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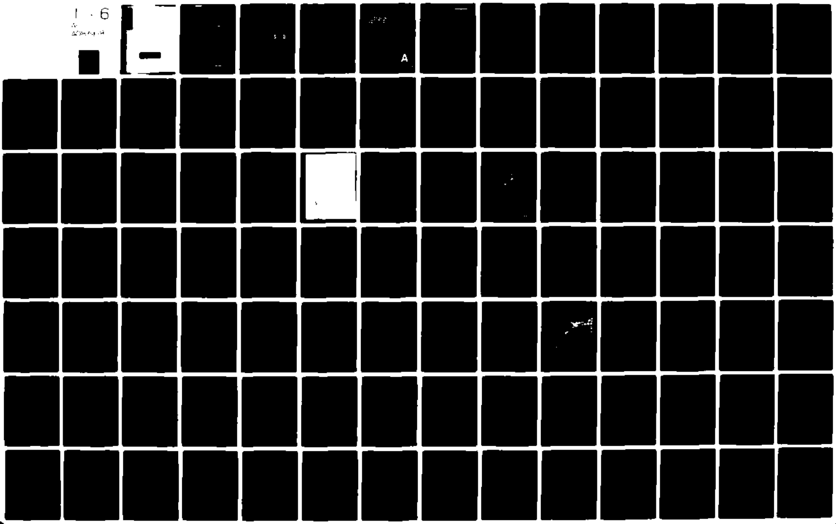

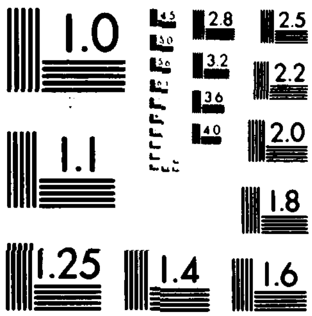
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this study is to help decision makers determine future water resource needs of the Delaware River Basin area and ways of meeting these needs. This report, undertaken in 1975 for the U.S. Army Corps of Engineers by an independent consultant firm described the natural features of the study area, land use, employment and population trends.

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A chapter in this volume focuses on the average annual flood damages of the area and reviews the existing flood damage reduction needs in the Delaware Basin. Water supply and water consumption for the Basin is also analyzed both for residential and industrial needs. Existing water supplies were inventoried and projections made to the year 2025. The most significant water supply need in the basin is found to be the flow necessary to prevent serious salinity intrusion in the Delaware Estuary.

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A COMPREHENSIVE STUDY OF THE

TOCKS ISLAND LAKE PROJECT AND ALTERNATIVES

JUNE 1975

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CHAPTERS I, II & III

A

ANALYSIS OF SERVICE AREAS AND RESOURCE NEEDS

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June 30, 1975

Study Management Team
Mr. Herbert Howard, Contracting Officer
U.S. Army Corps of Engineers
90 Church Street
New York, New York 10007

Gentlemen:

We are pleased to present the Comprehensive Study of the Tocks Island Lake Project and Alternatives. This final report consists of five parts, A through E. A summary report is also available.

This report is about the water resources of the Delaware River Basin. It is designed to help resolve a controversy about the way this water is controlled and used by the people. Controversy will probably always exist as long as there are thinking people and earth, air, fire and water. The important point is that there exists an orderly process through which such differences can be resolved. We hope this study is a useful part of such a process.

This report is concerned with change in the natural environment. It is also about the degree of change men should accept in order to control the violent moods of nature like floods and droughts. These are very complex questions and, in this particular case, have been studied intensively for years. This present study is a summing up or an overview. It critically examines the various ways the basin waters can be controlled and utilized; it sorts out the issues; it evaluates. The study looks at the comprehensive effects of resource development and management, most importantly the effect on the way of life of those now living in the basin.

Resource management questions are very important to all of us. Too important, as someone happily put it, to be left only to the experts. This report does not make recommendations; it attempts to give the decision makers the needed information to do so. It does indicate that needs exist, and will continue to exist, in the areas of water supply, flood control, electric power and recreation. We have also found that there are alternatives to the Tocks Island Project. Relative benefits, costs and impacts, however, of the Tocks Island Project and the alternatives vary widely.

Whatever decision is reached concerning the Tocks Island Project or its alternatives, the preservation of the Basins' essentially rural way of life will depend on the implementation of sound and strong land use planning and controls.

To accomplish the study the consultant worked under a broadly-based study management team. The make-up of this group is listed on the following page. For the consultant, Raymond Tillman acted as project director and Peter Mahony as his co-director. The important contributions of literally hundreds of public officials and private citizens are gratefully acknowledged.

Respectfully submitted,

Daniel W. Greenbaum, Exec. Vice Pres.
URS/MADIGAN-PRAEGER, INC.

James Rossant, Partner
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CONSULTANTS

Subconsultants utilized for portions of the overall study effort are listed below. The areas in which each provided study inputs are also noted.

Major Subconsultant firms are:

- Hammer, Siler, George Associates -- Regional and Development Economic, Recreation Analyses.
- URS/Forrest & Cotton, Inc. -- Flood Control Studies and Civil Engineering.
- URS Energy Services Company -- Electric Power.
- URS Research Company -- Environmental Studies.

Other Subconsultants involved in the study are:

- Mr. Edward Weinberg of Duncan, Brown, Weinberg & Palmer -- Legal Appraisals.
- Intasa -- Water Supply Projections.
- Ide Associates, Inc. -- Recreation Forecasting and Analyses.
- Prof. Myron B. Fiering, Harvard University -- Water Resources.
- Mr. William D. Giezentanner, Harvard University -- Recreation Planning.
- Dr. Joseph Shapiro, University of Minnesota -- Limnology.
- Stephen S. Susna & Associates -- Land Use Planning Policy.

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FIGURES - PART A

CHAPTERS I - III

INTRODUCTION

BACKGROUND

The Delaware River is one of the Northeast's major natural scenic resources. From early colonial days the River's water potential was recognized with the building of the municipal water works at Bethlehem and Philadelphia in the 1770's. During the early twentieth century, New York City built reservoirs on the Delaware River headwaters to assure its future supplies.

Two recent natural events have emphasized the need for the further study of the water resources of the Delaware River Basin. Severe flooding due to two tropical storms occurred in August 1955 and drought conditions prevailed during the years of the early and middle 1960's. After the floods of the mid 50's, Congress authorized the Corps of Engineers to undertake a comprehensive study of the Basin's water resources (House Document 522, 87th Congress, Second Session). This was completed in 1960.

The study recommended six new dams. Tocks Island, by far the largest of these, was authorized by Congress in the Flood Control Act of 1962. The project consists of an earthfill dam on the main stem of the Delaware River approximately five miles northeast of Stroudsburg, Pennsylvania and an impounded reservoir reaching 37 miles upstream to Matamoras, Pennsylvania and Port Jervis, New York. The impoundment is to provide storage for water supply, recreation and hydroelectric power and additional capacity for flood control. Later, Congress authorized the Delaware Water

Gap National Recreation Area to be developed in conjunction with the reservoir and also expanded the original authorization to permit the construction of the Kittatinny Mountain pumped storage facilities by private electric utilities.

Funds for land acquisition were first appropriated in 1968. Since that time about 67 percent of the project's land has been acquired and the Corps has continued its project planning. The final Environmental Impact Statement for the project was filed on October 2, 1971 with a draft supplement in August 1974.

Over the last several years many concerns have been expressed with respect to the project. These have generally involved environmental issues and the impact of the project on its surrounding area. Alternatives to Tocks Island have been suggested by various public and private groups and by individuals. Last summer, while Congress was considering the appropriations for Fiscal Year 1975, they recognized this continuing controversy and directed the Corps, in cooperation with the Delaware River Basin Commission, to have prepared a comprehensive and impartial review of the project and its alternatives and to make recommendations regarding the disposition of the project within one year. This is that review study.

PURPOSE

The overall purpose of the subject "Comprehensive Review Study of the Tocks Island Lake Project and Alternatives" is to provide the information, analyses, evaluations and perspectives required by the Delaware River Basin States and the Corps of Engineers for them to recommend to the Congress whether the Tocks Island Lake Project should proceed to construction at this time, be modified, be deferred, or be deauthorized.

SCOPE

In order to fulfill the foregoing purpose, the study was divided by the prescribed "Scope of Work" into the following five parts.

Part A - Analysis of Service Areas and Resource Needs

This part assessed and estimated the water resource-related needs of the Basin. Major elements of this work thus included: the delineation of service areas for the authorized project purposes (water supply, flood control, outdoor recreation, and electric power); economic analyses and forecasts for these areas; water quality studies; and the projection of water supply, flood control, recreation and electric power needs.

Part B - Review of Tocks Island Lake Project

This part consisted of: a brief review of technical engineering performed in the development of the project as well as reviews of the adequacy of project planning, cost estimates, planning criteria and procedures, and economic analyses; the study of water quality effects of TILP; the evaluation of construction impacts and the project's compatibility with its authorized purposes; and the identification and assessment of criticisms and concerns raised with respect to the project.

Part C - Analysis of Alternatives to Supply Resource Needs

This element of the study evaluated the full range of alternatives to the Tocks Island Lake Project in each "authorized purpose" area; developed and evaluated in detail combinations or programs of the most viable of these; and compared these alternative programs and their impacts to the previously identified needs of the Basin region and to TILP's performance with regard to the satisfaction of these needs.

Part D - Institutional Aspects

As one institutional aspect of the study, the factors affecting the need, merits, effects, and desirability of re-opening the 1954 Supreme Court decree were outlined and examined. Other institutional aspects and alternatives studied included the deauthorization and deferral of TILP and the development of a National Recreation Area without a lake.

Part E - Land Use and Secondary Effects of Tocks Island Lake Project

Studies performed under this part identified the full range of TILP impacts; investigated pertinent life styles and attitudes in the area; analyzed transportation facilities, demands and improvements; and identified and assessed land use plans and management strategies.

STUDY PROCESS

This study has involved a high level of public participation and direct interaction with concerned public agencies. At periodic meetings with the Consultant, a Study Management Team monitored progress and provided comments. Citizen Advisory Groups to State Governors were also established and meetings between them and the Consultant were regularly held.

Drafts of each of the study's five parts were broadly distributed to a wide variety of interest groups, government agencies, and individuals for review and comment. After a review period, public meetings were held and all comments were evaluated by the Consultant and reflected, where approprate, in the final text. Repositories for public scrutiny of relevant documents on the study, including study drafts, were established throughout the Study Area and, in addition, the files of the Consultant were available to the public throughout the study.

It has been the Consultant's objective to make study approaches, procedures and findings known at the earliest possible time during the study period; solicit all relevant comments and opinions; and perform all aspects of the work in as public a manner as possible.

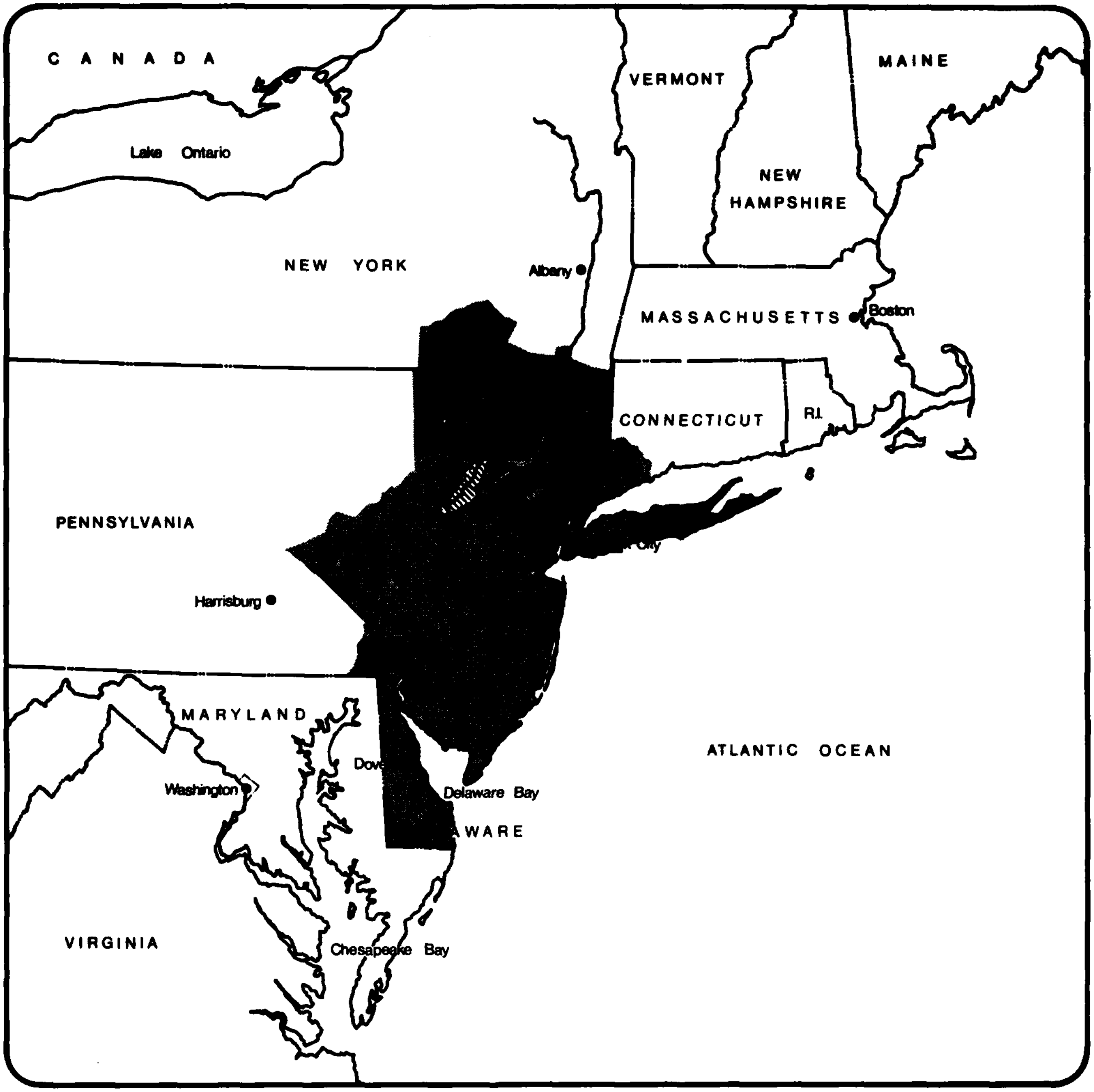
The Delaware River Basin drains a relatively long and narrow land area in the northeastern United States, extending some 330 miles southward from the upper Catskill Mountain valleys in New York to the Atlantic Ocean at the mouth of the Delaware Bay. Although the Delaware River and its drainage basin form the geographic focus of this study, the river with its system of tributaries serves a functional area extending on all sides beyond the basin itself, and encompassing various portions of the states of Delaware, Maryland, Pennsylvania, New York, New Jersey and Connecticut.

In this Chapter the economy of the region influenced by the Delaware River and its resources are analyzed, and its future economic trends are projected. This analysis is broken down into three main divisions: one, the general characteristics of the Delaware River region; two, the definition of the six service areas which form the basis of subsequent chapters concerned with the basin resources and needs; and three, the economy and economic projections for each of these six service areas.

I.A. GENERAL DESCRIPTION

For the purposes of describing the general characteristics of the region, a Delaware River influence area has been selected based on the geographic area which utilizes the Delaware River water resources. This influence area is essentially the same geographic area utilized in Corps 1962 Delaware River Basin Report (H.D. 522) and encompasses approximately 25,000 square miles comprising 53 counties in the states of Delaware, Pennsylvania, New York, New Jersey, and Connecticut, with a total population of 25,899,400 persons in 1973 (refer to Figure I-1).

The description which follows summarizes the physical and economic characteristics of this influence area, with special reference to the seven counties of Sussex and Warren (New Jersey); Northampton, Monroe and Pike (Pennsylvania); and Sullivan and Orange (New York), which adjoin the Tocks Island Lake Project and form the contiguous seven county impact area. These counties are the subject of the analysis of the project's secondary impact which are discussed in Part E of this Report. Although Part E examines the existing and future conditions of the impact area in greater detail, the attempt here is to provide a general understanding of the dynamics and major characteristics of the region which has and will continue to influence the future of that area. Included here are the natural features, land use patterns, transportation network, demography, and economy of the region and its growth characteristics.



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LEGEND

EXTENT OF DELAWARE RIVER INFLUENCE AREA

LIMITS OF DELAWARE WATER GAP NATIONAL RECREATION AREA

LOCATION MAP
DELAWARE RIVER BASIN
INFLUENCE AREA

1

A COMPREHENSIVE STUDY OF THE

TOCKS ISLAND LAKE PROJECT & ALTERNATIVES

URS/MADIGAN-PRAEGER, INC. & CONKLIN AND ROSSANT

I.A.1 NATURAL FEATURES

I.A.1(a) Physiography

The terrain of the Delaware River influence area spans five physiographic provinces: 1) The Appalachian Plateau Province; 2) The Valley and Ridge Province; 3) The New England Province; 4) The Piedmont Province and 5) The Coastal Plain Province. Each has distinctive land forms which are related to the types and structure of the underlying bedrock and the geologic history of the province. The physiographic features ranging from "hard rock" mountains in Pennsylvania to steep, narrow valleys, gentle hills, and the sandy coastal plain fall in three major regions which are discussed below and are indicated in Figure I-2.

Upper Region:

The upper third of the area is in the Appalachian Plateau Province which is generally north of the fall line. This area is underlain by gently folded beds of sedimentary rock which dip to the northwest. The folds gradually decrease in amplitude and asymetry to the northwest. The Delaware Water Gap is the clearest exposure of the folded structures. The high flat top divides which characterize the area have been carved by glaciation and sculpted by the tributaries of the Delaware River. Steep, narrow valleys are common in the upper portion of the region, especially in the Poconos of Pennsylvania. The Catskill Mountains, in the Northwest of the Province are characterized by a rugged terrain and have the highest altitudes of the basin. Slide Mountain, at the eastern border reaches an elevation of 4,200 feet.

Central Region:

The major portion of the Central Region is situated in the Valley and Ridge Province. Rock formations ranging in age from 150 million years to perhaps a billion years have been folded, faulted, thrust up into high mountains, then worn down into lowlands and innundated by ancient seas again and again in geologic time. The strongly folded and faulted structures contrast to the gentle to flat rock structures of the Appalachian Plateau Province. In the southwest portion of the province, is the Appalachian Mountain section, where the Blue-Mountain Kittatinny Ridge is located. The area is characterized by a series of high parallel ridges separated by narrow valleys which can be seen from the I-80 Highway. These sharp crested ridges, called "hogbacks" are residual remnants of a relatively hard layer of sedimentary rock that has withstood the relentless forces of erosion. The natural features of this section provide the most dramatic and contrasting landscapes of the basin.

The steep narrow valleys change to rolling hills and irregular ridges in the Piedmont Province, in the southeast, and finally to the gently undulating terrain, low hills, and broad shallow valleys in the lower Great Valley section of the Valley and Ridge Province. The Great Valley, which is about 8 to 20 miles in width, extends northeast and southwest across the basin.

The Central Region also encompasses the Reading Prong, a moderately rugged southwest extension of the New England Province. The Reading Prong rises 500 to 1,000 feet above the valleys and crosses the width of the basin at the lower edge of the Great Valley.

Lower Region:

The lower region falls within the Coastal Plain. Geologically, the area is composed of a simple "soft rock" structure formed by layers of unconsolidated and semi-consolidated clay, silt, sand and gravel. They overlap to form a great wedge that thickens from almost nothing at the fall line to more than 6,000 feet at the Capes. Physiographically the Lower Region is the emerged part of the Coastal Plain, a gently sloping surface that extends 125 to 175 miles southeasterly from the fall line to the Continental Shelf. The sea inundates the outer part of the Plain and drowns the lower reaches of the streams, forming bays, estuaries and tidal marshes. The Delaware Bay and Estuary are formed by a continuing rise from sea level.

The seven county area is situated in the Appalachian Plateau Province, the Valley and Ridge Province and the New England Province.[5] The abrupt interfaces between the provinces produce interesting contrasts in the regional landscape. For example, the intersection of the Ridge and Valley Province and the Appalachian Plateau Province forms the striking Pocono Escarpment which extends through Monroe and Pike counties.

The physiography of the area has been a major factor in the area's past development.

Monroe, Sullivan and Pike, the most mountainous and rugged of the seven counties are in the Appalachian Plateau Province. The numerous marshes, lakes and swamps have been formed by the scouring forces of glacial action. The natural features which have, to some degree, discouraged intense urban development, have provided the opportunity for recreational resource development.

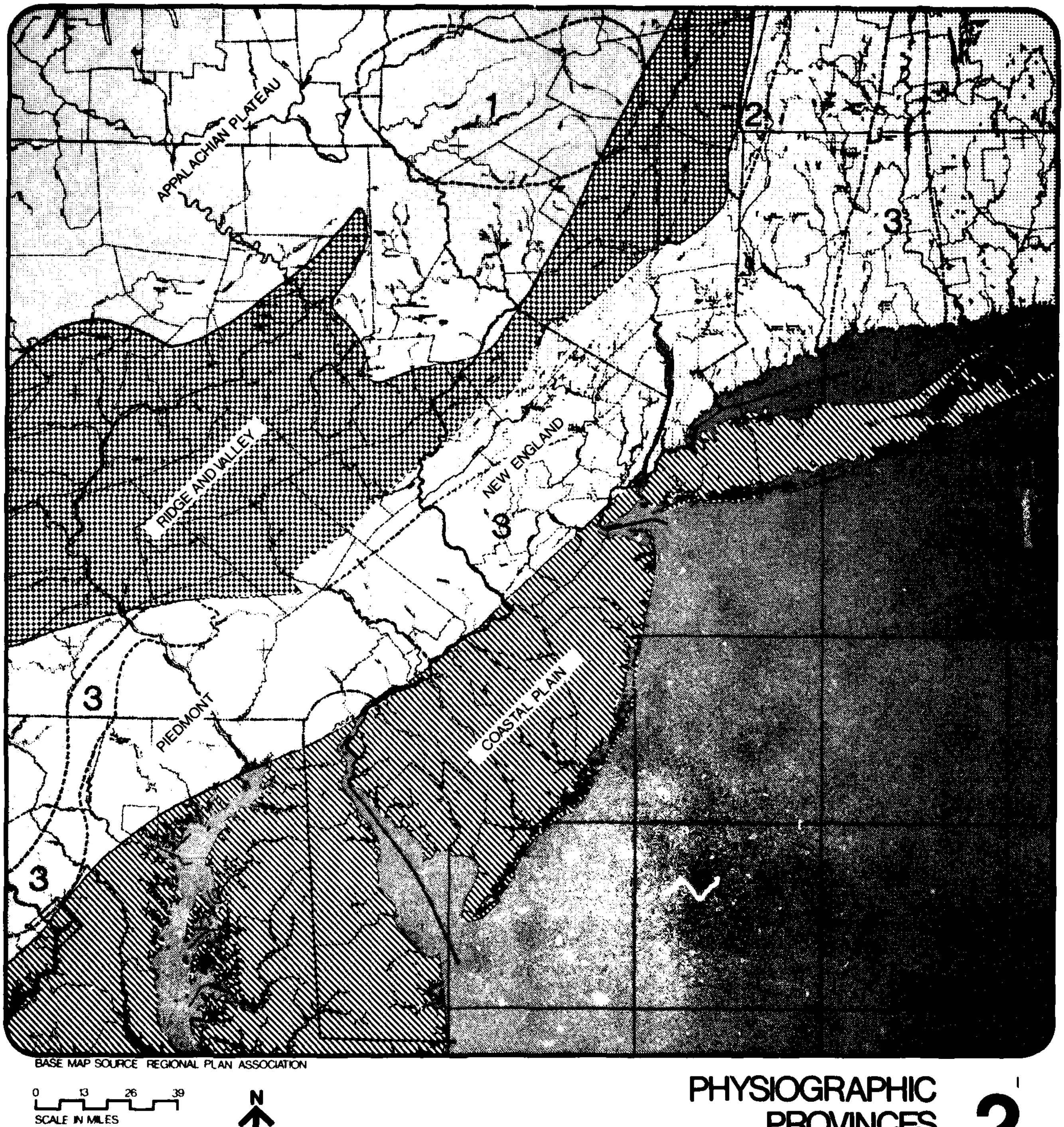
Southern Monroe County, northern Northampton, western Warren, Sussex, Orange and southern Sullivan Counties fall within the Appalachian section of the Ridge and Valley Province. The narrow valleys and high ridges form the setting for the proposed Tocks Island Dam and DWGNRA. The eastern portion of Sussex, Warren and Orange Counties lie within the gently sloping New England Province. The softer terrain and richer soils in these areas has made them attractive to agricultural use and suburban development.

I.A.1(b) Topography

The Catskill Mountains are the largest of the land masses, with elevations averaging about 2,000 feet, and with a number of peaks ranging between 3,000 and 4,204 feet. Moving southward, these elevations gradually decrease through the Pocono Mountains whose ridges vary from 1,000 to 2,130 feet and through the Great Ridge and Valley Province, whose elevations range from 500 to 1,000 feet. Elevations in the Coastal Plain range from sea level to 500 feet.

I.A.1(c) Geology

The ridge and valley structures which characterize much of the influence area can be attributed to alternating strata of resistant, semi-resistant, and non-resistant formations. In general, the rock formations are sedimentary and range from sandstones and conglomerates, which are relatively resistant to erosion processes, to less resistant carbonate limestone and shales. The strata directly relate to the physiographic regions discussed above.



PHYSIOGRAPHIC PROVINCES 2

SOURCE: NORTH ATLANTIC REGION WATER RESOURCES STUDY

LEGEND

APPALACHIAN PLATEAU PROVINCE
NEW ENGLAND PROVINCE
RIDGE AND VALLEY PROVINCE
COASTAL PLAIN PROVINCE
PIEDMONT PROVINCE
1 CATSKILL MOUNTAIN SUB-PROVINCE
2 TACONIC MOUNTAIN SUB-PROVINCE
3 TRIASSIC LOWLAND SUB-PROVINCE

The upland portion of the Piedmont Province is comprised of weathered crystalline rocks such as granite, gneiss and schist. The Piedmont Lowland is primarily underlain by soft shale and sandstone. The harder rocks in this lowland area such as diabase, basalt and argillite have resisted erosion thereby forming ridges, hills and plateau like surfaces. Chester Valley which extends across the Piedmont Upland is underlain by limestone and dolmite, which are soluable and therefore less resistant to erosion than the surrounding rocks.

The ridges of the New England Province are also formed by gneiss and hard crystalline rocks. In the northeastern part of the influence area in New Jersey, the ridges are blanketed by extensive deposits of glacial till. The valleys underlain by carbonate and shale contain even thicker deposits of glacial till and outwash which almost completely mask the bedrock.

The Great Valley exhibits similar characteristics. The higher northern area is formed by resistant shale, slate and sandstone while the southern lowlands reflect the weaker carbonate formations. Glacial deposits of varying thickness and permeability cover major portions of the northeastern section of the Great Valley.

The highest ridges, north of the Blue Mountain Ridge in the Valley and Ridge Province are formed by the region's hardest materials -- thick bedded quartzose, sandstone and conglomerate.

Folded beds of sandstone, shale and conglomerate can be found in the Appalachian Province. Glacial till mantles most of this area and the large valleys are filled with thick outwash.

The surficial geology of the seven county impact area reflects the geologic forces of the large basin. The western and northern portions of the regions are composed of semi-resistant sandstone and shale. The Blue-Kittatinny-Shawangunk Mountain ridges dominating the central landscape are formed by quartzite conglomerates. The oldest formations are found in the eastern sections of the area and consist of highly resistant metamorphic rocks such as gneiss, granite and marble.

I.A.1(d) Soils

The regions' soils fall within three major divisions: The Mountainous and Upland Plateau; the Ridge and Valley and Piedmont Plateau Area, including the Triassic Basin and the Scuthern New England Upland and Northern Shale and Limestone Belt; and the Coastal Plain Area.

Mountainous and Upland Plateau:

This region comprises the northern third of the Delaware River Basin. It is made up largely of sections of the Catskill and Pocono Mountains in the north and sections of the Appalachian Valleys and Ridges in the south.

Pocono-Catskill Section:

The soils in the Pocono-Catskill section are derived from glacial till and outwash material, which come from local non-calcareous sandstone and shales. Nearly all of the soils are gravelly or flaggy, and the steep slopes of the shallow soils are frequently stony. Occasionally, the outwash soils, such as Tunkhannock, occur in relatively extensive terraces, but in general the rolling, knobby kame predominates. Extensive areas of smooth, undissected bottom land soils, such as Barbour and Basher, are rare.

Appalachian Valley and Ridge Section:

In the Appalachian Valley and Ridge section, the soils are derived from a wide variety of parent rock materials, including acid gray sandstone and conglomerate; acid and calcerous gray and red shales; pure limestone and quartzite. Some of the principal soils are Hazleton, DeKalb, Weikert and Drifton.

The Ridge and Valley and Piedmont Plateau Area:

Ridge and Valley Section:

The Ridge and Valley area forms a belt running across the Delaware River Basin from northern New Jersey through eastern Pennsylvania. The two principal sub-divisions are the predominantly limestone areas along the south side of the area and the shale and slate belts to the north.

The main body of limestone in this area extends from Berks County to the Delaware River. The soil parent material is limestone and cement rock. Some of the principal, deep, soils are Washington which comes from glaciated material; Ryder, which was formed from cement rock; and Duffield, which was formed from unglaciated limestone material.

In the shale and slate sections, the principal soils are Kistler, Weikert, and Berks.

The Piedmont Plateau Section:

The Piedmont Plateau section is split by the Triassic Basin into two areas. The northern area forms a belt across the Basin from central New Jersey into eastern Pennsylvania. The southern part of the Piedmont Plateau lies in a broad belt across the extreme southeastern part of Pennsylvania and northern Delaware into south central New Jersey.

The soils of the Piedmont Plateau are mostly derived from gneisses, schists and quartzites. They have been formed by weathering in place of these local rocks. Gradual movement during a long period has built deep soils on the lower slopes; on steeper slopes, the soils are generally moderately deep. Slopes are generally moderate, but range up to very steep. The principal soils are Chester, Glenelg, Manor, and Glenville.

Triassic Basin:

The Triassic Basin is an area of sandstone and shale extending through the Piedmont in Pennsylvania and into New Jersey. It has a smooth or gently undulating to rolling relief.

Geologic conditions, such as faulting, folding and intrusions, make it hard to generalize for the whole area which sub-divides naturally into shale areas, sandstone areas, argellite ridges, and a number of other areas which do not fit well in any of these three groups.

The shale areas are predominantly areas of low hills. The sandstone areas have more rugged hills. The argellite ridges are distinctly higher than their immediate surroundings.

The largest part of the Triassic shale lands lies in Berks, Chester, Hunterdon, Montgomery, Mercer and Bucks Counties. It is an area of rolling uplands. Soils range from deep to very shallow, with moderately deep soils being most extensive. The soils are mostly residual from red shale formation. In extensive areas of Montgomery, Bucks, Mercer and Hunterdon Counties, the red shale is covered by a blanket of brown silt which makes the soil deeper and more uniform than is usual for a shale area. A compact silty pan creates poor drainage with some of the soils. The Penn soils are the most extensive soil series in the Triassic Basin. Most of these soils are moderately deep, except the Penn shale loam which is shallow.

Southern New England Upland Belt and Northern Shale and Limestone Belt: The two remaining areas that complete the make-up of the Region are the Southern New England Upland Belt and the Northern Shale and Limestone Belt. The entire section has been glaciated, and the soil materials consist of glacial till derived largely from the underlying rock which is calcareous and non-calcareous shale, slate, and limestone.

The Coastal Plain

The Coastal Plain area in the Delaware River Basin contains about 1,700,000 acres. The highly variable soil materials of the Coastal Plain were transported from higher elevations of the Atlantic slope and deposited in layers of unconsolidated beds. The deposits are probably a mixture of marine alluvial and glaciofluvial materials. The textural composition of the deposits varies from coarse gravels to fine clays. The surface varies from sands to silty clay loam and the subsoils range from sands to plastic clays. The interaction between the climate and parent materials make the soils naturally acidic.

The Coastal Plain consists of two major sub-divisions, an inner and an outer area, which are distinguished by the degree of sandiness and the extent of the clay strata. The innter Coastal Plain which comprises that area slanting toward the Delaware River contains a greater proportion of fine materials in the soils. Sub-soils are generally heavier than surface layers and sub-strata. The outer Coastal Plain which slants outward is relatively droughty and low in fertility because of the greater extent of deep, sandy soils. Although both the inner and the outer areas have wide flats of wet land, there is more marsh and swamp in the outer area. These soils include Sassafras, Collington, Golts, Butlertown, Christiana, Keyport, Woodstown, Fallsington and Elkton.

Most of the soils in the seven county area are residual and are derived from sedimentary shale or sandstone, which are neither deep nor productive. This is especially true of soils in Sullivan, Monroe and Pike counties. Only the narrow valleys of the Appalachian Mountain section have productive silty gravel and sandy loam soils. In Sussex and Warren counties there is a wide diversity of soils which relates to patterns of glacial deposition. Soils range from sand and loams through shale gravels to crystalline rock soil. In the Great Valley section, more fertile limestone soils of a clay loam type predominate.

I.A.1(e) Water Resources

Surface Water:

The surface water resources of the study influence area include numerous lakes and streams. In the steep mountain areas, excessive rainfall and the rapid melting of snow produce periodic flash floods due to excessive run-off.

Most of the region is dominated by the Delaware River and those tributaries which flow directly into it. The Delaware River is one of the largest on the east coast, with a drainage area of 6,780 square miles and average flow of 7,600 mgd at Trenton, New Jersey. The River's mean annual flow at the proposed damsite is approximately 6,735 cubic feet per second. Maximum and minimum daily stream flows at the damsite are estimated to be 230,000 and 513 cubic feet per second, respectively.

The Delaware River Basin periodically experiences large floods from heavy rains and spring thaws. Tropical hurricanes, northeasters, and localized thunderstorms have all resulted in record flows and significant flooding. The August, 1955, flood was a result of Hurricanes Connie and Diane.

Northern New Jersey streams have had fairly frequent and severe flooding from summer storms, hurricanes and continental storms. Some natural detention is provided by undeveloped lowlands, but narrow, constricted channels downstream and generally flat slopes result in considerable channel overflow. The New Jersey shoreline is subject to severe tidal flooding with damages resulting from inundation, wind, and storm-driven waves.

Low flows follow an annual cyclical pattern and usually last from three to four months. Seasonal low flow periods are associated with low rainfall, ground water outflow and high evapotranspiration. They generally occur in the summer and early fall, with the lowest run-off in the months of July through October. Four-month averages for this period range from about 10% to 15% of the annual average run-off in very dry years.

Ground Water:

The glacial cover is a major source of ground water and supplies good quality water to a large number of wells throughout the valley. Springs along the flank of the valley supply potable water. These springs, however, are highly dependent on rainfall cycles. The ground water resources west of the Kittatinny Ridge are also dependent upon rainfall; whereas east of the Ridge the area is heavily dependent on ground water transport along limestone aquifers. The limestone zones east of the Ridge provide groundwater recharge.

The water resources of the seven county area are also dominated by the Delaware River. Individual springs and wells provide potable water to rural areas throughout the region.

I.A.1(f) Climate

The Study Influence area, situated in the midatlantic temperate zone is influenced by two major north American weather systems. Low pressure cells originating in the south move along the coast bringing substantial rainfalls. Canadian high pressure systems bring heavy snowfall and cold temperatures to the upper northwest portions of the region. Cold temperatures are modified in the south and east by coastal influences.

Average temperatures vary with elevation; the upper region is 5 to 10 degrees cooler than southern areas. Annual rainfall varies from 42 to 60 inches in the upper region; from 42 to 50 inches in the central region and about 43 inches in the lower region. The highest monthly rainfall generally occurs in July or August, comprising 10 per cent of the annual total. February and October have the lowest average monthly precipitations.

The seven county area, located primarily in the central portion of the region has an average annual rainfall of 42 to 50 inches. The averages in northern sections range from 48 to 60 inches. Cooler temperatures in the upper region are important to winter recreation activities in the mountains.

Unique air drainage patterns created by land form configurations affect the region's micro climate. Cool air flowing southeastward from the plateau in the evenings rapidly chills the valley. The Kittatinny and Shawangunk ridges block air drainage. Thus extremely low temperatures occur in the valleys making them highly susceptable to frost and intense fog. Air inversions between the ridges and the plateau created by rapid cooling in the highlands are responsible for the stagnation of air in the valley. Because of this condition, the Stroudsburgs, Port Jervis and Milford could be susceptible to air pollution during periods of air stagnation.

I.A.1(g) Vegetation

The influence area's vegetation can be divided into three major sections: Marshlands; Riparian Vegetation and; Brush and Forests. (Refer to Figure I-3).

Marshlands:

The first section is directly influenced by salinity exchange and can be classified as saline to intermediate to brackish marshlands. This area extends from the entrance of the Delaware Bay up to the point of tidal intrusion around the Philadelphia-Camden area. Previously extensive marshes have been reduced by flood control measures such as diking and levying, and through direct intrusion by construction activities such as filling. Development activities upstream have indirectly contributed to the reduction of marshlands. The displacement of vegetation has increased erosion and therefore the degree of stream sedimentation. Once in the estuary, sediments were most likely to settle in areas with the slowest flows. Where marshes coincided with these areas, they were destroyed.

The remaining marshes, characterized by the degree of salinity required to sustain them can be divided into three types: saline, brackish and intermediate. Saline marshes depend on the highest degree of salinity; at least 25 parts per thousand, brackish 15 PPT, and intermediate marshes depend on the lowest; down to 5 PPT. A drastic shift in the salinity gradient could easily destroy the marshland ecology. This is caused by either reducing or increasing fresh water flows. The relationship of the project to salinity levels will be discussed in other portions of this Report.

Riparian Vegetation:

The Riparian vegetation zone extends along the Delaware River through the central and northern basin. Riparian vegetation is directly related to a stream or river and relies on water from these sources for subsistence. Species of riparian vegetation include River Birch, American Elm, Sycamore and Cottonwood, and Purple Losestrife.

Brush and Forested Areas:

The brush or grassland forest occurs in previously forested areas which have been cleared for either agricultural or development purposes. These areas, located primarily in the central portions of the basin interface with zones where native forests still remain. The native forests are located in the ridge areas and on the eroded slopes of the Delaware River's many tributaries and watersheds.

Before extensive clearing, the area extending from Wilmington, Delaware throughout the State of New York was most likely covered by an oak forest giving way to a beech or birch type forest in upstate New York.

The remaining oak-hickory forest can be seen within the reaches of New Jersey and Pennsylvania. This area gradually merges with an aspen birch forest near the tip of Pennsylvania extending through the New York area of the Delaware Basin watershed. A mixed oak pine forest can be found in the Pennsylvania side of the Delaware River. The pine, within this oak-pine mixture was probably part of the pine forest that totally covered Pennsylvania, but has been greatly reduced through intensive logging

BASE MAP SOURCE: REGIONAL PLAN ASSOCIATION

0 13 26 39
SCALE IN MILES

N

DELAWARE RIVER BASIN FOREST TYPES 3

LEGEND

- MAPLE · BEECH · BIRCH
- ASPEN · BIRCH
- OAK · HICKORY
- OAK · PINE
- LOBLOLLY · SHORTLEAF PINE
- WHITE · RED · JACK PINE
- ELM · ASH · COTTONWOOD
- OAK · GUM · CYPRESS
- NON FORESTLAND WITHIN DELARE RIVER BASIN
- DELAWARE RIVER BASIN BOUNDARIES

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activity. Remaining forests in the Atlantic Coast region are characterized by Loblolly, Shortleaf and other Pine stands.

Seven-County Vegetation:

The seven-county area is characterized by a free-flowing river containing a number of islands. The left bank of the river facing north consists of a fairly wide flood plain. The native, nutrient laden soils have been used for agriculture, thus disturbing a major portion of the native vegetation in the DWGNRA area.

The slopes on both sides of the river are still heavily forested with oak and hickory forests changing to beech or birch forests in the upper area near Port Jervis. Only very small sections of native riparian vegetation remain in the river basin, and these mainly around the Minisink Hills and on the two islands directly north and south of Tocks Island. The largest area of riparian vegetation is found on the eastern side of the stream bed between Flat Brookville and Wallpack Center. Agriculture in a very narrow strip around the riparian lands has displaced the native species. Numerous tributaries enter the DWGNRA area and are characterized by ravine vegetation which includes some native forest stands.

There are numerous marshes and swamps on both sides of the river in the plateau region, with small agricultural ponds or other very small bodies of water, often at the head of tributaries. The marshes were, in all probability, lakes which have been filled in by the activity of man and are approaching a "solid state" or the state of being able to support terrestrial vegetation. In their present form as marsh or freshwater swamp, they are reproductive and very valuable to the total eco-system.

Portions of the Delaware River bank area are steep sided and contain a variety of cliff vegetation probably not found anywhere else in the Basin. These rare varieties are found especially in the Milford/Matamoras areas, which are proposed to be flooded as part of the Tocks Island Lake Project.

I.A.2. LAND USE

This section describes the dominant land use patterns in the Delaware River influence area. Its scope is designed to provide a general understanding of the major land use trends and some of the elements distinguishing the subregions. More detailed land use information relating to the seven-county impact area is presented in Chapter XXII.

In general, the land uses in the Delaware River influence area are integrated in a regional system dominated by New York City and Philadelphia. The transportation network interconnects the various subcenters within the region to each other and to the major commercial and employment centers.

Existing land use patterns in the area are the result of a general expansion of population, industry and commerce from New York City and Phildelphia to suburban zones or development rings. To some extent, a similar process has occurred in the secondary centers such as Trenton, Harrisburg, Wilmington, and Scranton. The rings of development, defined primarily by density and their distance from New York and Philadelphia include: 1) urban core, 2) inner ring, 3) intermediate ring, and 4) outer ring.

The outward movement and expansion is related to the industrial needs for large tracts of land, and the growing demand for single family dwellings outside the urban cores and older suburbs. Vernon and Hoover, in their book, Anatomy of a Metropolis, show that the density gradient from the urban cores has been leveling off. They say that what "seems to be happening is that a ring of maximum population growth exists; and as the decades have gone by this ring has moved farther out from the core." The population statistics in Section I.A.4 show that this trend has continued.

The outward thrust in the geographic pattern of population distribution actually accelerated after 1970 in the New York Region. Historically, population growth in the New York Metropolitan cores was the first in the region to stabilize and within the past three years there has been a population decrease. The population of Manhattan peaked in 1910. Growth then shifted to counties such as Nassau, Fairfield and Westchester, directly surrounding the metropolitan core, which peaked in 1950. As the remaining building space became less available in these areas, their share of the region's growth began to decline and to shift to counties still further from the center. Thus, after 1950, Rockland, Putnam, Morris, and Ocean counties experienced the greatest proportion of growth. After 1970, growth extended even further outward as counties such as Sussex and Ulster, made accessible to core area by improved highways, began to capture larger portions of the New York Metropolitan area's growth.

Table 1-1 1970 Population Density in The Delaware River Basin Influence Area

Core Counties	Population Density per square mile
New York:	
The Bronx	35,895
Kings	18,400
Manhattan	66,923
Richmond	5,086
Queens	18,400
Pennsylvania:	
Philadelphia	15,175
Inner Ring Counties	
New York:	
Nassau	4,944
Westchester	2,019
New Jersey:	
Bergen	3,834
Camden	2,065
Essex	7,173
Hudson	12,933
Mercer	1,336
Middlesex	1,871
Passaic	2,400
Union	5,273
Pennsylvania:	
Delaware	3,270
Montgomery	1,258
Intermediate Ring Counties	
New York:	
Dutchess	273
Orange	266
Putnam	245
Rockland	1,306
Suffolk	1,213
New Jersey:	
Atlantic	308
Burlington	395
Cumberland	243
Gloucester	525
Hunterdon	165
Monmouth	970
Morris	819
Ocean	325
Somerset	646

Table 1-1 (Continued)

Pennsylvania:	
Berks	344
Bucks	679
Chester	365
Lehigh	734
Northampton	571
Delaware:	
New Castle	881
Connecticut:	
Fairfield	1,266
Outer Ring Counties	
New York:	
Delaware	31
Sullivan	54
Ulster	124
New Jersey:	
Cape May	223
Salem	165
Sussex	147
Warren	204
Pennsylvania:	
Carbon	125
Monroe	74
Pike	22
Schuylkill	204
Wayne	40
Delaware:	
Kent	138
Sussex	147

Source: U.S. Census County Data Book, 1972.

This outward expansion of population has been primarily oriented around access corridors to New York. Areas of greatest development within all rings can be found within easy access of the major interstate routes such as I-78, I-80, I-84, I-95, and the New Jersey Turnpike.

The gradual leveling off of the population density gradient from 1920 to 1970 resulted in a sharp rise in the urbanization and development of the outlying land areas. The Regional Plan Association estimates that within the 22 county region around New York City, less than 200 square miles of land were developed in 1920. Since that time, the total amount of developed land has been doubling about every twenty years. For example, between 1950 and 1970, the total development land in the New York region increased from 1,100 to about 2,200 square miles.

Land development in the intermediate ring counties proceeded at a faster pace than that in the older sections of the region, e.g., within the core and inner suburbs around New York City (22 counties) land consumption for new development from 1960 to 1970 averaged 50 square miles annually, compared to an average of 68 square miles for the entire New York region (31 counties).

Land in residential uses had the greatest increase from 1960-1970 in the New York region, and now accounts for approximately 62 percent of the region. Land in non-residential uses expanded at a somewhat slower rate and accounts for about 16 percent of developed land. Land for streets and highways expanded least of all and accounts for approximately 22 percent of developed land in the New York Metropolitan counties.

It is important to note, however, that while the existing land usė configuration represents dependence of industry and employment on New York, this dependence may be weakening. As more jobs move from the core areas and corporate headquarters internalize support services, the importance of the center city will decrease. This is reflected by some of the development in the last decade.

A similar process of outward expansion has occurred in the region surrounding Philadelphia. There has been a continual movement of population, commerce and industry since 1920 when the city's rate of growth began to decline. Philadelphia first developed along both sides of the Delaware and Schuykill Rivers especially near river crossings. The largest outward thrust occurred in the 1950's when commerce, industry and the population moved to the suburbs directly surrounding the city core to take advantage of available space and neighborhood amenities. It was during this period that Philadelphia's population actually began to decrease and areas to the north of the CBD along the Delaware River, such as Trenton and Princeton grew dramatically. The outward growth was accompanied by a large immigration from the south to the center city.

At the present time, outer areas including upper Bucks county, Burlington, Gloucester, Chester and Atlantic county are experiencing rapid suburbanization which accelerated after 1970.

Growth has occurred along the major transportation corridors which include I-95 and 76, and Routes 611, 309, and the Pennsylvania Turnpike in Pennsylvania, and Routes 73, 30, 70 and 38 in New Jersey. The Penn Central and Reading Railroads have also been significant in the region's growth (refer to Figure I-4).

The similarity of land uses within the rings and their relationship to regional processes within the influence area are indicated in the discussion of residential, commercial/industrial, and open space land uses below.

I.A.2(a) Residential

Residential land use characteristics are directly related to population density, growth and migration patterns. (Refer to Table 1-2 and Figure 1-4). From 1960 to 1970, the major metropolitan areas which had densities as high as 66,923 people per square mile in Manhattan, either lost population or had minimal gains. Manhattan's total population decreased 9.4 percent and Philadelphia's was reduced by 2.6 percent. Directly related to this fact is a negative or low in-migration rate. There was a net out-migration of 12.9 percent from Manhattan and -1.2 percent from the Bronx from 1960 to 1970. Older suburbs surrounding the metropolitan cores such as Passaic, Essex, Bergen and Union outside New York City; and Delaware, Salem and Camden counties around Philadelphia had low or negative in-migration rates. Typically, these suburbs have high densities ranging from 3,834 and 7,173 people per square mile in Bergen and Essex counties to 2,065 and 3,270 per square mile in Camden and Delaware. These older, relatively crowded areas which experienced their greatest growth during the 40's and 50's have already reached their maximum single family development potential.

Table 1-2 Population and Housing Densities in the Delaware River Influence Area, (1970)

	Population per Sq. Mile	Housing Density per Sq. Mile	% in One-Unit Structures
Urban Core			
High (Manhattan)	66,923	33,210	8.8
Medium (Queens)	18,400	6,510	64.7
Low (Philadelphia)	15,175	5,260	66.6
Inner Ring			
High (Hudson)	12,933	4,631	13.0
Medium (Union, N.J.)	5,273	1,688	57.1
Low (Montgomery)	1,258	389	75.3
Intermediate Ring			
High (Rockland)	1,306	353	70.5
Medium (Gloucester)	525	155	82.0
Low (Hunterdon)	165	52	81.6
Outer Ring			
High (Cape May)	223	106	74.8
Medium (Carson)	125	29	78.8
Low (Pike)	22	10	89.9

Source: United States Census: County Data Book, 1972

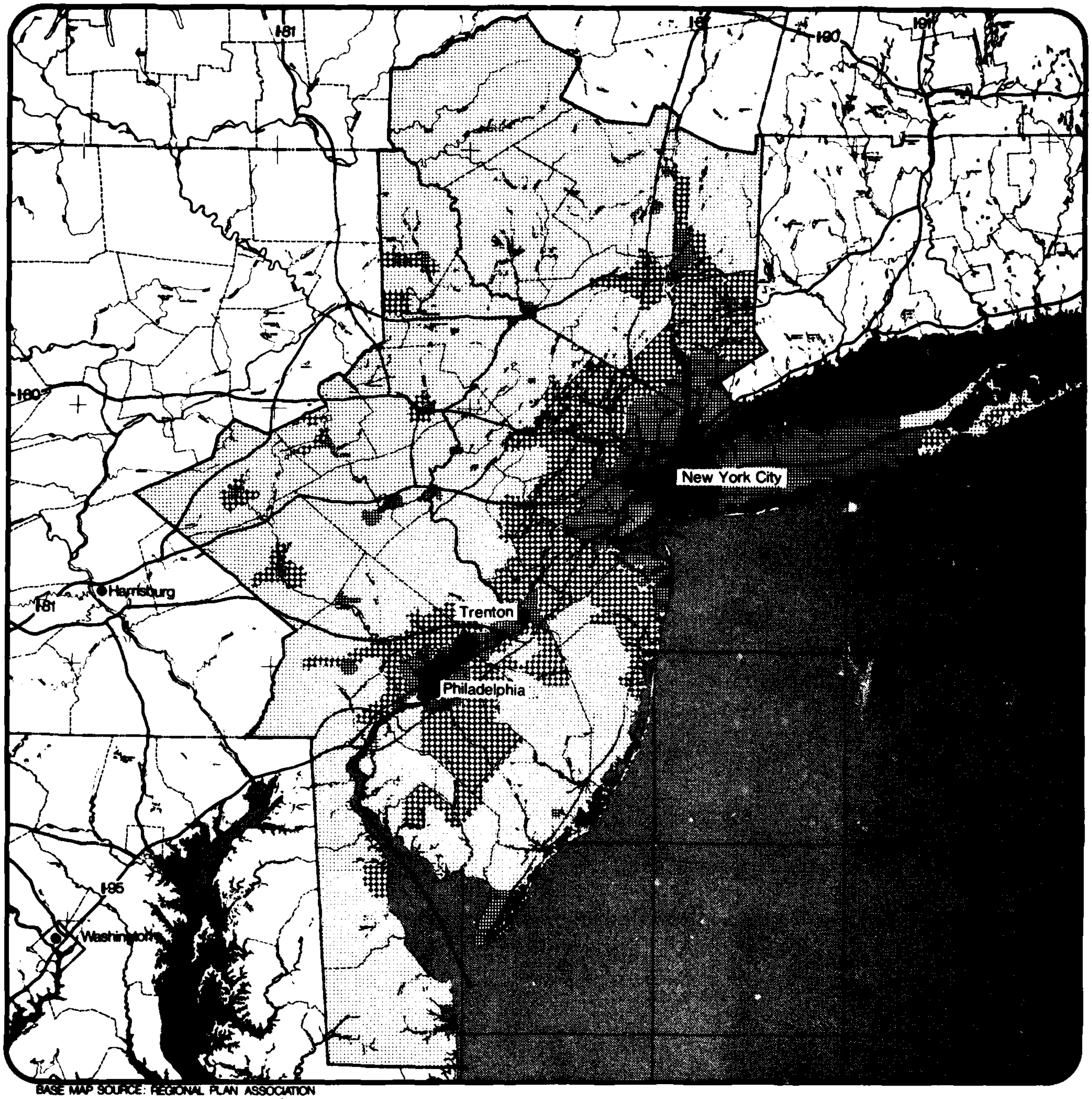
Out-migration and low growth rates were also experienced by the counties in outer rings of the influence area. Delaware County in New York, Schuylkill and Carbon Counties in Pennsylvania, and Salem and Sussex in Delaware have had out-migrations ranging from 1.4 to 8.2 percent.

From 1960 to 1970, suburbs closest to the urban cores experienced the greatest influx of people and residential development. The major portion of population expansion in Ulster, Orange, Sussex and Union Counties for example, was due to in-migration. The availability of large tracts of land for suburban communities and improved access connecting these areas with other parts of the region is directly related to their growth. These areas are attractive to people seeking lower densities and amenities associated with a semi-rural atmosphere. Densities in these areas average about 1,000 people per square mile.

The outlying areas around the western fringe of the Basin experienced relatively low growth, ranging from 4.8 percent in Wayne County to 12.2 percent in Lehigh County during the same period.

Patterns in housing density per square mile generally correspond to population density. There was an average of 33,210 units per square mile in the Manhattan region and 5,260 units per square mile in Philadelphia. Densities in the inner ring ranged from approximately 4,631 in Hudson County to 389 in Montgomery County.

Urbanizing counties in the intermediate ring have densities ranging from 353 to 52 and rural areas in the outer rings from 106 to 10 units per square mile.



BASE MAP SOURCE: REGIONAL PLAN ASSOCIATION

0 13 26 39
SCALE IN MILES

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INFLUENCE AREA DEVELOPMENT PATTERNS 4

LEGEND

URBAN DEVELOPMENT (PERSONS PER SQUARE MILE)

- DENSE (10,000 +)
- MEDIUM (1000 - 10,000)
- LIGHT (300 - 1000)
- RURAL (LESS THAN 300)

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On the whole, outside the urban centers, most people lived in detached structures with slightly more people living in single family homes in urbanizing areas. Tri-state Planning Commission's forecasts for the region suggest that town house and multi-family structures will capture greater shares of the new housing construction in all sectors of the influence area.

The seven county area lies in the intermediate and outer rings of the urban centers and has an average population density of 191 persons per square mile. Northampton and Warren Counties are geographically within the sphere of the secondary cities of Allentown, Phillipsburg, Bethlehem and Easton and are experiencing suburbanization related to the outward movement from these cities. Sussex and Orange Counties, with large tracts of potential development land and good highway access, has high growth rates associated with the continual migration from New York and its inner suburbs along the interstate corridors. The Newburg, Wallkill and Goshen areas in Orange County are developing into sub-regional centers.

While the respective population densities of Northampton, Orange, and Warren Counties have grown to 571, 266, 204 people per square mile, Pike, Monroe, and Sullivan Counties have had less absolute development during the past ten years. They are still largely rural, with densities of 22, 74 and 54 people per square mile, respectively (Refer to Table I-3).

Table 1-3 Population and Housing Density of Seven County Area

	Population per sq. mi.	Housing Units per sq. mi.	% Population in 1 unit Structures
Monroe	74	28.6	78.8
Northampton	571	187.0	75.0
Pike	22	10.1	89.9
Orange	266	84.1	65.5
Sullivan	54	23.0	68.5
Sussex	147	25.7	86.8
Warren	204	67.8	75.3
7 County Average	191	66.8	77.1

Source: 1970 Census of Housing, Department of Commerce.

Relative growth in residential construction show Sussex, Orange and Northampton Counties to be above state average increases. (Refer to Table 1-4).

Table 1-4 Total Housing Units: Seven County Impact Area, 1960-1970

	Total Units 1960	Total Units 1970	% Change 1960-1970
New Jersey	3,581,897	3,926,621	19.5
Sussex	31,218	25,098	24.4
Warren	24,964	21,324	17.1
New York	4,299,758	5,695,880	10.6
Orange	74,753	67,133	14.3
Sullivan	47,401	45,020	5.3
Pennsylvania	3,926,621	3,581,877	9.6
Northampton	70,548	64,028	10.2
Pike	10,139	9,612	5.5
Monroe	21,047	19,150	9.9

Source: United States Census Bureau, Department of Commerce, Census of Housing, 1970.

Second home development during the late sixties was an important factor in the development of Monroe, Pike and Sussex Counties. During the last few years, however, more and more second homes have been increasingly converted to year round residences. This trend is expected to continue and increase with the new highway improvements.

I.A.2(b) Commercial/Industrial

In 1970 non-residential developed land uses, including manufacturing/warehousing offices, commercial, retail and institutional buildings (schools, hospitals, libraries and museums) comprised about 40 percent of all developed land in the influence area. In the region encompassed by the Regional Plan Association, manufacturing and ware-housing consumed 33 percent of all non-residential floor space. Office buildings and commercial structures accounted for 13 and 26 percent of the total developed area, and institutional buildings consumed 26 percent of developed areas.

The geographic distribution of commerce and industry throughout the study area, like the residential land use patterns, has been shifting steadily and persistently from one decade to the next from the center city outward. The demand for space has been forcing manufacturing plants from the older urban cores like Manhattan, Philadelphia, and Wilmington to suburban locations for the past 50 years. Vernon and Hoover report that "after 1889, both the Inner and Outer Suburbs began to register relative increases as the cores showed a relative decline. Since then, the outward shift toward these areas has been uninterrupted and has proceeded faster even than before." In 1973, the

Regional Plan Association identified two major trends in the distribution of commercial and industrial activity; one, the concentration of national and international headquarters in New York with governmental headquarters in corresponding state and local capitals,and two, the location of industries in intermediate ring suburbs. The intermediate counties were able to attract the bulk of the region's industrial development from 1960-1970 because of relatively low land costs and land availability, low tax rates, good accessibility from the interstate highways, and a mobile and varied labor force. Counties along major intra-regional transportation corridors, such as Middlesex, Monmouth and Somerset captured a major portion of the growth. In the outer ring counties, low residential densities, fewer limited access highways, the lack of a technically skilled labor force, and environmental constraints limited manufacturing plant developments.

Inner ring counties such as Nassau, Westchester and Bergen experienced rapid office growth from suburbanization of headquarters, formation of regional or business service offices and location of clerical intensive operations.

The intermediate ring's growth in office development can be traced to the successful competition of prestigous suburbs with Manhattan for elite corporate headquarters and the internalization of support services that weaken industrial ties to the urban core.

The percentage of land devoted to commercial and industrial use varied widely throughout the area. Industrial land ranged from 5.4 percent in the inner core to 2.3 percent in the inner ring and 0.01 percent in the outer rural areas. Commercial uses ranged from 11.0 percent of the county in Manhattan to 0.5 percent in Northampton and 0.2 percent in Sussex Counties.

I.A.2(c) Open Space

Open Space can be divided into three categories: 1) Agricultural, 2) Recreational and 3) Undeveloped or vacant land.

Agriculture:

Agricultural land use directly relates to soil capability. Within the influence area most agriculture is located in the intermediate or outer rings. Land suitable for agriculture has been largely converted to suburban uses in inner rings, and steep mountains and poor soils limit agriculture in mountainous areas such as Monroe, Pike, Carbon and Schuylkill Counties. Those counties with more than 30 percent of their land in farms in 1969 include Delaware, Wayne, Dutchess, Orange, Northampton, Lehigh, Berks, Chester, Bucks, Salem, Cumberland, Mercer, Monmouth, Burlington and Hunterdon.

Since 1969 the total amount of agricultural land within the influence area has declined significantly and current agricultural uses range from none in the urban areas to 61% in the rural outer rings. Current statistics for the New York and New Jersey counties indicate that agricultural land has decreased by about 10 percent in the region. The Blueprint Commission on the Future of New Jersey Agriculture reported an annual average loss of 10,000 acres since 1968. While the rate is significant, it has decreased from an annual 20,000 acres prior to the enactment of the New Jersey Farmland Assessment Act in 1968. This act taxes agricultural land on the basis of

income rather than land value and therefore reduces the economic burden on the farmer. New York and Pennsylvania have similar legislation.

Outdoor Recreation

In general, the large state parks are located in the most rural portions of the influence area where densities are the lowest and a large percentage of the land is undeveloped. Municipal parks, on the other hand, occur mostly in the more central areas to serve their large populations. County parks are generally located in suburban fringe areas and provide facilities and activities which are not available in smaller municipal parks, but are more accessible than state parks.

The Delaware Valley Regional Planning Commission (DVRPC) has reported that in the eight county area surrounding Philadelphia 63 percent of public open space is in state parks. This means that the highest percentage of open space occurs in the outlying areas. Similarly, the Regional Plan Association estimates that the nine outer counties in the region contained 60 percent of the New York region's open space, while the inner 22 counties, with 91 percent of the population, had 40 percent.

The gap between the outdoor recreation needs and public open space land appears to be increasing in both the New York and Philadelphia regions. The DVRPC determined that there is a current deficiency in municipal park land of 16,500 acres in a region which encompasses Bucks, Chester, Delaware and Montgomery counties in Pennsylvania and Burlington, Camden, Gloucester and Mercer counties in New Jersey. The deficiency of county parks is 32,000 acres and of state parks is 84,000 acres.

The DVRPC estimates that by 1985 an additional 10,000 acres of municipal park land, 17,000 acres of county park land and 32,000 acres of state park land will be required to meet the needs of the region's growing population.

In order to meet the open space target of 1,150 square miles that was established by the Regional Plan Association and the Metropolitan Regional Council in 1960, the New York Region would have to acquire approximately 200 square miles of open space land. While the rate of land acquisition in the region increased dramatically in the late 1960's to an average 16.6 square miles annually, the rate of acquisition dropped after 1970 to 10 square miles annually. In 1973 only 7 square miles of open space were acquired.

The seven county area has a total of 318,533 acres of public open space land which includes state parks, forest and game land and land already acquired for the Delaware Water Gap National Recreation Area. Approximately 11 percent of the area is in outdoor recreation uses. This is compared to an estimated 7 percent in both the Delaware Valley and the New York Region encompassed by the Regional Plan Association.

The following Table 1-5 represents a sample range of land uses by development ring in the influence area on a county basis.

Table 1-5 Range of Land Use Mixes in Delaware River Influence Area Development Rings
(Percent of total acres)

	Residential	Commercial	Industrial	Agriculture	Open	Other
Urban Core						
Upper Range[1]	23.0	11.0	5.4	0	0.4	64.0
Lower Range[2]	53.3	8.2	16.1	0	11.3	31.1
Inner Ring						
Upper Range[3]	44.0	4.2	2.3	1.5	13.0	35.0
Lower Range[4]	19.5	1.4	1.4	7.9	22.9	45.9
Intermediate Ring						
Upper Range[5]	15.0	0.8	1.5	**	67.0	15.7
Lower Range[6]	4.0	0.2	*	9.0	50.0	36.8
Outer Ring						
Upper Range[7]	2.4	0.4	0.1	61.0	21.0	15.9
Lower Range[8]	1.8	0.6	0	5.8	80.0	12.2

Sources
1) Manhattan, Land Use and Natural Resource Inventory, New York State, 1969
2) Trenton, Planning Department, 1975
3) Nassau County, Land Use and Natural Resource Inventory, New York State, 1969
4) Suffolk County, Land Use and Natural Resource Inventory, New York State, 1974
5) Northampton County, 1972 Land Use Update, Lehigh Northampton Joint Planning Commission, 1973
6) Sussex County, Planning Department, 1975
7) Wayne County, Pennsylvania, Development Plan, 1971
8) Sullivan County, Land Use and Natural Resource Inventory, 1974

* Negligible
** Northampton statistics include agriculture and open-space in the same category.
*** Includes streets, utilities, swamp areas, developed recreation land.

I.A.3 TRANSPORTATION

Highway

A network of interstate, regional and local highways is the core of the transportation system presently serving the area. The main components of the highway network are: Interstate Highway 84, from Scranton through the north end of the Project to New York and Connecticut; and Interstate 80 passing through the Delaware Water Gap and extending from New York City to the western portion of the country. Links to the north, via I-81 and the New York Thruway (I-87), and connections to the south via the Northeast Extension of the Pennsylvania Turnpike, I-95 and the New Jersey Turnpike complete the major long distance links. Interstate 78, runs in an east west direction and provides access between Harrisburg, Allentown and Easton and Newark. These interstate and regional routes carry the bulk of long distance interstate commerce, business and recreational travel. A second system, more directly related to the seven county area serves the day trip and weekend travelers visiting the area and is subjected to the seasonal surges of this recreational travel. The principal routes in Pennsylvania are Routes 739, 402, 191, 940 and U.S. Routes 6, 209 and 611; in New Jersey, Routes 23, 94, 15, 521, 519, 31, 24, 46 and U.S. 206; in New York State, Routes U.S. 6, U.S. 209 and Routes 17, 42 and 52.

As mentioned above and as described more fully in Chapter XXV, almost the entire network of highways, especially those directly serving the area, is presently carrying heavy recreational traffic at capacity or near capacity conditions. Congestion and delays prevail during the summer weekend peak hours; particularly on Sunday and Friday evenings. To alleviate traffic conditions and to meet the demands of traffic growth, the Departments of Transportation of Pennsylvania and New Jersey have completed and are planning a number of improvements and additions to the highway network which would mainly serve the recreational travel to the seven county area.

These highways and the planned improvements were all developed prior to and during the 1960's. Route I-80 was completed through New Jersey in 1974 and I-84 through New York and into Pennsylvania in 1972 (except the uncompleted link to Scranton). The new awareness of the environment and the energy crisis have shifted the emphasis to public transportation, rail and bus. However, new expressways and improvements and upgrading of existing highways are planned to meet the increasing demands of recreational travel and of local travel, though their implementation is far from certain. Evidence of increasingly heavy traffic and congestion associated with normal growth of permanent and visitor populations is reflected by the following traffic volumes in Table 1-6. Chapter XXV.A.1(e) presents a detailed discussion of traffic patterns on major park access routes.

Table 1-6 Typical Traffic Levels (1974)

Location	Summer Sunday Average Peak Hour Traffic	Average Annual Daily Traffic	Hourly Capacity (Level E)
Route I-80 west of Route 94	3,300*	16,500	3,600*
U.S. 206 south of Andover	1,950	15,300	1,500
Route 23 west of U.S. 202	2,900*	23,900	3,600*
U.S. 209 north of Route 402	1,870	12,000	1,800
Route I-84 west of Route 17	1,760*	14,700	3,600*

*One-way volumes, others are two-way

Rail and Bus

Early in this century, the Delaware Water Gap and the Port Jervis areas were the crossroads of an excellent system of railroads serving the area and with connections to all major population centers in all directions. There was frequent and convenient passenger service to Philadelphia, Trenton and Camden, and to New York City and northern New Jersey. There has, however, been a steady decline in railroad passenger service to the seven county area including the discontinuation of service to Stroudsburg in 1960. The only rail passenger service to the area is provided by the Erie-Lackawanna's Hoboken - Port Jervis run. The passenger service to and from New York includes two morning and two evening trains, Monday through Friday, and one morning and evening train on Saturdays. Jersey Central's Newark - Phillipsburg, Reading Railroad's Philadelphia - Bethlehem Lines, and Erie-Lackawanna's passenger service to Netcong, New Jersey provide additional service to the eastern edge of Sussex County. Freight trains continue to serve most of the region on trackage which is in relatively good condition. These lines include the Lehigh and Hudson River, the Susquehanna, Lehigh-Valley, Reading, Penn Central, and Erie-Lackawanna and Central Railroad of New Jersey. The presence of trackage in key locations throughout the impact area permits the possible revival of rail service into the region if sufficient demand occurs, however electrification would have to be extended beyond Netcong. This subject is treated in further detail in Chapter XXV.

Bus service is primarily scheduled through the area to other locations. Points of origin or destination are not oriented around the proposed recreation area. The problem of limited rail access to the seven county area could be offset by improved bus transportation. A number of lines provide modest service to the area, connecting Scranton, Port Jervis, Milford, Newton, Sparta, and Blairston to New York City. Although most of the routes are scheduled for the commuter, some weekend service is presently available.

Of particular note is the fact that many of the lines expand service during the summer months, indicating a tourist demand for public transportation to this area.

The State Departments of Transportation have expressed a preference for improved bus rather than rail service as the overall costs of maintaining bus service would be less.

Air

Air transportation does not presently represent any significant component of the transportation system as far as volume of passengers to the area is concerned. A number of small county and private airports provide service. It is not anticipated that significant amounts of travel to the seven counties will be by this mode.

I.A.4 DEMOGRAPHY

The social and economic structure of the Delaware River Basin influence area has elements of both homogeneity and diversity. On the one hand, there is the unifying force of common orientation to the concentrated and diverse economies of the New York-Philadelphia urban complex -- in work patterns, traffic networks, economic interaction, use of natural resources and institutional arrangements of one kind or another. On the other hand, the area is permeated with differences representing a great variety of local economic activities, cultural patterns, political arrangements and land use profiles.

The pattern of horizontal development from the major urban nodes -- New York, Philadelphia -- has been clearly evident for more than a century. However, the process of expansion within the region has shown significant changes in recent decades. Industrial activity in the core cities and surrounding urbanized counties has not only leveled off but actually declined. New plants have moved in greater numbers into the second and third ring suburban and rural counties.

Accompanying this industrial decentralization has been a massive growth in outlying residential and commercial developments reflecting an expansion of commutation to central New York, Philadelphia and other major urban cores.

These spatial shifts in where people live and work, of course, are part of a national phenomenon. Behind these trends are basic changes in American living and working patterns -- increased mobility of the American family, rising demands for improved amenities in community life, increased personal income to support these demands, changes in transportation patterns, introduction of new technologies and other innovations affecting the physical location of homes and factories.

While these patterns of decentralization have been observed over many decades, they reached a peak during decades between 1950 and 1970. Since 1970 other factors such as the energy crisis, declining birth rates, rising cost of living, the economic recession, and the environmental resource preservation needs, have significantly altered the previous economic growth patterns and lifestyles within the region. The national birth rates have dropped below the replacement level and the average family size has declined to its lowest level in the nation's history. The rapid rise in cost of living coupled with a current major recession have significantly slowed the past cycle of economic expansion.

These patterns of decentralization, the recent decline in economic activity, the drastic drop in the birth rates and other similar factors affecting the patterns of where people work and live are clearly observed within the large, highly urbanized Delaware River influence area.

The Delaware River influence area embraces a significant proportion of the nation's population. The area contained one of every eight United States residents in 1973. However, it grew more slowly than the nation as a whole during the 1960-73 period. Consequently, its share of the nation's population declined as rapidly growing areas of the southeast and southwest absorbed a larger proportion of the nation's growth as shown in Table 1-7.

Table 1-7 Population Trends Comparison, Delaware River Basin Service Area, Northeast and United States, 1960-1973 (thousands)

	1960	1970	1973	Gain, 1960-1973 Amount	Percent
Influence Area	23,059	25,763	25,899	2,840	12.3%
Northeast	44,678	49,051	49,545	4,867	10.9%
United States	179,323	203,235	209,844	30,521	17.0%
Influence Area percent of:					
Northeast	51.61%	52.52%	52.27%	58.35%	
United States	12.86%	12.67%	12.34%	9.31%	

Sources: U. S. Census of Population, 1960 and 1970 and CPR Series P-25 and P-26.

During the thirteen-year period between 1960 and 1973, the nation's population increased by 30,521,000 persons -- a gain of 17.0 percent while the population in the influence area increased by 2,840,000 persons or a gain of 12.3 percent over the 1960-73 period; increasing from 23,059,100 persons in 1960 to 25,899,400 persons in 1973.

As shown in the above table, the influence area's share of the nation's population declined consistently over the period from 12.86 percent in 1960 to 12.34 percent in 1973. In contrast, the influence area's share of the northeast population increased over the 1960-70 period; declining however, over the 1970-73 period.

I.A. 4 (a) Components of Population Change, 1960-1973

The influence area's population growth from 1960 to 1973 was primarily due to a natural increase and an excess of births over deaths.

People were still migrating into the region during the 1960's but this trend reversed in the first three years of the 1970's as the influence area experienced net out-migration of population. The natural population increase accounted for 80 percent of the 1960-70 population gain and all of the gain from 1970 to 1973 as more people moved out of the region than moved into it.

Table 1-8 Components of Population Change, Delaware River Influence Area, 1960-1973

	Number
Population, 1960	23,059,100
Natural Increase	2,161,500
Net Migration	542,300
(Net Gain, 1960-1970)	(2,703,800)
Population, 1970	25,762,900
Natural Increase	408,800
Net Migration	-272,300
(Net Gain, 1970-1973)	(136,500)
Population, 1973	25,899,400

Source: U.S. Census of Populations, 1960 and 1970; CPR, Series 25 and 26; PHC (2) 1970.

The influence area added 2,703,800 people from 1960 to 1970 and 136,500 from 1970 to 1973. Natural increase resulted in a population gain of 2,161,500 80 percent of the total gain from 1960 to 1970. Although the rate of natural increase appreciably slowed in the first three years of the 1970's from a 1960-70 annual rate of 216,150 to a 1970-73 annual rate of 136,266 due to declining birth rates, 408,800 people were added from 1970 to 1973 because of a natural increase. Also adding to the population gain from 1960 to 1970 was the in-migration of 542,300 residents. This trend was reversed during the 1970-1973 period during which persons out-migrated from the area on a net basis.

I.A.4.(b) Population Shifts, 1960-1973

Two major population shifts were observed from 1960 to 1973 in the influence area. The first shift was from the core cities to their immediate suburbs and to outlying counties. The second major shift was out of the region entirely -- particularly evident from 1970 to 1973.

From 1960 to 1970, the fastest growing subareas were the suburban counties of the large SMSA's and non-SMSA counties just beyond the metropolitan fringe fueled by out-migration from the core cities. The core cities continued to lose population from 1970 to 1973, while the suburban counties of the large SMSA's continued to gain population. The fastest growth rates were observed in the non-SMSA counties, both those that had been undergoing urbanization in the previous decade and those that heretofore were essentially rural.

Table 1-9 Trends in Population, Delaware River Basin Influence Area, 1960-73

	1960	1970	1973	Percent Change 1960-70	Percent Change 1970-73
Large SMSA's	17,337,684	18,866,785	18,771,000	8.8%	-0.5%
Core Cities 1/	11,318,775	11,385,924	11,152,600	0.6%	-2.0%
Suburban Counties 2/	6,018,909	7,480,861	7,618,400	24.3%	1.8%
Small and Medium Size SMSA's 3/	4,505,477	5,356,200	5,466,200	18.9%	2.1%
Non-SMSA Urbanizing Counties 4/	902,370	1,179,193	1,270,900	30.7%	7.8%
Rural Counties 5/	313,608	360,499	391,300	15.0%	8.5%
Total	23,059,139	25,762,677	25,899,400	11.7%	0.5%

1/ Core cities include: New York City (5 boroughs); Philadelphia (Philadelphia Co.); Newark (Essex Co.) and Jersey City (Hudson Co.).

2/ Suburban counties include non-core counties in the New York, Philadelphia and Newark SMSA's.

3/ Small and medium-size SMSA's include Paterson-Clifton-Passaic; New Brunswick-Perth Amboy-Sayreville; Long Branch-Asbury Park; Atlantic City; Vineland-Milville-Bridgeton and Trenton, New Jersey; Fairfield Co., Connecticut; Poughkeepsie, New York; Reading and Allentown-Bethlehem and Carbon Co., Pennsylvania; and Wilmington, Delaware (less Cecil Co., Maryland).

4/ Urbanizing non SMSA counties include: Hunterdon, Ocean, Somerset and Sussex in New Jersey; Orange, Putnam and Ulster in New York; Monroe and Schuylkill in Pennsylvania.

5/ Rural non-SMSA counties include: Kent and Sussex in Delaware; Cape May, New Jersey; Delaware and Sullivan in New York; and Pike and Wayne in Pennsylvania.

Source: U. S. Census of Population, 1960 and 1970 and CPR Series P-25 and P-26.

The population of the suburban counties of the large SMSA's grew from 6,018,909 in 1960 to 7,480,861 in 1970, a gain of 24.3 percent. From 1970 to 1973, they grew by only 1.8 percent. Non-SMSA urbanizing counties grew by 30.7 percent over the 1960-70 decade and by 7.8 percent over the next three years. Rural counties, which had the fourth largest growth rate of the five subareas from 1960 to 1970, had the highest growth rate 8.5 percent from 1970 to 1973. Much of these areas' population growth came at the expense of the core cities which grew slightly over the 1960's but lost 2.1 percent of their 1970 population during the ensuing three years.

The effect of the population shifts of the 13-year period is clearly illustrated in the following table. The large SMSA's share of the influence area's population shrank while the small and medium-size SMSA's and non-SMSA urbanizing and rural counties grew. The large SMSA's had a 75.2 percent share of the area's population in 1960 but only a 72.5 percent in 1973 with the 2.7 percent share loss distributed among the three other subareas. Also, within the large SMSA's, the suburban counties increased their share of the influence area's population from 26.1 percent to 29.4 percent while the core cities had a declining share -- from 49.1 percent in 1960 to 43.1 percent in 1973.

Table 1-10 Distribution of Population in the Delaware River Basin Influence Area, 1960-73

	1960	1970	1973
Large SMSA's	75.2%	73.2%	72.5%
Core Cities	(49.1%)	(44.2%)	(43.1%)
Suburban Counties	(26.1%)	(29.0%)	(29.4%)
Small and Medium Size SMSA's	19.5%	20.8%	21.1%
Non-SMSA Urbanizing Counties	3.9%	4.6%	4.9%
Rural Counties	1.4%	1.4%	1.5%
Total	100.0%	100.0%	100.0%

Source: U. S. Census of Population, 1960 and 1970 and Current Population Report, Series P-25 and P-26.

The small and medium-size SMSA's and non-SMSA counties increased their portion of the influence area's population from 24.8 percent to 27.5 percent. The small and medium-size SMSA's contained 19.5 percent of the influence area's population in 1960 and 21.1 percent in 1973. The urbanizing non-SMSA counties increased their share by a full percentage point to 4.9 percent and the rural counties had an added 0.1 percent of the area's population.

The significant population shifts within the region and out from the region from 1970 to 1973 are brought into clearer focus by an analysis of net migration trends. The following table shows the tremendous out-migration of residents from the core cities from 1960 to 1973. All of that out-migration plus the influx of other in-migrants was accommodated in the areas outside the core cities from 1960 to 1970 but from 1970 to 1973, 272,300 left the influence area entirely to live in other parts of the country. This is a startling fact for an area that had experienced a steady stream of in-migrants since the time that the area was first settled in the 1700's.

Table 1-11 Net Migration, Delaware River Basin Influence Area, 1960-1973

	1960-1970	1970-1973	1960-1973
Large Metro. Areas	-78,500	-392,000	-470,500
Core Cities	(-843,100)	(-393,600)	(-1,236,700)
Suburban Counties	(764,600)	(1,600)	(766,200)
Small to Medium SMSA's	405,700	21,400	427,100
Non-SMSA Urbanizing Counties	194,900	73,200	268,100
Non-SMSA Rural Counties	20,200	25,100	45,300
Total	542,300	-272,300	270,000

Note: Minus (-) sign indicates net out-migration; no sign indicates net in-migration.

Source: U. S. Census Bureau, Current Population Reports (CPR), Series P-25 and P-26.

The core cities lost 1,236,700 residents from 1960 to 1973 with the rate of out-migration accelerating over the 1970-73 period. From 1960 to 1970, all of this out-migration from the core cities plus an additional 542,300 in-migrants to the influence area were accommodated in the less densely urbanized subareas. The suburban counties of the large SMSA's had the largest amount of in-migrants over the decade with significant in-migration also occurring in small and medium-size SMSA's and non-SMSA urbanizing counties. In contrast, 272,300 residents left the influence area entirely from 1970 to 1973 while population shifts continued within the region. The mainstream of in-migration from 1970 to 1973, however, was in the rural non-SMSA counties as well as the non-SMSA urbanizing counties and small and medium-size SMSA's. The suburban counties of the large SMSA's added only 1,600 people through in-migration reflecting a diminishing rate of in-migration into those areas.

I.A.5. ECONOMY

The Delaware River Basin Influence Area embraces one of the largest and most important economic agglomerations in the United States. Its concentrations of consumer and industrial markets are unmatched by any other urban node in terms of their size and affluence. Also, it contains many of the nation's leading financial institutions, corporate headquarters and highly sophisticated business services making it one of the foremost business centers.

The structure of the area's economy is at the same time very diverse in its scope yet highly integrated. The various subcenters of the region from small and medium-size SMSA's to rural, non-SMSA counties produce a full range of products for regional, national and international consumption and each plays an important economic role as a service center providing the necessary retail, financial, personal and professional services within its own sphere of economic influence. Yet all have a common orientation to the economies of the New York-Philadelphia urban complex. Each has common ties to the broader region and its two primary urban centers by way of interlinking work patterns, common transportation networks, intraregional economic interactions, the common usage and regulation of natural resources and institutional arrangements crossing county lines and state boundaries.

The economic geography of the Delaware River Basin influence area has been transformed in recent years by the horizontal expansion out from the major urban nodes. This has resulted in both inter- and intra-regional movements of economic activities.

The diseconomies associated with the Northeastern urban hierarchy and the large cities in particular, together with the development of other regions of the country, caused some firms to seek new locations in other areas when plants became obsolete or expansion was required. High wage rates, the large expense for industrial sites, rising governmental costs, worker attitudes and changes in the corporate structure itself causing the separation of administrative, production, distribution and research and development functions, favored the development of new facilities outside the Northeastern corridor. Many of these industries went to the Southeast, which has developed the transportation facilities and other infrastructure improvements necessary to support industrial development. With good access to the Northeast's large consumer and industrial markets via interstate highways, a lower cost of doing business and adequate infrastructure, these areas became increasingly competitive for industrial development. As a result of the movement of industry to other regions of the country, the influence area grew at a much slower pace than the rest of the nation.

Of course, not all of the firms moving out of New York and Philadelphia and other major urban nodes left the region. In fact, a majority of them relocated within the influence area. Suburban areas ringing the urban concentrations and even outlying, essentially rural counties realized the effects of the horizontal expansion.

These areas benefited from the availability of developable land, a growing labor supply from residential development, improved highway access and relative freedom from the problems of vandalism and congestion found in the big cities.

These industrial movements further reinforced the previous residential development trends and created a stepping stone effect making it possible for people to live even further out in the more rural areas of the influence area. It also resulted in the development of the service economies of these suburban areas and rural counties supported by growing populations and incomes in their market areas.

I.A.5 (a) Share of Nation's Employment

The Delaware River Basin Influence Area contains a large portion of the nation's jobs. The area had close to one of every seven United States jobs in 1972, an even greater share of jobs than population. However, employment grew at a slower pace that the nation from 1960 to 1972. This resulted from the migration of some manufacturing firms to the Southeast and other parts of the country as mentioned before. Consequently, the influence area's share of the nation's employment dipped from 15.59 percent in 1960 to 13.72 percent in 1972.

Table 1-12 Total Employment Comparisons, Delaware River Basin Influence Area, Northeast and United States, 1960-1972 (Thousands)

	1960	1970	1972	Gain, 1960-1972 Amount	Percent
Influence Area	8,455	10,066	9,986	1,531	18.1%
Northeast	15,613	18,672	18,633	3,020	19.3%
United States	54,234	70,593	72,764	18,530	34.2%
Influence Area Percent of:					
Northeast	54.15%	53.91%	53.59%		
United States	15.59¢	14.26%	13.72%		

Sources: U.S. Department of Labor: Employment and Earnings.

The nation added 18,530,000 jobs during the 12-year period from 1960 to 1972. National employment increased by 34.2 percent over that period compared with a rate of gain of 18.1 percent for the influence area which added 1,531,000 jobs over that time. Influence area employment grew from 8,455,000 in 1960 to 9,986,000 in 1972.

I.A.5 (b) Interregional Job Dispersion

The regional distribution of employment was characterized by a shift of jobs from the large SMSA's to small and medium-sized SMSA's and non-SMSA counties from 1960 to 1972. This horizontal expansion caused employment growth to lag behind in the large SMSA's such as New York, Philadelphia, Newark and Jersey City. Small and medium size SMSA's added twice the number of jobs as the larger SMSA's with the addition of manufacturing plants, corporate offices and resident-serving commercial activities. Growth was particularly large in those SMSA's forming a ring around the New York metropolitan area. The non-SMSA counties in the influence area had the fastest rate of growth although adding fewer jobs than the other subareas.

Table 1-13 Spatial Distribution of At-Place Employment Growth, Delaware River Basin Influence Area, 1960-1972

	1960	1970	1972	Gain, 1960-1972 Amount	Gain, 1960-1972 Percent
Large SMSA's	6,032.8	6,703.3	6,485.6	452.8	7.5%
Small and Medium Size SMSA's	2,019.1	2,810.2	2,914.0	894.9	44.3%
Non-SMSA Counties	403.3	552.0	586.5	183.2	45.4%
Total, Delaware River Basin Influence Area	8,455.2	10,065.5	9,986.1	1,530.9	18.1%

Source: U.S. Department of Labor: Employment and Earnings; State Departments of Labor.

The large SMSA's added 452,800 jobs from 1960 to 1972, a growth rate of 7.5 percent. Employment in small and medium-size SMSA's grew from 2,019,100 in 1960 to 2,914,000 in 1972, a gain of 894,900 jobs or 44.3 percent. Non-SMSA counties had the fastest employment growth rate, 45.4 percent adding 183,200 jobs over the period.

As a result of the greater growth in outlying areas, the degree of predominance of the large SMSA's as employment centers declined from 1960 to 1972. These large SMSA's contained 71.4 percent of the influence area's jobs in 1960 but had a 65.0 percent share in 1972. Correspondingly, the other SMSA's and non-SMSA counties had significant increase in their share of area employment.

Table 1-14 At-Place Employment Distribution, Delaware River Basin Influence Area, 1960-1972

	1960	1970	1972
Large SMSA's	71.4%	66.7%	65.0%
Small and Medium Size SMSA's	23.9	27.9	29.2
Non-SMSA Counties	4.8	5.5	5.9
Total	100.0%	100.0%	100.0%

Small and medium-size SMSA's share of employment grew from 23.9 percent in 1960 to 29.2 percent in 1972. Non-SMSA counties also increased their share -- from 4.8 percent in 1960 to 5.9 percent in 1972.

