

## SECTION 2

### EXECUTIVE SUMMARY AND RECOMMENDATIONS

As discussed in Section 1, Introduction, this report presents the results of Phase I Exeter River Study activities performed in 2005 and 2006. 2006 activities will be presented in detail while 2005 activities will be summarized. The details of 2005 activities can be found in a February 3, 2006 report titled, "*Exeter River Study Interim 2005 Report*".

Major findings of the 2005 and 2006 Exeter River Study reports are as follows:

- The Great Dam does not presently comply with New Hampshire Department of Environmental Services (NHDES) Dam Bureau Rule Env-Wr 303.11 that requires Class A dams be able to pass the 50-year storm event with at least one foot of freeboard above the water surface and the top of the dam abutments (see NHDES Letter of Deficiency (LOD) to the Town of Exeter dated July 25, 2000 and LOD amendments dated June 1, 2004). Hydraulic analyses performed as part of this study indicate that the left and right abutments are overtopped by 3.0 feet and 1.6 feet, respectively, during a 50-year return interval hydrologic event.
- The Great Bridge substantially affects water surface elevations and results in increased flood water elevations upstream of the dam. Hydraulic analyses indicate that the hydraulic restriction imposed by the bridge increases upstream water surface elevations by approximately 1.2 feet during a 50-year return interval hydrologic event.
- The existing low-level discharge gate has very limited ability to mitigate flood water elevations. During the 10-year storm event (approximately 3,000 cfs) the difference in water elevation at the Great Dam with the low-level outlet open and closed is 0.34 feet or approximately 4 inches. The existing gate's ability to lower water elevations upstream of the Great Dam is even less. The existing low-level outlet's capacity to mitigate flooding decreases as flows increase. The low-level outlet gate is presently manually operated, and, therefore, by NHDES Dam Bureau rules, the discharge provided by this gate cannot be included in determining the dam's overall discharge capacity.
- The installation of a larger low-level outlet at Great Dam would also have relatively minimal effect in reducing upstream flooding. The larger low-level outlets proposed for the three dam modifications concepts would lower the water surface elevation at Court Street from between 0.0 and 0.29 feet during the one-year storm event (approximately 1,000 cfs). The ability of the proposed low-level outlets to lower water surface elevations at Court Street decreases with increased flows.
- The hydraulic analyses suggest the impact of pre-emptive drawdowns of the Great Dam impoundment to reduce upstream flooding is minimal.
- The Great Dam was not constructed to be a flood control structure. It was built originally to provide water power to mills. Flood control dams are designed to mitigate flooding

downstream of the dam. The Great Dam, in its present or modified condition, has little ability to mitigate the impacts of upstream flooding.

- The hydraulic analysis results indicate the installation of the one-foot high “cap” on the dam crest and the fish passage facility caused the water surface elevation to be approximately 1.4 feet higher during the 50-year flood relative to conditions prior to their installation. The results also show that the dam abutments would be overtopped during the 50-year flood prior to the installation of the cap and fishpass (west abutment by 1.6 feet, east abutment by 0.2 feet).
- The Great Dam has been modified extensively through the years. Some of these modifications have decreased the dam's discharge capacity. Modifications that have decreased dam discharge capacity include construction of the fish passage facility, apparent loss of spillway length at the time the fish passage was constructed, construction of the one-foot cap on the spillway crest, and deactivation of the approximately 7-foot by 14-foot penstock. The dam's hydraulic capacity prior to the addition of the fishpass facility and the one-foot high cap on the spillway were evaluated as part of this study. The results of this analysis suggest that these modifications further diminished the dam's ability to pass the 50-year storm with one foot of freeboard, but that they had a minimal impact in increasing flood water elevations upstream of the dam.
- The presence of Great Dam on the Exeter River plays a limited role in upstream flooding. During the 50-year flood, the difference in water elevation at the Court Street Bridge with a dam and without a dam is approximately 1.2 feet. The natural river channel, ox-bows, bridge abutments and other restrictions to flow have a substantial affect in limiting river flows and backing up water as compared to the Great Dam.
- Three dam modification concepts were developed that would satisfy NHDES discharge capacity requirements and NHDES Dam Bureau Rule Env-Wr 303.11. The design criteria for the modifications included:
  - a) Dam crest elevation to remain unchanged
  - b) No increase in the east abutment elevation (west abutment elevation to match east abutment)
  - c) Achieve NHDES discharge capacity requirements
  - d) Maintain or improve performance of the existing fish passage facility
- The estimated cost of the three dam modification concepts range between 1 million and 1.4 million dollars.

