1.0 INTRODUCTION

This report identifies interstate flow management issues in the Delaware River Basin and recommends a strategy for resolving these and future issues. The report provides background on flow management so that readers may better understand and participate in the issue resolution process.

Section 1 summarizes the water resources features of the Delaware River Basin, outlines the role of the Delaware River Basin Commission in flow management, discusses the need for additional data and decision-making tools, presents the study goal, describes the study area, and lists the limitations of the study.

Section 2 describes the current state of the Basin's flow management and provides background on how the current policies have evolved. The policy background is considered crucial to formulating practical alternatives for resolving the issues.

Section 3 presents the recommended process for issue resolution. The process includes steps to build the scientific basis for developing flow relationships, as well as steps to use the flow relationships along with analytical tools to resolve the flow management issues.

Section 4 describes the current flow management issues for each of the study area stream segments. Recommended index displays (performance measures) describing the relationship between flows and stream uses are presented. Section 4 includes both stream-specific and general recommendations for developing the information necessary for defining flow relationships and other index displays. Section 4 also recommends development of toxic spill modeling, and suggests evaluation of water banking and conjunctive use alternatives as potential means of improving water management efficiency.

Section 5 of the report presents the results of several case studies carried out using the DRBC OASIS model, developed by HydroLogics, Inc. as part of this project, to illustrate the capabilities of the tools in the dispute resolution process.

1.1 Water Resources of the Delaware River Basin

The Delaware River and its tributaries flow from forested Appalachian highlands in upstate New York, northeastern Pennsylvania, and northwestern New Jersey, through the Piedmont region of eastern Pennsylvania and western New Jersey, to the New Jersey, Pennsylvania and Delaware coastal plain, and, ultimately, to the Delaware Bay and Atlantic Ocean. A map of the Delaware River Basin is shown in Figure 1.1.

The Delaware River is an exceptional scenic and recreational resource and supports the water supply needs of millions of people. The main stem is undammed and most of the river upstream from Trenton, New Jersey has been included in the National Wild and Scenic Rivers Program. In addition, sections of the Lehigh and Schuylkill Rivers have been designated as state scenic rivers. The Upper Delaware main stem and three tributaries - the East and West Branches of the Delaware, and the Neversink River, support outstanding trout fisheries. Further, most of the upper and middle portions of the main stem, from the Delaware Water Gap northward, have been classified under DRBC water quality regulations as Special Protection Waters, meaning that measurable degradation of the existing generally excellent water quality is prohibited. As water quality has improved with better waste treatment, recreational use of the Delaware Estuary has increased. All of these stream reaches are downstream from large reservoirs located on tributary streams, and all of the reaches are affected to varying degrees by releases from these reservoirs.

Relative to other major river basins, the Delaware River Basin is small – its 13,500 square mile area is about 0.4 percent of the land area of the 48 contiguous United States. Sixty U.S. river basins are larger. Yet, in spite of its small size, about five percent of the U.S. population (15 million people including the City of New York) depends on the Basin's resources for water supply. The Basin has a population greater than 40 of the 50 states. The largest and fifth largest U.S. cities, New York City and Philadelphia, obtain water from the Delaware River and its tributaries. The Delaware River is renowned as the longest undammed river east of the Mississippi. While there are no dams on the main stem, permanent storage capacity in tributary reservoirs totals over 400 billion gallons. Accordingly, flows in

the largest tributaries and the main stem Delaware River are affected by reservoir releases. In addition to water supply, the reservoir storage and releases are used for flood control, water quality management, hydropower generation, replacement of consumptive water use, support of aquatic habitat, and recreational fishing and boating.

The reservoirs, consumptive water use, and out-of-Basin diversions have altered the natural flow regime in the tributaries and main stem. The reservoirs fill by skimming high streamflows and reducing the number of high flow events. Conversely, during some dry periods, up to 90 percent of the flow of the Delaware River at Port Jervis, New York, and half of the flow at Trenton, New Jersey, consists of releases from major reservoirs.

