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# **NORTH NASHUA RIVER CHANNEL REHABILITATION STUDY**

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## **FITCHBURG LOCAL PROTECTION PROJECT FITCHBURG, MASSACHUSETTS**

**June 2003**



**US Army Corps  
of Engineers**

**New England District**

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Prepared By  
Water Management Section  
Water Resources Branch  
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US Army Corps of Engineers

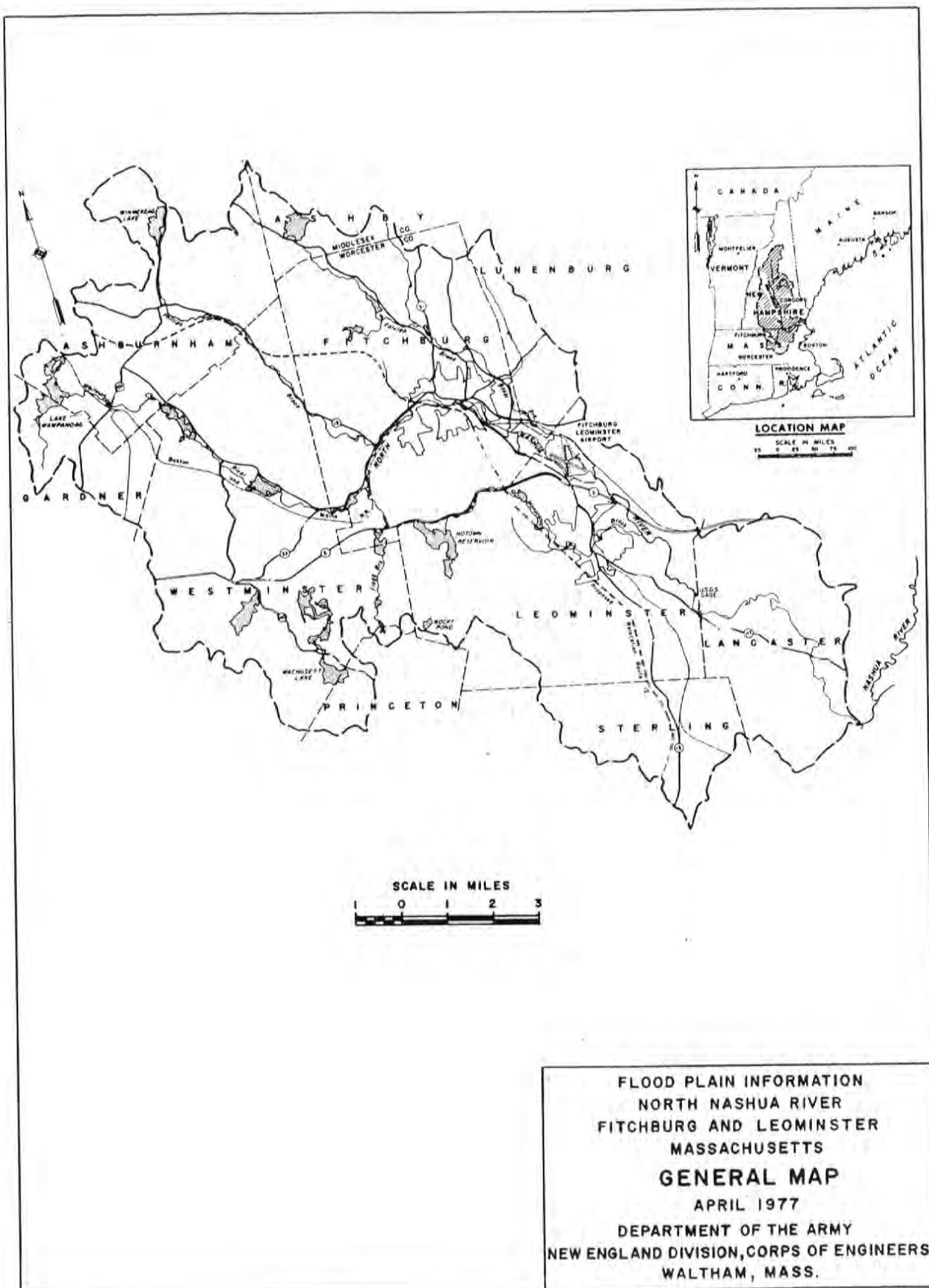
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NORTH NASHUA RIVER  
CHANNEL REHABILITATION STUDY  
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1. PURPOSE AND SCOPE

The purpose of this study, as funded by the Construction/Operations Division, New England District of the US Army Corps of Engineers, is to identify impacts on flood zones that would be brought about by the restoration of the North Nashua River channel, within the Fitchburg Local Protection Project (LPP). The scope of the study consists of a quantitative description of the hydrologic effect of channel rehabilitation (removal of vegetation and shoals) within the LPP, with indication of areas within the study area that would benefit significantly during flood events. The characteristic evaluated is flood elevation during the design event for the project, which is 9,000 cubic feet/second (cfs), with an emphasis on which reaches would realize a reduction in over-bank flooding or a reclamation of valuable free board. This report presents hydrologic data comparing the existing 9,000 cfs flood elevation to that expected with vegetation and shoals removed. Sections included are a description of the study area, study procedures, results and a summary.