The objective of the 2005 Exeter River Study activities was to generate information that would allow the Town of Exeter to better understand and quantify existing water quality and quantity concerns in the Exeter River. The following is a summary of 2005 activities.

## **Exeter River Study Interim 2005 Report**

### **Task A: Preliminary Base Plans**

Field surveys were performed at Great Dam, Colcords Pond Dam and Pickpocket Dam on November 15 and 16, 2005. The purpose of this work was to document existing conditions and to acquire elevation and dimensional details of the dams for hydraulic modeling. Preliminary existing condition base plans can be found in the 2005 interim report.

### **Task B: Great Dam Structural Evaluation**

Persistent high water in the Exeter River during the fall of 2005 prevented a visual structure inspection. This task was postponed until September of 2006 and it is included in the 2006 activities section of this report.

### **Task C: Qualitative Backwater Assessment**

A qualitative backwater analysis was performed on the Great Dam impoundment reach of the Exeter River in Exeter, New Hampshire. The primary purpose of this analysis was to quantitatively establish the limit of the backwater from the Great Dam on the Exeter and Little Rivers during low-flow conditions. In other words, this analysis was performed to attempt to determine how far the Great Dam impoundment extends up the Exeter and Little Rivers. The analysis was conducted by making observations of the impoundment area from a canoe on August 2 and November 21, 2005.

The results of the backwater analysis indicate the upstream limit of the Great Dam impoundment, using qualitative methods, may not be possible. Quantitative methods, such as hydraulic modeling, were suggested to help better establish the impoundment limits. It was estimated the Great Dam impoundment extends approximately to where the Exeter River and the Little River cross Court Street (NH Route 108). The backwater analysis is discussed in further detail in 2006 activities section.

### **Task D: Water Quality Sampling Analysis**

Water quality monitoring was performed as part of the 2005 work. This work included in-situ temperature monitoring at five locations and biweekly temperature and dissolved oxygen monitoring at six locations in the Exeter and Little Rivers in and adjacent to the Great Dam impoundment. The purpose of this work was to collect baseline information on temporal and spatial variations of temperature and dissolved oxygen in and adjacent to the Great Dam impoundment. It was expected this information could help determine potential causes and remedial measures associated with impaired water quality.

A preliminary evaluation of water quality data obtained in the Great Dam impoundment during the 2005 project work was used to evaluate 1) thermal gain through the impoundment, 2) thermal stratification and "turnover" within the impoundment, 3) dissolved oxygen levels within the impoundment, and 4) apparent dissolved oxygen depletion within the impoundment. The bi-weekly sampling was used to determine the occurrence of thermal "turnover" within the

impoundment. After the impoundment "turned over", 2005 water quality data collection ended and the in-situ temperature logging equipment was removed.

The temperature data indicated that the Great Dam impoundment does experience thermal gain, meaning water temperatures increase as water moves downstream through the impoundment. Thermal gain in impoundments is common and is typically caused by increased surface area and residence time in the river. These conditions in the impoundment allow the sun and ambient air to warm the water more than would be possible if the impoundment did not exist.

The temperature data also indicate the impoundment experiences thermal stratification, meaning water temperature varies from the bottom of the river to the surface. The data indicated that in 2005, the impoundment "turned over" on approximately September 26. Turn over occurs when the surface water temperature becomes cooler than the temperature of water on the bottom. The cooler water is denser and, therefore, sinks to the river bottom while the warmer water rises to the surface.

