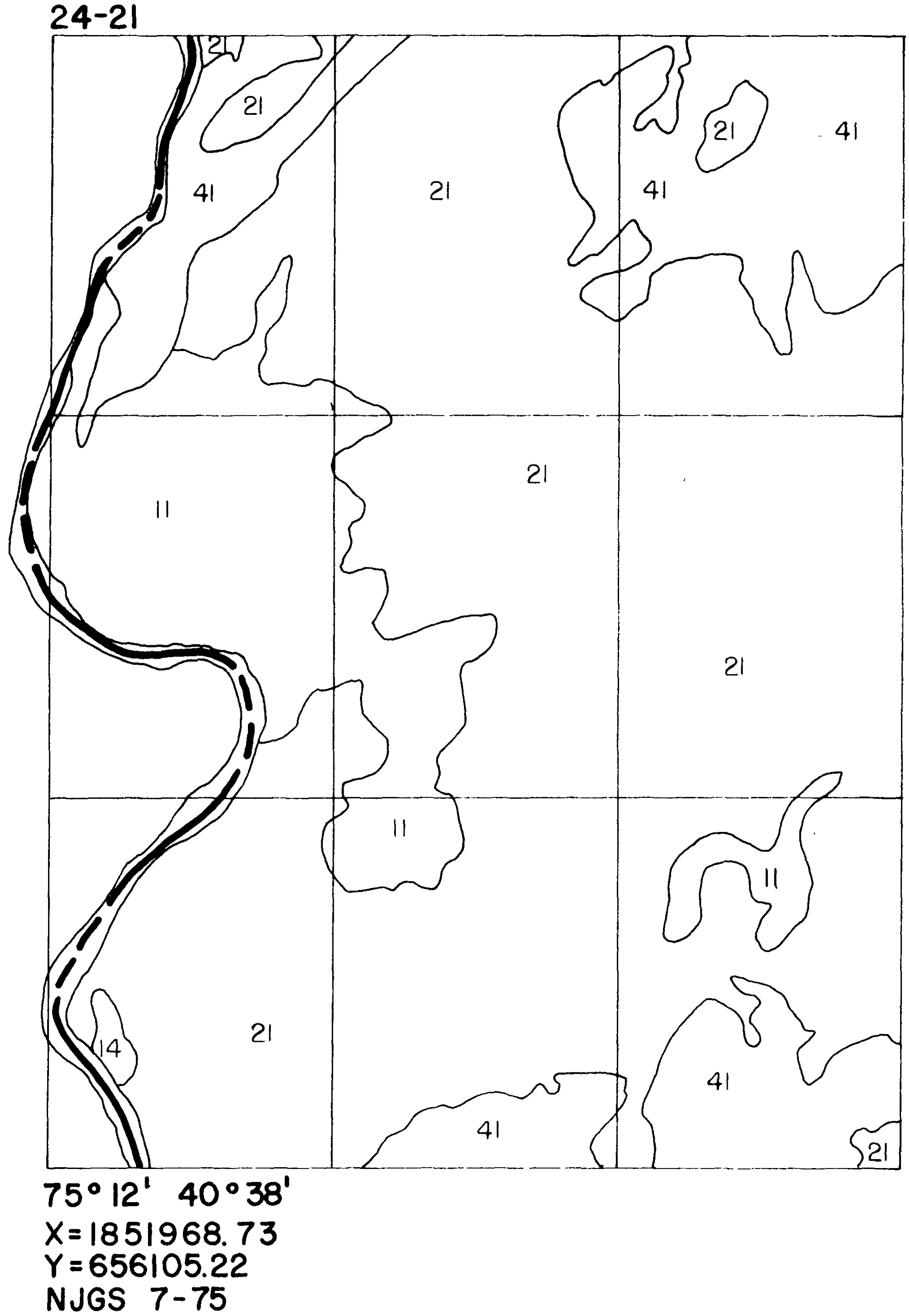
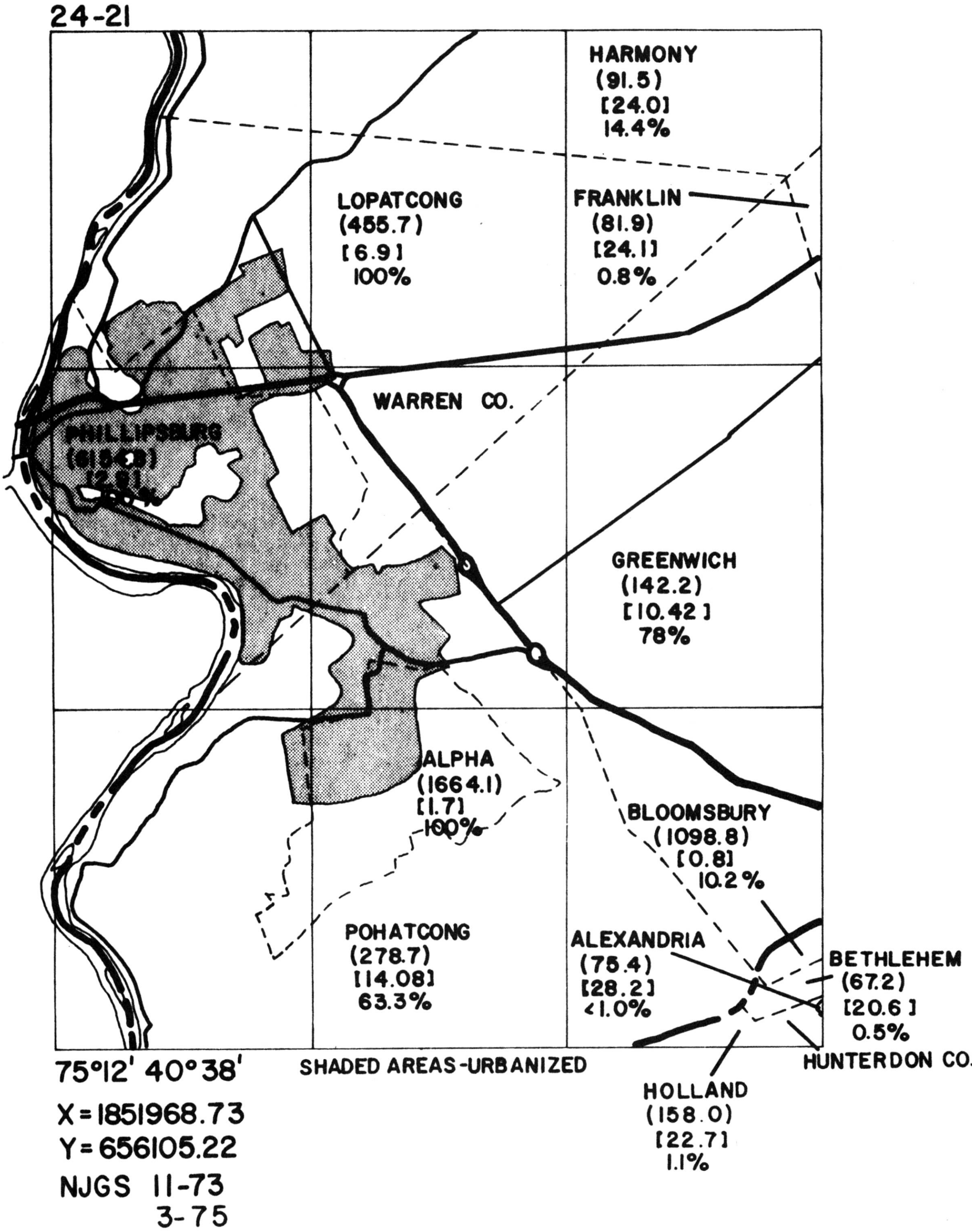