I.A.5(c) Economic Structure of the Influence Area

Despite the tremendous development of the outlying portions of the influence area over the past 12 years, the common orientation to the two major urban nodes remained. The New York and Philadelphia SMSA's still accounted for over 57 percent of the region's 1972 employment. In addition, the next three largest SMSA's, encircling New York, contained over 20 percent of the influence area's jobs.

Table 1-15 Major Employment Centers, Delaware River Basin Influence Area, 1972

	Employment 1972	Percent of Total
New York SMSA	3,932,500	39.4%
Philadelphia SMSA	1,796,700	18.0
Newark SMSA	785,700	7.9
Nassau-Suffolk SMSA	751,600	7.5
Patterson-Clifton-Passaic SMSA	520,200	5.2
(Subtotal)	(7,786,700)	(78.0%)
Balance, Delaware River Influence Area	2,199,400	22.0
Total, Delaware River Influence Area	9,986,100	100.0%

Source: U.S. Department of Labor: Employment and Earnings, State Departments of Labor.

The New York SMSA contained 3,952,500 jobs in 1972, 39.4 percent of the region's total. The five largest SMSA's representing the major urban concentrations in the influence area accounted for 78 percent of all employment while the remainder contained 2,199,400 or 22.0 percent of the area's employment.

Chapter I-A Footnotes

1. A Natural History Survey of The Proposed Tocks Island Reservoir National Recreation Area, U.S. Army Corps of Engineers, pg.II-1.(undated).

2. U.S. Geological Survey, Report on The Comprehensive Survey of The Water Resources of The Delaware River Basin, Appendix N, General Geology and Ground Water, 1959, pg.63.

3. U.S. Army Corps of Engineers, Volume I, House Document 522, 1962, pg.130.

4. Shimer, John A., This Sculptured Earth: The Landscape of America, New York: Columbia University Press, 1959, pg.164.

5. A Regional Framework, TIRAC, 1973, pgs.8-9.

6. Regional Plan Association, The State of The Region, A Digest of Selected Trends Through 1974, 1975, pg.6.

7. Regional Plan Association, The State of The Region, 1970, pg.35.

8. Estimate based on composite land use statistics provided by the Regional Plan Association, 1975, Tri-State Regional Planning Commission, 1970, Delaware River Valley Regional Planning Commission, 1970, and Lehigh-Northampton Planning Commission, 1972.

9. Regional Plan Association, The State of The Region, A Digest of Selected Trends Through 1974, 1975, pg.13.

I.B. SERVICE AREAS

Service areas are those geographic areas which are influenced to some discernible degree by aspects of developments such as the Tocks Island Project, by alternatives to it, or by the amount and availability of specific Delaware River Basin resources. Their dimensions vary greatly, depending upon the specific needs and water-related resources under consideration, and upon a range of physical and institutional factors that may also define their boundaries.

The following paragraphs discuss the criteria and considerations underlying the establishment of service area boundaries. The accompanying maps deliniate these and show the various subareas within each. These subareas were the basis for much of the analyses in the course of this study. Economic data and forecasts for them are presented in Appendix "A".

I.B.1. FLOOD CONTROL

The establishment of the flood control service area considered the characteristics, frequency and extent of flooding experienced in the region, and the location of damage centers and damage reaches caused by such flooding.

Damages from flooding occur generally throughout the entire Delaware River drainage area above Burlington, New Jersey and on various tributaries which drain into the tidal area downstream from Burlington. Therefore, the overall flood control service area is the basin of the Delaware River to Delaware City. It is to be noted that the flood control service area for the Tocks Island Lake Project itself would include only those counties lying within the basin boundary above Burlington, New Jersey.

I.B.2. WATER SUPPLY

The area relevant to water supply is that in the basin itself plus the areas indicated by authorized and suggested exports of water from the basin. These exports at the present time are the authorized 800 MGD diversion to New York City, the 100 MGD diversion to New Jersey and the suggested 300 MGD additional export to New Jersey. The service area of interest relative to water supply is thus the basin, the area to be ulimately serviced by the City of New York system, the area of New Jersey presently served by the existing 100 MGD diversion, and the area in New Jersey that would be served by the proposed 300 MGD diversion. This service area generally follows the DRB influence area shown on the accompanying map and is precisely defined by Figure III-2.

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A COMPREHENSIVE STUDY OF THE TOCKS ISLAND LAKE PROJECT AND ALTE--ETC(U)
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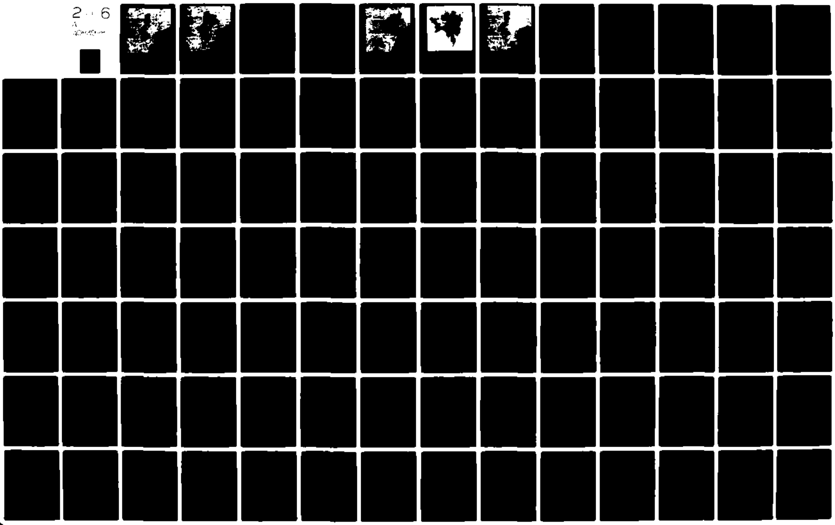

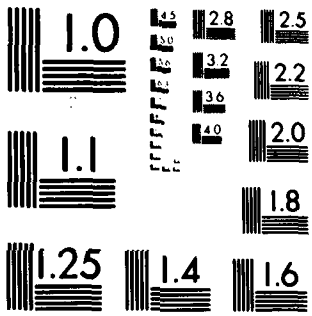

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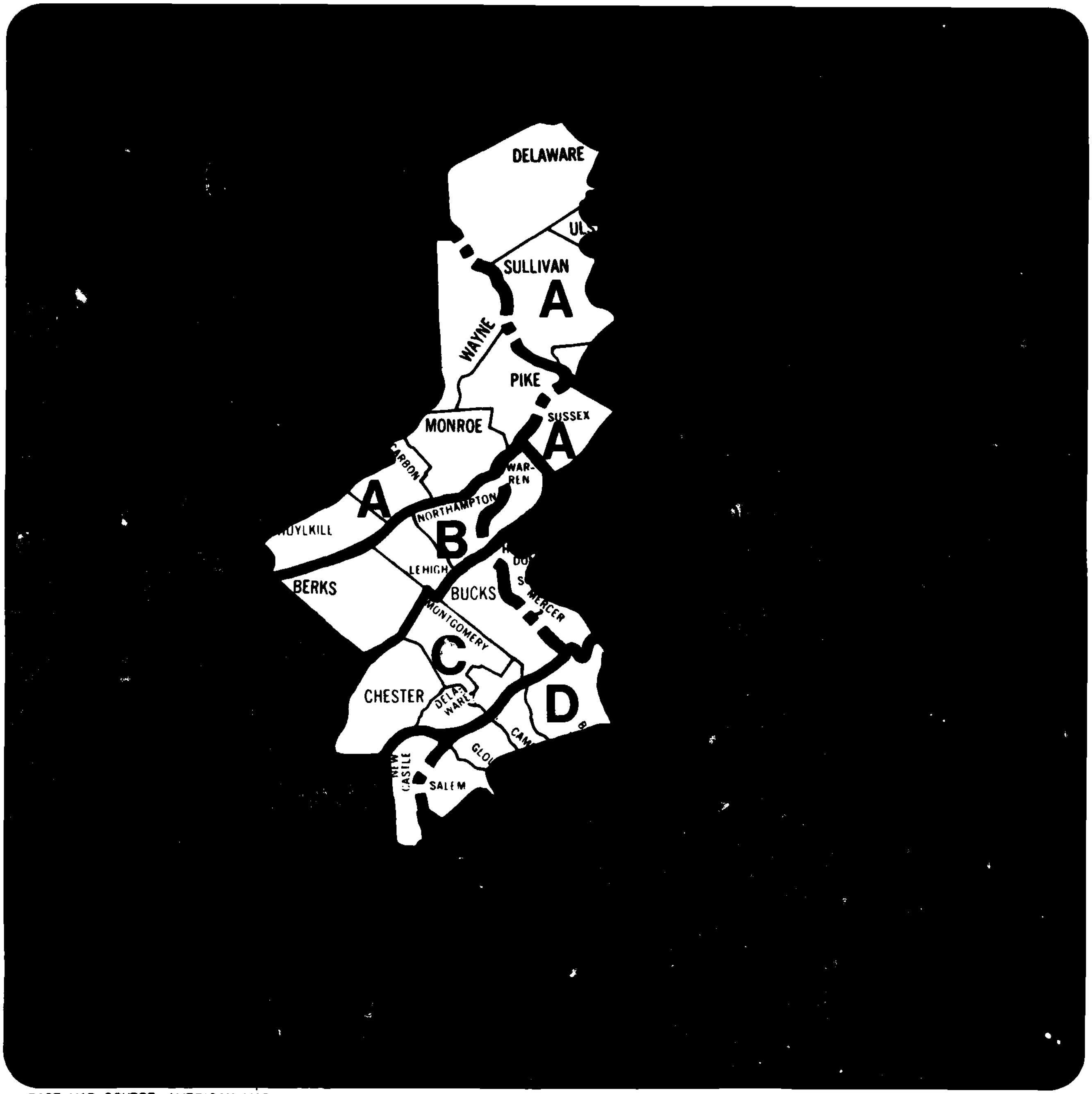

BASE MAP SOURCE: AMERICAN MAP CO.

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SCALE IN MILES

N

FLOOD CONTROL SERVICE AREA 5

LEGEND

SUB-AREA

- A UPPER BASIN
- B ALLENTOWN-BETHLEHEM-READING
- C PHILADELPHIA METRO
- D SOUTHERN BASIN

A COMPREHENSIVE STUDY OF THE
TOCKS ISLAND LAKE PROJECT & ALTERNATIVES
URS / MADIGAN-PRAEGER, INC. & CONKLIN AND ROSSANT

BASE MAP SOURCE AMERICAN MAP CO

0 6 12 18 24 30
SCALE IN MILES

N

DELAWARE RIVER BASIN INFLUENCE AREA 6

LEGEND

SUB AREA

- A NEW YORK METRO
- B METRO SUPPLEMENT
- C ALLENTOWN, BETHLEHEM, READING
- D TRENTON METRO
- E PHILADELPHIA METRO
- F WILMINGTON METRO
- G UPPER BASIN
- H SOUTHERN BASIN

A COMPREHENSIVE STUDY OF THE

TOCKS ISLAND LAKE PROJECT & ALTERNATIVES

URS / MADIGAN-PRAEGER, INC. & CONKLIN AND ROSSANT

I.B.3. OUTDOOR RECREATION

The recreation service area is principally defined by two criteria: a 100 mile radius from the center of the Delaware Water Gap National Recreation Area (DWGNRA), midway between Stroudsburg and Port Jervis on the Delaware River, or a 2 1/2 hour driving time from this point, whichever is greater. The area thus defined contains 81 counties in five states and includes the New York and Philadelphia urbanized regions. The fringe of the outdoor recreation service area is adjusted to include those counties centering around other principal urbanized regions such as Harrisburg, Wilmington, Scranton, Trenton and Albany.

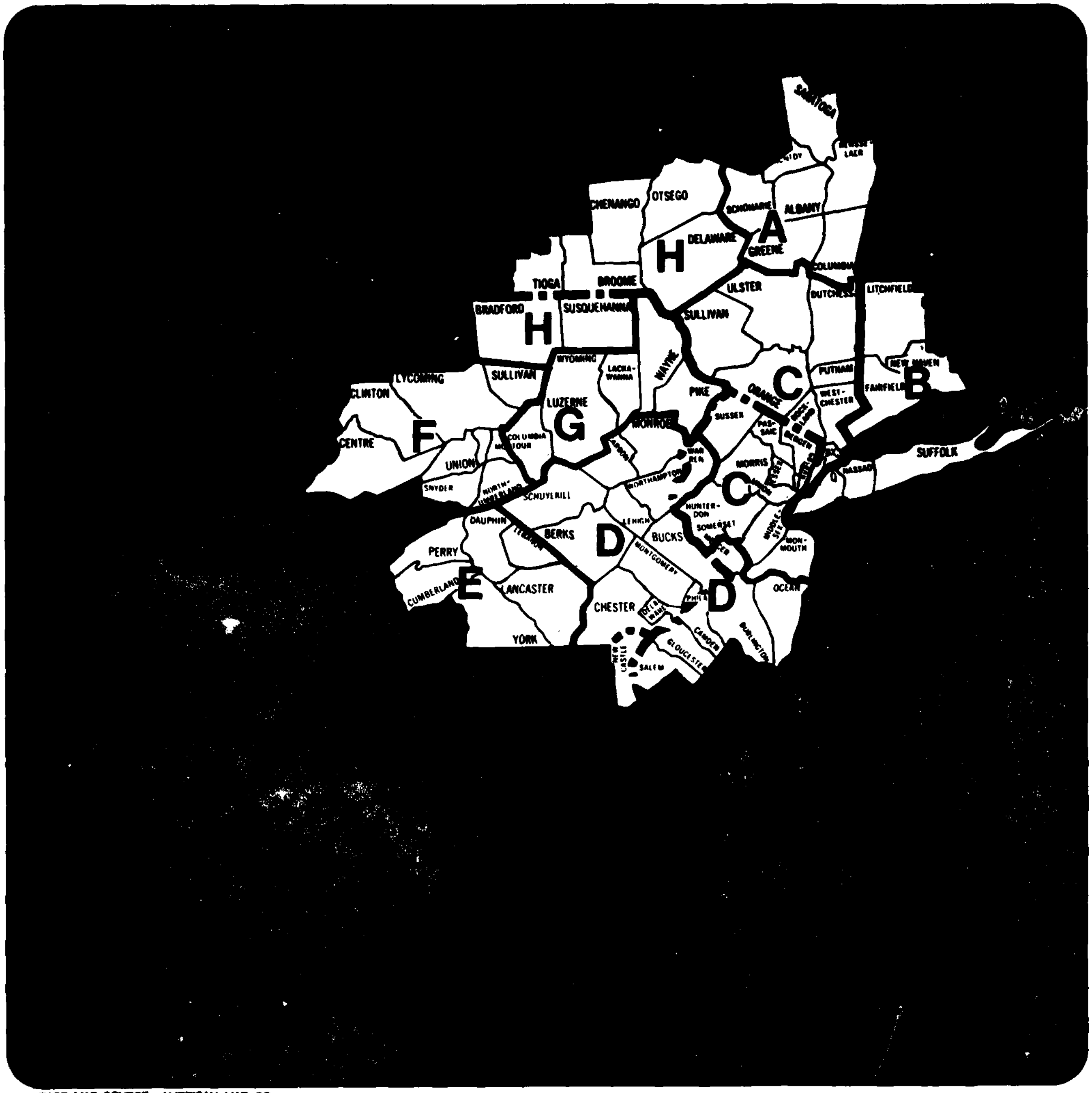
The historical basis for the recreation service area is contained in the Robert R. Nathan Report, "Potential Impacts of the DWGNRA on Its Surrounding Communities", February, 1966. This Report determined that approximately 80% of DWGNRA users will reside within 2 1/2 hours driving time or 100 miles, the maximum comfortable traveling distance for a non-peak day outing. The 2 1/2 hour drive distances have been updated to reflect the significant additions to the Interstate Highway system and other highway improvements constructed since 1966.

I.B.4. ELECTRIC POWER

This service area is based upon: the location of users of power generated in the Delaware River Basin; the areas served by each utility operating in the Basin, because the utility's Basin operations affecting its operations over its entire service area; the contiguous area surrounding the Basin connected by major transmission lines; and the location of out-of-Basin power generation sources which benefit Basin users. The foregoing criteria are satisfied by defining the electric power service area to be the Pennsylvania-New Jersey-Maryland (PJM) Interconnection Service Area, and to a lesser extent, the three New York utility service areas: Orange and Rockland Electric Company, New York State Electric and Gas Company, and Central Hudson Gas and Electric Company.

I.B.5. WATER QUALITY

The water quality impact area is the smallest after the flood control service area defined earlier and does not extend beyond the boundaries of the Delaware River Basin. Its limits are shown on the accompanying map of the Water Quality Service Area.



BASE MAP SOURCE: AMERICAN MAP CO.

0 15 30 45
SCALE IN MILES

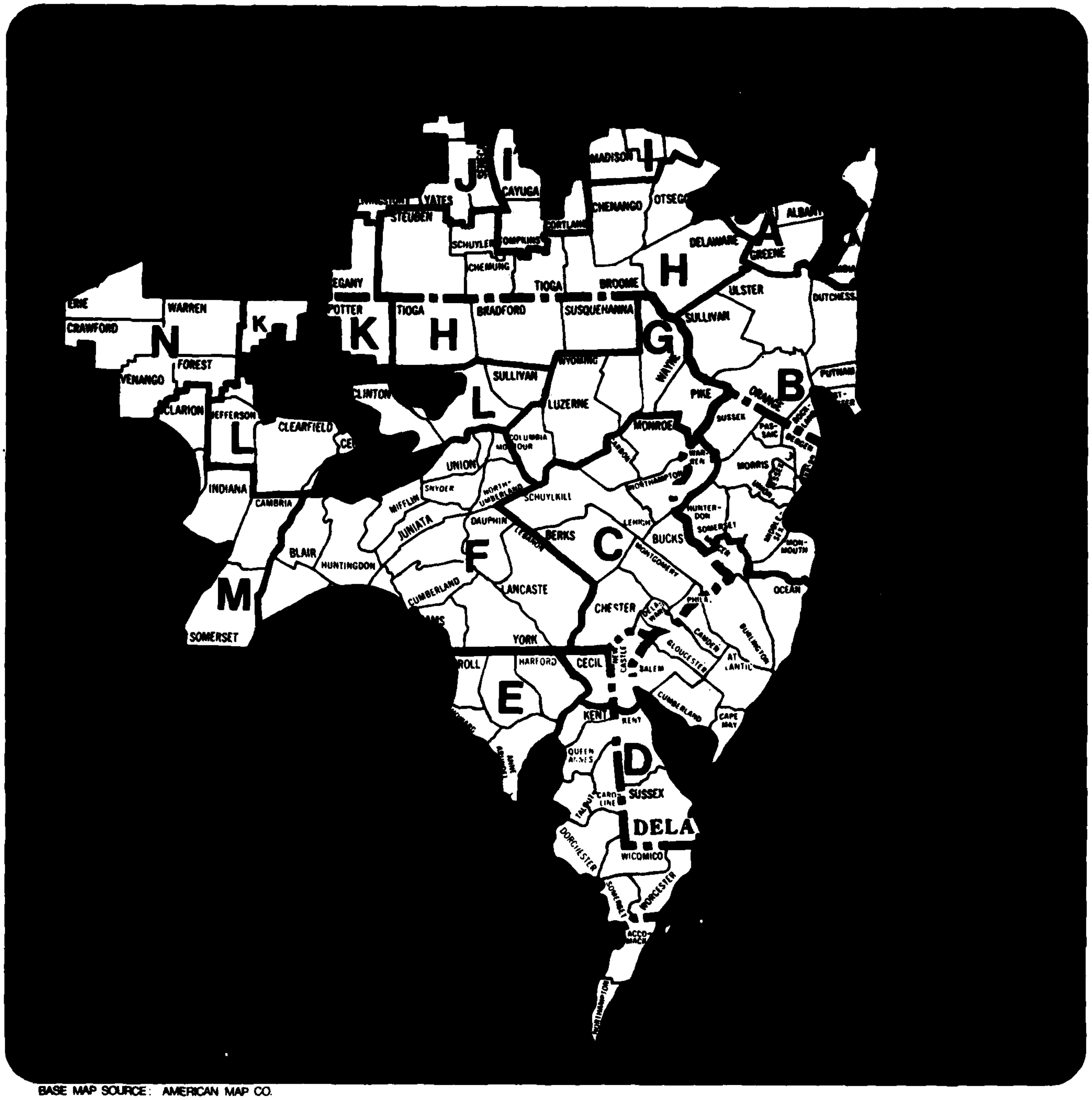
N

RECREATION SERVICE AREA 7

LEGEND

SUB AREA

A	ALBANY
B	WESTERN CONNECTICUT
C	NEW YORK METRO
D	PHILADELPHIA METRO
E	HARRISBURG
F	WILLIAMSPORT
G	SCRANTON
H	BINGHAMPTON



BASE MAP SOURCE: AMERICAN MAP CO.

0 15 30 45
SCALE IN MILES

N

ELECTRIC POWER
SERVICE AREA **8**

LEGEND

SUB-AREA

A	ALBANY/TROY	J	LAKE ONTARIO
B	NEW YORK METRO	K	ALLEGHENY
C	PHILADELPHIA METRO	L	WILLIAMSPORT
D	CHESAPEAKE BAY	M	JOHNSTOWN
E	WASHINGTON SUBURBAN	N	LAKE ERIE
F	HARRISBURG / ALTOONA		
G	SCRANTON / WILKES BARRE		
H	ELMIRA / BINGHAMPTON		
I	UTICA / SYRACUSE		

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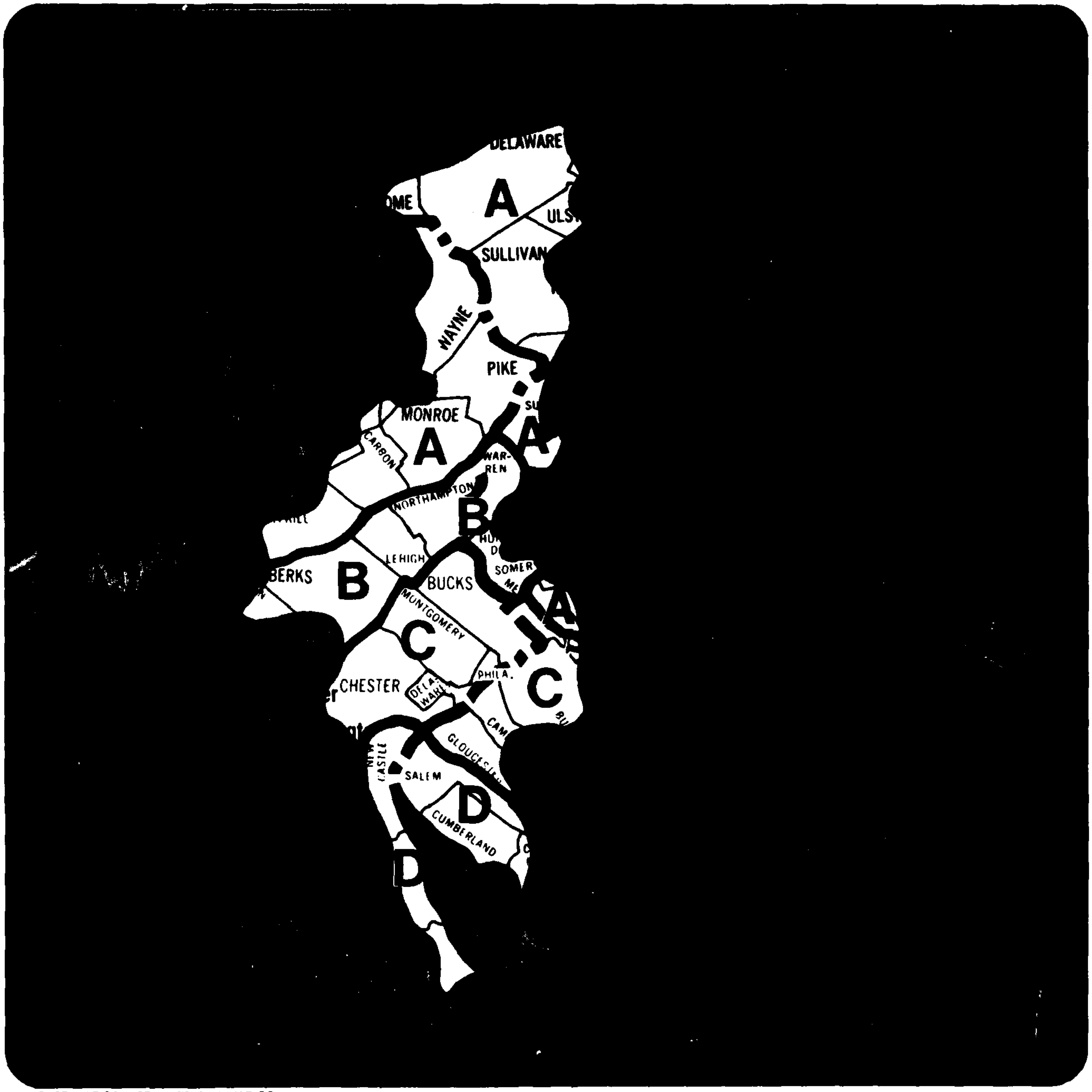

BASE MAP SOURCE AMERICAN MAP CO

0 6 12 18 24 30
SCALE IN MILES

N

WATER QUALITY
SERVICE AREA **9**

LEGEND

SUB-AREA

A	UPPER BASIN
B	ALLENTOWN-BETHLEHEM-EASTON
C	PHILADELPHIA
D	SOUTHERN BASIN

A COMPREHENSIVE STUDY OF THE

TOCKS ISLAND LAKE PROJECT & ALTERNATIVES

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I.B.6. PRIMARY ECONOMIC IMPACT

We defined as the primary economic impact service area the seven counties of Sullivan, Orange, Pike, Monroe, Northampton, Sussex and Warren. This area is also referred to as the seven-county Tocks Island Impact Area. Economic impact on the primary area, as well as impact on areas that extend beyond it and into the service areas defined before, are discussed in greater detail in subsequent sections of this report.

I.C. ECONOMIC BASE DATA

I.C.1 CURRENT ECONOMY

The six service areas that would benefit from the water resources products to be generated by the proposed Tocks Island Lake Project have already been defined. An analysis of the boundaries of the six service areas shows that they range in size from the 7-county Tocks Island Lake Impact Area to the Electric Power Service Area which covers large portions of Eastern Pennsylvania and New York, all of New Jersey and stretches as far down as Maryland and Virginia. Also seen is the fact that there is significant overlap among the service areas. The 7-county impact area, Flood Control and Water quality service areas are wholly contained in one or the other of the larger service areas for water supply, recreation and electric power. Consequently, the economic trends in the area tend to be similar although there are some of the service areas that have had greater growth than others.

Previously, the economic analysis has centered on the Water Supply Service Area (which has been referred to as the Delaware River Basin Influence Area.) This area was chosen to highlight growth trends in the broader region because it contains the two major urban nodes of Philadelphia and New York and encompasses the three smaller service areas and the major population and employment centers of the Recreation and Electric Power Service Areas. It is consistent with basic regions used in some previous reports also.

This section briefly summarizes the major current trends in population, employment, households and total personal income for all the service areas.

Economic trends by subarea of the larger service areas are contained in the appendix.

I.C.1.(a) Population Trends, 1960-1973

Generally, the service area's population grew at a modest rate from 1970 to 1973 although two service areas -- Electric Power and the 7-County Impact Area -- had substantial population gains. Four of the service areas had population gains ranging from 10.2 percent to 12.6 percent, well below national growth rates. The Electric Power Service Area and the 7-County Economic Impact Area had population growth rates of 21.2 percent and 24.5 percent, respectively, double the prevailing growth rate of the region and above the national growth rate from 1960 to 1973.

Table 1-16 Population Trends, Delaware River Basin Service Areas, 1960-1973 (Thousands)

Service Areas	1960	1970	1973	Gain, 1960-1973 Amount	Gain, 1960-1973 Percent	Annual Rate
7-Counties	592	698	737	145	24.5%	1.65%
Flood Control	5,301	5,797	5,840	539	10.2%	0.70%
Water Quality	6,226	6,922	7,010	784	12.6%	0.87%
Electric Power	16,226	19,049	19,666	3,440	21.2%	1.44%
Water Supply	23,059	25,763	25,899	2,840	12.3%	0.85%
Recreation	26,370	29,329	29,529	3,160	12.0%	0.83%

Source: U.S. Census of Population 1960 and 1970 and CPR Series P-25 and P-26.

The Electric Power Service Area had the largest growth rate from 1960 to 1973 and added the largest number of people, 3,440.000, reflecting the fact that it encompasses much of the suburban areas of Philadelphia and New York, but does not include the central cities of those SMSA's. Similarly, the 7-County Impact Area includes several of the growing suburban areas of New York, which accounts for its high growth rates. Two other service areas grew at a much slower pace, 10.2 percent for the Flood Control Service Area and 12.6 percent for the Water Quality Service Area, because most of their population is contained in the relatively slow-growing Philadelphia SMSA. The Recreation and Water Supply service areas cover a broad region, but their growth trends are predominated by New York and Philadelphia, consequently they had 1960-1973 growth rates of only 12.0 percent and 12.3 percent, respectively.

I.C.1.(b) Employment Trends, 1960-1973

For service areas of large regions, the number of workers living in an area is highly correlated with population. Therefore, employment trends for the service areas are very similar to population trends. The following table shows that the 7-County Impact Area and the Electric Power Service Area had the highest rates of employment growth from 1960 to 1973 with the other service areas showing similar growth tendencies. Despite the fact that there are great similarities between population and resident employment, it is interesting to note that employment grew faster than population over the period, reflecting greater participation in the work force, particularly among women.

Table 1-17 Employment Trends, Delaware River Basin Service Areas, 1960-1973 (Thousands)

Service Areas	1960	1970	1973	Gain, 1960-1973 Amount	Percent
7-County Impact Area	222	274	286	64	28.8%
Flood Control	2,089	2,356	2,375	286	13.7%
Water Quality	2,445	2,803	2,845	400	14.1%
Electric Power	6,344	7,699	7,995	1,651	26.0%
Water Supply	9,278	10,507	10,570	1,292	13.9%

Source: U.S. Census of Population, 1960 and 1970, OBERS projections (1974).

Employment in the 7-County Impact Area and the Electric Power Service Area encompassing suburban areas grew by 28.8 percent and 26.0 percent, respectively, compared with population gains of 24.5 percent and 21.2 percent. The remaining three service areas (excludes Recreation Service Area) had growth rates ranging from 13.7 percent to 14.1 percent.

I.C.1.(c) Employment in Major Water-Using Manufacturing Industries, 1972

Due to the extent of water usage by six major industries, special analysis of employment in the food, textile, paper, chemical, petroleum and primary metal industries was performed for the Water Supply Service Area. The Water Supply Service Area contains a sizeable concentration of water-using industries. In 1972, 775,400 persons were employed in the major water-using industries, 13.2 percent of United States employment in those industries, slightly greater than its over 12 percent population share. Specific concentrations are observed in the chemical and petroleum refining industries owing to the port facilities located in the Water Supply Area and and long-established nonmanufacturing complexes of these industries in Philadelphia, Wilmington, and areas of New Jersey.

Table 1-18 Manufacturing Employment Trends in Major Water-Using and Other Industries, Water Supply Service Area and United States, 1972

	1972 Water Supply Area	1972 United States	Water Supply, Percent of U.S.
Food	183,000	1,739,000	10.5%
Textiles	115,100	994,000	11.6%
Paper	90,700	689,000	13.2%
Chemicals	238,200	1,007,000	23.7%
Petroleum	30,500	194,000	15.7%
Primary Metals	117,900	1,240,000	9.5%
(Water-Using Industries)	(775,400)	(5,863,000)	(13.2%)
Other Manufacturing Industries	1,782,900	13,227,000	13.5%
Total, Manufacturing Employment	2,558,300	19,090,000	13.4%

Source: U.S. Department of Labor: Employment and Earnings; State Departments of Labor; County Business Patterns, 1972. Siler, George Associates.

The Water Supply Serivce Area contained 13.4 percent of the United States' manufacturing employment in 1972; 13.2 percent in major water-using industries and 13.5 percent in other manufacturing industries. Of the major water-using industries, it contained 23.7 percent of the United States' employment in chemical manufacturing and 15.7 percent of national petroleum refining employment. Other portions ranged from 9.5 percent of primary metals employment to 13.2 percent of employment in the paper industry.

I.C.1.(d) Household Trends, 1960-1973

Household growth trends from 1960 to 1973 also closely paralleled population trends over that period although the number of households grew at a much faster rate than population. As with population and employment, the Electric Power Service Area and the 7-County Impact Area had the most rapid rates of household growth. These household growth rates were considerably higher than population growth rates because of the decreasing size of households. Lower birth rates and the trend by the young and the elderly toward establishing their own homes has resulted in the sizeable addition of small households of only one or two persons.

Table 1-19 Household Trends, Delaware River Basin Service Areas, 1960-1973 (Thousands)

Service Areas	1960	1970	1973	Gain, 1960-1973 Amount	Percent
7-County Impact Area	178	216	236	58	32.6%
Flood Control	1,573	1,817	1,874	301	19.1%
Water Quality	1,834	2,146	2,231	397	21.7%
Electric Power	4,739	5,827	6,264	1,525	32.2%
Water Supply	7,125	8,279	8,628	1,503	21.1%
Recreation	8,158	9,443	9,833	1,675	20.5%

Source: U.S. Census of Population, 1960 and 1970.

The 7-County Impact Area and the Electric Power Service Area had 1960-1973 household growth rates of 32.6 percent and 32.2 percent, respectively, much greater than their population growth rates of 24.5 percent and 21.2 percent. Household growth rates in the other service areas ranged from a low at 19.1 percent in the Flood Control Service Area to a high of 21.7 percent in the Water Quality Service Area, with all service areas having greater rates of household growth than population growth.

I.C.1.(e) Total Personal Income Trends, 1959-1972

Increases in personal income in the service area from 1959 to 1972 reflects both increases in population, households and employment and the relatively greater affluence of individuals and families living within the service areas. As measured in constant 1967 dollars (to eliminate the effects of inflation), real increases in purchasing power over the period ranged from $1,106,000,000 in the 7-County Impact Area to $45,777,000,000 in the Recreation Service Area. The rate of real income growth, ranging from 54.8 percent to 77.0 percent, is much greater than any of the growth rates from other economic measures, reflecting the greater income going to individuals, households and employees.

Table 1-20 Total Personal Income Trends, Delaware River Basin Service Areas, 1959-1972 (Millions of Constant 1967 Dollars)

				Gain, 1959-1972	
Service Areas	1959	1969	1972	Amount	Percent
7-County Impact Area	$ 1,433	$ 2,257	$ 2,539	$ 1,106	77.2%
Flood Control	$14,893	$ 21,287	$ 23,057	$ 8,164	54.8%
Water Quality	$18,893	$ 26,547	$ 28,996	$ 10,870	60.0%
Electric Power	$45,366	$ 70,480	$ 76,923	$ 31,557	69.6%
Water Supply	$71,464	$105,732	$112,646	$ 41,182	57.6%
Recreation	$79,758	$117,962	$125,535	$ 45,777	57.4%

Source: U.S. Department of Commerce: Survey of Current Business, (May, 1974).

The 7-County Impact Area and the Electric Power Service Area had the largest percentage gains in total personal income from 1959 to 1972, having had gains of 69.6 percent and 77.2 percent, respectively. The growth rates for total personal income in the other two service areas ranged from 54.8 percent in the Flood Control Service area to 60.0 percent in the Water Quality Service Area.

I.C.2 ECONOMIC PROJECTIONS

Despite the persistent upward growth of the United States economy over the past two decades, the growth of states and regions has been uneven. These regional growth differences reflect not only the effect of interactions between the national economy and the regions, but also differences in the competitiveness among areas.

Regional growth is determined by complex interactions among private and public decisions as to the geographic allocation of their economic activities. The "state of the art" of the regional growth process, however, is limited, partly because of the complexities of the interregional relationships and partly because of the inadequacy of data to understand and describe them.

The future economy of a given region is not predetermined nor can it be fully anticipated because of the discretions which can be exercised by individuals, entrepreneurs and public agencies. The direction and dimensions of the future economy of a given region, however, can be approximated given its past performance within the broad regional and national circumstances. In a real sense, each area is competing with many other areas for the opportunities represented by national growth dimensions. The understanding of the past and future growth dimensions of the national economy, therefore, is of significant importance in setting the framework for and approximating the likely growth dimensions of a given region.

I.C.2(a) Projections of National Totals

In April 1974, the Office of Business Economics, U.S. Department of Commerce (OBE) and the Economic Research Service, U.S. Department of Agriculture (ERS) published a nation-wide economic base study for the Water Resource Council (WRC) for use in water and related land resource development planning. This set of latest national projections reflect and incorporate the latest national and sub-national-regional economic and demographic trends and projections to the year 2020 by selected intervening periods. This projection series labled as "Series E" national projections depict best estimates of what can be expected if there are no policy or program changes of an unusual nature or magnitude during the projection period.

Underlying Assumptions

The projections of national and regional economy are based on long-run trends and ignore the cyclical fluctuations which characterize the short-run path of the economy. Some of the assumptions which underlie the national projections are as follows:

1. Growth of population will be conditioned by the fertility rates of recent years.

2. "Series E" assumes a completed cohort fertility rate of 2.1 births per woman which represents replacement level. The fertility rates are assumed to increase from a present low level of 1.869 births per woman to 2.1 births per

woman by the year 2015 and stabilize at this level for the ensuing years.

3. Nationally, reasonably full employment, represented by a four percent unemployment rate, will prevail for the projection period. The regional disparity in unemployment rates is assumed to diminish over the long-run.

4. The projections are assumed to be free of the immediate and direct effects of wars.

5. Continued technological progress and capital accumulation will support a growth in private output per man-hour of 2.9 percent annually.

6. Growth in output can be achieved without ecological disaster or serious deterioration, although diversion of resources for pollution control will cause changes in the industrial mix of output.

7. The composition of personal consumption will continue to change.

Summary of National Projections

The key national economic and demographic indicators used in this analysis are: 1) gross national product; 2) population; 3) employment; 4) households; and 5) total personal income. While GNP is projected for the nation as a whole, the lack of data pertaining to gross regional accounts preclude the use of GNP indicators below the national level. However, total personal income has a close and comparatively constant relationship to GNP and data base for estimating future personal income at regional and local level exist providing a reasonable indication of likely gross regional product for any given area. As a result, no estimates are prepared for gross regional product.

The projection period for the purposes of this analysis is up to the year 2025 while the national projections published by OBERS extend up to the year 2020. The OBERS projections of the key indicators were extrapolated to the year 2025. The key national indicators depicting the future level of economic activity are summarized below.

Table 1-21 National Growth Assumptions (Series E) for Selected Population and Economic Indices, 1973-2025

	In Thousands			In Millions of 1967 Dollars	
	Population	Households	Employment	Personal Income	GNP
1973	209,884	68,737	84,409	$ 793,233	$ 922,363
2000	262,494	95,107	116,022	$1,929,331	$2,150,857
2025	299,713	111,005	134,100	$3,880,801	$4,172,870
Annual Rate Of Growth					
1973-2000	0.88%	1.14%	1.14%	3.30%	3.20%
2000-2025	0.48%	0.57%	0.55%	2.83%	2.70%

Source: U.S. Bureau of Census, CPR Series P-25; Department of Commerce: Survey of Current Business and OBERS Projections (March, 1974); U.S. Department of Labor: Employment and Earnings.

Approach to Regional and Service Area Projections

The regional and service area projections presented in this report represent approximate orders of magnitude based upon the general direction and probable future trend of the national economy and population as described above. For purposes of testing the sensitivity of demand for water resource products, three levels of forecasts are prepared for each of the six defined service areas of the Delaware River Basin. The differences in the forecast levels are based upon both explicit and implicit regional and local assumptions regarding general public policy and alternative governmental and public actions necessary to achieve or realize these differing levels of growth in the future.

Projection Methodology

As in all economic projections, the final profiles produced contain a substantial element of professional judgment expressed in the assumptions made at critical points during the projection period, based upon known and perceived trends, resource limitations, development capacities and capabilities.

The OBERS projections for the water resource areas, economic areas, metropolitan areas and non-metropolitan areas generally consisted of allocation of national totals based upon the past performance of these areas and the strengths, weaknesses and competitiveness of these areas for economic development. The OBERS projections for regions and subareas are generally void of local sensitivity factors affecting their growth.

The service area projection process generally consisted of the following steps:

1. Disaggregation of OBERS projections for metropolitan and economic areas included in the service area definition.
2. Comparison of service area and subarea trends with the projections prepared by OBERS.
3. Refinement of the OBERS forecasts in light of observed trends, development constraints and assumptions underlying the three alternative development strategies.

Alternative Development Strategies

The Alternative development strategies identified are:

1. Continuance of present trends.
2. Emphasis on maximizing sound economic growth.
3. Emphasis on limiting economic growth and preserving environmental resources.

Growth Assumptions Underlying The Development Strategies

The three growth strategy options assume that the states and the subregions have at their option the potential to modify the patterns and the scale of development in specific locations and regions. This assumption is a key determinant of the spatial distribution of population and economic activity for various service areas and subareas under alternative development strategies.

The spatial distribution of population and economic activity under the three development strategy options assumes a relatively greater amount of leverage available to the rural and urbanizing jurisdictions in either maximizing or limiting growth than the area's large core cities and metropolitan counties, areas which are already highly developed. These in fact are dual scenarios representing the resulting trade-off of growth between the rural/urbanizing to highly developed metropolitan jurisdictions under the various development strategies. Implicit in this is that the range of potential growth is substantially greater in the rural and urbanizing areas between the strategies than it is for highly developed metropolitan jurisdictions. While the overall growth under the "maximum" growth strategies will be greater, the large proportion of this growth will be in outlying urbanized and rural jurisdictions. Under the "low or limited" growth strategy the overall growth will be less than in the "maximum" or "present trend" growth options; the distribution of the growth will be more in the developed large metropolitan areas. The specific assumptions underlying each growth strategy are presented below followed by the discussion of specific forecasts of various economic indicators for the service areas.

Assumptions Underlying "Present Trend" Strategy

1. There will be no major change in the governmental policies and programs, or the degree of their implementation, at the national, regional and local levels which will affect the amount or the spatial distribution of economic activity and population.

2. The diseconomies represented in the urban hierarchy of the Northeast will continue to persist.

3. The horizontal expansion of the economic activity and population will continue.

4. No drastic shifts in the industrial structure of the service area is expected to occur. The pattern of inter- and intra-regional dispersal of industrial activity as observed in the past will continue.

5. The existing differences between the national fertility rates and the observed fertility rates in the large urban areas of the Northeast will continue, gradually converging to the national level over the long run.

6. As a result of the lower birthrates and changes in the life style patterns, the average household size will tend to be lower than the national average.

Assumptions Underlying Maximizing Sound Economic Growth Strategy

Maximizing sound economic growth assumes that while there are limits to growth in the Northeast corridor, that certain governmental policies and programs can and will exert leverages in accommodating and geographically distributing a larger share of national growth than observed in the recent past. The intra-regional geographic distribution of economic growth under this alternative will depend upon the disposition of a number of important economic factors. Among these are: the availability of developable land; the cost of labor; that the cost of doing business will remain competitive with other regions of the county; adequate transportation facilities supportive of assumed development levels will be provided;

sufficient public services (sewer, water and others) will be available without unduly burdening local taxpayers; and, local development policies will be articulated and institutional arrangements made to attract and accommodate industrial development.

Specific assumptions regarding a maximized level of sound economic growth include the following:

1. Policies will be developed at the national, regional and local levels affecting the Northeast and the study area. National policies would include: intensive investment in the area, rail and highway transportation facilities in the region massive aid to Northeastern cities to promote redevelopment of cities and to prop up overburdened fiscal systems; and, the provision of other economic incentives to stabilize the Northeastern economy. Regional and local policies might include the provision of adequate zoned land to promote industrial development and sound residential growth in outlying areas combined with infrastructure investment (transportation, sewer, water and schools) to support development; redevelopment of the inner cities and policies aimed at utilization of presently underutilized lands; and the creation of the necessary institutions to carry out policies of sound economic development on the regional level.

2. The diseconomies represented in the North will diminish as other regions of the country catch up in terms of wage rates, transportation costs and governmental costs.

3. The horizontal expansion of economic activity will continue and will be accommodated by outlying political jurisdictions. However, the inner cities will not continue to lose population and jobs at the pace they have in the recent past.

4. There will be no dramatic shifts in the industrial composition of the region. Rather, all sectors of the regional economy will benefit from the improved growth perspective although some industries will continue to grow faster than others as observed in the recent past and as predicted for the nation as technological advances and changing consumer patterns alter the nation's economic structure.

5. Existing differences between national and regional birth rates will continue although gradually converging over time.

6. Lower birth rates and changing lifestyle patterns will result in smaller household sizes for the nation and the region. The subject region will maintain an average household size smaller than the nation over the projection period although the difference will narrow over the years.

Assumptions Underlying the Economic Growth Limitation and Environmental Resource Preservation Strategy

The third set of alternative projections assumes that economic growth will be limited as a means of protecting environmental resources such as air, water and land resources. It assumes that policies will be created at the regional and local level to preserve to the maximum feasible extent those areas that currently have high levels of natural environmental quality and to stabilize those areas that have undergone rapid development in the past as a means of reversing the trend of environmental degradation. For the region as a whole, it would mean a slowdown of the horizontal expansion characteristics of the region in the recent past. It assumes the adoption of strict land use policies limiting the development of residential areas and economic activities by suburban jurisdictions and nonmetropolitan counties, foregoing investments in sewer and water improvements in unserved areas, cutting both investment in highways while perhaps increasing mass transit support (especially in urbanized areas) and implementing high standards for air quality and water usage. These policies would be developed comprehensively and enforced regionally so that no shifts would occur between enforcing and nonenforcing jurisdictions.

Under the alternative of limiting economic growth and preserving environmental quality, the following specific assumptions were made:

1. Policies will be adopted at the national, regional, and local levels to inhibit the spread of urbanization and the destruction of environmental resources. At the national level, policies of high environmental quality will be set requiring local jurisdictions to enforce strict development standards regarding the use of land, air pollution and water consumption and sewage disposal. Regional agencies with enforcement powers will be created to insure the uniform enforcement of environmental standards and to

curtail cases of cross-jurisdictional environmental degradation. Regional transportation policies will be aimed at reducing automobile usage and suburban sprawl. Local communities will adopt strict zoning ordinances to restrain the development of open space for residential purposes, to protect environmentally vulnerable areas, to cut down on long work-residence auto trips in accord with regional policies. These policies will be enacted and enforced uniformly over the entire region.

2. The diseconomies of the Northeast region will be aggravated by reducing land supply because of environmental restriction, creating greater densities in already built-up areas.

3. The highly urbanized portions of the region will slightly increase their shares of the region's population contrary to past observed trends. This will result as population is held in to the center because of development constraints in the fringe areas.

4. The industrial structure of the region will shift towards less environmentally harmful industry and towards a smaller proportion of manufacturing activity. The zoning and restriction of land use and standards regarding water and air pollution wil inhibit growth of manufacturing industries and particularly water-using industries. Greater concentration of administrative and service activities will occur.

5. Existing differences between national and regional birth rates will continue although gradually converging over the long run.

6. Similarly, declining birth rate and changing lifestyle patterns will result in smaller household sizes at the national and regional levels. The region will maintain a smaller average household size than the nation although the difference will narrow over time.

Service Area Projections

The resulting forecasts of population, employment, households and total personal income for each of the defined service areas of the Delaware River Basin are presented in the following four tables. These show the ranges of population and economic activity indicators over the 1973-2025 period for each of the six service areas under the three development strategies outlined in the previous paragraphs. Projections for the various subareas within each service area are provided in the appendix of this report.

For the purposes of simplicity the following discusses the resulting population forecasts under the three development strategies for only the seven county impact area and the 53-county water supply service area.

The population in the 53-county water supply area under the "present trend" option is projected to grow from 25,899,400 persons in 1973 to 33,713,000 by the year 2025, an increase of 7,813,600 people or 30.2 percent increase over the 52 year projection period. Under the "maximization of sound economic growth" assumptions, the water supply service area population is projected to increase by 11,775,600 or a gain of 45.5 percent over the

1973 population level. Conversely, under the "limited" growth option the population in the water supply service area is projected to increase by 15.7 percent or by 4,072,600 persons over the 1973-2025 period.

The range of population growth in the seven county impact area varies from 273,200 persons under the "limited" growth assumptions to 988,200 persons under the "maximum" growth assumptions. This range of difference between the projections under the various growth strategies reflect the assumptions made regarding the available and exercisable leverages over growth in the rural and urbanizing jurisdictions compared to existing highly developed metropolitan core cities and their suburbs. The specific implications of the development strategies and resulting forecasts of population, employment and other economic variables are discussed following the forecast tables.

Table 1-22 Population Projections, By Service Area, 1973-2025 (Thousands)

	7-County Impact Area	Flood Control	Water Quality	Electric Power	Water Supply*	Recreation Area
Actual, 1973	736.8	5,840.1	7,009.5	19,666.3	25,899.4	29,857.6
Projected, 2025						
Maximized Sound Growth	1,725.0	8,817.5	11,095.8	34,574.0	37,675.0	43,403.0
Present Trends	1,477.0	7,998.6	10,008.8	30,541.2	33,713.0	38,742.0
Limited Economic Growth	1,010.0	7,054.7	8,819.3	25,407.0	29,972.0	34,508.0
Numerical Change, 1973-2025						
Maximized Sound Growth	988.2	2,977.4	4,086.3	14,907.7	11,775.6	13,545.4
Present Trends	740.2	2,158.5	2,999.3	10,874.9	7,813.6	8,884.4
Limited Economic Growth	273.2	1,214.6	1,809.8	5,740.7	4,072.6	4,650.4
Percent Change, 1973-2025						
Maximized Sound Growth	134.1%	51.0%	58.3%	75.8%	45.5%	45.4%
Present Trends	100.5%	37.0%	42.8%	55.3%	30.2%	29.8%
Limited Economic Growth	37.1%	20.8%	25.8%	29.2%	15.7%	15.6%

Source: Current Population Reports, Series P-25.

* *As indicated by the 53-county DRB Influence Area*

Table 1-23 Household Projections, By Service Area, 1973-2025 (Thousands)

	7-County Impact Area	Flood Control	Water Quality	Electric Power	Water Supply
Actual, 1973	235.8	1,873.6	2,230.7	6,263.6	8,627.9
Projected, 2025					
Maximized Sound Growth	631.2	3,254.5	3,974.9	12,495.5	14,123.7
Present Trends	540.0	2,952.0	3,583.6	11,033.1	12,639.7
Limited Economic Growth	369.9	2,603.8	3,153.6	9,171.2	11,251.0
Numerical Change, 1973-2025					
Maximized Sound Growth	395.4	1,380.9	1,744.0	6,231.9	5,495.8
Present Trends	304.2	1,078.4	1,352.9	4,769.5	4,011.8
Limited Economic Growth	134.1	730.2	922.9	2,907.6	2,623.1
Percent Change, 1973-2025					
Maximized Sound Growth	167.7%	73.7%	78.2%	99.5%	63.7%
Present Trends	129.0%	57.6%	60.6%	76.1%	46.5%
Limited Economic Growth	56.9%	39.0%	41.4%	46.4%	30.4%

Table 1-24 Total Employment Projections, By Service Area, 1973-2025 (Thousands)

	7-County Impact Area	Flood Control	Water Quality	Electric Power	Water Supply
Actual, 1973	286.4	2,375.3	2,844.5	7,994.5	10,570.1
Projected, 2025					
Maximized Sound Growth	757.3	4,053.6	5,013.3	15,809.3	17,402.7
Present Trends	648.5	3,677.2	4,521.3	13,959.4	15,572.4
Limited Economic Growth	445.1	3,243.9	3,986.3	11,589.3	13,875.6
Numerical Change, 1973-2025					
Maximized Sound Growth	470.9	1,678.3	2,168.8	7,814.8	6,832.6
Present Trends	362.1	1,301.9	1,676.8	5,964.9	5,002.3
Limited Economic Growth	158.7	868.6	1,141.8	3,594.8	3,305.5
Percent Change, 1973-2025					
Maximized Sound Growth	164.4%	70.7%	76.2%	97.8%	64.6%
Present Trends	126.4%	54.8%	58.9%	74.6%	47.3%
Limited Economic Growth	55.4%	36.6%	40.1%	45.0%	31.3%

Table 1-25 Total Personal Income Projections, By Service Area, 1972-2025
TPI: Millions of 1967 dollars

	7-County Impact Area	Flood Control	Water Quality	Electric Power	Water Supply
Actual, 1972	$ 2,539	$ 23,057	$ 27,000	$ 77,311	$112,646
Projected, 2025					
Maximized Sound Growth	$23,711	$115,585	$146,182	$489,806	$523,927
Present Trends	$20,323	$107,225	$132,027	$432,722	$469,380
Limited Economic Growth	$14,028	$ 93,231	$116,953	$359,990	$422,407
Numerical Change, 1972-2025					
Maximized Sound Growth	$21,172	$ 92,528	$119,182	$412,495	$411,281
Present Trends	$17,784	$ 84,168	$105,027	$355,411	$356,734
Limited Economic Growth	$11,489	$ 70,174	$ 89,953	$282,679	$309,761
Percent Change, 1972-2025					
MaximizedSound Growth	833.9%	401.3%	441.4%	533.6%	365.1%
Present Trends	700.4%	365.0%	389.0%	459.7%	316.7%
Limited Economic Growth	452.5%	304.4%	333.2%	365.6%	275.0%

Source: U.S. Department of Commerce, Survey of Current Business.

I.C.2(b) Implications of Projections Representing Development Strategies

The ranges of population, employment, households and income contained in the three sets of projections representing distinct development strategies have broad implications for the service areas. This section will focus on implications for the regions in terms of a national framework and in terms of the spatial distribution of population and economic activity expected under the three levels of projected development. This analysis will dwell on the Water Supply Service Area, which encompasses the three smaller service areas and most of the population and employment in the Electric Power and Recreation Service Areas, in order to focus on the relevant implications of the three growth strategies.

National Framework

In recent years, the Water Supply Service Area has experienced a declining share of the nation's population and economic activity. This occurred because other areas of the country grew at a faster pace than the Water Supply Service Area siphoning off some of the area's growth. The set of projections representing the three development strategies for the service area imply that the region will maintain its present share of national population and economic activity under the "maximized sound growth" development alternative while it will have a steadily declining share under the "limited economic growth" development strategy. Implicit in these projections under "maximized sound growth" is that state and regional governments will develop effective strategies improving the quality of life and the quantity and quality of economic opportunities relative to other regions of the country. Maximized" growth would result in an increase in the service area's share of the national population from 12.34 percent in 1973 to 12.57 percent in 2025. In contrast, the "limited economic growth" development strategy implies that the service area will put a "cap" on its growth. This would divert some of the growth which may have occurred to other parts of the country, assuming the continuation of present trends. As a result, the Water Supply Service Area's share of national population would decline from its 1973 share of 12.34 percent to 10.00 percent by the year 2025 with corresponding declining shares of employment, income and households.

The "present trend" projections imply that the service area contains a gradually declining share of the nation's population and economic activity in line with recent observed trends. This implies that the diseconomies represented in the Northeast and the Water Supply Service Area in particular will continue to be operative causing some economic activities to expand in or move to other areas of the country. With present trend assumptions, share of the service area's population would drop to 11.25 percent in 2025 from its 1973 share of 12.34 percent.

Table 1-26 Summary of Most Probable High, Medium and Low Projections of Population, Employment, Households and Total Personal Income, Water Supply Service Area, 1960-2025

	Population	Employment	Households	Personal Income
Actual				
1960	23,059,100	9,277,900	7,124,900	$ 71,464.7
1970	25,762,700	10,506,800	8,279,500	$105.732.2
1973	25,899,400	10,570,100	8,628,000	$112,546.3
Probable Range: 1985				
"Maximized Sound Growth"	28,611,000	12,927,300	10,213,200	$168,480.8
"Present Trends"	27,939,000	12,626,200	9,974,400	$164,680.4
"Limited Growth"	26,782,000	12,117,400	9,569,100	$158,510.0
Probable Range: 2025				
"Maximized Sound Growth"	37,675,000	17,402,700	14,123,700	$523,925.9
"Present Trends"	33,713,000	15,572,400	12,639,700	$469,410.0
"Limited Growth"	29,972,000	14,274,600	11,251,000	$422,405.8
Service Area As a Percent of U.S.				
Actual				
1970	12.67%	13.25%	13.05%	14.92%
1973	12.34%	12.52%	12.55%	14.70%
Projected: 1985				
"Maximized Sound Growth"	12.22%	12.78%	12.57%	14.50%
"Present Trends"	11.94%	12.49%	12.27%	14.17%
"Limited Growth"	11.44%	11.98%	11.77%	13.64%
Projected: 2025				
"Maximized Sound Growth:	12.57%	12.98%	12.72%	13.50%
"Present Trends"	11.25%	11.61%	11.39%	12.10%
"Limited Growth"	10.00%	10.64%	10.14%	10.88%

1/ In Millions of 1967 Dollars.

The Water Supply Service Area -- population of 25,899,400 in 1973 -- is projected to contain varying shares of the nation's projected 2025 population of 299,713,000. Under the "maximized" growth strategy, the population of the service area is expected to reach 37,675,000 by 2025. Assuming "present trends", population would be 33,713,000 and under "limited growth", the population would be 29,972,000 by the end of the projection period.

Spatial Distribution Under Three Development Strategies

Besides affecting the total amount of population growth the Water Supply Service Area could expect, the three development strategies also imply different spatial distributions of that population. The core cities including Philadelphia, New York, Newark and Jersey City, currently retain the largest of the region's population although they have been losing population in the recent past. The suburban counties of the large SMSA's, small and medium-size SMSA's and urbanizing non-SMSA counties have been expected to continue under all three development strategies. Of the projected 1973-2025 population gain of 11,776,000 under the "maximized" growth projections, 5,177,000 is expected to go into the suburban counties of the large SMSA's, a 68.0 percent growth rate with significant increases also occurring in the small and medium-size SMSA counties. The core cities

Table 1-27 Distribution of Projected Population by Sub-Area
Delaware River Basin Influence Area 1973-2025

	Large SMSA's		Small & Medium	Non-SMSA Counties		Total Influence
	Core Cities	Suburban Cos.	Size SMSA's	Urbanizing	Rural	Area
ACTUAL, 1973	11,153	7,618	5,466	1,271	391	25,899
PROJECTED, 2025						
Maximized Sound Growth	11,515	12,795	9,335	3,030	1,000	37,675
Present Trends	10,939	11,068	8,257	2,637	812	33,713
Limited Growth	11,620	9,517	6,700	1,665	470	29,972
NUMERICAL GAIN, 1973-2025						
Maximized Sound Growth	362	5,177	3,868	1,759	609	11,776
Present Trends	-214	3,450	2,790	1,366	421	7,814
Limited Growth	467	1,899	1,233	394	79	4,073
PERCENT GAIN, 1973-2025						
Maximized Sound Growth	3.3%	68.0%	70.8%	138.4%	155.8%	45.5%
Present Trends	-1.9%	45.3%	51.0%	107.5%	107.7%	30.2%
Limited Economic Growth	4.1%	24.9%	22.6%	31.0%	20.2%	15.7%

Source: 1973 U.S. Census Bureau, CPR Series P-25 and P-26.

would reverse their current trend of population decline and add a relatively small amount of population.

The suburban counties would also accommodate the largest share of 1973-2025 population growth, assuming "limited" growth with 1,899,000 out of the projected addition of 4,073,000 in the service area. Under "limited economic growth" development strategy, the core cities are expected to add 467,000 people, a 4.1% gain because population growth would be held to the existing centers because of growth restrictions in outlying areas. New York and Philadelphia are projected to have population increases, while Newark and Jersey City would maintain stable population sizes.

Although the largest quantities of growth are expected to occur in the suburban counties of the large SMSA's and in small and medium-size SMSA's, the greatest relative impact would most likely be felt in urbanizing and rural non-SMSA counties like those contained in the 7-County Impact Area. These two sub-areas are expected to add 1,759,000 and 609,000, respectively, for growth rates of 138.4 percent for urbanizing counties and 155.8 percent for rural counties assuming "maximized" growth. While the numbers are not that large, the impact on the counties of a more than doubling of population would be significant. On the other hand, under the "limited growth" development strategy, the non-SMSA urbanizing counties would add only 394,000, a 31.0 percent gain; and the rural counties would add 79,000 people from 1973 to 2025, a 20.2 percent gain. The greater amount of leverage over growth by these two sub-areas is implied by their differences in growth rates under "maximized" growth and "limited" growth of over 100 percent. The range of growth rates in any of the other three sub-areas is never greater than 50 percent.

APPENDIX A TO CHAPTER I

ECONOMIC TABLES

Table A-1 Population Trends, Delaware River Basin 7-County Impact Area, 1960-1973

	1960	1970	1973	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1973 Amount	Gain, 1970-1973 Percent
Warren County	63,220	73,960	76,400	10,740	17.0%	2,440	3.3%
Sussex County	49,255	77,528	85,600	28,273	57.4%	8,072	10.4%
(New Jersey Portion)	(112,475)	(151,488)	(162,000)	(39,013)	(34.7%)	(10,512)	(6.9%)
Orange County	183,734	221,657	233,600	37,923	20.6%	11,943	5.4%
Sullivan County	45,272	52,580	57,700	7,308	16.1%	5,120	9.7%
(New York Portion)	(229,006)	(274,237)	(291,300)	(45,231)	(19.8%)	(17,063)	(6.2%)
Monroe County	39,567	45,422	49,300	5,855	14.8%	3,878	8.5%
Northampton County	201,412	214,545	221,300	13,133	6.5%	6,755	3.1%
Pike County	9,158	11,818	12,900	2,660	29.0%	1,082	9.2%
(Pennsylvania Portion)	(250,137)	(271,785)	(283,500)	(21,648)	(8.7%)	(11,715)	(4.3%)
Total, 7-County Impact Area	591,681	697,510	736,800	105,892	17.9%	39,290	5.6%

Sources: U. S. Census of Population, 1960 and 1970, CPR Series P-25 and P-26.

Table A-2 Population Trends Comparison, 7-County Impact Area, Northeast and United States, 1960-1973 (Thousands)

	1960	1970	1973	Gain, 1960-1973 Amount	Gain, 1960-1973 Percent
7-County Impact Area	592	698	737	145	24.5%
Northeast	44,678	49,051	49,545	4,867	10.9%
United States	179,323	203,235	209,844	30,521	17.0%
7-County Impact Area Percent of:					
Northeast	1.32%	1.42%	1.49%	2.98%	
United States	0.33%	0.34%	0.35%	0.48%	

Sources: U.S. Census of Population, 1960 and 1970 and CRP Series P-25 and P-26.

Table A-3 Household Trends, Delaware River Basin 7-County Impact Area, 1960-1973

	1960	1970	1973	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1973 Amount	Gain, 1970-1973 Percent
Warren County	19,233	23,338	25,050	4,105	21.3%	1,712	7.3%
Sussex County	14,434	22,809	25,250	8,375	58.0%	2,441	10.7%
(New Jersey Portion)	(33,667)	(46,147)	(50,300)	(12,480)	37.1%	(4,153)	9.0%
Orange County	53,919	65,607	69,730	11,688	21.7%	4,123	6.3%
Sullivan County	14,112	16,865	19,040	2,753	19.5%	2,175	12.9%
(New York Portion)	(68,031)	(82,472)	(88,770)	14,441	21.2%	(6,298)	7.6%
Monroe County	12,112	14,674	16,800	2,562	21.2%	2,156	14.7%
Northampton County	60,712	68,628	75,270	7,916	13.0%	6,642	9.7%
Pike County	3,130	4,130	4,610	1,000	31.9%	480	11.6%
(Pennsylvania Portion)	(75,954)	(87,432)	(96,710)	(11,478)	15.1%	(9,278)	10.6%
Total, 7-County Impact Area	177,652	216,051	235,780	38,399	21.6%	19,729	9.1%

Sources: U.S. Census of Population, 1960 and 1970, CPR Series P-25 and P-26.

Table A-4 Household Trends Comparison, 7-County Impact Area, Northeast and United States, 1960-1973 (Thousands)

	1960	1970	1973	Gain, 1960-1973 Amount	Gain, 1960-1973 Percent
7-County Impact Area	178	216	236	58	32.6%
Northeast	13,521	15,483	16,412	2,891	21.4%
United States	53,021	63,450	68,737	15,716	29.6%
7-County Impact Area Percent:					
Northeast	1.32%	1.40%	1.44%	2.01%	
United States	0.34%	0.34%	0.34%	0.37%	

Sources: U. S. Census of Population, 1960 and 1970 CPR Series P-25 and P-26.

Table A-5 Total Non-Agricultural Wage and Salary Employment
Delaware River Basin 7-County Impact Area, 1960-1972
(Thousands)

	1960	1970	1972	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1972 Amount	Gain, 1970-1972 Percent
Warren County	19.6	25.0	25.7	5.4	27.6%	1.7	2.8%
Sussex County	9.5	16.8	19.6	7.3	76.8%	2.8	16.7%
(New Jersey Portion)	(29.1)	(41.8)	(45.3)	(12.7)	(43.6%)	(3.5)	(8.4%)
Orange County	53.0	70.0	69.2	17.0	32.1%	-.8	-1.1%
Sullivan County	20.8	22.2	22.9	1.4	6.7%	.7	3.2%
(New York Portion)	(73.8)	(92.2)	(92.1)	(18.4)	(24.9%)	(-.1)	(- .1%)
Monroe County	14.8	20.3	22.9	5.5	37.2%	2.6	12.8%
Northampton County	78.2	90.0	87.5	11.8	15.1%	-2.5	-2.8%
Pike County	1.8	2.6	2.9	.8	44.4%	.3	11.5%
(Pennsylvania Portion)	(94.8)	(112.9)	(113.3)	(18.1)	(19.1%)	(.4)	(.4%)
Total, 7-County Impact Area	197.7	246.9	250.7	49.2	24.9	3.8	1.5%

Sources: Pennsylvania Department of Labor and Industry; New York State Department of Labor, Employment Review, 1972; New Jersey Department of Labor and Industry.

Table A-6 Total Non-Agricultural Wage and Salary Employment Comparisons, Delaware River Basin 7-County Impact Area, Northeast and United States, 1960-1972 (Thousands)

	1960	1970	1972	Gain, 1960-1972 Amount	Percent
7-County Impact Area	198	247	251	53	26.8
Northeast	15,613	18,672	18,633	3,020	19.3
United States	54,234	70,593	72,764	18,530	34.2
7-County Impact Area Percent of:					
Northeast	1.27	1.32	1.35	1.75	
United States	.37	.35	.34	.29	

Sources: Employment and Earnings.

Table A-7 Total Personal Income Trends, Delaware River Basin
7-County Impact Area, 1959-1972 (Millions)

	1959	1969	1972	Gain, 1959-1969 Amount	Gain, 1959-1969 Percent	Gain, 1969-1972 Amount	Gain, 1969-1972 Percent
Warren County	$ 129	$ 262	$ 337	$ 133	103.1%	$ 75	28.6%
Sussex County	98	245	333	147	150.0%	88	35.9%
(New Jersey Portion)	($ 227)	($ 507)	($ 670)	($ 280)	(123.3%)	($ 63)	(32.1%)
Orange County	$ 400	$ 820	$1,065	$ 420	105.0%	$245	29.9%
Sullivan County	101	187	229	86	85.1%	42	22.5%
(New York Portion)	($ 501)	($1,007)	($1,294)	($ 506)	(101.0%)	($287)	(28.5%)
Monroe County	$ 76	$ 150	$ 186	$ 74	97.4%	$ 36	24.0%
Northampton County	430	776	978	346	80.5%	202	26.0%
Pike County	15	38	53	23	153.3%	15	39.5%
(Pennsylvania Portion)	($ 521)	($ 964)	($1,217)	($ 443)	(85.0%)	($253)	(26.2%)
Total, 7-County Impact Area	$1,249	$2,478	$3,181	$1,229	98.4%	$703	28.4%

Sources: U. S. Census of Population, 1960 and 1970, U. S. Department of Commerce: Survey of Current Business (May, 1974).

Table A-8 Total Personal Income Comparisons, Delaware River Basin 7-County Impact Area, Northeast and United States, 1959-1972
(Millions)

	1959	1969	1972	Gain, 1959-1972 Amount	Gain, 1959-1972 Percent
Current Dollars					
7-County Impact Area	$ 1,249	$ 2,478	$ 3,181	$ 1,932	154.7%
Northeast	$109,452	$203,051	$248,319	$138,867	126.9%
United States	$381,890	$751,425	$947,066	$565,176	148.0%
Constant 1972 Dollars					
7-County Impact Area	$ 1,792	$ 2,827	$ 3,181	$ 1,389	77.5%
Northeast	$157,063	$231,681	$248,319	$ 91,256	58.1%
United States	$548,012	$857,375	$947,066	$399,054	72.8%
7-County Impact Area Percent of:					
Northeast	1.14%	1.22%	1.28%	1.39%	
United States	0.33%	0.33%	0.34%	0.34%	

Sources: U.S. Census of Population, 1960 and 1970, U. S. Department of Commerce: Survey of Current Business (May and August, 1974).

Table A-9 Projected Population, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin 7-County Economic Base Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Sussex County, N.J.	77.5	85.6	94.0	101.0	108.0	116.0	125.0
Warren County, N.J.	74.0	76.4	86.0	94.0	103.0	114.0	125.0
Orange County, N.Y.	221.7	233.6	249.0	263.0	277.0	291.0	305.0
Sullivan County, N.Y.	52.6	57.7	60.0	63.0	65.0	67.0	70.0
Monroe County, Pa.	45.4	49.3	54.0	57.0	61.0	65.0	70.0
Northampton County, Pa.	214.5	221.3	237.0	250.0	264.0	279.0	295.0
Pike County, Pa.	11.8	12.9	14.0	16.0	17.0	18.0	20.0
Total, Economic Base Area	697.5	736.8	794.0	844.0	895.0	950.0	1,010.0

Table A-10 Projected Population, Continuation of Present Trends Alternative, Delaware River Basin 7-County Economic Base Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Sussex Co., N.J.	77.5	85.6	127.0	158.0	185.0	209.0	230.0
Warren Co., N.J.	74.0	76.4	92.0	108.0	128.0	151.0	175.0
Orange Co., N.Y.	221.7	233.6	282.0	338.0	383.0	425.0	452.0
Sullivan Co, N.Y.	52.6	57.7	70.0	80.0	92.0	105.0	120.0
Monroe Co., Pa.	45.4	49.3	63.0	78.0	94.0	111.0	130.0
Northampton Co., Pa.	214.5	221.3	242.0	262.0	284.0	306.0	330.0
Pike Co., Pa.	11.8	12.9	18.0	22.0	27.0	33.0	40.0
Total, Economic Base Area	697.5	736.8	894.0	1,046.0	1,193.0	1,340.0	1,477.0

Table A-11 Projected Population, Maximization of Sound Economic Growth Alternative, Delaware River Basin 7-County Economic Base Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Sussex Co., N.J.	77.5	85.6	135.0	180.0	215.0	245.0	270.0
Warren Co., N.J.	74.0	76.4	97.0	121.0	149.0	179.0	210.0
Orange Co., N.Y.	221.7	233.6	290.0	358.0	414.0	465.0	505.0
Sullivan Co., N.Y.	52.6	57.7	75.0	90.0	110.0	130.0	150.0
Monroe Co., Pa.	45.4	49.3	70.0	90.0	110.0	135.0	160.0
Northampton Co., Pa.	214.5	221.3	250.0	277.0	306.0	340.0	370.0
Pike Co., Pa.	11.8	12.9	20.0	30.0	40.0	50.0	60.0
Total, Economic Base Area	697.5	736.8	937.0	1,146.0	1,344.0	1,544.0	1,725.0

Table A-12 Projected Households, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin 7-County Economic Base Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Sussex County, N.J.	22.8	25.3	29.7	33.3	36.7	40.4	44.3
Warren County, N.J.	23.3	25.1	29.9	33.7	37.6	42.1	46.3
Orange County, N.Y.	65.6	69.7	79.6	87.7	95.2	102.1	108.9
Sullivan County, N.Y.	16.9	19.0	21.0	22.7	23.8	24.8	26.0
Monroe County, Pa.	14.7	16.8	19.4	21.0	22.8	24.3	26.2
Northampton County, Pa.	68.6	75.3	84.9	92.3	98.5	104.5	110.5
Pike County, Pa.	4.1	4.6	5.2	6.1	6.5	6.9	7.7
Total, Economic Base Area	216.0	235.8	269.7	296.8	321.1	345.1	369.9

Table A-13 Projected Households, Maximization of Sound Economic Growth Alternative, Delaware River Basin 7-County Economic Base Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Sussex County, N.J.	22.8	25.3	42.7	59.4	73.1	85.4	95.7
Warren County, N.J.	23.3	25.1	33.7	43.4	54.4	66.1	77.8
Orange County, N.Y.	65.6	69.7	92.7	119.3	142.3	163.2	180.4
Sullivan County, N.Y.	16.9	19.0	26.2	32.4	40.3	48.1	55.8
Monroe County, Pa.	14.7	16.8	25.2	33.2	41.0	50.6	59.9
Northampton County, Pa.	68.6	75.3	89.6	102.2	114.2	127.3	138.6
Pike County, Pa.	4.1	4.6	7.5	11.5	15.4	19.2	23.0
Total, Economic Base Area	216.0	235.8	317.6	401.4	480.7	559.9	631.2

Table A-14 Projected Households, Continuation of Present Trends Alternative, Delaware River Basin 7-County Economic Base Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Sussex County, N.J.	22.8	25.3	40.2	52.1	62.9	72.9	81.6
Warren County, N.J.	23.3	25.1	31.9	38.7	46.7	55.7	64.8
Orange County, N.Y.	65.6	69.7	90.1	112.7	131.6	149.1	161.4
Sullivan County, N.Y.	16.9	19.0	24.5	28.8	33.7	38.9	44.6
Monroe County, Pa.	14.7	16.8	22.7	28.8	35.1	41.6	48.7
Northampton County, Pa.	68.6	75.3	86.7	96.7	106.0	114.6	123.6
Pike County, Pa.	4.1	4.6	6.7	8.4	10.4	12.7	15.3
Total, Economic Base Area	216.0	235.8	302.8	366.2	426.4	485.5	540.0

Table A-15 Projected Total Employment, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin 7-County Economic Base Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Sussex County, N.J.	29.7	32.6	38.5	42.4	46.4	51.0	55.0
Warren County, N.J.	29.3	30.0	36.1	40.4	45.3	51.3	56.3
Orange County, N.Y.	80.7	84.1	97.1	105.2	113.6	122.2	128.1
Sullivan County, N.Y.	20.1	21.9	24.6	26.5	28.0	28.8	30.1
Monroe County, Pa.	18.8	20.2	23.2	25.1	27.5	29.3	31.5
Northampton County, Pa.	90.9	92.9	109.0	117.5	124.1	128.3	135.7
Pike County, Pa.	4.3	4.6	5.5	6.4	7.0	7.6	8.4
Total, Economic Base Area	273.8	286.3	334.0	363.5	391.9	418.5	445.1

Table A-16 Projected Total Employment, Continuation of Present Trends Alternative, Delaware River Basin 7-County Economic Base Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Suxxes County, N.J.	29.7	32.6	52.1	66.4	79.6	92.0	101.2
Warren County, N.J.	29.3	30.0	38.6	46.4	56.3	68.0	78.8
Orange County, N.Y.	80.7	84.1	110.0	135.2	157.0	178.5	189.8
Sullivan County, N.Y.	20.1	21.9	28.7	33.6	39.6	45.2	51.6
Monroe County, Pa.	18.8	20.2	27.1	34.3	42.3	50.0	58.5
Northampton County, Pa.	90.9	92.9	111.3	123.1	133.5	140.8	151.8
Pike County, Pa.	4.3	4.6	7.0	8.8	11.1	13.9	16.8
Total, Economic Base Area	273.8	286.3	374.8	447.8	519.4	588.4	648.5

Table A-17 Projected Total Employment, Maximization of Sound Economic Growth Alternative, Delaware River Basin 7-County Economic Base Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Sussex County, N.J.	29.7	32.6	55.4	75.6	92.5	107.8	118.8
Warren County, N.J.	29.3	30.0	40.7	52.0	65.6	80.6	94.5
Orange County, N.Y.	80.7	84.1	113.1	143.2	169.7	195.3	212.1
Sullivan County, N.Y.	20.1	21.9	30.8	37.8	47.3	55.9	64.5
Monroe County, Pa.	18.8	20.2	30.1	39.6	49.5	60.8	72.0
Northampton County, Pa.	90.9	92.9	115.0	130.2	143.8	156.4	170.2
Pike County, Pa.	4.3	4.6	7.8	12.0	16.4	21.0	25.2
Total, Economic Base Area	273.8	286.3	392.9	490.4	584.8	677.8	757.3

Table A-18 Projected Total Personal Income, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin 7-County Economic Base Area, 1969-2025 (TPI = Millions of 1967 Dollars)

	1969	1972	1985	1995	2005	2015	2025
Sussex Co., N.J.	$ 223	$ 266	$ 432	$ 612	$ 863	$ 1,170	$ 1,509
Warren Co., N.J.	239	269	474	682	984	1,381	1,832
Orange Co., N.Y.	747	850	1,338	1,858	2,567	3,385	4,238
Sullivan Co., N.Y.	170	183	276	382	520	676	845
Monroe Co. Pa.	137	148	271	379	557	763	1,002
Northampton Co, Pa.	707	781	1,306	1,815	2,522	3,378	4,324
Pike Co., Pa.	35	42	97	122	166	214	278
Total, Economic Base Area	$2,258	$2,539	$4,194	$5,850	$8,179	$10,967	$14,028

Table A-19 Projected Total Personal Income, Continuation of Present Trends Alternative, Delaware River Basin 7-County Economic Base Area, 1969-2025 (TPI = Millions of 1967 Dollars)

	1969	1972	1985	1995	2005	2015	2025
Sussex Co., N.J.	$ 223	$ 266	$ 584	$ 957	$ 1,479	$ 2,108	$ 2,776
Warren Co., N.J.	239	269	507	784	1,223	1,829	2,565
Orange Co., N.Y.	747	850	1,515	2,388	3,550	4,944	6,281
Sullivan Co., N.Y.	170	183	322	485	735	1,059	1,448
Monroe Co., Pa.	137	148	316	519	859	1,303	1,861
Northampton Co., Pa.	707	781	1,333	1,902	2,713	3,706	4,837
Pike Co., Pa.	35	42	125	168	263	393	555
Total, Economic Base Area	$2,258	$2,539	$4,702	$7,203	$10,822	$15,342	$20,323

Table A-20 Projected Total Personal Income, Maximization of Sound Economic Growth Alternative, Delaware River Basin 7-County Economic Base Area, 1969-2025 (TPI = Millions of 1967 Dollars)

	1969	1972	1985	1995	2005	2015	2025
Sussex Co., N.J.	$ 223	$ 266	$ 620	$1,090	$ 1,718	$ 2,471	$ 3,259
Warren Co., N.J.	239	269	534	878	1,423	2,168	3,078
Orange, Co., N.Y.	747	850	1,558	2,529	3,837	5,409	7,017
Sullivan Co., N.Y.	170	183	345	545	879	1,311	1,811
Monroe Co., Pa.	137	148	351	599	1,005	1,584	2,291
Northampton Co., Pa.	707	781	1,378	2,010	2,923	4,117	5,423
Pike Co., Pa.	35	42	139	229	390	596	832
Total, Economic Base Area	$2,258	$2,539	$4,925	$7,880	$12,175	$17,656	$23,711

Table A-21 Population Trends, Delaware River Basin Electric Power Service Area, 1960-1973

Portions of States Within Electric Power Area	1960	1970	1973	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1973 Amount	Gain, 1970-1973 Percent
Delaware	446,292	548,104	575,700	101,812	22.8%	27,596	5.0%
New Jersey	6,066,782	7,171,112	7,361,400	1,104,330	18.2%	190,288	2.7%
New York	1,948,713	2,280,434	2,350,900	331,721	17.0%	70,466	3.1%
Pennsylvania	5,974,087	6,500,597	6,677,300	526,510	8.8%	176,703	2.7%
Maryland	1,742,589	2,504,828	2,656,400	762,239	43.7%	151,572	6.1%
Virginia	47,601	43,446	44,500	- 4,155	-8.7%	1,054	2.4%
Total, Electric Power Area	16,226,064	19,048,521	19,666,200	2,822,457	17.4%	617,679	3.2%

Sources: U. S. Census of Population, 1960 and 1970 CPR Series P-25 and P-26, and Hammer, Siler, George Associates.

Table A-22 Population Trends Comparison, Delaware River Basin Electric Power Service Area, Northeast and United States, 1960-1973 (thousands)

	1960	1970	1973	Gain, 1960-1973 Amount	Gain, 1960-1973 Percent
Electric Power Service Area	16,226	19,049	19,666	3,440	21.2%
Northeast	44,678	49,051	49,545	4,867	10.9%
United States	179,323	203,235	209,844	30,521	17.0%
Electric Power Service Area Percent of:					
Northeast	36.32%	38.84%	39.69%	70.68%	
United States	9.05%	9.37%	9.37%	11.27%	

Sources: U.S. Census of Population, 1960 and 1970 and CPR Series P-25 and P-26.

Table A-23 Household Trends, Delaware River Basin Electric Power Service Area, 1960-1973

	1960	1970	1973	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1973 Amount	Gain, 1970-1973 Percent
Portions of States Within Electric Power Area:							
Delaware	128,582	164,804	181,570	36,222	28.2%	16,766	10.2%
New Jersey	1,806,295	2,218,182	2,374,120	411,887	22.8%	155,938	7.0
New York	563,942	679,214	718,310	115,272	20.4%	39,096	5.8
Pennsylvania	1,754,292	2,015,721	2,122,580	261,429	14.9%	106,859	5.3
Maryland	470,867	734,218	850,930	263,351	55.9%	116,712	15.9
Virginia	14,528	14,393	16,120	- 135	-0.9%	1,727	12.0
Total, Electric Power Area	4,738,506	5,826,532	6,263,630	1,088,026	23.0%	437,098	7.5%

Sources: U.S. Census of Population, 1960 and 1970, CPR Series P-25 and P-26.

Table A-24 Household Trends Comparison, Delaware River Basin Electric Power Service Area, Northeast, and United States, 1960-1973 (Thousands)

	1960	1970	1973	Gain, 1960-1973 Amount	Gain, 1960-1973 Percent
Electric Power Service Area	4,739	5,827	6,264	1,525	32.2%
Northeast	13,521	15,483	16,412	2,891	21.4%
United States	53,021	63,450	68,737	15,716	29.6%
Electric Power Service Area Percent:					
Northeast	35.05%	37.63%	38.17%	52.75%	
United States	8.94%	9.18%	9.11%	9.70%	

Sources: U. S. Census of Population, 1960 and 1970 CPR Series P-25 and P-26.

Table A-25 Total Non-Agricultural Wage and Salary Employment Delaware River Basin Electric Power Service Area, 1960-1972 (Thousands)

Portions of States Within Electric Power Area	1960	1970	1972	Gain, 1960-1970		Gain 1970-1972	
				Amount	Percent	Amount	Percent
Delaware	153.8	213.8	231.6	60.0	39.0%	17.8	8.3%
New Jersey	2,017.1	2,608.5	2,673.9	591.4	29.3%	65.4	2.5%
New York	623.8	758.0	769.1	134.2	21.5%	11.1	1.5%
Pennsylvania	1,888.0	2,285.9	2,368.8	397.9	21.1%	82.9	3.6%
Maryland	820.0	1,098.2	1,143.0	278.2	33.9	44.8	4.1%
Virginia	6.8	8.9	9.9	2.1	30.9	1.0	11.2%
Total, Electric Power Area	5,509.5	6,973.3	7,196.3	1,463.8	26.6	223.0	3.2%

Sources: U. S. Census of Population 1960 and 1970; U. S. Department of Labor Employment and Earnings; New York State Department of Labor; New Jersey Department of Labor and Industry; Pennsylvania Department of Labor and Industry; Maryland State Employment Security Agency; Virginia Employment Commission.

Table A-26 Total Non-Agricultural Wage and Salary Employment Comparisons, Delaware River Basin Electric Power Service Area, Northeast and United States, 1960-1972 (thousands)

	1960	1970	1972	Gain, 1960-1972	
				Amount	Percent
Electric Power Service Area	5,509	6,973	7,196	1,687	30.6
Northeast	15,613	18,672	18,633	3,020	19.3
United States	54,234	70,593	72,764	18,530	34.2
Electric Power Service Area Percent of:					
Northeast	35.28	37.34	38.62	55.86	
United States	10.16	9.88	9.89	9.10	

Sources: Employment and Earnings.

Table A-27 Total Personal Income Trends, Delaware River Basin Electric Power Service Area, 1959-1972 (Millions)

Portions of State Within Electric Power Area	1959	1969	1972	Gain, 1959-1969 Amount	Gain, 1959-1969 Percent	Gain, 1969-1972 Amount	Gain, 1969-1972 Percent
Delaware	$ 1,172	$ 2,330	$ 2,931	$ 1,158	98.8%	$ 601	25.8%
New Jersey	15,999	30,925	38,676	14,926	93.3%	7,751	25.1%
New York	4,375	8,905	10,630	4,530	103.5%	1,725	19.4%
Pennsylvania	12,850	23,928	29,524	11,078	86.2%	5,596	23.4%
Maryland	5,100	11,184	14,476	6,084	119.3%	3,292	29.4%
Virginia	56	115	147	59	105.4%	32	27.8%
Total, Electric Power Area	$39,552	$77,387	$96,384	$37,835	95.7%	$18,997	24.6%

Source: U. S. Census of Population, 1960 and 1970, U. S. Department of Commerce: *Survey of Current Business* (May, 1974).