Six biweekly dissolved oxygen sampling events were performed as part of the 2005 project work. The purpose of this work was to document existing conditions in the Great Dam impoundment during the summer and through the fall turnover. The biweekly monitoring was performed at the following six locations:

- Location 1.* In the Exeter River where it passes under Court Street;
- Location 2.* In the Little River where it passes under Court Street;
- Location 3.* At the confluence of the Exeter and Little Rivers adjacent to the Town of Exeter's river pump station;
- Location 4.* At the bend in the Exeter River approximately 200 yards upstream of the Great Bridge;
- Location 5.* In the exit (upstream end) of the fishpass at the Great Dam; and
- Location 6.* Below String Bridge on the Exeter River.

The monitoring work was performed on the following dates in 2005:

- Monitoring Round 1. August 2,
- Monitoring Round 2. August 16,
- Monitoring Round 3. August 30,
- Monitoring Round 4. September 13,
- Monitoring Round 5. September 27, and
- Monitoring Round 6. November 7.

Sampling was not performed during the month of October due to persistent high water in the Exeter River.

The monitoring work documented a depletion of dissolved oxygen within the Great Dam impoundment. An in-depth discussion on the spatial and temporal variations in dissolved oxygen was presented in the 2005 report and included many figures and graphs. Dissolved oxygen levels typically decreased as water moved downstream through the impoundment. As

the water warms while moving through the impoundment, it cannot hold as much dissolved oxygen as cooler water. Dissolved oxygen levels were often lower near the bottom of the river, especially in the downstream end of the impoundment. Oxygen depletion in these areas can be caused by biological oxygen demand (BOD) of the organic matter and accumulated sediments at the bottom of the impoundment.

### **Task E: Assessment of Relevant Funding Opportunities**

An assessment of relevant funding opportunities for studies or improvements on Exeter River was presented in the 2005 report. The information was presented in a table format and identified potential state and federal funding agencies with applicable study or improvement categories. The study and improvement categories included Dam Safety, Dam Removal, Drinking Water Treatment / Protection, Fish Passage, Flood Hazard, Habitat Enhancement, Riparian / Wetland Restoration and Water Quality Improvement.

It was recommended that a more detailed review of these potential funding sources be conducted once the nature and scope of additional Exeter River studies or improvements are known.

### **Task F: Hydraulic Modeling of Great Dam**

A preliminary hydraulic model of Great Dam was developed to determine the dam's discharge capacity during floods of various return intervals. This model was also used to estimate the discharge capacity of the existing low-level gate and its ability to reduce flooding.

NHDES rules require all Class A dams must be able to pass the 50-year flood with one foot of freeboard. The modeling indicated that with the low level gate completely open, the existing dam abutments are overtopped during the 50-year flood. This modeling indicates that Great Dam requires significant modifications to increase its discharge capacity to meet NHDES requirements and that the low level gate has a marginal impact on mitigating flood impacts.

Flow duration curves were also developed as part of the hydraulic modeling task. The flow duration analysis was performed to provide information on flows in the Exeter River in the vicinity of Great Dam during target fish species migration periods. This information is used to better understand typical river flows during the migration periods of various diadromous fish species.

### **Task G: Meetings**

Representatives from Wright-Pierce and Woodlot Alternatives, Inc. attended the Exeter River Study public meeting on May 4, 2005 and the NHDES Dam Bureau public hearing on May 25, 2005. We also presented our findings of the Exeter River Study Interim 2005 Report to the Exeter River Study Committee on April 6, 2006.

### **Task H: Water Level Recording**

An evaluation was performed on the feasibility and costs associated with installing remote automated impoundment level monitoring equipment at each dam. Though this equipment is

most needed at Great Dam to better manage impoundment levels, this evaluation is also applicable to monitoring equipment for Colcords Pond Dam and Pickpocket Dam.

The total cost for an automated water level monitoring station at Great Dam would range from approximately \$8,400 - \$10,200. The cost for a water level monitoring station at Colcords Pond Dam and Pickpocket Dam could be higher due their increased distance from telephone and power utilities.

### **Task I: Low-Level Gate Hydraulics and Gate Operations**

An in-depth hydraulic analysis was performed on Great Dam's existing low level discharge gate. The purpose of this analysis was to determine the low-level gate's discharge capacity at various river flows and to determine if the gate could be operated in a manner that would reduce upstream flooding. This analysis was performed with the assumption that the inlet dimensions of the low-level outlet were similar to those of the outlet, as the lack of plans and persistent high water during the 2005 work prevented measuring the dimensions of the inlet of the low-level outlet.