2. DESCRIPTION OF STUDY AREA

a. General. The Fitchburg LPP includes approximately five miles of the non-tidally influenced North Nashua River, just above the confluence of Baker Brook. The project is located in a heavily urban and industrial area built about a reach of the river that is spanned by twenty-seven bridges (including roadways, railroad crossings and footbridges), and three dams that can significantly affect flow. Several dams previously existed within the area that became the LPP, but were mostly removed in order to allow free flow.

b. Hydrology. The drainage area of the river above the Baker Brook confluence is approximately 65-square miles (the upland half of the North Nashua River Watershed). Based on twenty-eight years of measurements recorded with U.S. Geological Survey (USGS) Gage 01094400, located near the Fifth Street bridge, the LPP experiences a mean flow of 122 cfs.

The headwaters of the North Nashua River form nearby in Flagg Brook, the Whitman River and Phillips Brook, which flow from hills located in the communities of Princeton, Westminster, Gardner and Ashburnham. The steep slopes of the channels of these tributaries, and the North Nashua River itself, combined with the frequent contractions of the channel introduced by the bridges, can give rise to high velocity flows after a storm event. For comparison, the North Nashua River's channel has an average gradient of approximately 41-feet/mile, while the South Nashua River is far more gradual at

approximately 12-feet/mile, and the Nashua River (formed by the confluence of the north and south branches) drops to approximately 10-feet/mile.

b. Climatology. The area has a variable climate, and frequently experiences periods of heavy precipitation produced by local thunderstorms and larger weather systems of tropical and extratropical origin. The area lies in the path of the prevailing westerlies, which generally travel across the country in an easterly or northeasterly direction, producing frequent weather changes. The climate is characterized as moderate, and the mean annual temperature is approximately 52 degrees Fahrenheit ( $^{\circ}\text{F}$ ). Temperatures for the area range from an average 24  $^{\circ}\text{F}$  in January to an average of 70  $^{\circ}\text{F}$  in July. The average yearly precipitation (water equivalent) is approximately 43 inches.

The North Nashua River Basin experiences storms of four general types, namely:

- (1) Extra-tropical continental storms, which move across the basin under the influence of the prevailing westerlies.
- (2) Extra-tropical maritime storms, which move northward along the eastern coast of the United States.
- (3) Storms of tropical origin, some of which attain hurricane magnitude (typically in the late summer and early fall).
- (4) Thunderstorms produced by local convective activity or fronts moving through the area.

It should also be noted that any rainstorm occurring as the winter's snowpack melts might produce a significantly increased channel flowrate, as the precipitation causes the melt to occur rapidly. This occurrence is most common in the late winter and early spring.

### 3. STUDY PROCEDURES

a. General. This section discusses the methods and assumptions used in the study of the rehabilitation of the North Nashua River channel in the Fitchburg LPP. The channel, over-bank areas, bridges and dams were hydraulically modeled in order to determine water surface elevations under varied conditions.

The model was calibrated to represent the condition of the LPP approximately two decades ago, when a major rehabilitation of the channel was undertaken (equivalent to the condition if the LPP were fully rehabilitated today). Next, changes to the LPP due to the vegetative growth and build-up of shoals during those two decades were represented in the model. The flood levels indicated by the model for the existing condition could then be used to determine which reaches of the river have been adversely affected by the intrusion of bank vegetation and channel shoaling. Among those reaches, areas where the increase in flood stage for the design event (9,000 cfs) caused new or additional over-bank flooding, or the increase seriously jeopardized the channel's ability to contain that



event, were targeted for prioritization by need for channel maintenance.

Finally, modeling of the LPP was performed to represent possible proposed conditions, with only select vegetation and shoaling considered removed, until those areas that caused the problematic flood stage increases were identified. This resulted in the ability to provide specific prioritized reaches (over-bank flooding taking precedence over loss of free board), and recommendations as to whether removal of nearby bank vegetation and/or shoals would be effective in alleviating the loss of the project's ability to contain the design event.

b. Model Specifics. The USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) computer model was used to conduct steady flow analyses. Input for the model included boundary conditions, flow regime, loss coefficients, structure characteristics, and cross section geometry. The principle model output of importance to this study was computed water surface elevations for the design event flow rate of 9,000 cfs, under different conditions as outlined above.