Table A-28 Total Personal Income Comparisons, Delaware River Basin Electric Power Service Area, Northeast and United States, 1959-1972
(Millions)

	1959	1969	1972	Gain, 1959-1972 Amount	Percent
Current Dollars					
Electric Power Service Area	$ 39,552	$ 77,387	$ 96,384	$ 56,832	143.7%
Northeast	$109,452	$203,051	$248,319	$138,867	126.9%
United States	$381,890	$751,425	$947,066	$565,176	148.0%
Constant 1972 Dollars					
Electric Power Service Area	$ 56,757	$ 88,299	$ 96,384	$ 39,627	69.8%
Northeast	$157,063	$231,681	$248,319	$ 91,256	58.1%
United States	$548,012	$857,375	$947,066	$399,054	72.8%
Electric Power Service Area, Percent of:					
Northeast	36.14%	38.11%	38.81%	40.93%	
United States	10.36%	10.30%	10.18%	10.06%	

Sources: U.S. Census of Population, 1960 and 1970, U.S. Department of Commerce: Survey of Current Business (May and August, 1974).

Table A-29 Projected Population, Maximization of Sound Economic Growth Alternative, Delaware River Basin Electric Power Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A: Albany-Troy	133.2	141.7	168.4	190.0	214.9	238.4	270.0
B: New York Metro	6,274.7	6,405.6	8,226.0	9,239.2	10,011.5	11,127.7	12,035.0
C: Philadelphia Metro	5,338.4	5,528.6	6,623.7	7,473.9	8,359.6	9,162.2	9,851.0
D: Chesapeake Bay	1,552.5	1,649.1	2,055.0	2,392.6	2,662.6	2,865.0	3,000.0
E: Washington Suburban	1,104.8	1,172.2	1,558.1	1,870.5	2,143.0	2,391.0	2,600.0
F: Harrisburg/Altoona	1,614.8	1,671.1	1,866.7	2,047.2	2,245.0	2,462.0	2,700.0
G: Scranton/Wilkes-Barre	692.1	707.7	744.2	776.0	809.3	843.9	880.0
H: Elmira/Binghamton	750.4	759.0	808.9	852.9	899.4	948.4	1,000.0
I: Utica/Syracuse	322.2	326.4	370.6	396.2	421.2	447.0	475.0
J: Lake Ontario	134.5	137.4	166.4	190.4	208.3	228.7	239.0
K: Allegheny	50.4	52.7	57.1	59.9	62.2	65.6	69.0
L: Williamsport	266.6	273.8	288.8	301.9	315.7	330.0	345.0
M: Johnstown	369.0	381.5	427.0	456.8	475.7	493.4	510.0
N: Lake Erie	444.4	459.5	514.4	547.3	572.2	590.5	600.0
Total, Electric Power Area	19,048.5	19,666.3	23.875.3	26,794.7	29,401.1	32,193.8	34,574.0

Table A-30 Projected Population, Continuation of Present Trends Alternative, Delaware River Basin Electric Power Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A: Albany-Troy	133.2	141.7	161.0	178.0	195.0	211.0	228.0
B: New York Metro	6,274.7	6,405.6	8,024.0	8,783.0	9,457.3	10,067.6	10,617.0
C: Philadelphia Metro	5,338.4	5,528.6	6,402.1	7,070.0	7,704.7	7,870.0	8,866.7
D: Chesapeake Bay	1,552.5	1,649.1	1,950.0	2,200.0	2,400.0	2,550.0	2,650.0
E: Washington Suburban	1,104.8	1,172.2	1,450.0	1,675.0	1,875.0	2,050.0	2,200.0
F: Harrisburg/Altoona	1,614.8	1,671.1	1,857.2	2,006.0	2,120.7	2,229.2	2,343.2
G: Scranton/Wilkes-Barre	692.1	707.2	725.0	738.0	753.0	766.0	780.0
H: Elmira/Binghamton	750.4	759.0	775.1	799.0	824.1	848.4	873.3
I: Utica/Syracuse	322.2	326.4	352.0	369.0	383.0	397.0	413.0
J: Lake Ontario	134.5	137.4	159.0	177.0	193.0	208.0	221.0
K: Allegheny	50.9	52.7	55.0	57.0	59.0	60.0	61.0
L: Williamsport	266.6	273.8	279.3	286.0	291.1	295.0	301.0
M: Johnstown	369.0	381.5	405.0	420.0	430.0	440.0	450.0
N. Lake Erie	444.4	459.5	490.0	508.0	522.0	532.0	537.0
Total, Electrical Power Area	19,048.5	19,666.3	23,084.7	25,266.0	27,207.9	28,524.2	30,541.1

Table A-31 Projected Population, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Electric Power Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A: Albany-Troy	133.2	141.7	144.1	151.7	159.6	168.0	185.0
B: New York Metro	6,274.7	6,405.6	7,491.7	7,780.7	8,063.7	8,327.0	8,690.0
C: Philadelphia Metro	5,338.4	5,528.6	5,841.4	6,122.2	6,433.4	6,721.6	7,039.0
D: Chesapeake Bay	1,552.5	1,649.1	7,798.3	1,932.8	2,077.5	2,232.9	2,400.0
E: Washington Suburban	1,104.8	1,172.2	1,277.2	1,371.8	1,473.5	1,582.7	1,700.0
F: Harrisburg/Altoona	1,614.8	1,671.1	1,761.6	1,840.7	1,923.4	2,009.7	2,100.0
G: Scranton/Wilkes-Barre	692.1	707.7	708.2	708.7	709.2	709.6	710.0
H: Elmira/Binghamton	750.4	759.0	764.9	769.9	774.9	779.9	785.0
I: Utica/Syracuse	322.2	326.4	334.8	342.0	349.5	357.1	365.0
J: Lake Ontario	134.5	137.4	146.2	153.9	162.1	205.2	215.0
K: Allegheny	50.9	52.7	52.8	52.8	52.9	52.9	53.0
L: Williamsport	266.6	273.8	272.9	272.2	271.5	270.7	270.0
M: Johnstown	369.0	381.5	386.6	390.9	395.4	400.1	405.0
N: Lake Erie	444.4	459.5	466.4	472.2	478.0	484.0	490.0
Total, Electric Power Area	19,048.5	19,666.3	21,447.1	22,362.6	23,324.6	24,301.4	25,407.0

Table A-32 Projected Households, Maximization of Sound Economic Growth Alternative, Delaware River Basin Electric Power Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2105	2025
A: Albany-Troy	42.4	46.3	58.3	67.9	78.5	88.0	100.0
B: New York Metro	1,929.7	2,043.9	2,779.1	3,219.2	3,550.2	3,988.4	4,329.1
C: Philadelphia Metro	1,626.8	1,747.4	2,215.3	2,577.2	2,933.2	3,249.0	3,506.0
D: Chesapeake Bay	457.4	531.5	708.6	854.5	968.2	1,057.2	1,111.1
E: Washington Suburban	326.0	372.7	530.0	661.0	773.6	875.8	955.9
F: Harrisburg/Altoona	509.7	540.6	643.7	731.1	816.4	908.5	1,000.0
G: Scranton/Wilkes-Barre	224.1	231.9	258.4	278.1	295.4	311.4	325.9
H: Elmira/Binghamton	229.2	235.4	267.8	292.1	314.5	336.3	355.9
I: Utica/Syracuse	96.4	100.3	121.3	134.3	145.7	156.6	166.9
J: Lake Ontario	39.3	40.5	53.3	63.7	71.5	79.8	86.8
K: Allegheny	16.0	16.9	19.5	21.1	22.3	23.8	25.2
L: Williamsport	83.5	87.9	98.9	107.4	114.8	121.8	127.8
M: Johnstown	111.7	120.2	143.7	159.7	169.8	178.6	185.1
N: Lake Erie	134.3	148.1	176.2	193.4	206.8	215.5	219.8
Total, Electric Power Area	5,826.5	6,263.6	8,074.1	9,360.7	10,460.9	11,590.7	12,495.5

Table A-33 Projected Households, Continuation of Present Trends Alternative Delaware River Basin Electric Power Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A: Albany-Troy	42.4	46.3	55.7	63.7	71.1	77.8	84.4
B: New York Metro	1,929.7	2,043.9	2,710.8	3,060.3	3,353.7	3,608.5	3,819.1
C: Philadelphia Metro	1,626.8	1,747.4	2,141.2	2,437.9	2,703.4	2,790.8	3,155.4
D: Chesapeake Bay	457.4	531.5	672.4	785.7	872.7	941.0	981.5
E: Washington Suburban	326.0	372.7	493.2	591.9	676.9	750.9	808.8
F: Harrisburg/Altoona	509.7	540.6	640.4	716.4	771.2	822.6	867.9
G: Scranton/Wilkes-Barre	224.1	231.9	251.7	264.5	274.8	282.7	288.9
H: Elmira/Binghamton	229.2	235.4	256.7	273.6	288.1	300.9	310.8
I: Utica/Syracuse	96.4	100.3	115.2	125.0	132.4	138.9	145.1
J: Lake Ontario	39.3	40.5	51.0	59.3	66.3	72.6	77.4
K: Allegheny	16.0	16.9	18.7	20.1	21.2	21.8	22.3
L: Williamsport	83.5	87.9	95.6	102.0	105.8	108.9	111.5
M: Johnstown	111.7	120.2	136.3	146.8	153.6	159.3	163.3
N: Lake Erie	134.3	148.1	167.8	179.5	188.4	194.2	196.7
Total, Electric Power Area	5,826.5	6,263.6	7,806.7	8,826.7	9,679.6	10,270.9	11,033.1

Table A-34 Projected Households, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Electric Power Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A: Albany-Troy	42.4	46.3	49.9	54.2	58.2	62.0	68.5
B: New York Metro	1,929.7	2,043.9	2,531.0	2,711.0	2,859.5	2,998.9	3,125.9
C: Philadelphia Metro	1,626.8	1,747.4	1,953.6	2,111.1	2,257.3	2,383.5	2,505.2
D: Chesapeake Bay	457.4	531.5	620.1	690.3	755.5	823.9	888.9
E: Washington Suburban	326.0	372.7	434.4	484.7	531.9	579.7	625.0
F: Harrisburg/Altoona	509.7	540.6	607.4	657.4	699.4	741.6	777.8
G: Scranton/Wilkes-Barre	224.1	231.9	245.9	254.0	258.8	261.8	263.0
H: Elmira/Binghamton	229.2	235.4	253.3	263.7	270.9	276.6	279.4
I: Utica/Syracuse	96.4	100.3	109.5	115.8	120.8	125.0	128.3
J: Lake Ontario	39.3	40.5	46.8	51.6	55.7	59.6	63.1
K: Allegheny	16.0	16.9	18.0	18.6	19.0	19.3	19.4
L: Williamsport	83.5	87.9	93.5	96.9	98.7	99.9	100.0
M: Johnstown	111.7	120.2	130.2	136.7	141.3	145.0	147.2
N: Lake Erie	134.3	148.1	159.7	166.9	172.6	176.6	179.5
Total, Electric Power Area	5,826.5	6,263.6	7,253.3	7,812.9	8,299.6	8,753.4	9,171.2

Table A-35 Projected Total Employment, Maximization of Sound Economic Growth Alternative, Delaware River Basin Electric Power Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A: Albany-Troy	51.3	55.1	71.5	82.5	94.4	104.2	118.5
B: New York Metro	2,509.9	2,626.3	3,701.7	4,250.0	4,705.4	5,230.0	5,656.4
C: Philadelphia Metro	2,223.4	2,245.1	2,914.4	3,363.3	3,845.4	4,214.6	4,433.4
D: Chesapeake Bay	636.5	676.1	904.2	1,076.7	1,224.8	1,289.2	1,350.0
E: Washington Suburban	486.1	527.5	747.9	897.8	1,028.6	1,147.2	1,222.0
F: Harrisburg/Altoona	662.1	701.8	840.0	941.7	1,055.2	1,132.5	1,215.0
G: Scranton/Wilkes Barre	269.9	276.0	320.0	341.4	364.2	379.8	396.0
H: Elmira/Binghamton	285.2	288.4	339.7	375.3	395.7	417.3	440.0
I: Utica/Syracuse	119.3	124.0	155.5	170.3	185.3	196.1	208.4
J: Lake Ontario	52.6	53.7	73.3	85.2	94.5	102.4	111.1
K: Allegheny	18.8	19.9	24.0	25.8	27.4	28.9	30.4
L: Williamsport	98.6	101.3	118.4	129.8	138.9	145.2	151.8
M: Johnstown	120.6	124.7	160.8	178.1	193.4	203.6	212.3
N: Lake Erie	164.4	174.6	216.0	235.3	252.0	259.8	264.0
Total, Electric Power Area	7,698.7	7,994.5	10,587.4	12,153.2	13,605.2	14,850.8	15,809.3

Table A-36 Projected Total Employment, Continuation of Present Trends Alternative, Delaware River Basin Electric Power Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A: Albany-Troy	51.3	55.1	68.3	77.3	85.7	92.6	100.2
B: New York Metro	2,509.9	2,626.3	3,610.8	4,040.2	4,444.9	4,731.8	4,990.0
C: Philadelphia Metro	2,223.4	2,245.1	2,816.9	3,181.5	3,544.2	3,620.8	3,990.0
D: Chesapeake Bay	636.5	676.1	858.0	990.0	1,104.0	1,147.5	1,192.5
E: Washington Suburban	486.1	527.5	696.0	804.0	900.0	984.6	1,034.0
F: Harrisburg/Altoona	662.1	701.8	835.7	922.8	996.7	1,025.4	1,054.4
G: Scranton/Wilkes Barre	269.9	276.0	311.8	324.7	338.9	344.7	351.0
H: Elmira/Binghamton	285.2	288.4	325.5	351.6	362.6	373.3	384.3
I: Utica/Syracuse	119.3	124.0	147.8	158.6	168.6	174.2	181.2
J: Lake Ontario	52.6	53.7	70.1	79.2	87.6	93.2	99.0
K: Allegheny	18.8	19.9	23.7	24.5	26.0	26.4	26.8
L: Williamsport	98.6	101.3	114.5	123.2	128.1	129.8	132.4
M: Johnstown	120.6	124.7	152.6	163.8	174.8	181.6	187.3
N: Lake Erie	164.4	174.6	205.8	218.4	229.7	234.1	236.3
Total, Electric Power Area	7,698.7	7,994.5	10,237.5	11,459.8	12,591.8	13,160.0	13,959.4

Table A-37 Projected Total Employment, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Electric Power Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A: Albany-Troy	51.3	55.1	61.2	66.0	70.8	73.8	81.2
B: New York Metro	2,509.9	2,626.3	3,371.3	3,579.1	3,790.0	3,932.5	4,084.3
C: Philadelphia Metro	2,223.4	2,245.1	2,570.2	2,755.0	2,959.4	3,091.9	3,167.1
D: Chesapeake Bay	636.5	676.1	791.3	869.8	955.7	1,004.8	1,080.0
E: Washington Suburban	486.1	527.5	613.1	658.5	707.3	759.7	799.0
F: Harrisburg/Altoona	662.1	701.8	792.7	846.7	904.0	924.5	945.0
G: Scranton/Wilkes Barre	269.9	276.0	304.5	311.8	319.1	319.3	319.5
H: Elmira/Binghamton	285.2	288.4	321.3	338.8	341.0	343.2	345.4
I: Utica/Syracuse	119.3	124.0	140.6	147.1	153.8	156.8	160.2
J: Lake Ontario	52.6	53.7	64.5	68.9	73.6	76.5	80.6
K: Allegheny	18.8	19.9	22.2	22.9	23.8	23.3	23.3
L: Williamsport	98.6	101.3	111.9	117.0	119.5	119.1	118.8
M: Johnstown	120.6	124.7	145.7	152.5	160.7	165.2	168.6
N: Lake Erie	164.4	174.6	195.9	203.0	210.3	213.0	215.6
Total, Electric Power Area	7,698.7	7,994.5	9,506.4	10,137.1	10,789.0	11,203.6	11,588.6

Table A-38 Projected Total Personal Income, Maximization of Sound Economic Growth Alternative, Delaware River Basin Electric Power Service Area, 1969-2025
(TIPI: Millions of 1967 dollars)

Subarea	1969	1972	1985	1995	2005	2015	2025
A: Albany-Troy	$ 432	$ 485	$ 901	$ 1,357	$ 2,028	$ 2,868	$ 4,022
B: New York Metro	$25,723	$27,658	$ 53,082	$ 76,362	$111,838	$147,754	$189,443
C: Philadelphia Metro	$19,879	$21,933	$ 26,422	$ 38,162	$ 55,073	$ 75,790	$108,371
D: Chesapeake Bay	$ 5,608	$ 6,139	$ 11,790	$ 17,904	$ 26,189	$ 35,884	$ 46,524
E: Washington Suburban	$ 5,022	$ 5,915	$ 11,271	$ 17,300	$ 25,741	$ 36,013	$ 47,551
F: Harrisburg/Altoona	$ 4,994	$ 5,315	$ 9,498	$ 13,708	$ 19,945	$ 27,941	$ 37,765
G: Scranton/Wilkes-Barre	$ 1,931	$ 2,049	$ 3,572	$ 4,841	$ 7,021	$ 9,464	$ 12,258
H: Elmira/Binghamton	$ 2,345	$ 2,291	$ 4,144	$ 5,780	$ 8,115	$ 11,006	$ 14,458
I: Utica/Syracuse	$ 979	$ 1,047	$ 1,848	$ 2,616	$ 3,826	$ 5,094	$ 6,749
J: Lake Ontario	$ 403	$ 441	$ 846	$ 1,267	$ 1,828	$ 2,544	$ 3,359
K: Allegheny	$ 148	$ 155	$ 265	$ 377	$ 522	$ 672	$ 834
L: Williamsport	$ 708	$ 751	$ 1,231	$ 1,719	$ 2,420	$ 3,291	$ 3,060
M: Johnstown	$ 946	$ 1,604	$ 1,879	$ 2,695	$ 3,802	$ 5,143	$ 6,728
N: Lake Erie	$ 1,349	$ 1,528	$ 2,625	$ 3,694	$ 5,168	$ 6,887	$ 8,684
Total, Electric Power Area	$70,467	$77,311	$129,374	$187.782	$273,516	$370,351	$489,806

Table A-39 Projected Total Personal Income, Continuation of Present Trends Alternative, Delaware River Basin Electric Power Service Area, 1969-2025 (TPI = Millions of 1967 Dollars)

Subarea	1969	1972	1985	1995	2005	2015	2025
A: Albany-Troy	$ 432	$ 485	$ 861	$ 1,270	$ 1,839	$ 2,540	$ 3,398
B: New York Metro	25,723	27,658	51,779	72,591	105,647	133,678	167,122
C: Philadelphia Metro	19,879	21,933	25,538	36,099	50,758	65,100	97,534
D: Chesapeake Bay	5,608	6,139	11,187	16,463	23,606	31,939	41,096
E: Washington Suburban	5,022	5,915	10,489	15,492	22,522	30,877	40,236
F: Harrisburg/Altoona	4,994	5,315	9,449	13,432	18,840	25,299	32,774
G: Scranton/Wilkes Barre	1,931	2,049	3,480	4,604	6,532	8,591	10,865
H: Elmira/Binghamton	2,345	2,291	3,971	5,415	7,436	9,846	12,626
I: Utica/Syracuse	979	1,047	1,758	2,440	3,479	4,526	5,868
J: Lake Ontario	403	441	809	1,178	1,693	2,312	2,992
K: Allegheny	148	155	255	360	496	615	736
L: Williamsport	708	751	1,190	1,632	2,232	2,942	3,759
M: Johnstown	946	1,604	1,782	2,480	3,438	4,590	5,944
N: Lake Erie	1,349	1,528	2,500	3,428	4,711	6,205	7,772
Total, Electric Power Area	$ 70,467	$ 77,311	$125,048	$176,884	$253,229	$329,060	$432,722

Table A-40 Projected Total Personal Income, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Electric Power Service Area, 1969-2025 (TPI = Millions of 1967 Dollars)

Subarea	1969	1972	1985	1995	2005	2015	2025
A: Albany-Troy	$ 432	$ 485	$ 772	$ 1,085	$ 1,508	$ 2,027	$ 2,759
B: New York Metro	25,723	27,658	48,344	64,307	90,080	110,566	136,789
C: Philadelphia Metro	19,879	21,933	23,301	31,260	42,383	55,601	77,436
D: Chesapeake Bay	5,608	6,139	10,317	14,463	20,434	27,967	37,219
E: Washington Suburban	5,022	5,915	9,239	12,688	17,699	23,839	31,091
F: Harrisburg/Altoona	4,994	5,315	8,963	12,325	17,087	22,808	29,373
G: Scranton/Wilkes Barre	1,931	2,049	3,399	4,421	6,152	7,958	9,890
H: Elmira/Binghamton	2,345	2,291	3,919	5,218	6,992	9,051	11,350
I: Utica/Syracuse	979	1,047	1,672	2,261	3,172	4,066	5,179
J: Lake Ontario	403	441	743	1,024	1,423	1,899	2,439
K: Allegheny	148	155	245	334	445	543	640
L: Williamsport	708	751	1,163	1,550	2,082	2,699	3,372
M: Johnstown	946	1,604	1,704	2,311	3,166	4,181	5,361
N: Lake Erie	1,349	1,528	2,380	3,187	4,313	5,645	7,092
Total, Electric Power Area	$ 70,467	$ 77,311	$116,161	$156,434	$216,936	$278,850	$359,990

Table A-41 Population Trends, Delaware River Basin Recreation Service Area, 1960-1970

Portions of States Within Recreation Area	1960	1970	1973	Gain, 1960-1970		Gain, 1970-1973	
				Amount	Percent	Amount	Percent
Delaware	307,446	385,856	400,000	78,410	25.5%	14,144	3.7%
New Jersey	5,750,497	6,815,141	6,979,500	1,064,644	18.5%	164,359	2.4%
New York	12,398,174	13,517,340	13,475,900	1,119,166	9.0%	-41,440	-0.3%
Pennsylvania	6,722,084	7,211,349	7,280,700	489,265	7.3%	69,351	1.0%
Connecticut	1,433,760	1,681,853	1,691,500	248,093	17.3%	9,647	0.6%
Total, Recreation Area	26,611,961	29,611,539	29,827,600	2,999,578	11.3%	216,061	0.7%

Sources: U.S. Census of Population, 1960 and 1970 and CPR Series P-25 and P-26.

Table A-42 Population Trends Comparison, Delaware River Basin Recreation Service Area, Northeast and United States, 1960-1973 (thousands)

	1960	1970	1973	Gain, 1960-1973	
				Amount	Percent
Recreation Service Area	26,612	29,612	29,828	3,216	12.1%
Northeast	44,678	49,051	49,545	4,867	10.9%
United States	179,323	203,235	209,844	30,521	17.0%
Recreation Service Area Percent of:					
Northeast	59.56%	60.37%	60.20%	66.08%	
United States	14.84%	14.57%	14.21%	10.54%	

Sources: U.S. Census of Population, 1960 and 1970 and CPR Series P-25 and P-26.

Table A-43 Household Trends, Delaware River Basin Recreation Service Area, 1960-1973

	1960	1970	1973	Gain, 1960-1970		Gain, 1970-1973	
				Amount	Percent	Amount	Percent
Portions of States Within Recreation Area:							
Delaware	88,406	115,774	126,060	27,368	30.9%	10,286	8.9%
New Jersey	1,706,552	2,099,203	2,239,190	392,651	23.0%	139,987	6.7%
New York	3,962,153	4,662,263	4,728,380	700,110	17.7%	66,117	1.4%
Pennsylvania	2,002,834	2,275,231	2,337,980	272,397	13.6%	62,749	2.8%
Connecticut	429,571	521,110	548,840	91,539	21.3%	27,730	5.3%
Total, Recreation Area	8,189,516	9,673,581	9,980,450	1,484,065	18.1%	306,869	3.2%

Sources: U.S. Census of Population, 1960 and 1970, CPR Series P-25 and P-26.

Table A-44 Household Trends Comparison, Delaware River Basin Recreation Service Area, Northeast, and United States, 1960-1973 (Thousands)

	1960	1970	1973	Gain, 1960-1973	
				Amount	Percent
Recreation Service Area	8,190	9,674	9,980	1,790	21.9%
Northeast	13,521	15,483	16,412	2,891	21.4%
United States	53,021	63,450	68,737	15,716	29.6%
Recreation Service Area Percent of:					
Northeast	60.57%	62.48%	60.81%	61.92%	
United States	15.45%	15.25%	14.52%	11.39%	

Sources: U. S. Census of Population, 1960 and 1970 CPR Series P-25 and P-26.

Table A-45 Total Non-Agricultural Wage and Salary Employment Delaware River Basin Recreation Service Area, 1960-1972 (Thousands)

Portions of States Within Recreation Area	1960	1970	1972	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1972 Amount	Gain, 1970-1972 Percent
Delaware	153.8	213.8	231.6	60.0	39.0%	17.8	8.3%
New Jersey	1,918.6	2,474.7	2,533.5	556.1	29.0%	58.8	2.4%
New York	4,821.5	5,517.3	5,361.5	695.8	14.4%	-155.8	-2.8%
Pennsylvania	2,343.3	2,799.9	2,829.8	456.6	19.5%	29.9	1.1%
Connecticut	377.0	471.2	467.8	94.2	25.0%	- 3.4	- .7%
Total, Recreation Area	9,614.2	11,476.9	11,424.2	1,862.7	19.4%	- 52.7	- .5%

Sources: U.S. Department of Labor: Employment and Earnings, 1974; Pennsylvania Department of Labor and Industry; New York State Department of Labor Employment Review, 1972; Connecticut Labor Department; New Jersey Department of Labor and Industry, 1961, 1971, and 1973.

Table A-46 Total Non-Agricultural Wage and Salary Employment Comparisons, Delaware River Basin Recreation Service Area, Northeast and United States, 1960-1972 (thousands)

	1960	1970	1972	Gain, 1960-1972 Amount	Gain, 1960-1972 Percent
Recreation Service Area	9,614	11,477	11,424	1,810	18.8
Northeast	15,613	18,672	18,633	3,020	19.3
United States	54,234	70,593	72,764	18,530	34.2
Recreation Service Area Percent of:					
Northeast	61.58%	61.47%	61.31%	59.93%	
United States	17.73%	16.26%	15.70%	9.77%	

Sources: Employment and Earnings.

Table A-47 Total Personal Income Trends, Delaware River Basin Recreation Service Area, 1959-1972 (Millions)

Portions of States Within Recreation Area	1959	1969	1972	Gain, 1959-1969		Gain, 1969-1972	
				Amount	Percent	Amount	Percent
Delaware	$ 903	$ 1,764	$ 2,210	$ 861	95.3%	$ 446	25.3%
New Jersey	15,358	29,685	37,068	14,327	93.3%	7,383	24.9%
New York	34,692	64,021	76,803	29,329	84.5%	12,782	20.0%
Pennsylvania	15,162	27,161	33,190	11,999	79.1%	6,029	22.2%
Connecticut	3,791	7,557	8,917	3,766	99.3%	1,360	18.0%
Total, Recreation Area:	$69,906	$130,188	$158,188	$60,282	86.2%	$28,000	21.5%

Sources: U.S. Census of Population, 1960 and 1970, U.S. Department of Commerce: Survey of Current Business (May, 1974)

Table A-48 Total Personal Income Comparisons, Delaware River Basin Recreation Service Area, Northeast and United States, 1959-1972 (Millions)

	1959	1969	1972	Gain, 1959-1972 Amount	Gain, 1959-1972 Percent
Current Dollars					
Recreation Service Area	$ 69,906	$130,188	$158,188	$ 88,282	126.3%
Northeast	$109,452	$203,044	$248,319	$138,867	126.9%
United States	$381,890	$751,425	$947,066	$565,176	148.0%
Constant 1972 Dollars					
Recreation Service Area	$100,315	$148,544	$158,188	$ 57,511	57.6%
Northeast	$157,063	$231,681	$248,319	$ 91,256	58.1%
United States	$548,012	$857,375	$947,066	$399,054	72.8%
Recreation Service Area, Percent of :					
Northeast	63.87%	64.12%	63.70%	63.57%	
United States	18.31%	17.33%	16.70%	15.62%	

Sources: U.S. Census of Population, 1960 and 1970, U.S. Department of Commerce: Survey of Current Business (April and August, 1974).

Table A-49 Projected Population, Continuation of Present Trends Alternative, Delaware River Basin Recreation Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A. Albany	831.3	865.0	943.0	993.0	1,041.0	1,088.0	1,135.0
B. Western Connecticut	1,681.9	1,691.5	1,866.5	2,009.0	2,147.0	2,290.0	2,417.0
C. New York Metro	17,479.8	17,489.3	18,570.0	19,552.0	20,382.0	21,099.0	21,739.0
D. Philadelphia Metro	6,272.5	6,401.1	7,093.6	7,630.4	8,132.1	8,590.6	9,003.0
E. Harrisburg	1,102.6	1,145.6	1,294.1	1,400.0	1,494.0	1,570.0	1,641.0
F. Williamsport	413.3	424.6	446.0	463.0	478.0	492.0	504.0
G. Scranton	708.5	725.5	744.0	758.0	774.0	788.0	802.0
H. Binghamton	1,107.9	1,115.0	1,210.2	1,286.7	1,359.9	1,430.4	1,501.0
Total, Recreation Area	29,597.8	29,857.6	32,167.4	34,092.1	35,808.0	37,348.0	38,742.0

Table A-50 Projected Population, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Recreation Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A. Albany	831.3	865.0	910.0	937.0	959.0	974.0	985.0
B. Western Connecticut	1,681.9	1,691.5	1,770.0	1,835.0	1,892.0	1,948.0	2,000.0
C. New York Metro	17,479.8	17,489.3	18,054.8	18,537.7	19,033.6	19,547.9	20,077.0
D. Philadelphia Metro	6,272.5	6,401.1	6,639.1	6,868.1	7,107.2	7,360.9	7,625.0
E. Harrisburg	1,102.6	1,145.6	1,217.0	1,274.0	1,312.0	1,350.0	1,385.0
F. Williamsport	413.3	424.6	428.0	431.0	433.0	435.0	435.0
G. Scranton	708.5	725.5	725.2	725.7	725.2	726.6	726.0
H. Binghamton	1,107.9	1,115.0	1,153.4	1,184.0	1,214.6	1,245.2	1,275.0
Total, Recreation Area	29,597.8	29,857.6	30,897.5	31,792.5	32,676.6	33,587.6	34,508.0

Table A-51 Projected Population, Maximization of Sound Economic Growth Alternative, Delaware River Basin Recreation Service Area, 1970-2025 (Thousands)

Subarea	1970	1973	1985	1995	2005	2015	2025
A. Albany	831.3	865.0	971.0	1,051.0	1,142.0	1,214.0	1,280.0
B. Western Connecticut	1,681.9	1,691.5	1,954.0	2,174.0	2,399.0	2,624.0	2,850.0
C. New York Metro	17,479.8	17,489.3	18,955.0	20,370.0	21,686.7	22,950.0	24,290.0
D. Philadelphia Metro	6,272.5	6,401.1	7,279.0	7,971.0	8,704.0	9,360.0	9,930.0
E. Harrisburg	1,102.6	1,145.6	1,347.0	1,479.0	1,607.0	1,739.0	1,865.0
F. Williamsport	413.3	424.6	465.0	500.0	533.0	566.0	598.0
G. Scranton	708.5	725.5	765.2	799.0	835.3	871.9	910.0
H. Binghamton	1,107.9	1,115.0	1,250.0	1,363.0	1,478.0	1,590.0	1,680.0
Total, Recreation Area	29,597.8	29,857.6	32,986.2	35,707.0	38,385.0	40,914.9	43,403.0

Table A-52 Population Trends, Delaware River Basin Flood Control Service Area, 1960-1973

Portions of States Within Flood Control Area	1960	1970	1973	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1973 Amount	Gain, 1970-1973 Percent
Delaware	307,446	385,856	400,000	78,410	25.5%	14,144	3.7%
New Jersey	368,938	432,407	455,800	63,469	17.2%	23,393	5.4%
New York	101,624	111,509	119,200	9,885	9.7%	7,691	6.9%
Pennsylvania	4,522,918	4,867,169	4,865,100	344,251	7.6%	-2,069	0.0%
Total, Flood Control Area	5,300,926	5,796,941	5,840,100	496,015	9.4%	43,159	0.7%

Sources: U. S. Census of Population, 1960 and 1970 CPR Series P-25 and P-26.

Table A-53 Population Trends Comparison, Delaware River Basin Flood Control Service Area, Northeast and United States, 1960-1973 (thousands)

	1960	1970	1973	Gain, 1960-1973 Amount	Gain, 1960-1973 Percent
Flood Control Service Area	5,301	5,797	5,840	539	10.2%
Northeast	44,678	49,051	49,545	4,867	10.9%
United States	179,323	203,235	209,844	30,521	17.0%
Flood Control Service Area Percent of:					
Northeast	11.86%	11.82%	11.79%	11.07%	
United States	2.96%	2.85%	2.78%	1.77%	

Sources: U.S. Census of Population, 1960 and 1970 and CPR Series P-25 and P-26.

Table A-54 Household Trends, Delaware River Basin Flood Control Service Area, 1960-1973

	1960	1970	1973	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1973 Amount	Gain, 1970-1973 Percent
Portions of States Within Flood Control Area:							
Delaware	88,406	115,774	126,060	27,368	30.9%	10,286	8.9%
New Jersey	107,718	132,485	146,070	24,767	23.0%	13,585	10.3%
New York	30,679	35,000	38,930	4,321	14.1%	3,930	11.2%
Pennsylvania	1,346,206	1,533,824	1,562,540	187,618	13.9%	28,716	1.9%
Total, Flood Control Area	1,573,009	1,817,083	1,873,600	244,074	15.5%	56,517	3.1%

Sources: U.S. Census of Population, 1960 and 1970, CPR Series P-25 and P-26.

Table A-55 Household Trends Comparison, Delaware River Basin Flood Control Service Area, Northeast, and United States, 1960-1973 (Thousands)

	1960	1970	1973	Gain, 1960-1973 Amount	Gain, 1960-1973 Percent
Flood Control Service Area	1,573	1,817	1,874	301	19.1%
Northeast	13,521	15,483	16,412	2,891	21.4%
United States	53,021	63,450	68,737	15,716	29.6%
Flood Control Service Area Percent of:					
Northeast	11.63%	11.74%	11.42%	10.41%	
United States	2.97%	2.86%	2.73%	1.92%	

Sources: U. S. Census of Population, 1960 and 1970 CPR Series P-25 and P-26.

Table A-56 Total Non-Agricultural Wage and Salary Employment Delaware River Basin Flood Control Service Area, 1960-1972 (Thousands)

Portions of States Within Flood Control Area				Gain, 1960-1970		Gain, 1970-1972	
				Amount	Percent	Amount	Percent
Delaware	114.9	155.8	162.7	40.9	35.6%	16.9	4.4%
New Jersey	163.3	239.1	262.7	75.8	46.4	23.6	9.9%
New York	38.1	39.7	40.7	1.6	4.2	1.0	2.5%
Pennsylvania	1,664.1	1,951.8	1,946.0	287.7	17.3%	-5.8	-.3%
Total, Flood Control Area	1,980.4	2,386.4	2,412.1	406.0	20.5	35.7	1.5%

Sources: Employment and Earnings, 1974, Pennsylvania Department of Labor and Industry; New York State Department of Labor, Employment Review; U. S. Census of Population, 1960 and 1970; New Jersey Department of Labor and Industry.

Table A-57 Total Non-Agricultural Wage and Salary Employment Comparisons, Delaware River Basin, Flood Control Service Area, Northeast and United States, 1960-1972 (thousands)

	1960	1970	1972	Gain, 1960-1972 Amount	Gain, 1960-1972 Percent
Flood Control Service Area	1,980	2,385	2,412	431	21.8
Northeast	15,613	18,672	18,633	3,020	19.3
United States	54,234	70,593	72,764	18,530	34.2
Flood Control Service Area Percent of:					
Northeast	12.68	12.77	12.94	14.27	
United States	3.65	3.38	3.31	2.33	

Sources: Employment and Earnings .

Table A-58 Total Personal Income Trends, Delaware River Basin Flood Control Service Area, 1959-1972 (Millions)

Portions of States Within Flood Control Area	1959	1969	1972	Gain, 1959-1969		Gain, 1969-1972	
				Amount	Percent	Amount	Percent
Delaware	$ 903	$ 1,764	$ 2,210	$ 861	95.3%	$ 446	25.3%
New Jersey	807	1,624	2,143	817	101.2%	519	32.0%
New York	241	433	525	192	79.7%	92	21.2%
Pennsylvania	11,033	19,552	24,012	8,519	77.2%	4,460	22.8%
Total, Flood Control Area	$12,984	$23,373	$28,890	$10,389	80.0%	$5,517	23.6%

Sources: U. S. Census of Population, 1960 and 1970, U. S. Department of Commerce: Survey of Current Business (May, 1974)

Table A-59 Total Personal Income Comparisons, Delaware River Basin Flood Control Service Area, Northeast and United States (Millions)

	1959	1969	1972	Gain, 1959-1972 Amount	Gain, 1959-1972 Percent
Current Dollars					
Flood Control Service Area	$ 12,984	$ 23,373	$ 28,890	$ 15,906	122.5%
Northeast	$109,452	$203,051	$248,319	$138,867	126.9%
United States	$381,890	$751,425	$947,066	$565,176	148.0%
Constant 1972 Dollars					
Flood Control Service Area	$ 18,632	$ 26,669	$ 28,890	$ 10,258	55.1%
Northeast	$157,063	$231,681	$248,319	$ 91,256	58.1%
United States	$548,012	$857,375	$947,066	$399,054	72.8%
Flood Control Service Area, Percent of:					
Northeast	11.86%	11.51%	11.63%	11.45%	
United States	3.40%	3.11%	3.05%	2.81%	

Sources: U. S. Census of Population, 1960 and 1970, U. S. Department of Commerce: Survey of Current Business (May and August, 1974).

Table A-60 Projected Population, Maximization of Sound Economic Growth Alternative, Delaware River Basin Flood Control Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	418.0	443.9	565.7	673.1	789.3	908.6	1,029.4
Subarea B: Allentown-Bethlehem-Reading	866.2	889.8	1,024.0	1,144.3	1,271.2	1,396.8	1,525.0
Subarea C: Philadelphia Metro	4,119.4	4,097.4	4,451.5	4,728.9	5,040.2	5,301.4	5,496.3
Subarea D: Southern Basin	393.4	409.0	499.8	569.6	642.1	708.5	766.8
Total, Flood Control Area	5,797.0	5,840.1	6,541.0	7,115.9	7,742.8	8,315.3	8,817.5

Table A-61 Projected Population, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Flood Control Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	418.0	443.9	465.1	483.8	504.1	524.2	546.1
Subarea B: Allentown-Bethlehem-Reading	866.2	889.8	976.0	1,053.1	1,134.5	1,215.1	1,297.3
Subarea C: Philadelphia Metro	4,119.4	4,097.4	4,225.1	4,329.3	4,433.4	4,536.5	4,667.3
Subarea D: Southern Basin	393.4	409.0	441.5	464.9	489.6	515.3	544.0
Total, Flood Control Area	5,797.0	5,840.1	6,107.7	6,331.1	6,561.6	6,791.1	7,054.7

Table A-62 Projected Total Employment, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Flood Control Service Area 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	178.7	190.0	204.2	217.2	231.3	240.5	250.5
Subarea B: Allentown-Bethlehem-Reading	363.8	373.7	449.0	495.0	533.2	558.9	596.8
Subarea C: Philadelphia Metro	1,652.5	1,643.9	1,864.3	1,951.1	2,042.4	2,086.8	2,147.0
Subarea D: Southern Basin	161.1	167.7	194.0	213.2	224.6	236.5	249.6
Total, Flood Control Area	2,356.1	2,375.3	2,711.5	2,876.5	3,031.5	3,122.7	3,243.9

Table A-63 Projected Population, Continuation of Present Trends Alternative, Delaware River Basin Flood Control Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	418.0	443.9	531.9	609.6	693.6	779.9	867.2
Subarea B: Allentown-Bethlehem-Reading	866.2	889.8	986.3	1,072.8	1,164.0	1,254.3	1,346.5
Subarea C: Philadelphia Metro	4,119.4	4,097.4	4,401.2	4,641.8	4,868.9	5,062.3	5,246.9
Subarea D: Southern Basin	393.4	409.0	488.5	548.8	607.1	654.9	698.0
Total, Flood Control Area	5,797.0	5,840.1	6,407.9	6,873.0	7,333.6	7,751.4	8,158.6

Table A-64 Projected Total Employment, Maximization of Sound Economic Growth Alternative, Delaware River Basin Flood Control Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	178.7	190.0	248.4	302.3	362.2	416.9	472.4
Subarea B: Allentown-Bethlehem-Reading	363.8	373.7	471.0	537.8	597.5	642.5	701.5
Subarea C: Philadelphia Metro	1,652.5	1,643.9	1,964.8	2,131.7	2,322.6	2,438.7	2,528.3
Subarea D: Southern Basin	161.1	167.7	219.4	261.0	294.4	324.7	351.4
Total, Flood Control Area	2,356.1	2,375.3	2,903.6	3,232.8	3,576.7	3,822.8	4,053.6

Table A-65 Projected Total Employment, Continuation of Present Trends Alternative, Delaware River Basin Flood Control Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	178.7	190.0	233.5	273.7	318.2	357.8	397.9
Subarea B: Allentown-Bethlehem-Reading	363.8	373.7	453.7	504.2	547.1	577.0	619.4
Subarea C: Philadelphia Metro	1,652.5	1,643.9	1,942.3	2,092.1	2,243.3	2,282.1	2,365.5
Subarea D: Southern Basin	161.1	167.7	214.5	251.7	278.5	300.3	320.0
Total, Flood Control Area	2,356.1	2,375.3	2,844.0	3,121.7	3,387.1	3,517.2	3,702.8

Table A-66 Projected Total Personal Income, Maximization of Sound Economic Growth Alternative, Delaware River Basin Flood Control Service Area, 1969-2025
(TPI: Millions of 1967 dollars)

	1969	1972	1985	1995	2005	2015	2025
Subarea A: Upper Basin	$ 1,332	$ 1,475	$ 2,393	$ 3,641	$ 5,415	$ 7,905	$ 11,241
Subarea B: Allentown-Bethlehem-Reading	$ 2,995	$ 3,281	$ 5,151	$ 7,369	$10,378	$14,457	$ 19,810
Subarea C: Philadelphia Metro	$15,159	$16,296	$24,305	$32,724	$43,799	$57,838	$ 74,750
Subarea D: Southern Basin	$ 1,801	$ 2,005	$ 2,484	$ 3,620	$ 5,162	$ 7,211	$ 9,784
Total, Flood Control Area	$21,287	$23,057	$34,333	$47,354	$64,754	$87,411	$115,585

Table A-67 Projected Total Personal Income, Continuation of Present Trends Alternative, Delaware River Basin Flood Control Service Area, 1969-2025
(TPI: Millions of 1967 dollars)

	1969	1972	1985	1995	2005	2015	2025
Subarea A: Upper Basin	$ 1,332	$ 1,475	$ 2,250	$ 3,298	$ 4,758	$ 6,785	$ 9,470
Subarea B: Allentown-Bethlehem-Reading	$ 2,995	$ 3,281	$ 4,961	$ 6,909	$ 9,503	$12,982	$ 17,491
Subarea C: Philadelphia Metro	$15,159	$16,296	$24,031	$32,121	$42,303	$55,230	$ 71,358
Subarea D: Southern Basin	$ 1,801	$ 2,005	$ 2,428	$ 3,488	$ 4,881	$ 6,666	$ 8,906
Total, Flood Control Area	$21,287	$23,057	$33,670	$45,816	$61,445	$81,663	$107,225

Table A-68 Projected Total Personal Income, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Flood Control Service Area, 1969-2025 (TPI: Millions of 1967 dollars)

	1969	1972	1985	1995	2005	2015	2025
Subarea A: Upper Basin	$ 1,332	$ 1,475	$ 1,967	$ 2,617	$ 3,458	$ 4,560	$ 5,963
Subarea B: Allentown-Bethlehem-Reading	$ 2,995	$ 3,281	$ 4,909	$ 6,782	$ 9,262	$12,576	$16,852
Subarea C: Philadelphia Metro	$15,159	$16,296	$23,069	$29,959	$38,526	$49,493	$63,475
Subarea D: Southern Basin	$ 1,801	$ 2,005	$ 2,194	$ 2,955	$ 3,936	$ 5,245	$ 6,941
Total, Flood Control Area	$21,287	$23,057	$32,139	$42,313	$55,182	$71,874	$93,231

Table A-69 Projected Households, Maximization of Sound Economic Growth Alternative, Delaware River Basin Flood Control Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	133.2	145.9	201.0	241.1	289.0	335.2	381.0
Subarea B: Allentown-Bethlehem-Reading	280.3	296.6	359.3	411.6	465.6	515.4	564.8
Subarea C: Philadelphia Metro	1,283.4	1,299.9	1,516.3	1,678.3	1,827.3	1,943.1	2,028.8
Subarea D: Southern Basin	120.1	131.2	169.2	200.1	229.5	256.8	279.9
Total, Flood Control Area	1,817.0	1,873.6	2,245.8	2,531.1	2,811.4	3,050.5	3,254.5

Table A-70 Projected Households, Continuation of Present Trends Alternative, Delaware River Basin Flood Control Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	133.2	145.9	189.1	218.4	253.9	287.6	320.9
Subarea B: Allentown-Bethlehem-Reading	280.3	296.6	346.1	385.9	426.4	462.8	498.7
Subarea C: Philadelphia Metro	1,283.4	1,299.9	1,491.7	1,629.2	1,730.6	1,809.1	1,873.9
Subarea D: Southern Basin	120.1	131.2	167.9	195.5	220.2	240.9	258.5
Total, Flood Control Area	1,817.0	1,873.6	2,194.8	2,429.0	2,631.1	2,800.4	2,952.0

Table A-71 Projected Households Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Flood Control Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	133.2	145.9	165.3	173.2	184.6	193.3	202.1
Subarea B: Allentown-Bethlehem-Reading	280.3	296.6	342.5	378.8	415.6	448.4	480.5
Subarea C: Philadelphia Metro	1,283.4	1,299.9	1,439.0	1,536.3	1,607.1	1,662.6	1,722.7
Subarea D: Southern Basin	120.1	131.2	149.4	163.3	174.9	186.7	198.5
Total, Flood Control Area	1,817.0	1,873.6	2,096.2	2,251.6	2,382.2	2,491.0	2,603.8

Table A-72 Population Trends, Delaware River Basin Water Quality Service Area, 1960-1973

Portions of States Within Water Quality Area	1960	1970	1973	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1973 Amount	Gain, 1970-1973 Percent
Delaware	383,321	469,155	491,400	85,834	22.4%	22,245	4.7%
New Jersey	1,220,497	1,487,622	1,548,900	267,125	21.9%	61,278	4.1%
New York	87,490	96,079	102,600	8,589	9.8%	6,521	6.8%
Pennsylvania	4,535,184	4,868,825	4,866,600	333,641	7.4%	-2,225	-0.1%
Total, Water Quality Area	6,226,492	6,921,681	7,009,500	695,189	11.2%	87,819	1.3%

Sources: U. S. Census of Population, 1960 and 1970 and CPR Series P-25 and P-26.

Table A-73 Population Trends Comparison, Delaware River Basin Water Quality Service Area, Northeast and United States, 1960-1973 (thousands)

	1960	1970	1973	Gain, 1960-1973 Amount	Gain, 1960-1973 Percent
Water Quality Service Area	6,226	6,922	7,010	784	12.6%
Northeast	44,678	49,051	49,545	4,867	10.9%
United States	179,323	203,235	209,844	30,521	17.0%
Water Quality Service Area Percent of:					
Northeast	13.94%	14.11%	14.15%	16.11%	
United States	3.47%	3.41%	3.34%	2.57%	

Sources: U.S. Census of Population, 1960 and 1970 and CPR Series P-25 and P-26.

Table A-74 Household Trends, Delaware River Basin Water Quality Service Area By State, 1960-1973

	1960	1970	1973	Gain, 1960-1970		Gain, 1970-1973	
				Amount	Percent	Amount	Percent
Portions of States Within Water Quality Area:							
Delaware	109,829	140,126	154,260	30,297	27.6%	14,134	10.1%
New Jersey	346,919	440,096	478,120	93,177	26.9%	38,024	8.6%
New York	26,433	30,195	33,510	3,762	14.2%	3,315	11.0%
Pennsylvania	1,350,361	1,535,123	1,564,800	184,762	13.7%	29,677	1.9%
Total, Water Quality Area	1,833,542	2,145,540	2,230,690	311,998	17.0%	85,150	4.0%

Sources: U.S. Census of Population 1960 and 1970, CPR Series P-25 and P-26 and Hammer, Siler, George Associates.

Table A-75 Household Trends Comparison, Delaware River Basin Water Quality Service Area, 1960-1973 (Thousands)

	1960	1970	1973	Gain, 1960-1973	
				Amount	Percent
Water Quality Service Area	1,834	2,146	2,231	397	21.6%
Northeast	13,521	15,483	16,412	2,891	21.4%
United States	53,021	63,450	68,737	15,716	29.6%
Water Quality Service Area Percent of:					
Northeast	13.56%	13.86%	13.59%	13.73%	
United States	3.46%	3.38%	3.25%	2.53%	

Sources: U. S. Census of Population, 1960 and 1970 CPR Series P-25 and P-26.

Table A-76 Total Non-Agricultural Wage and Salary Employment Delaware River Basin Water Quality Service Area, 1960-1972 (Thousands)

Portions of States Within Water Quality Area	1960	1970	1972	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain 1970-1972 Amount	Gain 1970-1972 Percent
Delaware	153.8	213.8	231.6	60.0	39.0%	17.8	8.3%
New Jersey	380.3	507.0	544.0	126.7	33.3	37.0	7.3%
New York	38.1	39.7	40.7	1.6	4.2%	1.0	2.5%
Pennsylvania	1,664.1	1,951.8	1,946.0	287.7	17.3%	-5.8	- .3%
Total, Water Quality Area	2,236.3	2,712.3	2,762.3	476.0	21.3%	50.0	1.8%

Sources: Employment and Earnings, 1974, Pennsylvania Department of Labor and Industry; New Jersey Department of Labor and Industry; New York State Department of Labor, Employment Review.

Table A-77 Total Non-Agricultural Wage and Salary Employment Comparisons, Delaware River Basin Water Quality Service Area, Northeast and United States, 1960-1972 (thousands)

	1960	1970	1972	Gain, 1960-1972 Amount	Gain, 1960-1972 Percent
Water Quality Service Area	2,236	2,712	2,762	526	23.5
Northeast	15,613	18,672	18,633	3,020	19.3
United States	54,234	70,593	72,764	18,530	34.2
Water Quality Service Area Percent of:					
Northeast	14.32	14.52	14.82	17.42	
United States	4.12	3.84	3.80	2.84	

Sources: Employment and Earnings .

Table A-78 Total Personal Income Trends, Delaware River Basin Water Quality Service Area, 1959-1972 (Millions)

Portions of States Within Water Quality Area	1960	1969	1972	Gain, 1959-1969 Amount	Gain, 1959-1969 Percent	Gain, 1969-1972 Amount	Gain, 1969-1972 Percent
Delaware	$ 973	$ 1,851	$ 2,324	$ 878	90.2%	$ 473	25.6%
New Jersey	2,909	5,724	7,348	2,815	96.7%	1,624	28.4%
New York	228	409	501	181	78.9%	92	22.5%
Pennsylvania	10,986	19,426	23,862	8,440	76.8%	4,436	22.8%
Total, Water Quality Area	$15,096	$27,410	$34,035	$12,314	81.6%	$6,625	24.2%

Sources: U. S. Census of Population, 1960 and 1970, U. S. Department of Commerce: Survey of Current Business (May, 1974).

Table A-79 Total Personal Income Comparisons, Delaware River Basin Water Quality Service Area, Northeast and United States, 1959-1972 (Millions)

	1959	1969	1972	Gain, 1959-1969 Amount	Gain, 1959-1969 Percent
Current Dollars					
Water Quality Service Area	$ 15,096	$ 27,410	$ 34,035	$ 18,939	125.5%
Northeast	$109,452	$203,051	$248,319	$138,867	126.9%
United States	$381,890	$751,425	$947,066	$565,176	148.0%
Constant 1972 Dollars					
Water Quality Service Area	$ 21,663	$ 31,274	$ 34,035	$ 12,372	57.1%
Northeast	$157,063	$231,681	$248,319	$ 91,256	58.1%
United States	$548,012	$857,375	$947,066	$399,054	72.8%
Water Quality Service Area, Percent of:					
Northeast	13.79%	13.50%	13.71%	13.64%	
United States	3.95%	3.65%	3.59%	3.35%	

Sources: U.S. Census of Population, 1960 and 1970, U.S. Department of Commerce: Survey of Current Business (May and August, 1974).

Table A-80 Projected Population, Maximization of Sound Economic Growth Alternative, Delaware River Basin Water Quality Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	409.7	431.6	547.6	647.4	754.4	863.0	972.2
Subarea B: Allentown-Bethlehem-Easton	866.8	891.0	1,025.5	1,145.9	1,273.0	1,398.3	1,526.5
Subarea C: Philadelphia	4,961.8	4,966.1	5.561.9	6,021.1	6,439.3	6,827.3	7,188.3
Subarea D: Southern Basin	683.4	720.8	932.6	1,078.5	1,205.1	1,316.7	1,408.8
Total, Water Quality Area	6,921.7	7,009.5	8,067.6	8,892.9	9,671.8	10,405.3	11,095.8

Table A-81 Projected Population, Continuation of Present Trends Alternative, Delaware River Basin Water Quality Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	409.7	431.6	516.0	588.8	666.0	744.7	823.8
Subarea B: Allentown-Bethlehem-Easton	866.8	891.0	987.9	1,074.5	1,165.6	1,255.6	1,347.5
Subarea C: Philadelphia	4,961.8	4,966.1	5,396.1	5,727.6	6,029.9	6,310.2	6,571.0
Subarea D: Southern Basin	683.4	720.8	888.8	1,004.6	1,104.9	1,193.4	1,266.5
Total, Water Quality Area	6,921.7	7,009.5	7,788.8	8,395.5	8,966.4	9,503.9	10,008.8

Table A-82 Projected Population, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Water Quality Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	409.7	431.6	455.8	475.6	496.0	516.7	537.0
Subarea B: Allentown-Bethlehem-Easton	866.8	891.0	976.4	1,053.0	1,133.7	1,213.4	1,294.9
Subarea C: Philadelphia	4,961.8	4,966.1	5,259.6	5,485.6	5,688.5	5,877.7	6,082.0
Subarea D: Southern Basin	683.4	720.8	774.8	813.9	848.7	879.6	905.4
Total, Water Quality Area	6,921.7	7,009.5	7,466.6	7,828.1	8,166.9	8,487.4	8,819.3

Table A-83 Projected Households, Continuation of Present Trends Alternative, Delaware River Basin Water Quality Service Area (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	131.4	142.9	180.3	211.0	243.3	274.3	304.4
Subarea B: Allentown-Bethlehem-Easton	280.2	296.9	346.6	386.5	426.9	463.2	499.0
Subarea C: Philadelphia	1,526.9	1,561.7	1,791.6	1,960.5	2,100.3	2,221.8	2,321.7
Subarea D: Southern Basin	207.0	229.2	300.7	350.9	393.7	430.4	458.5
Total, Water Quality Area	2,145.5	2,230.7	2,619.2	2,908.9	3,164.2	3,389.7	3,583.6

Table A-84 Projected Households, Maximization of Strong Economic Growth Alternative, Delaware River Basin Water Quality Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	131.4	142.9	191.3	232.2	275.5	317.6	359.2
Subarea B: Allentown-Bethlehem-Easton	280.2	296.9	359.8	412.2	466.2	516.0	565.3
Subarea C: Philadelphia	1,526.9	1,561.7	1,846.7	2,061.1	2,243.2	2,403.8	2,540.2
Subarea D: Southern Basin	207.0	229.2	315.4	376.9	429.5	474.9	510.0
Total, Water Quality Area	2,145.5	2,230.7	2,713.2	3,082.4	3,414.4	3,712.3	3,974.7

Table A-85 Projected Households, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Water Quality Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	131.4	142.9	159.3	170.6	181.0	190.3	198.3
Subarea B: Allentown-Bethlehem-Easton	280.2	296.9	342.6	378.7	415.2	447.7	479.6
Subarea C: Philadelphia	1,526.9	1,561.7	1,745.9	1,877.1	1,980.5	2,068.2	2,148.1
Subarea D: Southern Basin	207.0	229.2	262.1	284.2	302.4	317.1	327.6
Total, Water Quality Area	2,145.5	2,230.7	2,509.9	2,710.6	2,879.1	3,023.3	3,153.6

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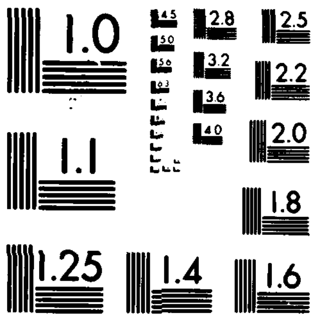

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Table A-86 Projected Total Employment, Continuation of Present Trends Alternative, Delaware River Basin Water Quality Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	173.9	183.8	226.6	264.5	305.9	341.5	377.7
Subarea B: Allentown-Bethlehem-Easton	363.7	374.0	454.0	504.5	547.5	577.3	619.5
Subarea C: Philadelphia	1,989.6	1,991.4	2,380.1	2,580.8	2,777.5	2,843.6	2,961.4
Subarea D: Southern Basin	275.3	295.3	380.7	442.3	490.8	530.2	562.7
Total, Water Quality Area	2,802.5	2,844.5	3,441.4	3,792.1	4,121.7	4,292.6	4,521.3

Table A-87 Projected Total Employment, Maximization of Sound Economic Growth Alternative, Delaware River Basin Water Quality Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	173.9	183.8	240.4	291.2	346.5	395.8	445.9
Subarea B: Allentown-Bethlehem-Easton	363.7	374.0	471.4	538.3	598.2	642.9	702.0
Subarea C: Philadelphia	1,989.6	1,991.4	2,453.3	2,713.2	2,966.2	3,076.8	3,239.7
Subarea D: Southern Basin	275.3	295.3	399.4	474.6	535.1	584.6	625.7
Total, Water Quality Area	2,802.5	2,844.5	3,564.5	4,017.3	4,446.0	4,700.1	5,013.3

Table A-88 Projected Total Personal Income, Maximization of Strong Economic Growth Alternative, Delaware River Basin Water Quality Service Area, 1969-2025
(TPI: Millions of 1967 dollars)

	1969	1972	1985	1995	2005	2015	2025
Subarea A: Upper Basin	$ 1,153	$ 1,596	$ 2,316	$ 3,502	$ 5,175	$ 7,508	$ 10,616
Subarea B: Allentown-Bethlehem-Easton	$ 3,000	$ 3,288	$ 5,158	$ 7,380	$10,393	$ 14,472	$ 19,829
Subarea C: Philadelphia	$18,308	$19,841	$30,368	$41,666	$55,958	$ 74,486	$ 97,761
Subarea D: Southern Basin	$ 2,393	$ 2,635	$ 4,635	$ 6,855	$ 9,689	$ 13,401	$ 17,976
Total, Water Quality Area	$24,854	$27,360	$42,477	$59,403	$81,215	$109,867	$146,182

Table A-89 Projected Total Employment, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Water Quality Service Area, 1970-2025
(Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: Upper Basin	173.9	183.8	200.1	213.9	227.5	236.7	246.0
Subarea B: Allentown-Bethlehem-Easton	363.7	374.0	448.8	494.7	532.7	558.0	595.5
Subarea C: Philadelphia	1,989.6	1,991.4	2,319.5	2,471.4	2,619.8	2,648.2	2,740.6
Subarea D: Southern Basin	275.3	295.3	332.6	360.0	378.6	392.7	404.2
Total, Water Quality Area	2,802.5	2,844.5	3,301.0	3,540.0	3,758.6	3,835.6	3,986.3

Table A-90 Projected Total Personal Income, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Water Quality Service Area, 1969-2025
(TPI: Millions of 1967 dollars)

	1969	1972	1985	1995	2005	2015	2025
Subarea A: Upper Basin	$ 1,153	$ 1,596	$ 1,928	$ 2,573	$ 3,403	$ 4,495	$ 5,864
Subarea B: Allentown-Bethlehem-Easton	$ 3,000	$ 3,288	$ 4,911	$ 6,781	$ 9,255	$12,559	$ 16,831
Subarea C: Philadelphia	$18,308	$19,841	$28,717	$37,960	$49,433	$64,126	$ 82,715
Subarea D: Southern Basin	$ 2,393	$ 2,635	$ 3,851	$ 5,173	$ 6,823	$ 8,953	$ 11,553
Total, Water Quality Area	$24,854	$27,360	$39,407	$52,487	$68,914	$90,133	$116,953

Table A-91 Projected Total Personal Income, Continuation of Present Trends Alternative, Delaware River Basin Water Quality Service Area, 1969-2025
(TPI: Millions of 1967 dollars)

	1969	1972	1985	1995	2005	2015	2025
Subarea A: Upper Basin	$ 1,153	$ 1,596	$ 2,183	$ 3,185	$ 4,569	$ 6,479	$ 8,996
Subarea B: Allentown-Bethlehem-Easton	$ 3,000	$ 3,288	$ 4,969	$ 6,920	$ 9,516	$ 12,995	$ 17,504
Subarea C: Philadelphia	$18,308	$19,841	$29,463	$39,635	$52,400	$ 68,844	$ 89,366
Subarea D: Southern Basin	$ 2,393	$ 2,635	$ 4,417	$ 6,385	$ 8,883	$ 12,146	$ 16,161
Total, Water Quality Area	$24,854	$27,360	$41,032	$56,125	$75,368	$100,464	$132.027

Table A-92 Population Trends, Delaware River Basin
Water Supply Service Area, 1960-1973*

Portions of States Within				Gain, 1960-1970		Gain, 1970-1973	
Water Supply Area	1960	1970	1973	Amount	Percent	Amount	Percent
Delaware	446,292	548,104	575,700	101,812	22.8%	27,596	5.0%
New Jersey	6,066,782	7,171,112	7,361,400	1,104,330	18.2%	190,288	2.7%
New York	11,293,713	12,314,927	12,240,100	1,021,214	9.0%	-74,827	-0.6%
Pennsylvania	4,598,763	4,935,720	4,934,400	336,957	0.7%	- 1,320	0.0%
Connecticut	653,589	792,814	787,800	139,225	21.3%	- 5,014	-0.6%
Total, Water Supply Area	23,059,139	25,762,677	25,899,400	2,703,538	11.7%	136,723	0.5%

Sources: U. S. Census of Population, 1960 and 1970, CPR Series P-25 and P-26.

Table A-93 Population Trends Comparison, Delaware River Basin
Water Supply Service Area, Northeast and United States, 1960-1973 (Thousands)

				Gain, 1960-1973	
	1960	1970	1973	Amount	Percent
Water Supply Service Area	23,059	25,763	25,899	2,840	12.3%
Northeast	44,678	49,051	49,545	4,867	10.9%
United States	179,323	203,235	209,844	30,521	17.0%
Water Supply Service Area Percent of:					
Northeast	51.61%	52.52%	52.27%	58.35%	
United States	12.86%	12.67%	12.34%	9.31%	

Sources: U.S. Census of Population, 1960 and 1970 and CPR Series P-25 and P-26.

* As indicated by the DRB Influence Area Subarea

Table A-94 Household Trends, Delaware River Basin Water Supply Service Area, 1960-1973

	1960	1970	1973	Gain, 1960-1970		Gain, 1970-1973	
				Amount	Percent	Amount	Percent
Portion of States Within Water Supply Area:							
Delaware	128,582	164,804	181.570	36,222	28.2%	16,766	10.2%
New Jersey	1,806,295	2,218,182	2,374,120	411,887	22.8%	155,938	7.0%
New York	3,625,730	4,095,858	4,234,390	470,128	13.0%	138,532	3.4%
Pennsylvania	1,369,964	1,556,833	1,586,250	186,869	13.6%	29,417	1.9%
Connecticut	194,314	243,806	251,640	49,492	25.5%	7,834	3.2%
Total, Water Supply Area	7,124,885	8,279,483	8,627,970	1,154,598	16.2%	348,487	4.2%

Sources: U.S. Census of Population, 1960 and 1970, CPR Series P-25 and P-26.

Table A-95 Household Trends Comparison, Delaware River Basin Water Supply Service Area, Northeast, and United States, 1960-1973 (Thousands)

	1960	1970	1973	Gain, 1960-1973	
				Amount	Percent
Water Supply Service Area	7,125	8,279	8,628	1,503	21.1%
Northeast	13,521	15,483	16,412	2,891	21.4%
United States	53,021	63,450	68,737	15,716	29.6%
Water Supply Service Area, Percent:					
Northeast	52.70%	53.47%	52.57%	51.99%	
United States	13.44%	13.05%	12.55%	9.56%	

Sources: U. S. Census of Population, 1960 and 1970 CPR Series P-25 and P-26.

Table A-96 Total Non-Agricultural Wage and Salary Employment Delaware River Basin Water Supply Service Area, 1960-1972 (Thousands)

Portion of States Within Water Supply Area	1960	1970	1972	Gain, 1960-1970 Amount	Gain, 1960-1970 Percent	Gain, 1970-1972 Amount	Gain, 1970-1972 Percent
Delaware	153.8	213.8	231.6	60.0	39.0%	17.8	8.3%
New Jersey	2,017.1	2,608.5	2,673.9	591.4	29.3%	65.4	2.5%
New York	4,442.8	5,074.1	4,920.1	631.3	14.2%	-154.0	-3.0%
Pennsylvania	1,664.1	1,951.8	1,946.0	287.7	17.3%	- 5.8	- .3%
Connecticut	177.4	217.7	214.5	40.3	22.7%	- 3.2	-1.5%
Total, Water Supply Area	8,455.2	10,065.9	9,986.1	1,610.7	19.0%	- 79.8	- .8%

Sources: Employment and Earnings, 1974; New Jersey Department of Labor and Industry; Pennsylvania Department of Labor and Industry; New York State Department of Labor Employment Review; Connecticut Department of Labor.

Table A-97 Total Non-Agricultural Wage and Salary Employment Comparisons Delaware River Basin, Water Supply Service Area, Northeast and United States, 1960-1972

	1960	1970	1972	Gain, 1960-1972 Amount	Gain, 1960-1972 Percent
Water Supply Service Area	8,455	10,066	9,986	1,531	18.1%
Northeast	15,613	18,672	18,633	3,020	19.3%
United States	54,234	70,593	72,764	18,530	34.2%
Water Supply Service Area Percent of:					
Northeast	54.15	53.91	53.59	50.70	
United States	15.59	14.26	13.72	8.26	

Sources: Employment and Earnings .

Table A-98 Total Personal Income Comparisons, Delaware River Basin Water Supply Service Area, Northeast and United States, 1959-1972 (Millions)

	1959	1969	1972	Gain, 1959-1972 Amount	Gain, 1959-1972 Percent
Current Dollars					
Water Supply Service Area	$ 62,305	$116,094	$141,146	$ 78,841	126.5%
Northeast	$109,452	$203,051	$248,319	$138,867	126.9%
United States	$381,890	$751,425	$947,066	$565,176	148.0%
Constant 1972 Dollars					
Water Supply Service Area	$ 89,408	$132,463	$141,146	$ 51,738	57.9%
Northeast	$157,063	$231,681	$248,319	$ 91,256	58.1%
United States	$548,012	$857,375	$947,066	$399,054	72.8%
Water Supply Service Area, Percent of:					
Northeast	56.92%	57.17%	56.84%	56.77%	
United States	16.31%	15.45%	14.90%	13.95%	

Sources: U.S. Census of Population, 1960 and 1970, U.S. Department of Commerce: Survey of Current Business (May and August, 1974).

Table A-99 Total Personal Income Trends, Delaware River Basin Water Supply Service Area, 1959-1972 (Millions)

Portions of State Within Water Supply Area	1959	1969	1972	Gain, 1959-1969 Amount	Gain, 1959-1969 Percent	Gain, 1969-1972 Amount	Gain, 1969-1972 Percent
Delaware	$ 1,172	$ 2,330	$ 2,931	$ 1,158	98.8%	$ 601	25.8%
New Jersey	15,999	30,925	38,676	14,926	93.3%	7,751	25.1%
New York	32,176	59,361	70,967	27,185	84.5%	11,606	19.6%
Pennsylvania	11,103	19,675	24,163	8,572	77.2%	4,488	22.8%
Connecticut	1,855	3,803	4,409	1,948	105.0%	606	15.9%
Total, Water Supply Area	$62,305	$116,094	$141,146	$53,789	86.3%	$25,052	21.6%

Sources: U. S. Census of Population, 1960 and 1970, U. S. Department of Commerce: Survey of Current Business (May, 1974).

Table A-100 Population Trends, Delaware River Basin Water Supply Service Area, 1960-1973

	1960	1970	1973	1960-70 Change Number	1960-70 Change Percent	1970-73 Change Number	1970-73 Change Percent
Subarea:							
A. New York City Metro Area	14,759,429	16,182,790	16,115,800	1,423,361	9.6%	-66,990	-0.4%
B. NYC Metro Supplement	1,379,454	1,755,311	1,792,200	375,857	27.2%	36,889	2.1%
C. Allentown-Bethlehem Reading Area	821,689	909,909	936,400	88,220	10.7%	26,491	2.9%
D. Trenton Metro Area	266,392	304,116	316,100	37,724	14.2%	11,984	3.9%
E. Philadelphia Metro Area	4,342,897	4,824,110	4,819,200	481,213	11.1%	-4,910	-0.1%
F. Wilmington Metro Area	366,157	446,202	462,300	80,045	21.9%	16,098	3.6%
G. Upper Basin Area	559,749	613,550	649,800	53,801	9.6%	36,250	5.9%
H. Southern Basin and Coastal Area	563,372	726,689	807,600	163,317	29.0%	80,911	11.1%
Total, Water Supply Area	23,059,139	25,762,677	25,899,400	2,703,538	11.7%	136,723	0.5%

Sources: U. S. Censuses of Population 1960 and 1970; CPR, P-25 and P-26.

Table A-101 Household Trends, Delaware River Basin Water Supply Service Area, 1960-1973

	1960	1970	1973	1960-70 Change Number	1960-70 Change Percent	1970-73 Change Number	1970-73 Change Percent
Subarea:							
A. New York City Metro Area	4,678,743	5,319,822	5,514,010	641,079	13.7%	194,188	3.7%
B. NYC Metro Supplement	400,650	524,109	552,080	123,459	30.8%	27,971	5.3%
C. Allentown-Bethlehem Reading Area	252,583	293,611	310,910	41,028	16.2%	17,299	5.9%
D. Trenton Metro Area	76,587	93,486	103,590	16,899	22.1%	10,104	10.8%
E. Philadelphia Metro Area	1,266,429	1,482,009	1,510,110	215,580	17.0%	28,101	1.9%
F. Wilmington Metro Area	105,470	134,455	146,540	28,985	27.5%	12,085	9.0%
G. Upper Basin Area	171,297	195,620	212,920	24,323	14.2%	17,300	8.8%
H. Southern Basin and Coastal Area	173,126	236,371	277,810	63,245	36.5%	41,439	17.5%
Total, Water Supply Area	7,124,885	8,279,483	8,627,970	1,154,598	16.2%	348,487	4.2%

Source: U. S. Censuses of Population, 1960 and 1970, CPR, P-25 and P-26.

Table A-102 Total Nonagricultural Wage and Salary Employment Trends, Delaware River Basin Water Supply Service Area, 1960-1972 (Thousands)

	1960	1970	1972	1960-70 Change		1970-72 Change	
				Number	Percent	Number	Percent
Subarea:							
A. New York City Metro Area	5,715	6,676	6,529	961	16.9%	-147	-2.2%
B. NYC Metro Supplement	382	494	497	112	29.3%	3	0.6%
C. Allentown-Bethlehem Reading Area	295	360	370	65	22.0%	10	2.9%
D. Trenton Metro Area	107	135	143	28	26.2%	8	5.9%
E. Philadelphia Metro Area	1,503	1,795	1,797	292	19.4%	2	0.1%
F. Wilmington Metro Area	133	178	187	45	33.6%	9	5.1%
G. Upper Basin Area	166	192	200	26	15.7%	8	4.2%
H. Southern Basin and Coastal Area	154	236	263	82	53.2%	27	11.4%
Total, Water Supply Area	8,455	10,066	9,986	1,611	19.1%	-80	-0.8%

Source: Employment and Earnings, State and Areas, 1939-72; Employment Security Commission, State of New York; Connecticut Labor Department, Employment Security State of New Jersey; Pennsylvania Department of Labor and Industry.

Total A-103 Personal Income Trends, Delaware River Basin
Water Supply Service Area, 1959-1972 (Millions of Current Dollars)

	1959	1969	1972	1959-69 Change Number	1959-69 Change Percent	1969-72 Change Number	1969-72 Change Percent
Subarea:							
A. New York City Metro Area	$42,265	$ 77,983	$ 93,857	$35,718	84.5%	$15,874	20.4%
B. NYC Metro Supplement	3,439	7,413	8,983	3,974	115.6%	1,570	21.2%
C. Allentown-Bethlehem Reading Area	1,835	3,461	4,327	1,626	88.6%	866	25.0%
D. Trenton Metro Area	680	1,227	1,594	547	80.4%	367	29.9%
E. Philadelphia Metro Area	10,835	19,539	24,104	8,704	80.3%	4,565	23.4%
F. Wilmington Metro Area	1,043	2,006	2,500	963	92.3%	494	24.6%
G. Upper Basin Area	1,046	2,006	2,503	960	91.8%	497	24.8%
H. Southern Basin and Coastal Area	1,162	2,459	3,278	1,297	111.6%	819	33.3%
Total	$62,305	$116,094	$141,146	$53,789	86.3%	$25,052	21.6%

Sources: Survey of Current Business, 1974.

Table A-102 Total Nonagricultural Wage and Salary Employment Trends, Delaware River Basin Water Supply Service Area, 1960-1972 (Thousands)

	1960	1970	1972	1960-70 Change Number	1960-70 Change Percent	1970-72 Change Number	1970-72 Change Percent
Subarea:							
A. New York City Metro Area	5,715	6,676	6,529	961	16.9%	-147	-2.2%
B. NYC Metro Supplement	382	494	497	112	29.3%	3	0.6%
C. Allentown-Bethlehem Reading Area	295	360	370	65	22.0%	10	2.9%
D. Trenton Metro Area	107	135	143	28	26.2%	8	5.9%
E. Philadelphia Metro Area	1,503	1,795	1,797	292	19.4%	2	0.1%
F. Wilmington Metro Area	133	178	187	45	33.6%	9	5.1%
G. Upper Basin Area	166	192	200	26	15.7%	8	4.2%
H. Southern Basin and Coastal Area	154	236	263	82	53.2%	27	11.4%
Total, Water Supply Area	8,455	10,066	9,986	1,611	19.1%	-80	-0.8%

Source: Employment and Earnings, State and Areas, 1939-72; Employment Security Commission, State of New York; Connecticut Labor Department, Employment Security State of New Jersey; Pennsylvania Department of Labor and Industry.

Total A-103 Personal Income Trends, Delaware River Basin
Water Supply Service Area, 1959-1972 (Millions of Current Dollars)

	1959	1969	1972	1959-69 Change Number	1959-69 Change Percent	1969-72 Change Number	1969-72 Change Percent
Subarea:							
A. New York City Metro Area	$42,265	$ 77,983	$ 93,857	$35,718	84.5%	$15,874	20.4%
B. NYC Metro Supplement	3,439	7,413	8,983	3,974	115.6%	1,570	21.2%
C. Allentown-Bethlehem Reading Area	1,835	3,461	4,327	1,626	88.6%	866	25.0%
D. Trenton Metro Area	680	1,227	1,594	547	80.4%	367	29.9%
E. Philadelphia Metro Area	10,835	19,539	24,104	8,704	80.3%	4,565	23.4%
F. Wilmington Metro Area	1,043	2,006	2,500	963	92.3%	494	24.6%
G. Upper Basin Area	1,046	2,006	2,503	960	91.8%	497	24.8%
H. Southern Basin and Coastal Area	1,162	2,459	3,278	1,297	111.6%	819	33.3%
Total	$62,305	$116,094	$141,146	$53,789	86.3%	$25,052	21.6%

Sources: Survey of Current Business, 1974.

Table A-104 Projected Population, Continuation of Present Trends Alternative, Delaware River Basin Water Supply Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: New York Metro	16,182.8	16,115.8	16,852.0	17,535.0	18,085.0	18,536.0	18,927.0
Subarea B: Metro Supplement	1,755.3	1,792.2	2,067.0	2,309.0	2,533.0	2,749.0	2,952.0
Subarea C: Allentown-Bethlehem-Reading	909.9	936.4	1,038.0	1,129.0	1,225.0	1,320.0	1,417.0
Subarea D: Trenton Metro	304.1	316.1	370.0	418.0	466.0	511.0	550.0
Subarea E: Philadelphia Metro	4,824.1	4,819.2	5,215.0	5,515.0	5,785.0	6,035.0	6,270.0
Subarea F: Wilmington Metro	446.2	462.3	546.0	611.0	671.0	725.0	770.0
Subarea G: Upper Basin	613.6	649.8	780.0	894.0	1,018.0	1,145.0	1,275.0
Subarea H: Southern Basin	726.7	807.6	1,071.0	1,230.0	1,356.0	1,464.0	1,552.0
Total, Water Supply Area	25,762.7	25,899.4	27,939.0	29,641.0	31,139.0	32,485.0	33,713.0

Table A-105 Projected Population, Maximization of Sound Economic Growth Alternative, Delaware River Basin Water Supply Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: New York Metro	16,182.8	16,115.8	17,172.0	18,207.0	19,161.0	20,072.0	21,040.0
Subarea B: Metro Supplement	1,755.3	1,792.2	2,142.0	2,483.0	2,807.0	3,128.0	3,455.0
Subarea C: Allentown-Bethlehem-Reading	909.9	936.4	1,067.0	1,195.0	1,327.0	1,467.0	1,605.0
Subarea D: Trenton Metro	304.1	316.1	385.0	445.0	515.0	570.0	625.0
Subarea E: Philadelphia Metro	4,824.1	4,819.2	5,320.0	5,715.0	6,150.0	6,535.0	6,840.0
Subarea F: Wilmington Metro	446.2	462.3	560.0	640.0	720.0	790.0	850.0
Subarea G: Upper Basin	613.6	649.8	830.0	990.0	1,162.0	1,340.0	1,515.0
Subarea H: Southern Basin	726.7	807.6	1,135.0	1,335.0	[illegible]	1,635.0	1,745.0
Total, Water Supply Area	25,762.7	25,899.4	28,611.0	31,010.0	33,342.0	35,537.0	37,675.0

Table A-106 Projected Population, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Water Supply Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2025	2015	2025
Subarea A: New York Metro	16,182.8	16,115.8	16,584.0	16,985.0	17,395.0	17,815.0	18,247.0
Subarea B: Metro Supplement	1,755.3	1,792.2	1,864.0	1,926.0	1,990.0	2,056.0	2,125.0
Subarea C: Allentown-Bethlehem-Reading	909.9	936.4	992.0	1,040.0	1,091.0	1,144.0	1,200.0
Subarea D: Trenton Metro	304.1	316.1	343.0	367.0	393.0	421.0	450.0
Subarea E: Philadelphia Metro	4,824.1	4,819.2	4,989.0	5,135.0	5,285.0	5,440.0	5,600.0
Subarea F: Wilmington Metro	446.2	462.3	490.0	515.0	541.0	569.0	600.0
Subarea G: Upper Basin	613.6	649.8	682.0	710.0	739.0	769.0	800.0
Subarea H: Southern Basin	726.7	807.6	838.0	865.0	892.0	920.0	950.0
Total, Water Supply Area	25,762.7	25,899.4	26,782.0	27,543.0	28,326.0	29,134.0	29,972.0

Table A-107 Projected Total Employment, Maximization of Sound Economic Growth Alternative, Delaware River Basin Water Supply Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2025	2015	2025
Subarea A: New York Metro	6,635.0	6,607.5	7,899.1	8,375.2	9,005.7	9,433.8	9,888.8
Subarea B: Metro Supplement	702.1	716.9	942.5	1,117.4	1,291.2	1,438.9	1,589.3
Subarea C: Allentown-Bethlehem-Reading	382.2	393.3	490.8	561.7	623.7	674.8	738.3
Subarea D: Trenton Metro	127.7	132.8	177.1	204.7	242.1	262.2	287.5
Subarea E: Philadelphia Metro	1,929.6	1,927.7	2,340.8	2,571.8	2,829.0	2,940.8	3,078.0
Subarea F: Wilmington Metro	182.9	189.5	246.4	294.4	331.2	363.4	391.0
Subarea G: Upper Basin	263.9	279.4	365.2	445.5	534.5	616.4	696.9
Subarea H: Southern Basin	283.4	323.0	465.4	547.4	630.0	686.7	732.9
Total, Water Supply Area	10,506.8	10,570.1	12,927.3	14,118.1	15,487.4	16,417.0	17,402.7

Table A-108 Projected Total Employment, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Water Supply Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: New York Metro	6,635.0	6,607.5	7,628.6	7,813.1	8,175.6	8,373.1	8,576.1
Subarea B: Metro Supplement	702.1	716.9	820.2	866.7	915.4	945.8	977.5
Subarea C: Allentown-Bethlehem-Reading	382.2	393.3	456.3	488.8	512.8	526.2	552.0
Subarea D: Trenton Metro	127.7	132.8	157.8	168.8	184.7	193.7	207.0
Subarea E: Philadelphia Metro	1,929.6	1,927.7	2,195.2	2,310.8	2,431.1	2,448.0	2,520.0
Subarea F: Wilmington Metro	182.9	189.5	215.6	236.9	248.9	261.7	276.0
Subarea G: Upper Basin	263.9	279.4	300.1	319.5	332.6	353.7	368.0
Subarea H: Southern Basin	283.4	323.0	343.6	354.6	374.6	386.4	399.0
Total, Water Supply Area	10,506.8	10,570.1	12,117.4	12,559.2	13,175.7	13,488.6	13,875.6

Table A-109 Projected Total Employment, Continuation of Present Trends Alternative, Delaware River Basin Water Supply Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: New York Metro	6,635.0	6,607.5	7,751.9	8,066.1	8,500.0	8,711.9	8,895.7
Subarea B: Metro Supplement	702.1	716.9	909.5	1,039.0	1,165.2	1,264.5	1,357.9
Subarea C: Allentown-Bethlehem-Reading	382.2	393.3	477.5	530.6	575.8	607.2	651.8
Subarea D: Trenton Metro	127.7	132.8	170.2	192.3	219.0	235.1	253.0
Subarea E: Philadelphia Metro	1,929.6	1,927.7	2,294.6	2,481.8	2,661.1	2,715.8	2,821.5
Subarea F: Wilmington Metro	182.9	189.5	240.2	281.1	308.7	333.5	354.2
Subarea G: Upper Basin	263.9	279.4	343.2	402.3	468.3	526.7	586.5
Subarea H: Southern Basin	283.4	323.0	439.1	504.3	569.5	614.9	651.8
Total, Water Supply Area	10,506.8	10,570.1	12,626.2	13,497.5	14,467.6	15,009.6	15,572.4

Table A-110 Projected Households, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Water Supply Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: New York Metro	5,319.8	5,514.0	6,074.7	6,385.3	6,614.1	6,773.8	6,938.0
Subarea B: Metro Supplement	524.1	552.1	619.3	664.1	703.2	739.6	769.9
Subarea C: Allentown-Bethlehem-Reading	293.6	310.9	351.8	379.6	404.1	426.9	447.8
Subarea D: Trenton Metro	93.5	103.6	120.4	132.5	144.5	155.9	166.7
Subarea E: Philadelphia Metro	1,482.0	1,510.1	1,691.2	1,801.8	1,894.3	1,978.2	2,051.3
Subarea F: Wilmington Metro	134.5	146.5	165.5	180.7	193.9	206.9	219.8
Subarea G: Upper Basin	195.6	212.9	240.4	256.3	271.7	284.8	296.3
Subarea H: Southern Basin	236.4	277.8	305.8	324.0	337.9	349.8	361.2
Total, Water Supply Area	8,279.5	8,627.9	9,569.1	10,124.3	10,563.7	10,915.9	11,251.0

Table A-111 Projected Households, Maximization of Sound Economic Growth Alternative, Delaware River Basin Water Supply Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: New York Metro	5,319.8	5,514.0	6,290.1	6,844.7	7,285.6	7,631.9	8,000.0
Subarea B: Metro Supplement	524.1	552.1	711.6	890.0	991.9	1,125.2	1,251.8
Subarea C: Allentown-Bethlehem-Reading	293.6	310.9	378.4	436.1	491.5	547.4	598.9
Subarea D: Trenton Metro	93.5	103.6	135.1	160.6	189.3	211.1	231.5
Subarea E: Philadelphia Metro	1,482.0	1,510.1	1,803.4	2,005.3	2,204.3	2,376.4	2,505.5
Subarea F: Wilmington Metro	134.5	146.5	189.2	224.6	258.1	287.3	311.4
Subarea G: Upper Basin	195.6	212.9	291.2	357.4	427.2	496.3	561.1
Subarea H: Southern Basin	236.4	277.8	414.2	500.0	568.2	621.7	663.5
Total, Water Supply Area	8,279.5	8,627.9	10,213.2	11,418.7	12,416.1	13,297.3	14,123.7

Table A-112 Projected Households, Continuation of Present Trends Alternative, Delaware River Basin Water Supply Service Area, 1970-2025 (Thousands)

	1970	1973	1985	1995	2005	2015	2025
Subarea A: New York Metro	5,319.8	5,514.0	6,172.9	6,592.1	6,876.4	7,047.9	7,196.6
Subarea B: Metro Supplement	524.1	552.1	686.7	827.6	895.1	988.8	1,069.6
Subarea C: Allentown-Bethlehem-Reading	293.6	310.9	368.1	412.0	453.7	492.5	528.7
Subarea D: Trenton Metro	93.5	103.6	129.8	150.9	171.3	189.3	203.7
Subarea E: Philadelphia Metro	1,482.0	1,510.1	1,767.8	1,935.1	2,073.5	2,194.5	2,296.7
Subarea F: Wilmington Metro	134.5	146.5	184.5	214.4	240.5	263.6	282.1
Subarea G: Upper Basin	195.6	212.9	273.7	322.7	374.3	424.1	472.2
Subarea H: Southern Basin	236.4	277.8	390.9	460.7	513.6	556.7	590.1
Total, Water Supply Area	8,279.5	8,627.9	9,974.4	10,915.5	11,598.4	12,157.4	12,639.7

Table A-113 Projected Total Personal Income, Continuation of Present Trends Alternative, Delaware River Basin Water Supply Service Area, 1969-2025
(TPI: Millions of 1967 dollars)

	1969	1972	1985	1995	2005	2015	2025
Subarea A: New York Metro	$ 71,023	$ 74,906	$106,673	$139,333	$178,680	$225,435	$280,498
Subarea B: Metro Supplement	$ 6,751	$ 7,169	$ 11,100	$ 15,563	$ 21,226	$ 28,645	$ 37,874
Subarea C: Allentown-Bethlehem-Reading	$ 3,152	$ 3,453	$ 5,221	$ 7,271	$ 10,001	$ 13,662	$ 18,407
Subarea D: Trenton Metro	$ 1,118	$ 1,272	$ 2,013	$ 2,855	$ 3,956	$ 5,340	$ 7,073
Subarea E: Philadelphia Metro	$ 17,795	$ 19,237	$ 28,474	$ 38,164	$ 50,272	$ 65,842	$ 85,272
Subarea F: Wilmington Metro	$ 1,827	$ 1,995	$ 3,145	$ 4,375	$ 6,032	$ 8,178	$ 11,011
Subarea G: Upper Basin	$ 1,827	$ 1,998	$ 3,299	$ 4,837	$ 6,984	$ 9,962	$ 13,120
Subarea H: Southern Basin	$ 2,240	$ 2,616	$ 4,755	$ 6,851	$ 9,384	$ 12,473	$ 16,125
Total, Water Supply Area	$105,733	$112,646	$164,680	$219,249	$286,535	$369,537	$469,380

Table A-114 Projected Total Personal Income, Limitation of Economic Growth and Preservation of Environmental Resources Alternative, Delaware River Basin Water Supply Service Area, 1969-2025
(TPI: Millions of 1967 dollars)

	1969	1972	1985	1995	2005	2015	2025
Subarea A: New York Metro	$ 71,023	$ 74,906	$104,977	$134,963	$171,863	$216,666	$270,421
Subarea B: Metro Supplement	$ 6,751	$ 7,169	$ 10,010	$ 12,981	$ 16,676	$ 21,424	$ 27,264
Subarea C: Allentown-Bethlehem-Reading	$ 3,152	$ 3,453	$ 4,990	$ 6,698	$ 8,907	$ 11,840	$ 15,588
Subarea D: Trenton Metro	$ 1,118	$ 1,272	$ 1,866	$ 2,507	$ 3,337	$ 4,400	$ 5,787
Subarea E: Philadelphia Metro	$ 17,795	$ 19,237	$ 27,240	$ 35,534	$ 45,927	$ 59,350	$ 76,160
Subarea F: Wilmington Metro	$ 1,827	$ 1,995	$ 2,822	$ 3,687	$ 4,864	$ 6,418	$ 8,580
Subarea G: Upper Basin	$ 1,827	$ 1,998	$ 2,885	$ 3,841	$ 5,070	$ 6,690	$ 8,736
Subarea H: Southern Basin	$ 2,240	$ 2,616	$ 3,721	$ 4,818	$ 6,173	$ 7,838	$ 9,871
Total, Water Supply Area	$105,733	$112,646	$158,511	$205,029	$262,817	$334,626	$422,407

Table A-115 Projected Total Personal Income, Maximization of Sound Economic Growth Alternative, Delaware River Basin Water Supply Service Area, 1969-2025
(TPI: Millions of 1967 dollars)

	1969	1972	1985	1995	2005	2015	2025
Subarea A: New York Metro	$ 71,023	$74,906	$108,699	$144,673	$189,311	$244,116	$311,813
Subarea B: Metro Supplement	$ 6,751	$ 7,169	$ 11,503	$ 16,735	$ 23,523	$ 32,594	$ 44,328
Subarea C: Allentown-Bethlehem-Reading	$ 3,152	$ 3,453	$ 5,367	$ 7,696	$ 10,834	$ 15,183	$ 20,849
Subarea D: Trenton Metro	$ 1,118	$ 1,272	$ 2,094	$ 3,039	$ 4,372	$ 5,957	$ 8,038
Subarea E: Philadelphia Metro	$ 17,795	$19,237	$ 29,042	$ 39,548	$ 53,444	$ 71,297	$ 93,024
Subarea F: Wilmington Metro	$ 1,827	$ 1,995	$ 3,226	$ 4,582	$ 6,473	$ 8,911	$ 12,155
Subarea G: Upper Basin	$ 1,827	$ 1,998	$ 3,511	$ 5,356	$ 7,971	$ 11,658	$ 15,589
Subarea H: Southern Basin	$ 2,240	$ 2,616	$ 5,039	$ 7,436	$ 10,380	$ 13,930	$ 18,131
Total, Water Supply Area	$105,733	$112,646	$168,481	$229,065	$306,308	$403,646	$523,927

Table A-116 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area, by Subareas 1962-1972

Subarea A. New York City Metro Area

	1962	1972	Gain 1962-1972 Amount	Gain 1962-1972 Percent
Food	133.1	102.2	-30.9	-23.2%
Textiles	60.7	64.8	4.1	6.8%
Paper	59.2	56.1	- 3.1	- 5.2%
Chemicals	126.3	146.4	20.1	15.9%
Petroleum	14.4	13.3	- 1.1	- 7.6%
Primary Metals	52.6	42.3	-10.3	-19.6%
(Water-Using Industries)	(446.3)	(425.1)	(-21.2)	- 4.8%
Other Manufacturing Industries	1,285.8	1,093.8	-192.0	-14.9%
Total, Manufacturing Employment	1,732.1	1,518.9	-213.2	-12.3%

Source: U. S. Department of Labor Employment and Earnings.