The results of this analysis indicated that the gate had a discharge capacity of between 264 cfs when the river flow was 750 cfs and 321 cfs when the river flow was 3,000 cfs. The affect on water surface elevation was 0.56 feet and 0.34 feet, respectively. These results confirm the low-level gate has a minimal impact on reducing the impacts of flooding.

### Exeter River Study 2006 Activities

The objective of the 2006 Exeter River Study activities was to build on and continue the work conducted in 2005, with the ultimate goal of producing information to better understand how the Great Dam affects water quality and quantity on the Exeter River. Information gathered in 2005 and 2006 was used to develop potential modification options to Great Dam that would increase its discharge capacity. The following is a summary of 2006 activities.

#### **Great Dam Inspection**

On September 6, 2006, a visual structural inspection was performed on Great Dam. This inspection was purely structural in nature and did not include any hydraulic or mechanical considerations. Overall, the dam and associated concrete structures appeared to be in good condition. No deficiencies that require immediate repair were observed. The complete inspection summary and recommendations can be found in Section 3 of this report.

#### **Bathymetric Survey of Great Dam Impoundment**

A high resolution bathymetric survey on the Great Dam impoundment was conducted in July, 2006 using boat-mounted sonar and GPS equipment. This survey was performed to provide more detailed information on the channel bathymetry and volume of the Great Dam impoundment. This survey obtained bathymetric data from the general vicinity of Great Dam up to the vicinity of the Court Street Bridge. Bathymetry of the Little River was obtained from its

confluence with the Exeter River to a point approximately 100 yards downstream of the Court Street Bridge. This survey indicated the impoundments hold approximately 62 million gallons in usable drinking water storage. The complete bathymetric survey summary can be found in Section 4 of this report.

### **Fish Passage Evaluation**

Based on work conducted in 2005, it was assumed that potential dam modification options would impact the performance of the existing Great Dam fish passage facility. It was believed dam modification impacts to the fish ladder would need to be identified and solutions developed that would maintain or improve its existing performance.

During subsequent discussions with the Exeter River Study Committee, it was determined that the existing spillway elevation of 22.53 feet (NGVD) and associated impoundment elevation was to remain the same under normal flow conditions. Dam modification Concepts 1 and 2 include the installation of crest gates that would maintain a normal crest elevation of 22.53 feet. During storm events, these crest gates would open and lower the spillway height to a level below the upstream entrance elevation to the fish ladder. Depending on the depth of the water flowing over the lowered crest gate, water may or may not enter the upstream fish ladder entrance. Dewatering of the fishpass during seasonal upstream migration periods of target fish species would not be acceptable to the New Hampshire Fish and Game Department (NHFGD), and coordination with the NHFGD regarding crest gate operations is, therefore, recommended.

Dam modification Concept 3 consisted of replacing the existing dam with a labyrinth weir with a crest elevation of 22.53 feet. This concept also included an 8-foot by 8-foot discharge gate. Similar to Concepts 1 and 2, gate operations during storm flows could cause the fish passage to go dry. Therefore, coordination with the NHFGD regarding discharge gate operations is recommended.

The complete fish passage evaluation is presented in Section 5.

### **Great Dam Modification Concepts and Hydraulic Modeling**

Through discussions with the Exeter River Study Committee, it was agreed that three dam modification concepts would be developed for evaluation. The Committee also requested two evaluations related to the dam, namely, impacts associated with complete dam removal and an estimate of how much discharge capacity was lost following the construction of the fish passage in the late 1960's.

The physical parameters of the three dam modification concepts were used as input data in the hydraulic model to predict how each option would discharge flood waters during various storm events. With respect to the two evaluations, the hydraulic model of the Exeter River was also run with estimated dam parameters that existed prior to the construction of the fish pass and with no dam at all.