For modeling purposes, channel/over-bank topography and structure details were obtained from a combination of sources, including existing Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) data, specifications from previous channel rehabilitation efforts, and new survey data collected specifically for this study in November and December 2001. The 2001 survey was conducted to update and expand upon the FEMA FIS data, as well as to determine the extent of shoaling in numerous locations.

The roughness coefficient, Manning's  $n$ , was modeled at certain locations as varying on the bank slopes to reflect changes in the ability of the channel to pass the design event due to impeding vegetation. Manning's  $n$  was varied on the banks as follows: the completely rehabilitated LPP was modeled as ranging from 0.025 to 0.045; the existing condition was modeled as having values that ranged from 0.030 to 0.060; and the channel with the recommendations made below implemented was modeled with values from 0.025 to 0.060. In all cases, the over-bank areas were modeled as having a constant Manning's  $n$  of 0.080, and the channel bed was modeled with values ranging from 0.025 to 0.045, though constantly remaining the same in any one location.

#### 4. RESULTS

a. General. The findings of this study detail where select vegetation and shoaling should be removed so that the specific reaches of the Fitchburg LPP that are most susceptible to over-bank flood levels will recover important capacity for major event flows. Results are provided within the reference of the LPP's design capacity of 9,000 cfs, but it is important to keep in perspective that larger events will occur in time, such as the 100-year event (15,000 cfs within the LPP). Each recommended removal of bank vegetation or shoaling has been found to cause a localized flood reduction at a crucial

point in the LPP, and no recommendation from this study has a significant flood reduction effect far removed from the area recommended for rehabilitation.

b. Recommended Rehabilitation Reaches. Below is an itemization of the reaches found to be in significant need of rehabilitation by removal of vegetation and/or shoaling, in ascending order from the downstream boundary of the LPP to the upstream boundary. Each reach is assigned a priority from "first" to "third", with "first" being the highest priority. All other reaches within the LPP have not been given a priority as they were either found to still have sufficient capacity to function during a design event with confidence, or that other factors (such as constrictions to the channel caused by a bridge) control the water surface elevation far more than the introduction of vegetation or shoaling. The downstream portion of the LPP (approximately from Airport Road to the Fitchburg Gas and Electric Dam) was found to not be in need of prioritization at this time. Please refer to Photos 1 and 2 in regards to the typical condition of this reach.

All values below are approximate. All references to left or right bank are oriented as if viewed facing downstream. All discussion refers to analysis of a 9,000 cfs event (design capacity for the LPP). The following numbered reaches are the areas where there is reason for significant concern due to the lost channel capacity from invading vegetation or the build-up of shoals. Due to the close proximity of some of these reaches to each other, full realization of potential benefits in a reach (as a result of the proposed channel maintenance) depends partly, but not mainly, on maintenance of a nearby downstream reach.

**(1) From the Fitchburg Gas & Electric Dam, to the railroad bridge upstream of the Sawyer's Passway Bridge, *third priority*:** The vegetation on the banks within this reach is causing the 9,000 cfs flood stage to increase by 0.7-feet upstream of Sawyer's Passway. This results in the reduction of the 1.5-feet of freeboard that Sawyer's Passway previously had (by approximately one half). Although 9,000 cfs can still be passed beneath Sawyer's Passway, the concern is that the small amount of remaining freeboard could be lost to further flood stage increases caused by debris buildup during the event. This would result in a design capacity event, or even events that would occur more frequently, cresting over Sawyer's Passway and the surrounding area. It is recommended for this reach that channel vegetation below 421-feet NGVD be removed downstream of Sawyer's Passway, as well as channel vegetation below 423-feet NGVD upstream of the same bridge, in order to restore the previously existing freeboard. Please refer to Photo 3, Profile 1 and Plate 1 in regards to the vicinity of this reach.

**(2) From the railroad bridge located upstream of Sawyer's Passway, to a point 500-feet further upstream, *third priority*:** The vegetation in this reach is causing the 9,000 cfs flood stage to increase 0.8-feet in the immediate area. This is a concern as the floodwall on the left bank has lost about a half of the 1.5-feet of freeboard previously



provided at the reach's least protected point (from the upstream face of the railroad bridge to a point approximately 100-feet upstream). For the same reasons indicated above, the removal of channel vegetation below 426-feet NGVD in this 500-foot reach is recommended, in order to decrease the frequency of floods capable of over-topping the floodwall just upstream of the railroad bridge. Please refer to Photo 3, Profile 1 and Plate 1 in regards to the vicinity of this reach.

