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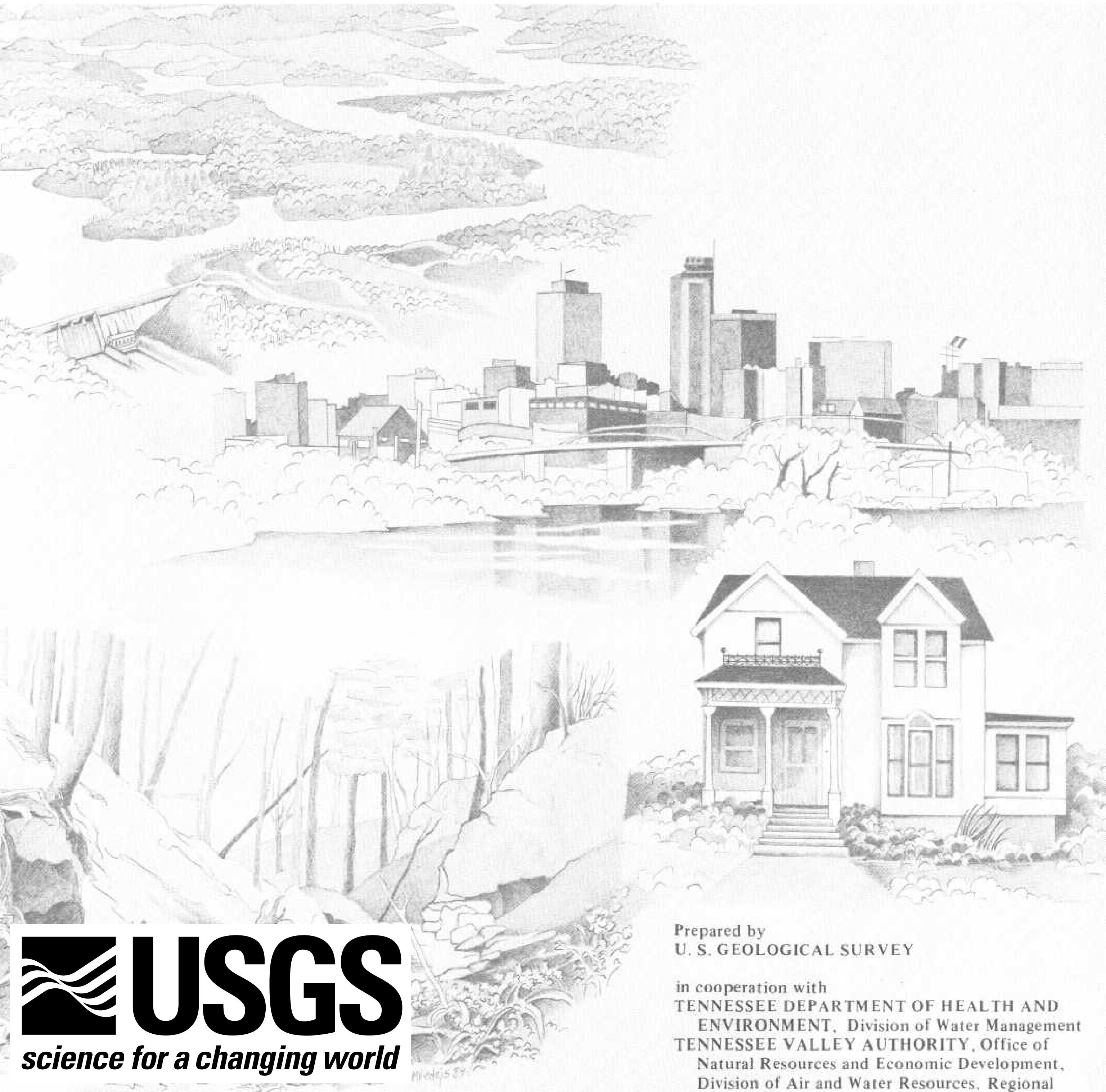
DROUGHT-RELATED IMPACTS ON MUNICIPAL AND MAJOR SELF- SUPPLIED INDUSTRIAL WATER WITHDRAWALS IN TENNESSEE--PART B



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Prepared by
U. S. GEOLOGICAL SURVEY

in cooperation with
TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT, Division of Water Management
TENNESSEE VALLEY AUTHORITY, Office of Natural Resources and Economic Development, Division of Air and Water Resources, Regional

the year, average rainfall ranges from 4.05 to 5.72 inches with March having the greatest rainfall. More specifically, in the Tennessee River Western Valley basin, analysis of long-term precipitation records for the period 1941 to 1970 for selected rainfall stations at Springville, Perryville, and Pickwick Landing Dam indicates that the driest months of the year normally are August, September, and October with precipitation ranging from 2.42 to 3.61 inches. During the rest of the year, precipitation ranges from 3.73 to 5.60 inches. January, February, and March are the wettest months.

Average annual runoff in this basin usually ranges from 19 to 24 inches as one moves from north to south. Average discharge data for selected hydrologic data stations in the Tennessee River Western Valley River basin are contained in table 51. Most of this runoff occurs during the winter and spring months.

Major Reservoirs

Major reservoirs located in the Tennessee River Western Valley basin and their storage in acre-feet at normal minimum pool are Kentucky Reservoir (2,121,000) and Pickwick Reservoir (688,000). Note, major parts of both of these reservoirs are located in the States of Kentucky and Alabama, respectively. Wilson Reservoir (587,000) which is located on the Tennessee River in north Alabama also has a significant impact on streamflow in the Tennessee River above Pickwick Landing Dam. Detailed information describing the location and operation pattern of Pickwick Landing and Wilson Reservoirs follows:

Pickwick Reservoir

Location and drainage area.--Pickwick Reservoir is formed by Pickwick Landing Dam which is located on the Tennessee River at river mile 206.7 in Hardin County. Pickwick Landing Dam controls 32,820 mi^2 of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Through the reference period, the minimum daily average discharge from Pickwick Landing Dam ranged from a low of about 5,200 ft^3/s (3,360 Mgal/d) in 1976 to a high of about 26,900 ft^3/s (17,386 Mgal/d) in 1979. The average, 1-day minimum discharge during the reference period was about 13,186 ft^3/s (8,522 Mgal/d).

Average number of days of zero flow.--None.

Existing agreements regarding reservoir releases.--Pickwick Landing Dam is operated to provide adequate releases to maintain a minimum tailwater elevation of 355 feet above sea level for navigation purposes. This requires substantial releases, particularly when Kentucky Reservoir is drawn down to its winter pool level elevation of 354 feet above sea level.

Wilson Reservoir

Location and drainage area.--Wilson Reservoir is formed by Wilson Dam which is located on the Tennessee River at river mile 259.4 in Colbert and Lauderdale Counties in North Alabama. Wilson Dam controls 30,750 mi^2 of drainage area.

Table 51.--Average discharge data for selected hydrologic data stations, Tennessee River Western Valley basin

Station name and location (county)	River mile	Drainage area (square miles)	Period of record (years)	Average discharge: Cubic feet per second	Average discharge: Inches per year	Average discharge: Cubic feet per second per square mile
Tennessee River at Savannah (Hardin).	189.9	33,140	50	55,311	-	1.67
Trace Creek upstream from Denver (Humphreys).	4.2	31.9	17	54.2	23.07	1.70
Big Sandy River at Bruceton (Carroll).	31.6	205	51	295	19.54	1.44

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Wilson Dam during the reference period ranged from a low of about 100 ft^3/s (64.6 Mgal/d) in 1969 to a high of about 20,400 ft^3/s (13,184.9 Mgal/d) in 1979. The average, 1-day minimum discharge during the period of record was about 11,881 ft^3/s (7,678.9 Mgal/d).

Average number of days of zero flow.--None.

Existing agreements regarding reservoir releases.--None.

Kentucky Reservoir

Kentucky Reservoir is formed by Kentucky Dam which is located on the Tennessee River at river mile 22.4 in Marshall and Livingston Counties in Kentucky and controls a total of 40,200 mi^2 of drainage area. When low elevations occur on the Ohio River, TVA operates Kentucky Dam to provide a continuous minimum flow to maintain tailwater elevations of not less then 300 feet.

Ground Water

Ground-water availability in the western valley of the Tennessee River in Tennessee is difficult to assess because the valley is underlain by both consolidated and unconsolidated sediments, some rock formations vary in thickness or are absent entirely, there are abrupt changes in the composition of unconsolidated sediments from sand to clay as one moves southward, and there are changes in the character of the regolith. No other subbasin of the Tennessee River in the State exhibits this variety of differences in regard to the occurrence of ground water. Because of this fact it would be prudent to obtain geologic advice prior to any search for ground water in this area in quantities exceeding that required for domestic use. Ground water availability will be discussed on the basis of occurrence in generally defined areas.