Table A-117 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area, by Subareas, 1962-1972

Subarea B. NYC Metro Supplement

	1962	1972	Gain, 1962-1972 Amount	Gain, 1962-1972 Percent
Food	7.6	7.7	.1	1.3%
Textiles	5.0	4.5	-.5	-10.0%
Paper	2.5	4.0	1.5	60.0%
Chemicals	4.2	6.2	2.0	47.6%
Petroleum	1.2	1.2	-	-
Primary Metals	8.6	7.3	-1.3	-15.1%
(Water Using Industries)	(29.1)	(30.9)	(1.8)	6.2%
Other Manufacturing Industries	132.4	136.3	3.9	2.9%
Total, Manufacturing Employment	161.5	167.2	5.7	3.5%

Sources: County Business Patterns and Employment and Earnings.

Table A-118 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area by Subareas, 1962-1972

Subarea C. Allentown-Bethlehem-Reading

	1962	1972	Gain, 1962-1972 Amount	Gain, 1962-1972 Percent
Food	10.7	11.4	.7	6.5%
Textiles	16.9	15.0	-1.9	-11.2%
Paper	5.1	5.4	.3	5.9%
Chemicals	4.2	4.4	.2	4.8%
Petroleum	-	-	-	-
Primary Metals	26.4	28.4	2.0	7.6%
(Water-Using Industries)	(63.3)	(64.6)	(1.3)	2.1%
Other Manufacturing Industries	87.8	94.9	7.1	8.1%
Total, Manufacturing Employment	151.1	159.5	8.4	5.6%

Source: Employment and Earnings, U.S. Department of Labor.

Table A-119 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area, by Subareas, 1962-1972

Subarea D. Trenton Metro

	1962	1972	Gain, 1962-1972 Amount	Percent
Food	1.4	1.1	- .3	-21.4%
Textiles	.4	.3	- .1	-25.0%
Paper	.8	1.1	.3	37.5%
Chemicals	2.3	3.0	.7	30.4%
Petroleum	-	.5	.5	-
Primary Metals	2.0	.9	-1.1	-55.0%
(Water Using Industries)	(6.9)	(6.9)	-	-
Other Manufacturing Industries	28.7	32.6	3.9	13.6%
Total, Manufacturing Employment	35.6	39.5	3.9	11.0%

Source: Employment and Earnings and New Jersey Department of Labor.

Table A-120 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area, by Subareas, 1962-1972

Subarea E. Philadelphia Metro

	1962	1972	Gain, 1962-1972 Amount	Gain, 1962-1972 Percent
Food	49.5	45.3	- 4.2	- 8.5%
Textiles	30.2	22.6	- 7.6	-25.2%
Paper	23.0	22.4	- .6	- 2.6%
Chemicals	39.5	40.4	.9	2.3%
Petroleum	18.1	15.7	- 2.4	-13.3%
Primary Metals	34.9	32.5	- 2.4	- 6.9%
(Water Using Industries)	(195.2)	(178.9)	(-16.3)	(- 8.4%)
Other Manufacturing Industries	348.9	321.0	(-27.9)	(- 8.0%)
Total, Manufacturing Employment	544.1	499.9	(-44.2)	- 8.1%

Table A-121 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area, by Subareas, 1962-1972

Subarea F. Wilmington Metro

	1962	1972	Gain, 1962-1972 Amount	Gain, 1962-1972 Percent
Food	2.0	2.0	-	-
Textiles	1.9	.8	-1.1	-57.9%
Paper	.3	1.2	.9	300.0%
Chemicals	21.7	29.7	8.0	36.9%
Petroleum	.4	.9	.5	125.0%
Primary Metals	3.7	2.4	-1.3	-35.1%
(Water-Using Industries)	(30.0)	(37.0)	(7.0)	23.3%
Other Manufacturing Industries	15.6	22.3	6.7	42.9%
Total, Manufacturing Employment	45.6	59.3	13.7	30.0%

Source: New Jersey Department of Labor and County Business Patterns.

Table A-120 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area, by Subareas, 1962-1972

Subarea E. Philadelphia Metro

	1962	1972	Gain, 1962-1972 Amount	Percent
Food	49.5	45.3	- 4.2	- 8.5%
Textiles	30.2	22.6	- 7.6	-25.2%
Paper	23.0	22.4	- .6	- 2.6%
Chemicals	39.5	40.4	.9	2.3%
Petroleum	18.1	15.7	- 2.4	-13.3%
Primary Metals	34.9	32.5	- 2.4	- 6.9%
(Water Using Industries)	(195.2)	(178.9)	(-16.3)	(- 8.4%)
Other Manufacturing Industries	348.9	321.0	(-27.9)	(- 8.0%)
Total, Manufacturing Employment	544.1	499.9	(-44.2)	- 8.1%

Table A-121 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area, by Subareas, 1962-1972

Subarea F. Wilmington Metro

	1962	1972	Gain, 1962-1972 Amount	Percent
Food	2.0	2.0	-	-
Textiles	1.9	.8	-1.1	-57.9%
Paper	.3	1.2	.9	300.0%
Chemicals	21.7	29.7	8.0	36.9%
Petroleum	.4	.9	.5	125.0%
Primary Metals	3.7	2.4	-1.3	-35.1%
(Water-Using Industries)	(30.0)	(37.0)	(7.0)	23.3%
Other Manufacturing Industries	15.6	22.3	6.7	42.9%
Total, Manufacturing Employment	45.6	59.3	13.7	30.0%

Source: New Jersey Department of Labor and County Business Patterns.

Table A-122 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area, by Subareas, 1962-1972

Subarea G. Upper Basin

	1962	1972	Gain, 1962-1972 Amount	Gain, 1962-1972 Percent
Food	3.0	2.0	-1.0	-33.3%
Textiles	3.8	5.5	1.7	44.7%
Paper	.5	.4	- .1	-20.0%
Chemicals	2.4	2.3	- .1	- 4.2%
Petroleum	-	-	-	-
Primary Metals	3.2	3.8	.6	18.8%
(Water Using Industries)	(12.9)	(14.0)	(1.1)	8.5%
Other Manufacturing Industries	45.8	46.0	.2	.4%
Total, Manufacturing Employment	58.7	60.0	1.3	2.2%

Sources: New Jersey Department of Labor, Pennsylvania Department of Labor, and County Business Patterns.

Table A-123 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin Water Supply Area, by Subareas, 1962-1972

Subarea H. Southern Basin and Coastal

	1962	1972	Gain, 1962-1972 Amount	Gain, 1962-1972 Percent
Food	8.6	11.3	2.7	31.4%
Textiles	1.0	1.6	.6	60.0%
Paper	.2	.1	-.1	-50.0%
Chemicals	3.5	5.8	2.3	65.7%
Petroleum	-	-	-	-
Primary Metals	.4	.3	-.1	-25.0%
(Water Using Industries)	(13.7)	(19.1)	(5.4)	39.4%
Other Manufacturing Industries	28.5	36.1	7.6	26.7%
Total, Manufacturing Employment	42.2	55.2	13.0	30.8%

Sources: New Jersey Department of Labor and Industry and County Business Patterns.

Table A-124 Manufacturing Employment Trends in Major Water Using and Other Industries, Delaware River Basin, Water Supply Area, 1962-1972 (thousands)

	1962	1972	Gain, 1962-1972 Amount	Gain, 1962-1972 Percent
Food	215.9	183.0	-32.9	-18.0%
Textiles	119.9	115.1	- 4.8	- 4.0%
Paper	91.6	90.7	- 0.9	- 1.0%
Chemicals	204.1	238.2	34.1	16.7%
Petroleum	34.1	31.6	- 2.5	- 7.3%
Primary Metals	131.8	117.9	-13.9	-10.5%
(Water Using Industries)	(797.4)	(776.5)	(-20.9)	(- 2.6%)
Other Manufacturing Industries	1,973.5	1,782.9	-190.6	- 9.7%
Total, Manufacturing Employment	2,770.9	2,559.4	-211.5	- 7.6%

Sources: U.S. Department of Labor Employment and Earnings; Pennsylvania Department of Labor and Industry; New Jersey Department of Labor and Industry; County Business Patterns, 1962 and 1972

Table A-125 Manufacturing Employment Trends in Major Water Using and Other Industries in the Northeast, 1962-1972 (thousands)

	1962	1972	Gain, 1962-1972 Amount	Percent
Food	409.1	352.5	- 56.6	-13.8%
Textiles	270.9	224.9	- 46.0	-17.0%
Paper	213.0	207.1	- 5.9	- 2.8%
Chemicals	267.4	291.2	23.8	8.9%
Petroleum	43.1	40.0	- 3.1	- 7.2%
Primary Metals	404.3	370.2	- 34.1	- 8.4%
(Water-Using Industries)	(1,607.8)	(1,485.9)	(-121.9)	(- 7.6%)
Other Manufacturing Industries	3,895.1	3,722.4	-172.7	- 4.4%
Total, Manufacturing Employment	5,502.9	5,208.3	-294.6	- 5.4%

Source: U.S. Department of Labor Employment and Earnings; County Business Patterns, 1962, 1972.

Table A-126 Manufacturing Employment Trends in Major Water Using and Other Industries in the United States, 1962-1972 (thousands)

	1962	1972	Gain, 1962-1972 Amount	Percent
Food	1,763	1,739	- 24	-1.4%
Textiles	902	994	92	10.2%
Paper	614	689	75	12.2%
Chemicals	848	1,007	159	18.8%
Petroleum	195	194	-1	-.5%
Primary Metals	1,166	1,240	74	6.3%
(Water Using Industries)	(5,488)	(5,863)	(375)	(6.8%)
Other Manufacturing Industries	11,365	13,227	1,862	16.4%
Total, Manufacturing Employment	16,853	19,090	2,237	13.3%

Source: U.S. Department of Labor: Employment and Earnings.

Table A-127 Manufacturing Employment Trends in Major Water Using and Other Industries: Delaware River Basin Water Supply Area as a Percent of Northeast and United States, 1962-1972 (thousands)

	Northeast			United States		
	1962	1972	Gain Amount	1962	1972	Gain Amount
Food	52.8%	51.9%	58.1%	12.2%	10.5%	12.9%
Textiles	44.3%	51.2%	10.4%	13.3%	11.6%	-39.2%
Paper	43.0%	43.8%	2.0%	14.9%	13.2%	-7.4%
Chemicals	76.3%	81.8%	143.3%	24.1%	23.7%	181.4%
Petroleum	76.3%	76.3%	77.4%	16.9%	15.7%	240.0%
Primary Metals	32.6%	31.8%	40.8%	11.3%	9.5%	-18.8%
(Water Using Industries)	(49.5%)	(52.2%)	(17.2%)	(14.5%)	(13.2%)	(-5.6%)
Other Manufacturing Industries	50.7%	47.9%	110.4%	17.4%	13.5%	-10.3%
Total, Manufacturing Employment	50.3%	49.1%	71.9%	16.4%	13.4%	-9.5%

Sources: U.S. Department of Labor Employment and Earnings; New Jersey Department of Labor and Industry; County Business Patterns 1962 and 1972.

Table A-128 Total Employment Projections by Place of Residence, Limited Economic Growth Alternative, Subarea A, New York Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	114,400	93,800	81,800		42,900
Textile Mill Products	61,000	50,700	40,900	29,300	17,200
Paper & Allied Products	45,800	39,100	32,700	33,500	25,700
Chemicals & Allied Products	160,200	156,300	163,500	159,100	154,400
Petroleum Refining	22,900	21,500	20,400	18,800	17,100
Primary Metals	30,500	27,300	24,500	20,900	17,100
Subtotal	(434,800)	(388,700)	(363,800)	(328,600)	(274,400)
All Other Manufacturing	1,701,200	1,541,100	1,394,000	1,203,700	1,012,000
Manufacturing, Total	2,136,000	1,929,800	1,757,800	1,532,300	1,286,400
Non-manufacturing	5,492,600	5,883,300	6,417,800	6,840,800	7,289,700
Total Employment	7,628,600	7,813,100	8,175,600	8,373,100	8,576,100

Table A-129 Total Employment Projections by Place of Residence, Continuation of Present Trends Alternative, Subarea A, New York Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	131,800	108,900	93,500	87,100	80,000
Textile Mill Products	69,800	56,500	42,500	43,600	35,600
Paper & Allied Products	62,000	56,500	59,500	52,300	53,400
Chemicals & Allied Products	178,300	185,500	195,500	200,400	204,600
Petroleum Refining	23,200	20,200	17,000	17,400	17,800
Primary Metals	31,000	28,200	25,500	17,400	17,800
Subtotal	(496,100)	(455,800)	(433,500)	(418,200)	(409,200)
All Other Manufacturing,	1,713,200	1,137,300	1,096,500	1,054,100	1,040,800
Manufacturing, Total	2,209,300	1,593,100	1,530,000	1,472,300	1,450,000
Non-manufacturing	5,542,600	6,473,000	6,970,000	7,239,600	7,445,700
Total Employment	7,751,900	8,066,100	8,500,000	8,711,900	8,895,700

Table A-130 Total Employment Projections by Place of Residence, Maximized South Growth Alternative, Subarea A, New York Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	134,300	113,100	99,100	94,300	89,000
Textile Mill Products	71,100	58,700	45,000	47,200	39,600
Paper & Allied Products	63,200	58,600	63,100	56,600	59,300
Chemicals & Allied Products	181,700	192,600	207,100	217,000	227,400
Petroleum Refining	23,700	20,900	18,000	18,900	19,800
Primary Metals	31,600	29,300	27,000	18,900	19,800
Subtotal	(505,600)	(473,200)	(459,300)	(452,900)	(454,900)
All Other Manufacturing	1,745,700	1,180,900	1,161,700	1,141,400	1,157,000
Manufacturing, Total	2,251,300	1,654,100	1,621,000	1,594,300	1,611,900
Non-manufacturing	5,647,800	6,721,100	7,384,700	7,839,500	8,276,900
Total Employment	7,899,100	8,375,200	9,005,700	9,433,800	9,888,800

Table A-131 Total Employment Projections by Place of Residence, Limited Growth Alternative, Subarea B: Metro Supplement, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	8,200	7,800	7,300	5,700	4,900
Textile Mill Products	3,300	3,000	2,700	2,400	2,000
Paper & Allied Products	4,900	4,300	3,700	3,300	2,900
Chemicals & Allied Products	11,500	11,300	11,000	10,400	9,800
Petroleum Refining	2,500	2,200	1,800	1,400	1,000
Primary Metals	4,900	4,300	3,700	3,300	2,900
Subtotal	(35,300)	(32,900)	(30,200)	(26,500)	(23,500)
All Other Manufacturing	153,400	153,400	152,900	148,500	142,700
Manufacturing, Total	188,700	186,300	183,100	175,000	166,200
Nonmanufacturing	631,500	680,400	732,300	770,800	811,300
Total Employment	820,200	866,700	915,400	945,800	977,500

Table A-132 Total Employment Projections by Place of Residence, Continuation of Present Trends Alternative, Subarea B: Metro Supplement, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	10,000	10,400	11,600	10,100	10,900
Textile Mill Products	3,600	3,100	3,500	2,500	2,700
Paper & Allied Products	6,400	7,300	8,200	10,100	10,900
Chemicals & Allied Products	14,600	17,700	19,800	22,800	24,400
Petroleum Refining	2,700	3,100	2,300	2,500	2,700
Primary Metals	5,400	5,200	3,500	3,800	4,100
Subtotal	(42,700)	(46,800)	(48.900)	(51,800)	(55,700)
All Other Manufacturing	171,900	181,800	191,100	194,700	203,700
Manufacturing, Total	214,600	228,600	240,000	246,500	259,400
Nonmanufacturing	694,900	810,400	925,200	1,018,000	1,098,500
Total Employment	909,500	1,039,000	1,165,200	1,264,500	1,357,900

Table A-133 Total Employment Projections by Place of Residence, Maximized Sound Growth Alternative, Subarea B: Metro Supplement, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	10,400	11,200	12,900	11,500	12,700
Textile Mill Products	3,800	3,400	3,900	2,900	3,200
Paper & Allied Products	6,600	7,800	9,000	11,500	12,700
Chemicals & Allied Products	15,100	19,000	22,000	25,900	28,600
Petroleum Refining	2,800	3,300	2,600	2,900	3,200
Primary Metals	5,600	5,600	3,900	4,300	4,800
Subtotal	(44,300)	(50,300)	(54,300)	(59,000)	(65,200)
All Other Manufacturing	178,100	195,500	211,706	211,700	238,400
Manufacturing, Total	222,400	245,800	266,000	280,600	303,600
Nonmanufacturing	720,100	871,600	1,025,200	1,158,300	1,285,700
Total Employment	942,500	1,117,400	1,291,200	1,438,900	1,589,300

Table A-134 Total Employment Projections by Place of Residence, Limited Economic Growth Alternative, Subarea C, Allentown-Bethlehem-Reading, 1985-2025

	1980	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	11,400	10,800	10,300	9,500	8,300
Textile Mill Products	8,700	7,800	6,700	5,300	3,900
Paper & Allied Products	3,700	4,400	5,100	5,300	6,100
Chemicals & Allied Products	9,100	9,300	9,500	9,700	9,900
Petroleum Refining	900	1,000	1,000	1,000	1,100
Primary Metals	19,600	18,600	16,400	13,700	11,600
Subtotal	(53,400)	(51,900)	(49,000)	(44,500)	(40,900)
All Other Manufacturing	97,200	98,700	97,100	93,400	91,600
Manufacturing, Total	150,600	150,600	146,100	137,900	132,500
Non-manufacturing	305,700	338,200	366,700	388,300	419,500
Total Employment	456,300	488,800	512,800	526,200	552,000

Table A-135 Total Employment Projections by Place of Residence, Continuation of Present Trends Alternative, Subarea C, Allentown-Bethlehem-Reading, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	12,600	12,900	13,000	12,600	13,000
Textile Mill Products	10,000	8,700	7,600	6,700	6,500
Paper & Allied Products	4,000	4,300	5,600	7,900	9,500
Chemicals & Allied Products	10,500	12,100	13,700	15,100	16,600
Petroleum Refining	1,000	1,000	900	900	800
Primary Metals	21,400	19,700	18,500	17,100	17,000
Subtotal	(59,500)	(58,700)	(59,300)	(60,300)	(63,400)
All Other Manufacturing	103,900	107,600	109,800	108,200	112,200
Manufacturing, Total	163,400	166,300	169,100	168,500	175,600
Non-manufacturing	314,100	364,300	406,700	438,700	476,200
Total Employment	477,500	530,600	575,800	607,200	651,800

Table A-136 Total Employment Projections by Place of Residence, Maximized Sound Growth Alternative, Subarea C, Allentown-Bethlehem-Reading, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	13,000	13,800	14,000	14,100	15,700
Textile Mill Products	10,300	9,200	8,200	7,400	7,800
Paper & Allied Products	4,100	4,500	6,100	8,800	11,400
Chemicals & Allied Products	10,800	12,800	14,800	16,800	19,900
Petroleum Refining	1,000	1,000	900	900	1,000
Primary Metals	22,000	20,800	20,200	19,000	20,600
Subtotal	(61,200)	(62,100)	(64,200)	(67,000)	(76,400)
All Other Manufacturing	106,800	114,000	118,900	120,300	134,900
Manufacturing, Total	168,000	176,100	183,100	187,300	211,300
Non-manufacturing	322,800	385,600	440,600	487,500	572,000
Total Employment	490,800	561,700	623,700	674,800	783,300

Table A-137 Total Employment Projections by Place of Residence, Limited Economic Growth Alternative, Subarea D: Trenton Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	1,400	1,300	1,100	1,000	800
Textile Mill Products	200	200	200	200	200
Paper & Allied Products	800	700	700	600	400
Chemicals & Allied Products	3,800	4,000	4,300	4,300	4,600
Petroleum Refining	800	700	700	700	600
Primary Metals	800	700	600	600	400
Subtotal	(7,800)	(7,600)	(7,600)	(7,400)	(7,000)
All Other Manufacturing	32,800	31,700	30,800	28,300	26,100
Manufacturing, Total	40,600	39,300	(38,400)	(35,700)	33,100
Nonmanufacturing	117,200	129,500	146,300	158,000	173,900
Total Employment	157,800	168,800	184,700	193,700	207,000

Table A-138 Total Employment Projections by Place of Residence, Continuation of Present Trends Alternative, Subarea D: Trenton Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	1,500	1,300	1,200	1,100	1,100
Textile Mill Products	200	100	100	100	100
Paper & Allied Products	800	800	800	700	700
Chemicals & Allied Products	4,200	5,100	6,300	7,000	7,700
Petroleum Refining	1,100	1,000	900	800	800
Primary Metals	800	700	700	600	600
Subtotal	(8,600)	(9,000)	(10,000)	(10,300)	(11,000)
All Other Manufacturing	35,900	34,500	34,100	32,400	32,900
Manufacturing, Total	44,500	43,500	44,100	42,700	43,900
Nonmanufacturing	125,700	148,800	174,900	192,400	209,100
Total Employment	170,200	192,300	219,000	235,100	253,000

Table A-139 Total Employment Projections by Place of Residence, Maximized Sound Growth Alternative, Subarea D: Trenton Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	1,600	1,400	1,400	1,200	1,200
Textile Mill Products	200	100	100	100	100
Paper & Allied Products	800	800	800	700	800
Chemicals & Allied Products	4,400	5,500	6,900	7,900	8,800
Petroleum Refining	1,100	1,100	1,100	1,000	900
Primary Metals	800	700	700	600	700
Subtotal	(8,900)	(9,600)	(11,000)	(11,500)	(12,500)
All Other Manufacturing	37,400	36,700	37,700	36,100	37,400
Manufacturing, Total	46,300	46,300	48,700	47,600	49,900
Nonmanufacturing	130,800	158,400	193,400	214,600	237,600
Total Employment	177,100	204,700	242,100	262,200	287,500

Table A-140 Total Employment Projections by Place of Residence, Limited Economic Growth Alternative, Subarea E, Philadelphia Metro, 1985-2025

	1985	1995	2025	2015	2025
Manufacturing					
Food & Kindred Products	37,300	34,700	29,200	24,500	20,200
Textile Mill Products	13,200	11,600	9,700	7,300	5,000
Paper & Allied Products	24,100	23,100	21,900	19,600	17,600
Chemicals & Allied Products	43,900	45,000	45,200	45,400	45,400
Petroleum Refining	17,600	16,200	14,600	14,700	12,600
Primary Metals	26,300	23,100	19,400	17,100	12,600
Subtotal	(162,400)	(153,700)	(140,000)	(128,600)	(113,400)
All Other Manufacturing	373,200	375,500	380,300	361,000	352,800
Manufacturing, Total	535,600	529,200	520,300	489,600	466,200
Non-manufacturing	1,659,600	1,781,600	1,910,800	1,958,400	2,053,800
Total Employment	2,195,200	2,310,800	2,431,100	2,448,000	2,520,000

Table A-141 Total Employment Projections by Place of Residence, Continuation of Present Trends Alternative, Subarea E, Philadelphia Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	44,700	39,000	35,400	30,400	29,100
Textile Mill Products	14,500	10,900	9,300	7,600	6,800
Paper & Allied Products	25,900	26,500	27,100	26,400	26,800
Chemicals & Allied Products	48,900	53,600	58,500	61,100	64,000
Petroleum Refining	19,300	16,900	15,700	14,100	13,800
Primary Metals	27,500	24,600	22,300	19,600	18,900
Subtotal	(180,800)	(171,500)	(168,300)	(159,200)	(159,400)
All Other Manufacturing	389,600	390,900	392,900	380,200	384,600
Manufacturing, Total	570,400	562,400	561,200	539,400	544,000
Non-Manufacturing	1,724,200	1,919,400	2,099,900	2,176,400	2,277,500
Total Employment	2,294,600	2,481,800	2,661,100	2,715,800	2,821,500

Table A-142 Total Employment Projections by Place of Residence, Maximized Sound Growth Alternative, Subarea E, Philadelphia Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	45,600	40,400	37,600	33,000	31,700
Textile Mill Products	14,700	11,300	9,900	8,200	7,400
Paper & Allied Products	26,500	27,500	28,800	28,500	29,200
Chemicals & Allied Products	49,900	55,500	62,200	66,200	69,900
Petroleum Refining	19,700	17,500	16,700	15,300	15,100
Primary Metals	28,100	25,500	23,700	21,200	20,600
Subtotal	(184,500)	(177,700)	(178,900)	(172,300)	(173,900)
All Other Manufacturing	397,400	405,100	417,700	411,700	419,500
Manufacturing, Total	581,900	582,800	596,600	584,000	593,400
Non-manufacturing	1,758,900	1,989,000	2,232,400	2,356,800	2,484,600
Total Employment	2,340,800	2,571,800	2,829,000	2,940,800	3,078,000

Table A-143 Total Employment Projections by Place of Residence, Limited Economic Growth Alternative, Subarea F: Wilmington Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	1,100	1,000	1,000	800	600
Textile Mill Products	600	500	500	500	300
Paper & Allied Products	1,100	1,000	1,000	1,000	800
Chemicals & Allied Products	44,200	47,000	47,800	48,800	49,700
Petroleum Refining	1,100	1,200	1,200	1,300	1,400
Primary Metals	1,300	1,200	1,000	1,000	800
Subtotal	(49,400)	(51,900)	(52,500)	(53,400)	(53,600)
All Other Manufacturing	45,500	45,700	43,300	40,300	37,500
Manufacturing, Total	94,900	97,600	95,800	93,700	91,100
Nonmanufacturing	120,700	139,300	153,100	168,000	184,900
Total Employment	215,600	236,900	248,900	261,700	276,000

Table A-144 Total Employment Projections by Place of Residence, Continuation of Present Trends Alternative, Subarea F: Wilmington Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	1,500	1,400	1,200	1,100	1,000
Textile Mill Products	700	600	600	500	500
Paper & Allied Products	1,400	1,400	1,500	1,600	1,600
Chemicals & Allied Products	49,400	52,000	53,800	61,700	66,900
Petroleum Refining	1,400	1,400	1,400	1,400	1,400
Primary Metals	1,500	1,400	1,300	1,200	1,100
Subtotal	(55,900)	(58,200)	(59,800)	(67,500)	(72,500)
All Other Manufacturing	50,400	57,800	59,800	56,100	55,000
Manufacturing, Total	106,300	116,000	119,600	123,600	127,500
Nonmanufacturing	133,900	165,100	189,100	209,900	226,700
Total Employment	240,200	281,100	308,700	333,500	354,200

Table A-145 Total Employment Projections by Place of Residence, Maximized Sound Growth Alternative, Subarea F: Wilmington Metro, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	1,600	1,500	1,300	1,200	1,100
Textile Mill Products	700	600	600	500	500
Paper & Allied Products	1,400	1,500	1,600	1,700	1,800
Chemicals & Allied Products	50,800	54,400	57,700	67,300	73,700
Petroleum Refining	1,400	1,500	1,500	1,500	1,600
Primary Metals	1,600	1,500	1,400	1,300	1,300
Subtotal	(57,500)	(61,000)	(64,100)	(73,500)	(80,000)
All Other Manufacturing	51,500	60,500	64,200	61,200	60,700
Manufacturing, Total	109,000	121,500	128,300	134,700	140,700
Nonmanufacturing	137,400	172,900	202,900	228,700	250,300
Total Employment	246,400	294,400	331,200	363,400	391,000

Table A-146 Total Employment Projections by Place of Residence, Limited Economic Growth Alternative, Subarea G, Upper Basin, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	4,500	4,200	3,000	2,900	2,900
Textile Mill Products	2,400	1,900	1,400	1,400	1,500
Paper & Allied Products	2,100	1,900	1,800	1,800	1,800
Chemicals & Allied Products	6,000	5,800	5,700	5,700	5,500
Petroleum Refining	900	700	700	600	500
Primary Metals	1,200	900	700	700	700
Subtotal	(17,100)	(15,400)	(13,300)	(13,100)	(12,900)
All Other Manufacturing	57,900	38,300	34,600	31,800	31,300
Manufacturing, Total	75,000	53,700	47,900	44,900	44,200
Non-manufacturing	225,100	265,800	284,700	308,800	323,800
Total Employment	300,100	319,500	332,600	353,700	368,000

Table A-147 Total Employment Projections by Place of Residence, Continuation of Present Trends Alternative, Subarea G, Upper Basin, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	4,100	4,400	5,200	5,300	5,900
Textile Mill Products	3,500	3,200	3,700	3,200	2,900
Paper & Allied Products	3,400	400	4,700	5,800	7,000
Chemicals & Allied Products	6,200	7,200	8,400	10,000	11,100
Petroleum Refining	300	400	500	500	600
Primary Metals	2,100	2,000	2,300	2,100	1,800
Subtotal	(19,600)	(17,600)	(24,800)	(26,900)	(29,300)
All Other Manufacturing	36,000	43,800	46,800	48,400	48,700
Manufacturing, Total	55,600	61,400	71,600	75,300	78,000
Non-manufacturing	287,600	339,900	396,700	451,400	508,500
Total Employment	343,200	401,300	468,300	526,700	586,500

Table A-148 Total Employment Projections by Place of Residence, Maximized Sound Growth Alternative, Subarea G, Upper Basin, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	4,400	5,350	5,900	6,200	7,000
Textile Mill Products	3,600	4,450	4,300	4,000	3,500
Paper & Allied Products	3,700	4,500	5,300	6,800	8,400
Chemicals & Allied Products	6,600	8,000	9,600	11,400	13,200
Petroleum Refining	400	450	500	600	700
Primary Metals	2,200	2,700	2,700	2,500	2,100
Subtotal	(20,900)	(25,450)	(28,300)	(31,500)	(34,900)
All Other Manufacturing	38,300	46,800	53,500	56,600	57,800
Manufacturing, Total	59,200	72,250	81,800	88,100	92,700
Non-manufacturing	306,000	373,250	452,700	528,300	604,200
Total Employment	365,200	445,500	534,500	616,400	696,900

Table A-149 Total Employment Projections by Place of Residence, Limited Economic Growth Alternative, Subarea H, Southern Basin and Coastal, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	12,400	12,100	12,000	12,000	11,600
Textile Mill Products	1,700	1,800	1,900	1,500	1,500
Paper & Allied Products	100	100	100	100	100
Chemicals & Allied Products	6,200	6,000	6,000	5,800	5,600
Petroleum Refining	--	--	--	--	--
Primary Metals	300	300	300	300	300
Subtotal	(20,700)	(20,300)	(20,300)	(19,700)	(19,100)
All Other Manufacturing	39,500	40,300	42,700	43,700	44,700
Manufacturing, Total	60,200	60,600	63,000	63,400	63,800
Non-manufacturing	283,400	294,000	311,600	323,000	335,200
Total Employment	343,600	354,600	374,600	386,400	399,000

Table A-150 Total Employment Projections by Place of Residence, Continuation of Present Trends Alternative, Subarea H, Southern Basin and Coastal, 1985-2025

	1985	1995	2005	2015	2025
Manufacturing					
Food & Kindred Products	17,500	19,600	21,300	22,500	23,400
Textile Mill Products	2,500	2,800	3,000	3,200	3,300
Paper & Allied Products	200	200	200	200	200
Chemicals & Allied Products	9,000	10,100	11,000	11,600	12,000
Petroleum Refining	--	--	--	--	--
Primary Metals	500	500	600	600	600
Subtotal	(29,700)	(33,200)	(36,100)	(38,100)	(39,500)
All Other Manufacturing	55,900	62,600	68,100	72,000	74,600
Manufacturing, Total	85,600	95,800	104,200	110,100	114,100
Non-manufacturing	353,500	408,500	465,300	504,800	537,700
Total Employment	439,100	504,300	569,500	614,900	651,800

Table A-151 Total Employment Projections by Place of Residence, Maximized Sound Growth Alternative, Subarea H, Southern Basin and Coastal, 1985-2025

	1985	1995	2025	2015	2025
Manufacturing					
Food & Kindred Products	18,600	21,300	23,600	25,200	26,300
Textile Mill Products	2,600	3,000	3,300	3,600	3,700
Paper & Allied Products	200	200	200	200	200
Chemicals & Allied Products	9,500	10,900	12,100	12,900	13,500
Petroleum Refining	--	--	--	--	--
Primary Metals	500	600	600	700	700
Subtotal	(31,400)	(36,000)	(39,800)	(42,600)	(44,400)
All Other Manufacturing	59,400	68,000	75,500	80,300	83,900
Manufacturing, Total	90,800	104,000	115,300	122,900	128,300
Non-manufacturing	374,600	443,400	514,700	563,800	604,600
Total Employment	465,400	547,400	630,000	686,700	732,900

APPENDIX B TO CHAPTER I

ECONOMIC PROJECTIONS
METHODOLOGY AND PROCESS

Economic Projections Methodology and Process

In response to the comments made on Chapter I of Part A, the following elaborates upon the methodology used in deriving the three alternative sets of population, employment, household and income projections for the various service areas and subareas within a given service area.

As has been noted in Chapter I, the projections represent approximate orders of magnitude reflecting the direction of most recent economic and demographic forces at the national, regional and subregional level. The methodology does not consist of a use of a specific empiric or econometric model but rather reflects the consultants' judgments at various points of things that are likely to happen based upon the most recent economic and demographic trends and factors operating in various subregional economies. The projection process consisted of the following major steps.

1. Analysis of past trends of population, employment, households and incomes by county.

    a. Analysis of structural shifts in particular metropolitan and subarea economies.

    b. Trends in population migration and natural increase components.

    c. Trends in average household size and per capita and total personal incomes.

2. Grouping of counties into economic subareas as defined by OBERS Series "E" projections.

3. Tabulation of population, employment and income data to the year 2020 by ten-year intervals for the metropolitan areas and economic subareas as projected by OBERS Series "E" projections.

4. Comparison of projected trends (OBERS) with actual past trends.

5. Review of the existing projections for states, regions and counties prepared by various state and local planning agencies and other sources. (Reference list attached at the end.)

6. Review and analysis of economic base and other planning studies for a number of jurisdictions in the service and undertaken by others as well as by this firm.

7. Based on the above evaluation including an assessment of the broad economic forces operating in specific jurisdictions, the OBERS projections for particular subareas were adjusted to reflect the local economic and demographic factors affecting future levels of growth.

8. A "top-down", "bottom-up" approach was deployed in the refinement process. This consisted of deriving a reasonable overall population and employment forecasts for the service area as a whole. Simultaneously, individual subarea economies were projected independently building up to a total service area growth parameters.

9. The assumptions stated in the text under "continuance of past trend alternative" were generally held true for all subareas.

10. Using employment participation ratio method, resident employment projections were then derived. The employment participation ratios used in OBERS were adjusted to reflect actual trends for each subarea.

11. Similarly, average household size estimates were developed reflecting Series "E" fertility rates and actual past trends. Based upon population forecasts, and average household size forecasts, number of future households were derived for each subarea.

12. Total personal income projections and implied per capita incomes contained in OBERS were similarly adjusted to reflect the local trends.

The high and low forecast alternatives were similarly developed using the top-down and bottom-up approaches. The essential assumptions underlying each of the two alternative strategies are detailed in the text. Judgments were applied to each subarea independently as to the existing and future limitations available to exercise development leverages or controls. However, out of necessity, the timing of the adoption of policies under each alternative were assumed uniformly for each jurisdiction and subarea.

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II.A. AVERAGE ANNUAL DAMAGES

II.A.I. INTRODUCTION

Major floods, such as have occurred seven times within the Delaware Basin since the turn of the century indicate the need for comprehensive flood control planning within the Delaware Basin.

This planning is necessary in light of the national experience that flood damages have been steadily increasing in spite of increased spending on major structural flood control problems. The reason for such a self-defeating situation is that while one river basin is being protected by various flood damage control measures, the floodplain of another basin is being indiscriminately developed.

The floods affecting the Delaware Basin were climaxed by the flood of 1955 which caused the loss of 99 lives along tributaries and flood damages in excess of $100 million based on 1955 price levels. Appendix D - Flood Damages (Volume 3 House Document No. 522) lists major damage centers along the Delaware River and tributaries (Table 2-1) based on consideration of the floods of 1942, 1945, 1950, and 1955, with primary interest being on the flood of 1955. Consideration has been given to the floods of other years since the flood of November, 1950 resulted in heavier damage within the upper basin along the East branch of the Delaware, its tributary streams, Beaver Kill, and Willowemoc Creek; and the flood of May, 1942 resulted in greater damage in the Lackawaxen Basin in the vicinity of Honesdale and Hawley. However, with only minor other exceptions in some of the tributary areas, the flood of August, 1955 was dominant in terms of property damages.

Below Tocks Island major flooding has occurred in the Schuylkill River basin as recently as 1971 and 1972. The 1972 flood brought on by hurricane Agnes was easily the worst in the recorded history for the Schuylkill. It should be pointed out that the Tocks Island Project would have had no effect on this flooding since it was outside the drainage area affected by the Tocks Island dam, but such flooding points out the need for flood control measures in the area.

Within the upper basin, consisting of those areas within New York State north of Port Jervis, damage centers listed in Table 2-1 include the Cities of Margaretville, Rockland, Roscoe, and Livingston Manor within the drainage basin for the East Branch of the Delaware River; and the Cities of South Fallsburg and Monticello within the drainage basin of the Neversink River. On the Pennsylvania side, damage centers included Honesdale, Hawley, South Sterling, Newfoundland, and Greentown, Pennsylvania, all of which are included within the Lackawaxen Basin.

Along the mainstem of the Delaware River damages were experienced at

Table 2-1 Distribution of Tangible Damages - Flood of August 1955, (Condensed from Table 4, Appendix D., H.D. Number 522

Delaware Basin Above Port Jervis	Damages in 1955 Dollars
Delaware Basin above Hancock, N.Y.	$ 11,400
Delaware River, Hancock to Lackawaxen River (Reach A-1)	705,100
Delaware River, Lackawaxen River-Port Jervis (Reach A-2)	1,618,100
Lackawaxen River Basin	5,227,000
Shohala Creek	665,400
Mongaup River	224,300
Neversink River	1,233,900
Minor Tributaries above Port Jervis	562,800
TOTAL, Delaware Basin above Port Jervis	$10,248,000
Delaware Basin from Port Jervis to Belvidere	
Delaware River (Reach B)	$ 3,804,400
Bush Kill Creek	1,150,700
Brodhead Creek	26,012,100
Paulins Kill	2,180,200
Minor Tributaries	1,222,600
TOTAL, Port Jervis to Belvidere	$34,370,000
Delaware Basin from Belvidere to Burlington	
Delaware River (including 8 Major Damage Centers, Reaches C-E) (21.7% of Grand Total)	$22,766,900
Lehigh River Basin	23,018,100
Minor Tributaries	193,000
TOTAL, Belvidere to Burlington	$49,978,000
Delaware River Basin below Burlington	
Delaware River, Burlington to Mouth (Reach F)	$ 268,800
Schuykill River Basin	6,240,400
Christina River Basin	1,140,100
Minor Tributaries	2,470,700
TOTAL, Burlington to Mouth	$10,120,000
GRAND TOTAL, Delaware River Basin	$104,716,000

Matamoras, Pennsylvania and Port Jervis, New York located at the confluence of the Delaware River and the Neversink River, and at the eight major damage centers downstream. These centers were Belvidere, Phillipsburg, Trenton, and Burlington, New Jersey; and, Easton, Riegelsville, New Hope, and Yardley, Pennsylvania. Major flood control storage, such as the proposed Tocks Island Project discussed in Part B of this report, would be primarily effective in reducing damages to the above eight damage centers along the mainstem of the Delaware River between Belvidere and Burlington. Below Burlington, upstream storage will have relatively little impact on flood stages since this lower area is primarily influenced by tidal fluctuation rather than by volume of stream flow.

Brodhead Creek, which drains an area of approximately 285 square miles, enters the Delaware River from the Pennsylvania side in the vicinity of East Stroudsburg, approximately two miles above the Delaware Water Gap. This area suffered extensive damage in the 1955 flood including the loss of seventy lives, and is not subject to protection by the Tocks Island Lake Project. Heavy losses were also experienced in Stroudsburg, East Stroudsburg, Canadensis, and Tannersville. As a result of this flood, local protection works have since been undertaken at Stroudsburg and East Stroudsburg which are designed to protect against recurrence of a flood of the 1955 magnitude, and Soils Conservation Service (SCS) project of three small dams is underway in the upper Brodhead to protect Canadensis, under PL 566.

The Lehigh River Basin is highly developed and includes numerous towns which have been subject to heavy flooding in both 1942 and 1955. This has led to construction of flood control projects such as Francis E. Walter Reservoir and in the upper Lehigh Basin, channel improvements in the vicinity of Allentown, and local protection works in the vicinity of Bethlehem and Weissport. The City of Easton faces a double threat from flooding on the Lehigh and from flooding on the mainstem of the Delaware River. It is significant to note that the flood heights at Easton in 1955 were due to the flooding along the mainstem of the Delaware River resulting in backwater flooding in the Easton area. Because of this geographical orientation the City of Easton can benefit by upstream flood control projects on the Delaware River or along the upper tributary systems such as the Lackawaxen River or Brodhead Creek areas, even though Delaware River projects have no effect on other towns within the Lehigh Basin.

The next major drainage system consists of the Schuylkill River and tributaries which discharges into the Delaware River at Philadelphia. This location is well into the tidal zone and downstream from the major damage centers on the Delaware River. Consequently, the impact of flooding on the Schuylkill River is negligible along the mainstem of the Delaware, but local damages have been extremely heavy, particularly in the Little Schuylkill Basin where heavy damages were sustained at Tamaqua. Heavy commercial and industrial damage was also experienced at Reading, Birdsboro, Pottstown, and Norristown. This reach was also extensively damaged by flooding from Hurricane Agnes in June, 1972.

The following Table 2-2 indicates the extent of area inundated within various drainage basins discussed above and the number of residential, commercial and industrial properties involved. Table 2-3 (page II-14) shows the total dollar damage for each of these basins based on 1955 dollars as reflected in Table 4 of Appendix D of the House Document.

From a hydrologic point of view, the Tocks Island site is significant because of its strategic location within the Basin relative to total drainage area intercepted (3,827 sq. mi.) all of which is located upstream from the eight major damage centers and in that area of the Basin which has historically produced the highest rates of runoff. The drainage area above the Tocks Island site represents better than 56% of the total drainage area above Trenton (6,780 sq. mi.), and normally contributes better than 75% of the runoff passing Trenton. It is recognized that storms can concentrate within the area below the Tocks Island Dam site in which case the control potential of the Tocks Island site would not be effective in regulating runoff. However, the drastic reduction in contributing drainage area afforded by a project at this location means that any storm confined to the downstream areas would have to be of much greater intensity and, accordingly, of much lower frequency before the characteristic volume buildup, which is required to produce significant flood damage in the lower Delaware mainstem areas, could be generated.

The tributary reservoirs which have been constructed since 1955, are vitally significant to flood control protection within the tributary

Table 2-2 Extent of Flooding in Major Damage Centers

Drainage Basin or Location	EXTENT OF FLOODING (Primarily 1955)			
		Structures		
	Acres	Residential	Commercial	Industrial
West Branch, Delaware River				
East Branch, Delaware River	245	211	77	4
Lackawaxen River	420	756	239	29
Neversink River	55	98	36	0
Matamoras & Port Jervis	300	564	75	6
Brodhead Creek	530	712	123	9
Lehigh River	1,093	445	113	48
8 Damage Centers	1,655	2,063	330	29
Schuylkill River	855	864	118	24
TOTAL BASIN	5,153	5,713	1,111	149

reaches involved downstream from the various projects, however their effect on stage reduction on the mainstem of the Delaware River is only nominal. The reason for this is the limited drainage area intercepted by these projects, which does not afford sufficient storm interception potential as to significantly affect the volume of water reaching the mainstem of the Delaware River. On the Delaware River flood problems are associated with high volume runoff from widely distributed storms throughout major portions of the Basin as opposed to the more rapidly rising "flash flooding" which is characteristic of the steeper and narrower tributaries.

House Document 522 addresses flood problems within the entire Delaware River Basin and the Tocks Island Project emerged as the key project for protection to the mainstem of the Delaware River and particularly to the eight major damage centers from Belvidere to Burlington. Consideration of the overall flood problem within the Basin involved detailed consideration of tributary requirements including reservoirs and other local protective works. These are important to overall basin planning and to the well-being of the communities within the various tributary reaches but are irrelevant to the purposes of this report which focuses on the Tocks Island Lake Project & Alternatives.

II.A.2 CLASSIFICATION OF FLOOD DAMAGES

With reference to classification of flood damages it should be noted that only tangible damages which can be measured in dollar amounts are utilized in determination of benefit/cost ratios for the specific purpose of evaluating projects. Tangible damages, in general, include physical damages through inundation, flood fighting costs, and business and financial losses resulting from disruption of normal activities by virtue of flooding. Intangible damages are those which cannot be given monetary values such as loss of life and health considerations. These types of damages are not considered in calculating B/C ratios. Non-recurring flood damages are also excluded in determination of average annual damages.

II.A.3 DETERMINATION OF AVERAGE ANNUAL DAMAGES

In determining average annual damages two basic techniques are available. The first involves assessment of a historical record with sufficient flood experience and data accumulation to permit evaluation of recurring damages throughout the period of record. This can then be expressed in terms of average annual damages as actual experience. The difficulty with this method lies in the fact that available records are usually of insufficient duration to provide an appropriate number of flood experiences for valid determination of averages. Furthermore, even given an extensive hydrologic record, land use patterns within the basin generally change to a marked extent so that historical damages, even given accurate data, usually are not representative of recurring damages which may be anticipated in the future. Consequently, this technique has only limited application, most usually in agricultural areas with relatively static economies and lengthy periods of historical record covering both stream flow and flood damages. Since the situation in the Delaware Basin does not conform to this pattern in any sense, this method is not considered appropriate for the determination of average annual damages.

The second technique, which has been employed by the Corps of Engineers in determination of average annual damages for the Delaware Basin has been to make a detailed survey of actual damages experienced in the most recent major flood of basinwide extent (i.e., August, 1955). This gives some consideration to spotty records at various points within the basin pertaining to other floods. The Corps then utilizes this information as the point of departure in determining average annual damages based on consideration of long term hydrological records, development of stage-discharge curves, discharge-frequency curves, and stage-damage curves for various damage reaches. They ultimately translate this into damage-frequency relationships from which average annual damages can be mathematically derived. This technique basically involves the following procedures:

Gages are established at critical points within the basin including both the mainstem and various points within the tributary system from which basic stage discharge relationships can be determined. These gages must have been in operation over a significant number of years in order to provide a representative record of the stream flow regime. Based on these records, stage-discharge relationships and water surface profiles for various levels of flooding can be developed at key points within the drainage basin. Statistical examination of this record also allows identification of discharge-frequency relationships for each of the gages.

Average annual damages cannot be determined by direct observation except by use of the historical technique as discussed above. Since basic data for application of this technique is lacking within the Delaware Basin and its application would be questionable in view of changing land use patterns over the years it is necessary to key damage estimates to specific observations such as were made possible by the 1955 flood and the rapid follow-up surveys to evaluate the resulting damages. The subject surveys, which made extensive use of field interviews immediately following the disastrous flood experience, while high water marks could still be observed and the memories of flood victims were still fresh, permitted a preliminary evaluation of specific flood damages which could be related to experienced stages. This in effect, became the basis for one point on the stage-damage curve for each of the damage areas investigated. A second point on the stage damage curve is afforded by the zero damage point which is relatively easy to define. Generally speaking, the zero damage point would conform to bankfull capacity. Once the stream gets out of banks damages begin to accumulate, usually at an accelerating rate with each increasing stage. The problem in evaluating damage centers is the fact that the average annual flood does not produce "the average annual damages". Major floods quite obviously produce major damages but at very infrequent intervals. Lesser floods produce lower damages but at more frequent intervals and the relationships between level of flooding, frequency of flooding, and level of damages are not straight line relationships.

The resolution of this problem involves the development of stage-damage curves in which damages to each structure are evaluated in terms of depths of flooding with a primary point of reference being the observed damage actually experienced during the 1955 flood. The J.B. Mellan report of 1966, which was prepared for the Corps of Engineers in connection with updating of damage estimates went to great lengths to estimate the level of damage to be anticipated to various types of structures at various levels of inundation. Consideration of vertical distribution of damages in this fashion affords a tool for determination of stage-damage relationships in any given area based on 1955 damage levels.

Once stage-damage curves are defined, and discharge-frequency curves are developed based on hydrologic studies covering the period of a stream flow record it is possible to develop damage-frequency curves. As indicated above, these curves will indicate very high damage for a very low percentage of flood experiences and minimal damage for a high percentage of flood experience; and the total area under the curve becomes the measure of average annual damage. The average annual damages determined are shown in comparison with the 1955 flood damages in various damage reaches in Table 2-3.

Appendix M. Volume 6 of House Document 5-2 on Hydrology addresses fully the considerations of rainfall and runoff; hydrology and flood frequencies; and presents historical information relative to storm patterns within the Delaware River drainage basin. It is not considered essential to burden this report with repetition of this information or with additional detail relative to more recent storms which have occurred on the tributaries, such as the June 23, 1972 flood on the Schuylkill River. Statistical probability of flooding is more significant to the tributary areas where intense storms of relatively small area can produce flash flooding. Such a reaction along the mainstem of the Delaware River is not to be anticipated. This reach, as discussed in Section II.A.1, is sensitive to volume of runoff and is not flashy in nature. Flood conditions here are associated with high volume runoff related to basin wide storms rather than local intense storms.

Table 2-3 Average Annual Damages versus 1955 Flood Damages

	AVG. ANNUAL DAMAGES* 1959 PRICE LEVELS (From Table Q-5, Proj. Doc.	1955 FLOOD DAMAGES 1955 PRICE LEVELS (From Table D-4, Proj. Doc.)
Delaware River Above Port Jervis	$ 265,800	
Lackawaxen River Basin	144,000	
Shohola Creek	11,700	
Neversink River	176,700	
TOTAL, DELAWARE BASIN ABOVE PORT JERVIS	$ 598,200	$ 10,248,000
Delaware River Below Port Jervis	$ 2,293,600	$ 30,840,100
Brodhead, Paulins Kill, Bushkill and Minor tributaries	297,900	30,565,600
Lehigh River Basin	1,183,800	23,018,100
Tributaries below Easton	84,600	2,663,700
Schuylkill River Basin	1,349,500	6,240,400
Christina River Basin	290,300	1,140,100
TOTAL, DELAWARE BASIN BELOW PORT JERVIS	$ 5,499,700	$ 94,468,000
TOTAL DELAWARE BASIN	$ 6,097,900	$104,716.000

*Remaining Annual Recurring Flood Damages after completion of projects authorized or under construction as of date of publication of H.D.522 (Aug., 1962)

II.A.4 UPDATING OF COSTS FOR AVERAGE ANNUAL DAMAGES

Following the initial flood damage survey of 1955 supplemental surveys were also instituted in 1958 and 1966 to update flood damage estimates. These updates considered price changes and additional structures developed within the floodplain areas as well as reduction in recurring damages due to relocations, and to local protection works completed subsequent to the floods of 1955. Escalation factors were developed to adjust 1955 estimates to 1958 and 1959 levels for the purposes of the project document and these have been revised annually in keeping with Corps policy relative to authorized projects. The latest published figures available relative to flood reduction benefits, were those prepared in connection with the 1974 Environmental Impact Statement Supplement prepared by the Corps, and amount to $3,517,497 per year initially, increasing to $4,136,148 per year between the 50th. and 100th. year, resulting in an average annual benefit of $3,824,000.

II.A.5 VALIDITY OF DAMAGE ESTIMATES

With reference to the validity of damage estimates it must be conceded that there are a large number of variables to be dealt with, each of which is subject to engineering judgement. For example, with reference to the vertical distribution of damages, tables were developed at the time of the 1966 survey as discussed above to reflect variation in damage levels with depth of inundation for various types of residential structures. A linear type distribution was used for estimates of variations in commercial and industrial damage values. Highway, utility, public, and rural damages were estimated to vary in the same fashion as residential damages, whereas, railroad damages were treated on a linear basis with depth of inundation. On the other hand, business losses and costs of emergency measures were generally related on a percentage basis to physical damage. Because of these judgmental factors, it must be recognized that damages do have an aspect of approximation which cannot be circumvented going even beyond the approximations which must be recognized as a natural outgrowth of the original survey and interview technique. On the other hand, it should be recognized that damages, as developed by the Corps of Engineers for the Delaware Basin represents the end product of an extensive effort at data accmulation and interpretation. It is our judgement that these damage estimates are reasonable and appropriate for the purposes of this Study.

II.B. CONSTRAINTS ON LAND USE.

II.B.1 OVERVIEW OF EFFECTS OF LAND USE IN FLOOD PLAIN ON FLOOD DAMAGE REDUCTION

Man has always found it advantageous to inhabit the flood plains of various rivers. Such rivers served as natural roadways for his travels. Also, the soils along these rivers, because of flooding, were usually rich and well suited to agricultural uses. However, there was and is a problem with the development of these flood plains; periodic flooding by the river. Initially, such flooding was accepted by man as part of his existence with flood protection being the responsibility of the individual. With the advent of technological development, steps have been taken to prevent such flooding to allow more development of the flood plain.

Until recently, most efforts to prevent floods in the flood plains have been by structural means; that is, dams, levees, flood walls, or other such structures. Only recently with the development of the environmental awareness in this country has there been any emphasis towards non-structural means of flood loss reduction. Such means are flood zoning, to prevent or control construction in the flood plain; flood insurance, to compensate individuals for the loss of homes and property; and flood plain purchase or the prevention of all development in the flood plain.

In this section we will look at the types of land use that presently exist in the Delaware River Basin. Also, future land uses in the basin will be estimated in light of recent federal and state and local floodplain management laws. Land use constraints will be analyzed as they are related to flood control, particularly the existing and future development of the floodplain as it effects non-structural and structural alternatives. For example, existing development may limit non-structural alternatives if its owners reject these measures. Future land use may preclude structural alternatives if the new flood management bills reduce development and make the benefits for structural alternatives no longer sufficient to warrant the costs.

Land uses along the upstream tributaries of the Delaware Basin are not directly applicable to the flood control aspects of the Tocks Island Lake Project, but may be to various alternatives. Such land uses on tributaries will be considered, as appropriate, in the analysis of the various flood control alternatives to T.I.L.P.

II.B.2 PRESENT LAND USE ON THE DELAWARE RIVER FLOOD PLAIN

There are two recent major inventories of land use along the Delaware River flood plain. One was conducted by the Environmental Defense Fund in 1972 and the other by Michael Baker and Associates in 1975. The Environmental Defense Fund determined the number of structures within the flood plain caused by the 100 year flood from Burlington New Jersey to Tocks Island (except in Trenton, where the inventory was based on a 100-200 year flood plain). According to their study, there was a total of 3,659 structures in the flood plain of which 1,414 (or 40%) were in the eight major damage centers of the 1955 flood. These damage centers were Yardley, New Hope, Riegelsville and Easton in Pennsylvania; and Belvidere, Phillipsburg, Trenton, and Burlington in New Jersey. In all cases except Trenton, Belvidere and Yardley the Environmental Defense Fund found that the number of structures had declined since 1955. The inventory was obtained by reviewing community applications for federal flood insurance, community land use plans, U.S. Geological Survey aerial photography, and interviewing municipal officials.

In the categorization of land use in the flood plain by type, the Environmental Defense Fund concluded that the basic 1955 land use breakdown used by the U.S. Army Corps of Engineers in their study of the Delaware River Flood Plain had not changed significantly. The following table shows the Corps' findings.

Table 2-4

DELAWARE RIVER FLOOD PLAIN CHARACTERISTICS
AREA FLOODED IN 1955 (ACRES)

	Tocks Island to Belvidere	Belvidere to Riegelsville	Riegelsville to Lumberville	Lumberville to Trenton	Total	%
Urban	422	505	428	1,172	2,527	27.4
Agricultural	650	161	884	828	2,523	27.3
Woodland	618	382	672	796	2,468	26.8
Transporation	285	500	366	554	1,705	18.5
River	1,518	1,403	1,566	1,988	6,475	-
Total	3,493	2,951	3,916	5,338	15,698	-
Total Excluding River	1,975	1,548	2,350	3,350	9,223	100.0

Source: U.S. Army Corps of Engineers, HD522, 87th. Congress, 2nd Session, Volume III, Appendix D.

The Michael Baker survey of land use was not limited to the main stem of the Delaware River flood plain but included the entire Delaware River Basin in Pennsylvania. The study focused on the communities which were subject to flooding by the Delaware and its tributaries. A total of 181 communities were studied in the following counties: Berks, Bucks, Carbon, Chester, Delaware, Lebanon, Lehigh, Luzerne, Monroe, Montgomery, Northampton, Philadelphia, Pike, Schuylkill and Wayne.

Eighty-five percent (85%) of the flood plain was for the most part underdeveloped while the remaining fifteen percent (15%) was approximately equally divided between residential/commercial and industrial uses.

The information provided by Mr. John Voycik of Michael Baker and Assoc. is limited to counties and communities on the Pennsylvania portion of the flood plain. The information provided is based on the 100-year flood and includes the areas subject to flood, population subject to flooding, land use patterns in flooded areas, and potential damage assessment to areas by land use type.

The information has been segregated by drainage area into six major categories: 1) mainstem of the Delaware, 2) Schuylkill River, 3) Lehigh River, 4) Lackawaxen River, 5) Neshaminy, 6) Minor Delaware tributaties. The results are presented in Tables 2-5 and 2-6.

Table 2-5 indicates that the percent of land in the communities along the mainstem of the Delaware and its tributaries which is flooded by the 100-year flood ranges between 5% and 1% with the average for the mainstem of the Delaware being 3%. In terms of population subject to flooding, the range is from a negligible percentage along the Schuylkill River to 6% along the mainstem of the Delaware. These percentages, however, are somewhat deceiving. Although the percent of population along the Schuylkill River subject to flooding is negligible, the actual numbers are 8,520. The percentage is small because all of Philadelphia is included in the basin population. The information in Table 2-5 does show that although 4% of the land in the communities in the total Delaware Basin in Pennsylvania is subject to flooding only 1% of the population is.

This difference is very important in understanding flood plain development. In the entire Pennsylvania portion of the basin flood plain, overall development is less dense than for all the communities taken as a whole. However, on the mainstem of the Delaware River while 3% of the land is subject to flooding, 6% of the population is subject to flooding, which indicates that the flood plain is more highly developed than the surrounding communities.

Table 2-6 shows a breakdown of the land uses in areas of the Delaware Basin in Pennsylvania subject to flooding. On an average nearly 87% of the land is undeveloped, while the remaining land uses are about equally divided between residential/commercial and industrial. However, on the mainstem of the Delaware, only 82% of the land subject to flooding is undeveloped with 15% being residential/commercial and only 3% industrial. This is an expected result since Table 2-5 indicated a more densely populated flood plain on the Delaware than in the basin as a whole.

TABLE 2-5

AREAS SUBJECT TO FLOODING AND POPULATION STATISTICS FOR DELAWARE RIVER BASIN

River Basin	1. Total Area of Minor Civil Divisions Wholly or Partially in Flood Plain	2. Total Area Subject to Flooding	Ratio (2/1)	3. Total Population of MCD	4. Total Population Subject to Flooding	Ratio (4/3)
Mainstem Delaware River	351,959.0	10,929.90	0.03	149,942	8,980	0.06
Schuylkill River	835,910.0	33,788.3	0.04	2,697,594	8,520	neg.
Lehigh River	163,424.0	6,487.3	0.04	285,459	3,678	0.01
Lackawaxen	55,593.6	1,379.4	0.02	10,367	158	0.02
Neshaminy River	16,069.8	657.2	0.04	35,364	340	0.01
Minor Tributaries	107,142.4	1,423.1	0.01	11,615	273	0.02
TOTAL	1,530,098.8	54,665.2	0.04	3,190,341	21,949	0.01

TABLE 2-6

LAND USE IN DELAWARE BASIN FLOOD PLAIN

River Basin	Total Area Subject to Flooding	R-C Land Subject to Flooding	Ratio (R-C to Total Area)	I Land Subject to Flooding	Ratio (I to Total Area)	U Land Subject to Flooding	Ratio (U to Total Area)
Mainstem Delaware River	10,929.9	1,677.6	0.15	280.4	0.03	8,971.5	0.82
Schuylkill River	33,788.3	1,334.7	0.04	2,660.9	0.08	29,792.70	0.88
Lehigh River	6,487.3	583.1	0.09	4,687	0.07	5,435.5	0.84
Lackawaxen	1,379.4	30.7	0.02	0	0.00	1,348.8	0.98
Neshaminy River	657.2	53.0	0.08	14.0	0.02	590.2	0.90
Minor Tributaries Delaware River	1,423.1	34.8	0.02	19.8	0.01	1,368.5	0.96
TOTAL	54,665.2	3,713.9	0.07	3,443.8	0.06	47,507.2	0.87

R-C: Residential-Commercial
I: Industrial
U: Underdeveloped

The information for the New Jersey portion of the Delaware Basin is not nearly as comprehensive as that for Pennsylvania. However, a recent inventory conducted by the Environmental Defense Fund for its report entitled Flood Control in the Delaware River indicated that the total number of structures existing on the Delaware River flood plain was approximately equally divided between Pennsylvania and New Jersey. Both this report and studies of aerial photography and observations of the area indicate that the Delaware flood plain is developed in New Jersey to the same general or overall degree as that which exists on the Pennsylvania side.

Nevertheless, it is felt that this lack of detailed information of a flood plain in New Jersey does not discount the conclusion reached from studying other source information that the flood plain of the Delaware River in New Jersey is as developed as the Pennsylvania portion and its needs for flood protection are similar. The U.S. Army Corps of Engineers concerned itself with land use in Volume III of their report on the Delaware River Basin, published in 1962. The Corps stated that "the pressure of social and economic factors already exerting their influence in the Delaware River Basin may serve as forces which will accelerate a more intensive use and re-development of the flood plain in the future." The report recognized that potential forces could change the development patterns in the flood plain and it went on to say "Additional forces that may also influence future development and potential flood damages are such factors as flood plain zoning, introduction of new building standards designed to minimize flood damages, flood insurance, and improved forecasting and flood warning systems." As a matter of fact, between 1962 and 1974 growth along the mainstem of the Delaware, below Tocks Island, has increased only slightly.

The Corps proposed three methods to project land use:

1. Historical and projected overall economic growth.
2. Actual flood plain development determined by field survey.
3. Measurement of changing patterns of land use in the flood plain.

The implementation of the first two were unsuccessful because of poor record-keeping in local governmental units and the self-imposed limitation on needed information on the flood plain. To implement the third method, aerial photo mosaics for the years 1938 and 1958 were compared for differences in land use. However, on the Delaware River the narrowness of the flood plain hindered visual interpretation of the photos. As a result, the Corps decided to widen the Study Area so as to include everything up to one-half mile from the center of the Delaware River. The assumption was made that "growth had been generally similar to that on the flood plain proper." Such an assumption may not have been appropriate even at that time, but the recent passage of federal and state laws affecting flood plain development has made this assumption clearly unacceptable.

The Corps has recognized this change of view in flood plain development.

Its "Supplemental Data Report and Supplemental Information to the Final Environmental Impact Statement" states that "Land use control in flood plains is advocated by the Corps of Engineers as a means of eliminating potential flood damage." However, the Corps goes on to say ". . . the timing of the Tocks Island Project construction is in no way related to the enactment or adoption of statewide land use controls." This last statement, however, tends to ignore the advantages of a coordinated non-structural or combined structural and non-structural approach to flood damage control.

In the Prairie du Chien area of Wisconsin, the Corps of Engineers has recommended a non-structural means to reduce flood damage. This plan takes the form of evacuation and floodproofing of structures in the Mississippi River floodplain, along with floodplain regulation measures.

The plan calls for removal of all structures not meeting land use criteria for floodway and floodplain areas as established by State law and City ordinances. Structures allowed to remain would be those which could either be floodproofed or raised, and meet the following additional criteria:

1. Inhabitable structures which are within 100 feet of the edge of the design flood outline and subject to less than 2 feet of flooding.

2. Industrial and businesses where public services could be economically maintained and flood damages prevented by floodproofing.

Such a plan for the Delaware Basin below Tocks Island would preclude future floodplain development and drastically reduce that development which already exists. The number of homes which would have to either be bought or relocated is near 3,500. Such a program as an alternative to Tocks Island is discussed in Chapter XV.

The instututional problems associated with implementation of such a plan are formidable. In Prairie du Chein the enactment of the plan requires primarily the approval of the Community; however, along the Delaware below Tocks Island the approval of two states, seven counties, and numerous communities is needed. Getting their approval for such a massive relocation effort appears less than likely, especially in light of State laws, both proposed and in effect, which explicitly allow existing structures to remain in the floodplain.

II.B.3. PROJECTED LAND USE ON THE DELAWARE RIVER FLOOD PLAIN

The projected land use in the Delaware River floodplain is dependent on passage of proposed floodplain legislation in Pennsylvania and the extent to which existing floodplain legislation is enforced in New Jersey. The Federal Flood Disaster Protection Act of 1973 and Federal Water Resources Development Act of 1974 will also play major roles in determining the future growth.

An additional factor affecting floodplain development is the final determination of flood control measures. If a structural means is used, the result could be increased confidence that construction in the floodplain is not as hazardous as it once was. Such a situation usually serves as an impetus for development of the floodplain to a much greater extent than at present.

Economically, the development of the floodplain can serve to increase the tax base of communities but, on the other hand, can cause extra demands for public services and can be environmentally undesirable.

It would be beneficial at this point to look closely at the proposed and existing federal and state laws affecting flood plain management. By better understanding their provisions, some idea as to their effects on floodplain development can be obtained.

Essentially, the Federal Flood Disaster Protection Act of 1973 requires every community formally identified by HUD as having areas within a flood hazard zone to participate in the National Flood Insurance Program by July 1, 1975, or one year after identification. While participation in the program is not mandatory by law, it is a prerequisite for federal or federally-related financial assistance for acquisition or construction of structures in identified flood prone areas. Additionally, federally regulated lending institutions must require flood insurance as a condition for a loan for property located in flood hazard areas.

A major intent stated in the Act is to "Require states or local communities as a condition of future Federal Financial Assistance . . . to adopt adequate floodplain ordinances with effective enforcement provisions consistent with Federal standards to reduce or avoid future losses; . . . " Because of the strict sanctions associated with noncompliance, national, state and local officials feel that the Act will be an effective instrument in controlling land use in floodplains. However, some provisions of the Act are ambiguous and overly stringent, which may delay implementation by a number of communities.

Numerous communities along the Delaware River in New Jersey and Pennsylvania are eligible for participation in the Federal Flood Insurance Program as of March 31, 1975. The following are between Tocks Island and Philadelphia:

New Jersey:

Township of Alexandria
Town of Belvidere
City of Berverly
City of Burlington
Town of Delaware
Township of Edgewater Park
Borough of Frenchtown
Township of Harmony
Town of Kingwood
City of Lambertville
Town of Ewing
Township of Hamilton (Mercer County)
Township of Hopewell
Town of Phillipsburg
Township of Pohatcong
Township of Riverside
Borough of Stockton
City of Trenton
Township of West Amwell
Township of White

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A COMPREHENSIVE STUDY OF THE TOCKS ISLAND LAKE PROJECT AND ALTE--ETC(U)

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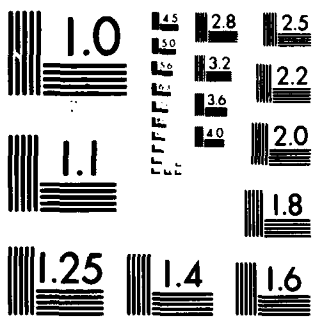


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

Pennsylvania:

Township of Bensalem
Township of Bridgeton
Borough of Bristol
Township of Durham
City of Easton
Borough of East Stroudsburg
Township of Falls (Bucks County)
Township of Lower Makefield
Township of Lower Mount Bethel
Borough of Morrisville
Borough of New Hope
Township of Nockamixon
Township of Plumstead
Borough of Portland
Borough of Riegelsville
Township of Smithfield (Monroe County)
Township of Solebury
Borough of Tullytown
Township of Tinicum (Bucks County)
Township of Upper Makefield
Borough of Yardley
Township of Williams

As of March 31, 1975 the following areas between Tocks Island and Philadelphia have had special flood hazard areas identified, but are not in the Federal Flood Insurance Program:

New Jersey:

Town of Belvidere
City of Bordenttown
Township of Bordentown
Town of Delanco
Borough of Fieldsboro
Township of Florence
Township of Holland
Township of Knowltown
Township of Lipatcong
Township of Mansfield
Borough of Milford

Pennsylvania:

Borough of Delaware Water Gap
Township of Forks
Township of Middle Smithfield
Township of Upper Mount Bethel

The Federal Water Resources Development Act of 1974 may indirectly have an effect on the strength of state and local mechanisms for controlling land uses in the floodplain. It allows federal agencies, recommending non-structural alternatives for preventing or reducing flood damages, to contribute to the fund up to eighty percent (80%) of the costs of acquiring land easements, rights-of-way, and relocation on a project by project basis. The costs previously were borne completely by non-federal interests. Under provisions of this Act funds have already been allocated for non-structural flood control measures in various parts of the country.

The importance of this Federal law is that it begins to shift some of the economic costs of non-structural alternatives from state and local governments to the Federal government. It should be pointed out, however, that the Federal funding of 80% of the costs of non-structural alternatives is less than the 100% Federal funding of major structural flood control alternatives such as the Tocks Island Lake Project.

A previous Federal initiative which dealt with floodplain management was Executive Order 11296 issued in 1966 by President Johnson. This Order required that all new Federal structures should only be constructed after the potential for flooding had been evaluated and steps were taken to preclude such problems. This same review should be done before the disposal of Federal property. Additionally, existing Federal structures should be flood proofed where practical and economically feasible.

The Order went on to require that all executive agencies responsible for the administration of Federal grants, loans, or mortages affecting construction in the floodplain evaluate these hazards to minimize potential flood damage. The potential effects of this Order have now been overshadowed and expanded by the Flood Disaster Protection Act of 1973. Nevertheless, its concern for floodplain management helped lead the way.

State laws affecting floodplain development are in effect in New Jersey and are in the process of being passed in Pennsylvania. New Jersey State Act 58:16A-50 et seq. authorizes the State Department of Environmental Resources to delineate the state's flood hazard areas and after delineation, to adopt floodway land-use regulations. It also directs the Department to delineate the flood fringe areas and to promulgate minimum standards for local rules and regulations governing uses and development in the area.

The implementation of these and similar laws in New Jersey has resulted in the general limitation of floodways for open-space uses, with the exception of needed bridges and utilities. The law accomplishes this by setting up a system requiring permits for all construction with the municipalities having jurisdiction over development of the flood fringe. New Jersey's program will serve to control land use in the future, but has little impact on existing structures.

The potential of the New Jersey law is to greatly decrease the future development in both the floodway and the flood fringe. Structures, both temporary and permanent, will be required to obtain permits. These permits are intended to be given only if they do not have undue or significant effects on flood flows, velocities, or heights; local runoff; erosion or sedimentation; or ground water or surface water quality. Additionally, any structures in the floodway or flood fringe damaged beyond repair will need a permit to be replaced.

The Pennsylvania Flood Disaster Prevention Act has been passed by the Senate and now must be approved in the House. The stated purpose of the Act is to: 1) encourage planning and development in flood prone areas which is consistent with sound water and land-use practices, and 2) authorize a comprehensive program for managing flood areas consistent with State and Federal supervision. The Act, if passed in present form, would give the Department of Environmental Resources the authority to review and process municipal floodplain management programs and, where municipal plans are inadequate, to implement the provisions of the Act. A major mechanism of control in the Act is the Flood Area

Permit. Section 205 of the Act states that "no person shall construct, request bid proposals for construction, modify, remove, abandon, or destroy an obstruction in a flood area" without a permit. Section 302 requires "joint or regional flood area planning, management, regulation, and enforcement programs by county and municipal governments." Pennsylvania's law thus directs the State to develop minimum standards for land use management in floodways.

The potential of the Pennsylvania law is similar to that in the New Jersey law. That is to regulate or prohibit structures in the "flood area". The enforcement of the law is given primarily to the local governments. The implementation of this law would result in a significant slowing of any growth in the "flood area" which would have otherwise occurred.

In terms of local government control of floodplain management, Bucks County, Pennsylvania has taken the lead. A Department of Natural Resources has been instituted by the County and works in conjunction with the County Planning Commission. These two agencies are working to institute a floodplain management plan for the County and not merely zoning ordinances. To this extent, Section 503 of the County's Subdivision Regulations states that a flood hazard area cannot be developed unless the steps are taken to remedy this hazard. It should be understood, however, that the actual adoption of floodplain management techniques including zoning are the prerogative of the communities in Bucks County and not of the County. Nevertheless, the activities of such a county function can do much to elicit cooperation from the minor sub-divisions.

All of these laws will control the type of development in the floodplains of the mainstem of the Delaware River and should result in a decrease in residential/commercial development, along with a lesser decrease in industrial uses of the land. On the other hand, recreation and open-space uses of the floodplain should increase.

II.B.4. LAND USE CONSTRAINTS ON FLOOD CONTROL ALTERNATIVES

The two major divisions as to methods of flood control in the Delaware Basin are structural and non-structural alternatives. The basic difference between the two is that structural alternatives are flood control measures involving construction of some type of protection system or change in stream flow characteristics to prevent flooding. Non-structural alternatives take no such steps to prevent flooding. Their method of attack is to control the development of the floodplain in order to minimize property damages and human suffering when such flooding occurs.

These two methods result from two basically different views of flood control. One constrains natural forces, i.e., floods; while the other view advocates non-structural alternatives which conform or adapt to natural forces. Practical considerations dictate that both views be reflected in government programs, particularly where significant numbers of dwellings exist on a floodplain.

If the floodplain were totally undeveloped, then non-structural alternatives alone would undoubtedly be more easily achieved; if the floodplain were heavily developed, then a large proportion of structural alternatives would be more cost effective. Since the information presented earlier in this section shows that neither condition predominates throughout the Delaware River Basin floodplain, a combination of structural and non-structural flood control measures is a reasonable approach regarding flood control along the Delaware and its tributaries. However, the structural flood control measures should be directed to protection of existing development; not towards encouraging future floodplain development.

II.C. ECONOMIC IMPACTS

II.C.1 INTRODUCTION

The economic impact of flooding in the Delaware Basin is obviously extensive when one considers that the 1955 flood produced damages in excess of $100 million. During the 1958 survey, these potential damage estimates were revised upwards to $123,500,000 to reflect price escalation and flood plain changes in the intervening three year period. Of this amount, potential damages, which were considered to be approximately 70% of the total were valued at $86,725,200. The distribution of damages throughout the basin has been indicated in Table 2-1 and gives consideration to physical damage through inundation incurred by residential, commercial and industrial establishments; highways, utilities, public facilities, and rural areas; railroads; as well as business losses and emergency aid and relief costs.

II.C.2 ESTIMATE OF ECONOMIC IMPACT

In evaluating the potential impact of future damages the factor of primary interest relates to what most probably will happen in the future rather than to what has actually happened historically. The historical observations provide the basis for evaluating future probabilities, but they must be supplemented by judgements concerning probable trends of development within the flood plain, probable price changes, which have already resulted in considerable escalation of values utilized in the initial 1955 survey, and possible changes within the floodplain which may be anticipated based on consideration of floodplain zoning legislation or other structural or non-structural measures which may be adopted to reduce future potential damage.

Trends of development within the floodplain thus become one of the primary factors which have to be estimated in evaluation of future daamges. For the purpose of this report, the primary tool for projecting trends of development has been an assessment of the floodplain areas based on comparison of aerial photography as flown in 1962 versus similar coverage flown in 1974. Aerial mosaics were assembled for the mainstem of the Delaware River only, and floodplain limits based on the 1966 survey data were transferred to each of these mosaics. This permitted a detailed comparison of changes within the floodplain as reflected in the aerial mosaics over the twelve year period from 1962 to 1974. The future damage implications for the mainstem of the Delaware below Tocks Island depend largely on the implementation of existing floodplain management laws in New Jersey and the passage of such laws in Pennsylvania.

The following table indicates the number of potentially damageable structures identified in each of the eight major damage centers extending from Belvidere to Burlington based on photo comparisons and compares this with information accumulated by the Corps of

Engineers for 1955.

Since the 1955 flood, a number of flood control measures have been implemented within the Delaware River Basin including construction of reservoirs on some of the tributary streams and implementation of local protective works in Burlington and Trenton, New Jersey; and Easton, Pennsylvania. Specifically, the protective works at these three communities include:

> Burlington: Earthen dikes, a retention pond, and an open park, all installed immediately after the 1955 flood. Also old structures have been condemned and are being removed from the floodplains, the river bank elevation has been raised, and riverfront fill will be converted into a park.
>
> Trenton: Many of the structures damaged in the 1955 flood have been replaced by a flood-proof complex of State office buildings. The city is also in the process of revising zoning ordinances and building codes to comply with floodplain management objectives.
>
> Easton: The number of structures on the floodplain inundated in 1955 have been reduced by more than half. The location of major damage is now the site of an urban renewal project including the removal of old structures and the creation of a new public park.

Table 2-7 indicates these reductions for Burlington and Easton. However, for Trenton the table indicates the opposite. The number of structures subject to damage is over twice that which occurred in 1955. The reason for such an increase is that the flood line used in the aerial mosaic interpretation was not that of the 1955 flood, but rather that of the 1955 flood plus an additional three feet of flooding. This line not only includes the floodways but also the flood-fringe and is

Table 2-7 Extent of Losses in Eight Major Damage Centers

	1955 CORPS OF ENGINEERS REPORT			AERIAL MOSAICS INTREPRETATION			
				1962 Flight		1974 Flight	
	Number of Structures Damaged			Potential No. of Structures Damaged		Potential No. of Structures Damaged	
	Residential	Commercial	Industrial	Residential -Commercial	Industrial	Residential-Commercial	Industrial
Burlington, N.J.	875	77	4	31	4	33	4
Trenton, N.J.	358	46	9	808		748	7
Yardley, Pa.	223	26	0	245		291	
New Hope, Pa.	146	0	0	124		176	
Riegelsville, N.J.	134	25	1	168		173	
Easton, Pa.	237	117	12	229		154	
Phillipsburg, Pa.	32	17	3	61		61	
Belvidere, N.J.	58	20	0	142		132	
	2,063	328	29	1,808	4	1,768	11

felt to give more realistic damage potentials.

With reference to the local protection works and urban renewal projects, discussed above, it is estimated that these would, in the event of repetition of a 1955 flood, result in damage reduction to the extent of 10% to 20% of that actually experienced during the 1955 flood. If the number of structures removed, or protected from flooding, are the criteria applied in formulating this judgement, the damage reduction would be on the order of 10%. However, it must be recognized that, even though it is difficult at this point in time to produce data in support of this view, those structures which have been removed or otherwise protected probably received a higher proportion of damage during the 1955 flood than those which still remain. In view of this, an estimate of 20% reduction in damages is believed to be reasonable for the eight damage centers.

II.D. ENVIRONMENTAL IMPACTS

II.D.1. INTRODUCTION

In this section, the effects of flooding which occurs in the Delaware River Basin will be reviewed to ascertain both adverse and beneficial environmental impacts. Additionally, the types of environmental impacts caused by any flood reduction structures which are constructed on the Delaware River or on its tributaries will be examined.

Periodic flooding of the Delaware Basin is a natural phenomenon. Populations of aquatic and terrestrial organisms and vegetation inhabiting the floodplain become adapted to flooding and carrying capacities for floodplain inhabitants are "geared" to include natural hazards such as flooding. Flooding may cause wildlife habitat to be destroyed, fish spawning cycles to be interrupted and bird nesting areas to be lost.

Beneficial effects resulting from periodic flooding of the Delaware River Basin also should be determined so that their loss from construction of flood containment facilities is considered as part of the ecological price of structural flood control. Only with these understandings of the part flooding of the Delaware plays in the environmental setting can the full magnitude of the impacts brought on by a change in this setting be appreciated.

II.D.2. FLOODING ON THE DELAWARE

Present flooding of the Delaware River is produced by a combination of heavy runoff from the upper basin and tidal influence in the lower basin. The Town of Burlington, New Jersey can be considered the line below which spring tides and winds have the greatest effects. Natural causes of flooding include but are not limited to the melting of ice jams, snowpacks, hurricanes, unusually high tides, and stalled fronts accompanied by heavy rainfall.

Environmental impacts from flooding upon the basin area are, for the most part, short-term. The common period of inundation by flooding is usually 3 to 5 days. However, severe flooding has been known to have an extended impact upon fish populations and fishing. A flood such as occurred in 1955 in the Delaware River Basin could require a minimum of three years for re-establishment of the resident fish population. If the timing of the flood is such that anadromous fish are migrating upstream, a year class may be lost.

II.D.3. ADVERSE ENVIRONMENTAL EFFECTS FROM FLOODING

Floodwaters will contribute large loads of sediment to the mainstem of the Delaware River. The results upon the water quality include an increase in turbidity and nutrients, a lowering of temperature due to large volumes of water moving rapidly downstream, and a drop on the dissolved oxygen levels attributable to the increased biological demand resulting from suspended sediments and detritus.