(3) **From the Water Street bridge, to the Laurel Street bridge, *second priority*:** This reach is most vulnerable towards the middle of its 1,200-foot length. Currently, the vegetation in this area is responsible for raising the 9,000 cfs flood stage by 1.6-feet, which brings that event within 0.3-feet of flooding developed property along the left bank. Removal of channel vegetation in the downstream half of this reach that is below 429-feet NGVD is recommended, as is channel vegetation below 431-feet NGVD in the upstream half. Please refer to Photo 5, Profiles 1 and 2, and Plate 1 in regards to the vicinity of this reach.

(4) **From the Laurel Street bridge, to the Cushing Street bridge (including railroad bridge in between), *first priority*:** This reach is the most likely area in the LPP to experience problems from flooding. Survey work performed for the purposes of this study, during late 2001, has shown that this reach is under tighter constrictions to flow from the railroad bridge and abutments than was assumed for earlier hydrological investigations. The resulting analysis (with the more detailed survey data) shows that the design capacity that was adopted for the rehabilitation was not realized in the vicinity of this railroad bridge. That is to say that even if the LPP were perfectly maintained, a 9,000 cfs event would still crest over the railroad bridge (previously thought to barely pass the flow) and cause flooding in the left over-bank area of this reach (flood crest of approximately 2-feet higher than previously thought).

Regardless, this is where primary attention should be given to maintenance of the LPP. Currently, the 9,000 cfs event would rise 0.9-feet higher due to the vegetation and shoaling in this reach. The vegetation and shoaling are roughly equally responsible for this rise, 0.4 and 0.5-feet respectively. Since this amount of flow will over-top the railroad bridge and left bank even with the channel maintained (unless significant new rehabilitation of the area is undertaken), all improvements would be realized as direct reduction of flood levels that would impact the area.

It should also be noted that under existing conditions, no freeboard exists for the right overbank, and a minimal amount exists for the Cushing Street bridge (for the 9,000 cfs flood stage), but removal of the vegetation and shoals would improve that measurement of safety by the 0.9-feet. Left in the current condition, the LPP only passes 6,000 cfs under the railroad bridge. It is recommended that channel vegetation below 436-feet NGVD and shoaling be removed from this reach. Please refer to Photo 6, Profile 2 and Plate 1 in regards to the vicinity of this reach.



(5) **From the Commercial Street bridge, to a point 100-feet upstream of the Railroad bridge upstream of Putnam Street, *first priority*:** Under existing conditions, the railroad bridge would be over-topped by the 9,000 cfs event with 0.3-feet of floodwater. Removal of vegetation from the Commercial Street bridge to a point 100-feet upstream of the railroad bridge would allow the flood stage to drop 0.7-feet, and thus the flow would pass beneath the bridge. Left in the current condition, the LPP only passes 8,500 cfs under the railroad bridge. It is recommended for this reach that channel vegetation below 443-feet NGVD be removed downstream of Putnam Street, as well as that which is below 446-feet NGVD upstream of the same bridge. Please refer to Photos 7 and 8, Profile 2 and Plate 2 in regards to the vicinity of this reach.

(6) **From railroad bridge downstream of Rollstone/Broad Street bridges, to a point 200-feet downstream of the Rollstone/Broad Street bridges, *third priority*:** Towards the middle of this reach, existing conditions provide only 1.0-feet of freeboard for the floodwall protecting the overbank area. Removal of the channel vegetation in this reach that is below 455-feet NGVD is recommended, in order to recover 1.2-feet of the freeboard that has been lost, for a total of 2.2-feet. Please refer to Photo 9, Profile 2 and 3, and Plate 2 in regards to the vicinity of this reach.

(7) **From the Circle Street bridge, to the lower River Street bridge, *second priority*:** Due to vegetation and shoaling, the floodwall between these two bridges has lost much of the previously existing freeboard. At one point (180-feet upstream of the Circle Street bridge), only 0.3-feet of the previously existing 1.9-feet of freeboard is still available. The shoaling that has developed upstream of the Circle Street bridge is mostly responsible for this, but the vegetation's influence is considerable as well. Removal of the shoaling would restore 1.0-feet of freeboard, while removal of the vegetation would gain the remaining 0.6-feet. Vegetation removal would be of higher priority in the lower half of this reach, but total removal of vegetation between the two bridges would restore valuable freeboard throughout. It is recommended that channel vegetation below 462-feet NGVD and shoaling be removed from this reach. Please refer to Photo 11, Profile 3 and Plate 2 in regards to the vicinity of this reach.