The Highland Rim physiographic province and (or) its spurs and outlying remnants occur in all areas of the Tennessee River's western valley in Tennessee with the exception of some areas in the western part. The regolith or blanket of clay, chert blocks and fragments, siliceous silt, and some sand of this old erosion surface is commonly 100 feet or more in thickness, particularly east of the Tennessee River. Water-bearing zones capable of furnishing enough water for domestic purposes (5 to 15 gal/min) are common in the regolith. However, their occurrence is erratic and their locations cannot be predicted with certainty. In areas where the regolith is primarily residuum from the weathering of the Fort Payne Formation, permeable bedded chert may be encountered at or near the top of unweathered rock. This zone is sometimes capable of yielding up to 100 gallons of water per minute. In areas where the regolith is composed primarily of residual chert and clay derived from rock formations younger than the Fort Payne Formation, it yields little or no water. Dug wells in these areas are used as cisterns. Ground water occurs in cracks in the rocks underlying the Highland Rim regolith. These cracks have been enlarged by the dissolving action of percolating ground water. The largest solution channels usually occur within the first 100 feet below the top of fresh rock. These cracks become narrower with depth and are generally nonexistent below 300 feet. Chances of encountering highly mineralized water containing considerable amounts of hydrogen sulfide increase with depth. Water quality is usually good but may be acidic.

The Highland Rim is underlain at various depths by the Chattanooga Shale. The Chattanooga is a carbonaceous black shale which, when present, acts as an impervious barrier to the downward migration of ground water. This shale is present over large areas of the western valley of the Tennessee River. However in a number of places, it is very thin or absent. Its impervious nature causes its top to be a prominent spring horizon wherever it crops out along the valley walls. These springs issuing from the overlying limestone are often relatively large, yielding as much as 1,000 gal/min, particularly during the rainy season. The yields of these springs fluctuate seasonally but, because of the Highland Rim regolith's ability to store large quantities of water, they do not decrease in flow as much as most limestone springs, particularly as much as those on the floor of the valleys. The quality of water from these springs is good. Due to the impervious character of the Chattanooga Shale, almost all of the wells encountering water-filled openings beneath the shale yield water too highly mineralized to be economically treated. Consequently, it is advisable not to drill below the top of the shale. Possible exceptions to this are areas where the shale is directly underlain by the Camden and Harriman Cherts, is very thin, or exists only as slump blocks in the residuum.

Another occurrence of ground water is in chert gravel. There are two types of gravel occurrences of different ages other than recent alluvium. The older is the Tuscaloosa Formation consisting primarily of unconsolidated sub-rounded pebbles and gravel, reaching a maximum diameter of 6 inches, with small amounts of sand and clay. This gravel is present in rather large areas in southern Wayne and Hardin Counties. Because of erosion it exists only in isolated patches north of these counties, but caps the dividing ridge between the Cumberland and Tennessee Rivers in Stewart County. This formation is moderately permeable. Ground water moves vertically to the water table and then laterally toward the discharge areas near streams or moderately large springs. Because the pore spaces in the sand and gravel are partially clogged and cemented by iron precipitating from solution, water in amounts greater than that sufficient for domestic use is not often available to wells unless a perched water table condition is encountered. The younger gravel deposits are remnants of high-level terrace gravel deposited by the Tennessee River and its tributaries at different levels. These deposits are present from place to place throughout the western valley. The ground-water characteristics of this gravel are similiar to those of the Tuscaloosa. Water from both is relatively soft, being reasonably low in dissolved solids.

Extensive alluvial deposits occur on the flood plains of the Tennessee and Buffalo Rivers and their tributaries. These deposits of gravel, sand, and silty clay are moderately permeable and furnish domestic supplies to wells dug to the water levels of the streams. Larger yields can be obtained by increasing the diameter of the well.

Ground water occurs in three formations of different ages beneath the horizon of the Chattanooga Shale. These formations are the Camden Chert, Harriman Chert, and Decaturville Chert. The rock units essentially consist of bedded chert resulting from almost complete removal of the lime content of siliceous limestones. The Camden Chert is underlain by the Harriman Chert. Because these two formations are lithologically similar, they can be treated as one unit. The Camden-Harriman crops out in Benton, northern Decatur, and eastern Perry Counties. It also appears in a few places along the west side of the Big Sandy River in Henry County. Due to local variations in lithology, the unit varies in thickness from about 100 feet to a feather-edge. The chert is hard and flint-like resembling novaculite. The relatively thin beds are extremely fractured and are permeable as a result. This unit furnishes water to numerous springs in the outcrop area and to dug and drilled wells. Wells generally yield domestic supplies, but yields of 100 to 300 gal/min have been reported. Water quality ranges from soft to hard, probably due to the degree of removal of the lime content by leaching. Turbidity may be a problem in the larger yield wells due to thin clay layers. Hydrogen sulfide may be encountered at depths of 200 feet or more. The Decaturville Chert lies below the Camden-Harriman and is much thinner. It crops out as far north as southern Benton County, Hardin County to the south, and is widely distributed over Decatur County. However, it may be locally absent due to erosion. It is thin-bedded and porous, furnishing moderate quantities of water of a quality similar to the Camden-Harriman.

Two different units of unconsolidated sand occur in the western valley. The older Eutaw Formation caps the tops of ridges and hills in Hardin County on the south on the eastern side of the Tennessee River. On the western side of the river it underlies the higher elevations in Hardin County and is present along the eastern boundary of McNairy and Henderson Counties. It continues northward, occupying the western half of Decatur County and its outcrop area continually decreases in width northward through central Benton to eastern Henry County. The Eutaw Formation consists of alternating layers of sand and clay. In relatively short distances, the sand grades into a sandy clay, silty clay, or clay. In some places, the clay layers thicken laterally into lenses several feet in thickness. The clay units are essentially nonwater-bearing, however, the sand units are fair water-bearing zones. The Eutaw can furnish ample water for domestic or farm use, but it may be difficult to develop wells supplying more than 300 gal/min. The quality of water varies in amount and character of dissolved solids, but is generally soft and acceptable. It is sometimes high in iron and may require aeration.

The other unit of unconsolidated sand present in the western valley is the McNairy Sand. It occurs at a higher horizon than the Eutaw and, where present, is separated from the Eutaw by nonwater-bearing beds of clay. The McNairy occurs along the western edge of the western valley from south to north and thins northward. As it dips westward at a rate of approximately 30 feet to the mile, it underlies all younger formations to the west. Even though the McNairy contains thin layers of clay and locally thick clay lenses, it is a good aquifer yielding from about 200 to 350 gal/min. The water is soft, but commonly contains enough carbon dioxide and iron to require aeration.

Much of the topographically lower part of the western valley is underlain by Paleozoic limestones and shales, often interbedded with limestone. Ground water occurs in cracks that have been enlarged to varying degrees by solution. Wells in these rocks generally do not yield more than 50 gal/min. Turbidity, iron, and hydrogen sulfide are often a problem. Most of the wells are probably no more than 150 to 200 feet in depth. It is not advisable to drill deeper than 300 feet.

Because of the geologic complexity of the western valley of the Tennessee River in Tennessee and lack of ground-water data, potential ground-water supplies cannot be accurately assessed at this time.

Demography

Historical (1970) and recent (1980) population (U.S. Department of Commerce, 1982), total wage and salary employment including both full- and part-time workers, and per capita personal income data for the county boundary approximation of the Tennessee River Western Valley basin are presented in table 52. Counties included in this approximation are Benton, Decatur, Hardin, Henderson, Henry, Houston, Humphreys, and Wayne. Principal urban and metropolitan centers in the basin and their 1980 census population are Camden (3,279), Lexington (5,934), Paris (10,728), and Savannah (6,992).

Public and Self-Supplied Commercial and Industrial Water Users

Currently, there are a total of 24 public water-supply facilities and 9 large, self-supplied commercial and industrial water users whose use exceeds 0.1 Mgal/d in the Tennessee part of the Tennessee River Western Valley basin. Detailed inventories containing pertinent information and data relative to each community or self-supplied user's source of water, average daily water use, source capacity, population served, treatment plant and storage capacities, and water-supply shortage problems are found in tables 25 and 26 of appendix I, respectively. Total water use or withdrawal at the present time for public and large, self-supplied commercial and industrial purposes in the Tennessee River Western Valley basin amounts to approximately 100.4 Mgal/d. The general location and water-supply source of all public and large, self-supplied commercial and industrial water users inventoried in the Tennessee River Western Valley basin are depicted in figures 39 and 40, respectively.

Public water systems currently serve about 85,000 people or 63 percent of the basin's 1980 population. Average daily water use for public purposes equals about 9.1 Mgal/d, of which approximately 4.4 Mgal/d or 48 percent is withdrawn from surface-water sources and 4.7 Mgal/d or 52 percent from ground-water sources. Major public water-supply facilities whose average daily use exceeds 1.0 Mgal/d include the following:

Facility name	Average water use (Mgal/d)
Savannah Public Utilities Department	1.400
Lexington WS	1.600
Paris Board of Public Utilities	2.000

These three systems combined account for about 55 percent of the basin's total water use for public purposes.