Benthic (bottom dwellers) organisms can be greatly affected by the increased sediment loads within the flood waters. This group of organisms is usually of a stationary mode and cannot leave an area in time of disaster. Benthic organisms can easily be buried or smothered by heavy siltation which clogs their internal pumping mechanism or ripped from their holdfasts and washed downstream. The increased turbidity will decrease light penetration, thereby slowing the process of photosynthesis. Thus, the normal food source of phytaplankton becomes scarce.

The occurrence of a flood during the fish spawning period can have an adverse effect upon the fish population. Silt carried by severe flood waters may cover fish eggs and prevent them from hatching. Anadromous fish can adjust to short term water level fluctuations and delay spawning. After flooding, the fish may begin to spawn in the shallow waters created by the flood. If flood waters remain high enough, the spawn has a high probability of being viable. However, a rapid drop in flood waters would expose the eggs left above the normal river level.

Aside from smothering eggs by silt, nests can be scoured by flood waters moving eggs to an area where they may be stranded and exposed as flood waters recede. Also, free floating eggs can be eaten by resident fish. Those larvae which do hatch may find the base of the food chain (primary producers) so disrupted as to leave little food available.

The terrestrial biota is the hardest hit segment of the ecosystem by flooding. A prolonged flood can cause drowning, starvation, destruction of nesting areas, and loss of habitat. Short-term floods, as the 1955 flood, result in a lower net loss from chronic factors such as starvation or habitat reduction.

Different categories of terrestrial dwellers each have varying success at surviving the short-term flood. Squirrels are known to survive fairly well by staying in the trees and depending on arboreal routes of travel. Likewise, mice and similar rodents can move up into the trees and nest. However, this group cannot travel from tree to tree and may be lost to total inundation if caught in low brush. Rabbits and woodchucks are fairly mobile and can move to adjacent areas above the water level. Raccoons are fairly adept swimmers and are known to travel on clumps of debris or swim from high spot to high spot. Mink and other members of the weasel family, are also known to survive without problems.

Opossum and muskrat can suffer due to flood conditions as protective habitat for both animals is destroyed. Thus, migration can lead these species to an area lacking the vegetative cover they are normally used to for protection. Severe predation can result. Beaver populations are reduced as high water velocities destroy dams and lodges. Young beavers are especially subject to death by drowning.

Reptiles and amphibians can be severely affected by flood damage. Salamanders and lizards are not competent swimmers and can easily drown. Many of these animals can be exposed to easy predation by birds of prey.

Birds, other than those making their nests on the ground, are usually not affected adversely by short-term flooding. High flood waters may act to sway or vibrate trees and disrupt birdnests.

Increased flow and high water velocities can have adverse effects on ground vegetation by dislodging those plants with a low root system foliage ratio; or those plants having a surface roots system. Plants which are submerged under water for more than one or two days may die from lack of oxygen. The effects of flooding upon vegetation are usually of modest impact and followed by rapid re-establishment (See XVI.C).

In general, adverse effects of flooding are less in areas where land is moderately graded towards the river channel thereby affording easy drainage. Most animals are able to move adjacent to the rising river and simply relocate until the flooding has resided. Low-lying areas separated from the river by a ridge or dike can trap flood waters and isolate fish from the mainstem. These fish are doomed, when waters recede, to increased temperatures, loss of dissolved oxygen and death.

II.D.4. BENEFICIAL EFFECTS OF FLOODING

Floods are a natural part of a balanced ecosystem. However, the role of flooding within ecosystem functions is not entirely understood. One of the definite benefits of flooding is the placement of fertile alluvial soil upon the floodplain. Man's earliest settlements were based in river valleys offering rich agricultural soils,

The overall effect of flooding is generally more beneficial than harmful to aquatic life. The short-term disruption is usually followed by greater biological activity. This can be evidenced by an increase in game fish and a decrease in non-game species. This view must be taken as a general one for flood results throughout the United States. Floods from true natural catastrophies could indeed be fatal to the aquatic as well as terrestrial biota.

One of the beneficial effects of flooding results from the increased nutrients available from river silt. Zooplankton population are known to bloom directly after a flood. The increased and primary producers can then support increased populations of predators at all levels of the food chain, (assuming the adult fish are alive to utilize the results of the productivity increase). This may mean higher survival rates for young fish, especially game species.

Flooding could also have beneficial effects upon the oysters of the Delaware Bay Estuary. Flood waters may push the salt gradient downstream into areas which are usually totally saline. Since oysters can withstand lower salinity, parasites and predators such as the oyster drill are killed by the advance of fresh water. However, it must be realized that the beneficial effects must result from short-term flooding. Long-term floods resulting in prolonged low salinities could harm the oyster beds.

The Delaware River normally carries large, nutrient rich silt loads in high flow periods. When flood levels recede, much of this settles out on a portion of the floodplain. Thus, soils are fertilized and enriched forming prime agricultural lands. Nutrient rich sediments may also be deposited in those areas of the river having hard rock or clean gravel bottom characteristics. These flood deposited sediments may then be available to support benthic life. Flood waters can also change the course of a stream thereby removing existing siltation problems.

II.D.5. ENVIRONMENTAL EFFECTS CAUSED BY VARIOUS TYPES OF FLOOD REDUCTION STRUCTURES

The Tocks Island Dam is considered one of the methods of controlling, or at least lessening, flood damage upon the Delaware River Basin. The dam was designed to handle the maximum probable storm. The effects of such a storm were figured by considering rainfall patterns from two major storms on record (1933, 1942), and then increasing the projected rainfall somewhat above the predicted levels. The 1955 storm was used as the basis for the standard flood.

The spillway designed on the Tocks Island Dam can pass waters resulting from the "standard flood" without damage to the reservoir. Floods less severe than the 1955 experience are expected to pass downstream without channel damage, the downstream channel having a capacity of 70,000 cfs. Such conditions would produce short-term flooding and have a minimal environmental impact.

Two types of storms would produce flood damages. If snow melt and heavy rainfall were combined as in the 1936 flood, or concentrated runoff from a hurricane or hurricanes as in the 1955 flood occurred, floods would result. However, a structural flood control measure could significantly reduce floodplain inundation.

Construction of the Tocks Island reservoir as a flood reduction measure would involve numerous construction impacts and operational impacts which will be discussed later in this Report. These impacts would extend throughout the area including the lower reaches and estuary.

Alternative methods of flood control do exist. The damming of Delaware River tributaries is one such method. This could be in the form of actual impoundments or "dry dams". The dry dam consists of an embankment built across the tributary containing an outlet large enough to pass slightly more than normal stream flow. In flood conditions, water is trapped behind the dam to form a temporary reservoir. The water then drains out through the outlet over an extended period of time, thereby reducing flows to a minimum. A possible problem resulting from the dry dam method involves the trapping of debris behind the impoundment after the water level has dropped. Also, stream water may be trapped long enough to stagnate, causing problems downstream. In addition, these areas of stagnation could harbor insects with their associated health hazards.

A third structural alternative technique is the construction of protective works along the areas which may undergo inundation due to a flood. Aside from the construction impact in building levees and dikes, such structures would impede access to the mainstem of the river. Such action may have detrimental effects upon the wildlife through changing the actual character of the riverbank.

Numerous alternative non-structural flood measures have been proposed.

These include measures ranging from floodproofing structures to increasing flood insurance. The most stringent method is to restrict buildings on the floodplain. The floodplain is then allowed to undergo all natural processes which will maintain an equal balance between aquatic and terrestrial environments. Population growth is allowed to occur only in non-flood prone urban centers. Such a measure has the least environmental impact, but is the most restrictive of flood plain development.

II.E. FLOOD DAMAGE REDUCTION NEEDS

II.E.1. INTRODUCTION

In previous sections of this report we have looked at the average annual damages caused by flooding along the Delaware River as well as the constraints on land use which such flooding brings about, the economic impacts of such flooding, and the environmental impacts of such flooding. In this section we will attempt to give an overview of flood damage reduction needs for the Basin using the information which has been generated previously.

II.E.2 EXISTING FLOOD DAMAGE NEEDS

First, it should be noted that the existing frequency of flooding of the Delaware River Basin will cause much economic hardship because of man's development of the floodplain. Therefore, the economic need for flood damage reduction is real. From the environmental standpoint, the need for flood reduction is questionable since the ecosystem is in balance, with both adverse and beneficial impacts of flooding as part of this balance. The main reason for flood damage reduction needs is, therefore, not environmental but rather economic; if man had not developed the floodplain there would be no need for flood damage reduction. However, as the flood plain is developed, existing conditions cannot be ignored.

The average annual damages given in Section II.A of this Chapter present some concept of the existing economic hardship which is caused by flooding. These damages do not take into account the possibility of the loss of life resulting from a major flood. Nevertheless, such a possibility is an ever present threat, pointing to the need for flood damage reduction. Land use development and the potential for increased development along the lower Delaware floodplain exists. And, while it is realized that national legislation affecting floodplain development, along with pending or passed state and local legislation, will in all probability reduce the potential for future development of the floodplain, such disincentives did not exist previously. As a result, the floodplain has been developed creating the present flood damage reduction needs that now exist.

II.E.3 FUTURE FLOOD DAMAGE REDUCTION NEEDS

The possibilities of future flood damage reduction needs are examined in this section. Since there is not a direct correlation between floodplain development and economic growth levels, or between flood damage reduction needs and economic growth levels, this section will outline three levels of flood reduction needs which, while compatible with various economic growth levels, depend more on institutional preferences and public policy decisions for a determination of suitability under given economic and other conditions.

II.E.3(a) High Future Flood Damage Reduction Needs

The high flood damage reduction need can be expected if the floodplain of the Delaware is developed without restrictions. This would result from the failure of the New Jersey Flood Plain Management Act to effect changes in floodplain development, the failure of the Pennsylvania Assembly to pass a flood management plan, and the weakening of the Federal Flood Insurance Act.

At present, the mainstem of the Delaware River floodplain is more densely developed than the surrounding areas. Such a differential between the floodplain development and the remaining area could be expected to become even larger without management laws.

This increased development could raise the average annual damages in the floodplain by 20% over the next 50 years. This percentage may seem low but it must be viewed in light of the small development which has occurred in the floodplain since the 1955 flood. However, it must be noted that the present thinking, both in the nation and in this area, as to the importance of floodplain management, makes even this high damage reduction need unlikely to occur.

II.E.3(b) Medium Future Flood Damage Reduction Needs

A medium flood damage reduction need forecast is based on the passage of flood management acts by Pennsylvania and the continuing enforcement of those acts which have been passed by New Jersey and the Federal Government. The result would be controlled development of the floodplain. Since this development would be guided by such existing laws it could be expected that along the mainstem of the Delaware River the upland surrounding communities' development would gradually exceed that of the floodplain.

Under this set of circumstances development in the floodplain could be expected to increase by no more than 10% due to the permit systems required by both the New Jersey and Pennsylvania laws. The required floodproofing of such development would result in any increase in flood damages being much less than 10%, probably in the neighborhood of 3%-5%.

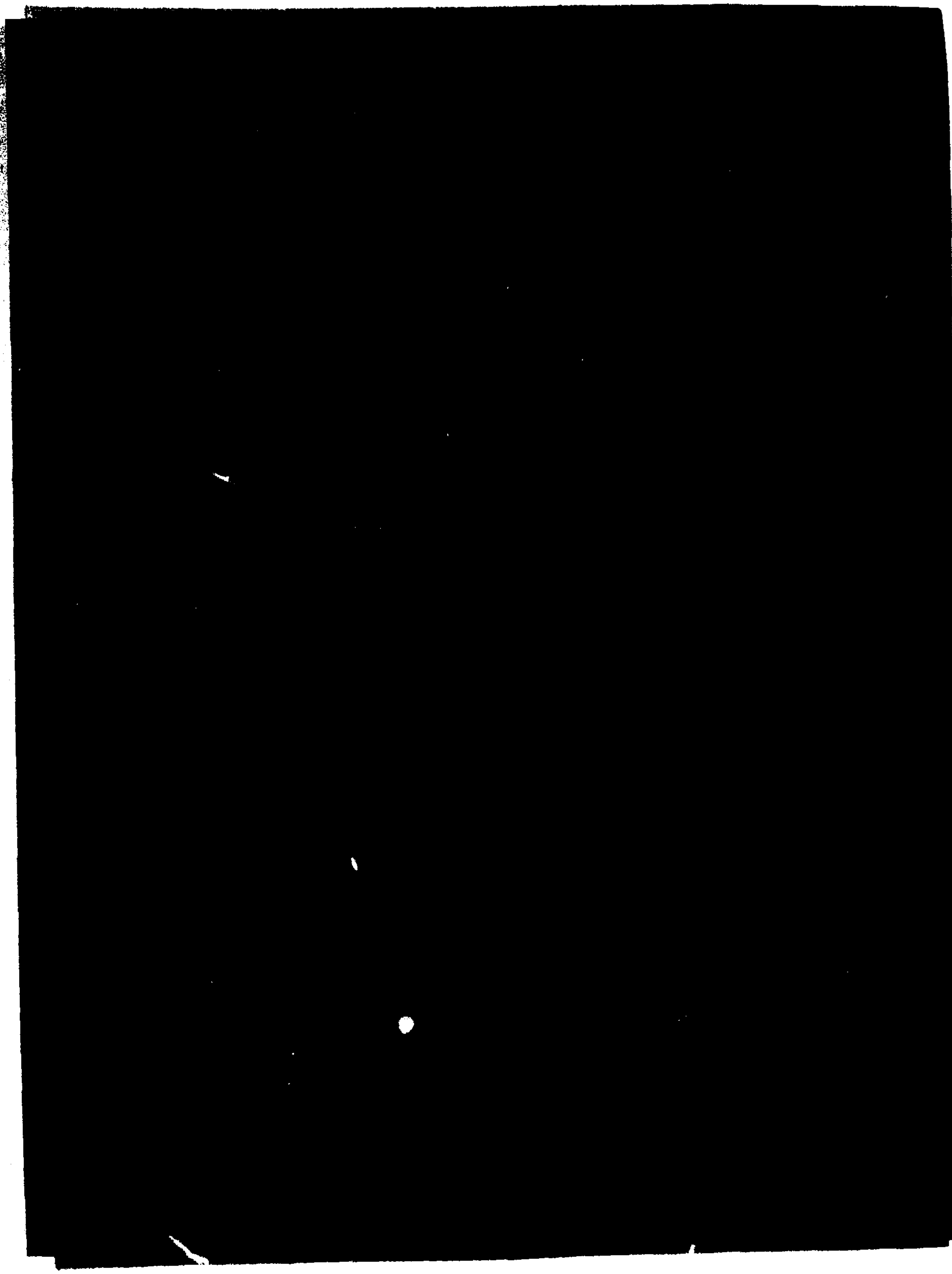
II.E.3(c) Low Future Flood Damage Reduction Needs

The low forecast for flood damage reduction needs is based on extremely stringent laws which would prohibit any development in the floodplain. The closest existing law which approximates this case is the existing New Jersey law which places a great emphasis on restriction of floodway development, while the Pennsylvania and Federal laws do not. It is probable that no such development standard will be completely enforceable nor can it be expected that the Federal and State governments would pass such stringent legislation. However, if fully implemented, the development in the floodplain will actually decrease as existing structures are removed by attrition and age. This could result in a decrease in average annual flood damages by as much as 20% over the next 50 years. However, it is felt that a low flood damage reduction need forecast is unrealistic.

II.E.4 CONCLUSIONS

Upon reviewing the existing flood damage reduction needs in the Delaware Basin, and also looking at possibilities of how such needs will develop in the future, it can be said with some assurance that needs for flood damage reduction now exist and will continue to exist throughout the forecast period. While development in the floodplain will not proceed as fast as growth along the surrounding areas, growth will still occur. Therefore, estimates of average annual damages, environmental impacts, and economic impacts will tend to increase somewhat with the passage of time.

It will take time for the new floodplain management laws to show success in reducing development of the floodplain. Those structures that exist will be allowed to stand until such time as they can no longer serve their purpose. With their demise, the effects of non-structural flood control alternatives will become more apparent. For the forseeable future, however, given the existing and future unprotected growth within the flood plain, more effective action with respect to flood damage control is clearly required.



III.A. INTRODUCTION

This Chapter is concerned with the projection of future water needs for the Tocks Island Project water supply service area. The Water supply service area consists of the Delaware River Basin plus supplemental subareas in northern New Jersey and southeastern New York. The latter two areas are included because they are presently served or have been projected to be served by water from the Delaware River Basin. The southeastern New York subarea is made up of those counties that are presently served or are projected to be served by water from the City of New York system. The northern New Jersey subarea is that area that is presently served by the authorized 100 MGD diversion from the Delaware through the Delaware and Raritan Canal, or would be served by the proposed 300 MGD diversion from the Delaware Basin. The purpose of including out of Delaware River Basin areas is to evaluate present and proposed diversions with the relative supply and demand in these areas.

Water used consumptively within the Delaware River Basin is given particular attention in this Chapter because of its relationship to possible salinity intrusion in the Delaware Estuary. The water consumptively used in the supplemental subareas is not emphasized, and the fact that it is not is fundamental to the understanding of water requirements in the Delaware River Basin and the supplemental subareas.

Consider for example two identical toilets, one in New York and one in Philadelphia, each with a brick in its tank placed there by the owner with the aim of reducing the tank's volume, hence the amount of water used for each flush.[1] What, in fact, does each brick accomplish as far as water supply in the Delaware is concerned? New York takes its water by pipeline from the upper reaches of the Delaware Basin and discharges its wastewater into the saline lower Hudson River. The New York toilet brick, by reducing the drain on the upper Delaware reservoirs, could conceivably allow more water to flow down the Delaware River if, in fact, this diversion were not frozen by the 1954 Supreme Court decree and subsequent basin compact.

The Philadelphia toilet brick is different. Philadelphia replaces its water a little farther downstream. Thus, this water is available for reuse farther downstream and is not lost from the basin, with the exception of the small amount (approximately 10%) that is lost through evapotranspiration during the municipal use process.

Thus, it is possible to see that usage of Delaware River water within the basin is markedly different from usage of Delaware River water outside the basin in terms of its impact on general water availability within the basin. Water taken out of the basin through diversion to New York or to New Jersey is lost forever as far as the basin is concerned and is not available for reuse by basin users. On the other hand, water used within the basin is available for reuse by other users in the basin, with the exception of the amount that is used consumptively, i.e., that which is lost from the system through evaporation or plant transpiration. The problem of determining water

1. Most of the material in this and the next paragraph is inspired by similar material from Sinden (1974).

supply requirements that must be met from the Delaware Basin is thus divided into the problem of establishing the validity of diversions from the basin and the problem of determining the effect of increased consumptive use within the basin on the probability of salinity intrusion.

The basic approach taken is to project water demands, both within and without the basin, with the latter being confined to those demands that are presently satisfied or proposed to be satisfied through diversion from the basin. For example, increased municipal demand within the northern New Jersey and southeast New York subareas could be supplied through diversions from the Delaware River. On the other hand, electric power plant cooling requirements are likely to be met through supplies that the power companies would develop themselves, primarily along the Hudson River and estuary. Thus, electric power cooling demand estimates are not made for the northern New Jersey and southeastern New York subareas, since they are not likely to be met through diversions from the Delaware.

The Supreme Court decree of 1954 and subsequent Delaware River Basin compact, for all practical purposes, guarantees an 800 MGD diversion to southeast New York if the 1750 cfs minimum flow requirement of Montague is met. Nonetheless, water demand projections and an inventory of existing and programmed supplies are made for this subarea so as to be able to compare supply with demand and thus determine the relationship of the 800 MGD diversion to overall demand and supply.

The focus of the northern New Jersey subarea evaluation is somewhat different in that only 100 MGD has been authorized to New Jersey under the Supreme Court decree of 1954. The State has requested an additional 300 MGD diversion from the Delaware, as yet not authorized. The demand for water in northern New Jersey is projected and supplies inventoried to determine the relationship of the proposed 300 MGD diversion to demand and supply.

Water demand projections for the Delaware River Basin are made in order to establish consumptive use because of the importance of this issue relative to possible salinity encroachment in the Delaware Estuary. During the drought of the early 1960's salinity concentrations began to increase in the estuary and for a time there was concern that the Torresdale water intake would draw water contaminated with excessive chlorides. Because of the possible danger of salinity encroachment under existing conditions, and because increased consumptive use within the basin will further reduce present flows, the salinity problem has been investigated in considerable detail. Particular attention is given to the establishment of the probability of observing given chloride concentrations at Torresdale and the Camden Well fields.

III.B. GROSS WATER DEMANDS

III.B.1 MUNICIPAL AND INDUSTRIAL

III.B.1(a) Introduction

Municipal and industrial water demands are projected in this section. In order to facilitate the understanding of this and subsequent sections certain terminology used to describe and subdivide water demand and water supply is described and illustrated as follows:

1. Publicly Supplied Water - water supplied by public systems, including that used for domestic, commercial, and industrial purposes. Presently, approximately 92% of publicly supplied water is for domestic and commercial purposes; 8% is for industrial purposes.

2. Self-supplied Industrial Water - water supplied by industries for meeting their own needs.[1]

3. Self-supplied Domestic and Commercial Water - water developed by domestic and commercial users for meeting their own needs.

4. Total Water Used for Domestic-Commercial Purposes - the total amount of water used for domestic and commercial purposes. It can be either self-supplied or publicly supplied although it is usually the latter.

5. Total Water Used for Industrial Purposes - the total amount of water used for industrial purposes. It can be either self-supplied or publicly supplied although as indicated under item 1 above, it is usually the former.

These definitions are illustrated in Figure 3-1, where a small overlap is shown between publicly supplied water and total industrial water.

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1. Sources of water for self-supplied industry include saline sources, such as Newark Bay, groundwater, rivers and streams. Saline water is the largest single source, and it is certain that saline sources will become even more important in the future as the potential for further development of groundwater and fresh surface supplies become exhausted.

The importance of the foregoing concepts will become more evident in Section III.D.5 where projections are made as to the source of water that will be required by those industries which are presently self-supplied.

In addition to the basic demand projections, selected sensitivity projections are made to reflect selective modifications in certain of the components of demand listed above.

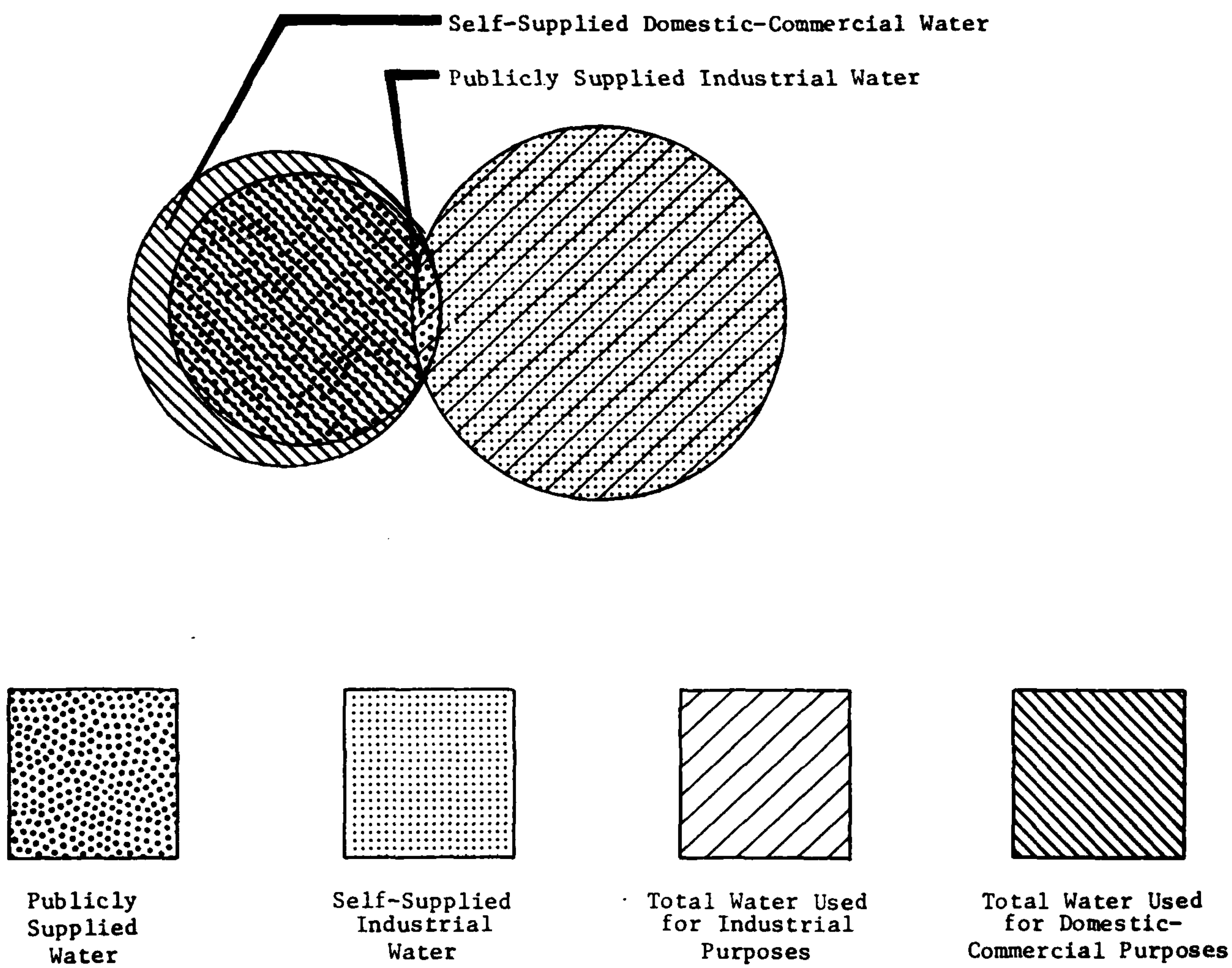
The "basic" set of demand projections is with high, medium and low growth rates. This set of projections assumes changes in basic water demand components in accordance with observable historic trends and expected future conditions. An "increased implementation" demand projection is made that assumes greater or lesser degrees of imposition of certain policies related to per capita demand. Such policies would be those regarding the use of water conserving devices, metering, industrial water recycling, and lawn sprinkling.

III.B.1(b) Methodology

Municipal and industrial water demand projections were made using the methodology developed by INTASA (1974)[1]. The methodology as reported in INTASA (1974) was used to project water demands in the New York Metropolitan area as a part of the NEWS study. The projection methodology is based on a detailed modeling of components that are known to affect water demand including the following:

1. Selected modifications were made for the purposes of this study and are found in Appendix A, at the end of this chapter.

INTERRELATIONSHIPS BETWEEN WATER DEMAND AND SUPPLY



Factors affecting municipal demand:

availability of public supplied water
availability of sewers
use of clotheswashers and dishwashers
lawn sprinkling
water conserving devices
metering
population trends
price of water[1]

Factors affecting industrial demand:

gross product originating per employee
internal recirculation rate
technological change
price of water[1]

Industrial projections were made for the following six major water using industries that account for a high percentage of the total industrial water demand:

food and kindred products
textile
paper
chemicals
petroleum
primary metals

III.B.1(c) Assumptions

In utilizing the results of the demand studies, the following assumptions and constraints should be borne in mind:

No judgment is made as to whether any of the alternative demand projections represent a most likely case in consideration of future uncertainties. Each projection set should be evaluated on the merits of the individual assumptions made for each parameter of water demand together with the underlying assumptions for the population and employment projections.

In the development of the water demand parameters, no constraint was placed on extending their values through time based upon their cost.

---

1. Demand projections are made independent of the price of water. The influence of price on water demand is discussed in section XII.B.8.

This is especially true for those assumptions made with respect to industrial recirculation and technology. It is considered, however, that insofar as most of the assumptions reflect known trends or national or regional averages, they do represent reasonably obtainable goals.

In developing the industrial projections, it was necessary to obtain basic data for industrial use both in terms of publicly supplied industrial water as well as self-supplied industrial water. In making the projections, no assumption is made with respect to the future sources to meet the industrial demands. Consideration of future sources is contained in section III.D.5.

Water demands as projected for the service area for the Delaware River Basin are shown in Figure 3-2. The service area is divided into the Delaware River Basin proper, the area presently served or proposed to be served by the presently authorized 800 MGD diversion to southeastern New York (New York City System Subarea), and the area presently served or proposed to be served by the currently authorized 100 MGD and proposed 300 MGD diversions to New Jersey (Northern New Jersey Subarea).

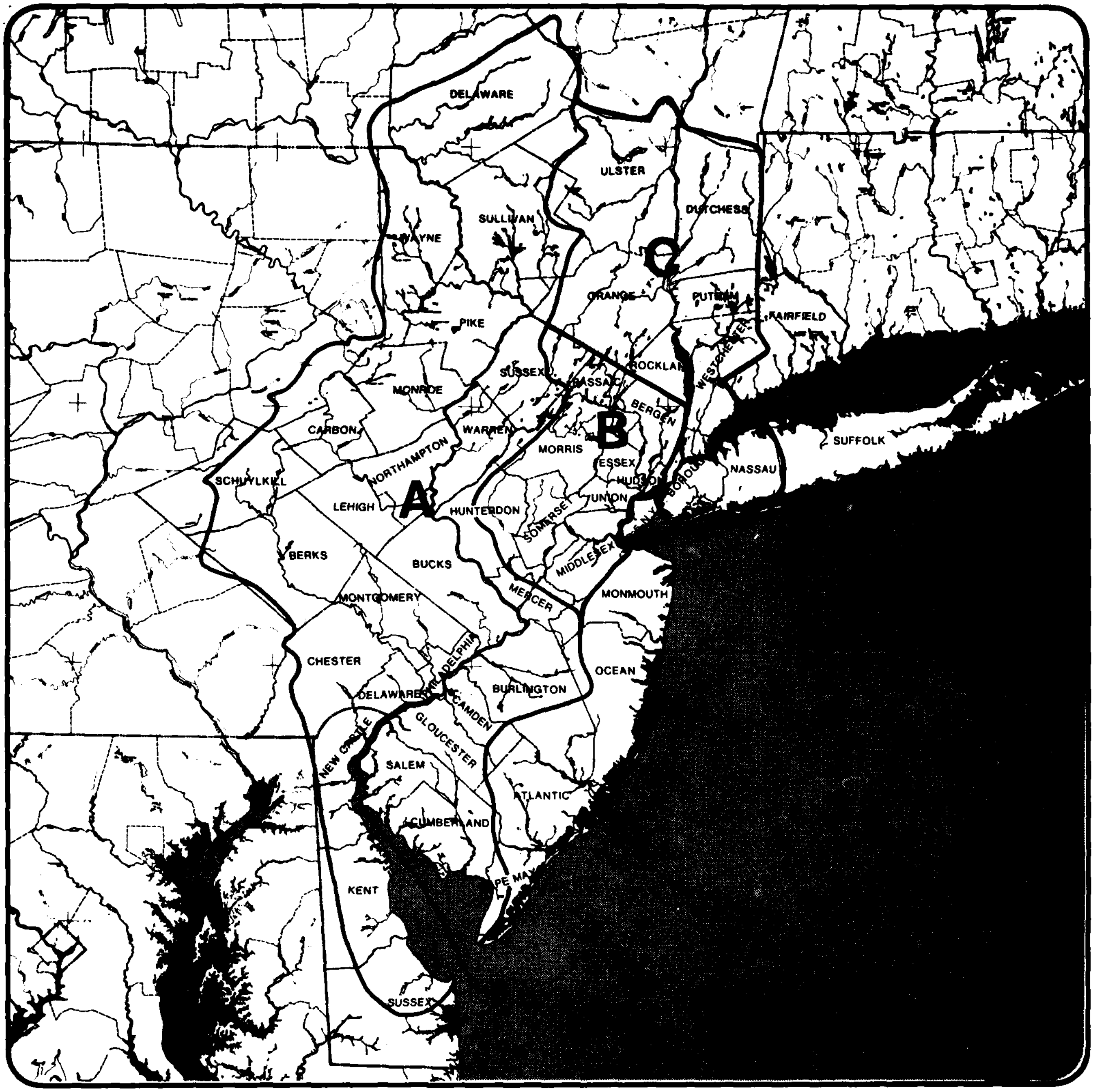
III.B.1(d) Data Base

Basic economic and population data was assembled according to the economic subregions which are the same as those employed in C of E (1962, Vol.IX). These economic subregions are shown in Figure 3-3. The data base for projecting municipal and industrial demands follow.

Data for Base Projections --

1. Population Projections for Delaware River Basin and Supplemental Service Areas in Northern New Jersey and Southeast New York

High, medium and low population projections are presented in Table 3-1 for the Delaware River Basin, the Northern New Jersey Subarea, and the New York City System Subarea. The weights used for each economic subregion are presented in Table 3-2 and are based on present distribution of population over the area.



WATER SUPPLY SERVICE AREA

III

2

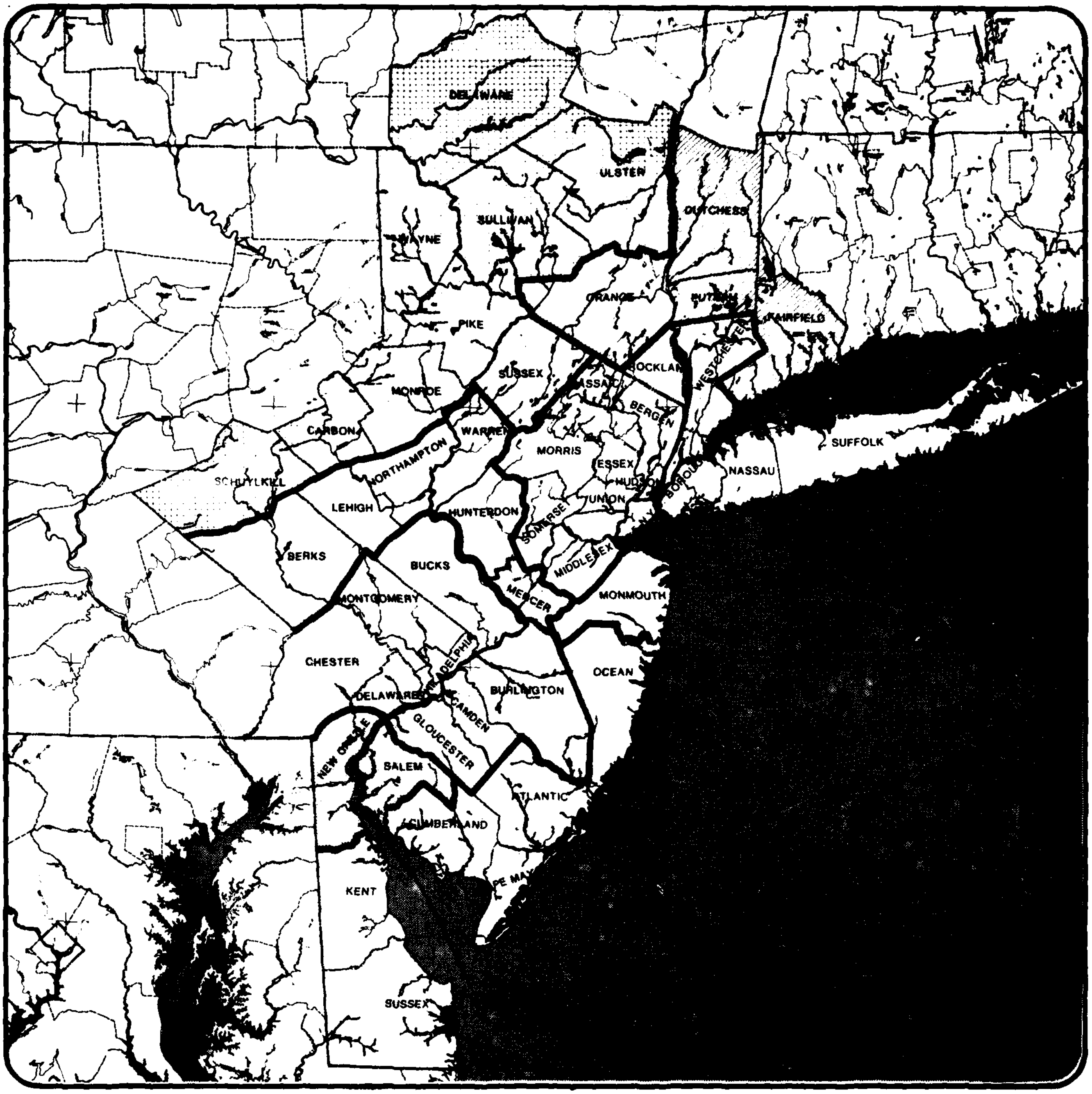
LEGEND

- NEW YORK CITY MET. AREA (Standard Area)
- NEW YORK CITY MET. AREA (Supplement for Expanded Area)
- BETHLEHEM-ALLENTOWN AND READING MET. AREA
- TRENTON METROPOLITAN AREA - NEW JERSEY
- PHILADELPHIA METROPOLITAN AREA
- WILMINGTON METROPOLITAN AREA
- UPPER BASIN AREA
- SOUTHERN BASIN AND COASTAL AREA

A COMPREHENSIVE STUDY OF THE

TOCKS ISLAND LAKE PROJECT & ALTERNATIVES

URS/MADIGAN-PRAEGER, INC. & CONKLIN AND ROSSANT



ECONOMIC SUBREGIONS EMPLOYED FOR WATER DEMAND PROJECTIONS

III

3

LEGEND

- NEW YORK CITY MET. AREA (Standard Area)
- NEW YORK CITY MET. AREA (Supplement for Expanded Area)
- BETHLEHEM-ALLENTOWN AND READING MET. AREA
- TRENTON METROPOLITAN AREA - NEW JERSEY
- PHILADELPHIA METROPOLITAN AREA
- WILMINGTON METROPOLITAN AREA
- UPPER BASIN AREA
- SOUTHERN BASIN AND COASTAL AREA

Table 3-1 Population for Delaware River Basin Water Supply Area: Existing for 1970 and Projected for 1985-2025

	Existing	High			Medium			Low		
	1970	1985	2005	2025	1985	2005	2025	1985	2005	2025
Delaware River Basin	6,907	7,982	9,622	11,068	7,775	8,947	9,986	7,293	7,826	8,399
North New Jersey Subarea	4,688	4,989	5,594	6,165	4,893	5,272	5,540	4,807	5,049	5,305
New York City System Subarea	11,101	11,940	13,504	15,000	11,699	12,693	13,427	11,442	12,020	12,628

Table 3-2 Distribution of Existing Population Over Area

	% of Population in DRB	% of Population in the North N.J. Subarea	% of Population in the NYC System Subarea
A. NYC Metro Area (Standard)	-	28.4	64.5
B. NYC Metro Area (Supplemental)	.2	-	28.6
C. Bethlehem-Allentown and Reading Metro Area	94.1	-	5.2
D. Trenton Metro Area	81.7	18.3	-
E. Philadelphia Metro Area	98.8	-	-
F. Wilmington Metro Area	100.0	-	-
G. Upper Basin Area	57.2	5.0	23.6
H. Southern Basin and Coastal Area	32.4	-	-

2. Per Capita Demand

The estimated per capita demand for each subarea in base year 1970 is presented in Table 3-3. It is obtained by first estimating the total demand in 1970 for municipal, self-supplied domestic and self-supplied industrial. The total of the three components is then divided by the total population in each subarea to obtain the per capita demand. The apparent per capita demand differences are largely a result or variation of self-supplied industrial use for each subarea.

For the Delaware River Basin, the component demands are obtained from DRBC(1972). These estimates were spot-checked with recent results of a water use survey for the Delaware River Basin, DRBC(1972) and found to be in agreement.

For the Northern New Jersey and New York City System subareas, the municipal demand is obtained based on per capita demand estimates for counties made in INTASA (1974) and the county population served by public water in the service subareas. The self-supplied domestic demand is obtained based on the county population in the service subareas not served by public water and on a self-supplied per capita use estimate of 50 gpcd. The self-supplied industrial use is obtained based on an estimate of its average use per employee by industry in each state and the number of employees in each industry for the service subareas. Details of the calculations and data are presented in Appendix A.

Table 3-3 Per Capita Demands by Subareas in 1970

	Total Demand in MGD				Population in Thousands	Per Capita Demand in gpcd
	Municipal	Self-Supplied Domestic	Self-Supplied Industrial	Total		
Delaware River Basin	875	54	2,649	3,370	7,143*	501
North New Jersey Subarea	642	14	1,501	2,320	4,688	460
New York City System Subarea	1,753	15	1,577	3,142	11,101	301

* This population estimate was developed by DRBC and relates directly to the water estimates and was subsequently used to obtain the 1970 per capita demand.

Data for Extension of Public Water and Sewer System --

1. <u>Present and Future Percentage of Population Served by Public Water</u>

The percent of population served by public water in 1970 and 2025 is presented in Table 3-4. The 1970 percentages for the three service subareas are obtained as the weighted average of the percentages for each county as given by the 1970 Census Data, where the weights are proportional to each county's population in the subarea.

Table 3-4 Percentage of Population Served by Public Water

		2025		
Subarea	1970	High	Medium	Low
Delaware River Basin	86	91	89	87
Northern New Jersey Subarea	94	98	98	98
New York City System Subarea	97	98	98	98

The estimates for the percentage of population served by public water in 2025 are obtained as follows. For the Delaware River Basin it is assumed from DRBC(1973) that the population with self-supplied domestic water will remain constant at 1,100,000 through 2025. Subtracting this population from the totals projected for 2025 and dividing the results by the total population, the percentage of population served by public water in 2025 for high, medium and low population growth are obtained. For the New Jersey and New York subareas, the percentages are based on a weighted average of county by county projections of public water use as given in INTASA (1974) and Tri State (1973).

Percentages of population served by public water in 1985 and 2005, not shown in Table 3-4 but used in the projections, are based on the assumption that the new population will be served at the final percentage assumed, and that the present population will be upgraded to this percentage at a uniform rate over the 50-year period. This assumption reflects the faster increase in percentage served expected in areas with new development.

2. Increased Per Capita Demand As Result of Public Water Extension

The per capita demand increases by about 25 gpcd when public water is used instead of self-supplied water. This estimated increase is based on observations made by Linaweaver, et. al.(1967) where for 13 areas in the Eastern United States with metered public water and public sewers, the mean residential water use was 76 gpcd. Also, DRBC(1972) presents an example of a large residential community in the Delaware River Basin with a public water system and 76 gpcd average demand. The per capita use for self-supplied domestic use is estimated at 50 gpcd, DRBC(1972).

3. Present and Future Percentage of Population Served by Public Sewers

The percent of population served by public sewers in 1970 and 2025 is presented in Table 3-5. The 1970 percentages for the three subareas are obtained as the weighted averages of the percentages for each county as given by the 1970 Census Data, where the weights are proportional to each county's population in the subarea.

Table 3-5 Percentage of Population Served by Public Sewer

Subarea	1970	2025		
		High	Medium	Low
Delaware River Basin	78	86	85	82
Northern New Jersey Subarea	89	97	97	97
New York City System Subarea	88	95	95	95

The estimates for the percentage of population served by public sewer in 2025 are obtained as follows. For the Delaware River Basin it is assumed, following the assumption for public water service, that the population without public sewers will remain constant through 2025. For 1970, the population without public sewers is 22% of the total population, or 1,519,000. Subtracting this population from the totals projected and dividing the result by the total population, the percentage of population served by public sewers in 2025 for high, medium and low population growth are obtained. For the New Jersey and New York subareas, the percentages are based on a weighted average of county by county projections of public sewer service as given in INTASA(1974) and Tri State (1973).

Percentages of population served by public sewers in 1985 and 2025 are based on the assumption that public sewer service is only provided with public water service, and the new population is served at the final percentage assumed while the present population is upgraded at a uniform rate over the 50-year period.

4. Increased Per Capita Demand As Result of Public Sewer

The per capita demand increases about 20 gpcd when public sewers are added to an area having only septic tanks, according to observations by Linaweaver, et. al.(1967). This increase appears to be reasonable, as indicated in Fig. 3-4 where estimated per capita non-industrial demand is plotted against percent of population served by public sewer systems for counties in the Tri-State Regional Planning Commission's jurisdiction (INTASA (1974)).

Data for increased use of Water Consuming Appliances --

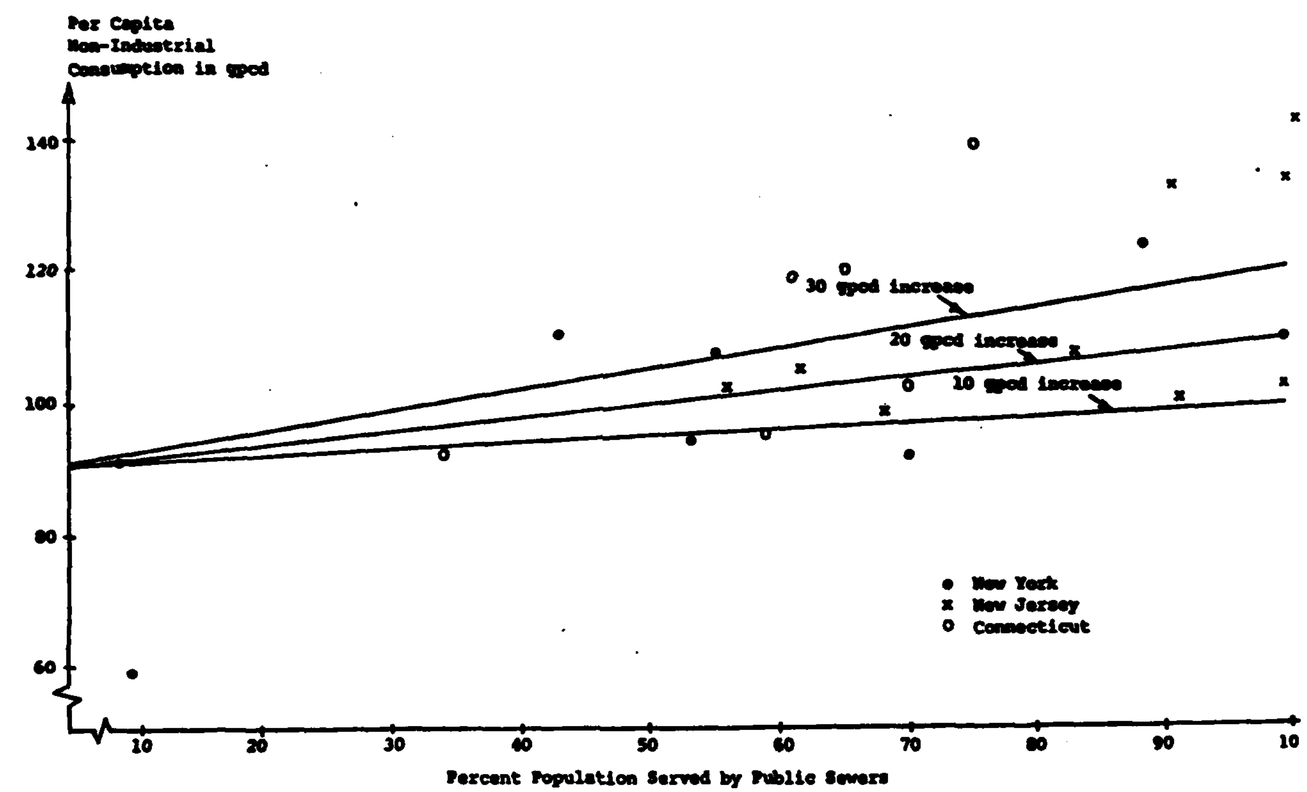
1. Present and Future Use of Clotheswashers and Dishwashers

The percent of population with clotheswashers and dishwashers in 1970 and 2025 is presented in Table 3-6. The 1970 percentages for the three subareas are obtained as the weighted average of the percentages for each county as given by the 1970 Census Data where weights are proportional to each county's population in the subarea.

Table 3-6 Percentage of Population with Clotheswashers and Dishwashers

Subarea	Clotheswashers 1970	Clotheswashers 2025	Dishwashers 1970	Dishwashers 2025
Delaware River Basin	76	95	21	95
Northern New Jersey Subarea	64	95	21	95
New York City System Subarea	50	95	17	95

PUBLIC SEWERS AND PER CAPITA NON-INDUSTRIAL CONSUMPTION



No projections for future use of clotheswashers and dishwashers by percentage of population were available. However, based on Bureau of Census Data for historical growth in the nationwide percentages of wired homes with clotheswashers and dishwashers, three alternative rates of growth can be considered. The growth rate used in this study is based on the trend of the last 20 years, resulting in a 1 and 2 percent annual increase in percentage of population with clotheswashers and dishwashers, respectively. It is further assumed that the maximum percentage for both clotheswashers and dishwashers is 95 percent. Percentages for 2005 and 2025 were obtained by linear interpolation.

2. Increased Per Capita Demand as Result of Clotheswashers and Dishwashers

No empirical data on the increase in per capita demand resulting from adding a clotheswasher or dishwasher were available. Three alternative estimates were made of which the average one is used (INTASA (1974)). In all cases, the per capita increase is based on 3.1 persons per dwelling unit for the entire study period. No reduction in persons per dwelling unit is warranted because of the uncertainty of the overall estimates involved.

The following estimate is used for clotheswashers:

7 gpcd, equivalent to about one wash every other day with 45 gallons per wash.

The following estimate is used for dishwashers:

9 gpcd, equivalent to about two washes daily with 14 gallons per wash.

3. Other Uses

In addition to the increases due to the large number of water consuming appliances, it is assumed that the use of these appliances will also increase over time. To account for this, a total increase of 8 gpcd is assumed by 2025, where the increase is linear over time.

Data for Changes in Sprinkling Demand Due to Density Changes --

1. Present and Future Net Residential Density and People Per Dwelling Unit

Present and future net residential densities in dwelling units per acre for the three subareas are presented in Table 3-7. The values are based on net residential densities used in INTASA(1974). In this report, weighted averages for the New York and New Jersey part are obtained as well as for the study areas as a whole, where the weights are proportional to the population of the counties in each area. The results are presented in the top half of Table 3-7. For the Northern New Jersey and New York City System service subareas, the values obtained for the corresponding parts of the New York study area are used. For the Delaware River Basin, no direct data is available so that data from the New York study area was used as representative for the Delaware River Basin. The resulting assumptions are presented in the bottom part of Table 3-7.

Table 3-7 Net Residential Density in 1970 and 2025 (dwelling units per acre)

	1970	2025
New York Study Area as Developed in INTASA (1974)	4.7	6.8
New York	6.8	6.8
New Jersey	3.7	4.3
Connecticut	2.1	1.9
Delaware River Basin	4.5	5.0
Northern New Jersey Subarea	3.7	4.3
New York City System Subarea	6.8	6.8

The number of people per residence needed for per capita calculations is assumed equal to the value of 3.1 in 1970 and 2.75 in 2025. These are obtained through comparison with the area covered by Tri-State(1973) where the first is the average for the area and the latter is a planning target at capacity (Tri-State (1973)).

2. Lawn Sprinkling Requirements

The potential lawn sprinkling requirements of 13 areas in the East with metered public water and public sewers, based on evapotranspiration and effective precipitation, is about 15.0 inches per year per irrigable acre according to data presented by Linaweaver, et. al.(1967). The actual lawn sprinkling, however, was about 7.0 inches per year, while for areas with similar potential requirements but with septic tanks, the actual sprinkling decreased to about 1.0 inch per year. Based on these data, the potential requirement (namely the 15.0 inches per year) was reduced by a factor of 0.5.

Data for Increased Industrial Use --

1. Water Intake Per Employee

The water intake in gallons per day per employee, for establishments using more than 20 million gallons per year, is presented in Table 3-8. The data is disaggregated by state and by the six major industrial classifications used for this study. These estimates are obtained by dividing the values for total water intake of each state by values for total number of employees in establishments using more than 20 million gallons annually, USDC (1967), and rounding to the next 100 gallons. The values are based on 1967 data which are considered to be sufficiently accurate given the uncertainties in much of the other assumptions and data. (The final report of the 1972 Census of Manufacturers on Water Use is not available yet and is scheduled for release in 1975.)

Table 3-8 Water Intake Per Employee in Gallons Per Day (1967) for Establishments Using More Than 20 Million Gallons Per Year

Two-Digit Industrial Classification	Delaware	Pennsylvania	New Jersey	New York	Delaware River Basin
20 Food	1,100	2,800	2,000	2,700	2,400
22 Textile	N.A.	900	1,700	1,000	1,300
26 Paper	39,800	12,300	6,800	14,100	9,600
28 Chemicals	15,900	16,000	9,100	11,700	16,000
29 Petroleum	N.A.	32,500	64,300	64,300*	32,500
33 Primary Metals	N.A.	16,000	3,400	9,500	16,000

* Assumed same as for New Jersey; no direct estimate available because of disclosure problems.

For the Northern New Jersey and New York City System parts of the New York Metropolitan Area, the respective state estimates are used. For the Delaware River Basin, the estimates are based on how much of each industry can be expected in the different states. As a result, an average between New Jersey and Pennsylvania is used for food, textiles and paper and the value for Pennsylvania is used for chemicals, petroleum and primary metals.

2. Present and Future Employment Data

The 1972 employment of all establishments is presented for subareas and industrial groups in Table 3-9. These values are obtained from the basic economic data gathered for this study for economic subregions. The weights used for economic subregions C through H are presented in Table 3-2 and are based on present distribution of population over the area. The weights used for economic subregions A and B are presented in Table 3-10 and are based on present distribution of employment in each industry group over the area developed from County Business Patterns and Census Data.

Table 3-9 Number of Employees by Subarea and Industry Group (1972)*

	Industry	Delaware River Basin	Supplemental Sub Areas New Jersey	New York
20	Food	63.2	45.0	59.0
22	Textiles	41.0	25.5	43.2
26	Paper	29.5	26.7	31.1
28	Chemicals	79.3	102.8	45.7
29	Petroleum	16.8	6.1	7.6
33	Primary Metals	64.2	30.1	13.1

* Figures in thousands.

Table 3-10 Percentage of Employment in Economic Subregions A and B Allocated to Subareas

Industr	Economic Subregion A		Economic Subregion B	
	NJ Subarea	NY Subarea	NJ Subarea	NY Subarea
Food	43.7	56.3	-	19.5
Textiles	38.7	61.3	-	56.0
Paper	47.2	52.8	-	37.5
Chemicals	69.7	30.3	-	22.6
Petroleum	35.1	64.9	-	-
Primary Metals	70.2	29.8	-	6.8

The employment data and water intake per employee is used to calculate industrial per capita demand. While the employment data is based on 1972 estimates and the data for water demand per employee are for 1967, it is considered that the calculated industrial per capita data using these estimates is a reasonable base for analysis.

The percentage of employees in establishments with water use of more than 20 million gallons per year is given in Table 3-11. These values are obtained from the 1967 Census of Manufacturers by comparing for each state and industry group, the employment in establishments with more than 20 million gallons per year water use, USDC (1967), with the total employment, USDC (1967). For the New Jersey and New York part of the supplemental service subareas of the New York Metropolitan Area, the respective state estimates are used.

For the Delaware River Basin, the estimates are based on how much of each industry can be expected in the different states. As a result, an average between New Jersey and Pennsylvania is used for food, textiles and paper and the value for Pennsylvania is used for chemicals, petroleum and primary metals.

Table 3-11 Percentage of Employees in Establishments Using More Than 20 Million Gallons Per Year

Industry	Pennsylvania	New Jersey	New York	Delaware River Basin
Food	32.8	40.2	36.1	36.5
Textiles	16.8	12.5	12.4	14.6
Paper	35.1	24.8	23.2	30.0
Chemicals	60.4	60.8	49.8	60.4
Petroleum	77.5	68.2	68.2*	77.5
Primary Metals	81.9	48.9	73.0	81.9

*Assumed same as for New Jersey; no direct estimate available because of disclosure problem.

High, medium and low employment projections for 1975-2025 are presented in Tables 3-12a, b and c, respectively. These are derived from the populations for the economic subregions. The weights used are the same as for 1972 employment and are presented in Tables 3-2 and 3-10.

Table 3-12a Employment Projections by Subareas and Industries - HIGH*

SIC	Industries	Year	Delaware River Basin	Supplemental Service Area New York Metro New Jersey	New York
20	Food	1985	68.8	59.2	79.4
		2005	63.8	43.9	60.4
		2025	60.7	39.5	50.1
22	Textiles	1985	28.0	27.7	47.1
		2005	21.7	17.7	31.2
		2025	18.4	15.5	27.3
26	Paper	1985	34.3	30.2	36.9
		2005	35.6	30.2	38.3
		2025	46.9	28.6	38.7
28	Chemicals	1985	120.7	127.8	60.6
		2005	148.2	146.1	70.8
		2025	180.7	160.8	79.5
29	Petroleum	1985	22.9	8.5	15.5
		2005	20.0	6.5	11.9
		2025	18.6	7.2	13.1
33	Primary Metals	1985	52.2	22.4	11.4
		2005	46.1	19.2	9.9
		2025	43.1	14.1	7.7

*Figures in thousands

Table 3-12b Employment Projections by Subareas and Industries - MEDIUM*

SIC	Industries	Year	Delaware River Basin	Supplemental Service Area New York Metro: New Jersey	Supplemental Service Area New York Metro: New York
20	Food	1985	66.8	58.1	77.8
		2005	59.3	41.3	56.8
		2025	53.9	35.5	49.2
22	Textiles	1985	27.4	27.2	46.2
		2005	20.1	16.7	29.2
		2025	16.2	13.9	24.4
26	Paper	1985	33.4	31.5	38.3
		2005	32.0	28.5	35.9
		2025	41.7	25.7	34.4
28	Chemicals	1985	117.5	125.3	59.3
		2005	138.1	137.8	66.4
		2025	162.3	144.6	71.0
29	Petroleum	1985	22.5	8.4	15.2
		2005	18.8	6.2	11.2
		2025	16.8	6.4	11.7
33	Primary Metals	1985	50.8	23.4	11.7
		2005	42.8	18.1	9.3
		2025	37.5	12.7	6.8

*Figures in thousands

Table 3-12c Employment Projections by Subareas and Industries - LOW*

SIC	Industries	Year	Delaware River Basin	Supplemental Service Area New York Metro: New Jersey	Supplemental Service Area New York Metro: New York
20	Food	1985	56.4	50.5	67.7
		2005	46.1	36.1	48.7
		2025	34.5	19.0	26.2
22	Textiles	1985	23.9	23.8	40.3
		2005	18.0	15.9	27.3
		2025	10.4	6.8	12.2
26	Paper	1985	30.3	21.9	26.7
		2005	29.1	15.7	19.3
		2025	25.3	12.3	15.4
28	Chemicals	1985	104.7	112.7	53.0
		2005	110.1	115.0	53.9
		2025	112.6	108.7	50.8
29	Petroleum	1985	20.5	8.2	15.1
		2005	17.5	7.3	13.5
		2025	15.7	6.1	11.3
33	Primary Metals	1985	47.2	21.6	10.7
		2005	36.6	17.3	8.6
		2025	25.0	12.1	6.1

*Figures in thousands

3. Present and Future Gross Product Originating Per Employee

The present and future gross product originating per employee is presented in Table 3-13. These values are based on national averages as projected in OBERS, Series E, and are obtained as the product of the earnings per employee and the projected ratios of gross product originating over earnings, USWRC(1974). The earnings per employee are derived by dividing the number of employees in a particular industry into the earnings of that industry. The same values are used for the high, medium and low projections.

Table 3-13 Gross Product Originating Per Employee*

	1970	1985	2005	2025
Food	$12.59	$17.29	$29.18	$45.77
Textiles	9.42	13.97	25.29	42.13
Paper	13.72	18.79	30.75	46.84
Chemicals	24.42	35.69	59.91	90.34
Petroleum	24.55	35.81	65.96	106.03
Primary Metals	13.67	18.35	26.54	37.04

*Figures in dollars.

Data for Increased Recirculation and Technological Change --

Present recirculation rates, by industry, for the U.S. and for the four states in the study area are presented in Table 3-14. These values are obtained

Table 3-14 Present Recirculation Rates

	1967 Water Use in Manufacturing					Middle Atlantic States 1970
	USA	Delaware	New Jersey	New York	Pennsylvania	
Food	1.66	1.55	2.03	1.30	1.40	1.46
Textiles	2.13	N.A.	1.05	1.42	1.12	1.01
Paper	2.90	1.00	7.25	2.04	2.94	2.34
Chemicals	2.10	1.65	1.47	1.48	1.46	1.57
Petroleum	5.08	N.A.	2.03	N.A.	3.24	2.20
Primary Metals	1.55	N.A.	1.62	1.80	1.36	1.42
Total	2.31	1.42	1.94	1.75	1.62	1.61

from the Water Use in Manufacturing Census in 1967, USDC (1967), by dividing gross water usage by water intake. The recirculation rates are also presented in Table 3-15 for the Middle Atlantic States. These are based on data for 1970 provided by the Department of Commerce. The recirculation rates for the Middle Atlantic States, which may be assumed representative of the study area, are lower than the national average.

For the "basic" demand projections as defined in section III.B.1(a) it is assumed that these rates are increasing linearly and will have reached the present national average by 2005[1]. In the alternative demand projections based upon greater and lesser degrees of implementation, appropriately greater and lesser recirculation rates are utilized. The former reflect the recirculation factors presented in INTASA (1974) and are used together with the average recirculation rates for the U.S. in 1967. It is noted that except for chemicals and primary metals, the assumed increases are approximately linear.

Technological change may result in a reduction in water use per unit of production. For the "basic" case, no such reduction is assumed while the modification for the other demands are assumed about the same as that assumed by INTASA (1974). An examination of available data suggests that currently water use per value of output in the overall study area is lower than that for the nation as a whole. Partly for this reason, it is assumed in the "basic" case that no further technological improvements are made beyond those already accounted for in the other recirculation estimates.

---

1. Includes effect of increased recirculation due to implementation of P.L. 92-500.

Table 3-15 Present and Projected Recirculation Rates

	USA	Middle Atlantic States	Under "Basic" Demand Conditions			With Greater Degree of Implementation of Demand Reducing Policies*		
	1967	1970	1985	2005	2025	1985	2005	2025
Food	1.66	1.46	1.55	1.66	1.77	1.66	2.08	2.49
Textiles	2.13	1.01	1.50	2.13	2.77	2.13	3.30	4.47
Paper	2.90	2.34	2.58	2.90	3.22	2.90	3.77	4.64
Chemicals	2.10	1.57	1.80	2.10	2.40	2.10	5.25	8.40
Petroleum	5.08	2.20	3.43	5.08	6.73	5.08	10.16	15.24
Primary Metals	1.55	1.42	1.49	1.55	1.61	1.55	2.40	3.25

* Per section III.B.1(a)

Further, in developing these estimates for making projections, no attempt has been made to otherwise constrain the values based on cost factors. Also, no distinction is made between recirculation rates for self-suppled and public supplied uses. The projected reductions for both the "basic" and "increased implementation" cases are presented in Table 3-16 and compared with the reductions presented in INTASA (1974).

Table 3-16 Projected Reductions in Water Use Per Unit of Production in % of 1970 Usage

	"Basic"			"Increased Implementation"			Reductions in 2025 Using Technological Change Factors from INTASA(1974)
	1985	2005	2025	1985	2005	2025	2025
Food	100	100	100	95	87	80	77
Textile	100	100	100	95	87	80	77
Paper	100	100	100	93	84	75	71
Chemicals	100	100	100	89	75	60	59
Petroleum	100	100	100	92	81	70	67
Primary Metals	100	100	100	95	87	80	77

Data for Water Conserving Devices and Policies --

Estimates for the percent of domestic use, its projected savings using appliances with water conserving deviced, and total resulting savings as a percentage of domestic use are presented in Table 3-17 for each domestic function. These estimates are obtained from a study made by Howe, et. al.(1971). An average value of estimated domestic demand of 80 gpcd is assumed based on observations by Linaweaver, et. al.(1967).

This results in a reduction of 20 gpcd for persons living in a home using appliances with water conserving devices, where the model used assumes that only new homes will be provided with these water saving devices. In the "basic" case, it is assumed that the number of new homes using water conserving devices will be negligible, and in the other case it is assumed that 50% of all new homes will achieve the 20 gpcd savings.

With universal metering, the metering ratios for the counties comprising New York City are presented in Table 3-18. These are obtained from a study made by the Temporary State Commission on Water Supply Needs of Southeastern New York (1973). The parameter reflecting a decrease in demand per capita as a result of increasing the metering ratio by one percent is obtained from the same study and for the average case is equal to 0.679. This parameter is based on a regression between non-industrial demand and metering ratios for various cities in the United States where part of the differences may be attributable to other than metering ratios. As such, the value of 0.679 is subject to a fair amount of uncertainty and higher and lower values should be considered in sensitivity evaluations.

Table 3-17 Savings from Water Conserving Devices for Domestic Use.

	Percent of Domestic Use 1970	Percent Savings On Each Use	Total Percent Savings In Domestic Use
Drinking and Cooking	5	0	0
Bathing and Personal other than shower	12	0	0
Shower	18	40.0	7.2
Laundry and Dishes	20	5.0	1.0
Toilet	45	40.0	18.0

Table 3-18 Metering Ratios[1] with Universal Metering in New York City.

	Metering Ratio in Percent
Bronx and Manhattan	13.86
Brooklyn	30.76
Queens	22.64
Richmond	59.56

[1] Metered water divided by total usage.

III.B.1(e) Demand Projections

As discussed earlier, demand projections are made for high, medium and low growth and for "basic" and "increased implementation" cases. The characteristics that differentiate the projections are as follows:

> The "Increased Implementation" case differs from the "Basic" case in the following aspects:
>
> - in the "basic" case it is assumed that recirculation rates by 2005 will be equal to the present national average and that there are no improvements in technology resulting in reduced water use per unit of production. While recirculation will have to be increased substantially in some cases to meet present national averages, it is believed that this will be accomplished by 2005 without the imposition of specific policies by the government, especially since P.L. 92-500 is presently resulting in increased recirculation.
>
> - in the "increased implementation" case, it is assumed that recirculation rates will be equal to the present national average by 1985, then will increase to rates based on recirculation factors found by INTASA(1974). It is furthermore assumed that further reductions in water use per unit of production as a result of improved technology will be realized (see also data on recirculation and technological change in a later section)[1].
>
> - from the "basic" case, a policy change resulting in a 50% reduction in lawn sprinkling is assumed.
>
> - no water conserving devices are assumed in the "basic" case, while in the other case it is assumed that water conserving devices resulting in a 20 gpcd reduction will be used effectively in 50% of new homes.

Tables 3-19, 20 and 21 summarize the results for the high, medium and low demand projections. Values for years 1975, 1995 and 2015 are obtained by linear interpolation. Table 3-19 presents the total demand in MGD

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1. The "increased implementation" case is only an example of a large number that could be assumed.

Table 3-19a "Basic" Demand in MGD for Study Area and Subareas[1]

	1970	1975	1985	1995	2005	2015	2025
HIGH							
Delaware River Basin	3,460	3,857	4,651	5,550	6,507	7,700	8,928
Northern New Jersey Subarea	2,156	2,343	2,716	3,100	3,518	4,000	4,507
New York City System Subarea	3,341	3,633	4,217	4,650	5,092	5,650	6,197
Total	8,958	9,833	11,584	13,300	15,116	17,350	19,632
MEDIUM							
Delaware River Basin	3,460	3,815	4,525	5,250	6,054	7,100	7,986
Northern New Jersey Subarea	2,156	2,328	2,672	3,050	3,320	3,650	4,047
New York City System Subarea	3,341	3,612	4,154	4,450	4,784	5,050	5,552
Total	8,958	9,755	11,351	12,750	14,159	15,800	17,585
LOW							
Delaware River Basin	3,460	3,650	4,152	4,550	5,114	5,500	5,906
Northern New Jersey Subarea	2,156	2,250	2,521	2,750	3,035	3,050	3,384
New York City System Subarea	3,341	3,500	3,965	4,200	4,483	4,650	4,813
Total	8,958	9,400	10,638	11,500	12,632	13,200	14,103

1. See introduction to this subsection for assumptions of the "basic" projections.

Table 3-19b "Increased Implementation" Demand in MGD for Study Area and Subareas[1]

	1970	1975	1985	1995	2005	2015	2025
HIGH							
Delaware River Basin	3,460	3,600	3,988	3,320	3,756	3,800	3,932
Northern New Jersey Subarea	2,156	2,180	2,349	2,225	2,206	2,225	2,281
New York City System Subarea	3,341	3,400	3,811	3,830	4,008	4,200	4,376
Total	8,958	9,180	10,148	9,475	9,970	10,225	10,589
MEDIUM							
Delaware River Basin	3,460	3,600	3,886	3,650	3,494	3,500	3,521
Northern New Jersey Subarea	2,156	2,180	2,311	2,180	2,081	2,000	2,048
New York City System Subarea	3,341	3,400	3,746	3,780	3,767	3,850	3,922
Total	8,958	9,180	9,943	9,610	9,341	9,350	9,491
LOW							
Delaware River Basin	3,460	3,496	3,569	3,283	2,997	2,800	2,743
Northern New Jersey Subarea	2,156	2,160	2,188	2,009	1,942	1,950	1,844
New York City System Subarea	3,341	3,423	3,590	3,562	3,534	3,540	3,548
Total	8,958	9,079	9,348	8,854	8,473	8,390	8,134

1. See introduction to this subsection for assumptions for the "increased implementation" projections.

Table 3-20 Projections of Increased Per Capita Demand for Study Area and Subareas (in gpcd)

	1970	1975[1,2]	1985	1995[2]	2005	2015[2]	2025
HIGH							
Delaware River Basin	501	540	582	630	672	730	807
Northern New Jersey Subarea	460	490	544	582	629	678	731
New York City System Subarea	301	323	353	363	377	393	413
Average	395	423	465	495	526	562	609
MEDIUM							
Delaware River Basin	501	540	582	628	677	723	800
Northern New Jersey Subarea	460	491	546	583	630	678	731
New York City System Subarea	301	323	354	363	377	393	414
Average	395	423	465	495	526	561	607
LOW							
Delaware River Basin	501	533	569	614	653	686	703
Northern New Jersey Subarea	460	480	524	570	601	630	638
New York City System Subarea	301	318	346	363	373	380	381
Average	395	416	452	480	507	528	536

1 These are projected estimates.
2 Based upon linear extrapolations.

Table 3-21a Projected Changes in Per Capita Demand in 2025 for "Basic" Case (in gpcd)

	Total Changes in Per Capita Demand	Per Capita Changes by Component: Extension of Water and Sewer Service	Sprinkling Due to Density Changes	Increased Use of Domestic Appliances and Others	Industry w/o Increased Recirculation or Technological Changes	Increased Recirculation & Technological Changes	Water Conserving Devices & Policies
HIGH							
Delaware River Basin	306	2	-4	16	648	-356	-
North N.J. Subarea	271	2	-7	17	607	-347	-
NYC System Subarea	112	1	0	18	255	-162	-
Average	214	2	-3	17	457	-264	-
MEDIUM							
Delaware River Basin	299	2	-4	16	639	-355	-
North N.J. Subarea	271	2	-7	17	605	-346	-
NYC System Subarea	113	1	0	18	255	-162	-
Average	212	2	-3	17	455	-264	-
LOW							
Delaware River Basin	202	1	-4	16	515	-326	-
North N.J. Subarea	178	2	-7	17	465	-299	-
NYC System Subarea	80	1	0	18	211	-150	-
Average	141	1	-3	17	359	-236	-

Table 3-21b Projected Changes in Per Capita Demand in 2025 for "Increased Implementation" Case (in gpcd)

	Total Changes in Per Capita Demand	Per Capita Changes by Component: Extension of Water and Sewer Service	Sprinkling Due to Density Changes	Increased Use of Domestic Appliances and Others	Industry w/o Increased Recirculation or Technological Changes	Increased Recirculation & Technological Changes	Water Conserving Devices & Policies
HIGH							
Delaware River Basin	-146	2	-2	16	648	-807	-3
North N.J. Subarea	- 89	2	-3	17	607	-709	-3
NYC System Subare	- 10	1	0	18	255	-281	-3
Average	- 72	2	-1	17	457	-544	-3
MEDIUM							
Delaware River Basin	-148	2	-2	16	639	-801	-3
North N.J. Subarea	- 90	2	-3	17	605	-708	-3
NYC System Subarea	- 8	1	0	18	255	-281	-3
Average	- 72	2	-1	17	455	-542	-3
LOW							
Delaware River Basin	-175	1	-2	16	515	-702	-3
North N.J. Subarea	-113	2	-3	17	465	-591	-3
NYC System Subarea	- 21	1	0	18	211	-248	-3
Average	- 89	1	-1	17	359	-462	-3

for the entire study area and for the Delaware River Basin, the Northern New Jersey service subarea, and the New York City System subarea. The projected increase in per capita demand is presented in Table 3-20 for the entire study area and its three subareas. The differences between high, medium and low are mainly due to differences in ratios between employment and population in the different industries. This is illustrated by Table 3-22. Another but less important reason is the difference assumed in percentage of population served by public water and sewers in the Delaware River Basin.

The projected changes on total per capita demand by 2025, together with the components that make up this change, are presented in Tables 3-21a and b. The most important components of change are the ones connected with industrial demand.

If a higher or increased degree of implementation with respect to demand reducing measures could be achieved, 2025 demand for the "medium" growth level is estimated at only 9,491 MGD as noted in Table 3-19b as opposed to the 17,585 MGD noted in Table 3-19a. If the policies implicit in the "basic" demand forecast cannot be implemented, then that 2025 figure may exceed 20,000 MGD according to other analyses made as part of this study. The per capita demands outlined in Table 3-20 will exhibit similar variations.

Between 1985 and 2005, there is a substantial reduction in per capita demand for the "increased implementation" case. This can be explained by the sharp

Table 3-22 Low Population and Employment as Percentage of High Population and Employment in 2025 (in thousands)

	Delaware River Basin			New Jersey			New York		
	Low	High	Low as % of High	Low	High	Low as % of High	Low	High	Low as % of High
Population	8,399	11,068	76	5,305	6,165	86	12,628	15,000	86
Industry									
Food	34.5	60.7	57	19.0	39.5	48	26.2	50.1	52
Textiles	10.4	18.4	57	6.8	15.5	44	12.2	27.3	45
Paper	25.3	46.9	54	12.3	28.6	43	15.4	38.7	40
Chemicals	112.6	180.7	62	108.7	160.8	68	50.8	79.5	64
Petroleum	15.7	18.6	84	6.1	7.2	85	11.3	13.1	86
Primary Metals	25.0	43.1	58	12.1	14.1	86	6.1	7.7	79

increase in recirculation rates for the chemicals and primary metals as illustrated in Figures 3-3a and b.

The projected changes on total per capita demand by 2025, together with the components that make up this change, are presented in Tables 21a and b for the "basic" and "increased implementation" cases, respectively. The most important components of change are the ones connected with industrial demand, in particular the chemical and petroleum industries. The demand of these industries is significantly higher than any other category of demand. Table 3-23 summarizes in MGD the reductions in demand that would result with the "increased implementation" case. This table contains a breakdown for only the Northern New Jersey and New York City System subareas because demand reduction, per se, is not relevant to water supply in the Delaware River Basin itself. As discussed previously, only a reduction in projected future consumptive use will enhance the overall water supply in the Delaware River Basin.

Categories of reduction for the Northern New Jersey and New York City System subareas are the same except the latter subarea shows the reduction in demand that would result from the imposition of a policy requiring universal metering.

Table 3-23 indicates that by far the greatest potential for demand reduction lies in increased recirculation in the major water using industries. In particular, increased recirculation in the chemical and petroleum industries could result in a demand reduction of nearly 2,000 MGD in New Jersey alone by the year 2025. However, these reductions, while large, must be considered

Table 3-23

REDUCTION IN DEMAND IN "INCREASED IMPLEMENTATION" CASE IN MGD

	1970	1975	1985	1995	2005	2015	2025
I. Northern New Jersey Subarea							
Recirculation	0	0	362	803	1242	1623	2004
1) Food	0	0	7	14	20	28	37
2) Textile	0	0	2	2	2	2	3
3) Paper	0	0	12	22	31	41	51
4) Chemicals	0	0	206	592	978	1294	1609
5) Petroleum	0	0	131	159	187	230	273
6) Primary Metals	0	0	4	14	24	28	31
Reduction in Sprinkling	0	0	86	88	89	89	90
Water Conserving Devices	0	0	4	6	9	12	14
TOTAL	0	0	452	897	1340	1724	2108
II. New York City System Subarea							
Recirculation	0	0	390	632	994	1293	1595
1) Food	0	0	11	22	34	48	62
2) Textile	0	0	2	2	2	2	2
3) Paper	0	0	28	51	74	102	131
4) Chemicals	0	0	103	300	496	664	833
5) Petroleum	0	0	237	228	338	418	499
6) Primary Metals	0	0	9	29	50	59	68
Metering	0	0	131	138	142	147	151
Water Conserving Devices	0	0	9	16	22	28	35
Reduction in Sprinkling	0	0	101	107	112	118	124
TOTAL	0	0	631	893	1270	1588	1905

in the light of the actual portion of industrial demand that will be satisfied by public supplies as discussed in section III.D.5 and XII.B.10.

III.B.1(f) Sensitivity Evaluations

The sensitivity of water demand to changes in components of demand follow.

Industrial Demand --

The sensitivity of per capita demand to changes in several problem parameters for industrial demand is presented in Tables 3-24a and b. The cases considered are the following:

For the "basic" case with medium growth, the increase in recirculation rates is reduced such that the national averages are achieved in 2025 as presented in Table 3-24b. The result is an increase of 58 gpcd.

For the "increased implementation" case, the recirculation rates are reduced by a factor .9 and .8, which results in an increase of 8 and 18 gpcd, respectively. About half of this increase is due to chemicals.

For the "increased implementation" case, the recirculation rates after 1985 are assumed to be a linear extrapolation of the rates between 1970-1985. As can be seen from Table 3-25 and Figure 3-5b, this results in a substantial reduction of the rates for 2005 and 2025. The result is an increase of 58 gpcd.

For the "basic" case and medium growth, no additional increase in water use by the chemical and petroleum industries is assumed for the Delaware River Basin. The result is a decrease in per capita demand for 2025 of 207 gpcd, and a relative constant per capita demand for the entire planning period.

Estimated Sprinkling Use --

The estimated sprinkling use per capita for the "basic" case and medium growth is presented in Table 3-26. The values decrease over time as net residential density increases and increase over time as number of people per dwelling unit decreases. Thus, even though the residential density in the New York City System subarea is assumed constant, the per capita sprinkling demand increases slightly because the number of people per dwelling unit is decreasing.

Table 24a Sensitivity of Per Capita Demand in 2025 to Alternative Recirculation Rates - Medium Growth

	Average Per Capita	Net Industrial Total	Food	Textile	Paper	Chemicals	Petroleum	Primary Metals
"Basic" Case	607	191	6.2	-.3	13.2	159.4	13.9	-1.5
National Averages Reached in 2025	665	249	7.0	-.2	15.9	192.2	33.1	.2
"Increased Implementation"	328	-87	.6	-.6	2.0	-32.8	-27.2	-29.6
Recirculation Rates 90% of values assumed	336	-79	1.0	-.6	2.9	-28.9	-25.4	-28.3
Recirculation rates 80% of values assumed	346	-69	1.5	-.5	3.8	-24.2	-23.2	-26.8
Linear extrapolation of 1970-1985 recirculation rates for chemicals to 2025	386	-29	.6	-.6	2.0	25.5	-27.2	-29.6

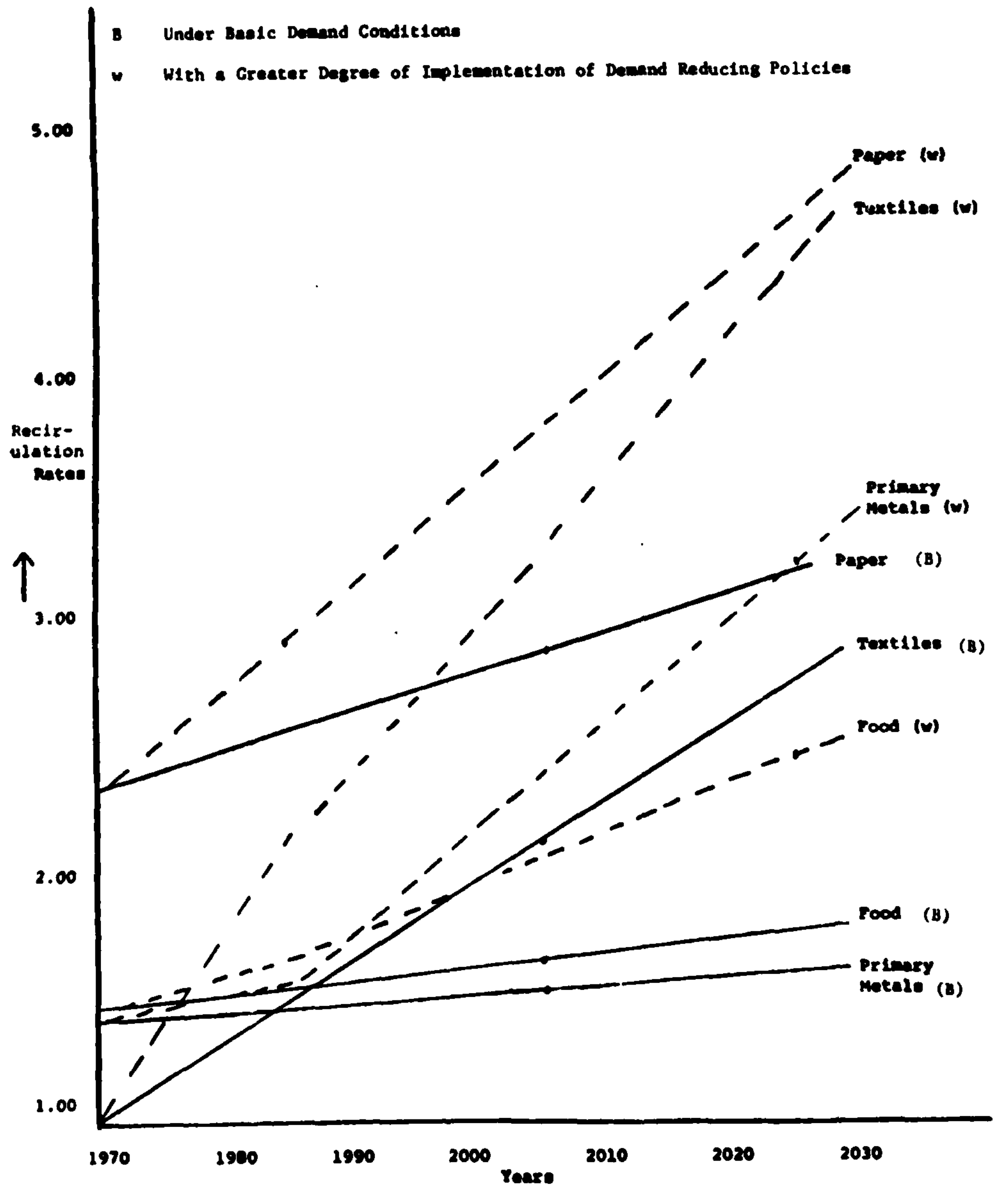
Table 3-24b Sensitivity of Per Capita Demand To No Additional Water Use For Chemicals and Petroleum In Delaware River Basin Subarea for Medium Growth and "Basic" Demand Case

	1970	1985	2005	2025
Basic Medium Growth Case	395	465	526	607
Same but no added water use chemicals & petroleum in Delaware River Basin	395	397	399	400

Table 3-25 Recirculation Rates Used For Sensitivity Study

	National Averages Reached in 2025			Linear Extrapolation of 1970-1985		
	1985	2005	2025	1985	2005	2025
Food	1.51	1.59	1.66	Same as "National Averages" case		
Textiles	1.31	1.72	2.13	Same as "National Averages" case		
Paper	2.49	2.70	2.90	Same as "National Averages" case		
Chemicals	1.71	1.91	2.10	2.10	2.75	3.40
Petroleum	2.99	4.04	5.08	Same as "National Averages" case		
Primary Metals	1.47	1.51	1.55	Same as "National Averages" case		

EXTRAPOLATION OF RECIRCULATION RATES:
FOOD, TEXTILES, PAPER AND PRIMARY METALS



EXTRAPOLATION OF RECIRCULATION RATES: CHEMICALS & PETROLEUM

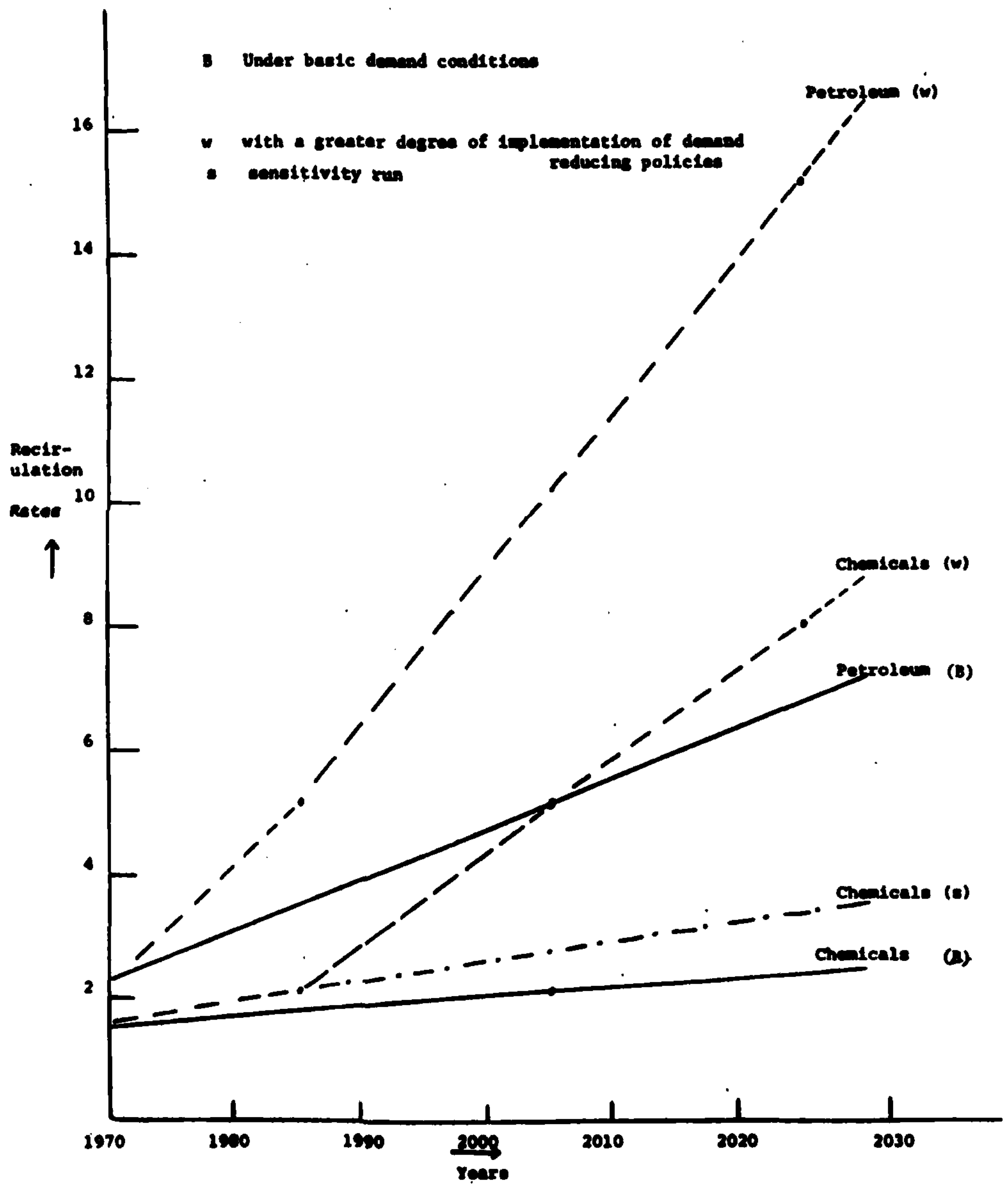


Table 3-26 Estimated Per Capita Sprinkling Use for Medium Growth in "Basic" Case

	1985	2005	2025
Delaware River Basin	27.9	27.3	27.3
Northern New Jersey Subarea	35.2	33.6	33.0
New York City System Subarea	17.3	17.6	18.5
Average	24.0	24.0	24.0

III.B.1(g) Comparison with Other Demand Projections

To compare the study projections, there is first presented a comparison of the projections for the Delaware River Basin followed by a comparison of projections for the two supplemental subareas.

a. Delaware River Basin

The present projections for the Delaware River Basin are compared with those made by the Corps in 1955 and by the Delaware River Basin Commission in 1972. For the purposes of comparison, the projections made by the Corps were converted to a total per capita including self-supplied industrial demands. The "basic" Corps projections assume no industrial recirculation while the "increased implementation" projection assumes recirculation rates as specified in U.S.C. of E. (1962, Vol. IX).