(8) **From railroad bridge downstream of the Oak Hill Road bridge, to a point 500-feet upstream of the Oak Hill Road bridge, *first priority*:** Upstream of the Oak Hill Road bridge, the vegetation and channel shoaling are causing the 9,000 cfs flood stage to rise 1.5-feet higher than the case would be for a fully maintained channel (1.1-feet from vegetation plus 0.4-feet from shoaling). This increase in stage creates flooding that will over-top the Oak Hill Road bridge by 0.4-feet. Downstream of the Oak Hill Road bridge, the vegetation between the two bridges of this reach is causing 1.0-feet of freeboard to be reduced to 0.2-feet. If the vegetation within this reach and the shoaling upstream of Oak Hill Road bridge was removed, flooding would be less likely to occur in the over-bank areas, and the Oak Hill Road bridge would just manage to pass the design

capacity. Left in the current condition, the LPP only passes 8,500 cfs under the Oak Hill Road bridge. Within this reach, it is recommended that channel vegetation below 501-feet NGVD and shoaling upstream of the Oak Hill Road bridge, as well as channel vegetation below 499-feet NGVD that is downstream of the bridge, be removed. Please refer to Photos 14 and 15, Profile 5 and Plate 3 in regards to the vicinity of this reach.

NOTE: Although flooding was determined for the reach above Sheldon Street under the design capacity condition, the area was not prioritized due to the results of the analysis. It was found that the Sheldon Street bridge is the significant controlling factor in the immediate vicinity, and that no appreciable change in flood elevation can be gained from vegetation or shoal removal. However, it is recommended that the pier upstream of the bridge (no longer in use, having formerly supported a demolished building that spanned the river) be removed, so that debris carried downstream during flood events is less likely to collect and further constrict flow under the bridge. Please refer to Photo 13, Profile 4 and Plate 3 in regards to the vicinity of this reach.

## 5. SUMMARY

The hydraulic analysis examining the need for removal of vegetation and shoaling considered the effects of such maintenance on flood elevations. The HEC-RAS model was used to analyze the existing conditions and potential removal scenarios. The reaches identified as requiring maintenance cover approximately 5,800 linear feet in total channel length, representing only about 25% of the LPP.

This is positive news, signifying that the majority of the project can pass the design event without rehabilitation. This is not to imply that these reaches can be ignored in the future, only that wholesale vegetation and sediment removal is not required in order to maintain the LPP to the project design standard. Another cautionary note is necessary regarding the potential for vegetation to be swept downstream during a flood event, typically collecting at bridge openings and thus obstructing flow. The entire length of the LPP should be maintained free of fallen and/or dead vegetation, in order to decrease the likelihood of such flow obstructions that can be the single most limiting factor when determining the channel's capacity to contain high flow rates.

## REFERENCES

Federal Emergency Management Agency, *Flood Insurance Study – City of Fitchburg, Massachusetts (Worcester County), Community #250304*, September 18, 1991.

U.S. Army Corps of Engineers, New England Division, *Flood Plain Information, North Nashua River, Fitchburg and Leominster, Massachusetts*, April, 1977.

U.S. Army Corps of Engineers, New England Division, *Water Resource Development Project, Channel Rehabilitation Project, Local Protection, North Nashua River Basin, Fitchburg, Massachusetts, General Design Memorandum No. 1*, December, 1977.

U.S. Army Corps of Engineers, Hydrologic Engineering Center, *HEC-RAS River Analysis System, User's Manual*, January, 2001.



APPENDIX A  
PHOTOGRAPHS

FITCHBURG LOCAL PROTECTION PROJECT  
North Nashua River, Fitchburg, Massachusetts



Photo 1: View upstream from Airport Road (formerly Falulah Road).



Photo 2: View upstream from Bemis Road.



FITCHBURG LOCAL PROTECTION PROJECT  
North Nashua River, Fitchburg, Massachusetts



Photo 3: View upstream from Sawyer's Passway (railroad bridge in background).



Photo 4: View downstream from Water Street.



FITCHBURG LOCAL PROTECTION PROJECT  
North Nashua River, Fitchburg, Massachusetts



Photo 5: View upstream from Water Street.



Photo 6: View upstream from below Laurel Street (railroad bridge in center).



FITCHBURG LOCAL PROTECTION PROJECT  
North Nashua River, Fitchburg, Massachusetts



Photo 7: View downstream from Putnam Street (Commercial Street bridge in background).