Self-supplied commercial and industrial water users presently withdraw about 91.3 Mgal/d. Of this amount, about 90.7 Mgal/d or 99 percent is withdrawn from surface-water sources, primarily the Tennessee River, and 0.6 Mgal/d or 1 percent from ground-water sources. The basin's principal self-supplied water

Table 52.--County population, employment, and per capita personal income data, Tennessee River Western Valley basin

[Per capita income based on 1970 income converted to 1980 dollars]

County	Population		Employment		Per capita personal income 1980 dollars	
	1970	1980	1970	1980	1970	1980
Benton	12,126	14,901	2,188	3,489	$5,365	$6,676
Decatur	9,457	10,857	3,454	3,947	5,127	5,696
Hardin	18,212	22,280	4,611	6,716	4,542	6,037
Henderson	17,360	21,390	4,625	5,775	5,244	5,621
Henry	23,749	28,656	7,728	12,006	5,662	7,212
Houston	5,853	6,871	1,097	1,490	5,565	6,394
Humphreys	13,560	15,957	4,787	6,997	5,596	7,205
Wayne	12,365	13,946	3,776	2,904	4,643	5,291
Total	112,682	134,858	32,266	43,324	-	-

users include Hardy Sand Co. (8.8 Mgal/d) in Benton County, Tennessee River Pulp and Paper Co. (19.5 Mgal/d) in Hardin County, and Consolidated Aluminum Corp. (6.0 Mgal/d) and E. I. DuPont and Co., Inc. (52.5 Mgal/d) in Humphreys County. Total consumptive water use for large, self-supplied commercial and industrial water users in the basin averaged slightly over 2.3 Mgal/d.

Summarized below is a list of the specific water-supply problems now being experienced by individual communities and self-supplied commercial and industrial water users in the Tennessee River Western Valley basin. The number in parentheses following each identified problem indicates the number of communities and (or) self-supplied water users who are now or have experienced this problem in the past. Note, these problems are not listed in order of frequency of occurrence or overall severity.

- Occasional turbidity following heavy rains. (4)
- Inadequate storage capacity. (3)
- Periodic clogging of the water intake pumps due to excessive accumulations of leaves and mud. (1)
- Serious water leaks due to faulty mains and distribution lines. (1)
- Occasional water shortages. (1)

Water-Supply Adequacy Analysis

Total land and water area encompassed in the Tennessee River Western Valley basin area equals 3,664 mi^2 or 2,345,000 acres. The basin's surface- and ground-water resources are replenished by plentiful rainfall whose long-term (1941-70) average equals 52.01 inches. Average annual runoff across the basin varies from 19 to 24 inches as one moves southward through the basin. Normally, the driest months of the year are August, September, and October with the highest rainfall occurring during January, February, and March.

Total water withdrawal or use for public and self-supplied water users in the Tennessee River Western Valley basin equals about 100.4 Mgal/d. Of this amount, water use for public purposes equals 9.1 Mgal/d of which 4.4 Mgal/d or 48 percent are withdrawn from surface-water sources and 4.7 Mgal/d or 52 percent from ground-water sources. Self-supplied commercial and industrial water use equals 91.3 Mgal/d of which 90.7 Mgal/d or 99 percent is withdrawn from surface-water sources and 0.6 Mgal/d or 1 percent from ground-water resources. Major self-supplied industrial water users include Hardy Sand Co. (8.8 Mgal/d) in Benton County, Tennessee River Pulp and Paper Co. (19.5 Mgal/d) in Hardin County, and Consolidated Aluminum Corp. (6.0 Mgal/d) and E. I. DuPont De Nemours and Co. (52.5 Mgal/d) in Humphreys County. Consumptive water use by large, self-supplied commercial and industrial water users equals slightly more than 2.3 Mgal/d.

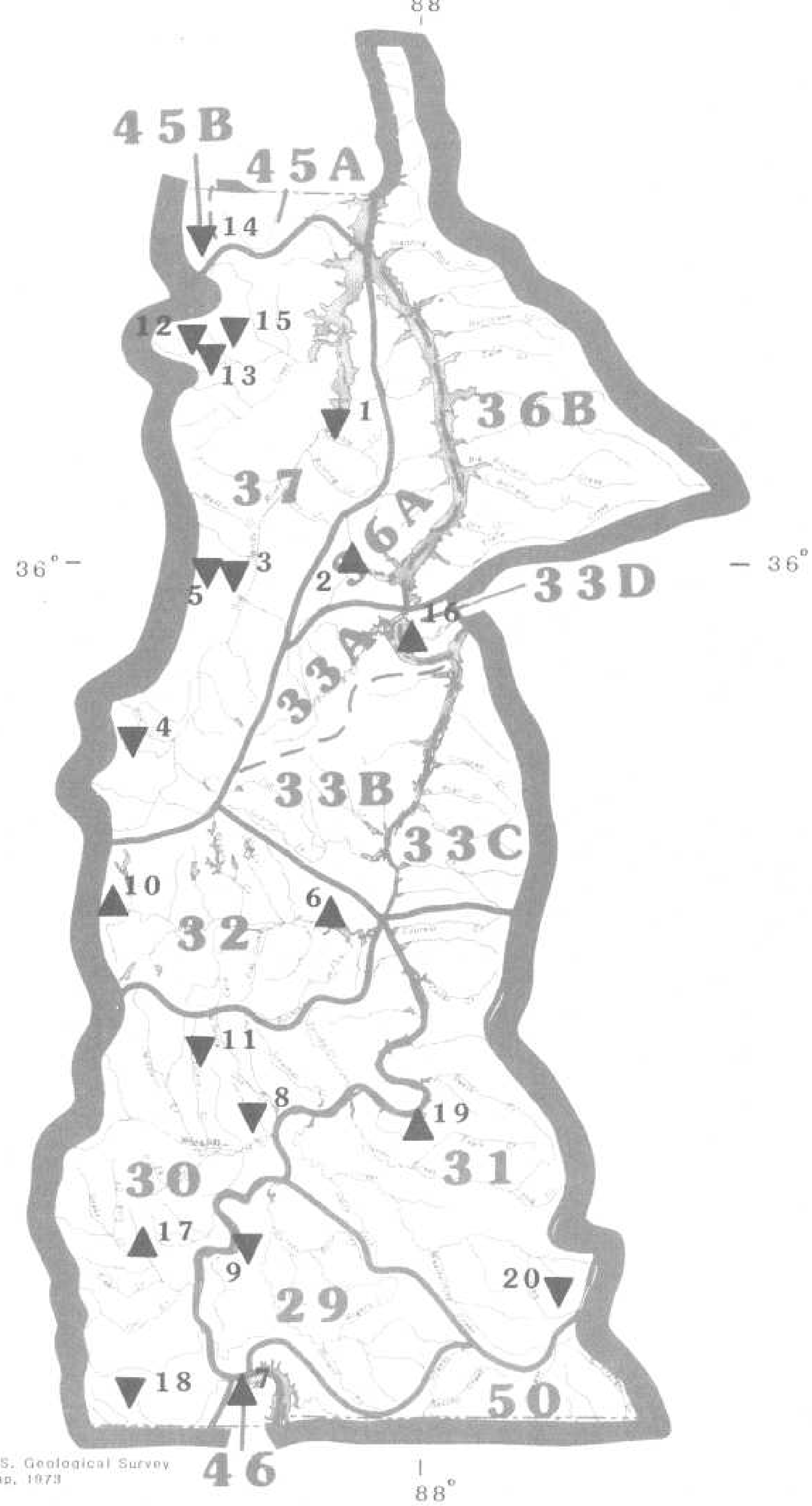
While most of this basin's public systems and self-supplied water users are utilizing surface- and ground-water sources whose source capacity comfortably exceeds their average daily use, a number of communities and self-supplied commercial and industrial facilities are utilizing surface- and ground-water resources whose long-term, dependable source capacity is unknown. Specific communities involved include Bruceton and Clarksburg in Carroll County, Puryear and the West Tennessee Water Co. in Henry County, Michie in McNairy County, and Collinwood in Wayne County. All of these communities are currently served by

Figure 39--Explanation

Site No.	Facility name
1	Big Sandy WS
2	Camden WD
3	Bruceton WS
4	Clarksburg UD
5	Hollow Rock WS
6	Parsons WS
7	First UD of Hardin County
8	Saltillo UD
9	Savannah Public Utilities Department
10	Lexington WS
11	Sardis WS
12	Henry County Water Co.
13	Paris Board of Public Utilities
14	Puryear WS
15	West Tennessee Water Co.
16	New Johnsonville WS
17	Adamsville WS
18	Michie WD
19	Clifton WD
20	Collinwood WD

ground-water sources and are characterized by average uses ranging from 0.089 to 0.350 Mgal/d. While none of these communities are currently experiencing any water-supply, quantity-related problems; it is conceivable that they might experience such shortages in the event of a severe and extended drought. Recognizing that much of the Tennessee River Western Valley basin is underlain by unconsolidated sediments (sand) which commonly yield from 0.100 to 0.200 Mgal/d of generally good-quality water, it would be more cost effective for these communities to supplement their existing supplies from ground-water resources requiring no treatment other than aeration rather than surface-water sources requiring both treatment and filtration.