The Basin has been a focus of interstate water management programs. The most severe basinwide drought in the Delaware River Basin occurred during the 1960s, and drought plans designed for basinwide reservoir operation during a repetition of the 1960's drought have been implemented. Water quality of the Estuary, once so polluted that it blocked the passage of migratory fish, is greatly improved due to the concerted efforts of federal, state and local governments, industry, watershed organizations, and individuals.

The Basin's reservoirs provide storage for fisheries habitat, recreation, electricity generation, water supply, water quality maintenance and other uses of the water in the Basin. The Delaware River Basin's history has been marked by competition for its waters, and increasingly by competition for the use of reservoir storage.

Figure 1.1 Delaware River Basin

1.2 Delaware River Basin Commission's Role in Flow Management

The Delaware River Basin Commission (DRBC, Commission) was created in 1961 by an interstate Compact among the four states that share the Delaware Basin – Delaware, New Jersey, New York, and Pennsylvania – and the federal government. The Commission members are the Governors of the four Basin States and a federal representative appointed by the President. Prior to the signing of the Compact, conflict over water diversions from the Basin had resulted in two United States Supreme Court decisions: a 1931 Decree and an Amended Decree in 1954**.** The 1954 Amended Decree granted an increased out-of-Basin water allocation to New York City and mandated compensating releases from New York City reservoirs to maintain a flow target at Montague, New Jersey. The Amended Decree also granted an out-of-Basin water allocation to the State of New Jersey.

The DRBC Compact, and its relationship to the 1954 Amended Decree, involves the Commission and the Decree Parties (the four Basin states and New York City) in any future modification of the formulae for diversions to

New York City and New Jersey as well as downstream releases from the New York City Delaware Basin Reservoirs. Subsequent agreements by the Decree Parties - the most significant of these being the Good Faith Recommendations of 1982[1] - were adopted by the Commission, resulting in drought operating plans for a system of reservoirs which includes the three New York City Delaware Basin Reservoirs. The reservoirs covered by this study support basinwide drought operations and contain a total permanent storage capacity of 394 billion gallons. They include the three New York City reservoirs (Cannonsville, Pepacton, and Neversink); two privately-owned hydroelectric reservoirs (Lake Wallenpaupack and the Mongaup system); the privately-owned Merrill Creek pumped storage reservoir; Blue Marsh, Beltzville, Francis E. Walter, owned by the U.S. Army Corps of Engineers; and the State of Pennsylvania's Nockamixon Reservoirs. The Good Faith Recommendations also resulted in the Commission's adoption of operating plans for fisheries protection in the New York City reservoir tailwaters.

During *drought emergency* conditions **only**, the Compact gives the Commission, with the unanimous consent of the Commission members, the authority to temporarily adjust the releases and diversions of the 1954 Decree. During all other conditions, the Compact requires that any adjustments to releases and diversions specified in the 1954 Decree receive unanimous approval of the Decree Parties and subsequent approval by the DRBC. This concept is essential for understanding flow management in the Delaware River Basin. The Compact forbids any signatory state or its political subdivisions from applying for a modification of the Decree, but does give the states, acting together through the Commission and under the terms of the DRBC Compact**,** the authority to adjust the Decree formulae if there is unanimous consent of the five Decree Parties. This allows the Decree Parties to negotiate and use the Commission's Compact provisions to avoid litigation over the interstate allocation of the waters in the Basin.

While the Commission does not own or operate any of the dams within the Basin, it has purchased a portion of the storage in two Corps of Engineers reservoirs. This storage is financed through a surface water charging program and consists of 9.2 billion gallons in Beltzville Reservoir and 2.6 billion gallons in Blue Marsh Reservoir.

The Commission provides a forum for comprehensive water resources planning and has broad regulatory power. In matters relating to the 1954 Amended Decree, the Compact provides explicit limits to the Commission's authority. The Commission's activities related to the Amended Decree and DRBC drought operating plans are generally referred to as "flow management" and are conducted through the DRBC Flow Management Technical Advisory Committee (FMTAC), which consists of Decree Party and Commission representatives.