Figure 9
Population Map



BRIEF ANALYSIS OF THE USERS

The request profiles of the users of the data bank are expected to result from user query categories as follows:

- Point information: information sought by a citizen or corporation such as prospective owner or builder who is interested in a point or limited area, where he needs all information which can influence his future construction or planned use of his property
- Area information: information sought by a planner from the local, county, State or Federal level who needs all information which can affect the planning decisions
- Vertical, group information: specified governmental or research agencies or corporations interested in special group information only, such as Bureau of Water Pollution Control
- Horizontal, point or areal information, prevent or avoid: looking for information concerning a point or an area, possibly only of a certain type, due to some legal or financial problem

Any one of these user categories may involve request matching or cross-correlation of information.

STORING DATA BY TAPE, FILM AND COMPUTER, INCLUDING ITS EVALUATION

Studies were conducted as to methods of storage and retrieval at lowest cost and highest efficiency. The gathered data were classified as follows:

- Areal or map type information
- Descriptive type data including references
- Point type information or data pertaining to smaller standard size area, especially in land use, streamflow records, water quality gaging stations, etc.

The available methods could be summarized into:

- Computerized data systems
- Map type information service based on maps and microfilms
- Descriptive MTST methods

It was determined that all or most of the information in the program would have been compiled in a descriptive or map-type form before the data could be put into a computer program. In seeking information on the data required and method of storage and recovery, discussions were held with experts in computer science dealing with various computer programs including data bank. 9/ As a result of these discussions and from preliminary estimates of what would be required for New Jersey, it was found that once maps were prepared for use with a microfiche reader/printer, recovery would be quicker (about 30 seconds) than by using computer plotting devices. Furthermore, the survey revealed that regions of less than 50,000 km^2 in size could not use efficiently a computerized system unless they are part of and tied into a larger system. On the other hand, any other method such as microfilms, tape recording, etc. cannot compete with a computerized one if they embrace larger areas or have a wealth of itemized point type information.