Self-supplied water users dependent on water supplies of unknown capacity include Hardy Sand Co. in Benton County and H. C. Spinks Clay, Southern Clay, and Tennessee Asphalt Companies in Henry County. Average daily water use for these users ranges from 0.252 to 0.610 Mgal/d with the exception of Hardy Sand Co. whose daily use is 8.772 Mgal/d. While only Hardy Sand Co. is reporting any water-supply shortages at the present time, both Hardy Sand and Tennessee Asphalt Companies are characterized by a relatively large daily water use, particularly Hardy Sand Co. These companies are dependent, for the most part, on surface-water streams of unknown capacity and ponds whose estimated available storage could only meet their companies' daily water demands for a very limited time. Both companies could expect to face serious water-supply shortages in the event of an extended drought and the need to supplement existing water supplies from nearby public water-supply systems or a combination of



EXPLANATION

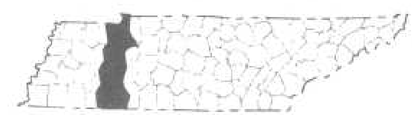
Tributary basin divide

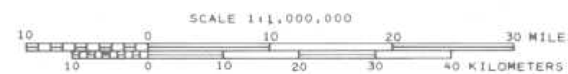
Tributary basin subdivision

36A Tributary basin identification number

▲7 Surface water supply

▼1 Ground water supply





Base from U.S. Geological Survey
State base map, 1973

Figure 39.--Public water-supply facilities, Tennessee River Western Valley basin.

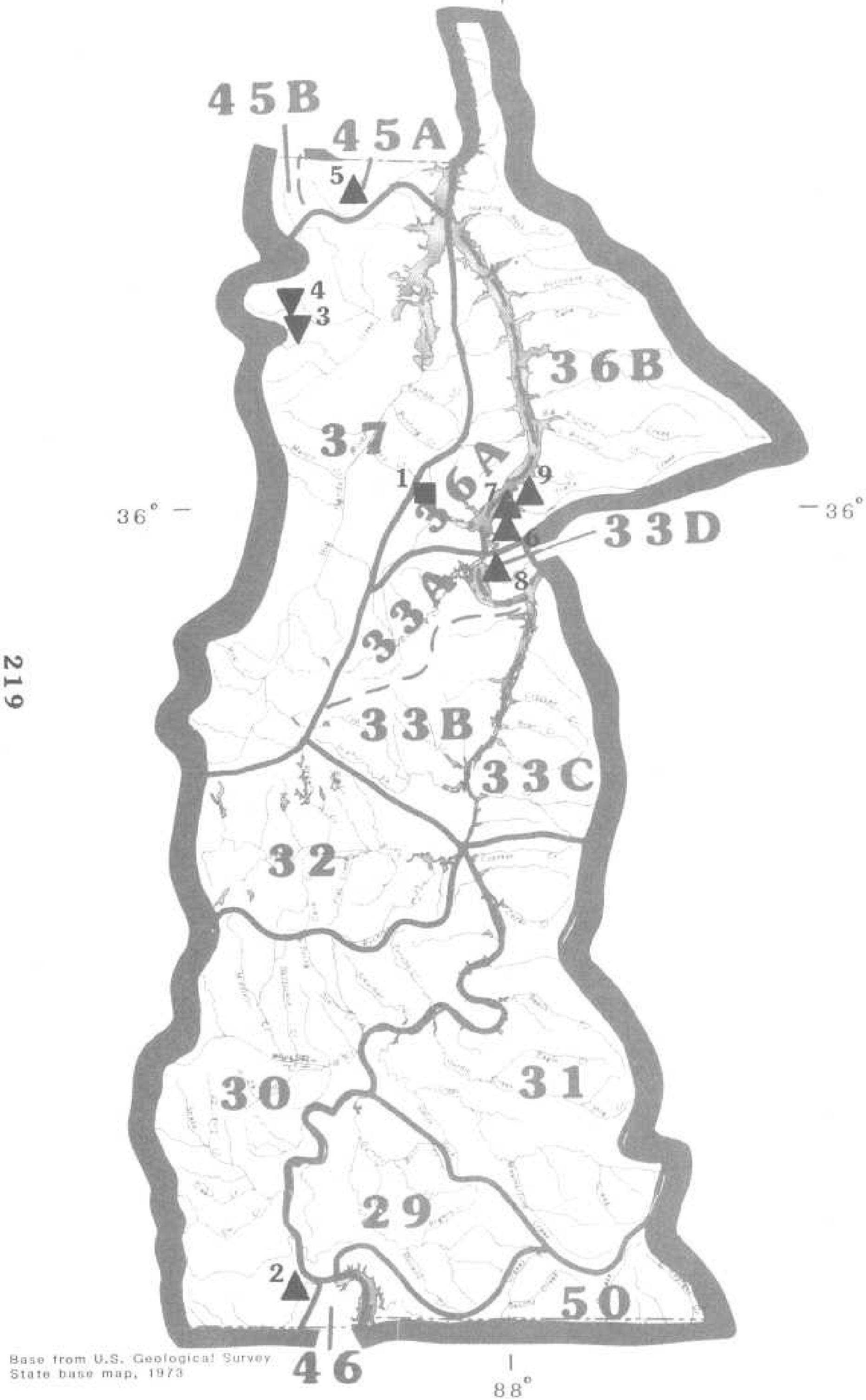
Figure 40--Explanation

Site No.	Facility name
1	Hardy Sand Co. (Camden)
2	Tennessee River Pulp and Paper Co. (Counce)
3	H. C. Spinks Clay Co., Inc. (Paris)
4	Southern Clay, Inc. (Paris)
5	Tennessee Asphalt Co. (Buchanan)
6	Consolidated Aluminum Corp. (Waverly)
7	E. I. DuPont De Nemours and Co., Inc. (New Johnsonville)
8	Foote Mineral Co. (New Johnsonville)
9	Inland Container Corp. (New Johnsonville)

surface- (Tennessee River) and ground-water sources. If necessary, both H. C. Spinks and Southern Clay Companies could probably supplement their existing supply through purchases from the Paris Board of Public Utilities or the development of additional ground-water supplies.

Water systems which are currently utilizing surface- and (or) ground-water resources which are inadequate or of unknown capacity should consider exploring the availability of alternative, cost-effective water-supply sources to augment or meet their future water needs if necessary. While the basin's water resources are subject to contamination from a variety of sources, existing and pending Federal, State, and local statutes relative to water-quality protection and maintenance or improvement should ensure that current water quality will be maintained with little, if any, future degradation of the basin's water resources. Potential sources of contamination include (1) leachate from municipal and industrial water disposal facilities and septic tank systems; (2) agricultural pollution from fertilizers, pesticides and herbicides, and livestock wastes; and (3) urban runoff.

Although there are periods of extended drought which cause seasonal water table declines and periodic local problems with adequate ground-water supplies, observation-well data indicate there are no long-term, regional water table declines. Periodic local problems associated with a decline in an areas's water table are caused by excessive withdrawals and inadequate spacing of production wells. To alleviate this problem, adequate well spacing should be considered prior to test drilling and optimum ground-water withdrawal rates should be determined during the initial test pumping of the source.



EXPLANATION

Tributary basin divide

Tributary basin subdivision

36A Tributary basin identification number

▲9 Surface-water supply

▼3 Ground-water supply

■1 Surface- and ground-water supply

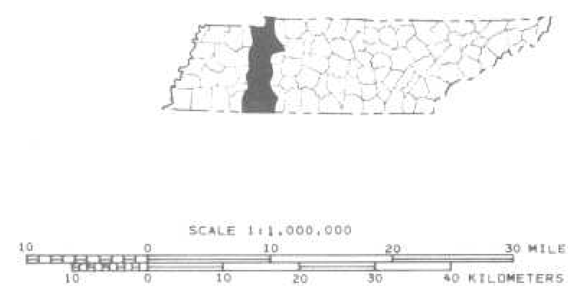


Figure 40.--Self-supplied commercial and industrial water users, Tennessee Western Valley basin.

POTENTIAL IMPACTS OF DROUGHT-RELATED WATER-SUPPLY PROBLEMS

The basic cause of drought-related water shortages is a deficiency in precipitation. However, the overall effect or impact of drought on an area will vary from place to place due to the unequal and irregular distribution of rainfall; topographic and soil differences; erratic distribution of drainage features; and weather conditions, particularly temperature and wind velocity. In some cases, man's erratic development, alteration, and misuse of natural resources will significantly affect the extent and severity of the drought.

While precipitation deficiences and irregularities as well as incomplete or unwise use and development of existing natural resources are the principal causes of drought-related water-supply shortages, there are a number of other water-related problems and issues which have the potential for exacerbating or worsening existing water-supply shortages and increasing the likelihood of additional water-supply shortages, particularly during times of severe and (or) extended drought. Included among these problems and issues are conflict and competition between diverse water uses for a limited, finite water supply; financial constraints; institutional issues, and so forth. More detailed background information describing these and other water-related problems and issues which have the potential either for increasing the severity of existing water-supply shortages or accelerating the time when other communities and self-supplied water users will experience similar supply shortages is provided in Appendix II.