1.3 Study Background and Authorization

Discussions leading to this study began in 1996, when U.S. Geological Survey (USGS) findings on the relationship between Delaware Estuary chloride levels and chloride concentrations in nearby water supply wells in the Camden, New Jersey area were presented to the FMTAC. The findings, which were based on particle track modeling, showed that the effect of estuary chlorides on these wells was less than had previously been determined in the absence of such modeling.

One of the bases of the Commission's flow management policy is the repulsion of estuary chloride intrusion to protect the wells in the vicinity of Camden. This is implemented by making reservoir releases to maintain a flow target at Trenton, New Jersey, located at the head of tide for the Delaware Estuary. In light of the USGS findings, the need to continue the current level of protection using the existing set of flow targets was questioned. Given the multiple uses of managed flows in the Delaware; the complex legal and policy history of interstate water apportioning and flow management; and the continued need for the Trenton flow target to protect other estuary uses, developing a better understanding of the relationships between flow and multiple water uses, as well as the ability to integrate these in decision-making, became a priority for the FMTAC. Subsequently, the FMTAC recommended that this study be undertaken to provide a plan, or strategy, for increasing the technical bases for flow management decision-making and incorporating these in the decision process. The study was authorized and funded by the Commission in June of 1999.

[1] officially the "Interstate Water Management Recommendations of the Parties to the U.S. Supreme Court Decree of 1954 to the Delaware River Basin Commission Pursuant to Commission Resolution 78-20"

1.4 The Need for Additional Tools for Flow Management Decision-making

The starting point and a major effort in this study was an assessment of flow management issues for the stream segments downstream of the reservoirs included in the Commission's drought operating plans. This involved working with state and federal agencies, public utilities, businesses, interest groups, and individuals throughout the Basin to identify flow management issues and to quantify, to the extent possible with existing information, the relationships between the quality of use and streamflow. This effort to define flow relationships revealed that for most of the stream reaches, more data and analysis are needed to establish the relationships between flow and stream use.

Over the past several decades, recreational water use has increased within the Delaware River Basin. Recreational use is linked to water quality, scenic attributes, boating opportunities, and aquatic habitat.

An understanding of the relationships between flow and stream uses such as these is needed to support flow management decision-making. The following are examples of questions which require such an understanding:

1) Can the existing flow augmentation program be more efficient?
2) How much flow augmentation is required for downstream water supply?
3) How much flow augmentation should support water quality?
4) How much flow augmentation should be provided for stream channel maintenance and the protection of fisheries and other natural resources?
5) How much money does the Commission save water purveyors and industry by its program of flow augmentation for salinity control?
6) How much flow augmentation is required to support recreation?
7) How much, if any, flood control storage should be reallocated for flow augmentation?
8) Are flow objectives that more closely replicate the variability of natural flows better than fixed flow objectives?
9) Should freshwater flows to the Delaware Estuary be increased and, if so, at what cost?[2]
10) What indices can be used to measure progress toward flow management objectives?

To answer these questions, knowledge of the relationships between flow and habitat, recreation, water quality, and water supply capability is required. These flow relationships can be used to develop performance measures which will assist different user groups in evaluating how well their objectives are attained by a particular flow regime. In many cases, these relationships are not currently known for the regulated stream segments within the scope of study. There is a need to understand, as scientifically and as quantitatively as possible, the relationship between the range of streamflows and the various stream uses.

Flow models can be used to evaluate the impact on flows and storage of alternative reservoir operating plans. For this reason, a daily flow model, known as the DRBC OASIS model, was developed by HydroLogics, Inc. as a part of this study. Flow relationships link flow model results to the performance of various release alternatives.

In addition to the use of analytical tools, flow management decision-making must consider the policy background and policy constraints surrounding the apportioning of water and the use of storage. This is an especially important matter given the interstate setting and water management history of the Delaware River Basin.

The development of flow relationships and performance measures, the use of analytical models, and the recognition of water supply and policy constraints are included in the issue resolution process recommended in this report.

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[2] Action item W-6 of the Delaware Estuary Program specifies: "Support efforts to ensure freshwater flows to the Estuary to meet water supply needs to the year 2020." One of the "Measures of Success" for this item is "...increased freshwater flows."