The results of these comparisons are shown in Figure 3-6. Inasmuch as the projections originally developed by the Corps of Engineers were based on economic subregions rather than on the actual River Basin boundaries, the only meaningful comparison that can be made is on a per capita basis.

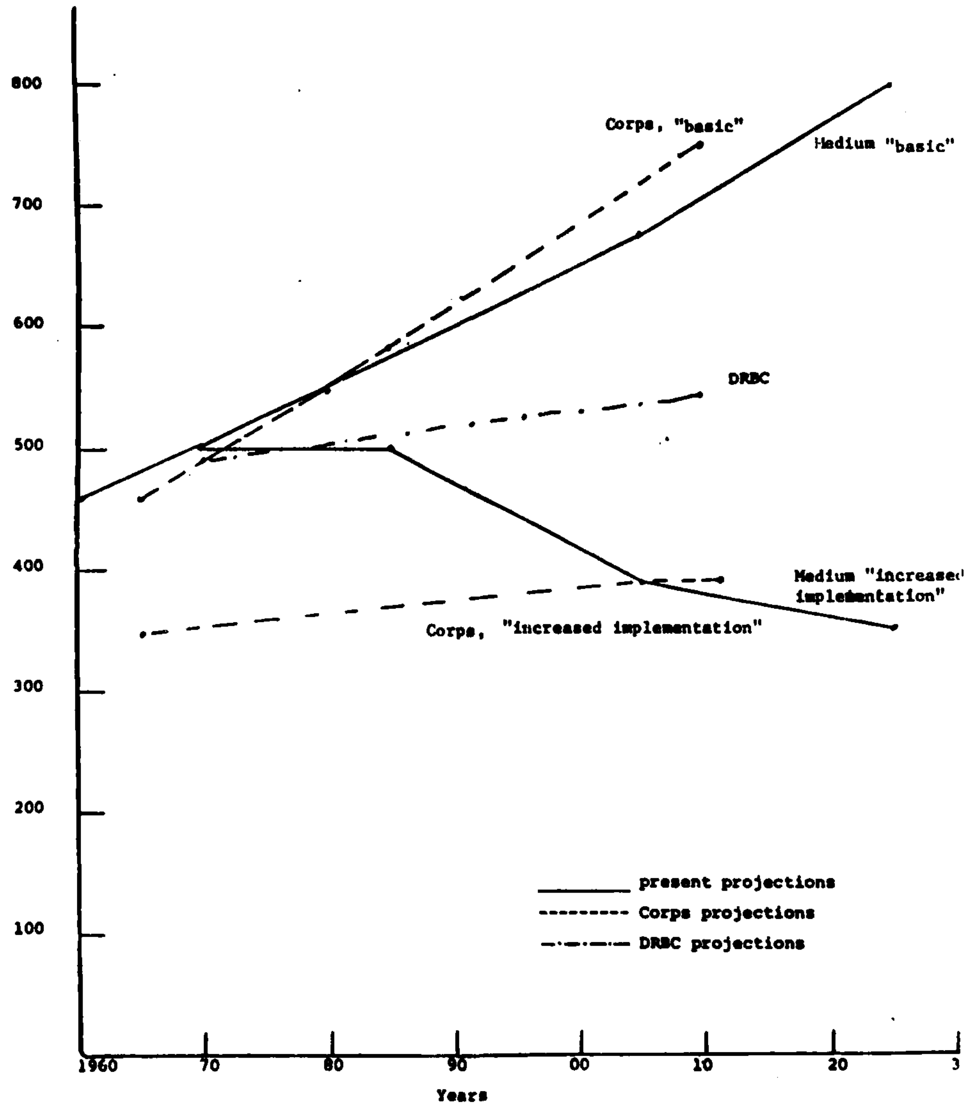
Several observations can be made from Figure 3-6 as follows:

> The Corps "basic" projections and the medium "basic" projections made in this study appear to be fairly close through the period 1980-2000. At about that point, the Corps projections illustrate a higher per capita demand.
>
> The Corps "increased implementation" projections and the medium "increased implementation" projections developed in this study show a significant per capita difference in the early projection years but tend to converge around the year 2000. This can probably best be explained by the fact that the Corps apparently was assuming higher recirculation rates in the early part of the projection period.
>
> The DRBC projections appear to fall midway between the medium "increased implementation" and "basic" projections developed in this study.

b. Supplemental Subareas

For the supplemental subareas, the present projections can be compared with those made by the Corps in 1974 (INTASA (1974)). The basis for comparisons must, however, be made not on the final total or per capita demands, but on the basis of the assumptions for the main components of change. As such, meaningful comparisons can be made with respect to the apparent differences and judgments made as to which projections are most relevant from a planning perspective.

DEMAND PROJECTIONS FOR DELAWARE RIVER BASIN



Both the Corps and current projections used essentially the same methodology, namely modelling future changes to per capita demands. The source of differences in comparison of these projection sets arises both from the data base and assumptions on key parameters. These differences and where applicable similarities are described below together with an indication of their impact.

Service Area Size - The service area configuration for the original Corps projections is somewhat larger that that used in the present study. This is illustrated by a comparison of the 1970 population estimate.

	Corps Projections	Current Projections
New York City System Subarea	12,217,000	11,101,000
Northern New Jersey Subarea	5,135,000	4,688,000

This difference would manifest itself in generally higher demand projections in the Corps report assuming no major differences in the population growth assumptions.

Base Demand Estimates - In the Corps projections, only publicly supplied water demands are projected. In the current study self-supplied industrial and self-supplied domestic and commercial are included in the base estimate and are projected in the future. There is shown below a comparison of the base (1972) per capita data reflecting these differences.

	Current Study	Corps Study
Northern New Jersey Subarea		
Total	460	-
Self-Supplied Industrial	320	-
Publicly Supplied Industrial	26	142
Domestic - Commercial	114	
New York City System Subarea		
Total	301	-
Self-Supplied Industrial	142	-
Publicly Supplied Industrial	14	158
Domestic - Commercial	145	

As noted above, the current and Corps study estimate of base domestic-commercial and industrial per capita are roughly the same. The major difference is the inclusion of self-supplied industrial projections in the current study.

Domestic - Commercial Use Assumptions - These assumptions relate to the parameters of public water and sewer systems, water consuming appliances, sprinkling and water conserving devices. With minor variations, the assumptions made with respect to future changes in these parameters are essentially the same in both the Corps and the current projections. This when related to the fact that the base domestic-commercial per capita in both studies are similar which suggests that on a disaggregated basis, the domestic-commercial use would roughly be the same when projected on a per capita rate.

Industrial Use Assumptions - The most striking difference in the Corps and the current projections centers on differences in industrial water use. First, as noted above, the Corps did not predict changes in self-supplied use. In effect, the assumption is made that all future industrial requirements would be publicly supplied with no explicit assumption made with respect to the self-supplied base. This could either remain constant over time or be reduced. Beyond this, assumptions are made in this study with respect to industrial recirculation rates. Shown below are the end year recirculation rates used in both studies.

	2025 Current Projections		2025 Corps Projections
	"Increased Implementation"	"Basic"	
Food	2.49	1.77	2.49
Textiles	4.47	2.77	4.47
Paper	4.64	3.22	4.64
Chemicals	8.40	2.40	8.40
Petroleum	15.24	6.73	15.24
Primary Metals	3.25	1.61	3.26

The above suggests that given a proportional decline in self-supplied use, if added to the Corps projections, then the industrial water demands in the Corps projections would be about the same as the current "increased implementation" series and significantly less than current "basic" projections. This assumes approximately the same levels of overall economic activity in both studies.

III.B.2 ELECTRIC POWER COOLING

The methodology employed to estimate water requirements for electric power cooling is described in Chapter V. Table 3-27 summarizes withdrawal and consumptive use requirements for power plants in the Delaware Basin. It is assumed that power plants in the Northern New Jersey and New York City System subareas are presently self-supplied and will continue to be self-supplied in the future, and thus will not represent a demand on the water resources of the Delaware Basin.

Table 3-27 Electric Power Cooling Requirements for the Delaware Basin (MGD)

YEAR	LOW		MOST PROBABLE		HIGH	
	Gross Withdrawal (1)	Consumptive Use (2)	Gross Withdrawal (1)	Consumptive Use (3)	Gross Withdrawal (1)	Consumptive Use (4)
1975	5,170	42	5,170	42	5,170	42
1985	5,810	58	8,400	94	13,550	225
1995	6,130	65	11,610	129	20,000	258
2000	6,460	68	12,910	145	25,810	319
2025 (5)	6,460	68	12,910	145	25,810	319

NOTES: (1) Rough estimates
(2) Estimates based on average of Scenario B-2 and D-2, Chapter V
(3) Estimates based on Probable Scenario, Chapter V
(4) Estimates based on average of Scenario A-1 and C-1, Chapter V
(5) It is assumed that water use by the power industry in 2025 will not increase significantly above 2000 levels because of new technology and different siting methods.

III.B.3 AGRICULTURAL WATER DEMANDS

Until 20 or 30 years ago, the use of water for irrigation purposes had been confined primarily to the arid West. However, the advent of improved sprinkler irrigation equipment after World War II and the increased demand for truck crops have resulted in the use of irrigation water as a means of supplementing rainfall in the humid East.

Irrigation water has been used primarily as a means of supplementing precipitation during periods of drought. It can also be used to maintain soil moisture at optimum conditions and thereby increase yields even during normal or relatively wet years. There is thus an increasing trend in the direction of increased water usage for irrigation as more farmers recognize the increased crop yields that can be obtained through greater agricultural water usage.

III.B.3(a) Data Used in Projecting Agricultural Water Demands

The following data sources were used as a means of developing agricultural water demands as follows:

1. The 1962 Corps of Engineers Report to Congress (C. of E. (1962, Vol.IV). While future irrigation water requirements were projected in this report and are plotted in Figure 3-7, some of the most valuable information contained in this document were the results of a special survey conducted by the U.S. Department of Agriculture to determine actual water use by farmers during 1955.

2. NARWRS Study. As part of the North Atlantic Regional Water Resources Study, the Soil Conservation Service made projections, on a river basin-by-river basin basis, of water requirements needed to maximize plant growth. As a part of this study, projections were made of future irrigated acreage for three alternative growth strategies.

3. 1969 Census of Agriculture. The U.S. Department of Agriculture conducts a Survey of Agriculture every five years that includes the estimate of irrigated acreage and irrigation water use.

4. Commonwealth of Pennsylvania Agricultural Survey. The Commonwealth of Pennsylvania conducts its own agricultural survey to establish irrigated acreage and water usage.

5. Personal Contact with the Delaware River Basin Commission and the Chester County Water Authority, and Personnel Connected with the Studies and Surveys Listed under Items 1-4 Above. Contacts were made in order to learn further of the methodology and data that were the basis of the surveys and the methodologies used.

III.B.3(b) Methodology and Projections

In order to gain perspective as to the water required to maximize plant growth and the actual amount of water that has been estimated to have been used historically, projections and data from a number of sources were plotted. Figure 3-7 shows the 1962 Corps of Engineers projections, the projections developed as part of the NARWRS study, and historically observed or estimated water usage on an acre-foot per irrigated acre basis in the Delaware Basin.[1]

The earliest estimated water usage considered in this study was made in the special survey by the U.S. Department of Agriculture as part of the Corps

1. Irrigation demands are shown here for the Delaware Bain only. The demand in the supplemental subareas is small and would therefore not materially affect required diversions from the Delaware Basin.

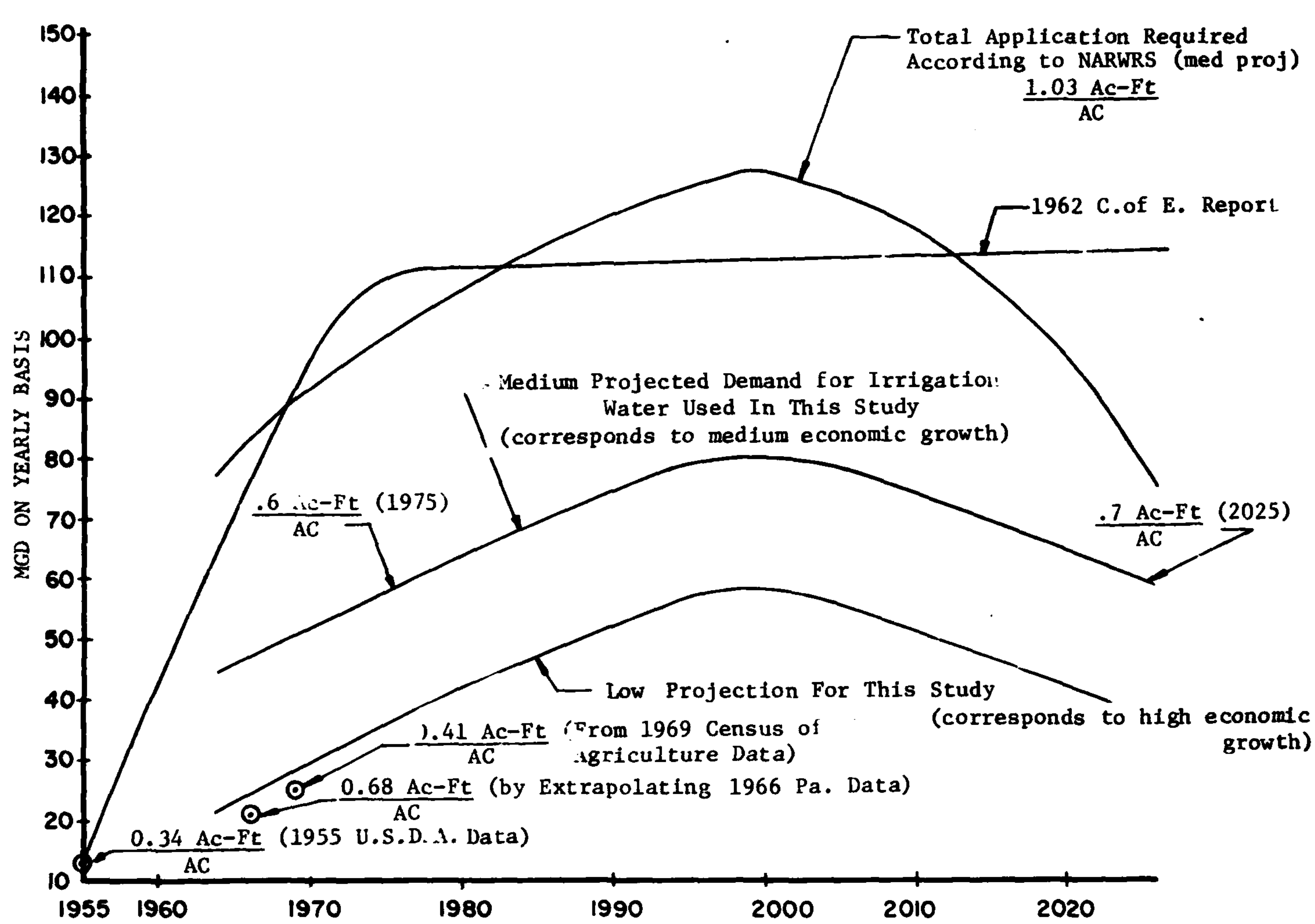
Engineers Comprehensive Study of the Delaware Basin mentioned above. The USDA selected several counties in the Delaware Basin with significant irrigation usage and developed estimates of irrigated acreage and water usage through individual contacts with farmers. Their evaluations indicated that .34 acre-feet of water per acre of irrigated land was the average water usage during the relatively dry year of 1955.

The 1969 Census of Agriculture for the counties within the Delaware Basin indicates that approximately .41 acre-feet of water per acre was used during the year 1969, which was a normal-to-wet year. While this amount is higher than in 1955, a drier year, the 1969 Census of Agriculture has been criticized by some as not being reliable relative to estimated water usage.

Nineteen Sixty-Six data for Pennsylvania was obtained from the Pennsylvania Department of Environmental Resources and it was found that .68 acre-feet per ace of water was used.

The above data compare with 1.03 acre-feet per acre of water believed to be necessary in order to maximize plant growth, according to the NARWRS study. In considering the water requirements specified in this study, it is important to recognize that the projection of requirements is made on the basis that water will be applied so as to maximize plant growth. Addtionally, these requirements include approximately 0.34 acre-feet per acre of water to be applied in excess of the amount required to maximize plant growth to allow for percolation to groundwater, surface runoff, and

AGRICULTURAL WATER DEMAND PROJECTIONS



evaporation of the applied water before it reaches the plant surfaces or the ground.

The important consideration in evaluating the NARWRS requirements is whether in fact farmers actually apply water in a way that maximizes plant growth. The estimated water actually applied historically provides some guidance as to what farmers are actually applying and more important the amount farmers are likely to apply in the future. In 1955, the farmers were applying less than half (.34) of the amount of water required to maximize plant growth, according to the NARWRS study. It appears that they applied more in 1969 (.41) and even more in 1966 (.68). Based upon these historical estimates, it is our judgment that .6 acre-feet per acre would be a reasonable amount of water to expect farmers to apply during a relatively dry year. It is assumed that this application will increase to .7 acre-feet per acre by the year 2025. A demand curve based on this assumption and used as the medium demand estimate for agricultural use in this study is shown in Figure 3-7.

Given the total demand for irrigation water as just developed, the next step is to estimate consumptive use. Since it is assumed that farmers will not apply all the water necessary to maximize plant growth, they are not likely to apply water in excess of what the soil can accommodate and hold for plant growth. Consequently, there will be little, if any, surface runoff and percolation to groundwater. The applied water will either evaporate before it reaches the ground, be lost through evaporation from the ground or transpiration through plant growth. It appears that a 100 percent consumptive use factor is appropriate, and the consumptive use for agricultural water is thus the same as the demand curve shown in Figure 3-7.

The NARWRS study discussed above co·sidered three alternative growth strategies. The national efficiency strategy defined by NARWRS corresponds closely to the "Continuation of present trends" strategy adopted in this study, the medium projection shown in Figure 3-7.

The NARWRS study also developed a regional development strategy and an environmental quality strategy. The environmental quality strategy of NARWRS corresponds closely to the growth strategy that maximizes environmental aspects as adopted for this study. The regional development strategy does not correspond to any of the three alternative growth strategies adopted for this study.

In order to make the agricultural projections consistent with the other projections made in this study, it was necessary to develop an agricultural water demand curve to correspond with the maximization in national income strategy adopted for this study. This strategy assumes enhanced urban and industrial growth and consequent further encroachments upon the present land being used for agricultural purposes. Consequently, with such a strategy, irrigation water demands will be less than that demanded under a strategy the provides for a maximum consideration of environmental values, or even that required under the continuation of a present trends growth strategy. The agricultural demands for the three growth strategies are thus different from the municipal and industrial demands because such demands are maximized under a maximum growth strategy, whereas agricultural demands are minimized.

Figure 3-8 contains a demand curve for the environmental quality growth strategy. A similar assumption was made regarding .6 acre-feet per acre being used in 1975 and .7 acre-feet per acre being used in 2025. A demand curve, corresponding to the maximization of national income growth strategy as used in this study, was plotted arbitrarily to lie below the continuation of present trends growth strategy plotted in Figure 3-7 as the medium projection.

Table 3-28 summarizes demand and consumptive use over the 50-year study period for each of the growth strategies adopted for use in this study.

Table 3-33 below shows a breakdown by month and indicates that irrigation demands are highly seasonal.

Table 3-28. Irrigation Demand and Consumptive Use in MGD

	LOW (Corresponds to high economic growth)	MEDIUM (Corresponds to medium economic growth)	HIGH (Corresponds to low economic growth)
1975	36	58	100
1985	48	70	160
1995	56	78	248
2005	56	78	297
2015	47	69	318
2025	38	60	322

III.B.4 SALINITY CONTROL REQUIREMENTS

As discussed in the Introduction, the need for low flow augmentation that may be necessary to stablize salinity below Philadelphia and Camden for water supply protection, is necessarily bound up in the probability of given salinity concentrations adjacent to the Philadelphia Torresdal intake or the Camden aquifers. A more detailed discussion of possible salinity control requirements is contained in Section III.E., below.

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A COMPREHENSIVE STUDY OF THE TOCKS ISLAND LAKE PROJECT AND ALTE--ETC(U)
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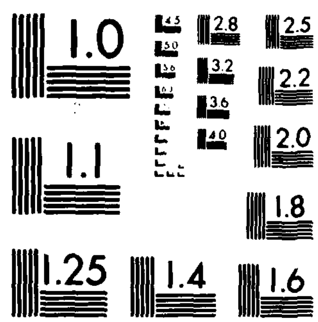
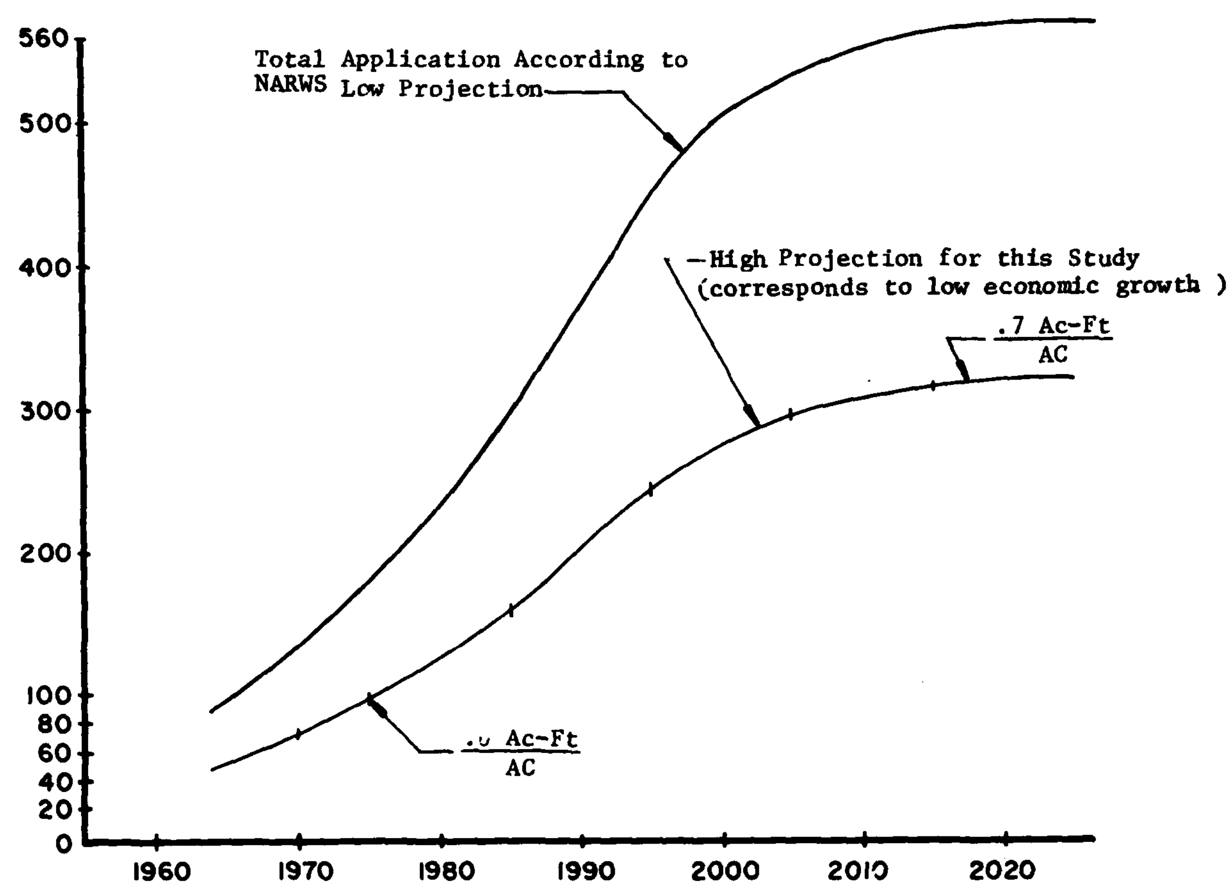


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963 A

IRRIGATION WATER DEMAND FOR LOW PROJECTION



III.C. CONSUMPTIVE USE DETERMINATION

The projection of future consumptive use within the Delaware Basin is the most important determination relative to estimation of water needs in the Basin. Consumptive use determinations are made for municipal, industrial, electric power and irrigation water demands.

III.C.1 Consumptive Use Coefficients

Consumptive use coefficients are used to estimate consumptive use for particular water uses. Consumptive use coefficients represent the fraction of the total withdrawal that is permanently lost from the water resources of the Delaware through evapotranspiration. Consumptive use coefficients range from 1/2 of 1 percent for some cooling uses to as much as 30% for certain industrial uses. An evaluation was made of consumptive use coefficients that have been published on a state-by-state basis by Murray and Reeves (1972). Additionally, contact was made with the Delaware River Basin Commission to learn of their experience in determining consumptive use coefficients. Based on the Murray and Reeves study and our discussions with the Delaware River Basin Commission, the following consumptive use coefficients were adopted for this study:

1. Domestic-Commercial - 10%
2. Industrial
   a. Cooling - 1%
   b. Noncooling - 10%
3. Electric Power - (see Chapter V)
4. Irrigation - 100% (see Section III.B 3 above for the basis of this coefficient)

III.C.2 Consumptive Use

Consumptive use is summarized in Table 3-29. Domestic-commercial and total industrial consumptive use was determined by multiplying the above consumptive use coefficients by the demand for domestic-commercial and total industrial water given in Section III.B.1(e). Electric power consumptive use is taken from Section III.B.2 and irrigation consumptive use is taken from Section III.B.3.

Table 3-29 contains a miscellaneous column which represents livestock and rural domestic consumptive use. Because the consumptive use associated with livestock and rural domestic demand was observed from DRBC (1973) to be so small, a detailed projection was not carried out and the consumptive use given in DRBC (1973) was adopted. The miscellaneous consumptive use is assumed to remain relatively constant over the 50 year study period.

III.C.3 Distribution of Consumptive Use in the Basin

In addition to the magnitude of consumptive use in the Delaware River Basin, its distribution is also important. Consumptive use serves to reduce flows within the Delaware Basin. The primary impact of reduced or low flows in the Basin is the possible encroachment of salinity up the estuary. The primary force that acts against this encroachment is the fresh water inflow at Trenton. Fresh water inflows below Trenton are also important, but their importance decreases from north to south through the estuary to the ocean. The Delaware River Basin Commission has recently accepted the results of a study by the UE&C (1974) which concludes that fresh water inflows (or con-

Table 3-29 Summary of Consumptive Use by Type of Water Demand

Medium Projections

Year	Domestic-Commercial	Total Industrial	Electric Power	Irrigation	Miscellaneous*	Total
1975	74	123	42	58	12	309
1985	85	148	94	70	12	409
1995	94	174	129	78	12	487
2005	103	201	145	78	12	539
2015	108	238	145	69	12	572
2025	114	274	145	60	12	605

* Livestock and rural domestic.

sumptive use) south of the mouth of the Cohansey do not significantly affect salinity concentrations in the upper estuary.

The distribution of consumptive use around the Delaware Basin is governed primarily by the location of municipal, industrial, electric power and irrigation water usage. The location of electric power consumptive use is governed by the siting of present and future power plants.

Figure 3-9 shows the Delaware River Basin divided into four sub-basins. The first sub-basin is that portion of the Delaware Basin above Trenton. The second includes that portion of the Basin between Trenton and the mouth of the Schuylkill. The third, between the mouth of the Schuylkill and the mouth of the Cohansey, and the fourth between the mouth of the Cohansey to the ocean. This definition of sub-basins is based in part on the recent water pricing policy of the Delaware River Basin Commission which is based on the assumption discussed above that consumptive use in sub-basin 4 has no effect on salinity in the upper estuary. The DRBC further assumes as part of the pricing policy that the impact of withdrawals in sub-basin 3 varies from a negligible impact at the mouth of the Cohansey to full impact at the mouth of the Schuylkill.

Withdrawals in sub-basins 2 and 1 are assumed by the DRBC to have full impact relative to salinity intrusion in the estuary. The basin above the mouth of the Schuylkill is divided into two sub-basins to allow for the

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DIVISION OF DELAWARE BASIN INTO SUB-BASINS FOR CONSUMPTIVE USE DISTRIBUTION EVALUATIONS

III
9

possibility that consumptive use and fresh water inflows between the mouth of the Schuylkill and Trenton have a lesser effect on salinity encroachment than fresh water inflows at Trenton.

In determining the effect of a possible change in the future distribution of consumptive use in the basin that would affect salinity intrusion, each category of consumptive use was analyzed for trends that would indicate a future shift in distribution. In the case of municipal and industrial demand, a determination was made of the present distribution of population in sub-basins 1 through 4. Population is a good index as to municipal and industrial water demand. Of particular interest was the possibility that this distribution would change significantly over the 50 year study period so as to result in a different distribution of municipal and industrial consumptive use in sub-basins 1 through 4 than is observed at present. Our examination of the basic economic and demographic data (population, earnings, etc.) for each of the economic subregions in the basin indicated that the present distribution of population in the 4 sub-basins will not vary by more than about 10% over the next 50 years. Consequently, the present distribution of municipal and industrial consumptive use can be considered to remain relatively constant over the next 50 years.

The estimated future distribution of electric power consumptive use is discussed in Chapter V. The percentage distribution among the four sub-basins is contained in Table 3-30. No entry is shown for sub-basin 4 because this sub-basin was considered to be part of the ocean as far as electric power siting determinations were concerned, as discussed in Chapter V.

Table 3-30 Percent of Basin Consumptive Use by Sub-basin (2025)

Sub-basin	Municipal Industrial	Electric Power	Irrigation
1	15.8	40	11
2	71.2	13	18
3	8	47	18
4	5	-	53

Table 3-30 also contains the percentage distribution of consumptive use for each of the four sub-basins for municipal-industrial and irrigation components. Table 3-31 shows the distribution of consumptive use among the four sub-basins for the year 2025. It was obtained by multiplying the appropriate figures in Table 3-29 by the percentages in Table 3-30.

The projected distribution of consumptive use for the year 2025 is not readily comparable to that obtained by the DRBC because the four sub-basins delineated in Figure 3-9 do not entirely correspond to the sub-basins defined by the DRBC. It appears, however, that the DRBC projects a greater percentage of the 2020 consumptive use to occur in sub-basins 3 and 4 (as defined in this study).

Table 3-31. Consumptive Use in MGD for Sub-basins 1-4 for the Year 2025, "basic" medium projections

Sub-basin	Municipal Industrial	Electric Power	Irrigation	Miscellaneous*	Total	% of Consumptive Use in Each Sub-basin
1	61.3	58.0	6.6	3	128.9	21.3
2	276.3	18.9	10.8	3	309.0	51.0
3	31.0	68.1	10.8	3	112.9	18.7
4	19.4	-	31.8	3	54.2	9.0
Total	388	145	60	12	605	100

*Livestock and rural domestic assumed to be distributed uniformly among the four sub-basins.

The effect of the consumptive use distribution projected in this study when compared to that projected by the DRBC, is that this study projects a greater portion of the 2025 consumptive use that will reduce fresh water inflows at Trenton. It is generally accepted that fresh water inflows at Trenton are more important as a counterforce to salinity intrusion, for the same magnitude of flow, than fresh water flows into the estuary south of Trenton.

Consequently, the net effect of the projections in this study as compared with the DRBC projections is to forecast a greater likelihood of salinity intrusion up the estuary than would be projected if the DRBC projected distribution is applied. The likelihood of salinity intrusion with the distribution of consumptive use projected in this study is evaluated in detail in Section III.E. below.

Table 3-32 is the estimated monthly distribution of water demand by category of use for the years 1966-1970. This table, developed by the DRBC, appears to be a reasonable distribution of monthly demands and it is assumed in this study to be an appropriate projection of monthly demand breakdown for the 50 year study period. Table 3-33 contains estimated monthly consumptive use of water in MGD for the entire basin for the year 2025. It was developed to show monthly variations from the mean annual consumptive use for categories of demand shown in Table 3-31.

Table 3-34 displays the estimated consumptive use at Trenton by month for the year 2025. It is obtained by multiplying the estimated monthly distribution of consumptive use for the year 2025 in Table 3-33 by the percentage of consumptive use occuring above Trenton given in Table 3-31 for sub-basin 1. This table provides the basis in sub-section III.E.2(g) for adjusting historic and synthetic monthly flows at Trenton to reflect 2025 conditions in regard to consumptive use.

Table 3-32 Estimated Monthly Distribution of Water Demands by Category of Use 1966-1970

	Percentage of Total Annual			
Month	Municipal	Industrial	Electrical	Irrigation
January	8.1	7.6	6.9	-
February	8.2	7.2	6.9	-
March	7.9	7.2	7.3	-
April	7.7	8.0	8.0	-
May	8.0	8.4	8.7	3.7
June	8.9	9.5	10.1	27.7
July	9.3	10.0	10.0	37.8
August	9.1	10.1	10.0	26.9
September	8.6	10.0	9.0	3.9
October	8.2	9.1	8.5	-
November	8.0	6.2	7.7	-
December	8.0	6.7	7.0	-
Total	100.0	100.0	100.0	100.0

Source: DRBC (1973)

Table 3-33. Estimated Monthly Consumptive Use in MGD of Water by Category of Use for Entire Basin - 2025

Month	Domestic/Commercial	Total Industrial	Electrical	Irrigation	Misc.	TOTAL	Percent By Month
January	111	250	120	0	12	493	6.8
February	112	237	120	0	12	481	6.6
March	108	237	127	0	12	484	6.7
April	105	264	139	0	12	520	7.1
May	109	277	152	27	12	576	7.9
June	122	313	176	199	12	822	11.3
July	127	329	174	272	12	915	12.6
August	124	333	174	194	12	836	11.5
September	117	329	157	28	12	644	8.9
October	112	300	148	0	12	571	7.9
November	109	204	134	0	12	459	6.3
December	109	221	122	0	12	463	6.4

Table 3-34. Consumptive Use at Trenton by Month for 2025

Month	Consumptive Use (MGD)
January	105
February	102
March	103
April	111
May	123
June	175
July	195
August	178
September	137
October	122
November	98
December	99

III.D. AVAILABLE SUPPLIES

III.D.1 DELAWARE BASIN

Table 3-35a lists major present and programmed water supply reservoirs in the Delaware Basin. These reservoirs are used as a basis for determining overall water supply in the basin and more importantly, flow augmentation available to reduce the probability of salinity encroachment in the estuary.[1]

III.D.2 NORTHERN NEW JERSEY SUB-AREA

An inventory was made of yields for existing water supply facilities and potential future projects. Sources of information included the NARWRS studies, the NEWS Study Group at the North Atlantic Division of the Corps of Engineers and the New Jersey Department of Environmental Protection.

Existing "safe" yields[2] of surface public water supply systems are summarized on a county-by-county basis in Table 3-35b. Also listed are additional yields that can be developed from ground and surface sources in each county.

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1. While a reservoir may be operated entirely for water supply purposes, the water provided by the reservoir for this purpose becomes available (less consumptive use) for augmenting low flows after its release by the last user.

2. The "safe" yield is defined as the maximal sustainable yield that can be obtained continuously during the drought of record, in this case the drought of the early 1960's. This concept is accepted as an operational definition in the interpretation of other studies, although a separate analysis based on a lesser drought is contained in Section III.D.5(d) below. Additionally, the concept of "safe" yield is not used in connection with the evaluation of the probability of salinity intrusion in the estuary as contained in Section III.E.2, below.

Table 3-35a. MAJOR WATER SUPPLY RESERVOIRS (Existing or Programmed) in the Delaware River Basin upstream of Trenton

		Storage in ac. ft.	"Safe" Yield in MGD	Location	Year in Operation
1.	F. E. Walter	70,000	127	Lehigh River	1961
2.	Beltzville	27,880	59	Lehigh River	1971*
3.	Trexler	40,000	31	Lehigh River	Under Const.
4.	Tocks Island	425,600	633	Delaware River	Programmed
5.	Neversink	107,170	(1)	Neversink Rv.	1955
6.	Pepaction	429,660	(1)	E. Branch Del. River	1955
7.	Cannonsville	293,000	(1)	W. Branch Del. River	1964

*Presently being modified for water supply storage.

(1) Total "Safe" Yield of Neversink, Pepaction, and Cannonsville Reservoirs is 500 MGD.

Table 3-35b. Existing and Potential Water Supply Sources in the Northern New Jersey Sub-area

County	Existing "Safe" Yield (MGD)	Estimated Additional Potential "Safe" Yield (MGD)
Bergen	86	10
Essex	149	2
Hudson	94	-
Hunterdon	2	11*
Middlesex	96	14
Morris	28	20
Passaic	118	6
Somerset	11	-
Union	128**	3
Other	-	-
Total	712 MGD	66 MGD

* Includes Raritan, Millstone, and D&R Canal allocations.

** Additional yield that can be developed locally, including 10 MGD from the state-owned Raritan supplies.

Table 3-35c. Potential Intrasubarea Projects Within the Northern New Jersey Subarea

Project	"Safe" Yield in MGD
1. a) Outlet modification at Round Valley Reservoir	80 *
b) An increase in the dike and height of dam at Round Valley	27
2. Two Bridges on Passaic River in Morris County	100 **
3. Longwood Reservoir on Rockaway River (Morris County)	10
4. Washington Valley Reservoir on Whippany River (Morris County)	7
5. Increased diversion from Ramapo River to Wanaque Reservoir	18
6. Pumping from Passaic River to Wanaque Reservoir	80
7. Monksville Reservoir	7
8. Confluence Reservoir in Somerset County	50
9. Six-Mile Run Reservoir in Somerset County for utilizing full 100 MGD diversion from Delaware River through D&R Canal	63 ***
10. Reuse of water in Raritan and Passaic River Basins	180
11. Ground Water Development in Raritan and Passaic River Basins	110
Total (not including item 2)	632 MGD
Total (not including items 5, 6 and 7)	627 MGD

* Round Valley Reservoir along with related projects would receive high flows skimmed from the Raritan.

** The Two Bridges project competes for the same water as items 5, 6 and 7.

*** Allowed 100 MGD diversion from the Delaware River plus 10 MGD from local inflow along the D&R Canal less present average use of 47 MGD.

From Table 3-35b, the present "safe" yield for the Northern New Jersey sub-area is 712 MGD. This yield is composed of approximately 82% surface water sources (584 MGD), and approximately 18% ground water sources (128 MGD). An additional 66 MGD is the estimated potential yield that can be developed from existing county sources (approximately 42 MGD from the surface water sources and approximately 24 MGD from ground water sources). Thus, the Northern New Jersey sub-area can develop a total yield of 778 (712 + 66) MGD.

Potential future intra-subarea projects within the Northern New Jersey sub-area are listed in Table 3-35c.

Potential sources outside of the sub-area that could help satisfy demands within the sub-area are listed in Table 3-35d.

Table 3-35d. Potential Sources Outside the Northern New Jersey Subarea

Potential Source	"Safe" Yield in MGD
1. Development of well fields in Southern New Jersey, including the Pine Barrens, Wharton Tract and Lebanon State Forest located predominantly in Burlington County with smaller portions in Atlantic, Camden and Ocean Counties	200
2. Additional reservoirs in the Ramapo River Sub-basin in New York State, with diversion from Hudson River	200
3. Hudson high flow skimming for New Jersey from West Bank Tunnel	70 *
Total	470 MGD

* Resulting from better transmissibility of water supplies using the aquaduct from West Park, New York to Great Notch, New Jersey.

III.D.3 NEW YORK CITY SYSTEM SUB-AREA

An inventory, similar to that discussed in the previous section for the Northern New Jersey sub-area, was made of existing and potential water supplies for the New York City System sub-area. Sources of information included the NARWRS, NEWS, and Temporary Commission on the Water Needs of Southeast New York Studies, and the New York State Department of Environmental Conservation.

"Safe" yields of existing public water supply systems are summarized on a county-by-county basis in Table 3-36. Also listed are additional yields that could be developed in each county.

From Table 3-36, the present "safe" yield for the New York City System sub-area is 1,619 MGD. This yield represents approximately 72% surface water sources (1,166 MGD), and approximately 28% ground water sources (453 MGD). An additional 20 MGD yield is the estimated potential that can be developed from county sources (approximately 15 MGD from surface water sources and approximately 5 MGD from ground water sources). The New York City System sub-area can thus develop a yield of 1,639 MGD without instituting any new intracounty projects. This 1,639 MGD is strictly within the sub-area and includes a "safe" yield of approximately 500 MGD from the Delaware Basin, as authorized by the 1954 Supreme Court Decree (maximum authorized diversion, 800 MGD).

Table 3-36. Existing and Potential Water Supply Sources in the New York City System Sub-area

County	Existing "Safe" Yield (MGD)	Estimated Additional Potential "Safe" Yield (MGD)
Dutchess	18	17
Nassau	159	-
Orange	28	-
Putnam	2	-
Rockland	36	-
Ulster	13	3
Westchester	28	-
NYC System	1,335	-
Subtotal	1,619 MGD	20 MGD

Potential future sources outside of the New York City System sub-area that could help satisfy demands within the sub-area are as follows:

	Accumulative Total MGD
1. High flow skimming of Hudson River at West Park, New York (250 MGD)	250
2. Hinckley Reservoir in Herkimer County, New York (575 MGD)	825
3. Schaghticoke Reservoir in Rensselaer County, New York (400 MGD)	1,225
4. Forestport (Oneida County) and McKeever (Herkimer County) Reservoirs in the Black River Basin (350 MGD)	1,575

As discussed in the previous section, it might be possible to consider a lesser drought thereby increasing yields.

III.D.4 EXISTING AND PROPOSED BASIN IMPORTS, EXPORTS AND IN-BASIN DIVERSIONS

Water is imported to the basin as shown in Table 3-37. Major imports are described as follows:

1. The Chester Water Authority imports the largest quantity of water into the Delaware River Basin drawing 28.1 MGD in 1970 from the Susquehanna River Basin. The Authority is presently authorized to divert 30 MGD from Octoraro Creek and an additional 30 MGD from the Susquehanna River.

2. The Octoraro Water Company imported 1.7 MGD in 1970 from the Octoraro Creek in the Susquehanna River Basin to service several communities in Chester County, Pennsylvania. The authorized diversion is 4.0 MGD.

3. The Newton Water and Sewer Authority, Newton, New Jersey, imported 0.9 MGD in 1970 from Morris Lake, New Jersey in the Hudson River Basin. Their total authorization is 2.0 MGD.

The total authorized imports to the Delaware River Basin is presently 66 MGD.

The actual imports to the basin in 1970 were 30 MGD.

Basin exports are listed in Table 3-38. Major exports are described as follows:

1. The largest quantity of water exported from the Delaware Basin is taken by the City of New York. In 1970, 600 MGD was diverted, although the City is authorized to take a maximum of 800 MGD under the Supreme Court Decree of 1954.

2. 65 MGD was exported to northeastern New Jersey in 1970 from the Delaware River Basin; 100 MGD is presently authorized under the Supreme Court Decree of 1954.

TABLE 3-37

AUTHORIZED AND ACTUAL 1970 AND ESTIMATED FUTURE AVERAGE ANNUAL

IMPORTATION OF WATER TO THE DELAWARE RIVER BASIN, 1970-2020*

(In million gallons per day)

Importer	1970 Authorized	1970 Imported	1980 Estimated	2000 Estimated	2000 Estimated	From
Newton Water and Sewer Authority, Newton, New Jersey	2.0	0.9	1.6	1.6	1.6	Morris Lake, N.J. (Hudson River Basin)
Octoraro Water Co., Claymont, Delaware	4.0	1.7	2.0	4.0	6.0	Octoraro Creek Pa. (Susquehanna River Basin)
Chester Water Authority, Chester, Pa.	60.0	28.1	43.8	60.0	60.0	Octoraro Creek & Susquehanna River, Pa. (Susquehanna River Basin)
TOTAL (rounded)	66.0	30.0	47.0	66.0	68.0	

*Source: Delaware River Basin Commission (1973).

Table 3-38 Authorized and Actual 1970 and Estimated Future Average Annual Exportation of Water From the Delaware River Basin 1970-2020* (In MGD)

Exporter	1970 Authorized	1970 Exported	1980 Estimated	2000-2020 Estimated
City of New York, N.Y.	800.0	600.0	800.0	800.0
Otisville State Training School Otisville, N.Y.	0.5	0.3	0.5	0.5
Village of Woodridge, N.Y.	0.5	0.4	0.5	0.5
Pa. Gas and Water Co.	3.0	1.0	3.0	3.0
Hazelton Joint Sewer Authority	3.0	2.0	3.0	3.0
Flemington, N.J.	0.5	0.5	0.5	0.5
State of New Jersey (Delaware and Raritan Canal)	100.0	65.0	100.0	100.0
State of New Jersey (Frenchtown Diversion)	NONE	0	0	300.0 **
Mahanoy Twp. Authority	0.1	0.05	0.1	0.1
Wildwood, N.J.	3.5	3.5	3.5	3.5
TOTAL	911.0	673.0	911.0	1211.0

*Source: DRBC(1973)

**Proposed at this time

New Jersey has requested an additional 300 MGD diversion.

3. Additional authorized exports from the Delaware River Basin total 11.1 MGD, although only 7.75 MGD was diverted in 1970.

The total authorized basin exports are 911 MGD; 673 MGD were actually diverted in 1970.

Major in-basin diversions are summarized in Table 3-39.

Table 3-39 In-Basin Diversions in the Delaware River Basin

The following major diversions and water withdrawals occurred in the Delaware Basin in 1970:

Hazle Creek - 3.03 cfs

Borough of Morrisville - 2.5 cfs

City of Trenton - 61.0 cfs

Belmont Intake - 110 cfs

Queen Lane Intake - 156 cfs

Torresdale Intake - 334 cfs

Source: Disco (1973)

III.D.5 COMPARISON OF DEMAND WITH SUPPLY IN THE NEW YORK CITY SYSTEM AND NORTHERN NEW JERSEY SUB-AREAS

Evaluation of the presently authorized 800 MGD diversion to the New York City System Sub-area and the proposed 300 MGD diversion to the Northern New Jersey Sub-area can be made by considering the demands and supplies estimated in previous sections. The relative balance between supply and demand in the Delaware Basin is necessarily bound up in the potential salinity encroachment problem in the estuary, the discussion of which is contained in Section III.E.2(m) below.

While both the New York City System and Northern New Jersey Sub-areas are discussed relative to their unsatisfied need, the primary focus of attention is the Northern New Jersey Sub-area. The Northern New Jersey Sub-area is emphasized because the 300 MGD diversion from the Delaware is only proposed, not authorized. In the case of the New York City System, the 800 MGD diversion is authorized and the discussion in Chapter XVII demonstrates that the modification of this authorized amount is not institutionally feasible. Thus, while it is of interest to know the relationship of the authorized 800 MGD diversion to the unsatisfied need in the New York City System Sub-area, the relationship is much less important than the relationship of the proposed 300 MGD diversion to the unsatisfied need in the Northern New Jersey Sub-area.

III.D.5(a) Development of Scenarios for the Future Source of Supply for Presently Self-Supplied Industry

The evaluation of the authorized 800 MGD and proposed 300 MGD diversions must take into account not only future demands and present and programmed public supplies, but also the future mix of self-supplied and publicly supplied industrial demand. In fact, it is this projected mix that plays a major role in determining the need for the 800 and 300 MGD diversions.[1]

Because the future mix of self-supplied and publicly supplied industrial demand is so crucial in determining the need for these diversions, three scenarios are considered regarding this mix, as follows:

1. The current industrial demand satisfied through self-supplied sources remains constant.
2. The current proportion of self-supplied demand for each major water using industry to total industrial demand remains constant over the 50 year study period.
3. The future supply of industrial water is distributed as follows:
   a. Water used for cooling purposes will be self-supplied;
   b. Water used for process and sanitary purposes (non-cooling) will be publicly supplied;
   c. The current self-supplied component remains constant.

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1 The reader may wish to return to Section III.B.1(a) and Figure 3-1 to review the definition, interrelationship and sources of self-supplied and publicly supplied industrial water.

The determination of the proportion of the industrial demand that must be supplied through public sources can readily be determined for Scenarios 1 and 2 because the 1970 mix of publicly supplied and self-supplied industry is known. The determination of that portion of industry in the future that must be supplied from public sources is somewhat more difficult to determine for Scenario 3. In order to project the mix of self- supply and public supply for future industrial growth, according to Scenario 3, an evaluation was made of this mix for each of the six major water using industries. Data were obtained from the 1967 Census of Manufacturers for the Delaware/Hudson Region and are reproduced in Table 3-40a. Table 3-40b also from the 1967 Census of manufacturers, shows the percentage breakdown between cooling and non-cooling.

The data from the Census of Manufacturers for the Delaware/Hudson Region was compared with data for the Northern New Jersey sub-area and was found to be reasonably consistent.

The above three scenarios are only three of the many which could be developed to project the future mix of self-supply and public supply of industrial water. The most recent study in which this problem was addressed was the Joint Venture Report of the NEWS Study. The study area of the NEWS Study corresponds roughly with the Northern New Jersey and New York City System sub-areas, with the exception of a portion of Connecticut and Suffolk County, New York, which are not included in the study area in this report, and also a few other relatively minor counties. The Joint Venture Report estimated that, exclusive of brackish or salt water for cooling purposes, that company-owned industrial supplies provide less than 200 MGD in the Joint Venture study area.

It was also assumed in this report that opportunities for industry to develop additional supplies are fast disappearing. It was further assumed that most industries will rely on public water supply systems in the future. While it was assumed that not all future water requirements for presently self-supplied industry would be met through public sources, it is not clear from the Joint Venture report what the final assumptions were in regard to this important matter.

Tables 3-41, 42, and 43 contain a projected breakdown of source of industrial supplies for each of the three scenarios discussed above. It can be seen in Scenario 3, which is based on historic and thereby more realistic data, that the future supply of presently self-supplied industries remains largely self-supplied. This appears reasonable because the largest users in the northern New Jersey and New York System Sub-areas are the chemical and petroleum industries, and these industries use 82% and 87% of total water demand respectively for cooling purposes, as shown in Table 3-40b. It is believed that these industries presently rely and will continue to largely rely on saline water for cooling purposes.

Table 3-40a. Percentage of Self-Supplied and Publicly Supplied Demand by Major Water Using Industry (Applicable to Scenario 2)

Industry	Self Supply	Public Supply
Food and Kindred Products	54	46
Textiles	48	52
Paper	94	6
Chemicals	90	10
Petroleum	98	2
Primary Metals	94	6

Table 3-40b Percentage of Cooling and Non-Cooling Demand by Major Water Using Industry (Applicable to Scenario 3)

Industry	Cooling	Non-Cooling
Food and Kindred Products	56	44
Textiles	25	75
Paper	34	66
Chemicals	82	18
Petroleum	87	13
Primary Metals	77	23

Table 3-41 Breakdown of Industrial Demand According to Source of Current and Projected Future Sources (Scenario 1)

		1970	1975	1985	1995	2005	2015	2025
Northern New Jersey Subarea	Total Industrial	1622	1777	2086	2372	2657	3104	3350
	Self-Supplied	1501	1501	1501	1501	1501	1501	1501
	Publicly Supplied	121	276	585	871	1156	1503	1849
New York City System Subarea	Total Industrial	1732	1942	2363	2552	2741	3042	3342
	Self-Supplied	1577	1577	1577	1577	1577	1577	1577
	Publicly Supplied	155	365	786	975	1164	1465	1765

Table 3-42 Breakdown of Industrial Demand According to Source of Current and Projected Future Sources (Scenario 2)

		1970	1975	1985	1995	2005	2015	2025
Northern New Jersey Subarea	Total Industrial	1622	1777	2086	2372	2657	3104	3350
	Self-Supplied	1501	1634	1899	2155	2411	2724	3036
	Publicly Supplied	121	143	187	217	246	280	314
New York City System Subarea	Total Industrial	1732	1942	2363	2552	2741	3042	3342
	Self-Supplied	1577	1774	2169	2338	2506	2778	3050
	Publicly Supplied	155	168	194	214	235	264	292

Table 3-43 Breakdown of Industrial Demand According to Source of Current and Projected Future Sources (Scenario 3)

		1970	1975	1985	1995	2005	2015	2025
North New Jersey Subarea	Total Industrial	1622	1777	2086	2372	2657	3104	3350
	Self-Supplied	1501	1623	1866	2092	2318	2595	2872
	Publicly Supplied	121	154	220	280	339	409	478
New York City System Subarea	Total Industrial	1732	1942	2363	2552	2741	3042	3342
	Self-Supplied	1577	1731	2039	2182	2325	2549	2773
	Publicly Supplied	155	211	324	370	416	499	569

III.D.5(b) Estimation of Unsatisfied Need to be met by Public Systems in the Northern New Jersey and New York City System Sub-areas

It is now possible to estimate the unsatisfied water supply needs for the northern New Jersey and New York City System sub-areas for each of the three scenarios discussed above. The following breakdown is provided for each of these scenarios:

Scenario 1

Northern New Jersey Sub-area	Remaining Demand in MGD
2025 demand	4047
less 6 MGD self-supplied domestic-commercial	4041
less 712 MGD presently publicly supplied domestic-commercial	3329
less 1501 MGD assumed future self-supplied industrial	1828

Of the 1828 MGD remaining, 66 MGD could be supplied by potential public supplies from county sources, an additional 632 MGD from potential intra-sub-area sources, and an additional 470 MGD from potential sources outside of the sub-area other than from the Delaware. This would leave an unsatisfied demand of 1828-66-632-470=660 MGD that would have to be met by additional sources from outside of the sub-area. The proposed diversion from the Delaware could supply 300 MGD of this amount.

New York City System Sub-area	Remaining Demand in MGD
2025 demand	5552
less 13 MGD self-supplied domestic-commercial	5539
less 1619 MGD presently publicly[1] supplied domestic-commercial	3920
less 1577 MGD assumed future self-supplied industrial	2343

1 Includes 500 MGD "safe" yield from Delaware (corresponds to 800 MGD authorized diversion).

Of the 2343 remaining, 20 MGD could be supplied from potential public supplies from county sources and 1575 MGD from potential sources from outside the sub-area. This would leave an unsatisfied demand of 2343-20-1575=748 MGD that would have to be met by additional sources from outside of the sub-area.

Scenario 2

Northern New Jersey Sub-area	Remaining Demand in MGD
2025 demand	4047
less 6 MGD self-supplied domestic-commercial	4041
less 712 MGD presently publicly supplied domestic-commercial	3329
less 3036 MGD assumed future self-supplied industrial	293

Of the 293 remaining, 66 MGD could be supplied by potential public supplies from county sources, and 632 MGD from potential inter-sub-area sources. Thus potential sources that are entirely within the sub-area are greater (66 + 632 = 698) than the unsatisfied demand of 293 MGD and it would be possible to meet water demands for the year 2025 entirely by developing water supplies from within the sub-area. 300 MGD diversion from the Delaware would thus not necessarily be required. It should be pointed out, however, that many of the potential intra-sub-area projects included above and described in more detail in Section III.D.2 have had a history of opposition as long or longer than that for the Tocks Island project. Consequently, it cannot be assumed that if the conditions regarding the future supply of the presently self-supplied industry assumed in Scenario 2 hold, that the sub-area water needs in 2025 will be met without relying on proposed sources outside of the sub-area. Two hundred ninety three MGD of the 698 MGD of intra-sub-area projects would have to be implemented in order to avoid relying on sources outside of the sub-area, such as the proposed 300 MGD diversion from the Delaware.

New York City System Sub-area	Remaining Demand in MGD
2025 demand	5552
less 13 MGD self-supplied domestic-commercial	5539
less 1619 MGD publicly supplied domestic-commercial	3920
less 3050 assumed future self-supplied industrial sources	870

The unsatisfied demand of 870 MGD could be met out of the 1595 MGD in county and other proposed sources outside of sub-area.

Scenario 3

Northern New Jersey Sub-area	Remaining Demand in MGD		
	High	Medium	Low
2025 demand	4,507	4,047	3,384
less 6 MGD self-supplied domestic-commercial	4,501	4,041	3,378
less 712 MGD presently publicly supplied domestic-commercial	3,789	3,329	2,666
less future self-supplied industrial sources (amount varies for the three alternative growth levels)	810	457	282

The unsatisfied demand noted in the bottom line of the above table must be met from either the potential 66 MGD from county sources, 632 MGD potential intra-subarea sources or from sources outside the sub-area. These latter could include projects contributing to the 470 MGD figure noted previously or other out-of-subarea projects.

New York City System Sub-area	Remaining Demand in MGD		
	High	Medium	Low
2025 demand	6,197	5,552	4,813
less 13 MGD self-supplied domestic-commercial	6,184	5,539	4,800
less 1619 MGD presently publicly supplied domestic-commercial	4,565	3,920	3,181
less assumed future self-supplied industrial sources	1,516	1,147	803

As noted under the previous scenarios, the unsatisfied demands noted on the bottom line of the foregoing table could be met out of the 20 MGD proposed for county sources or the proposed 1575 sources noted previously.

In terms of the reasonableness of Scenarios 1 through 3, Scenario 1 unduly understates the potential for future industrial self-supply. This is because the largest portion of industrial water usage is for cooling purposes and it is not likely, particularly in the petroleum and chemical industries, that such industries would be willing to pay the higher cost of publicly supplied cooling water. If expanded present or new industry cannot gain access to cheap sources of self-supplied cooling water, they may locate elsewhere and water demand would thereby be reduced.

In regard to Scenario 2, it is unrealistic to assume that the present mix of self-supplied and publicly supplied industrial water use will remain constant. This conclusion is drawn for two reasons: 1) the potential for developing additional surface and ground water resources is becoming more limited; and 2) the potential for additional development of surface and ground water resources has already been considered in estimating the future yield that may be obtained within the sub-area for public supply as discussed in Sections III.D.2 and 3.

Scenario 3 is the most reasonable scenario that can be made with presently available data. Additionally, this scenario makes the most logical prediction of what industry is likely to do in regard to meeting their water supply needs, considering the differences in costs of self-supplied and publicly supplied water to be used for cooling purposes.

It is significant, again, that under the assumptions of Scenario 3 , the proposed 300 MGD diversion from the Delaware River Basin would not necessarily be required under the medium and low growth alternatives and only partially required under the high growth alternative. Additionally, the discussion under Scenario 2 for the Northern New Jersey sub-area regarding the possible opposition to developing intra-sub-area sources also applies.

The implications of the foregoing statement should, however, also be received with considerable caution because a good projection of the future mix of self-supplied and publicly supplied industry can only be determined through a detailed field investigation of each industry, its plans for expansion, and the location of available sites with ready access to cheap sources of self-supplied cooling water for those industries wishing to build entirely new plants.

III.D.5(c) Consideration of a Balanced Supply/Demand Condition within the Northern New Jersey Sub-area

In regard to the issue of the mix of self-supplied and publicly supplied industrial water, it is possible to determine the mix that would produce a balance between overall supply and demand within the northern New Jersey sub-area in the year 2025. The following table presents approximations of the amounts of industrial water which must be self-supplied under the three economic growth strategies adopted for this study.

Table 3-44. Approximate Self-Supplied Industrial Water Needs in 2025 Assuming a Balanced Overall Supply/Demand Relationship in the Northern New Jersey Sub-area (in MGD)

Category of Supply or Demand	Economic Growth Level High	Medium	Low
Total Public Supply			
Present (1975)	800	800	800
Potential (through 2025)	600	600	600
	1,400	1,400	1,400
Domestic - Commercial (virtually all from public sources)	800	700	600
Publicly Supplied Water that could be available to meet Industrial Needs	600	700	800
Total Industrial Water Demand	3,700	3,400	2,700
Portion of Industrial Water Demand that must be Self-Supplied	3,100	2,700	1,900

As indicated under the high, medium and low economic growth levels, industry in the northern New Jersey sub-area would themselves be required to furnish 3,100, 2,700 and 1,900 MGD of water in 2025 respectively. At present it is estimated that industry is only supplying itself approximately 1,600 MGD of water in the sub-area.

It is possible to tentatively conclude, therefore, that if industrial development consistent with a high economic growth level is to be sustained, and no out-of-sub-area sources are to be utilized for industrial water purposes, an additional 1,500 MGD of water must be available for self supply to new and expanded industry at locations and costs that are acceptable to this industry. Implicit in this is the availability of industrial sites along bodies of water (primarily saline) that may be drawn upon for water supply. The locations of such sites must also possess transportation connections, proximity to labor pools and material sources, and other attributes necessary for industrial development.

Under the medium growth level, an additional 1,100 MGD of water for industrial purposes must be developed by the industries themselves. This is an increase of approximately 70 percent over presently self-supplied industrial water requirements.

Under the low economic growth alternative only 300 MGD are needed over that presently utilized. The comments outlined above regarding the need for industrial water supplies to be accessible to otherwise adequate industrial sites applies also, thought to a less constraining degree, to the requirements under the medium and low economic growth alternatives.

As indicated in the above table, the approximations discussed assume that all of the publicly supplied water that could be available to meet industrial needs is in fact developed and applied to meet these needs. Under this assumption, therefore, these water sources must be located in areas subject to industrial development and more importantly, the specific industries utilizing this publicly supplied water must be willing to pay the higher rate that publicly supplied water commands. Certain industries, particularly those producing high valued products, do not view water as a significant cost factor and would pay any reasonable price to conveniently obtain it. Other industries might not locate in an area in which they were dependent upon high priced publicly supplied water. Thus, industrial development could be constrained and industries could be lost to the sub-area.

In summary, the foregoing table and discussion outlines the industrial water demand in 2025 which must be met from self-supplied sources. To the extent that these supplies can not be met, either due to inadequacy of water resources or due to the inconvenient location of water resources with respect to potential industrial sites, water must be imported into the sub-area.

The proposed 300 MGD diversion from the Delaware River Basin to the northern New Jersey sub-area is one source for this water. It is to be noted, however, that particularly under the high growth alternative, it is only 10 percent of the 2025 self-supplied industrial need. While because of its probably reasonable cost and availability it could provide a measure of this need, it is to be emphasized that major sources suitable for industrial self supply within the sub-area (primarily those with access to saline water sources) must be exploited to the fullest if industrial development in the area is not to be constrained.

Additional points to be emphasized and which are essential in the placing of the foregoing summary in proper perspective relate to: (1) the need for further information regarding the availability and location of water suitable for industrial pusposes; (2) the relationship between industrial water availability and economic growth; and (3) the possibility, and even likelihood in some cases, of appreciable difficulties with respect to the development of intra-subarea water supply sources. In regard to this last point, it is to be noted that a single sub-area sometimes includes more than one drainage basin; always includes many political jurisdictions; and, generally, includes a range of interests and opinions regarding water resource policies and measures. The existence of potentially developable water supply sources within a sub-area is hence not a basis for the assumption that the supply can in fact be developed and utilized.

III.D.5(d) Consideration of a Lesser Drought than the Drought of Record for Water Supply Planning Purposes

The inventory of available yields for existing and potential water supply projects contained in Sections III.D.2 and 3 above, is based on the concept of "safe" yield. The "safe" yield is that yield which can be obtained continuously throughout the drought of record which for the northeast is the drought of the early 1960's. Because the drought of the early 1960's has been estimated to occur only once in every several hundred years, the use of this criterion for water supply planning may result in overly conservative planning. Consideration of a lesser drought may be particularly appropriate for water supply planning in the late twentieth century because of the diminishing availability of structural water supply options that can be instituted with a minimum of environmental damage.

The subject of one of the studies completed in connection with the NEWS study was a probabilistic yield analysis of major water systems in the Northern New Jersey subarea. A review of the study indicated that conservatively, a 5% increase in yield might be expected if a drought were considered that occurred on the average of once every 100 years rather than the drought of the early 1960's. It is likely that this percentage will differ from water system to water system, but 5% may be an appropriate figure for discussing the additional yield that could be available for meeting the unsatisfied water supply needs in the Northern New Jersey sub-area. A 5% increase in yield for the existing public supply in the sub-area would increase the supply from 712 MGD to 748 MGD. It is not likely that the yield of self-supplied industrial sources could be increased since such yields, consisting of primarily saline sources, but also of run-of-the-river diversions and groundwater, are not greatly dependent on the "safe" yield concept. The increased yield of 36 MGD would serve to reduce the unsatisfied need for the high, medium and low demands in sub-section III.D.5(b) to 774 MGD, 421 MGD and 246 MGD, respectively.

Yields of potential sources could be similarly increased.

III.E. IMPACT OF DIVERSIONS AND CONSUMPTIVE USE ON THE DELAWARE ESTUARY

III.E.1 INTRODUCTION

Much of the analysis in previous sections has been concerned with the relative balance of supply and demand within the Northern New Jersey and New York City System sub-areas. This section is concerned with supply and demand in the Delaware Basin itself, particularly in the Delaware estuary. The Delaware estuary is the primary subject of the analysis because it is the focus of the net effect of basin-wide consumptive use and diversion. While diversion and consumptive use affect water resources in other parts of the basin by reducing flows, the net effect of consumptive use and diversion impacts upon the estuary. Additionally, the impact of consumptive use and diversion on the salinity of the estuary may be marked, while the impact of these factors on tributary streams not subject to salinity intrusion is more tractable and better defined. A major area of concern relative to increased consumptive use and diversion on the estuary is the increased probability of salinity intrusion in the estuary as it may affect public water supply. The effect of increased consumptive use and diversion on estuary fishery resources is also investigated.

III.E.2 PROBABILITY OF SALINITY INTRUSION

This Section contains the following subsections:

III.E.2(a) Introduction

An estuary is that part of the mouth or lower course of a river where river currents meet ocean tides and are thereby subject to their effects. As an ocean is by definition saline, a possible effect of the interaction of river currents with ocean tides is the mixing of river and ocean water. Consequently, it can be expected that an estuary, being a mixture of river and ocean water, would have a salinity greater than the river, but less than the ocean and the relative salinity could be expected to depend upon the magnitude of the relative dynamic forces operating in the estuary, namely the magnitude of river flows and tidal currents. Because fresh water flows depend on random hydrologic phenomena, such as precipitation, they are in themselves random. Tidal currents are also random, since they are affected by wind, although the randomness of such currents may not be as great as that for fresh water inflows.

Because river flows are a dynamic force opposing the tidal effects of the ocean, it can be expected that salinity will increase in the estuary when river flows are low. On the other hand when fresh water inflows are high and the dynamic force of the river is thus higher, salinity can be expected to decrease. The interaction of ocean tidal currents and fresh water flows are of no particular concern unless the interaction affects the environment. In the case of the Delaware estuary, the effect of the interaction of the Delaware River and the ocean, in particular the effect of this interaction on salinity in the estuary, is indeed of considerable concern because estuarial water resources are used for water supply purposes by the cities of Philadelphia and Camden, and excessive salinity would be observed by the water supply consumers of these cities.[1] Industrial users of water are also affected by increased salinity, although the problem is not nearly as great because such water is not used for human consumption.[2]

The possible intrusion of salinity into the Camden and Philadelphia water systems has been of concern for a number of years. During dry periods, particularly extended dry periods, salinity has increased in the estuary. During the drought of the early 1960's, there was considerable concern that excessive salinity concentrations would be observed adjacent to Philadelphia's Torresdale water intake. While chloride concentrations never did reach an unacceptable level at the intake, the possibility that they could have reached such a level generated a considerable amount of discussion and analysis during the drought by concerned governmental units including the development of plans for an emergency intake extension to Trenton out of reach of salinity intrusion in the estuary. In addition the DRBC assumed extraordinary authority in administering the 1954 Supreme Court decree requirements to aid in alleviating the problem.

A number of studies have been made of salinity intrusion in the Delaware estuary, both before and after the drought of the mid 1960's. Some of the studies have been based on an intuitive evaluation of the observed data and

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1 The City of Chester, Pennsylvania formerly used water from the Delaware estuary, but changed to the Susquehanna River Basin as a source. Chester would like to use the Delaware again in the future, if the reliability of salt free water could be assured.

2 A more detailed discussion of industrial use of the Delaware estuary for water supply may be found in Strandberg (1975).

a projection of what might occur during another drought. Others have been more quantitative and others have attempted to estimate the return interval of given salinity concentrations by estimating the return interval of previous droughts. Much of the later work has defined drought in a rather arbitrary fashion and since no one has conclusively established the probability of given salinity concentrations in a manner that is generally accepted as valid, the issue has never been resolved.

The work contained in this section is an attempt to clarify the basic issue of the probability of given salinity concentrations in the estuary as related to the Tocks Island Project. The focus of the work is relatively narrow: to determine the probability of given salinity concentrations under future conditions of consumptive use and basin diversions in the year 2025, with and without the Tocks Island Project. The work does not provide a basis for determining the rate of movement or extent of salinity encroachment or the salinity concentrations that would result from a specific set of freshwater inflows or consumptive use patterns.

The following sections include a review of past studies and evaluations of the salinity problem in the estuary by others and a discussion of the basis of the approach used herein in an effort to clarify the issue. The approach is discussed in terms of its statistical basis, the use of simulation to generate synthetic fresh water inflows at Trenton and the consideration of future consumptive use in the basin.

III.E.2(b) Review of Past Work

Over the years a considerable number of studies and evaluations have been carried out to establish the likelihood of given salinity concentrations in the estuary.

Most of the work can be categorized as follows: that based on an intuitive analysis of salinity and flow data and that based on the quantitative evaluation of the problem through the use of physical and mathematical models. In addition, there have been at least two investigations using statistical approaches, one of which is of particular significance and will be discussed in more detail later in this section. An excellent summary of past work is contained in Strandberg (1975) and is not repeated here. However, the usefulness of the results of the three categories of studies described above is discussed as follows:

Intuitive Evaluations --

Many of the early studies particularly those completed prior to 1960, involved an evaluation of observed salinity concentrations and their rate of movement in the estuary. While such intuitive analyses of the data may have usefully explained observed phenomena, they are of limited value in predicting the likelihood of observing given salinity concentrations in the future under unobserved conditions of freshwater inflow to the estuary.

Use of Physical and Mathematical Models --

An actual physical model of the estuary was set up and calibrated by the Corps of Engineers Waterways Experiment Station in the early 1950's. The application of this model provided a good deal of insight into the salinity movements in the estuary. With the advent of high speed digital computers in the late 1950's and early 1960's, it was possible to carry out detailed quantitative evaluations of the salinity intrusion problem. Several computerized mathematical models of the estuary were developed, the first being applied in connection with a comprehensive water quality investigation of the estuary by predecessor agencies of the U. S. Environmental Protection Agency. The most recent application and one of the most significant applications of a mathematical estuary model, was carried out in connection with siting evaluations of a nuclear power plant in the lower estuary, UE&C (1974). The model results were in agreement with observed salinity concentrations as well as the results of a similar model application by the DRBC.

Statistical Evaluations --

At least two statistical evaluations of the salinity intrusion problem have been carried out. A study by Keighton (1966) is particularly significant because it suggested that a statistical approach for estimating the probability of given salinity concentrations corresponding to fresh water inflows at Trenton was possible. A valid statistical approach opens the possibility of establishing the likelihood of given salinity concentrations by means other than the speculative evaluation of data characteristic of many of the early studies of the problem, or the time consuming and expensive deterministic approaches through the use of the mathematical or physical models described above.

The work of Keighton provides a statistical relationship of chloride concentration as a function of antecedent monthly average flow at Trenton.

Variations from the relationship developed, including magnitudes and causes, were discussed. The basic correlation between the salinity and flow is strong enough for the purposes of this study's decision framework, i. e., the relationships incorporate deterministic and unexplained random components that accomodate remaining variations. More importantly it suggested that a more refined statistical evaluation of the relationship between flow and salinity would lead to a relationship with even better statistical validity, thereby providing useful relationships between freshwater inflow at Trenton and salinity concentrations at various points in the estuary.

III.E.2(c) Development of Approach

Of particular importance in evaluating salinity intrusion in the Delaware estuary is not so much the possibility of given salinity concentrations at various points in the estuary, but rather the probability of such occurrences. After the drought of the early 1960's and the associated encroachment of salinity in the estuary, a good deal of effort was given to establishing the probability of that drought. As discussed in Section VII.D., several studies have addressed the issue of the probability of the drought and have developed return intervals. As discussed in Section VII.D., there has been a general tendency to deal with the return interval or frequency of drought in a way similar to the manner in which the return interval for floods are specified. This procedure is dangerous because the element of duration is a very important component of the drought event whereas it is much less so for floods. Thus, in order to define a return interval for a drought, it is first necessary to define the drought event in terms of magnitude and duration. This specification is necessarily arbitrary and consequently the return periods that are established for such an arbitrarily defined drought are tenuous at best.

A much more meaningful evaluation in regard to possible salinity intrusion in the Delaware estuary is the establishment of the return period of given salinity concentrations directly, rather than establishment of the return period of the drought that produces such salinity concentrations. In other words, it was felt that it would be more useful to establish probabilities and return intervals of the effects of the drought rather than the drought itself. In this way it is possible to avoid arbitrarily defining the drought event and thereby proceed directly to the subject of interest, namely the observance of given salinity concentrations in the estuary.

The review of the work of Keighton discussed earlier and the availability of conductance and flow data collected by the U. S. Geological Survey at a number of stations in the upper estuary suggested that it might be possible to develop an improved statistical relationship between flow and salinity that could be used along with fresh-water inflows at Trenton to yield given salinity concentrations at various points in the estuary.[1]

It is felt that the establishment of such a relationship between fresh-water inflows at Trenton and salinity concentrations in the estuary would permit the application of synthetic hydrology and simulation techniques to develop a synthetic trace of fresh water inflows at Trenton that would

1 The terms "salinity" and "chloride" are used interchangeably in this study to refer to the concentration of chlorides.

in turn permit the generation of synthetic salinity concentrations in the estuary. The generation of synthetic hydrology within a river basin and the use of simulation models as a means of simulating basin flows has become a well-established engineering technique. Synthetic hydrology and simulation techniques have been successfully applied in a number of river basins across the country over the last 15 years. In particular these techniques were applied successfully by Hufschmidt and Fiering (1966) to the Lehigh and main stem Delaware Rivers. Shiao and McSparran (1971) generated synthetic hydrology in connection with a reappraisal of the water resources of the Delaware Basin after the drought of the early 1960s (DRBC (1967)).

With the possibility of developing a valid statistical relationship between salinity concentrations in various points in the estuary and fresh water inflow at Trenton, and the availability of standard simulation and synthetic hydrology generating techniques, it appeared possible that the return interval and probability of given salinity concentrations at various points in the estuary could be established.[1] The basic approach taken in this study was 1) to dev-

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1 Return intervals determined in this study vary in length, but it is necessary to point out that when return invervals and periods of analysis (sample sizes) are of the same order of magnitude, the return interval is not a useful design parameter because of sampling instability. A more useful statistic is the number of exceedances of a particular event during the period of analysis. In this study, return interval is used operationally as a substitute for the latter concept.

Only recently (1975) have there been reliable studies on the stability of the distribution of flow, Q_T. Generally speaking, the estimate of $E[Q_T]$ from a sample of annual flow events significantly underestimates the severity of the event. For example, to estimate the 50 year flow from a 20 year record of flows with a log normal distribution and a skew coefficient of 0.5, it would be necessary to estimate from the observations, the 150 year flow to obtain an unbiased estimate of the desired expected value. For events with long recurrence intervals, the estimating process is very unstable.

elop a statistical relationship between freshwater inflows at Trenton and salinity concentrations in the estuary, 2) to generate synthetic flows at various stations in the Delaware basin above Trenton using a standard technique for generating such hydrology and 3) to apply a standard river basin simulation program to these flows so as to establish synthetic freshwater inflows at Trenton. The statistical flow-salinity relationship would then be used to develop synthetic salinity concentrations in the estuary. Such synthetic concentrations would provide the basis for estimating probabilities or return intervals for salinity concentrations at points in the estuary and for estimating the water supply consequences of these episodes.

III.E.2(d) Statistical Analysis of Conductance and Salinity Data

Introduction --

As discussed in previous paragraphs, the approach selected for this study for estimating the probability of given salinity concentations involves the statistical analysis of conductance and salinity data in order to obtain a relationship betweei freshwater inflow into the estuary and chloride concentrations at points of interest in the estuary. The statistical analysis is based on the following considerations:

1. The correlation between freshwater inflow at Trenton and chloride concentrations in the estuary. Inherent in this consideration is the explicit inclusion in the analysis of only that portion of the consumptive use projected to occur above Trenton.
2. The selection of Torresdale and Pier 11 as locations where the basic statistical analysis was carried out.
3. Correlation of flow with conductance rather than actual chloride data as determined by wet chemistry and the related issue of the existance of ocean derived salts when chloride concentrations are less than 50 mg/l.

Each of these considerations is discussed in more detail in the following paragraphs.

The freshwater inflow at Trenton was selected for correlation because it has been found to be singly the most significant influence on salinity in the estuary. The flow at Trenton is the largest single source of fresh water inflow and additionally, it impacts upon the freshwater portion of the estuary thus producing the maximal effect in repelling salinity (Strandberg (1975)). In addition, a good correlation between freshwater inflow and salinity in the lower estuary was obtained by Keighton (1966), as discussed in subsection (b) above.

It could be argued that a more defensible relationship would result from considering freshwater inflow at the mouth of the Schuylkill, or perhaps the total freshwater inflow entering the estuary. It is to be pointed out that the total freshwater inflow into the estuary is correlated with the freshwater inflow at Trenton because the Delaware River flow at Trenton is by far the largest single component of freshwater into the estuary. Additionally, the hydrology of the basin is similar and wide variations in freshwater inflow, particularly on a monthly basis, cannot be expected.

Correlation of salinity in the estuary with freshwater inflow at Trenton necessarily implies explicit consideration of only that portion of the consumptive use that occurs above Trenton. Conceptually, consumptive use may be considered to be negative streamflow in the sense that consumptive use is by definition that portion of withdrawals that is lost through evapotranspiration. Freshwater inflows into the estuary can be adjusted for future consumptive use by deducting net future consumptive use from freshwater inflows.

Consumptive use for each ten year period, 1975-2025, is projected in Section C above. Also discussed in that section is the finding that the pattern and distribution of consumptive use around the basin cannot be expected to change significantly during the period 1975-2025. The uniformity in the distribution of consumptive use in the future thus permits the consumptive use to be implicitly included in freshwater inflow. Such use is implicitly considered since above Trenton it is explicitly considered by deducting it from the freshwater inflow at Trenton and since the total freshwater inflow into the estuary is correlated with the freshwater inflow at Trenton.

Figure 3-10 shows the location of USGS monitoring stations. Data from the Torresdale and Pier 11 monitoring stations were the basis of the correlation between freshwater inflow at Trenton and salinity concentration. The Torresdale station was selected because it is immediately adjacent to the Torresdale intake. Pier 11 was selected because it is adjacent to the Camden aquifers. Other stations could have been selected in the lower estuary for the purpose of determining probabilities of given salinity concentrations that may be useful in determining the effect of increased consumptive use and diversion on industrial water supplies.[1] Because such supplies have little public health significance, the analysis in this study was confined to Torresdale and Pier 11.

Conductance data was used in the correlation analysis for Torresdale and Pier 11 rather than chloride data as determined by wet chemistry. According

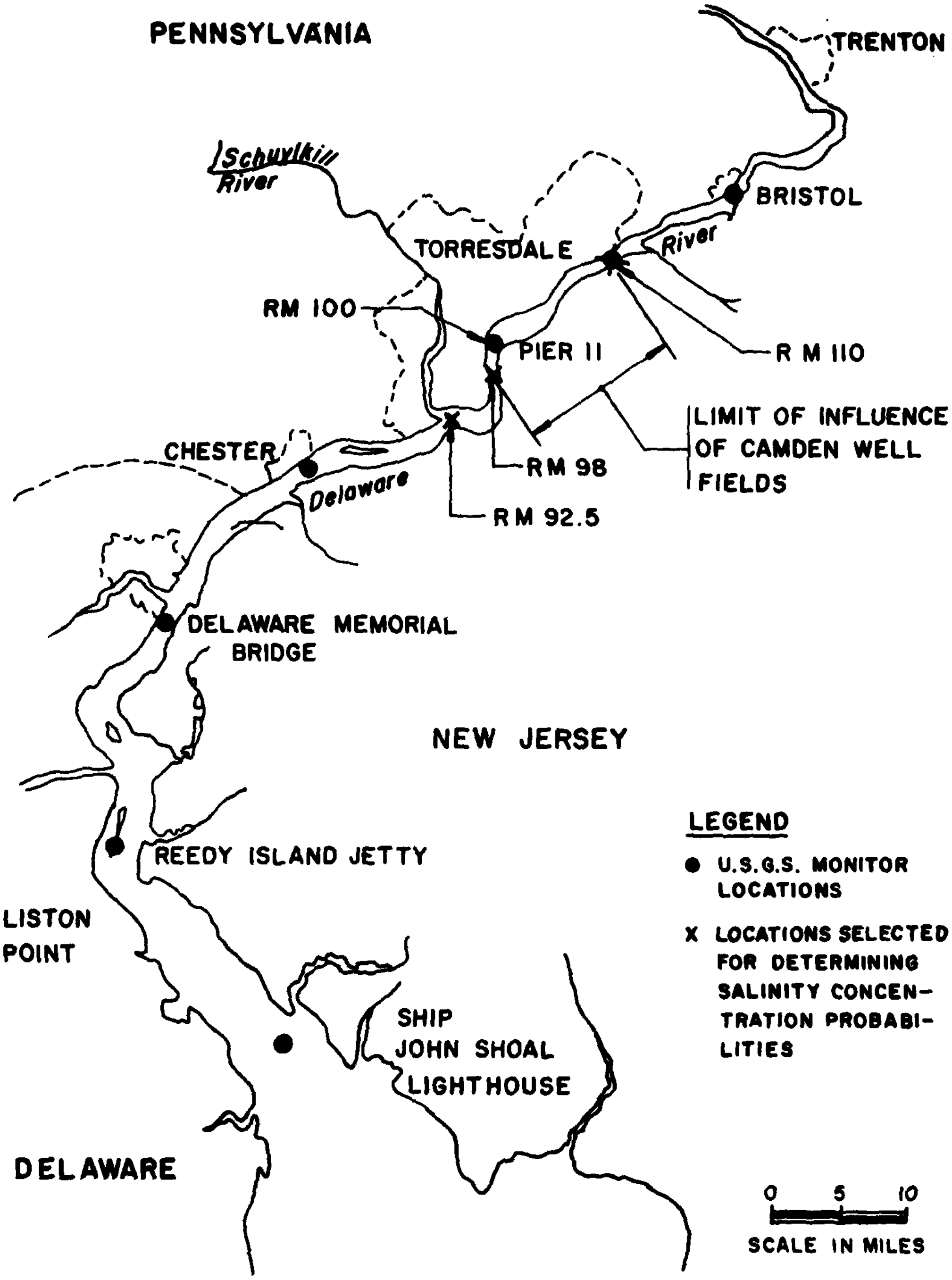
1 Correlations could have been developed for stations lower in the estuary for the purpose of demonstrating the general response of salinity concentrations in the estuary to freshwater inflows at Trenton. However, the success of Keighton (1966) in correlating freshwater inflows at Trenton with salinity concentrations in the estuary, including one a mile north of the mouth of the Schuylkill River, demonstrated that valid correlations could be developed for those stations.

to the Philadelphia Office of the USGS, which is responsible for collecting conductance and chloride data in the estuary, there is a good relationship between conductance and chloride concentrations in excess of 50 mg/l. The 50 mg/l figure is important since it corresponds to the chloride standard set by the DRBC and the purpose of much of the analysis in this study is to determine expected exceedances of this value at Torresdale.