Therefore, it was decided to have a data bank with a combined method using:

- Microfiche films and printer/reader for map-type information
- Magnetic tape/selectric typewriter's tapes for general descriptive and reference material and
- Computerized system (Fortran or similar) for land use, stream-flow record, water quality control, etc.

This combined method has the advantage of considerably cutting the cost by 94% in establishing the data bank (from an estimated $1,000,000 in 1972 to a real $60,000 in 1973/74) and the efficiency of information service for such size of area as New Jersey is better than any other non-combined system including the computerized one since it needs the least time for recovery. The disadvantage of the method is its apparent complexity. But, even with such diversity in training the necessary personnel and in purchasing the needed equipment, there could be no comparison in price including budget for continuous service and maintenance of equipment because of the still high cost of the computer at present. A further disadvantage of the combined system is a capacity limitation. Therefore, the whole data bank must be prepared in such a form that it can be converted easily into a fully computerized system. The itemized information should fit without any difficulties for computer feeding, storage and recovery in the future.

REFERENCES

1. Halasi-Kun, G. J. (1971), "Aspects hydrologiques de la pollution et des ressources en eau, dans les domaines urbains et industriels," Actes du Congres: Sciences et Techniques An 2000. Paris: Societee des Ingenieurs Civils de France.

2. Halasi-Kun, G. J. (1972), "Data Collecting on Water Resources and Computations of Maximum Flood for Smaller Watershed," International Symposium on Water Resources Planning, Vol. I (Mexico: Secretaria de Recursos Hidraulicos).

3. Halasi-Kun, G. J. (1973), "Improvement of Runoff Records in Smaller Watersheds Based on Permeability of the Geological Subsurface," Symposium on the Design of Water Resources Projects with Inadequate Data, Vol. I (Madrid: UNESCO-WMO-IAHS).

4. Halasi-Kun, G. J. (1974), "Ground Water Computations in New Jersey, U.S.A.," Nordic Hydrology 5.

5. Halasi-Kun, G. J. (1975), "Ground Water Capacity and Extreme Surface Flow Values of Smaller Watersheds," Proceedings of Columbia University Seminars on Pollution and Water Resources, Vol. V (Columbia University - State of New Jersey).

6. Halasi-Kun, G. J. (1975), "Water Resources Data Bank in New Jersey and Computations of Extreme Flows" in G. C. Vansteenkiste, Modeling and Simulation of Water Resources Systems (North Holland Publishing Company).

7. Vladimirov, A. M., and Chebotarev, A. I. (1973), "Computation of Probabilistic Values of Low Flow for Ungauged Rivers," Symposium on the Design of Water Resources Projects with Inadequate Data, Vol. II (Madrid: UNESCO-WMO-IAHS).

8. Widmer, K. (1964), The Geology and Geography of New Jersey (Princeton: Van Nostrand).

9. Enviro Control, Inc. (1972), The Development of A Procedure for Acquiring and Disseminating Information on Water Use, Vol. I-II (Washington, D.C.).

10. Widmer, K. and Halasi-Kun, G. J. (1974), Land Oriented Reference Data System, Bulletin 74, New Jersey Geological Survey.

NOTES

1/See also Kemble Widmer, The Geology and Geography of New Jersey, Princeton: Van Nostrand, 1964.

2/George J. Halasi-Kun, "Aspects Hydrologiques de la pollution et des ressources en eau, dans les domaines urbains et industriels," Actes du Congres: Sciences et Techniques An 2000. Paris: SCEF, 1971.

3/For better orientation and recording, information about the geodetic survey network monuments was added (13,600 monuments).

4/George J. Halasi-Kun, "Data Collecting on Water Resources and Computations of Maximum Flood for Smaller Watershed," International Symposium on Water Resources Planning, Vol. I, Mexico, 1972.

5/George J. Halasi-Kun, "Improvement of Runoff Records in Smaller Watersheds Based on Permeability of the Geological Subsurface," Symposium on the Design of Water Resources Projects with Inadequate Data, Vol. I, Madrid: UNESCO-WMO-IAHS, 1973.

6/George J. Halasi-Kun, "Ground Water Computations in New Jersey, USA," Nordic Hydrology, 1, 1974.

7/George J. Halasi-Kun, "Ground Water Capacity and Extreme Surface Flow Values of Smaller Watersheds," Proceedings of Columbia University Seminars on Pollution and Water Resources, Vol. V, 1974 (in print).

8/A.M. Vladimirov, A.I. Chebotarev, "Computation of Probabilistic Values of Low Flow for Ungauged Rivers," Symposium on the Design of Water Resources Projects with Inadequate Data, Vol. II, Madrid: UNESCO-WMO-IAHS, 1973.

9/See also: Enviro Control, Inc., The Development of a Procedure for Acquiring and Disseminating Information on Water Use, Vol. I-II, Washington, D.C., 1972.