1.5 Study Goal

The goal of this study is to develop a strategy for resolving interstate flow management issues for the stream segments downstream of the reservoirs included in the DRBC drought operating plans. This strategy is a recommended set of steps necessary to improve the scientific basis and the process for flow management decision-making. This study recommends steps to determine additional flow relationships and to incorporate them in a recommended issue resolution process**.**

1.6 Study Area Description

The 12 stream segments included in this study are downstream from the large reservoirs included in DRBC's drought operating plans. They are listed in Table 1.1, and shown in Figures 1.2 and 1.3.

Table 1.1 – Stream Segments Included in this Study

Segment	Length in Miles
1. East Branch Delaware River from Pepacton Dam to junction with West Branch	33
2. West Branch Delaware River from Cannonsville Dam to junction with East Branch	18
3. Neversink River from Neversink Dam to mouth	42
4. Main Stem Delaware River from Hancock, NY to Trenton, NJ	197
5. Lackawaxen River from Lake Wallenpaupack hydropower generating station to mouth	13
6. Mongaup River from Swinging Bridge Reservoir to mouth	18
7. Lehigh River from F.E. Walter Dam to mouth	78
8. Pohopoco Creek from Beltzville Dam to mouth	5
9. Tohickon Creek from Nockamixon Dam to mouth	11
10. Delaware Estuary and Bay from Trenton to mouth	134
11. Tulpehocken Creek from Blue Marsh Dam to mouth	7
12. Schuylkill River from confluence with Tulpehocken Creek to mouth	77

A range of stream uses – including recreational and commercial fishing, recreational boating, swimming, sightseeing, water supply, waste assimilation, navigation, and recreation – take place within the study segments. The specific objectives of flow augmentation vary between stream segments and among different groups of water users.

1.7 Study Limitations

This report does not provide a plan to manage flows in the Delaware River Basin. It does not present a specific operating policy or propose new facilities or conservation measures as a prescription to remedy problems or to enhance one or more uses. Rather, this report presents the recommended steps for a process to improve the basis for flow management decision-making. Changes in flow management policy relating to the Commission's drought operating plans can only be implemented with the unanimous consent of the Decree Parties and the approval of the DRBC.

Issues presented in this report were identified by reviewing available reports, meeting with resource agency personnel, and interviewing many individuals with expert knowledge of the river segments and their users. The process involved over six months of gathering information from data sources and interviews. The issues were presented in a preliminary issues report, and the report was distributed in January of 2001 with a two-month comment period provided.

The major limitation of the study was the lack of available information with which to quantify new flow relationships. The process of identifying instream flow issues and relationships is complicated because augmented flows are only one part of the dynamic river system that supports natural resources and human needs in the Basin. Reservoir flow augmentation, for example, provides a volume of water that will vary in its physical and chemical characteristics. Changes in flows affect the depth, temperature, dissolved oxygen levels, chemical concentrations, wetted perimeter, and velocity at a specific location. Most of the recent research on the Delaware River has focused not on flow changes and their impacts, but on other characteristics of water resources at specific locations. The effect

of this is that most reports, such as the extensive Delaware Estuary Study, do not directly address flow rates and their impacts.

Previous fisheries work by the New York Department of Environmental Conservation and the Pennsylvania Fish and Boat Commission has produced useful flow versus habitat relationships for the Upper Delaware tailwaters and the Tulpehocken Creek below Blue Marsh Dam, respectively. The Federal Energy Regulatory Commission (FERC) relicensing process has also produced such relationships for the Mongaup and Lackawaxen Rivers. Previous work by the U.S. Army Corps of Engineers and the DRBC has quantified the relationship between flow and chloride intrusion in the Delaware Estuary. Additional work to quantify flow relationships with habitat (channel maintenance), water quality, and recreation suitability has yet to be undertaken. The scope of this study did not include conducting the original research needed to define these relationships. HydroLogics, Inc. believes that the recommended process in Section 3 and the technical work recommended in Section 4 would help to produce these tools.