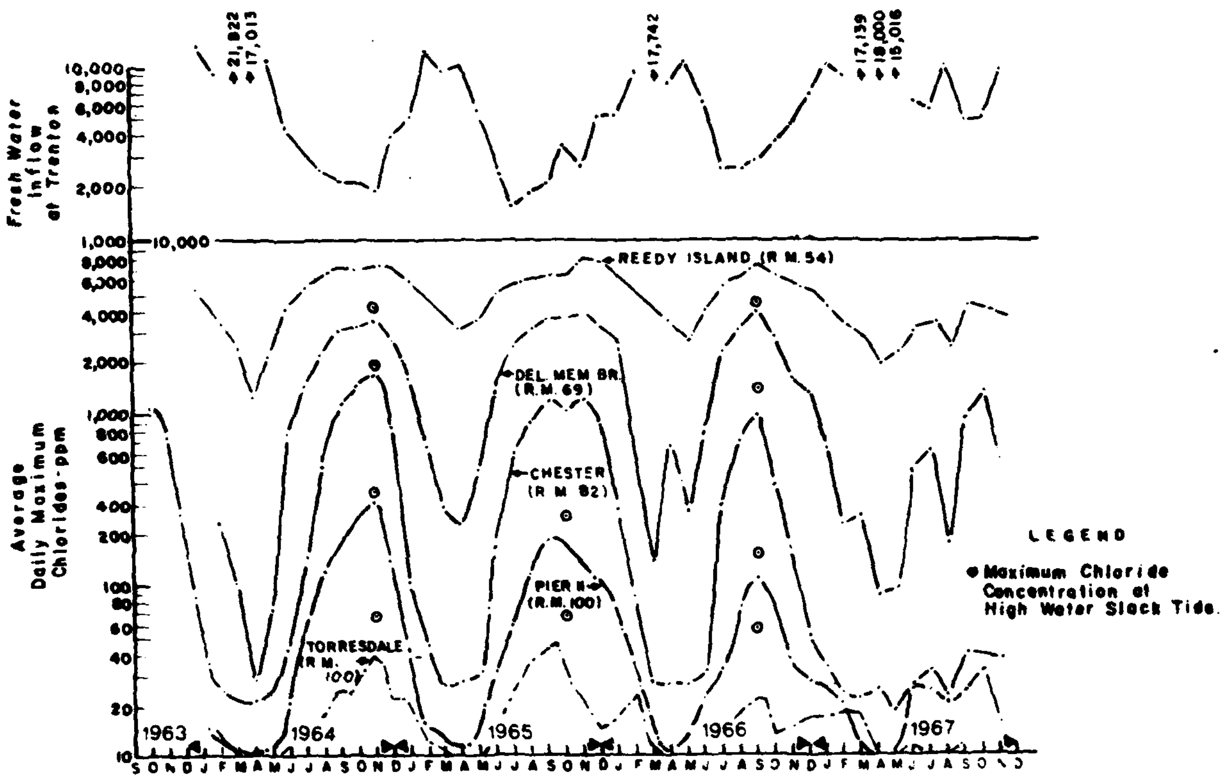
When chloride concentrations less than 50 mg/l are observed in the Delaware estuary, a question can be raised as to the portion contributed by freshwater inflow and wastewater discharges to the estuary, and that portion derived from the ocean. Opinion among those who have studied the estuary over the years varies on the subject. However, it is clear that in an estuary environment, with sea water diffusing throughout the system, it is impossible to tag ions as to their ultimate origin. The advective and convective processes cause sea water to mix upstream, to contribute salts to upstream reaches, and generally to cloud the discrimination. Even though chloride concentrations at Torresdale as determined by conductance were less than 50 mg/l almost all the time during the period 1964-1971, it is believed that their influence was taken into account in the random behavior of the total chloride concentration.

The validity of the Torresdale analysis is strengthened by a similar correlation between freshwater inflow and conductance developed for the Pier 11 station. Figure 3-10a shows a plot of chloride concentrations for the Torresdale and Pier 11 monitoring stations for the period

LOCATION OF SALINITY MONITORING STATIONS AND OTHER POINTS OF INTEREST RELATIVE TO SALINITY ENCROACHMENT IN THE DELAWARE ESTUARY



III



Source: Similar plot in Strandberg (1975); original plot in Goodell (1968)
Torresdale points added in this study

FLOW-CHLORIDE RELATIONSHIP AT USGS MONITORING STATIONS,

1964-67

1964-1967. Other stations lower in the estuary are also shown. If a threshold of 50 mg/l is accepted as that concentration that is generally considered to indicate the presence of significant ocean derived salts, it can be seen that concentrations as high as 300 mg/l were observed during the period 1964-1966 at Pier 11. Chloride concentrations in excess of 50 mg/l were present at Pier 11 for six months in 1964, seven months in 1965, and three months in 1966. Because the results of this study are based not only on the Torresdale conductance data but also on Pier 11 conductance data, it is clear that the data base used in the study includes adequate conductances corresponding to ocean derived chlorides.

In the following discussion, flows are measured at Trenton (in cfs) and conductances are measured at Torresdale and Pier 11 (in micro-mhos). Conductances may be converted to a concentration of total dissolved solids by using relationships derived in the study by Keighton (1966) referred to earlier as follows:

$$TDS = 0.52K + 16 \quad \text{for } K < 300$$

$$TDS = 0.6K \quad \text{for } 300 \leq K < 4000 \text{ and}$$

$$TDS = 0.8K - 800 \quad \text{for } K \geq 4000$$

where: TDS is total dissolved solids in mg/l, and

K is conductance in micro-mhos.

The total dissolved solids are employed to obtain chloride concentration (salinity) through another set of relationships developed by Keighton (1965) in an earlier study. These relationships, contained in Figure 3-11, show the composition of the total dissolved solids in the Delaware estuary, of which chloride concentration is one component.

Spectral Analysis of Conductance Data --

Spectral analysis is a statistical technique for analyzing the characteristics and interrelationships among time-varying functions, particularly in regard to their phase differences and periodicity. Spectral analysis is of benefit in that it can be used to analyze the variation of dissolved solids in the estuary, freshwater inflow at Trenton, and the time relationships between them.

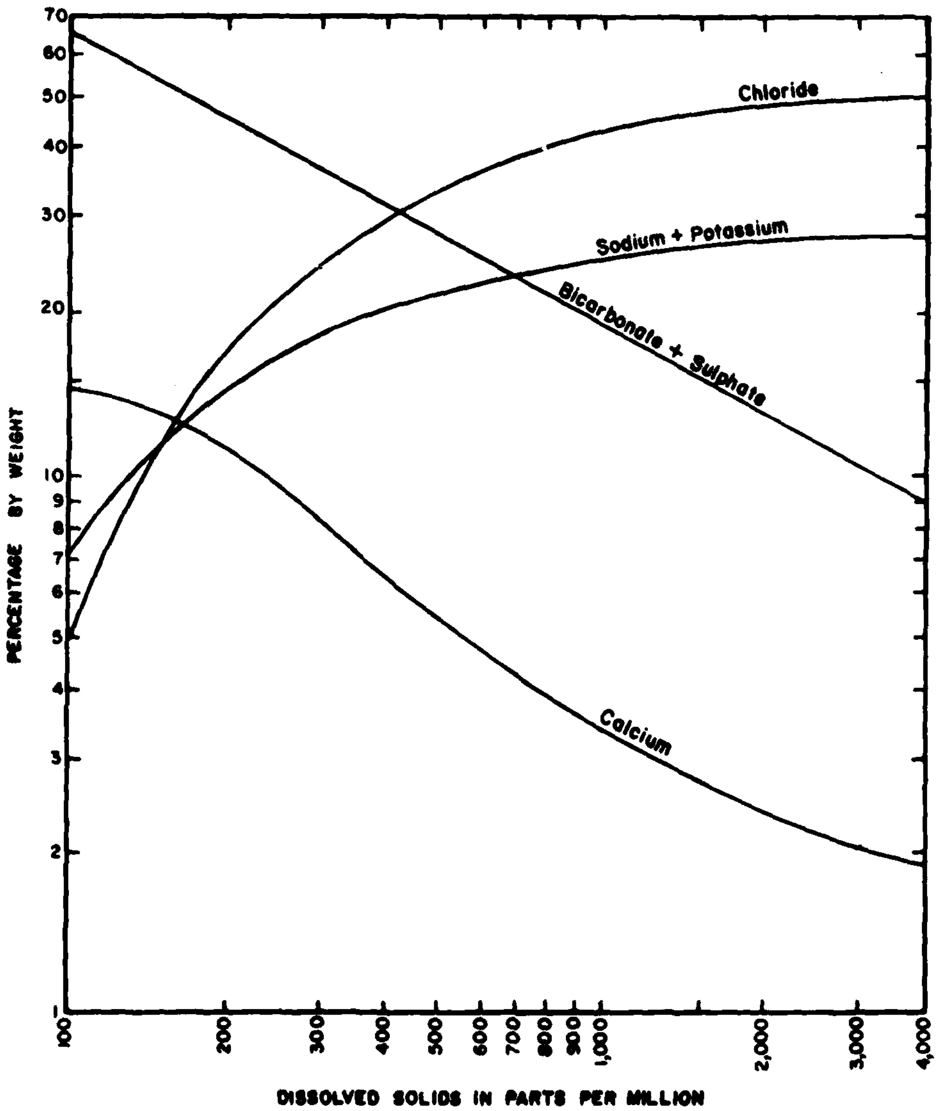
Two years of conductance and freshwater inflow data were examined in detail in the spectral analysis. The two years were water year 1965, representing a typical dry year, and water year 1971, a typical normal year.[1] It could be argued that years other than 1965 and 1971 would yield different results; surely this is true. But statistical analysis does not explain a system, it merely describes it. The two years selected span a wide range of flow conditions and the results of analyses are very close. Therefore, it was felt that the inclusion of other years would add little to the development of the methodology used in this study. Also, specially constructed sequences could skew or bias the propriety of the model developed in the study. It is thus essential that results be based on realistic combinations (i.e., observations) rather than on critical sequences that could surely be derived independently. Because the approach used in this study is to obtain expected chloride concentrations[2] in the probabilistic sense rather than results stemming from the consideration of critical sequences, actual observed conductances and flows, such as found in the 1965 and 1971 data, were examined.

---

1 It is important to point out that while two years of data were used for the spectral analysis, eight years (1964-71) were used in the correlation analysis discussed below.

2 while preserving their variance.

COMPOSITION OF DISSOLVED SOLIDS
IN DELAWARE ESTUARY



source: Keighton (1965)

A spectral analysis was made of the daily measurements of conductance and inflow, represented as two time-varying series, by plotting their serial relationships (auto-correlations), and examining the characteristics of these correlations and the periodicities of the time series. The plotted information resulting from the spectral analysis is not used to develop correlation coefficients, but to develop a feeling for the temporal and spatial characteristics of various flow and conductance parameters and to validate regression estimators suggested below. On the basis of these analyses, multivariate regression procedures were used to calculate the coefficients in the logarithmic relationship between conductance and inflow.

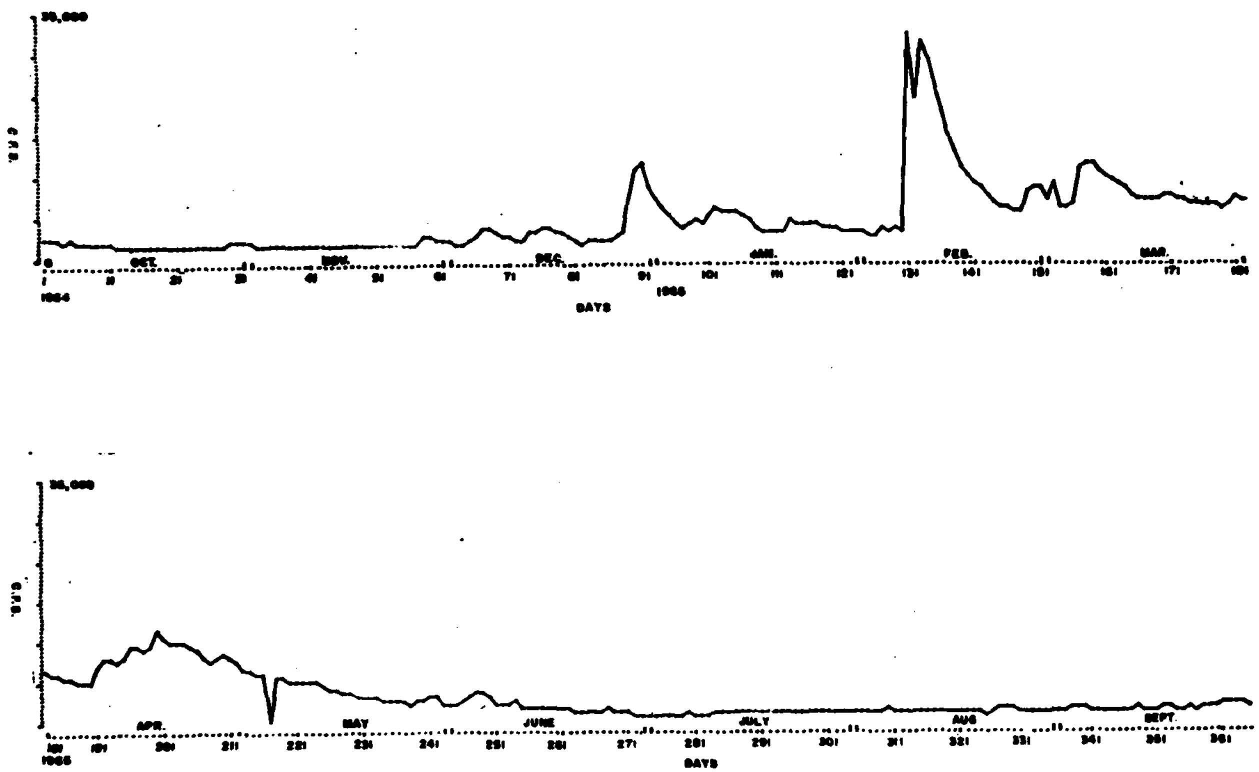
Figures 3-12 and 3-13 show the daily average inflows at Trenton for the water years 1965 and 1971, respectively. Figures 3-14 and 3-15 show the corresponding chronological variations of specific conductances for these two years. The uniformity of this parameter should be noted. Despite relatively wide swings in the daily flows, as shown in Figures 3-12 and 3-13, the specific conductances remained relatively uniform. This fact immediately suggests that any meaningful relationship between flow and conductances should be based on some long-term or smoothed function of the flows because the daily perturbations do not significantly influence the conductance (or salinity).

Figure 3-16 shows the autocovariances of flows at Trenton. If the plotted values are divided by the variance of the flows, the result would be the autocorrelation function, bounded by ± 1. It is of interest to note that for a normal year, i.e., 1971, after a lag of approximately 60 days, at which point the autocovariance goes to zero, it remains negative, but only barely, so that from the shape of the curve it is possible to postulate readily a decaying or exponential autocovariance function typical of a Markov process. This further suggests that a particularly relevant time lag for the flow process is of the order of 60 days, or two months, and that thereafter the process either works to control itself (by introducing negative feedback or correlations) or that it does not significantly effect the flow regime. Similarly, the function for 1965, a "dry" year, shows the same general exponentially decaying behavior but a longer period of effective positive correlation, roughly 75 days, whereupon the autocovariance becomes negative.

It is tempting to think that the negative autocovariance, larger for 1965 than for 1971, suggests a different correlation pattern, but this may not necessarily be true because the correlation coefficients must be derived by scaling these plots by dividing by the variances. Because the flows in 1971 are generally larger than those in 1965, and because the fluctuations of 1965 follow a different pattern, these variances themselves may be quite different. Therefore, both systems would seem to reflect a tendency to recovery after about two months. What this means is that long periods of continuous drought, such as those observed during the early 1960's, lie outside the ability of the data to represent the phenomena at reasonable levels of statistical significance. If these phenomena are deemed worthy of special concern, they must be accommodated by special techniques and estimators.

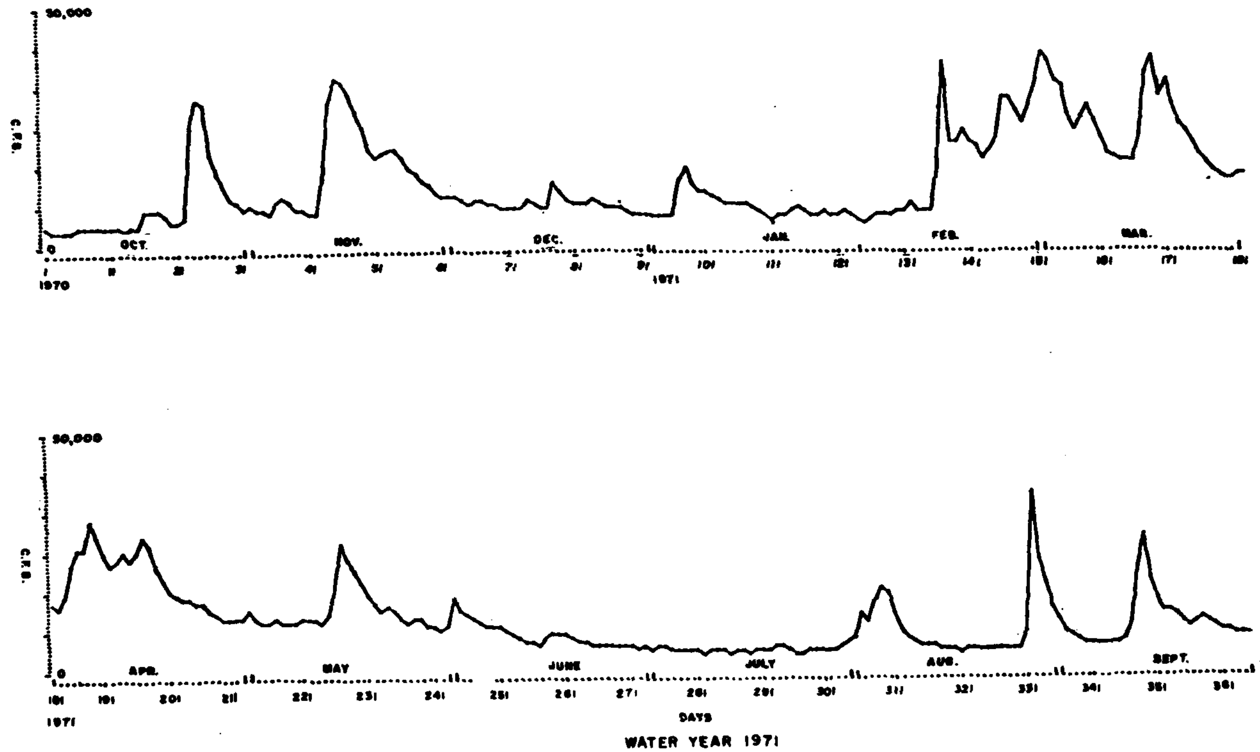
Figure 3-17 shows the autocovariances of the conductance, and the generally decreasing values confirm the absence of long-term correlation or persistence among these data.

DAILY AVERAGE INFLOW AT TRENTON

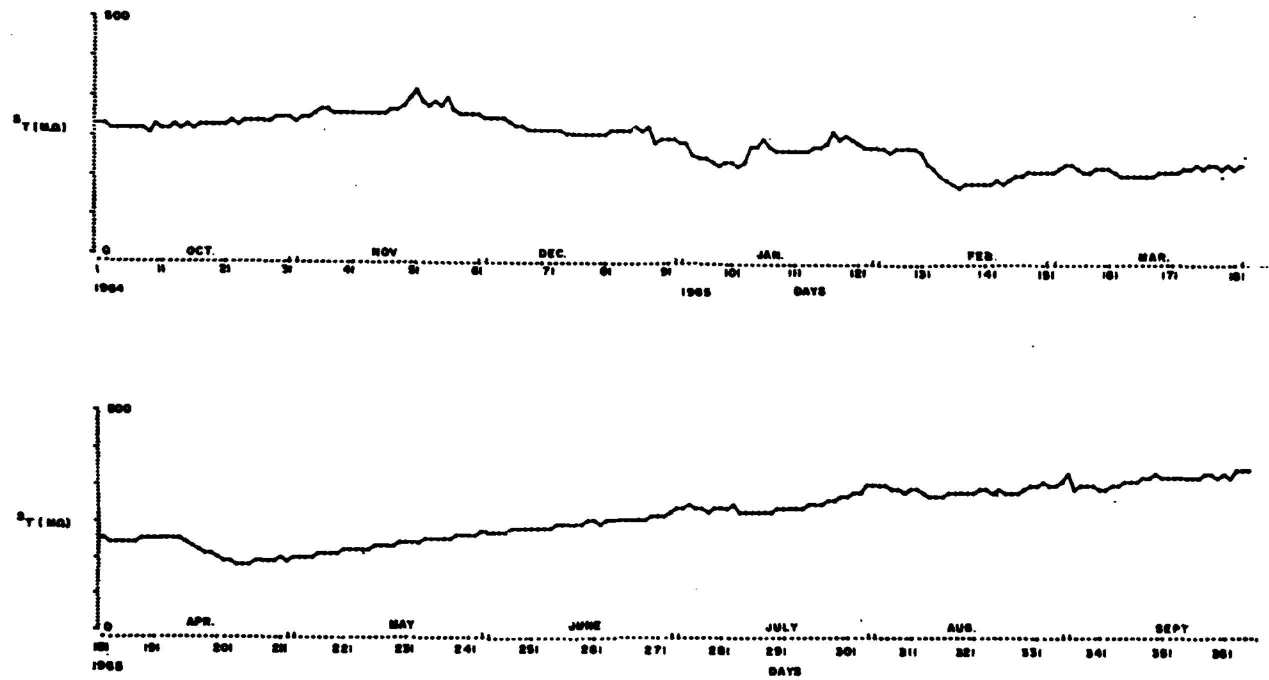


WATER YEAR 1965

DAILY AVERAGE INFLOW AT TRENTON

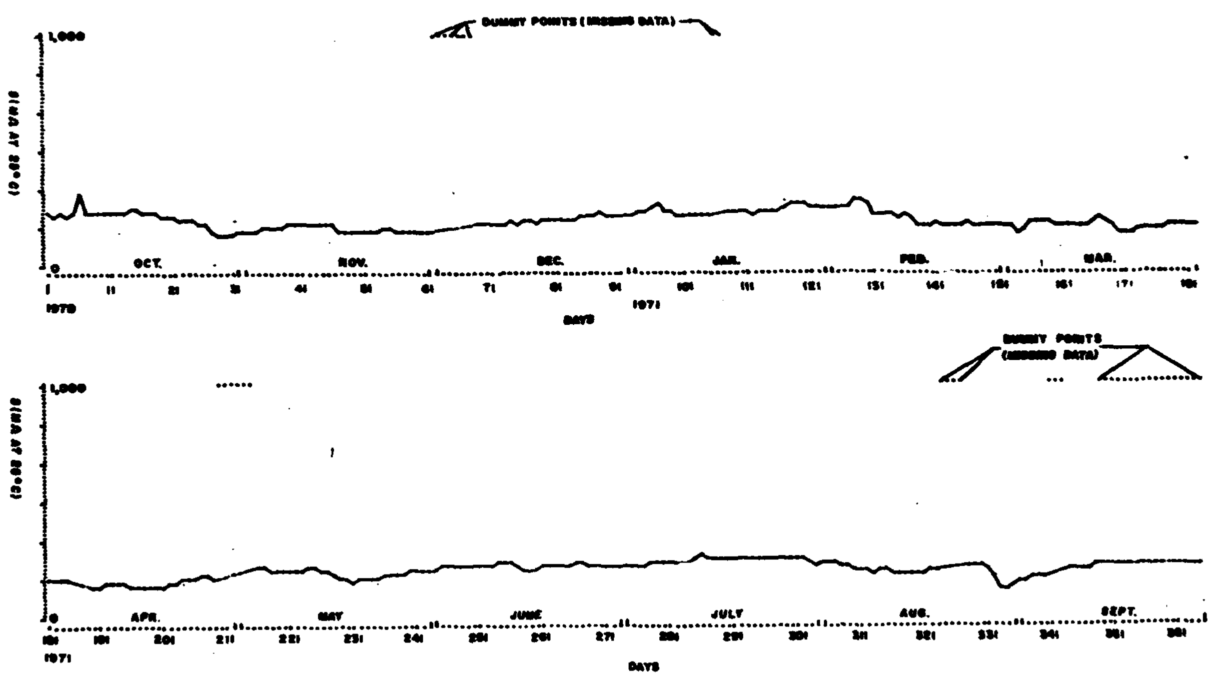


DAILY AVERAGE CONDUCTANCE AT TORRESDALE



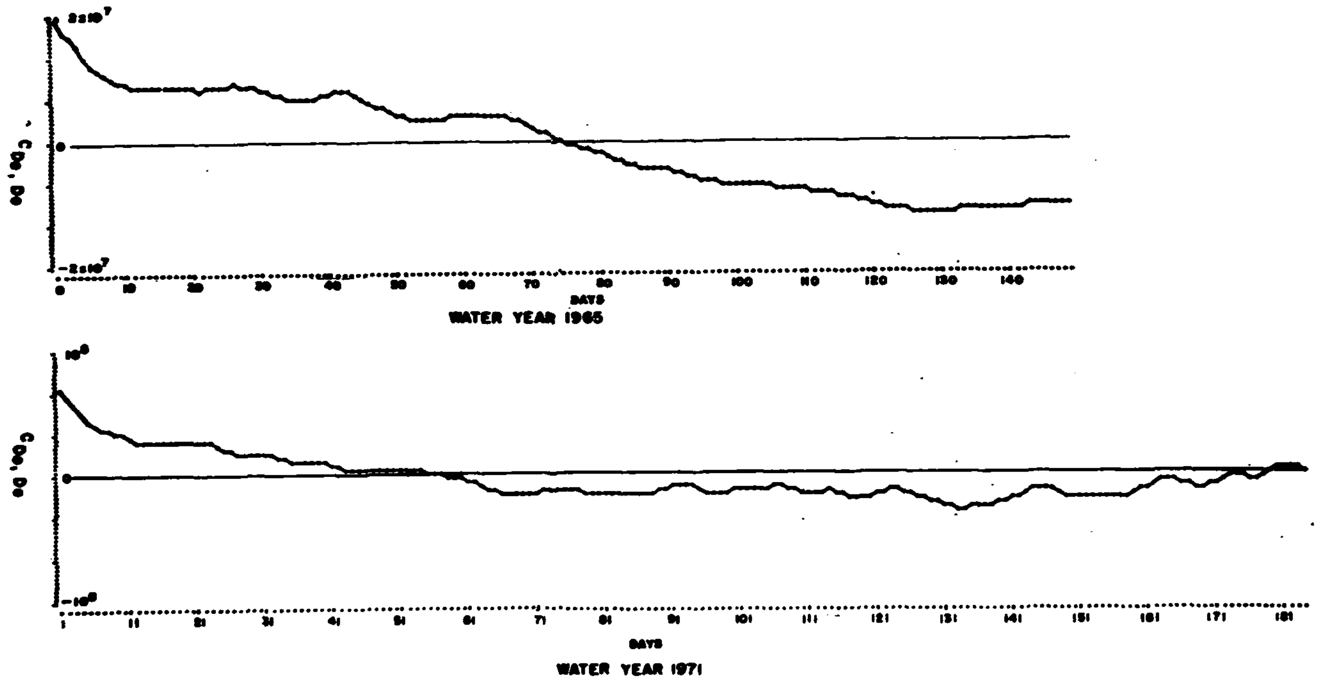
WATER YEAR 1965

DAILY AVERAGE CONDUCTANCE AT TORRESDALE



WATER YEAR 1971

AUTOCOVARIANCE OF DAILY AVERAGE INFLOW AT TRENTON



AUTOCOVARIANCE OF DAILY AVERAGE CONDUCTANCE AT TORRESDALE

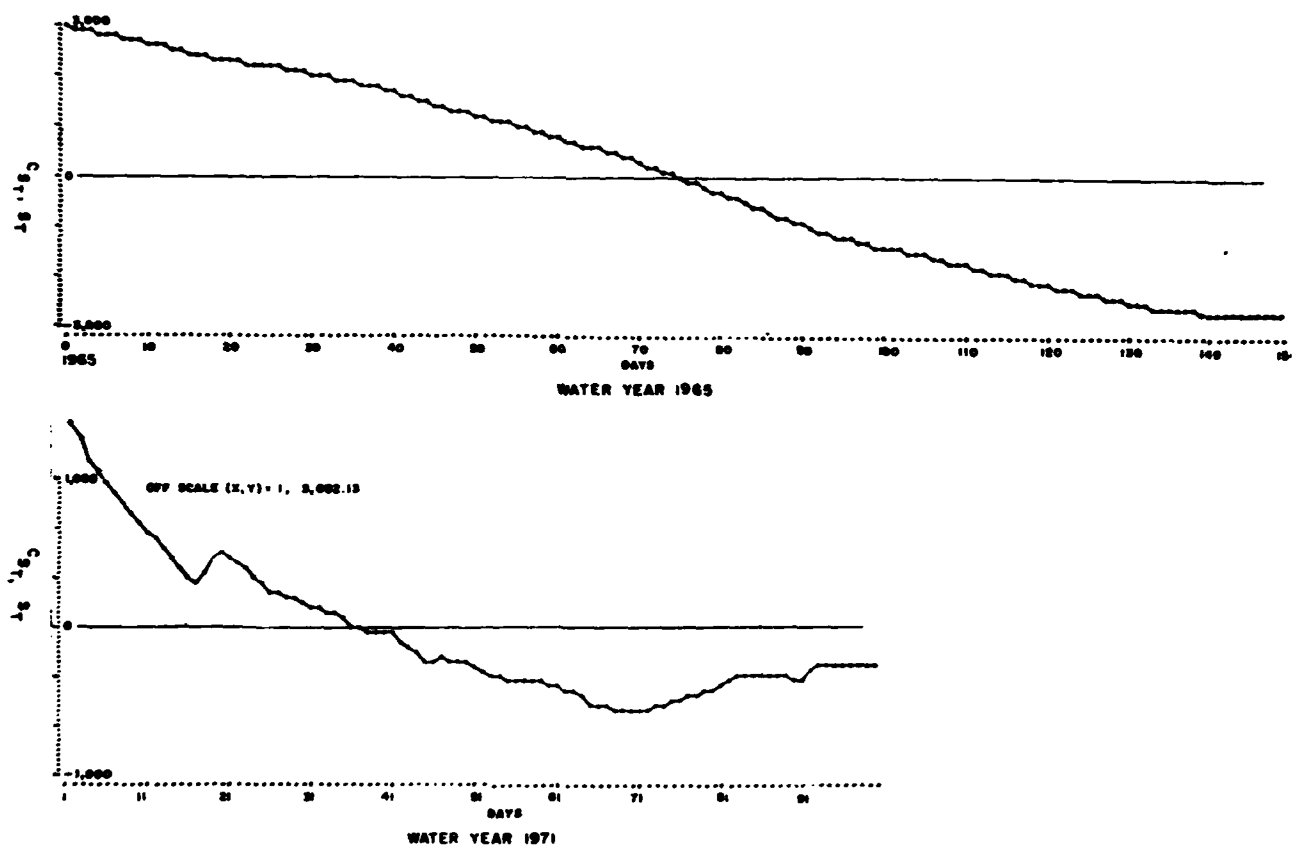


Figure 3-18 shows the cross-correlations between daily flows and lagged or previous conductances. It demonstrates an important result: for the normal year, the correlation is negative for all lags up to exactly 30 days, indicating, as could be expected, that the sign of the correlation coefficient between salinity (or conductance) and flows during the first antecedent month should be negative. The correlation for the next group of lags, ranging roughly from 30 to 100 days, is slightly positive. This would suggest that there is a flushing period after which high flows imply high conductance (or salinity), which is counter to intuition. However, it should be recalled that there is another relationship at work here, namely, that between the flows in the first antecedent month and those in the second. The multivariate regression techniques employed in this study suggest that the lagged (positive) relationships between the current and antecedent months are sufficiently strong to overcome the lagged (negative) relationship between discharge and salinity. For 1965, the lagged cross-correlation analysis shows that the period of negative relation extends for exactly two months, and thereafter is positive. This suggests that different coefficients would be appropriate for estimating equations in periods of high and low flow, and forms the basis for the discrimination among the data points used in subsequent analyses. The clarity of these results reinforces one's intuition about system behavior and provides insight into how to formulate estimating equations for obtaining salinity concentrations from freshwater inflows.

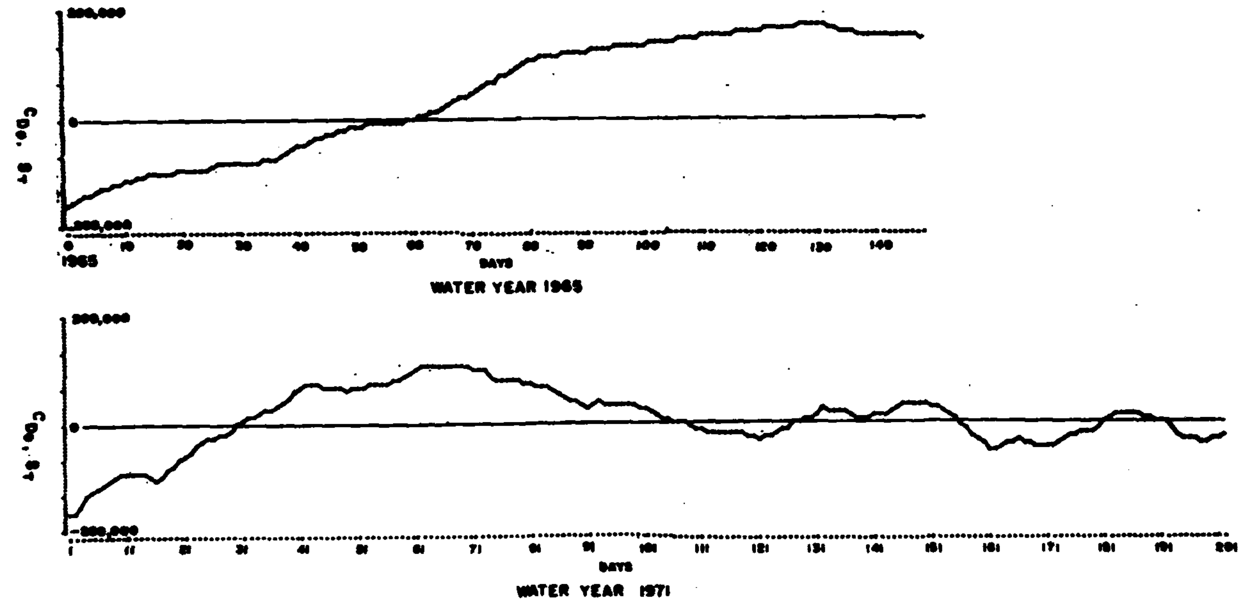
Figure 3-19 shows the 10-day average flow at Trenton, and Figure 3-20 shows the autocovariance function of 10-day average flows, both plotted from 1971 data. These graphs are expectedly smoother than the similar ones based on daily values as their source data have passed through an averaging process. They add relatively little to our understanding of the system, so similar plots for 1965 data are not presented.

Figure 3-21 shows the cross-correlation of 10-day average flow and conductance for 1971. This reinforces the earlier conclusion that the significant extent (in days) of the negative cross-correlation is approximately one month. Nevertheless, the step-wise regression functions developed in a later section include a contribution from the antecedent 10-day flow.

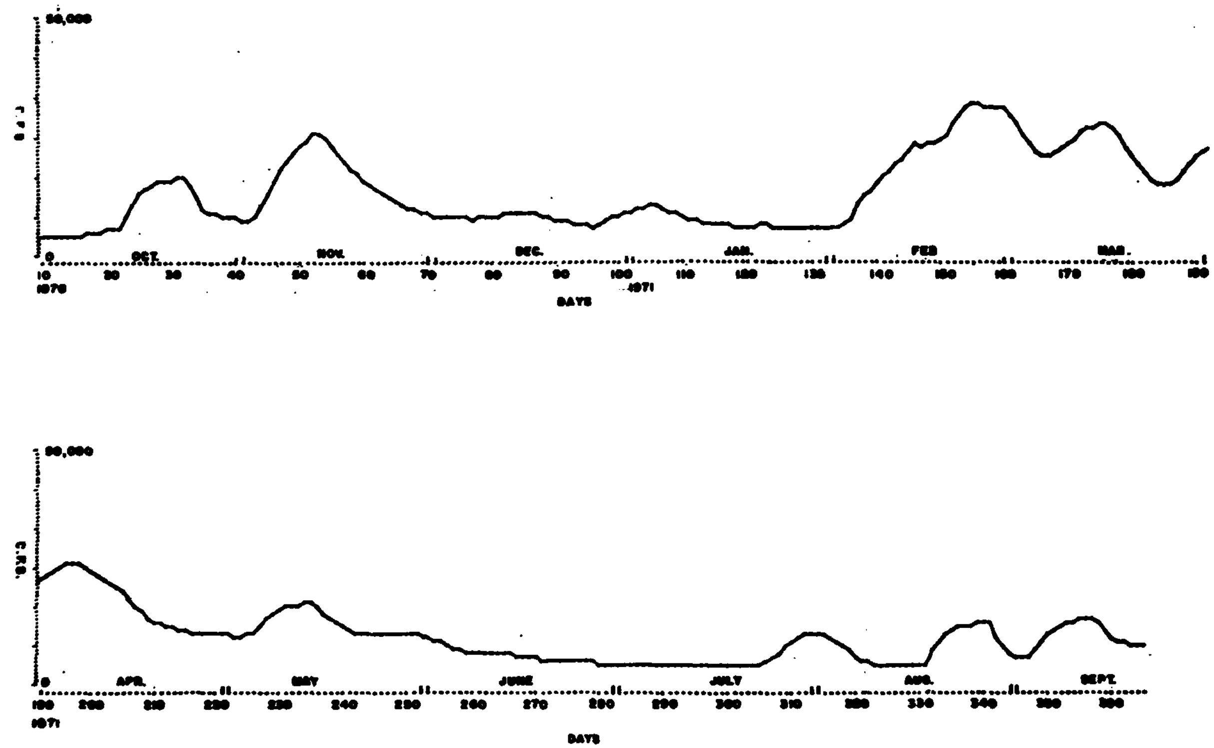
Having examined the serial characteristics of the flow and conductance parameters, the analysis next considers the frequency domain to determine whether diurnal fluctuations, tidal effects, or other periodic or oscillatory movements within the system significantly affect the way in which the variance is assigned to the several frequencies. As shown in Figure 3-22, apart from the initial spike associated with the lowest frequencies (or the largest wave lengths T_1), there is nothing remarkable about the spectral density functions for 1971 and 1965. The same conclusions can be drawn for spectral density functions of the conductance as shown in Figure 3-23.

Figure 3-24 shows the coherence spectrum of flow and conductance. Its significance warrants detail explanation as follows:

CROSS CORRELATION OF DAILY AVERAGE INFLOW AT TRENTON AND CONDUCTANCE AT TORRESDALE

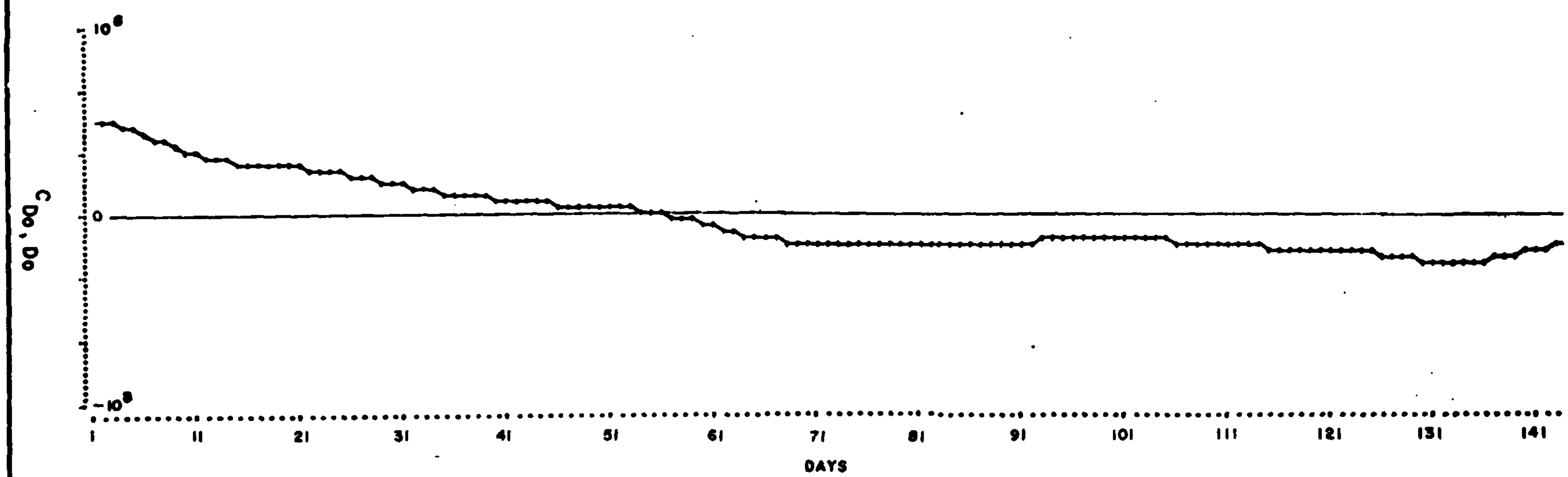


10-DAY AVERAGE INFLOW AT TRENTON



WATER YEAR 1971

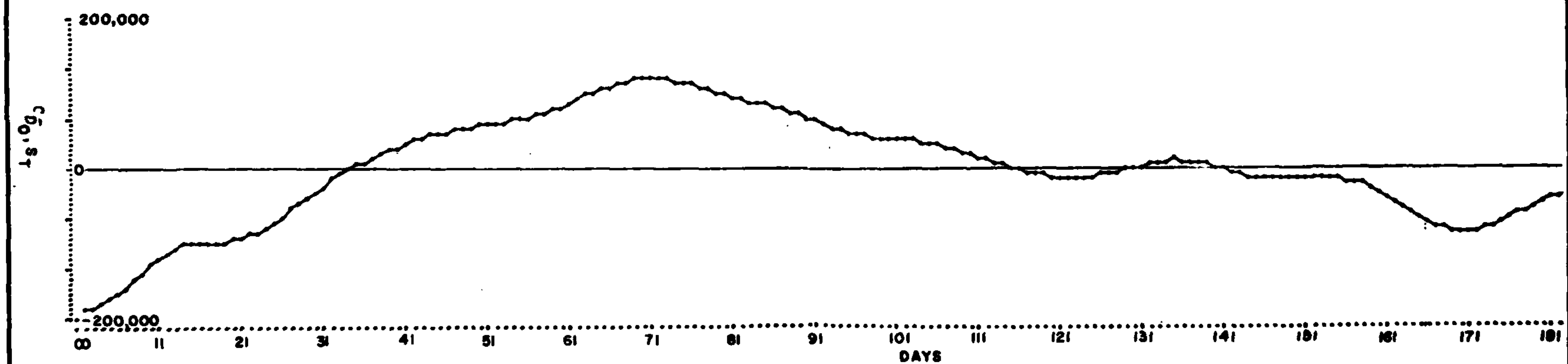
AUTOCOVARIANCE OF 10-DAY AVERAGE INFLOW AT TRENTON



WATER YEAR 1971

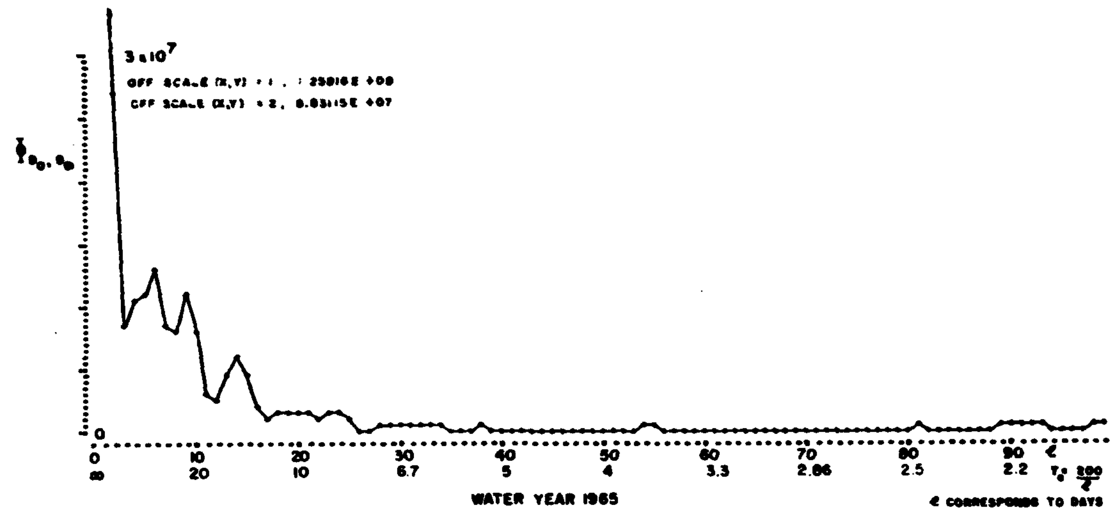
20

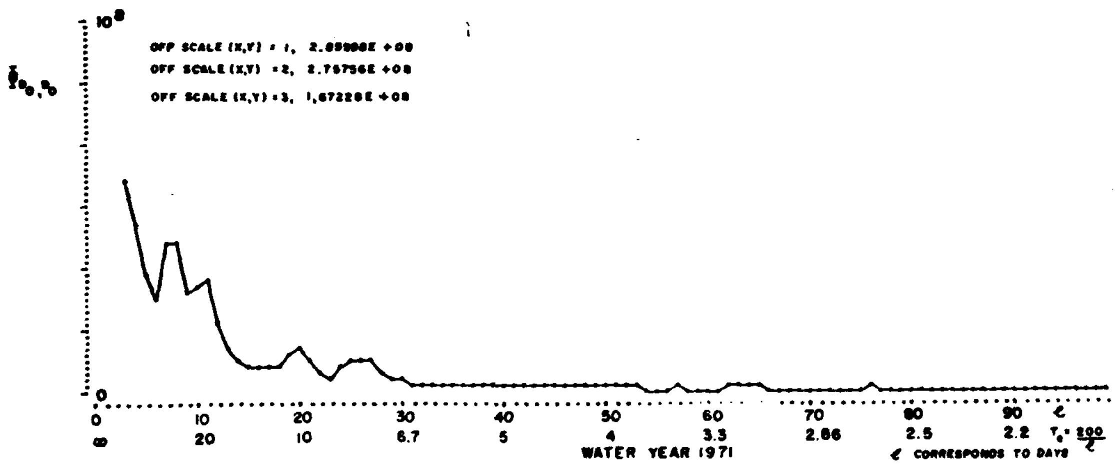
CROSS CORRELATION OF 10-DAY AVERAGE INFLOW
AT TRENTON AND CONDUCTANCE AT TORRESDALE



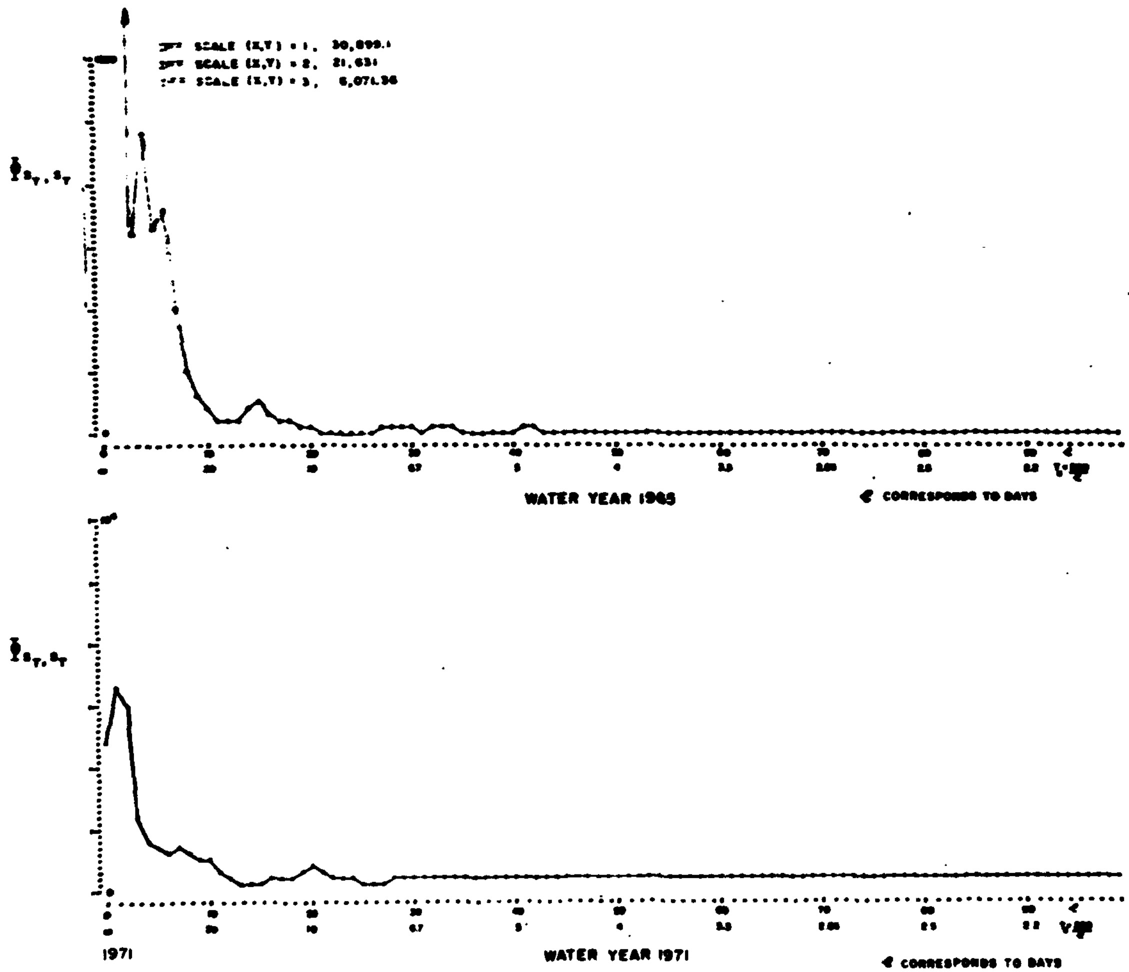
WATER YEAR 1971

SPECTRAL DENSITY OF DAILY AVERAGE INFLOW AT TRENTON

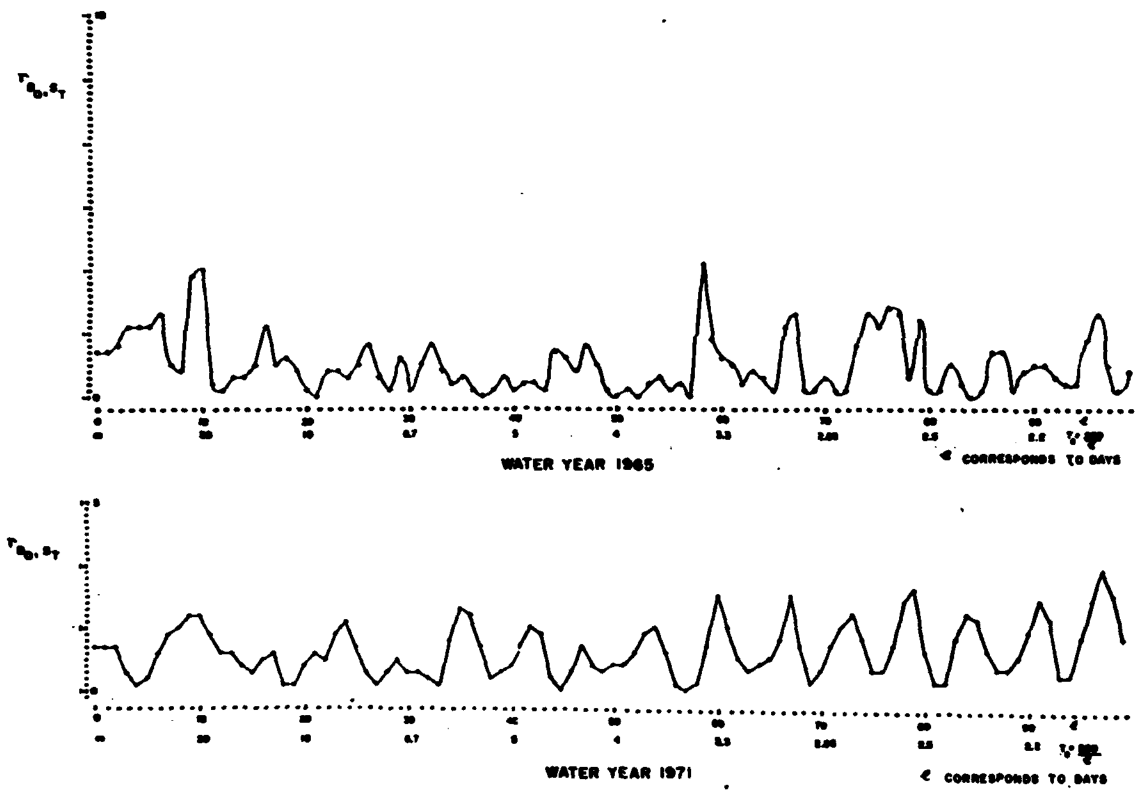




SPECTRAL DENSITY OF CONDUCTANCE AT TORRESDALE



COHERENCE SPECTRUM OF DAILY AVERAGE INFLOW AT TRENTON AND CONDUCTANCE AT TORRESDALE



Consider two time series, $x_1(t)$ and $x_2(t)$. The autocovariance functions are defined by

$$\phi_{1,2}(\tau) = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} x_1(t)\ x_2(t+\tau)dt$$

$$\phi_{2,1}(\tau) = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} x_2(t)\ x_1(t+\tau)dt$$

The co-spectrum and the quadrature spectrum are defined as follows:

$$A_{1,2}(\omega) = \frac{1}{2\pi}\int \phi_{1,2}(\tau)\cos(\omega t)d\tau$$

$$B_{1,2}(\omega) = \frac{1}{2\pi}\int \phi_{1,2}(\tau)\sin(\omega t)d\tau$$

where ω represents frequency and is mappable directly into wavelength . The subscripts 1, 2 apply to the series x_1 and x_2, respectively.

A random time series may be thought of as a superposition of an infinity of periodic functions. If we consider a wave of frequency derived from each time series, we can attempt to calculate their phase or angular displacement. The degree of linear associaiton in the frequency domain is analogous to the product-moment correlation coefficient in the amplitude domain, and is called the <u>coherence spectrum</u>. It is a function of ω and is calculated by the relationships

$$\Gamma_{1,2}(\omega) = \frac{A^2_{1,2}(\omega) + B^2_{1,2}(\omega)}{\mu}$$

$$\Gamma_{2,1}(\omega) = \frac{A^2_{2,1}(\omega) + B^2_{2,1}(\omega)}{\mu}$$

where

$$\mu = \left(\frac{1}{2\pi}\int\phi_{1,1}(\tau)\exp(-i\omega\tau)d\tau\right) x \left(\frac{1}{2\pi}\int\phi_{2,1}(\tau)\exp(-i\omega\tau)d\tau\right)$$

It has the same form as a correlation coefficient, involving some cross-power terms in the numerator and the product of standard deviations (or variance terms) in the denominator. The value of the function $\Gamma(\omega)$ is the degree of lin·ar association in the frequency domain corresponding to an argument ω. If any values are particularly high over a range of frequencies, it suggests an oscillatory or periodic association between driving forces (for example, the tide) and some other parameter or statistic. Thus, for the purpose of developing a meaningful relationship between fresh water inflows at Trenton and salinity concentration at various points in the estuary, there does not appear to be any strong relationship (in Figure 3-24) to offer in lieu of the estimating equations that are developed below to determine salinity from fresh water inflow at Trenton. That is, there is no evidence that long-term average (of the order of 1 to 2 months) should not be used. This is a very important consideration because it precludes the use of specialized daily relationships and biases derived from differential equation modes. The computational requirements might otherwise make it awkward to employ the simulation procedure in obtaining the synthetic salinity concentrations.

The spectral analysis discussed in previous paragraphs was performed for only the Torresdale conductance data. A spectral analysis was considered for the Pier 11 data, but was not carried out because of the similarity between the shape of the Torresdale chloride concentration curve and the chloride concentration curve at Pier 11, as illustrated by Figure 3-10a. It can be seen from this figure that the lag between the observed low flow at Trenton and the times of peak, are very similar for the Torresdale and Pier 11 stations. It is also apparent that the general characteristics of the basic chloride curves, particularly the lags between observed low flow at Trenton and times of peak are fairly uniform throughout the estuary. It is likely that a spectral analysis of the Chester, Delaware Memorial Bridge and Reedy Island data would lead to the same conclusion relative to lag times and other statistical properties of the data.

Correlation between Flow and Salinity --

Having determined that it is reasonable to use a relationship that derives the daily salinity values in the estuary from antecedent long-term or monthly flows, it is necessary to develop an algorithm for dividing average monthly synthetic flows into daily components so that the antecedent values corresponding to mid-month periods can be generated from the calendar monthly volumes. This manipulation is not entirely trivial, and it distinguishes the estimating procedure used in this study from Keighton's method, which uses salinity as the dependent variable in a relationship for which the independent variable is the monthly volume in the preceding calendar month. In the Keighton approach, if the salinity is required on the 15th day of the month, the antecedent month may be quite far removed because it represents flows between 15 and 45 days earlier. Even worse, if the salinity is desired on the 28th or 29th of the month, the "previous monthly" flow is fully 31 to 60 days removed. This may introduce unnecessary unreliability, as it is shown by the autocovariance graphs that correlation coefficients could change from negative to positive within a 30- to 60-day period.

To minimize this type of unreliability, an algorithm has been devised to provide the means of calculating the antecedent monthly flow as that flow, or estimate thereof, that occurred in the previous 30 days, recognizing that this will involve some averaging over more than one calendar month. In essence, it is assumed that a daily hydrograph may be constructed by defining the flow in the mid-month day (15) as the mean monthly flow derived from the synthetic hydrology generator and that linearity of daily flow is guaranteed between the 15th of any month and the 15th of its immediate neighbors, prior and subsequent. The monthly values are therefore susceptible to linear interpolation between the 15th day of each month and that of its immediate neighbors, whereupon the antecedent flows can be developed for each previous day from 1 to 60. This enables the development of an estimating equation based on a least-squares linear function that has conductance as the dependent variable and the following independent variables: current flow, flow one day previous, average flow over the previous 10 days, average flow over the previous 30 days, and average flow from antecedent day 31 to antecedent day 60.

With this vector of antecedent flows, various combinations of regression functions were obtained and examined, including individual functions based on annual data for each water year of record, a single function based on aggregation of all data from 1964 to 1971, and two separate functions based on high and low monthly flows aggregated from 1964 to 1971. In addition, regression functions were obtained for logarithmic transformed values of the dependent variables (conductance and chloride content) and of the independent variables (flows). Estimation of the conductance is based on two regression functions of the form:

$$C = K + \beta_1 \log (Q_{1-10}) + \beta_2 \log (Q_{1-30}) + \beta_3 \log (Q_{30-60}) + R \times SE.$$

where C is the estimated monthly average conductance[1],

K is a constant incorporating the means of the several variables,

Q_{1-10} is the mean flow of the antecedent 10 days,

Q_{1-30} is the mean flow of the antecedent 30 days,

Q_{30-60} is the mean flow of the antecedent 31 days and 60 days,

β's are the partial regression coefficients,

R is a standardized random normal deviate, and

SE is the standard error of estimate.

The discriminant flow (independent variable) that determines which function to use for the estimation of the conductance is set at 8000 cfs at Trenton. With respect to the selection of 8000 cfs, the data arrayed in Figure 3-26 below show that at 8,300 cfs there is a definite break in the slope of the salinity-flow function, so that at an average monthly flow of approximately 8000 cfs, the relationship undergoes a substantive change. Both portions of the curve are thus utilized.

It is to be pointed out that the use of two regression functions almost always results in higher salinities at Torresdale and Pier 11 than the use of a single function regardless of flow at Trenton; and hence, gives a more conservative estimate (higher salinities) for the study.

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[1] To obtain an indication of higher daily conductances, the average ratio of daily maximum to daily average conductance was computed. An average of 1.15, determined from 8 years of conductance data at Pier 11 (1964-1971) was used. Because chloride concentrations reported in subsection (j) below are based on conductances only slightly greater than monthly averages, such chloride concentrations will be less than daily or instaneous maxima obtained from observations or model results reported elsewhere.

Without the last term R, the expression for C is a traditional multiple regression function, but the variance of C is not preserved because part of the variance is removed (or "explained") by the fit between C and the independent variables. Indeed, it is the purpose of "least squares" to minimize this residual variance. But when used in a simulation model it is important to build back into the system the variance observed among the original C-values in order to maintain the statistical validity of the model. This is accomplished by adding an independent random component whose mean is zero but whose variance is the "unexplained" variance so that the total variance is the sum of explained and unexplained terms, or the original variance of C. This procedure is documented in the water resources literature.

It is traditional among scientists who seek causal relations to be skeptical of statistical relationships. This is a healthy symptom. But the regression model used in this study builds into the output all the variance present in the observations on the dependent variable (C, or conductance). In other words, the arguments of the regressions carry the estimate reasonably far, and the additive random component completes the task by incorporating variations (or perturbations about the system) that reflect the true uncertainty inherent in model error.

Once the conductances are estimated, the relationship between flow at Trenton and salinity (chlorides) can be constructed at Torresdale and Pier 11. From Strandberg (1975) it is then possible to obtain the salinity at the southern limit of influence of the Camden well fields and at the mouth of the Schuylkill River from Pier 11 salinity values.[1]

Regression coefficients of the estimating functions for the Torresdale and Pier 11 stations are summarized in Table 3-45. All salinities are estimates of the maximal or peak daily values during the month. These estimates are based on empirical corrections drawn from observed data. The coefficients of determination are high enough to justify the use of these regressions in this study.

It is useful to note that the correlation is greater for low flows than for high flows, and at Pier 11 than at Torresdale. At Pier 11, R^2 is greater than 0.64 so that R is greater than .8, a highly significant value. It should also be noted that when concentration is arrayed against discharge, discharge is part of concentration, so that some correlation is spuriously built into the relationship. This does not reduce the predictive power of the regression, only its ability to quantify causality.

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1 Certain of the results reported in Strandberg (1975) are based on the application of mathematical models for which there may not have been adequate salinity data for their proper validation. However, the use of these results for this purpose is considered to be in keeping with the overall accuracy of the analysis of this study.

Table 3-45 Partial Regression Coefficients for Salinity - Flow Estimator

High Flows	K	β_1	β_2	β_3	SE	R^2
Torresdale	570.8	-94.7586	-1.3932	-.2227	21.4017	.4633
Pier 11 North	823.5	-149.4361	8.053	3.3645	31.9713	.4944

Low Flows	K	β_1	β_2	β_3	SE	R^2
Torresdale	689.3	-78.328	-30.8218	-16.2577	25.6919	.5395
Pier 11 North	1909.5	-134.6529	-187.6774	-103.9396	73.7582	.6487

where R^2 is the mean square deviation.

III.E.2(e) Generation of Synthetic Hydrology

Figure 3-25 is a schematic diagram of the Delaware River Basin above Trenton showing major reservoirs now in operation or planned for the future. In order to maintain an order of consistency with earlier evaluations and simulations completed by the Corps of Engineers, the DRBC and TAMS(1972), notation similar to that used in the earlier studies is retained.

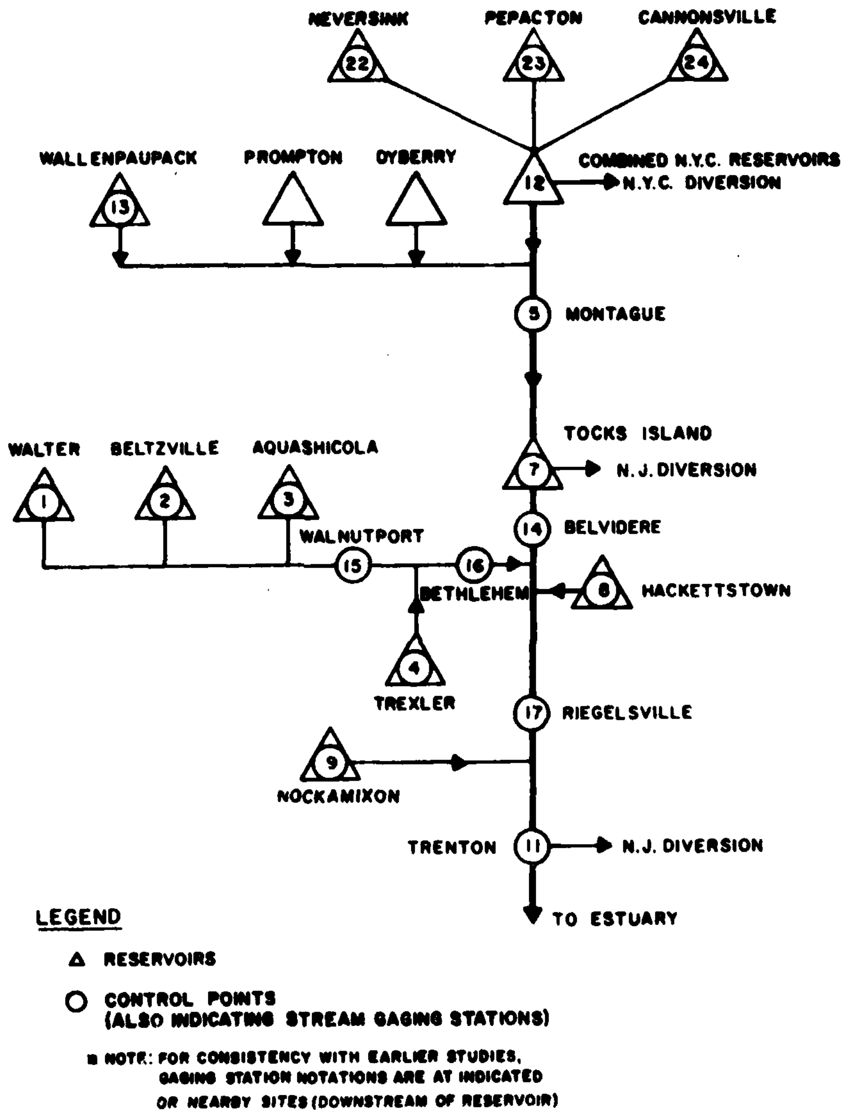
Figure 3-25 also shows the control point at which monthly flows have been determined by the USGS. These data are the basis of the generation of synthetic monthly flows.[1]

The use of synthetic generation techniques is well established in water resources engineering practice. Several mathematical models have been developed for generation purposes, including Fiering(1964) and U.S.C. of E(1971). Both employ Markov processes to express the auto-regressive properties of natural flow events. A model (HEC-4), developed by the U.S. Corps of Engineers Hydrologic Engineering Center (U.S.C. of E(1971)) was selected for use in this study.

In order to simplify the computational processes, not all the gaging stations indicated in Figure 3-25 were used. Several (Aquashicola, Trexler, Hackettstown, and Nockamixon) were considered to have insignificant contribution to the simulation and were omitted. Their influence on basin streamflows are included in the values for downstream stations. Furthermore, in discussions with the DRBC, it was learned that the

1 It is generally necessary to eliminate the effect of regulation on measured flow, before such flow can be used for generating synthetic flows. Measured flows, adjusted by the U S G S for the DRBC to eliminate regulation, were used to generate the synthetic flows used in this study.

SCEMATIC DIAGRAM OF THE DELAWARE RIVER AND ITS MAJOR RESERVOIRS (EXISTING OR PLANNED) ABOVE TRENTON



data in some simulations appeared to be over-stated when the Walnutport and Riegelsville gauging stations were included. Consequently, these two stations were omitted from the generation process and their influence included in downstream stations.

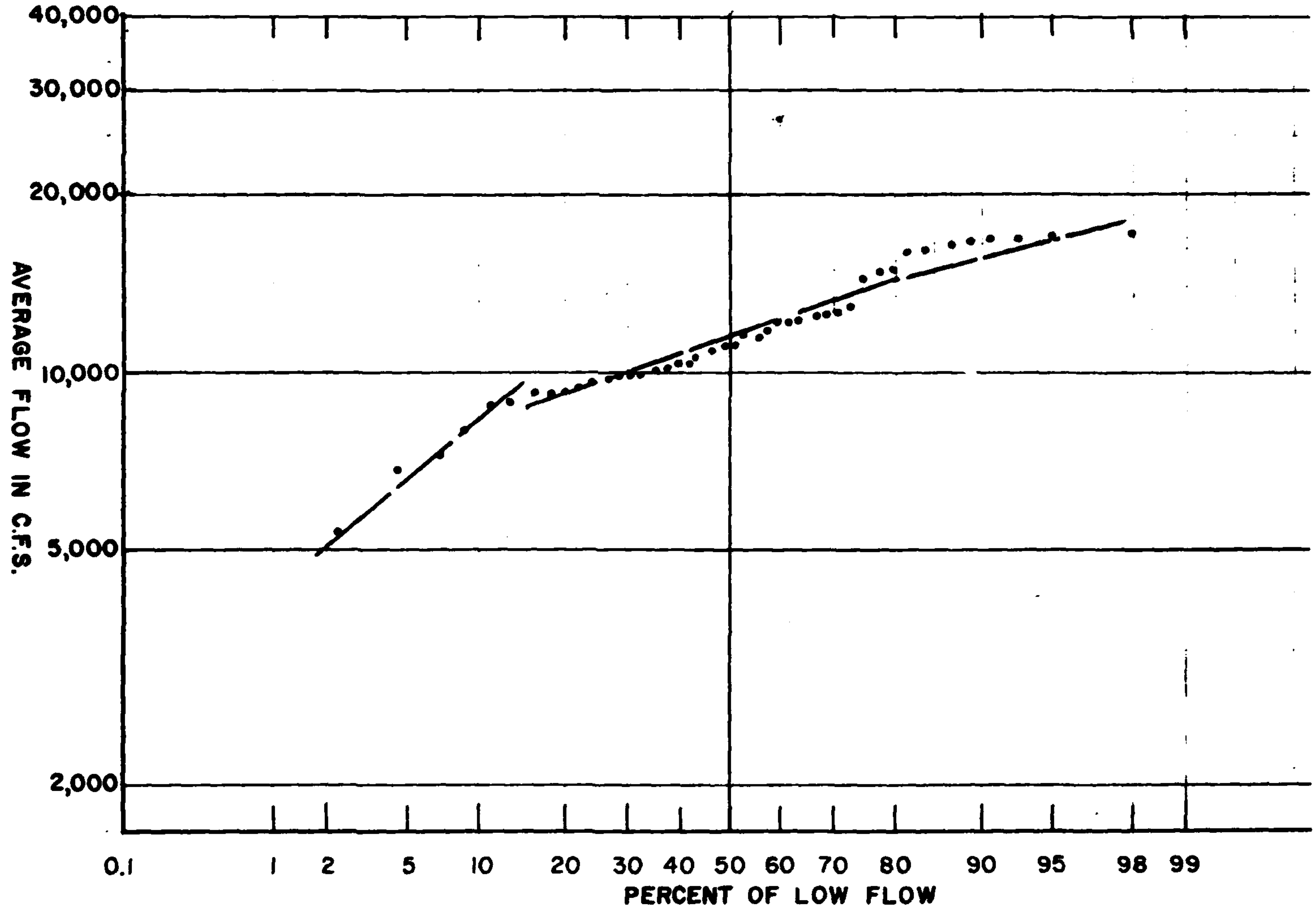
The final formulation consisting of 10 stations from which flows were generated is illustrated by circular nodes in Figures 3-31, 32, and 33 in subsection (f) below. The historical data base for these stations is the period 1923 - 66. These flow data were used in previous studies where they were transformed to eliminate the effect of river regulation.

A simulation period of 500 years was selected for use in this study. It is always difficult to specify a simulation period; a simulation trace is <u>not</u> a prediction, and therefore does not include any long term trends and periodicities. It encompasses short-term perturbations which lay within anticipated sampling variations. Many earlier studies have successfully treated these variations with simulation periods under 500 years, and others have suggested many thousands of years for higher-moment analysis. A 500-year trace was selected because many analyses of the Delaware system posit that the return interval of the 1960's drought is of that order, and that consequently it would be wise to use that length of simulation in order to generate a reasonable likelihood that a major event is developed.

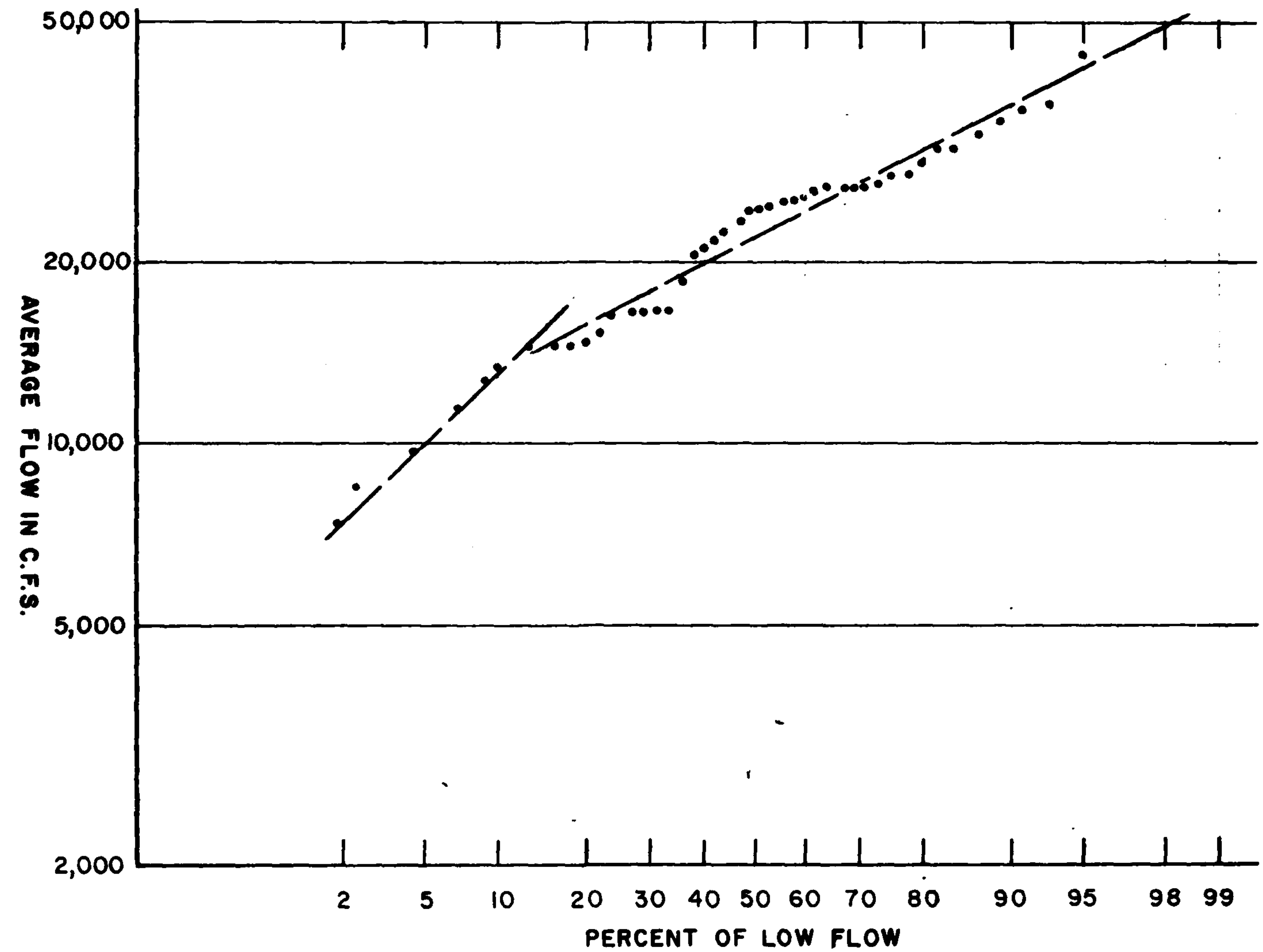
The first attempt to use HEC-4 to generate a 500-year sequence of monthly synthetic flows with the entire historical data from 1923 to 1966 revealed that the moments of generated flow did not properly preserve the historical patterns. The statistics of the synthetic flows sequence generally showed that the mean of the standardized variates for a number of months were of the order of 0.18 and larger, differing significantly from their expected (population) values of zero. Moreover, approximately 75% of monthly average deviates were positive as contrasted to an expected 50%. This suggested immediately that the generated flow sequences would be too high in that they would not properly preserve the low-flow values and that their skewnesses would be markedly different from zero. This indeed turned out to be the case, so it was necessary to re-examine the use of the log-normal distribution implicit in the use of HEC-4.

Flow-duration curves were constructed on log-probability paper to ascertain the log-normality at several of the stations of monthly average and total annual flow. Typical plots are shown in Figures 3-26 and 3-27. In virtually all cases, and in all sets of monthly values at the same stations, the 5 or 6 smallest flows seemed to derive from a different log-normal population in that a straight-line fit through the remainder of the points deviated considerably from these 5. This led to the hypothesis that the flows in the Delaware are in fact derived from (at least) two distinct populations, one associated with protracted low-flow events and one with the more normal or wet years such as shown schematically in Figure 3-28. It would be a serious error to attempt to force a single distribution to fit these two distinct populations, as demonstrated in Figure 3-28. It is possible to calculate the moments of the bimodal distribution which is formed from both log-normal sets and to impose a unimodal distribution (with the same moments) over the joint or composite

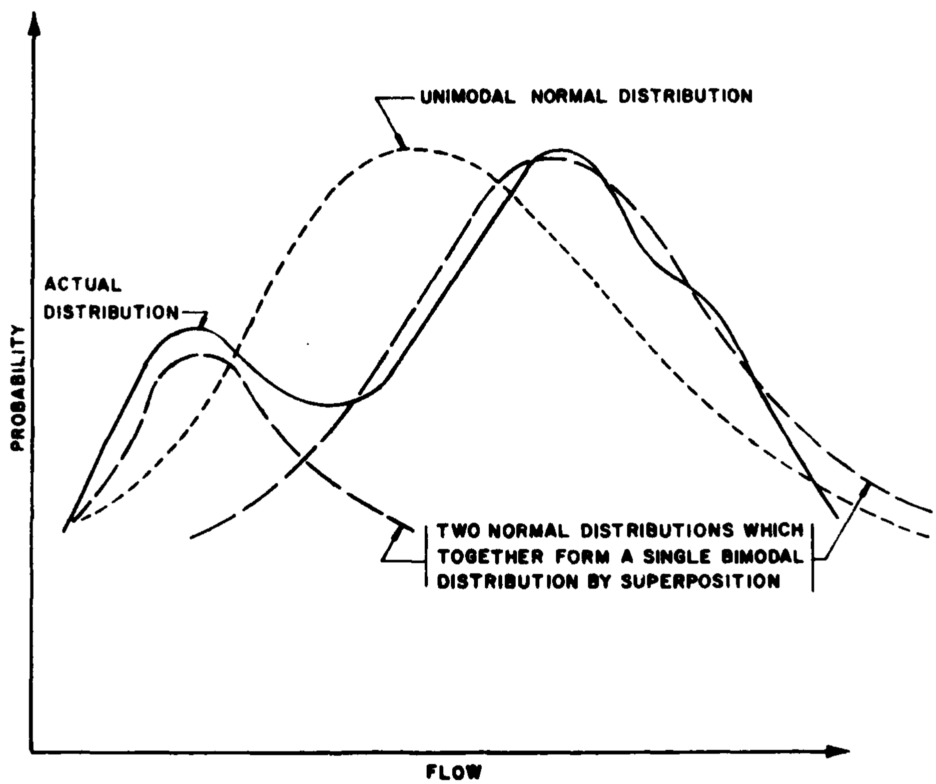
FLOW-DURATION CURVE AT TRENTON
ANNUAL AVERAGE FLOW 1923 to 1966



TYPICAL MONTHLY AVERAGE FLOW-DURATION CURVE AT TRENTON
FOR MONTH OF APRIL, 1923 TO 1966



SCHEMATIC DIAGRAM OF TWO-POPULATION DISTRIBUTION



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A COMPREHENSIVE STUDY OF THE TOCKS ISLAND LAKE PROJECT AND ALTE--ETC(U)
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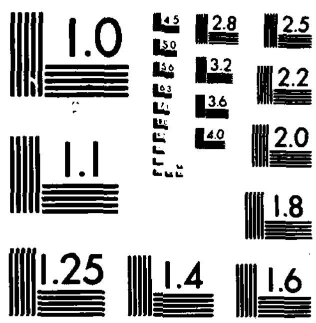


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

population. This has the tendency to mis-estimate both low and high flows, agreeing only in specification of the first two moments. It is more reasonable to suggest that the composite flow patterns are derived from two distributions, and to divide the generating process into steps that sample from each of the two distributions in accordance with an appropriate set of probabilities. Another consideration is that the droughts tend to be protracted. It is therefore not enough merely to sample from one distribution α percent of the time and from the other $(1-\alpha)$ percent of the time. There has to be some persistence or tendency for low-flow events to aggregate, and at the same time to maintain their appropriate density or probability of occurance taken in the large.

Efforts toward resolving this issue resulted in developing a formalism which divides the "state" of the system into 6 distinct categories: S_0 (normal or wet year), S_1 (1 dry year), S_2 (2 dry years in a row)....,S_5 (5 dry years in a row). The existence of a transition matrix was postulated and is shown in Figure 3-29. The elements in the matrix are the probabilities that the system, originally in some state, will move to another state in the course of one time period or year.

A "six-state" matrix was selected for this study so that the model would refuse to allow droughts to extend beyond five years; there is no historical evidence that this is a possibility in the Delaware system, and many generalized meteorological models suggest this is a reasonable upper limit. There is strong meteorological evidence to suggest that droughts extend on the order of 5 or 6 years and then macroscopic climatological effects tend to produce normal precipitation [Namias (1968)]. It is therefore reasonable to require that from state S_5, the system must return to state S_0 because there is no possibility that the drought will extend into a sixth year. There is much controversy about this phenomenon, but it is a reasonable working hypothesis for this study.

Many of these elements are zero because it is impossible, for example, to move from S_0 to S_2. It is possible to go only from S_0 to S_0 (remain in the normal state) or to S_1 (enter a drought in its first year).

Similarly, the matrix of transition probabilities can be shown to have at most two non-zero entries in any row. The sum of these two entries is necessarily unity because the system must go someplace, given that it starts in any one of the 6 allowable states. The non-zero elements were tried and adjusted so that the transition probabilities make climatological sense and so that the derived marginal probabilities, or steady-state probabilities deduced from the transition matrix, are consistent with actual experience. In other words, the model is "tuned" to mirror reality.

After the transition matrix was satisfactorily adjusted, the following strategy was adopted for obtaining the generated 500 year sequence of synthetic flows in the Delaware Basin:

subsequent state, time t+1

current state, time t	S_0	S_1	S_2	S_3	S_4	S_5
S_0			0	0	0	0
S_1		0		0	0	0
S_2		0	0		0	0
S_3		0	0	0		0
S_4		0	0	0	0	
S_5		0	0	0	0	0

A SIX-STATE TRANSITION MATRIX

subsequent state, time t+1

current state, time t	S_0	S_1	S_2	S_3	S_4	S_5
S_0	.965	.035	0	0	0	0
S_1	.0625	0	.9375	0	0	0
S_2	.125	0	0	.875	0	0
S_3	.25	0	0	0	.75	0
S_4	.5	0	0	0	0	.5
S_5	1.0	0	0	0	0	0

TRANSITION MATRIX OF SYNTHETIC FLOW SEQUENCES IN THE DELAWARE

1. Establish two log-normal populations, and classify the smallest 5 observations at Trenton into the population that defines the low-flow events and the remainder of the observations into that which defines the normal events. No effort was made strictly to retain the annual sequencing of events because the use of the special probability transfer matrix reflects the tendency of low-flow models to imply long-term persistence. In any case, persistence characteristics derived from 5 observations are grossly unstable.

2. Generate two sequences of flows with HEC-4: one for the population defined by the five low flow years, 1930, 1941, 1962, 1964, 1965; and another for the population of all the remaining historical data.

3. Start the initial synthetic flow sequence in a normal year and draw a random number to determine if the following year is normal or dry. If normal, continue in the normal synthetic sequence for the next flow values. If dry, substitute a flow value drawn from the low-flow population and then utilize another random normal number in the range 0 - 1 to determine if the drought continues into its second year.

4. This process then continues, terminating in return to a normal year or in extension of the drought until either a normal year is achieved or the drought completes its fifth year.

The only remaining task was then to assign reasonable values to the non-zero elements in order to satisfy good hydrologic sense and the available data. The difficulty, as anticipated, was that the length of hydrologic record was too short thus making it virtually impossible to assign stable numerical values on the basis of empirical evidence. It is possible to obtain guidelines, to be sure, but these cannot be maintained in a rigorous sense. A number of different trial matrices were analyzed in terms of the steady-state probabilities that resulted and the matrix shown in Fig 3-30 was finally adopted.

The steady-state probabilities are the probabilities that the system is in some given state; these are equivalent to long-term equilibrum estimates of the "residence" probabilities, and are derived from the transition matrix. They are:

P (normal)	=.886
P (1-yr. drought)	=.031
P (2-yr. drought)	=.029
P (3-yr. drought)	=.025
P (4-yr drought)	=.019
P (5-yr. drought)	=.009

These probabilities effectively assign certain return intervals to long-term droughts; in particular, the 5-year drought has a probability of occurrence of 0.009, somewhat less than 1 percent, which suggests that it will recur on the average every 100 years. This is different from the probability which has been assigned on the basis of more traditional or formal probability analyses, but what is really at issue here is not so much the probability of a single low-flow but rather that of a cascade of low flows that can jointly and in some combination, be classified as a "drought." The concept of drought as discussed earlier, is an elusive and slippery concept; thus it is not appropriate to argue about whether this number can be justified on the basis of existing probability demonstrations. The point is that this assignment is not unreasonable, and that stability and sensitivity analyses over a wide range of reasonable hypotheses do not strongly suggest that this probability assessment should be changed.

Using the above-described algorithm for merging two synthetic series representative high-flow and low-flow populations, a final synthetic trace of average monthly flows is produced and is used in subsequent simulations. The composition of this final synthetic trace, in terms of chronological occurrences and durations of the low flow data, is shown in Table 3-46.

It is interesting to note in this schematic event, no "drought" of one-year duration is present. This agrees with the general meteorological observation that when a "drought" begins, it tends to remain a "drought." No drought longer than 5 years is present since the algorithm forces the simulation to come out of a "drought" in five years.