Even though drought seems to be a cyclical phenomenon, there is no precise way of forecasting its occurrence because so little is understood about the interaction of those weather factors which influence future weather conditions. Other factors or considerations which preclude the forecasting of drought conditions with any degree of certainty include changing climatic conditions, natural events, and technological developments which in many instances are capable of and do alter some of the factors which influence our weather conditions.

Normally, drought impact is the greatest in those areas not supplied by major water-supply projects. While many public water systems and self-supplied users in Tennessee receive their water from major reservoirs or from major Tennessee rivers, a good many are dependent on small, intermittent streams or ground-water sources whose long-term, dependable source capacity is less than or nearly equal to the community or self-supplied users average daily use. Many of these communities and users could face serious water-supply shortages during severe and extended drought conditions. In addition, the limited source capacity could seriously limit the attractiveness of these communities as potential sites for large water using commercial and industrial facilities thereby limiting the community's potential for economic growth and development.

As might be expected, most of the impacts associated with drought are of a negative nature. However, there are also some benefits which can be realized from a drought related water-supply shortage. Usually, these benefits accrue to only a few people or small segments of the business community. Summarized below is a broad, general discussion of the potential economic, environmental, and social implications of a severe and extended drought on an area.[1]

Economic Impacts

The major drought-related problems for local citizens, commercial and industrial facilities, and institutional (city government) entities normally consist of a mixture of monetary losses and constant inconveniences. During periods of severe and extended drought, these losses can be very high.

Commercial and industrial operations probably suffer a greater financial loss than any other segment of society. Usually, these losses come in the form of (1) increased water costs due to rate hikes and (2) the costs of hauling water or of putting in additional wells and storage tanks to maintain their existing level of operation. However, many businesses such as car washes and laundromats as well as some smaller industries may experience even a greater loss of income because they could be forced to close or severely curtail their level of operation during a serious drought due to the unavailability of water or the excessive costs of tapping additional supplies. Not only would businesses and industries lose income, but the area's overall economic and social well-being would be adversely affected because of plant layoffs and employment cutbacks resulting in lower demands for labor, raw materials, transportation, and other services provided by secondary or supporting area businesses and industries. During a recent drought in Illinois, several businesses such as restaurants and beauty shops experienced economic losses because of operational changes to reduce water use which in turn resulted in their customers staying at home or going elsewhere.

Institutional problems associated with drought generally manifest themselves in terms of maintaining adequate water supplies to maintain normal community services such as fire fighting, street washing, and so forth. For example, in a small midwest city in Illinois, officials made the decision not to fight any major fire during the spring of 1981 because of the lack of water. Another drought-related impact noted in this city was the deterioration of the city's sewer system. Local hospitals and nursing homes in the city which are heavy water users were also impacted adversely because of the need to (1) seek for and develop or acquire additional water supplies and (2) plan for the movement of patients in the event of an emergency. Throughout this drought, local and community officials in Illinois were under a great deal of public pressure to act and provide needed services and water supplies. In dealing with these shortages, both the city and local officials along with institutional and industrial administrators faced increased legal costs in addition to the costs of acquiring or developing supplemental water-supply sources.

The third major loser in a severe drought is always the general public. In general, these public losses manifest themselves in the form of (1) increased anxiety over extended water-supply shortages, (2) conflict between water interest groups, and (3) additional costs for water. A major public impact noted in Illinois was the extensive use of (1) costly water conservation

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[1]Basic resource materials used in preparing this section on drought-related impacts included (1) the Governor of Illinois' Drought Task Force report entitled "Drought in Illinois, An Assessment with Recommendations" published in March 1977, (2) a document entitled "The 1980-81 Drought in Illinois: Causes, Dimensions, and Impacts" which was published by the Illinois State Water Survey in 1982; and (3) various TVA library and file documents.

measures and (2) time consuming steps to reuse water. In addition, consumers can expect to face increased costs for a wide variety of daily necessities such as food and electricity due to reduced agricultural production and crop failure, increased utilization of coal-fired and nuclear power generation facilities due to reduced hydropower generation, the passing along of increased commercial and industrial costs through product price increases, and increased institutional costs for local water-related services.

In addition to the foregoing impacts which are more community-oriented, serious and extended drought conditions would pose several additional economic hardships on Tennessee residents and business interests.

- Reduced visitation and expenditures by tourists and local residents at marinas, boat rentals, bait shops, and other concessionaires due to low water (streams and reservoirs) conditions.
- Reduced income for agricultural interests due to crop failures and reduced production.
- Decreased water levels in navigable waterways resulting in barges moving at less than full capacity thereby greatly increasing the unit cost of transportation for Tennessee shippers and barge interests.
- Reduced hydropower generation due to low streamflows resulting in increased power costs to residents and commercial and industrial users.
- Structural foundation problems (cracks and settlement) and occasional failure of buildings and other structures during extended drought periods due to the extensive desiccation (drying out) of surficial soils.
- Decreased water levels in wells resulting in increased pumping costs and the possible abandonment of some wells.

While many drought-related impacts are negative in nature, there are some who benefit from these periods of drought. Among those who benefit are the consulting and engineering firms involved in the search for additional water supplies, well drillers, and those involved in the hauling of water to supplement existing, but shrinking water supplies. In addition, drought-related impacts and publicity may provide the impetus needed to gain approval for Federal grants and (or) low interest loans to develop much needed new and (or) expanded community water-supply distribution and treatment facilities.

Environmental Impacts

Drought's short- and long-term impacts on environmental resources will, of course, depend largely on the length and severity of the drought and its impact on the State's water resources. Failure to maintain adequate lake levels, instream flows, and waterfowl/wildlife habitat areas could (1) affect the quality of future fishing and hunting experiences and (2) require special programs for fish stocking and waterfowl/wildlife rehabilitation to restore a strong, healthy fishery and waterfowl/wildlife population. Outlined below are some of the more specific impacts of serious extended drought conditions on the State's water and related land resources.

- During low flow conditions, streams develop low dissolved oxygen and high carbon dioxide levels that may become lethal to fish.

- In small, unregulated streams and small ponds, water levels may decrease to the point where stream flows cease entirely and ponds become stagnant resulting in the death of fish and other aquatic organisms.
- The reduction or elimination of aquatic vegetation due to drought and declining water levels results in the destruction of valuable habitat areas for invertebrate animals, fish, and numerous waterfowl species which could lead to the destruction or alteration of individual species populations.
- Reduced water quality during periods of low streamflows, particularly in streams receiving municipal and industrial wastes, resulting from a reduction of the stream's capacity to assimilate additional wastes.
- Restricted use of available surface-water resources for water-oriented, human contact sports such as swimming and water-skiing.
- Increased potential for wildland (grass) and forest fires due to the extremely dry vegetation thereby (1) increasing the potential for serious erosion and sedimentation problems and (2) reducing the amount of water (precipitation) infiltration into the soil.
- Increased susceptibility of forest trees to damage from insects and disease.
- Degraded aesthetics of lakes and streams with broad expanses of exposed shoreline areas due to low streamflows and lake levels.
- Changed migratory behavior of waterfowl due to the depletion of natural and planted waterfowl foods during drought periods.
- Increased public health concerns due to the potential for elevated concentrations of pollutants in drinking water supplies, particularly in those areas served from surface-water sources.

Social Impacts

Analysis of published materials describing the recent drought in Illinois indicates that the two primary social impacts on the State's residents were (1) heightened anxiety levels among the public and (2) conflict between those who favored the utilization of water conserving measures and those who did not. The setting of mandatory water-use limits also resulted in some conflict, particularly between those who reported on others who "broke the rules" by exceeding the water-use limits.

Another area of influence on human behavior is related to the extra effort and work required by residents to get water. The implementation of water conservation measures to conserve water also required extra effort. These time-consuming activities took away valuable time from other more routine activities.

A positive impact was that the drought seemed to draw residents in many drought-impacted communities closer together in a spirit of "community togetherness" based on the feeling that everyone was suffering and attempting to conserve water in a team effort.

RESPONSES TO DROUGHT CONDITIONS (SOME PROPOSALS)

Most people have two basic beliefs about water. First, water is cheap, and second, water is plentiful. Why worry? If water becomes short, most believe we can buy our way out of the problem, or in the long run, some new technology or source of water will solve the problem.

These are common beliefs about water, but they run counter to the theme found ever more frequently in national popular magazines and scientific journals, which frequently contain articles addressing national water problems. A common statement found in them is that the water problems of the future will surpass the magnitude of the energy problems.