Photo 8: View upstream from Putnam Street (railroad bridge in center).



FITCHBURG LOCAL PROTECTION PROJECT  
North Nashua River, Fitchburg, Massachusetts



Photo 9: Upstream face of railroad bridge (approximately half way between Putnam and Rollstone Streets).



Photo 10: View downstream from Circle Street (Rollstone Street bridge barely viewable in background).



FITCHBURG LOCAL PROTECTION PROJECT  
North Nashua River, Fitchburg, Massachusetts



Photo 11: View downstream from River Street (lower crossing).



Photo 12: View upstream from River Street (lower crossing).



FITCHBURG LOCAL PROTECTION PROJECT  
North Nashua River, Fitchburg, Massachusetts



Photo 13: View upstream from Sheldon Street (pier supported demolished building).



Photo 14: View upstream from Daniels Street (railroad bridge in center).



FITCHBURG LOCAL PROTECTION PROJECT  
North Nashua River, Fitchburg, Massachusetts

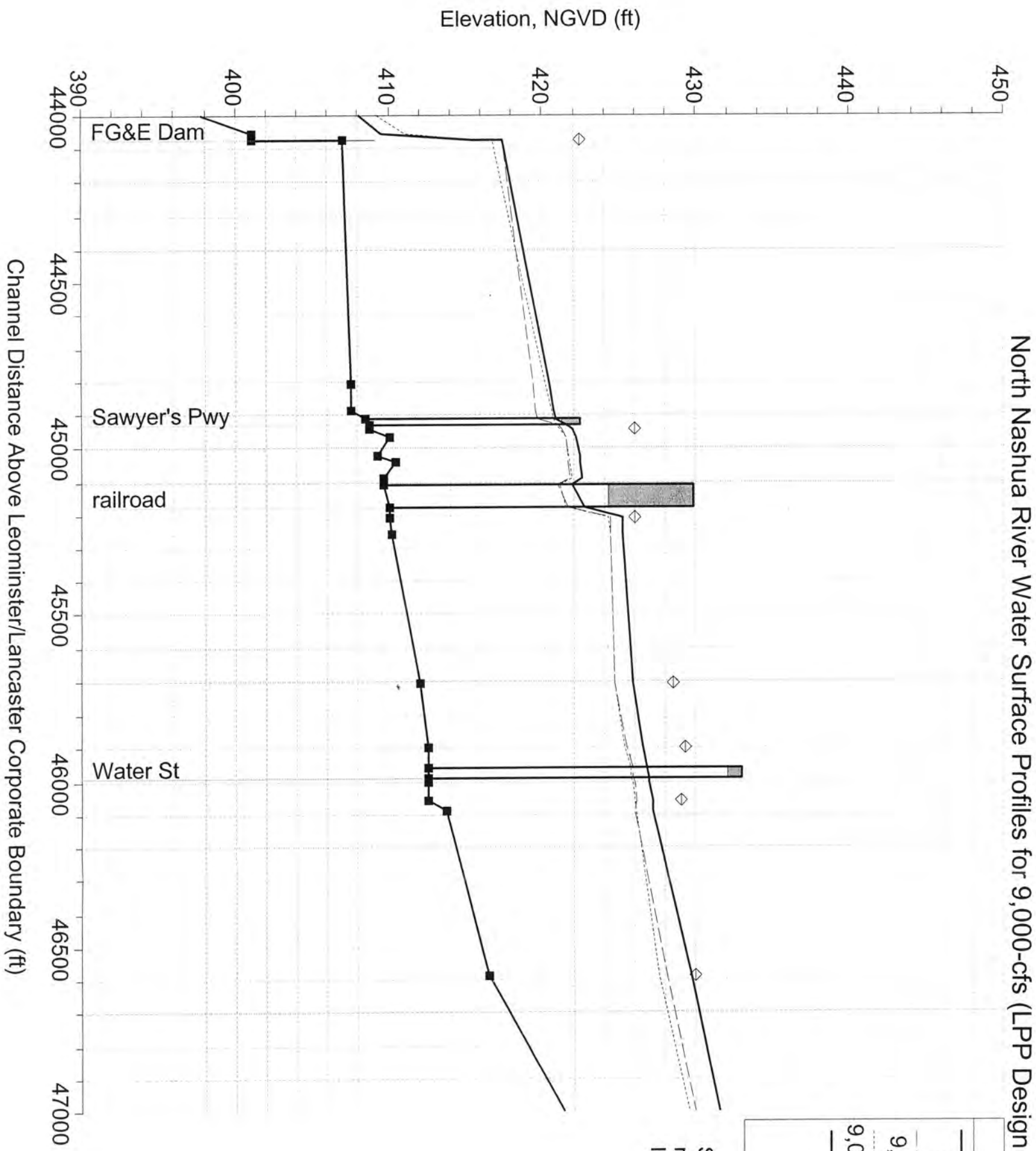


Photo 15: View of upstream side of Oak Hill Road bridge.