A brief description of the three dam modification options and two evaluations are as follows:

Concept 1:

- Remove the 1-foot high concrete "cap" along the entire length of the spillway
- Install a 1-foot high crest gate along spillway length
- Increase height of southwest abutment 1.3 feet to match height of northeast abutment
- Install a new appropriately sized discharge low-level gate

Concept 2:

- Remove 3 feet of dam crest along the entire length of the spillway
- Install a 3-foot high crest gate along spillway length
- Increase height of southwest abutment 1.3 feet to match height of northeast abutment
- Install a new appropriately sized discharge low-level gate

Concept 3:

- Select one among the three alternative approaches below to increase spillway capacity:
  - 1) Extend spillway into Founders Park
  - 2) Construct an emergency spillway in Founders Park
  - 3) Replace the existing dam with a "labyrinth weir" style dam
- Increase height of southwest abutment 1.3 feet to match height of northeast abutment
- Install a new appropriately sized discharge low-level gate

Evaluation 1:

- Estimate Great Dam discharge capacity prior to the construction of the fish pass in the late 1960's.

Evaluation 2:

- Evaluate the impacts and costs associated with complete removal of Great Dam

The hydraulic model used for this study is called Hydrologic Engineering Center's River Analysis System (HEC-RAS) that was developed by the U.S. Army Corps of Engineers. River geometry data used in the model was obtained from the bathymetric survey conducted as part of this study and digital elevation model (DEM) topographic data produced by the U.S. Geological Survey. The model was run with different river flows that included typical summer flow and the following return interval flood events: 1-year, 10-year, 50-year and 100-year.

The hydraulic analysis was conducted to evaluate the discharge capacity of the three dam conceptual options, the degree to which the Great Dam may hydraulically control river flows, and to estimate the extent of backwater impacts during various storm events. The model was also run with the two evaluation scenarios.

## **Hydraulic Analysis Results**

### Discharge Capacity of Dam Modification Options

The modeling confirmed previous analyses indicating the existing Great Dam configuration has inadequate spillway capacity to pass the 50-year storm event. The calculated water surface elevation for the 50-year storm is 28.7 feet, which would overtop the left and right dam abutments by 3.0 and 1.6 feet, respectively.

Concept 1 could pass the 50-year storm event with slightly less than the required one foot of freeboard required between the water surface and the top of the abutments (.77 feet of freeboard). Minor modifications to this design could be made to achieve the one foot of freeboard requirement. Concept 1 could pass the 100-year storm event without overtopping the dam abutments. An 8-foot tall by 16-foot long gate was used to model this concept.

Concept 2 could pass the 50-year storm and 100-year storm events with more than one foot of freeboard. A 6-foot tall by 8-foot wide discharge was used to model this concept.

The model results indicated Concept 3 could also pass the 50-year and 100-year storm events with more than one foot of freeboard. A discussion of how to interpret the model results for a labyrinth weir is included in Section 6. A 6-foot tall by 8-foot long gate was used to model this concept.

The model was run with Great Dam parameters that were believed to exist prior to the construction of the fish passage and the one-foot cap. The model results indicate that the Great Dam, prior to the construction of the fish passage and the cap, had inadequate spillway capacity for the 50-year storm event and that the abutments would be overtopped (west abutment by 1.6 feet, east abutment by 0.2 feet).

The construction of the fish ladder and cap increased calculated water surface elevations at the dam for the 50-year storm event by 1.4 feet. This result indicates that overtopping of both dam abutments would have occurred at both abutments during the 50-year storm event. A complete discussion of the discharge capacities of various dam modifications is included in Section 6.

### Hydraulic Effects of Great Bridge

The model was run to predict the hydraulic effects of Great Bridge on river flows. The purpose of this analysis was to evaluate how the presence of the bridge impacts surface water elevations during various storm events.

The results of the analysis indicate the Great Bridge does act as a hydraulic restriction to river flows. The degree to which the Great Bridge restricts river flows is substantial and increases as river flows increase. During the 50-year and 100-year storm events, water elevations upstream of Great Bridge are between one and two feet higher than downstream elevations for the existing dam configuration and the three proposed dam modification concepts. A complete discussion of the Great Bridge hydraulic restriction is included in Section 6.

## Backwater Analysis between Great Dam and Court Street Bridge

The model was run to conduct a backwater analysis to determine water surface profile elevations associated with the different dam modification concepts and with different operating conditions for each concept. This analysis would help determine how far impoundment limits extend up the river during different storm events and different dam operating conditions. The analysis was performed with: a) high flows and b) low flows subject to low level gate operations.