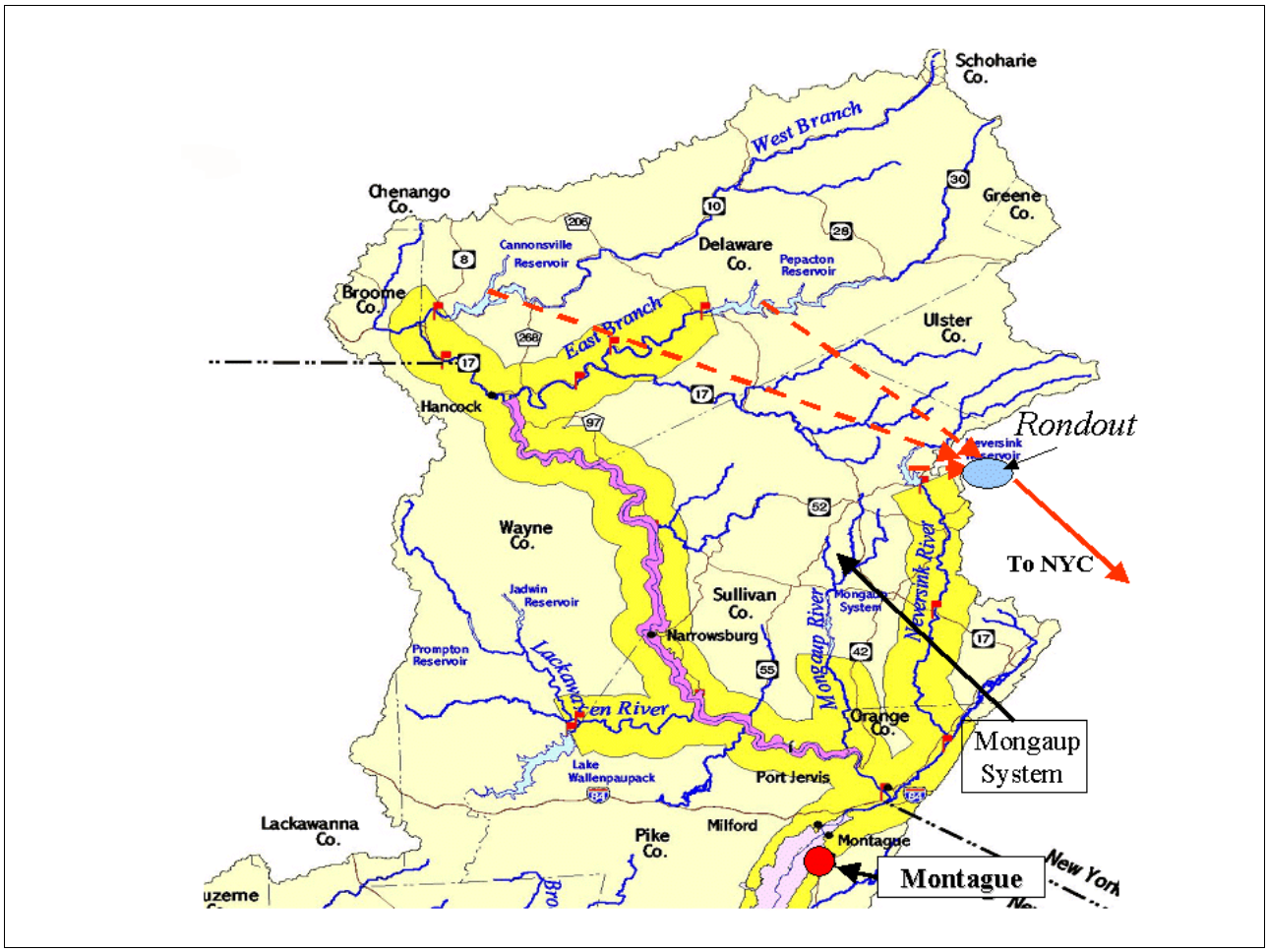

Figure 1.2 Upper Basin Stream Reaches

Figure 1.3 Lower Basin Stream Reaches