Nevertheless, with the "cheap and plentiful" perception, most individuals view water-supply problems as infrequent, isolated events with some easily attainable solution. This perception is further fueled by the oft-stated position that "Tennessee is a water rich State." However, increasing concerns have been noted by recently completed studies and planning efforts regarding the adequacy of existing water resources in Tennessee to meet current and projected needs. For example, Tennessee's "Safe Growth Plan" published in January of 1981 notes the need to examine carefully the quality and adequacy of Tennessee's water resources to meet the State's water demands during the late 1980's. Information compiled through and reported in the recent Second National Water Assessment report entitled "The Nation's Water Resources: 1975-2000" (U.S. Water Resources Council, 1978) notes that a number of communities throughout Tennessee, particularly those along the rim and headwater areas of the State's major river basins, are experiencing periodic water-supply shortages during times of drought.

Basic water-use data and information compiled on public water-supply systems and large, self-supplied commercial and industrial users through this study confirmed that some of the State's systems and users are currently experiencing occasional supply shortages or are utilizing water sources which are marginal in terms of their dependable, long-term source capacity. Thus, it would appear that concerns regarding the adequacy of present-day water supplies to meet current and future needs are well-founded and warrant further, more detailed consideration and study by planners and decisionmakers at all levels of government.

Essentially, there are three basic "truisms" connected with water shortages.

- First, there is no way to escape the reality that a water shortage is basically a local problem. This does not imply that State and Federal governments are unconcerned about water-supply shortages, but rather recognize that solutions to those shortages are most commonly found at the local level.
- Second, money alone will not solve the problem of water-supply, quantity-related shortages. Very simply, the solution is water and water is not provided as a result of having access to large amounts of money. While money is important and necessary, the development of new impoundments and wells is of no value if adequate runoff is not available from upstream watersheds to fill the impoundments or ground- water aquifers which the new wells can tap.
- Third, conservation is undoubtedly an effective means of solving a water shortage. Successful conservation efforts can minimize and often resolve

short-term water-supply shortages, thereby providing time for planners and managers to concentrate on the development of solutions for more serious, long-term water-supply shortages.

Recognizing the validity of the foregoing "truisms" and the limited, but nevertheless real existence of and potential for periodically severe, wide-spread water-supply shortages throughout Tennessee, this section attempts to delineate some broad, general responses and suggestions for Tennessee decisionmakers at the State, substate, and local levels of government to consider and discuss as they continue their efforts to meet the challenges of water management in the 1980's. More specifically, this section will address the following areas:

- The establishment of an "emergency preparedness program" to respond to and deal with critical water-supply, quantity-related shortages.
- Federal, State, and local agencies' responsibilities and roles in addressing and resolving identified water-supply, quantity-related problem areas and issues.
- The next step or future activities to be undertaken in Tennessee is to focus more detailed study on identified water-supply problem areas and begin identifying possible solutions to these problems.

Basic suggestions and ideas presented on the following pages for each of these areas are not intended in any way to restrict or limit the range of alternatives and options available to decisionmakers as they conceptualize and promulgate viable water-related policies and programs for addressing and resolving or alleviating, to the extent possible, water-supply, quantity-related problems and issues. Rather, these are provided simply as food for thought to stimulate discussion and to note specific project and program actions which have proven successful elsewhere in dealing with drought-related water-supply shortages.

Emergency Preparedness Program

Development and implementation of an "emergency preparedness program" to respond to and deal with critical water-supply shortages in a timely and orderly manner is not an easy task to undertake. Most Americans assume water is available upon demand, inexpensively, and in virtually limitless quantity. In light of this widely held misconception, it is essential that individuals and communities be made aware of their water-supply problems and encouraged to take positive action to solve the problems. Futhermore, it is not enough to deal with the emergency shortage alone; long-term solutions must be developed and implemented.

Emergency preparedness programs generally include three basic responses to water-supply shortages: emergency, short-term, and long-term.

- Emergency responses are utilized to meet immediate needs for water. They are applicable when a community or self-supplied user has or is about to run out of water.
- Short-term remedies are appropriate for individuals and self-supplied users and communities that are not yet at the crisis stage, but wish to take steps to alleviate continuing drought conditions.
- Long-term responses are viewed as relatively permanent solutions to water-shortage problems and are likely to require a considerable amount of time

and money to implement. If history is any guide, it can be predicted that long-term solutions will be moved to the "back burner" as soon as the immediate crisis is over.

The specific responses and suggestions identified herein for dealing with water-supply shortages are intended to create constructive discussion among water-related decisionmakers at the State, substate, and local levels of government and provide ideas for individual communities and self-supplied users' consideration. There is no one remedy that is appropriate for each individual water-supply shortage. Each water-supply system has a unique set of demands placed upon it. Consequently, each system must select those responses or suggestions which are politically feasible and most likely to enable it to meet its needs in a cost effective, timely, and orderly manner.

The first step in analyzing a water-supply shortage is to assess the quantity and quality of the existing supply. This should include not only the system's usual source of water, but also the availability of any other sources that have not been tapped. Once the supply has been evaluated in terms of both quantity and quality, the system's needs and priorities should be assessed to determine existing water-supply commitments (residential, commercial, industrial, fire protection, irrigation, and so forth). Utilizing this information, it is possible to prepare a supply and demand projection thereby enabling planners and water resources managers to develop and implement appropriate remedial measures which are both efficient and cost effective. However, the need for planners and decisionmakers to give full consideration to both water quantity- and quality-related data and information in developing and implementing politically, economically, and environmentally feasible water management programs cannot be overemphasized.

Specific responses and suggestions are presented below for consideration as possible elements to be included in any "emergency preparedness program" for dealing with serious water-supply shortages.

Water Conservation

One effective and inexpensive way to deal with drought is through conservation. Conservation is a broad, general term which encompasses within its meaning a number of specific actions including public information and education, water-user ordinances, recycling, water-use rates, repair and maintenance of deteriorating water-supply systems, and evaporation suppressants. However, conservation entails more than specific remedies. Conservation has frequently been described as an ethic, but as such it is by no means a universal ethic. To be fully effective, water conservation techniques must be understood and accepted by the public.

The first step in conservation involves the steps that can be taken by the community and individual water user to make sure that water is not being lost through leaks or waste. Secondly, local ordinances restricting certain uses of water and increasing water rates can serve as conservation measures if voluntary methods fail. When all else fails, rationing should be considered; it is presently being used in several places in California with some degree of success.

If water is to be conserved, the public must be convinced of the need to conserve. The media is, of course, an important resource in this effort, but other avenues should be considered. School systems can teach conservation. Citizen's Advisory Committees can be established to get out the message that conservation is important. Water distributors can enclose conservation information with their bills. Citizen groups can be mobilized to go door to door with information. Through such groups, water-saving devices could be sold, at cost, and installed free of charge.

Municipalities can encourage water conservation in several ways:

- Install water meters on all residential services as studies have shown that water demands generally are lower in metered areas than in flat-rate areas.
- Adopt domestic use water pricing structures which encourage wise use of water, such as peak demand commodity or inclining commodity rates.
- Require installation of water-saving fixtures and fittings in new construction and remodeling projects through local plumbing and building codes.
- Encourage proper irrigation techniques through consumer education.
- Enforce water use restrictions when shortages arise. Restrict use of water for lawn and garden watering, swimming pools, ornamental fountains, and drinking fountains during extreme drought period.
- In critical supply situations read meters monthly and restrict consumption to 50 gallons per family member per day.
- Educate customers to the fact that conserving water, besides assuring them of a more reliable supply, will save them money on their water and sewer bills.

A special report (Virginia Water Resources Research Center, 1982) noted that an analysis of Virginia Beach, Virginia's, response to the 1980-81 drought indicates that requests for voluntary reductions in the consumption of water and a ban on nonessential uses did not significantly reduce the city's total daily consumption of water. However, the establishment of a water-allotment (rationing) program with surcharges based on a maximum-use allowance was quite effective in reducing water use.

Virginia Water Resources Research Center (VWRR) research has stressed that the success of any conservation program is dependent on (1) the public's perception of the program's fairness and (2) a thorough public information and education program to inform water users of the droughts' seriousness and delineation of water-saving practices.

Public Information and Education

A key element in any program for dealing with both short- and long-term, drought-related water-supply shortages is a strong and effective public information and education program. During drought periods, State and local governments must make a concerted effort to (1) demonstrate to the public that there is a serious drought, (2) educate the public about the value of water, (3) provide information about alternative water conservation measures, and (4) enlist popular support both for voluntary water conservation and any legislative action required to deal with the drought.

To be fully effective, a viable public information and education program should utilize a wide variety of methods including the news media, community and civic organizations, public schools, and speakers. More specifically, drought-related information should be provided to the public through a wide variety of vehicles including newspaper articles and features; radio and television talk shows and public service announcements; printed brochures, and information letters, for mailout with utility bills; signs and billboards; conservation-oriented courses in the public schools; citizens meetings and seminars; and presentations by State, local, utility, and university officials who are knowledgeable about the drought and ways of coping with drought. Slide shows, filmstrips, and films portraying the drought and its seriousness as well as various means for conserving water should be an integral part of many of the above.