The study area for this backwater analysis consisted of the section of river from the Great Dam to where the Exeter River crosses Court Street. This area was selected because during the 2005 activities, this section of river was identified as the likely Great Dam impoundment area based on a qualitative analysis. In 2006, a bathymetric survey of the study area was performed for eventual use in the model. The model could not be run for sections of the Exeter River upstream of Court Street because no bathymetric data was obtained from this area.

The results indicate that the backwater imposed by Great Dam extends upstream of the Court Street Bridge (limit of study area) but that the increase in flood water elevations (hence, areal extent of backwater) caused by Great Dam diminishes substantially as flows increase. The difference in backwater elevation at the Court Street Bridge from the existing dam condition and the complete dam removal condition are approximately 1.25 feet for the 50-year and 100-year storm events. The differences in water surface elevations between the existing dam condition and dam removal condition likely diminish substantially upstream of the Court Street Bridge due to the restriction imposed by the Court Street Bridge and its adjacent approach embankments.

A low-flow analysis was conducted to determine to what degree low-level gate operations could affect upstream water levels. The model was run with the one-year storm event (1,000 cfs) on the various dam concepts in an effort to understand each low-level structure's ability to regulate upstream water levels. The results of this analysis indicate that the ability to manipulate water level in the Great Dam impoundment, using the low-level gate in the dam modifications, is limited. Therefore, the affect of pre-emptive drawdowns on upstream water levels is expected to be minimal. A complete discussion of the backwater analysis is included in Section 6.

### Impoundment Limits

The upstream limit of the Great Dam impoundment will vary depending on the flow of the river. In addition, the definition of the upstream limit of the impoundment is subject to interpretation. One impoundment definition is to define the "level pool", that is, the area defined by extending the Great Dam crest elevation (22.53') to where the bottom of the river is 22.53 feet. Based on this definition, the impoundment would extend approximately 31,000 feet upstream, to approximately where the Boston and Maine railroad bridge crosses the Exeter River. In comparison, the bathymetric data indicated the natural high point on the bottom of the river between Great Dam and the Court Street Bridge is located approximately 1,000 feet downstream of the Lary Lane well (or 8,500 feet upstream of Great Dam). This location is confirmed from hydraulic modeling of the dam removal condition as river flow speed abruptly increases at this location.

Hydraulic analysis of river flows, produced by storms of various magnitudes, indicate the impoundment limits extend upstream of the Court Street bridge during high flows. The complete discussion on impoundment limits is included in Section 6.

### Great Dam Modification Costs

Estimated construction costs for the three dam modification options and the dam removal evaluation were prepared. These costs are summarized in the following table. A complete cost break-down and cost preparation assumptions are presented in Section 7.

	Concept 1 1' Crest Gate 8' x 16' Tainter Gate	Concept 2 3' Crest Gate 8' x 8' Crest Gate	Concept 3 Labyrinth Weir 8' x 8' Crest Gate	Complete Dam Removal
<b>TOTAL</b>	<b>\$ 1,005,000</b>	<b>\$ 1,125,000</b>	<b>\$ 1,430,000</b>	<b>\$ 850,000</b>

### RECOMMENDATIONS

Activities conducted for the Phase I Exeter River Study indicate that the Great Dam has a significant impact on water quantity issues, and, to a lesser degree, water quality issues, on the Exeter River. Significant modifications are needed to the Great Dam to satisfy NHDES rules that require Class A dams constructed prior to February 19, 1981 to be able to pass the 50-year flood event with at least one foot of freeboard remaining between the water surface and the top of the dam abutments. We recommend the Exeter River Study committee review the proposed dam modification options and solicit comment from local interest groups, Exeter Mill Apartments, NHDES-Watershed Bureau, NHDES-Wetlands Bureau, NHFGD and the U.S. Army Corps of Engineers. We also recommend the Town attorney review the report to determine the legal implications of proposed dam modifications on existing water right agreements. Based on feedback from local stakeholders and regulatory agencies, the most appropriate dam modification concept will need to be identified and a plan developed to design, fund and construct the selected dam modification concept.