## APPENDIX B

### PROFILES





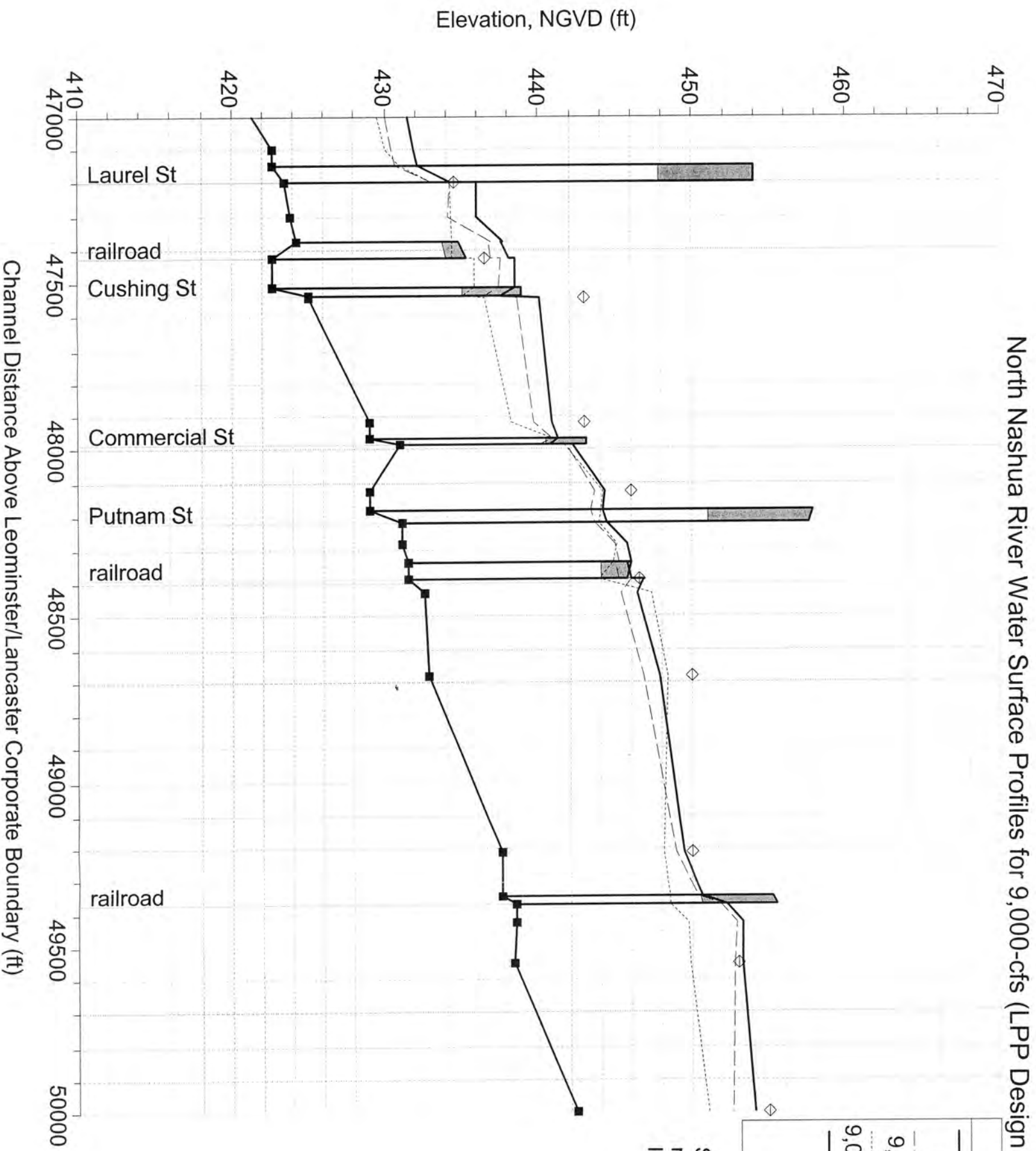
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|--------|----------------------------------------------|
|        | Existing 9,000-cfs Water Surface (WS)        |
|        | 9,000-cfs WS with New Recommendations        |
|        | 9,000-cfs WS Goal of Previous Rehabilitation |
|        | Channel Minimum                              |
|        | Approximate Low Bank                         |

Shaded areas of bridge cross-sections represent the approximate range of the high low chord to the low top of road.