One of the most effective means for dealing with long-term, future droughts is water use education in the schools. Through the introduction of conservation-oriented units in the science curriculum of the elementary grades and extending on through high school, young people could be conscientiously educated about water and its value, drought and its effects, and ways in which water can be conserved.

Ordinances

Essentially, two entities - local and State governments - are responsible for the wise use and management of the State's water resources. Note, local government includes all utility districts, water departments, and so forth. While local governments have the primary responsibility for management of their water supplies, the State's role is basically a regulatory one which entails the definition by State statute of the powers and limitations of local governments in managing local water systems. More specifically, these statutes define the local administration's jurisdiction, duties, and taxing and bonding powers in regard to the establishment and maintenance of an adequate water system. Furthermore, modifications or extensions of local water systems must be in compliance with the health and safety standards established by the State agencies.

In maintaining water service during a serious and extended drought, local governments may need to consider and should have recourse to the implementation of contingency ordinances designed to encourage the conservation of water. To facilitate the development of viable, publicly acceptable contingency ordinances, communities should reassess their rating (pricing) system for water consumption to encourage water conservation by the system's customers. Specific ordinances to be considered for implementation might be the (1) installation of meters in previously unmetered areas and (2) establishment of a reverse rate (price) system in which the large consumer of water is charged more than the small consumer.

When the public well-being is endangered by a water shortage, the local government should have the authority to prohibit nonessential uses of water and enforce conservation. The local government should also have a water conservation ordinance that defines the government's emergency powers, type of prohibition upon the use of water, restricted uses of water, and exceptions to these measures. Specific prohibitions should include the use of water for swimming pools, lawns, fountains, and any other use that is declared unnecessary or noncritical. Furthermore, the local administration should be empowered by the ordinance to close or place restrictions upon a business or an industry that uses large quantities of water. However, such restrictions should be placed judiciously upon any business or industry effecting the public's health and well-being.

During drought periods, State government will need to work closely with local governments to resolve problems and issues which arise during the implementation of contingency measures. For example, a local community attempting to reduce excessive water losses by repairing a badly deteriorated water-supply system may find that existing statutory limits on water taxes and bonds do not provide adequate revenue for the needed improvements. To resolve problems of this nature and others, the State's General Assembly could be of assistance to local water resources managers by considering (1) an increase in the taxing and bonding power to finance the development of new water systems and repair and (or) extension of existing water systems; (2) the review of existing State water law, policy, and agency programs to determine their relevancy to current water-use patterns, particularly during times of drought; and (3) establishment of a procedure or mechanism to work with and assist local communities in resolving water-supply shortages and ensure that the communities are working together against the drought, rather than against each other.

Alternate Water-Supply Sources

During a drought, a community or self-supplied water user may find it necessary to supplement their original source of water or find a new one. This can be accomplished by a variety of methods as described briefly below:

- Temporary Pipelines. If another source of water is reasonably close, it may be possible to run a temporary pipeline to the treatment plant or the distribution system. Ideally, such a source would be a developed system with treated water such as a nearby municipality or an industrial supply with surplus water. It might also be a surface supply such as a gravel pit, lake, river, or even a creek. While this type of supply can be discharged readily into an existing reservoir for untreated water, it is not readily adaptable to a system utilizing a ground-water source.

- Additional Wells. This remedy may not be a suitable solution if existing wells have fully developed the aquifer. If this is the case, it may be necessary to go some distance to another aquifer. Another alternative might be to deepen the existing well to obtain a greater quantity of water by tapping a deeper aquifer. Well logs in some areas indicate substantial yields of good-quality water can be found at greater depths than those usually drilled. Often highly mineralized water will be encountered by drilling deeper.

- Hauling Water. If all other water shortage responses fail to provide a minimal water supply, the hauling of water may be necessary in order to protect the community and individuals from serious health, sanitary, and safety-related consequences. However, the decision to haul water should be made only after all other responses fail because the hauling of water is expensive, time consuming, and is unlikely to supply all of the water-related needs. Should the hauling of water be initiated, every possible conservation measure must be utilized, since hauled water will only provide minimal water needs.

- Water Recycling. The recycling of water intended for human consumption is a process which must be approached with caution. It is suitable for use only in extreme situations. However, the reuse or recycling of water used exclusively in some commercial or industrial operations is a common practice and should be considered by firms located in areas experiencing a water shortage. Any community which is considering the reuse or recycling of water as an alternative water source should seek guidance and assistance from the appropriate State agencies with statutorily mandated water quantity and quality responsibilities.

  The most conspicuous opposition to recycling for domestic use is likely to be that of uninformed individuals who object on general principles. However, it should be recognized that most water works on the lower reaches of long streams are treating water that already has been reused repeatedly. The most serious technical problem associated with recycling is that our treatment processes do not remove dissolved minerals. Therefore, the second or third cycle is likely to make the water too salty for further domestic use. Other objections involve the resistance of viruses to chlorination and the concentration of heavy metals.

Rehabilitation of Existing Water Supply Facilities

Recognizing the number of communities identified as experiencing large water losses through leaking mains and distribution lines, the repair and maintenance of community water mains and distribution lines should have top priority along with the implementation of water conservation measures for resolving water-supply shortages. Each community needs to undertake an immediate and intensive effort to locate and repair major and minor sources of water loss within its water distribution and meter system. This effort should include full citizen participation in the identification of water loss locations.

Weather Modification

Practical weather modification may be available to us in the near future. Cloud seeding is that form of weather modification of the most interest as a possible agent of drought relief. It is accomplished by placing very large numbers of very small particles in a promising cloud. Silver iodide is most commonly used. This has proven to be effective in some cases, but prediction and control are not adequate for use in populous areas. Control must become very reliable before the existing legal hazards could be faced realistically.

Cloud seeding can often result in adversary conflicts that may lead to injunctions or damage suits. In a drought situation, different communities could contend for the same group of clouds. At the other extreme, there are those who would suffer serious losses from rain falling at a particular time. An example would be a dirt contractor that has contracted to meet a deadline with work that can be performed only in dry weather. Another uncertainty is the environmental effect of silver iodide. The dissemination of silver iodide for research purposes to date has occurred in such minute concentrations that no harm has been observed.

Dredging

Another alternative for increasing available water supplies is to remove excessive deposits of silt and debris from the area surrounding community surface-water supply intake facilities. This is particularly true for those communities who get their water from small, unregulated streams or small surface-water impoundments. Several of these communities have noted problems with the siltation and clogging of water intake facilities as a result of excessive sedimentation and debris. Care must be taken, however, in the silt removal to protect key environmental resources such as fisheries and other aquatic and waterfowl-wildlife habitat areas for degradation or damage as a result of the deposition of the dredged materials.

Water Resources Planning

Planning and hydrologic data collection should be essential elements in any attempt by the State water management agencies to develop and implement an effective and viable "emergency preparedness program" to respond to and deal with critical water-supply shortages in both the short- and long-term future. In the short-term future, planning and data collection activities should concentrate primarily on the development of individual water-supply studies for specific communities who are experiencing water-supply shortages be they drought-related or otherwise. Essentially, such studies would (1) develop pertinent information and data regarding existing water quantity and quality, (2) determine the extent and severity of the problem, (3) identify the general corrective measures to be implemented, (4) delineate the general time and funding schedule for detailed design and implementation of the corrective measures. Following the development of this plan comes the detailed design and scheduling for financing and implementation of the corrective measures identified in the plan. Throughout the planning process, local constituencies (officials, public and civic organizations, and private citizens) must be fully informed and provided the opportunity to participate meaningfully in the planning process. In addition, all planning and detailed design aspects of each study must be fully coordinated with those State agencies having technical, regulatory, or financial responsibility for water-supply planning- and management-related projects.

However, in order to deal more effectively with future drought-related water-supply shortages, minimize the potential for these shortages, provide opportunity for economic growth and development, maintain the environmental integrity of the State's natural resources, and achieve the optimum use and management of the State's valuable water resources, it is imperative that the "emergency preparedness program" provide for the establishment and implementation of a long-range, comprehensive water and related land resources planning process. More specifically, such a planning process should consider and accommodate, to the fullest extent possible, all pertinent water uses and interests to achieve as many of society's basic goals and objectives as possible. Not only should the planning process be comprehensive in nature; but it must be dynamic, that is, plans must be periodically updated in view of the fact that all water uses and interests are interrelated and constantly changing to reflect society's changing goals and objectives and the availability of new technologies. Throughout the planning process, planners should seek out and actively involve in the planning process all pertinent Federal, State, regional, and local agencies with statutory water-related responsibilities or interests as well as a wide range of public and private organizations, associations, clubs, and so forth. This is necessary if the plans are to be politically, economically, environmentally, and socially viable. In formulating such a planning process, several basic questions must be considered:

- How should the relationship between management agencies and water user constituencies at all levels of government be cast so that the contributions of each can be considered appropriately?

- What procedure and institutional form will ensure that the individual agencies' technical competence, power, and institutional resources can be utilized to the fullest extent without encroaching on the public policy process?