Table 3-46 "Droughts" in Synthetic Trace

Year of 500 Year Trace when Low-Flow Begins	Total Duration (in Years) of Low-Flow
16	4
24	4
51	5
61	4
137	2
185	2
201	4
222	2
228	5
321	4
356	4
361	4
387	3
391	3
489	4

III.E.2.(f) Simulation of Delaware River Flows

In order to obtain synthetic freshwater inflows at Trenton, a generalized simulation program (HEC-3) developed by the Hydrologic Engineering Center of the U.S. Corps of Engineers was used (U.S.C of E (1974)). Two groups of simulation runs were made: group A (without Tocks Island Reservoir) and group B (with Tocks Island Reservoir).

Input to the HEC-3 program consists of synthetic monthly streamflows and operating rules for the existing and planned reservoirs for the basin. Generally speaking, the input data describing the physical parameters of the reservoirs and rule curves used in this study follow those used by the Corps of Engineers and the DRBC in their earlier studies, with the exception that in this study, several of the less significant reservoirs (Trexler, Aquashicola, Hackettstown and Nockamixon) were omitted. The aggregate effect of the omission of these reservoirs in the simulation is to underestimate freshwater inflow at Trenton by about 215 cfs. Another deviation of the input in this study from that used in earlier studies is that the gaging stations at Walnutport and Riegelsville are not included for reasons cited in the previous subsection.

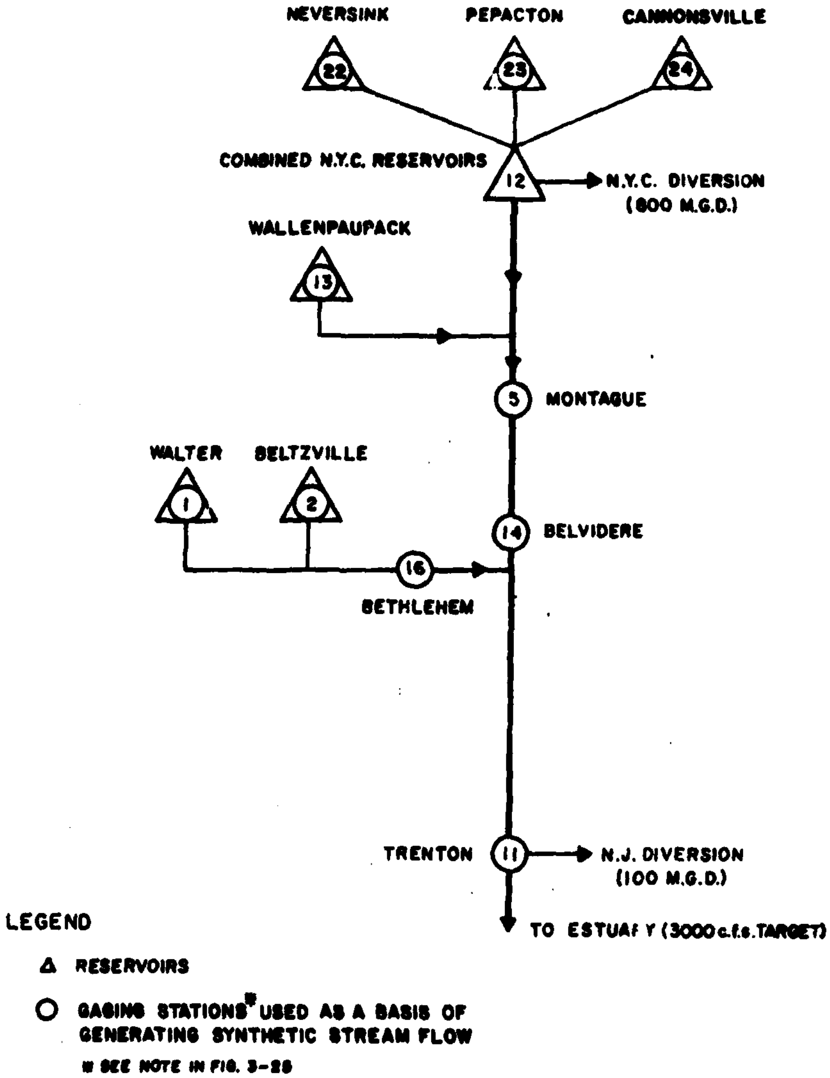
Run A-1 of the simulation model, the schematic diagram of which is show in Figure 3-31, assumes that the New York City Delaware Reservoirs are operated to provide an 800 MGD diversion to the City of New York to the extent to which reservoir storage is available. The maintenance of the

1750 cfs low-flow objective at Montague is met only if the 800 MGD diversion is made and excess storage is available in the New York City reservoirs. While run A-1 is counter to the Supreme Court Decree of 1954 in that Montague flows are assumed to have secondary priority, the run was made because it represents the "worst case" in terms of releases to the basin from the City's reservoirs system. Thus, the probability of given salinity concentrations that would be associated with the actual operation of the Supreme Court Decree will be smaller than those obtained from run A-1.

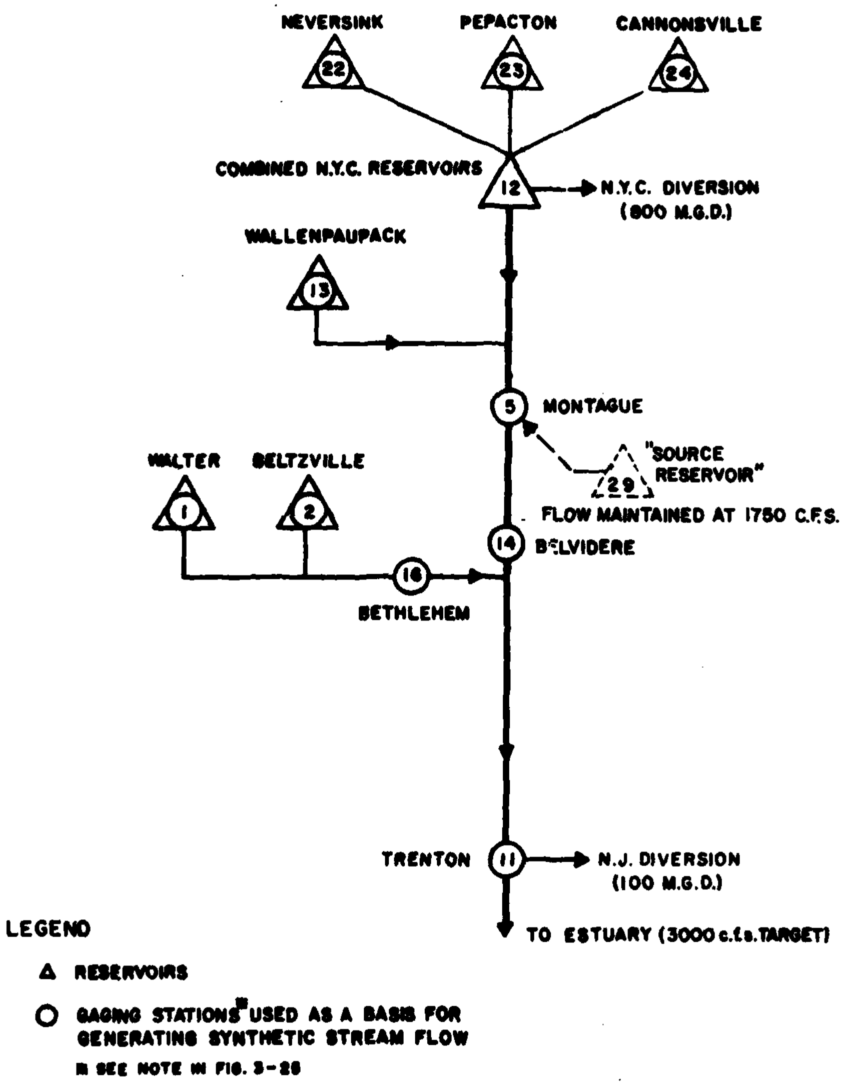
Run A-2, the schematic of which is shown in Figure 3-32, is carried out so that the 1750 cfs minimum flow at Montague is met with first priority. The 800 MGD diversion to the City of New York is met only if the 1750 cfs flow at Montague is met and New York City reservoir storage is available. Run A-2 is consistent with the Supreme Court Decree of 1954, although it does not represent the most likely operation of the City's system because historically the City has not ceased diverting from the basin when the 1750 cfs low-flow requirement at Montague was not met. Run A-2 is opposite to run A-1 in that it may represent the "best case" as far as salinity in the estuary is concerned. This is because this run favors the basin in its assumed releases. Runs A-1 and A-2 thus likely "bracket" the range of salinity intrusion probabilities.

The HEC-3 program does not permit the reduction of a specified diversion to meet a minimum flow requirement at another control point. To overcome this problem, an adjustment is made to the program by introducing a "source" reservoir supplying Montague, as shown in Figure 3-32. This "source" reservoir makes up whatever shortfall occurs from the required minimum 1750 cfs at Montague

SCHEMATIC DIAGRAM OF SIMULATION RUN A-1



SCHEMATIC DIAGRAM OF SIMULATION RUN A-2



and deducts the amount from the 800 MGD diversion to New York City. The maximum yield that the "source" reservoir can provide is of course, 800 MGD. Additionally, the "source" reservoir cannot supply water to Montague if the City's reservoirs are dry.

Run A-3 represents an intermediate, or possibly compromise case; it is identical to run A-2 in all respects except that the flow to be maintianed at Montague is arbitrarily set at 1350 cfs.[1]

Run B-1, a schematic of which is shown in Figure 3-33, makes the same assumptions as run A-1 except that it includes the planned operation of Tocks Island Reservoir (300 MGD diversion to New Jersey and 3000 cfs low-flow objective at Trenton).

The specification of 3000 cfs as a low-flow objective at Trenton was necessary for run B-1 since the Tocks Island Project would be operated to achieve this objective. Since the HEC-3 simulation model used in this study required that a low-flow target be set at Trenton for the A-1, A-2 and

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1 While runs A-1 and A-2 are useful for bracketing the range of salinity probabilities, it is essential to point out that the results of run A-2 as well as A-3 indicate that the City of New York would be unable to make diversions from its Delaware System for long periods of time (a year in at least one instance). This characteristic of the output is not an issue relative to the salinity evaluations because the purpose of these runs was to evaluate the effect of diversion and low-flow maintenance objectives on salinity concentrations. It should be recognized, however, that the results of runs A-1, A-2 and A-3 are likely to be of limited value and in fact may be very misleading, when used to answer other questions of interest such as further run of the river diversions from the Delaware.

A-3 runs, 3000 cfs was specified for these runs as well. The 3000 cfs amount was selected to provide for maximum comparability of runs A-1, A-2 and A-3, with run B-1.[1]

The results of all runs consist of a 500-year trace of monthly freshwater inflows at Trenton.

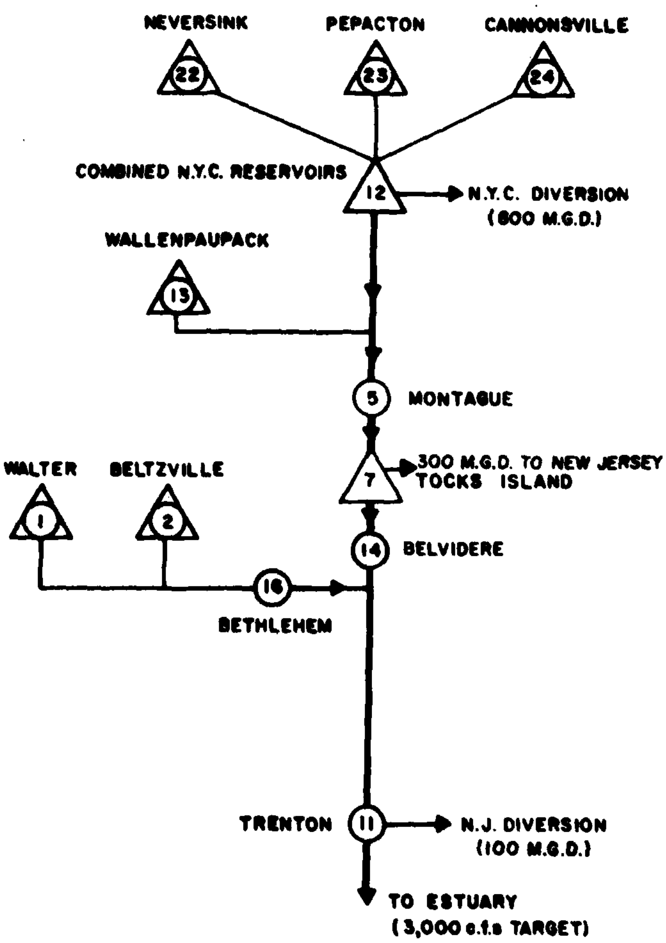
III.E.2.(g) Consideration of Consumptive Use

An evaluation of the magnitude and distribution of consumptive use in the Delaware Basin for the period 1975-2025 is contained in Section C above. This subsection is concerned with the consideration of future consumptive use in the simulation of the Delaware Basin and generation of synthetic salinity concentrations in the estuary.

Synthetic stream flows at Trenton determined by the simulation program must be adjusted for future consumptive use. The synthetic generation was carried out using stream flows adjusted for the effect of regulation for the years 1923-1966. Because there has been habitation and manufacturing in the Delaware River Basin continuously for the last several hundred years, the historic flows adjusted for the effect of regulation and used for generating synthetic flows are actually smaller than the flows that would have been observed had no development taken place by man in the basin. These flows are less because the water lost in the basin through consumptive

[1] The 3000 cfs amount is significant since the DRBC has specified it as a low flow objective at Trenton. Subsection (m) below reviews the 3000 cfs DRBC objective relative to salinity intrusion prevention in view of the results of this study. Subsection (1) below discusses the effect of a 3000 cfs target for runs A-1, A-2 and A-3 on the results of this study.

SCHEMATIC DIAGRAM OF SIMULATION RUN B-1



LEGEND

Δ RESERVOIRS

O GAGING STATIONS* EMPLOYED FOR GENERATING SYNTHETIC STREAM FLOW

* SEE NOTE IN FIG. 3-25

use (evaporation or transpiration) is not reflected in the gaged flows.

It is thus necessary to estimate the average consumptive use over the period 1923-1966 so as to be able to determine net projected consumptive use. In order to make this adjustment, projected consumptive use was plotted for the years 1975-2025. The consumptive use estimate developed in this study and those of the DRBC were plotted separately to provide the basis for projecting consumptive use for the period 1923-1966.

Because no estimates of consumptive use were available prior to 1965, a surrogate parameter was needed to aid in establishing the shape of the consumptive use curve prior to 1970. Population of the Delaware Basin would have been an acceptable parameter but because population data was available only as far back as 1915, a plot of the population of the states of Pennsylvania, New Jersey and Delaware from 1790 onward was also made. New York population data was excluded because of the small percentage of Delaware Basin population residing in New York.

These plots are shown in Figure 3-34. It can be seen from examination of this figure that high consumptive use is a relatively recent phenomenon. The large increase beginning after the turn of the century has resulted from the general industrialization and accompanying power generation in the Basin. In addition, the increased provision of water through public systems which results in more water usage and thus more water used consumptively, has also contributed to the phenomenon.

Examination of Figure 3-34 indicates that the average consumptive use during the period of 1923 to 1966 was about 100 MGD. This amount is the consumptive use in the Basin as a whole and must be adjusted for the amount that occurs upstream of Trenton. This adjustment was established in Section C and is obtained from Table 3-31 as 21.3%.[1]

Table 3-47 contains 1) the 2025 gross consumptive use above Trenton as taken from Table 3-34 above, 2) the 1923-1966 increment, and 3) the net 2025 consumptive use. The net 2025 increment is that amount that must be deducted from synthetic freshwater inflows at Trenton prior to the establishment of synthetic salinity concentrations in the estuary that could be observed in the year 2025. The average annual net consumptive use above Trenton is 167 cfs.

III.E.2(h) Development of Probabilities and Return Intervals for Salinity Concentrations

This section describes the mode of presentation of synthetic traces and peak values of monthly salinity at locations selected for determining salinity concentration probabilities as shown in Figure 3-10. These locations correspond to 1) the Torresdale intake which is also the approximate northern limit of influence of the Camden Well Field, 2) Pier 11, which is adjacent to the Camden Well Field, 3) the approximate southern limit of influence of the Camden Well Field, and 4) the mouth of the Schuylkill River. The basis of selection of the first three locations is apparent;

[1] Figure 3-34 considers consumptive use only. Diversions from the Basin are included in each of the simulation runs as discussed in the previous subsection.

HISTORICAL AND PROJECTED POPULATION AND CONSUMPTIVE USE

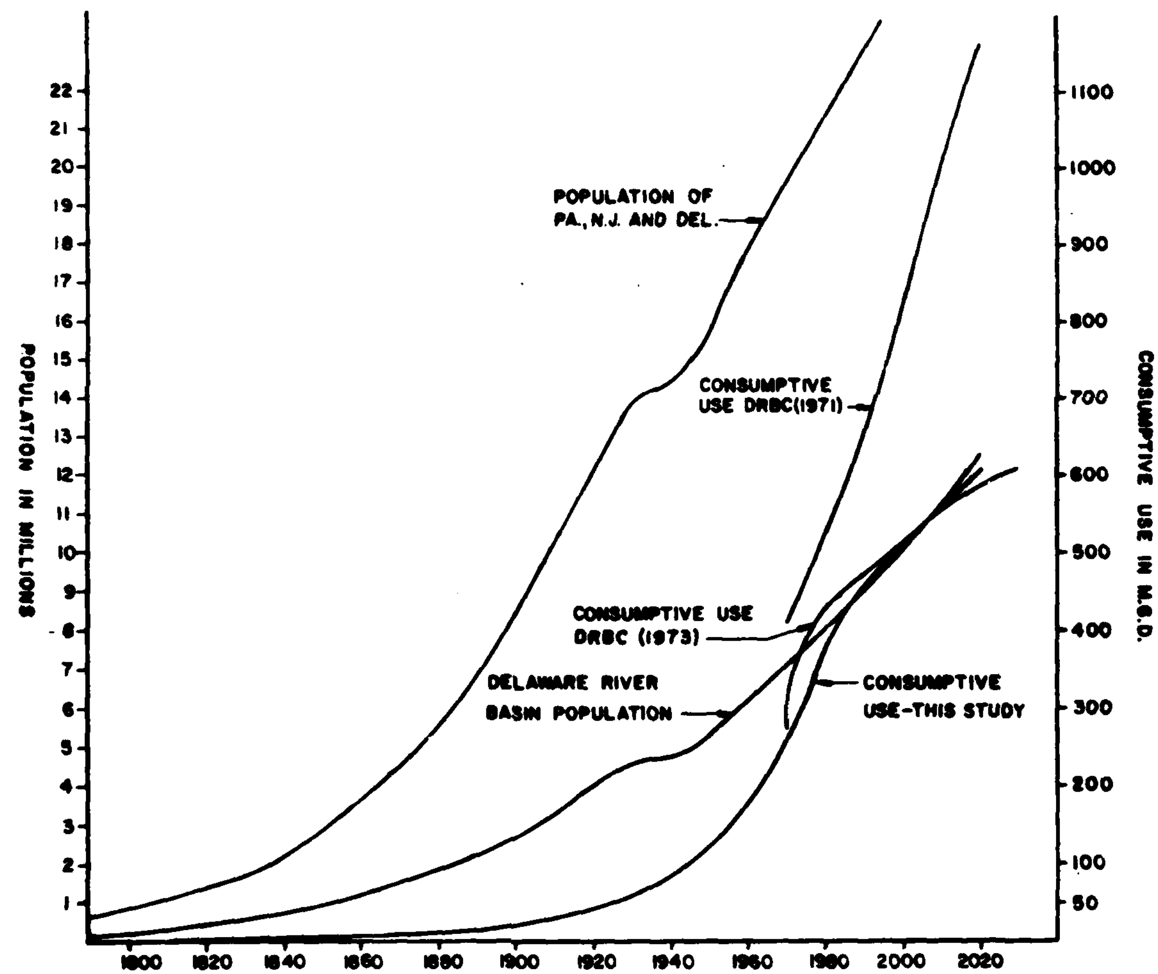


Table 3-47 Projected Net Consumptive Use Above Trenton by Month for the Year 2025.

Month	Gross 2025 Consumptive Use (MGD)	1923-1966 Increment (MGD)	Net 2025 Consumptive Use (MGD)	Net 2025 Consumptive Use (cfs)	Percent By Month
January	164	21.0	143	222	6.8
February	161	21.0	140	217	6.7
March	164	21.0	143	222	6.8
April	177	23.0	154	239	7.4
May	195	25.0	170	264	8.1
June	266	34.0	232	360	11.1
July	289	37.0	252	391	12.0
August	269	34.0	235	364	11.2
September	214	27.0	187	290	8.9
October	193	25.0	168	260	8.0
November	160	24.0	136	211	6.5
December	157	20.0	137	212	6.5

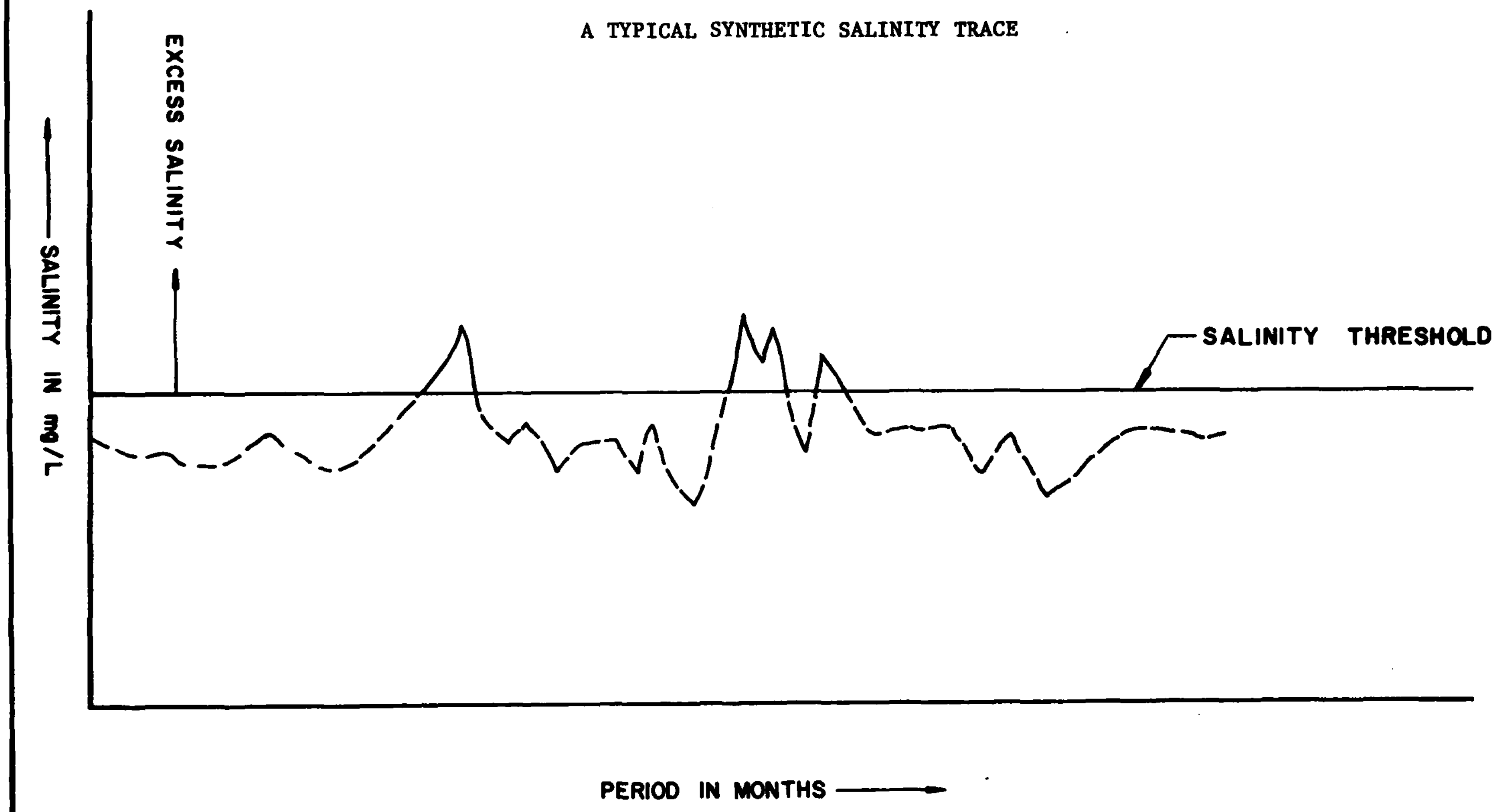
the Schuylkill location was chosen, not because it has any particular water supply significance but because it has been a point of reference in previous salinity studies.

Data used to develop probability densities for salinity concentrations was obtained from flows at Trenton as previously discussed and can be plotted as a time series. A typical plot of a part of such a trace is shown in Figure 3-35. Months during which the salinity is below a threshold salinity concentration are of no particular interest. Thus the values shown as dotted lines in figure 3-35 can be ignored. However, consecutive monthly occurrences of excess salinity do not define separate events. An interval of at least two months of normal salinity is required to separate events. The total number of occurrences (in months) of excess salinity divided by the simulation period (6000 months) times 100 gives the percent of time that the salinity in the estuary at a particular location of interest exceeds the prescribed limit or

$$J = \frac{N}{6000} \times 100$$

Where J is the probability of occurrence and N is the total number of months during which excess salinity is estimated to have occurred.

T_r, the reciprocal of J, is the estimated return interval of occurrence.



A TYPICAL SYNTHETIC SALINITY TRACE
EXCESS SALINITY
SALINITY THRESHOLD
SALINITY IN mg/L
PERIOD IN MONTHS

It must be pointed out that the estimated return interval thus obtained indicates simply that excess salinity would occur on the average of once every T_r years. It must also be noted that T_r is an unstable statistic if it approaches the length of the 500 year period of analysis adopted in this study. As discussed previously, a statistic such as a return interval is more valuable when coupled with a duration index expressing the length (or extent) of the exceedance of threshold values. In the present study, wherein the average monthly flow is used as the basic unit, the salinity flow-estimator indicates that the salinity content has exceeded the threshold level at one time during the month. No statement concerning duration of exceedance within the month can be made because the data does not discriminate this feature.

III.E.2.(i) Discussion of Appropriate Standards for Chloride Concentrations

It is always difficult to specify a standard when it is implied that the standard must be adhered to without exception. This is because the resource cost that must be expended to guarantee that the standard is met 100% of the time may be very high. Frequently, standards are developed that are related to the probabilistic nature of the parameter for which the standard is set. For example, in specifying a dissolved oxygen standard for a stream, it is desirable to have a given dissolved oxygen level all of the time, but it is recognized that there are certain times when stream flows are especially low and temperatures high and that it would be exceedingly expensive to treat wastewater discharges such that minimal dissolved oxygen levels are met during such periods.

Recognizing that it would be very expensive to require that dissolved oxygen objectives always be met, public agencies responsible for setting stream standards have frequently adopted the ten-year-7 day low-flow rule. This rule specifies that stream assimilative capacity be allocated among dischargers such that dissolved oxygen objectives are met except every ten years or so when the low-flow sequence is such that the assimilative capacity of the stream is overtaxed. This regulatory philosophy, which is current and set in accordance with P.L. 92-500, recognizes the additional cost to society that would result if dissolved oxygen levels had to be met all of the time.

In connection with the evaluation of chloride concentration probabilities in the study, several chloride standards may be considered. The Delaware River Basin Commission has established a maximum 15-day mean chloride concentration of 50 mg/l for that portion of the estuary between Trenton and just below Torresdale. The U.S. Public Health Drinking Water Standards, promulgated in 1962, recommend a limit of 250 mg/l for chlorides. Recently, the U.S. Environmental Protection Agency has taken over the responsibility for setting drinking water standards and has recently published interim standards for drinking water. The USPHS 250 mg/l recommended chloride standards for drinking water has been maintained by the EPA.

As reported in Strandberg (1975), the primary basis for the limitation of salinity as given in the 1962 USPHS standards is one of taste. There may be health considerations as well for those who suffer from particular ailments. High sodium concentration, necessarily associated with ocean derived salts, may be a particular problem. However, special treatment to remove sodium or provision of bottled water may be a more cost effective means of protecting the health of persons suffering from particular ailments than possible structural measures needed to prevent salt from entering a public water supply.[1]

The 50 mg/l standard set by the DRBC is not related to the basic probabilistic nature of salinity intrusion in the estuary as in the generally adopted 10-year-7 day low-flow water quality objective discussed above. Another approach to be considered, therefore, would be a two-part standard that recognizes the basic probabilistic nature of the salinity intrusion problem. For example, the 50 mg/l standard could ordinarily apply but chloride concentrations would be permitted to exceed this limit on occasions, but only up to 250 mg/l. In the following subsections, probabilities and return intervals at the points of interests selected in this study are evaluated relative to the exceedance of 50 and 250 mg/l chloride thresholds as appropriate.

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1 Strandberg (1975) and Sinden (1974) contain excellent further discussion of this possibility.

III.E.2.(j) Evaluation of Results

The results of the investigation of the probability of salinity intrusion in the estuary can be presented in terms of the frequency of threshold exceedance and estimated magnitude of salinity in excess of threshold values. Points of interest relative to salinity concentrations are shown in Figure 3-10 and are discussed in earlier sections. A 50 mg/l threshold corresponding to the chloride standards discussed in the previous subsection, was used in evaluating the results at the Torresdale location. A threshold of 250 mg/l was selected for Pier 11 and the transformation of Pier 11 to the southern limit of influence of the Camden Well Fields and the mouth of the Schuylkill River. It should be recognized, however, that evaluations relative to the Camden Well Field are fundamentally different than those for Torresdale: Philadelphia draws water directly from the Delaware River at Torresdale, Camden does not. While there is a net inflow of water from the Delaware to the Camden aquifer, the aquifer draws water from other areas not subject to saline intrusion thus making the Camden water system less sensitive to salt water intrusion. For this reason, thresholds were set at 50 mg/l at the north end of the field (Torresdale) and 250 mg/l at the south end.

Estimated Return Intervals of Salinity Concentration--

Estimated return intervals for salinity concentrations corresponding to the 167 cfs consumptive use above Trenton projected in this study at the points of interest, are contained in Table 3-48. This table uses abbreviations for the assumed conditions under which the return interval estimates were made in the simulation runs. These abbreviations, first adopted in subsection (f) above, are summarized below and used throughout the remainder

Table 3-48 Summary of Salinity Return Intervals Corresponding to a Projected Consumptive Use of 167 (cfs) Above Trenton

Station	Salinity Threshold (Chlorides in mg/1)	Return Interval in Years: Run A-1	Run A-2	Run A-3	Run B-1
Torresdale	50	96	> 500	> 500	> 500
Pier 11	250	>500	> 500	> 500	> 500
Southern limit of influence of Camden Well Fields (SCWF)	250	310	> 500	> 500	> 500
Mouth of the Schuylkill River (MOS)	250	112	185	133	340

of this chapter:

Run	Definition
A-1	without Tocks Island, an 800 MGD diversion target to the City of New York with first priority and 1750 cfs low-flow target at Montague with secondary priority.
A-2	without Tocks Island, a 1750 cfs flow maintenance target at Montague with first priority, and an 800 MGD diversion target to New York with second priority.
A-3	without Tocks Island, a 1350 cfs flow maintenance target at Montague with first priority, and an 800 MGD diversion target to New York with second priority.
B-1	Same as run A-1 except that the operation of Tocks Island reservoir is included (300 MGD diversion to New Jersey, 3000 cfs low-flow objective at Trenton).

Table 3-48 shows that at Torresdale under the conditions of run A-1, the salinity concentration return interval for the exceedance of a 50 mg/l threshold is somewhat less than 100 years. For runs A-2 and A-3 when the New York City diversion is not as heavily favored as in Run A-1, the estimated return interval of an exceedance of the 50 mg/l threshold is in excess of 500 years.

Similarly, at the southern limit of influence of the Camden Well Field, the estimated return interval of an exceedance of the salinity threshold is about 300 years for run A-1 and exceeds 500 years for other runs. At the mouth of the Schuylkill River, which is a point of reference established by earlier studies, the estimated return interval of an exceedance of the 250 mg/l threshold is about 110 years for run A-1 and varies from 130 years to 340 years for the other runs.[1]

It is to be noted that at Pier 11, the 250 mg/1 threshold is never exceeded in any of the runs. The significance of the Pier 11 results is discussed below.

Expected Magnitudes of Salinity Concentrations--

Table 3-49 summarizes maximum estimated magnitudes of salinity concentrations. It can be seen that for the Torresdale location, while there were exceedances of the DRBC 50 MG/1 standard, there were no exceedances of the 250 mg/1 USPHS standard. The estimated magnitude of the maximum salinity concentration is 65 mg/1. At the Pier 11 station there was no exceedance of the 250 mg/1 USPHS Standard.

The Pier 11 results are of interest because they offer a check of the results obtained for Torresdale. If, in accordance with the discussion in subsection (d) above, it is believed that there may be inadequate ocean derived salts at Torresdale to develop a valid correlation during the period corresponding to the data base used in the correlation of Torresdale conductance data, then Pier 11 results may be used to set an absolute upper

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1 The reader may wish to review the second footnote to appear in subsection(c)above relative to the instability of estimates of return intervals, when such estimates are of the same order of magnitude as periods of analysis (sample sizes). Such return intervals given in Table 3-48 should be considered to be merely suggestive of the true interval under these circumstances.

Table 3-49 Maximum Estimated Magnitudes of Salinity Concentrations for Locations of Interest for 167 cfs Consumptive Use

Station	Maximum Estimated Magnitude of Salinity in mg/l			
	Run A-1	Run A-2	Run A-3	Run B-1
Torresdale	65	50	50	50
Pier 11	245	185	195	190
Southern limit of influence of Camden Well Fields	318	240	253	247
Mouth of the Schuylkill River (MOS)	539	407	429	418

bound on the salinity at Torresdale. Even though Pier 11 is 10 miles below Torresdale, the chloride concentration at this Station never exceeded the 250 mg/l standard set by the USPHS.

III.E.2.(k) Sensitivity Analysis

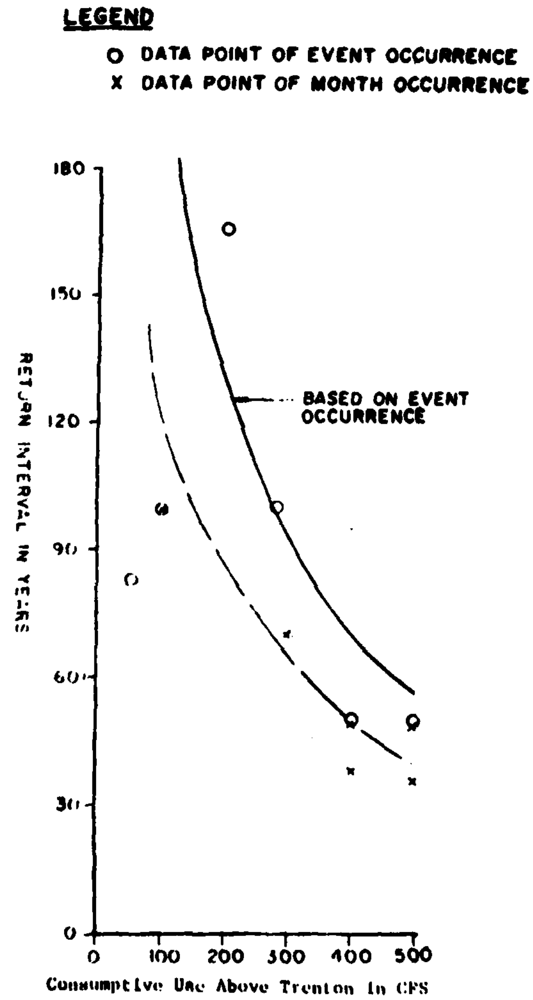
One of the greatest benefits that has resulted from the availability of computerized mathematical models is that it is possible to obtain results from such models for a wide variety of assumed conditions. It is thus possible to determine how sensitive given results are to changing input conditions. The sensitivity of the estimated return interval to increased consumptive use (decreased fresh-water inflow at Trenton) was evaluated. Figures 3-36 to 3-42 show the sensitivity of salinity statistics to increased consumptive use.

As discussed earlier, the actual projected consumptive use above Trenton determined in the study is 167 cfs. While the sensitivity evaluation considers consumptive use as high as 500 cfs occuring above Trenton, it is to be pointed out that the results in the range beyond 200 cfs or so, while adequate for sensitivity evaluation purposes, cannot be used for evaluating the feasibility of additional withdrawals above Trenton because the results in this interval are based to some extent on the use of the basic correlation procedure beyond the range of observations.

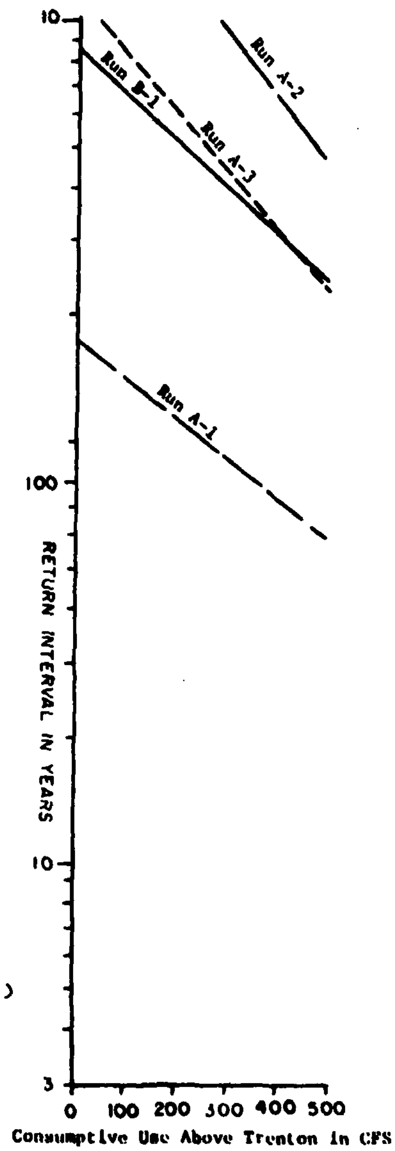
Figure 3-36 shows the sensitivity of estimated return intervals at Torresdale for run A-1, where the curves are plotted by eye. The "event" is defined in two different ways. The solid line represents the preferred definition, where one exceedance of the salinity threshhold is considered to include the entire period in which there is at least one exceedance in any three-consecutive-months.

The dashed line represents each monthly exceedance as a separate event. Both curves are included to show the sensitivity of the estimated return interval to its definition, and to suggest a measure of the instability of the parameter. In Figure 3-36, the actual data points are plotted, and the curves were fit by eye. In Figures 3-37 and 38, the data points are omitted for clarity, but it should be noted that the closeness of fit is virtually nowhere less than in Figure 3-36.

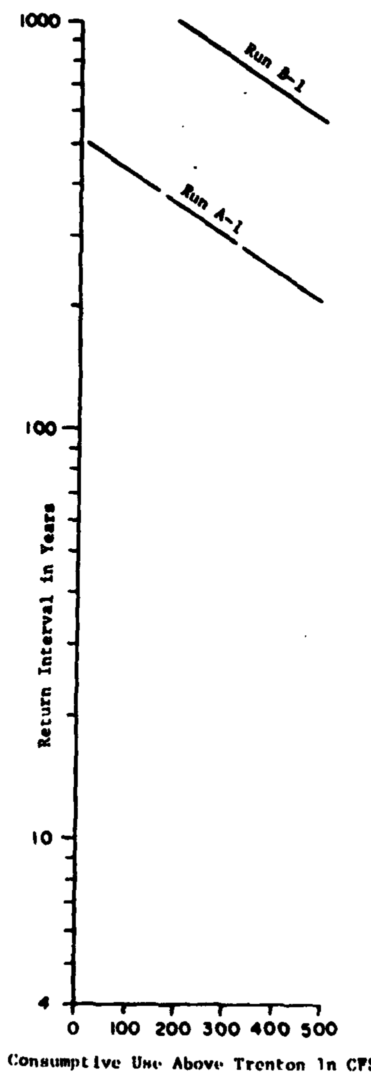
Results are presented for runs A-1, A-2, A-3 and B-1 at Torresdale and the southern limit of influence of the Camden Well Fields. The results are plotted on semi-log paper in Figures 3-37 and 38 respectively, and the preferred definition of an "event" is used. For low consumptive use, there are correspondingly few instances of salinity threshold exceedance, so the statistics associated with such instances are necessarily based on small sample sizes and are therefore unstable and appear to result in a discontinuous plot. This should not be interpreted to mean that the model and the mode of presentation of results are invalid.



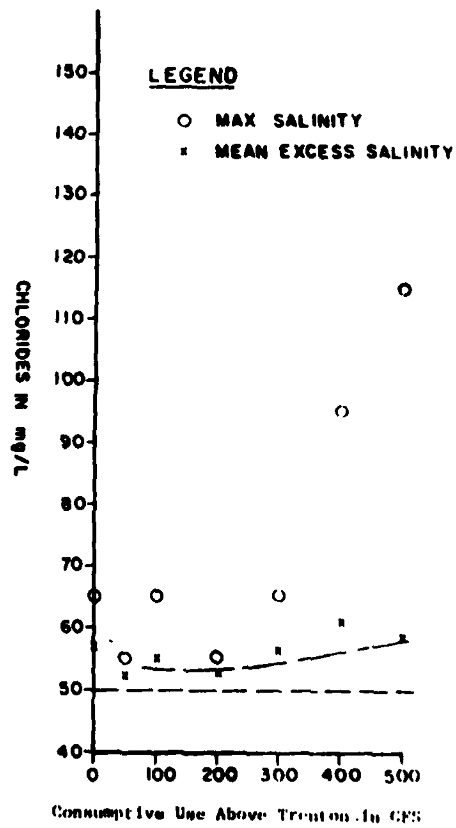
COMPARISON OF RETURN INTERVALS OF EXCESS SALINITY BASED ON MONTHS AND EVENTS



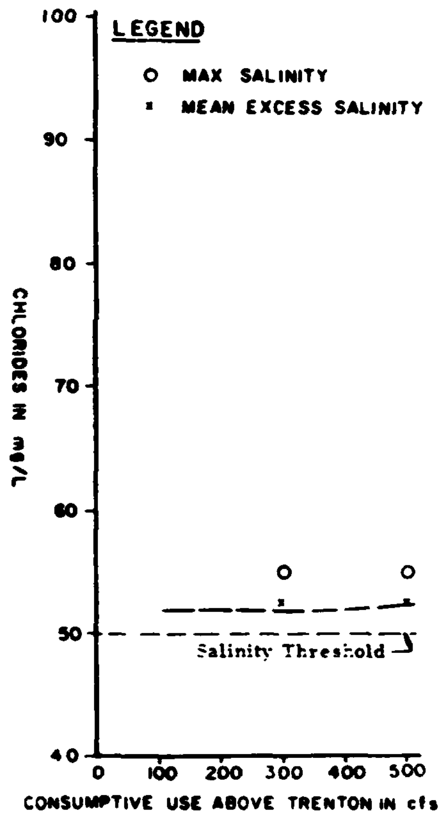
RETURN INTERVAL OF EXCESS SALINITY AT TORRESDALE



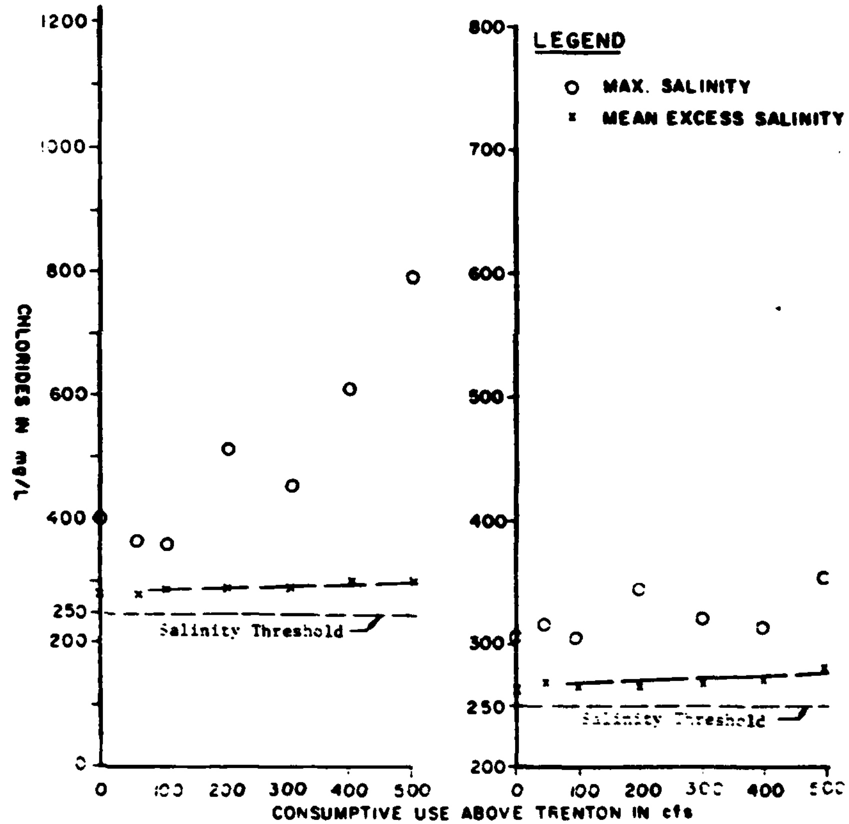
RETURN INTERVAL OF EXCESS SALINITY AT SCWF



MAX. & MEAN EXCESS SALINITIES AT TORRESDALE - RUN A-1



MAX. & MEAN EXCESS SALINITIES
AT TORRESDALE - RUN A-2



MAX. & MEAN EXCESS SALINITIES AT MOS
RUN A-1 - RUN A-2

40, 41&42

Figures 3-39 to 3-42 show the sensitivity of estimated magnitudes of salinity concentrations as a function of consumptive use above Trenton. Two types of data are offered. These are the maximal and mean salinities for two runs (A-1 and A-2), and they are shown in Figures 3-39 and 40 for Torresdale and Figures 3-41 and 42 for the Mouth of the Schuylkill River.[1] The scattering of data points reflects certain instabilities in the output due to the fact that extremes, based necessarily on a sample size of one, are vastly more variable than measures of central tendency. No attempt is therefore made to sketch the maximal salinity curves, even by eye.

The data points of the means of the salinity concentrations exhibit predictably smoother functions, but even here, for low consumptive use and few exceedances, the results reflect small sample fluctuations.

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1 Only those salinity concentrations that exceed the threshold are used in computing the mean.

III.E.2(1) Discussion of Assumptions Used in the Analysis

Throughout the salinity intrusion evaluation discussed in previous sections, an effort was made to provide a conservative analysis. Conservative in the context of this chapter refers to the selection of assumptions that tend to increase the probability magnitude or return interval of salinity in the estuary. For example, when it was necessary to select operating rules for the simulation runs, one run (A-1) was selected that would increase the probability of observing salinity concentrations in the estuary by minimizing fresh-water inflow at Trenton. The purpose of the approach was thus to define the maximal probability of salinity intrusion by establishing the "worst case" condition. Under actual or most likely operating conditions, estimated return intervals and magnitudes of salinity concentrations could be expected to be less than those given in Tables 3-48 and 3-49 above. A number of these assumptions are listed and discussed as follows:

1. Selection of a simulation run that maximizes diversions from the Basin. As discussed in earlier subsections, results here developed in the study are for the assumed conditions for run A-1, A-2, A-3, and B-1. Run A-1 would represent the "worst" operating condition relative to the Basin because under the assumed conditions of this run, the City of New York would always divert 800 MGD from the Basin as long as storage was available in its reservoir system, and would only meet the 1750 cfs low-flow requirement at Montague if there was excess flow available after first meeting the 800 MGD diversion. This run was selected because it would establish a shorter return interval for

an exceedance of salinity thresholds than any reasonable operating policy that could be developed. Run A-1 does not represent the way the basin would actually operate. The City of New York would not always take the full 800 MGD diversion. On the other hand, the City would not always meet the 1750 cfs low-flow augmentation requirement. A more realistic diversion from the City's reservoir system might be something more than the 500 MGD "safe" yield of the City's system. Thus if the City withdrew only 600 MGD during a drought period, at least an additional 200 MGD (310cfs) would be available for low-flow augmentation purposes at Trenton beyond that associated with run A-1.

2. Use of a two-part regression function in the flow - salinity correlation. As discussed in subsection (d) above, the use of a two-part regression function almost always results in higher salinity at points of interest in the estuary because special consideration is given to the relationship between fresh-water inflow at Trenton and salinity concentrations in the estuary under low-flow conditions. It is not possible, however, to estimate the amount by which higher salinities are estimated.

3. Exclusion of several existing or programmed reservoirs above Trenton. As discussed in subsection (f) above, the Trexler, Aquashicola, Hackettstown and Nockamixon Reservoirs were excluded because individually they were less significant than those included. The aggregate effect of the omission of these reservoirs is the simulation was to underestimate fresh-water inflow at Trenton by about 215 cfs. A much larger number of smaller reservoirs were also omitted.

It should also be pointed out that all programmed reservoirs (with an aggregate 281 cfs yield) in the Schuylkill Basin were excluded from the analysis. While this yield cannot be directly converted to a Trenton equivalent, their inclusion would surely reduce the estimated return intervals and magnitudes of salinity concentrations at Torresdale and Pier 11 as shown in Tables 3-48 and 3-49 above.

4. Consideration of a 3000 cfs target at Trenton. In order to properly simulate the operation of the basin as described in subsection (f) above, it was necessary to specify a low-flow target at Trenton in addition to the one for Montague. A target of 3000 cfs was selected for Trenton and the reservoirs that augment low-flow made releases to meet the target in the simulation runs.

Because Table 3-48 has shown that the probability of salinity intrusion is very low under the assumed conditions of the runs, a lower target could have been specified at Trenton. If a lower target were specified, the computed probabilities would have been even smaller. This is because less augmentation would have been provided by those reservoirs that augment low-flow when flows were somewhat less that 3000 cfs at Trenton thus preserving their storage for augmentation when flows were substantially below 3000 cfs. With a lower Trenton target, the lowest of the low flows would be higher while flows somewhat below 3000 cfs would be somewhat lower. The use of a lower target would in effect allocate reservoir storage so as to provide augmentation when it is critically needed rather than when it is not as critically needed.[1]

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1. A related issue, the relationship of the DRBC's 3000 cfs low-flow objective at Trenton to salinity probabilities, is reviewed in the next subsection.

In evaluating synthetic salinity concentrations corresponding to the 500 years of fresh-water inflow at Trenton, it was observed that many of the concentrations were just under 50 mg/l and that those that were over 50 mg/l were not over by very much. It is quite possible that had the conservative assumptions discussed above not been made, particularly assumptions 1 and 3 which underestimated fresh-water inflow at Trenton significantly, several of the salinity concentrations that were slightly above 50 mg/l, could well have dropped below 50 mg/l. It is thus possible that none or only one or two exceedances would have occurred during the 500-year period of analysis. Consequently, if the 50 mg/l standard set by the DRBC is believed applicable even under rarely observed circumstances, it is very likely that exceedances of this standard would have very rarely or never occurred during the 500-year period.

III.E.2(m) Comparison of Demand and Supply in the Delaware River Basin

As discussed in previous sections, the most important issue relative to water demand in the Delaware Basin is consumptive use rather than gross withdrawals. Thus the comparison of supply and demand in the basin differs from the comparisons for the New York City System and Northern New Jersey subareas contained in Section D.5 above, where gross demands were important.

The comparison in the Delaware Basin differs in another significant respect. The flow requirement necessary to prevent excessive salinity from entering public water systems is a significant need in the basin that is not present in the New York City System and Northern New Jersey subareas. Additionally, the amount of flow needed is necessarily related to the probabilistic nature of basin hydrology.

The institution of additional water supply projects planned by the DRBC for meeting in-basin demands, as listed in their Comprehensive Plan (DRBC (1973)), appears to be adequate to meet withdrawal requirements during the 50-year period of analysis adopted for this study.[1] This is because withdrawal requirements (demands) projected in this study are comparable to those projected by the DRBC which were used as the basis for formulating the water supply projects in the Comprehensive Plan. Consumptive use requirements, on the other hand, are necessarily bound up in the evaluation of the probability of salinity intrusion since consumptive use depletes the water resources of the basin.

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1. This applies to all the projects in the Comprehensive Plan with the exception of Tocks Island whose primary water supply purpose, aside from low-flow augmentation, is to provide for a diversion to the Northern New Jersey subarea.

The approach used in evaluating salinity intrusion probabilities in this study was not based on the concept of a fixed low-flow augmentation requirement that would complete prevent threshold exceedances during the 500 year simulation period. However, for the purpose of evaluating the 3000 cfs low-flow requirement specified in the DRBC Comprehensive Plan, relative to its need for protection against salinity intrusion, the basic regression equation given in subsection (d) above was evaluated with constant Trenton fresh-water inflows in a series of evaluations from 3000 to 200 cfs (50 cfs steps). Two separate runs were made; one with the standardized random normal deviate R of the regression set at its highest possible value, the other with R set at its lowest possible value.

The required constant low flow at Trenton to keep salinity from exceeding 50 mg/1 at Torresdale can thus be bracketed by the results of the foregoing evaluation, and it was found that the delimiting values would be 2300 and 200 cfs.

In accordance with the probability distribution of R, as manifested in the regression equation, it is extraordinarily unlikely that the required low-flow augmentation to maintain salinity below 50 mg/1 at Torresdale would be higher than 2300 cfs. By the same token it is extraordinarily unlikely that the required low flow would be below 250 cfs. In regard to the latter conclusion, however, it is necessary to point out that the consideration of flows this low is beyond the range of observations of flow at Trenton.

From the foregoing analysis, it is apparent that the DRBC minimum required flow at Trenton of 3000 cfs is not likely to be needed in order to prevent salinity from exceeding 50 mg/l at Torresdale during a typical 500 year period.[1] The concept of a required minimum flow at Trenton is not the real issue however. While a minimum flow at Trenton of 2300 cfs would prevent any threshold exceedances during a typical 500 year simulation period, according to our analysis, it is important to question whether any minimum flow, 2300 or 3000 cfs, is required given that there are so few exceedances of the threshold when no minimum flow is maintained.

III.E.2(n) Comparison of Results With Past Work

It is very important to point out that the computational model used in this study to estimate the probability of observing salinity concentrations associated with fresh-water inflows at Trenton is not a prediction model nor is it a cause and effect model. The model cannot predict salinity concentrations that are associated with specific conditions of fresh-water inflow or consumptive use patterns. The model is correct only in terms of expected value. This means that the output of this model is consistent in a probability sense. The model produces salinity concentration estimates that are consistent with the underlying probability distribution that produces the estimate. This is because the regression model incorporates a random additive component which preserves the first two moments of the conductance and on the assumption of log normality made in the study, maintainance of these two moments is a necessary and sufficient condition for preserving the distribution. Specific estimates are

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[1] There may be other bases for a 3000 cfs requirement however.

distributed in accordance with the underlying probability distribution and are therefore not specific predictions of salinity concentrations in the usual sense.

As discussed in subsection (b) above, a number of salinity studies have been carried out over the years, including several involving the use of mathematical or hydraulic models. While none of these studies estimated the possibility of observing given salinity concentrations in the estuary, several have related fresh-water inflows into the estuary, particularly at Trenton, to salinity concentrations in the estuary. Most of this work has been carried out with the use of mathematical models, either steady-state or time-varying or with the Waterways Experiment Station hydraulic model. The usual approach has been to first select a given sequence of observed or assumed fresh-water inflows to the estuary and then to apply the model to determine salinity concentrations in the estuary. Because the basic approach used in the prior studies is fundamentally different from that used in this study, it was not possible to make a direct comparison of the results of this study with results that had been developed in prior studies.

Possible differences in the results of this study as compared with results developed in prior studies may stem from the general tendency of prior studies to select a critical sequence of fresh-water inflows as the basis of the analysis. It is absolutely certain that salinity thresholds can be greatly exceeded if the proper critical conditions are assumed.[1] The real question when such an approach is taken, is the probability that the selected critical sequence will actually be observed. Indeed, it was the fundamental probabilistic nature of the problem that led to the approach taken in this study.

The foregoing discussion necessarily identifies the driving mechanism that produced the salinity concentration probability estimates contained in Tables 3-48 and 3-49 above. This driving mechanism, alluded to in the previous subsection, was necessarily the 500-year trace of synthetic flows at Trenton. The salinity concentration estimates were based on sequences of flow that could actually be expected in a typical 500-year period rather than on critical sequences arbitrarily selected or constructed.

It might be possible to design a comparison between the approach used in this study and one that would employ a time-varying estuary model such as has been applied in earlier work. Such a comparison could be made by substituting the use of such a model for the relationship between fresh-water

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1 A hypothetical combination of fresh-water inflow coupled with hurricane tides in the estuary for example.

inflow at Trenton and salinity concentrations in the estuary developed in this study. However, to make the results directly comparable to those developed in this study, it would be necessary to use as input to such a model, a synthetic trace of fresh-water inflows similar to that used in this study. It would likely be necessary that such a trace include not only Trenton inflows but also any other tributary inflow that may be required by the particular model selected. Additionally, it might be desirable to develop the 500-year synthetic trace on a daily basis rather than the monthly basis used in this study if a time-varying model were selected.[1] The estuary model would use as input, the 500-year trace of daily fresh-water inflows and would, in turn, determine salinity concentrations corresponding to such inflows. The salinity concentrations thus obtained would then be subjected to the same type of probability analysis used in this study to develop return interval estimates for the exceedance of salinity thresholds.

This approach was actually considered for use in this study and it is only because a good correlation between fresh-water inflow at Trenton and salinity concentrations in the estuary was obtained that an estuary model was not used.

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1. It is likely that a steady state model would not be fully applicable because of the transient nature of the problem.

III.E.3. EFFECT ON FISHERY RESOURCES

The development of water resources for water supply purposes in the Delaware Basin can affect fishery resources in the estuary to the extent to which low-flow conditions are aggravated. As increased amounts of water are used in the basin for water supply purposes, the amount of water lost from the basin through evapotranspiration increases as discussed in Section C above. Increased consumptive use results in further reduction of natural low flows unless supplementary storage for low-flow augmentation is provided.

Low flows have a potential impact on fishery resources particularly shellfish which cannot move easily from one portion of the estuary to another. Under conditions of low flow, the conch line (the 15 ppt isochlor) would move up the estuary and would expose young oysters to their predators. This would result in a certain loss in oyster production.

Motile species would move to areas of greater dissolved oxygen and lower temperature when low flows occured at Trenton. Shad, being an anadromous species, might be somewhat affected under such low flows.

Because droughts, floods and other natural phenomena play a bona fide role in nature, the full effects of which cannot be completely evaluated, it cannot be said that the observance of a sequence of low flows at Trenton is necessarily adverse. It appears that the condition of increased consumptive use above Trenton coupled with an absence of Tocks Island Reservoir would not have any significant adverse effects on estuary fishery resources.

III.F. SUMMARY OF FINDINGS

The investigation of water supply service area needs contained in previous sections is summarized as follows:

The water supply service area was defined to include the Delaware River Basin, Southeastern New York, and Northern New Jersey. The service area included the latter two subareas so as to be able to compare the authorized diversions to New York and New Jersey under the Supreme Court Decree of 1954 and the proposed additional 300 MGD diversion to Northern New Jersey, with the unsatisfied needs in these two subareas.

Water demands were projected for municipal and industrial, electric power, and agricultural categories for all three areas. Additionally, a consumptive use determination was made for the Delaware River Basin proper since consumptive use rather than gross demand is more important in evaluating water supply in the basin. The projection of municipal and industrial water demands considered a wide range of parameters that affect water demand. Particular attention was given to the potential for industrial recirculation, use of water conserving devices, and metering as a means of reducing water demand. The water supply demand projected in this study was similar in magnitude to that projected over the years by others such as the Corps of Engineers and the Delaware River Basin Commission. The projected consumptive use was similar to that projected by the DRBC in 1973.

Existing supplies in the water supply service were inventoried and it was found that they are inadequate for meeting the 2025 demand in the

Southeastern New York (New York City System) and Northern New Jersey subareas. In evaluating supplies, particular consideration was given to estimating industrial water provided on a self-supplied basis and the potential for industry to provide their own supply of water in the future. This consideration is crucially important in determining the portion of industrial water that must be supplied by public projects in the future. It was found that while a reasonable scenario can be developed for estimating the portion of industrial demand that is likely to be provided on a self-supplied basis in the future, there is still a fair measure of uncertainty as to its magnitude.

An evaluation was made of the water supply need in the Northern New Jersey and New York City Subareas unsatisfied by present or programmed projects. The evaluation showed that in the year 2025 there would be an unsatisfied need in the Northern New Jersey Subarea of 810, 457, and 282 MGD for the high, medium, and low growth levels, respectively. These needs may be met from subarea projects which, if all were developed, could have a total yield of about 700 MGD, from the Tocks Project, or from out-of-subarea projects.

In the New York City System Subarea, the water supply need unsatisfied by present or programmed projects in the year 2025 would be 1,516, 1,147 and 803 MGD for the high, medium and low levels of growth, respectively. It will not be possible to meet the needs dictated by any of the growth levels without importing substantial amounts of water from outside the subarea even with the presently authorized 800 MGD diversion from the Delaware Basin.

A separate evaluation was made of water supplies considering the estimated additional yield that would be available from existing and potential sources if a drought condition with a return interval of 100 years were used as a basis for planning rather than the drought of the early 1960's, which is the present planning criterion employed for water supply projects in the water supply service area. It was found that the unsatisfied need in the Northern New Jersey Subarea could be reduced to 774, 421, and 248 MGD for the high, medium and low growth levels, respectively, if the 100 year drought were used as a basis for yield calculations instead of the drought of record. Yields of potential sources would also be increased under this assumption.

A detailed investigation of the impact of Delaware Basin diversions and consumptive use on the Delaware estuary was made. The focus of the investigation was to estimate return-intervals for given salinity concentrations in the vicinity of the Philadelphia Torresdale intake and the Camden Well Fields. The investigation involved the generation of synthetic hydrology in the basin, the simulation of the Delaware Basin above Trenton to obtain synthetic fresh-water inflows at Trenton, and the development of a relationship between fresh-water inflow at Trenton and salinity concentration in the estuary. This relationship was then used in conjunction with the synthetic fresh-water inflows at Trenton to estimate the corresponding salinity concentrations in the estuary.

A review was made of standards for chloride concentrations in public water supplies in light of the basic probabilistic nature of the salinity intrusion problem in the Delaware estuary. The Delaware River Basin Commission has set a standard of 50 mg/1, and U.S. Public Health Service a recommended 250 mg/1. The latter standard is set on the basis of taste rather than on public health considerations. However, since neither take into account the basic probabilistic nature of the salinity intrusion problem, a more restrictive standard that applies in all instances except on rare occasions when salinity may be a problem may be appropriate and should be considered.

Return intervals for exceedance of salinity standards were estimated for Torresdale and several other points of interest in the Delaware Basin. It was found that the 50 mg/1 standard set by the DRBC would be exceeded only on the average of once every hundred years and that the USPHS standard would be exceeded only in excess of five hundred years.

A number of conservative assumptions were built into the analysis for the purpose of defining the "worst case" relative to salinity intrusion in the estuary. These assumptions were then analyzed to provide insight as to expected exceedances of the 50 mg/1 DRBC standard under conditions that are more likely to prevail in the basin than those assumed in defining "worst case" conditions. Based on this evaluation it is believed that there is a good chance that no exceedances of the 50 mg/1 DRBC standard set by the DRBC would be observed in the five-hundred year simulation period.

An evaluation was made of the relative water supply and demand in the Delaware River Basin. Water supply projects other than Tocks Island as identified in the DRBC comprehensive plan appear to be adequate to meet withdrawal requirements during the 50 year period of analysis adopted for this study. The most significant water supply need in the basin, however, is the flow necessary to prevent serious salinity intrusion in the estuary. The 3,000 cfs low-flow requirement specified in the DRBC comprehensive plan, based on the methodology applied in this study to evaluate salinity intrusion, was found to be higher than necessary for salinity protection purposes.

APPENDIX A TO CHAPTER III

MODIFICATIONS IN DEMAND MODELS

APPENDIX A. MODIFICATIONS IN DEMAND MODELS

A.1. Public Water and Sewer Service

The projections made in this study are for the combined demand of municipal, self-supplied industrial and self-supplied domestic. As such, they differ from INTASA (1974). The population served with public water is not projected herein in order to arrive at the basic population figures to be used in estimating municipal demand, but in order to determine the number of people switching from self-supplied to public supplied domestic. The model used to estimate the increase in per capita demand is similar to the one for extension of public sewers. In this study, the effect of public water and sewer extension is combined, and the model used can be described as follows.

$$\Delta f_{sc}(t,i,) = (s(t,i) - s(0,i) \quad \Delta S/c(t,i) +$$
$$(c(t,i) - c(0,i) \quad \Delta C$$

where

$\Delta f_{sc}(t,i)$	is the change in per capita demand due to increased public water and sewers;
$s(t,i)$	is the portion of population served by public sewers at time t in area i;
$c(t,i)$	is the portion of population served by public water at time t in area i;
ΔS	is the increase in demand in gpcd as a result of increased public sewers;
ΔC	is the increase as demand in gpcd as a result of increased public water.

A.2. Industrial Demand

Employment projections are available for each subarea in the study area and for this reason, the model for industrial demand was modified. Subareas are made equivalent to states and economic areas in the problem formulation. In addition, factors relating to percentage of population served by public water and the portion of industrial demand supplied by public systems can be deleted since the projections are for all demands and are not concerned with the question of who supplies what part. As a result, the present per capita industrial water demand is estimated as follows:

$$f_I(0,i,j) = \frac{h(0,i,j)\ E(0,i,j)}{P(0,i)}\ g(0,i,j)$$

where

i and j	are indices to represent the subareas and the industry;
$f_I(0,i,j)$	is the present industrial demand per capita for subarea i and industry j in gpcd;
$h(t,i,j)$	is the portion of employees in establishments with water use of more than 20 million gallons per year for industry j at time t and subarea i;
$E(0,i,j)$	is the present employment in subarea i and industry j;
$P(t,i)$	is the population in subarea i at time t;
$g(0,i,j)$	is the present water use per employee for establishment with water use of more than 20 million gallons per year for industry j and subarea i.

Future changes in per capita demand for industrial water in an area are based on changes in the area's gross product originating per capita for each industry, where the gross product originating is the market value of output of goods and services for that particular industry. The gross product originating by an industry group is obtained as the product of the number of employees in that industry and the national average of gross products originating per employee for that industry.

The ratio between an area's gross product originating per capita at time t and at the present is then expressed as follows:

$$B(t,i,j) = \frac{e(t,i,j,)O(t,j)/P(t,i)}{e(0,i,j)O(0,j)/P(0,i)}$$

where

$e(t,i,j)$ is the total employment for industry j in subarea i at time t;

$O(t,j)$ is the national average gross product originating per employee for industry j at time t.

The change in per capita demand for industrial water to be supplied by public systems is then expressed as follows:

$$\Delta f_I(t,i,j) = (B(t,i,j) - 1) \; f_I(0,i,j)$$

A.3. Changes in Recirculation and Technology

Improvements in defining the basic parameters involved in measuring changes in recirculation and technology have been included in this study. Recirculation rates used in the presentation are absolute rates obtained by dividing gross usage by intake. From INTASA (1974).

$$R(t,j) = \frac{r(t,j)}{r(o,j)}$$

where

$r(t,j)$ is the recirculation rate at time t for industry j.

Technological change is expressed in terms of reduction in water use per unit of production. From INTASA (1974):

$$T(t,j) = \frac{1}{b(t,j)}$$

where

T(t,j) is the ratio of present gross water requirements per unit of production to gross water requirement at time t for industry j (gross includes recirculated water).

b(t,j) is the reduction in water use per unit of production obtained by dividing use a time t over present use per unit.

APPENDIX B TO CHAPTER III

DETAILED LISTINGS OF SUBBASINS AND COUNTIES IN SUBAREAS

APPENDIX B. DETAILED LISTING OF SUBBASINS AND COUNTIES INCLUDED IN SUBAREAS

Table 3-50 Distribution of Population Over the Study Area

Subarea State/County	Percent of Population in Delaware River Basin	Percent of Population in Northern New Jersey Subarea	Percent of Population in New York City System Subarea
Delaware			
Kent	86.1		
New Castle	100.0		
Sussex	24.6		
Pennsylvania			
Berks	97.9		
Bucks	100.0		
Carbon	100.0		
Chester	93.9		

Table 3-51 Distribution of Population Over the Study Area (Cont'd)

Subarea State/County	Percent of Population in Delaware River Basin	Percent of Population in Northern New Jersey Subarea	Percent of Population in New York City System Subarea
Pennsylvania (cont'd)			
Delaware	100.0		
Lehigh	100.0		
Monroe	100.0		
Montgomery	100.0		
Northampton	100.0		
Philadelphia	100.0		
Pike	100.0		
Schuylkill	55.6		
Wayne	97.7		
New Jersey			
Atlantic	18.8		
Bergen	-	100.0	
Burlington	98.4		
Camden	96.5		
Cape May	25.7		
Cumberland	100.0		
Essex	-	100.0	
Gloucester	89.2		
Hudson	-	100.0	
Hunterdon	32.2	67.8	
Mercer	81.6	18.4	
Middlesex	-	100.0	
Monmouth	.9	-	
Morris	3.4	96.6	
Ocean	26.8		
Passaic	-	100.0	
Salem	100.0		
Somerset	-	100.0	
Sussex	60.0	40.0	
Union	-	100.0	
Warren	100.0		
New York			
New York City			100.0
Delaware	67.3		
Dutchess			100.0
Nassau			100.0
Orange			100.0
Putnam			100.0
Rockland			100.0
Sullivan	91.9		8.1
Ulster	.3		97.7
Westchester			100.0

APPENDIX C TO CHAPTER III

MUNICIPAL, SELF-SUPPLIED DOMESTIC AND SELF-SUPPLIED INDUSTRIAL FOR NEW JERSEY AND NEW YORK SUPPLEMENTAL SERVICE AREAS

APPENDIX C. MUNICIPAL, SELF-SUPPLIED DOMESTIC AND SELF-SUPPLIED INDUSTRIAL FOR NEW JERSEY AND NEW YORK SUPPLEMENTAL SERVICE AREAS

C.1 Municipal Demand Estimate

The municipal demand for that part of each county that is in a supplemental service area is obtained by multiplication of that county's per capita demand, that county's percentage of population served by public water, and that county's population in the supplemental service area. The municipal demand for the New Jersey and New York service subarea is then obtained by accumulating the demand contributed by each of the counties located entirely or in part in that supplemental service area. The results are presented in Table 3-52 and 3-53. Since the population estimates used in the above calculation, based on 1970 Census are slightly different from the results in Table 3-1, the resulting municipal demand is adjusted in proportion to population differences.

C.2 Self-Supplied Domestic Demand Estimate

The self-supplied domestic demand is obtained by multiplication of the self-supplied population in each supplemental service area by the self-supplied per capita demand. The results are presented in Table 3-54.

C.3. Self-Supplied Industrial Demand Estimate

The results of estimating the self-supplied industrial demand are presented in Table 3-55. First, the self-supplied use per employee in each state is estimated by industry. The basic data used is that of the Census in "Water Use in Manufacturing". The self-supplied industrial use is obtained by subtracting public supplied industrial from the total use. This is divided by the number of employees to obtain the self-supplied use per employee. Next the number of employees for each industry in each supplemental service area is obtained, as described in Section III.B.1 and multiplied by the use per employee so as to arrive at the self-supplied use for each industry. Finally, for each supplemental service area, the results for all industry are accumulated. This estimate of self-supplied industrial is over-estimated because 1972 employment data is used, and under-estimated because 1967 water use data is used.

Table 3-52 Municipal Demand Estimate: Northern New Jersey Subarea

	County Pop. in Subarea (1,000's)	% of Pop. w/Public Water	County Pop. w/Public Water (1,000's)	Per Capita Municipal Demand (in gpcd)	Municipal Demand (in MGD)
New Jersey Subarea					
Bergen	898	98	880	115	101.2
Essex	930	99	921	160	147.3
Hudson	609	100	609	160	97.5
Hunterdon	47	37	17	105	1.8
Mercer	56	79*	44	115*	5.1
Middlesex	584	95	555	160	88.7
Morris	371	79	293	115	33.7
Passaic	461	95	438	180	78.8
Somerset	198	68	135	110	14.8
Sessex	31	79	24	115*	2.8
Union	543	100	543	140	76.0
TOTAL	4,728				647.8
Adjustment based on 1970 Population in Table II-1.	4,688				642.3

* Assumed same as Morris County.

Table 3-53 Municipal Demand Estimate: New York City System Subarea

	County Pop. in Subarea (1,000's)	% of Pop. w/Public Water	County Pop. w/Public Water (1,000's)	Per Capita Municipal Demand (in gpcd)	Municipal Demand (in MGD)
New York Subarea					
NYC Boroughs	7,895	100	7,895	176	1,389.5
Dutchess	222	60	133	130	17.3
Nassau	1,428	100	1,428	125	178.5
Orange	222	69	153	115	17.6
Putnam	57	37	21	70	1.5
Rockland	230	91	209	110	23.0
Sullivan	4	63*	3	110*	.3
Ulster	141	57	80	105	8.4
Westchester	894	96	858	135	115.9
TOTAL	11,093				1,752.0
Adjustment based on 1970 Population in Table II-1	11,101				1,753.3

* Obtained as average between Orange and Ulster County.

Table 3-54 Self-Supplied Domestic Demand Estimate

	Total Population in Thousands	% Population Self-Supplied	Self-Supplied Population in Thousands	Per Capita Self-Supplied Demand in gpcd	Self-Supplied Demand in MGD
Northern New Jersey Subarea	4,688	5.9	277	50	13.9
New York City System Subarea	11,101	2.7	300	50	15.0

Table 3-55 Self-Supplied Industrial in New Jersey and New York Supplemental Service Areas

	For Entire State			For Supplemental Service Areas	
	Self-Supplied Industrial in MGD	Number of Employees (1,000's)	Self-Supplied Per Employee in gals/day	Number of Employees (1,000's)	Self-Supplied Industrial in MGD
New Jersey					
20 Food	7.9	24.3	891	45.0	40.1
22 Textiles	.3	3.5	235	25.5	6.0
26 Paper	16.2	8.0	5,548	26.7	148.1
28 Chemicals	175.4	58.9	8,159	102.8	838.7
29 Petroleum	103.0	4.5	62,709	6.1	382.5
33 Primary Metals	19.0	18.4	2,829	30.1	85.2
TOTAL					1,500.6
New York					
20 Food	20.9	40.7	1,407	59.0	83.0
22 Textiles	1.0	6.9	397	43.2	17.2
26 Paper	69.2	13.8	13,738	31.1	427.3
28 Chemicals	116.7	31.6	10,118	45.7	462.2
29 Petroleum	-	-	64,300	7.3	469.4
33 Primary Metals	175.1	53.2	9,017	13.1	118.1
TOTAL					1,577.4

APPENDIX D TO CHAPTER III

COMPARISON OF DEFICIT FOR BASIN DIVERTERS AND ESTUARY WATER USERS

APPENDIX D. COMPARISON OF DEFICITS FOR BASIN DIVERTERS AND ESTUARY WATER USERS

The following Appendix is not an essential part of this study, but is rather an exploration of an interesting and potentially useful approach that may be employed in the necessary future planning and decision making by appropriate public bodies.

This Appendix provides an analytic basis and indicates procedures for evaluating structural and non-structural measures affecting the Delaware River's water regime -- the Tocks Project is noted in the context of an example of this. It notes how structural measures could relate to salinity concerns during drought periods, for example, and sets forth a logical basis for equitable negotiations between interested parties.

Again, this Appendix is not intended to be suggestive of any point of view, but is merely intended to be helpful in organizing future substantive discussions.

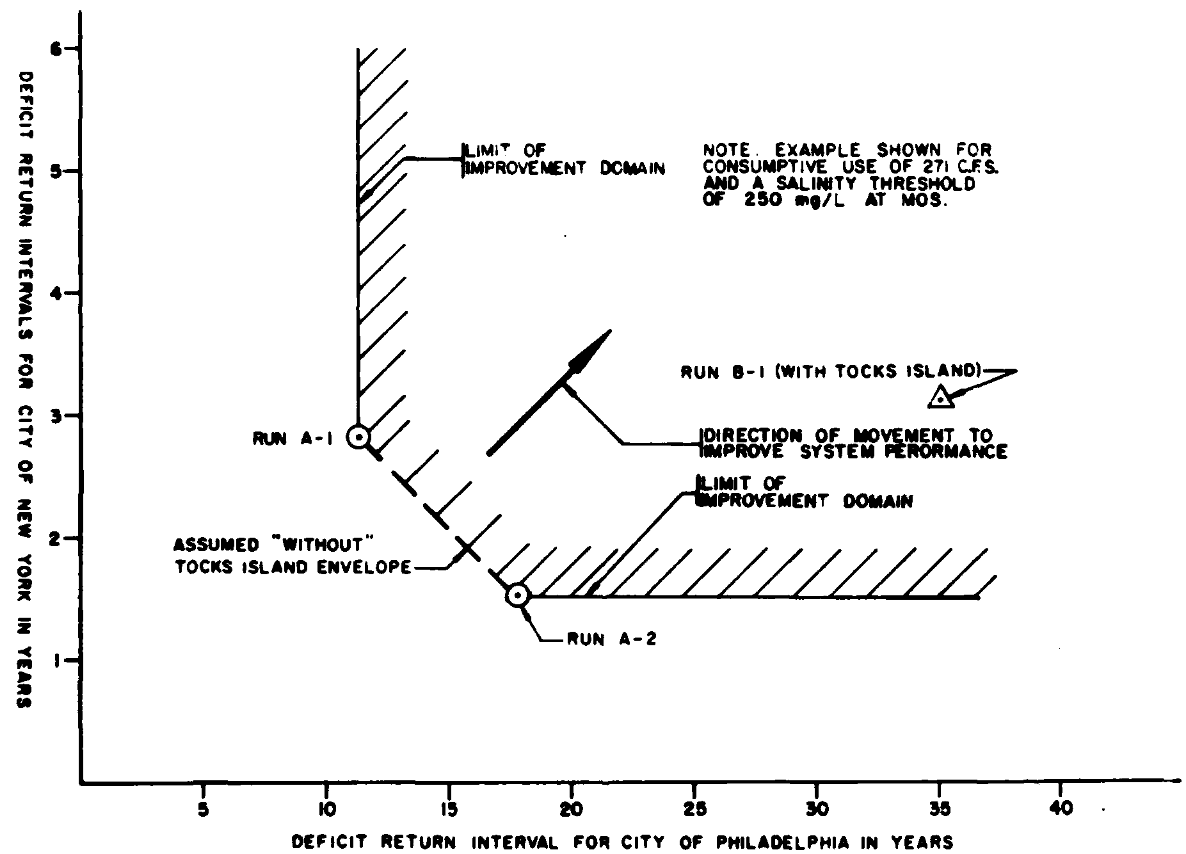
One way to consider the problem of Delaware River regulation with or without Tocks Island Reservoir is to compare the return intervals of estimated deficits during droughts that are borne by the Delaware basin diverters and Delaware estuary water users. The interests of these two parties are contradictory in that should diverters continue to make diversions from the basin during droughts, estuary users would be subject to increasing risk of salinity intrusion. On the other hand, should the demands of the estuary users be met with the highest priority, the basin diverters would suffer a loss of diversion to meet their needs. Tocks Island Reservoir relates in that it would help with the deficit problems because it would increase general water availability in the basin during periods of drought.

Basin diverters are listed in section III.D.4 above. The largest diverter by far is the City of New York with an 800 MGD authorized diversion, although the State of New Jersey is also authorized to divert 100 MGD. Estuary water users are the Cities of Philadelphia and Camden and certain industries. The City of Philadelphia is the most important of these relative to possible salinity intrusion because it withdraws water directly from the upper Delaware estuary for water supply purposes. In the ensuing paragraphs, resolution of water allocation problems stemming from drought in the basin are discussed in terms of the Cities of New York and Philadelphia but it should be recognized that these users, while the largest respectively in the categories of basin diverters and estuary water users are by no means the only diverters or users.

During a prolonged drought, the New York City Delaware reservoirs would become increasingly drawn down and would ultimately be unable to meet the authorized diversion to New York and also the downstream flow requirement at Montague. If Tocks Island were in existence, even though it is not an authorized purpose of that reservoir to supply the City of New York, it might be reasonable to draw upon its waters to help the drought situation in the estuary through increased releases thus permitting the City of New York reservoir system to continue their full 800 MGD diversion to New York City. In other words, instead of maintaining the flow requirement in the Delaware at Montague, it might be reasonable to transfer that requirement to Trenton during periods of drought allowing Tocks Island Reservoir to contribute to the flow at Trenton, thereby relieving some of the pressure on the New York City System. It is immaterial to argue over whether this is a programmed or planned use of the Tocks Island Reservoir; it is virtually certain that should the reservoir be in existence, and should there be a prolonged and serious emergency such as that which existed in the early 1960's, the reservoir would likely be pressed into service and made to meet basin demands without regard to the actual purposes for which it was built.

Figure 3-43 summarizes deficit relationships between basin exporters and estuary water users as represented by the Cities of Philadelphia and New York. The axes of the diagram show the return interval for deficits for New York (measured in terms of the Delaware system's inability to meet the 800 MGD diversion), and deficits for Philadelphia (in terms of the system's inability to prevent an exceedance of a salinity threshold of 50 mg/1).

DEFICIT RELATIONSHIP OF DELAWARE BASIN WATER USAGE



To be sure, these surrogates for failure are dependent only on a frequency and specifically ignore the notion of magnitude or duration of the excess. This is a characteristic of the two-dimensional nature of the graph, not an inherent weakness of the method illustrated here for comparing the deficits. Any numerical algorithm, or computerized version thereof, could very easily take account of more dimensions than can conveniently be plotted in the figure. Such an algorithm could also consider other basin diverters and estuary users and their associated deficit return intervals.

Along the envelope indicated as "without" Tocks Island, two end points associated with runs A-1 and A-2, are identified. These represent the two typical boundary cases (serving New York and Philadelphia with absolute priority respectively). The estimate envelope drawn through these points represents the possible locus of failures associated with the present Delaware system that does not include the Tocks Island reservoir.

From the point of view of return interval, any point which lies above and to the right (or to the northeast) of any other point is preferred because the return intervals are larger (or at least not smaller) than any point that lies to the southwest. In mathematical jargon, the point to the northeast dominates the point to the southwest. It is therefore desirable to move from the "without" envelope in a northeast direction into the "Improvement Domain" to a point, say, B-1 which reflects the effect upon deficit return intervals with the inclusion of Tocks Island Reservoir in the system. Any rational person would agree to do so except for the fact that such movement ordinarily implies a cost. This cost is not reflected only by the cost of the physical structure and whatever operation and maintenance costs are involved, but also in the environmental cost associated with the construction of the structure and its appurtenances. In other words, it is not always cost-free to move from the current position along the "without" envelope to a better position in the Improvement Domain. Different individuals, representing the different points of view associated with basin diverters and estuary water users, will prefer to move in one direction or another. As shown on the diagram, a representative of New York would certainly like to move due north at the expense of Philadelphia, while a representative of Philadelphia would certainly prefer to move due east at the expense of New York. These movements, or shifts of the return interval space, are reflected by costs perceived differently by the various participants. The real planning question, clearly, is whether these movements can be made at a cost which is somehow less than the benefits associated with the movements in the plane. This is the real issue because movements to the east, reflecting benefits to Philadelphia only, but with costs shared by New York, are certainly desirable from Philadelphia's point of view; the converse holds. The more usual situation is that the movement should not necessarily be along one of the coordinate directions, but in some compromise direction, in a northeasterly way, so that both parties share in the costs and benefits.

The plotted points in Figure 3-43 correspond to a "do nothing" option (Runs A-1 and A-2) and a "with Tocks" option. It is also possible to compare the performance relative to salinity of the alternative programs identified in Chapter XVI. The alternative programs including the protection of the Philadelphia and Camden system (Program A) would plot in the extreme easterly direction in Figure 3-43 because virtually complete protection from salinity intrusion in the estuary would be provided. The reservoirs-on-the-tributaries option (included in programs A & B) would provide only limited protection depending on the degree of implementation. This is because these reservoirs are programmed to provide only the 300 MGD proposed diversion to New Jersey, but not the low flow augmentation component of 333 MGD. However, the low flow augmentation component could be provided by an implementation of the high flow skimming alternative. A combination of the reservoirs-on-the-tributaries and the high flow skmimming option would plot very close to the Run B-1 point in Figure 3-43.

In classical economic analysis, the direction of movement in Figure 3-43 is dictated by the stronger party. This does not necessarily mean stronger in military terms, although in earlier days this was certainly true. It can mean stronger with respect to political influence, administrative fiat, court decision, or whatever. This is more properly the subject of detailed and painstaking negotioations, but the essential point of the matter is that the graph does define the locus of feasible negotiations and lays out the range of trade-offs which each party will necessarily be called upon to make in terms of improving the benefits or performance of the system as a whole.

If the dimensionality of the problem is expanded to include magnitude of deficit as well as frequency, the two-dimensional locus becomes a warped surface in three dimensions (or more), but the graphical representation of this becomes difficult. Under these circumstances modern mathematical devices and algorithms exist for search techniques that will identify stable optima along the warped surface, and are therefore useful as guides to negotiation. There is, despite current or popular reason to believe to the contrary, no mathematically and economically unambiguous way to identify an optimal solution unless someone decides in advance what the relative weights, or political clouts, of the parties shall be. This is another way of saying that the proximity of the final solution to one edge or another, to one corner of the pie or another, is based on issues that lie outside mathematics. And indeed, every recent negotiation proves this to be the case.

It is perhaps mathematically difficult but politically and economically naive to identify optimal solutions if all the parties agree on the objective function. With this hope in mind, systems analysis became a favorite tool of water-resource planners in the early days of computing machines and applied mathematical statistics. But this expectation dissolved into meaninglessness as actual cases were encountered because it virtually never was true that all of the individuals involved could agree on what the objective function for a complicated resource development should be. The many persons involved in water-resource projects over the years have perceived their costs and benefits along different scales, used different metrics in terms of environmental versus developmental issues, and basically could not agree on an objective function unless someone imposed a definite policy such as maximization of national income.

But even in many of these cases, maximization of national income had to be tempered by such political and economic issues as redistribution in favor of minorities or certain unemployed sectors, certain regions of the country, etc. Thus even the simplest kinds of economic analysis could not be applied to the very sophisticated mathematical models that had been developed over the past