- How should the principal participants in the policy process be organized to increase its productivity and the power of all of its components?

Recognizing that water supplies which are classified as potable water supplies need to be closely monitored and protected to prevent their degradation, any short- and (or) long-range water-supply planning activities should consider and plan for the immediate implementation of appropriate pollution abatement techniques to protect both public health and fish and wildlife concerns during a severe and (or) extended drought.

In addition to the above, all potable ground-water sources should be geographically located and topographic recharge areas to the sources delineated. The potential sources of ground-water contamination within the recharge area should be identified, and the potential for future contamination of the source should be evaluated. In those areas with the highest potential for future contamination, measures should be implemented to protect ground-water resources.

Institutional

Recognizing that many of the small public water-supply systems and large, self-supplied users in Tennessee are utilizing water supplies whose source capacity is less than or only slightly greater than the community or user's current average daily water withdrawal, it seems that one practical means of providing for a permanent, dependable water supply for these communities, self-supplied commercial and industrial users, and rural users would be to plan for and develop a regional water grid system on a county or multicounty basis.

William R. Walker, Director, VWRR Center, noted in a presentation at the National Conference on Water in Washington, D. C., in April of 1975 that one means of providing safe, continuous water supplies and adequate wastewater management for small communities and rural areas was through the regionalization of small water-supply wastewater treatment systems, either physically or administratively, into larger more economically viable units (U.S. Water Resources Council, 1975). This concept seems to be equally applicable today in view of the decreasing population in small communities and rural areas, high development costs, stringent Federal and State health and environmental standards, and limited financial resources. While the concept of regionalization would likely be resisted by many at the local level since it would diminish local autonomy by making local governments contractors for rather than providers of services, this concept would provide the most cost-effective means for meeting small communities and rural areas water supply and wastewater treatment needs. One viable alternative which might be considered is the creation of a Statewide, semi-governmental corporation which would provide both water-supply and wastewater treatment services on a contract basis with local governments. Rates and quality of service could, of course, be regulated and controlled by a corporation in the same manner as other regulated utilities.

Federal, State, and Local Agencies Responsbilities and Roles

Effective water management during times of severe and extended drought must come largely from individuals and local officials who know the situation and are in a position to take timely action. However, intrastate and possibly interstate or regional coordination may become necessary and even essential in the event of a serious drought which reduces available public and self-supplied commercial and industrial water supplies to the point that local authorities begin calling for emergency assistance. While water-supply planning and the resolution of drought-related water-supply shortages are largely a State and local responsibility, Federal agencies with water-related responsibilities can be of considerable assistance to the State and local communities and water users in coping with drought-related water shortages. More specifically, the Federal agencies should:

- Assume leadership in the development, testing, and implementation of viable engineering and management approaches to water use during drought periods.
- Assist in resolving interstate water-related needs and problems arising during extended and severe drought.
- Conduct pertinent research and data collection activities to learn more about the patterns of climatic variability and the dynamics of climatic change on an area or region's water supplies.
- Continue to provide technical and financial assistance to State and local officials to help them establish, build up, and maintain the capability (staff and financial resources) and experience in the development and implementation or operation of viable water resources plans, projects and programs.

While the State's role in water-supply planning and management is multifaceted in nature including such elements as data collection, planning, information dissemination, and technical assistance, its basic role is a regulatory one which entails the definition by State statute of the powers and limitations of local governments in managing local water-supply systems. In general, these statutes should define the local administration's jurisdiction, duties, and taxing and bonding powers in regard to local communities' establishment and maintenance of an adequate water-supply system. More specifically, the State could:

- Provide local communities and water users with pertinent information on (1) alternate water sources relative to quantity and quality, (2) existing water and weather conditions in the drought area, and (3) long-range precipitation predictions.
- Provide certain facilities such as pipelines, pumps, and trucks to assist local communities in transporting water, where necessary, to meet local demands.
- Assist local communities in establishing and implementing appropriate water use rates and mandatory use limits during drought periods.
- Provide appropriate information on the effects of reduced water levels in lakes and reservoirs on the fish and other health- and environment-related conditions.
- Provide guidance and assistance to local communities and (or) industries considering the possibility of recycling or reuse of water as an alternative to developing new or additional surface and (or) ground-water supplies.
- Work with and assist local communities in resolving drought-related water-supply shortages to ensure that the communities are working together rather that against each other.
- Assist local communities in acquiring and utilizing available technical and financial assistance from pertinent Federal agencies.
- Establish and maintain a strong, effective public information and education program to educate the public about (1) the value of water, (2) the potential for severe and extended drought conditions, (3) alternative measures for conserving and (or) reducing water use, and (4) enlist popular support for voluntary water conservation and needed legislative action to deal with drought-related shortages.
- Work with local officials in the development of short-term individual water-supply studies for specific communities who are experiencing water-supply shortages.
- Develop and implement a long-range comprehensive, coordinated water and related land resources planning process which considers and accommodates, to the fullest extent possible, all pertinent water uses and interests in planning for the wise use and management of the State's valuable water resources.

Effective water management, particularly during times of serious drought conditions, must come largely from individuals and local officials who know the local situation and are in a position to take needed actions in a timely and orderly manner. More specifically, local officials could:

- Define local needs and problems.
- Develop plans to operate storage and distribution systems to achieve optimum use of available water supplies.
- Reduce serious water losses by replacing and (or) repairing deteriorating water-supply mains and distribution lines.
- Introduce and encourage local residents to utilize practical conservation measures.
- Inform the appropriate State, regional, and Federal agencies of their community's drought-related needs and problems.

- Seek and acquire, to the extent possible, available technical and financial assistance from pertinent Federal agencies.

Next Step or Future Water-Supply Study Activities

Summarized below are several suggestions regarding specific, more detailed study activities which might be undertaken in Tennessee to facilitate and expedite the resolution or alleviation, to the extent possible, of identified water-supply problem areas.

- Select one or more river basins such as the Holston and (or) Clinch River basins which are characterized by periodic water-supply shortages during the late summer and fall months, competing and (or) conflicting water uses, serious water quality problems, etc., and initiate the conduct of a comprehensive, coordinated study outlining each basin's overall objectives for water resources management and conservation. More specifically, the study should identify and describe existing, short-term (3 to 5 years), and mid-term (6 to 10 years) water-related needs and problems, key environmental resources, economic and social goals, and possible alternative solutions - structural and nonstructural - to meeting and resolving or alleviating, to the extent possible, critical water-related needs and problems.
- To facilitate the development of a single, consistent data base for the State of Tennessee regarding community water-supply facilities, a coordinated effort should be undertaken by the pertinent Tennessee agencies with water-related responsibilities in conjunction with appropriate Federal agencies such as TVA, Geological Survey, Environmental Protection Agency, Soil Conservation Service, and the Army Corps of Engineers to analyze and review their existing data bases relative to community water-supply facilities in Tennessee. The analysis should also address the procedure for developing and maintaining these data bases in order to (1) resolve differences and inconsistencies; (2) develop a comprehensive, integrated data base and survey format which meets the State's needs; and (3) reduce the potential for duplication of survey work by individual State and Federal agencies and differences in basic data collected.
- Develop and implement a long-range comprehensive, coordinated water and related land resources planning process which considers and accommodates, to the fullest extent possible, all pertinent water uses and interests in developing a State water plan to guide planners and decisionmakers in the wise use and management of Tennessee's valuable water and related land resources.
- Design appropriate models to assist planners and decisionmakers in simulating and describing various aspects of water-supply availability and use including the (1) flow of water through a watershed or water body; (2) statistical estimation of peak, annual, and seasonal variations in regional water use rates; (3) estimation of low flow conditions and total annual runoff volumes; (4) integration of water quantity and quality considerations; (5) establishment of minimum instream flow requirements; (6) analysis of existing surface- and ground-water interrelationships; (7) evaluation of the effects of pricing on water use; (8) effect of water conservation techniques on water use and supply relationships; (9) development of flow routing models to aid in the development of reservoir control strategies to resolve or alleviate water-supply shortages, etc.

- Develop and implement a long-range hydrologic data collection program designed to provide planners and decisionmakers with pertinent data and information regarding the physical location, quantity, quality, distribution, use, and movement of the Valley's surface- and ground-water resources.
- Undertake appropriate studies and (or) research to (1) locate and determine the quantity and quality of existing ground-water resources, (2) better understand the processes involved in ground-water contamination, (3) identify alternative methods for preventing future pollution and controlling existing pollution, (4) trace and predict the movement of pollutants in aquifers, (5) design effective monitoring techniques, (6) establish effective and accurate systems for monitoring ground-water pollution, and (7) identify alternative measures and procedures for restoring degraded aquifers and protecting uncontaminated aquifers.
- Further study and research is needed to (1) identify, evaluate, and make available to developers pertinent information and data regarding low-technology, low-cost innovative septic tank systems and (2) evaluate the adequacy of existing State regulations controlling the governing and siting of septic tank systems to protect the quality of potable water supplies and prime fish and wildlife habitat (waterfowl) areas.