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PROFILE 1



| Legend |                                              |
|--------|----------------------------------------------|
|        | Existing 9,000-cfs Water Surface (WS)        |
|        | 9,000-cfs WS with New Recommendations        |
|        | 9,000-cfs WS Goal of Previous Rehabilitation |
|        | Channel Minimum                              |
|        | Approximate Low Bank                         |

Shaded areas of bridge cross-sections represent the approximate range of the high low chord to the low top of road.

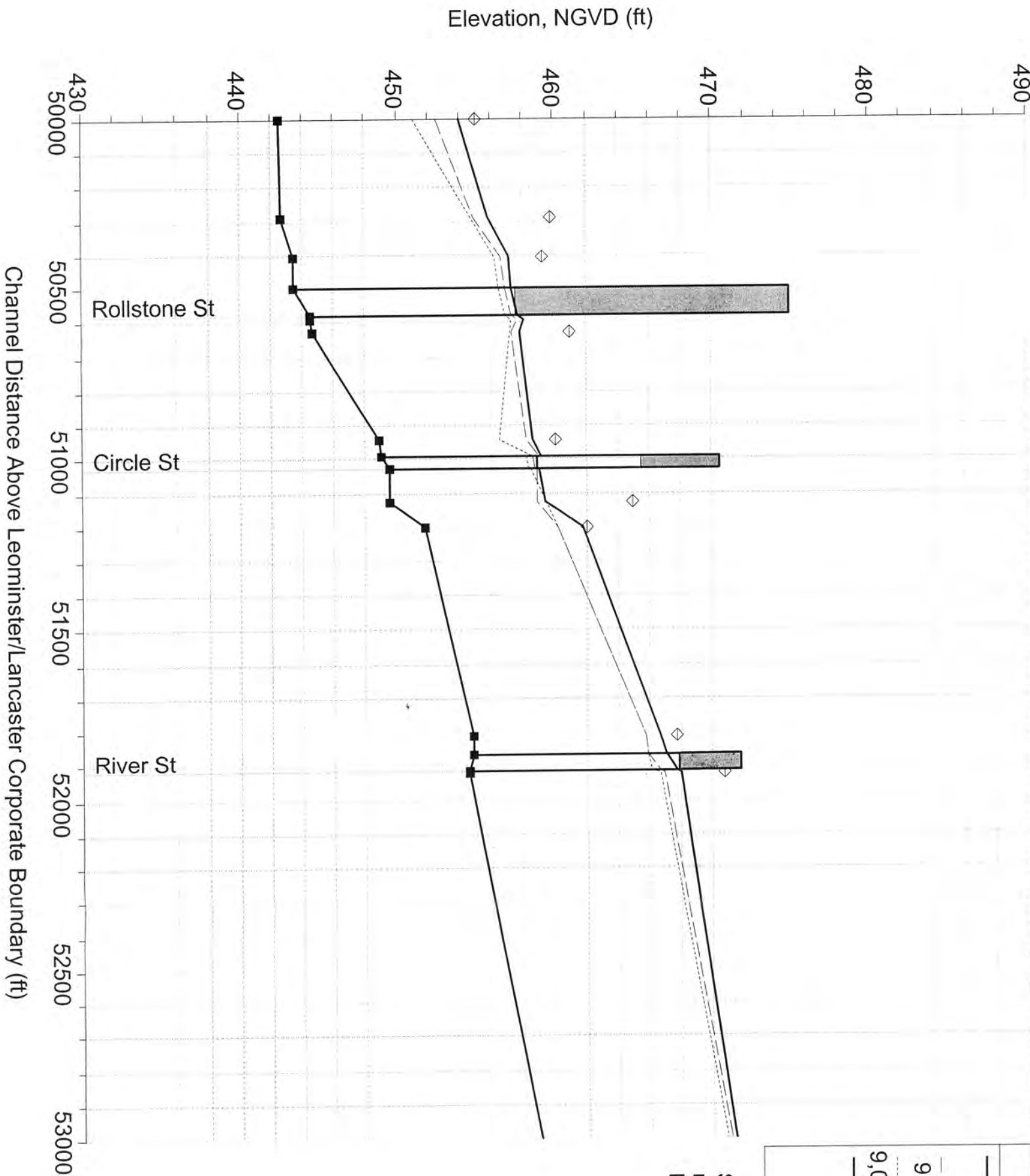


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PROFILE 2



North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



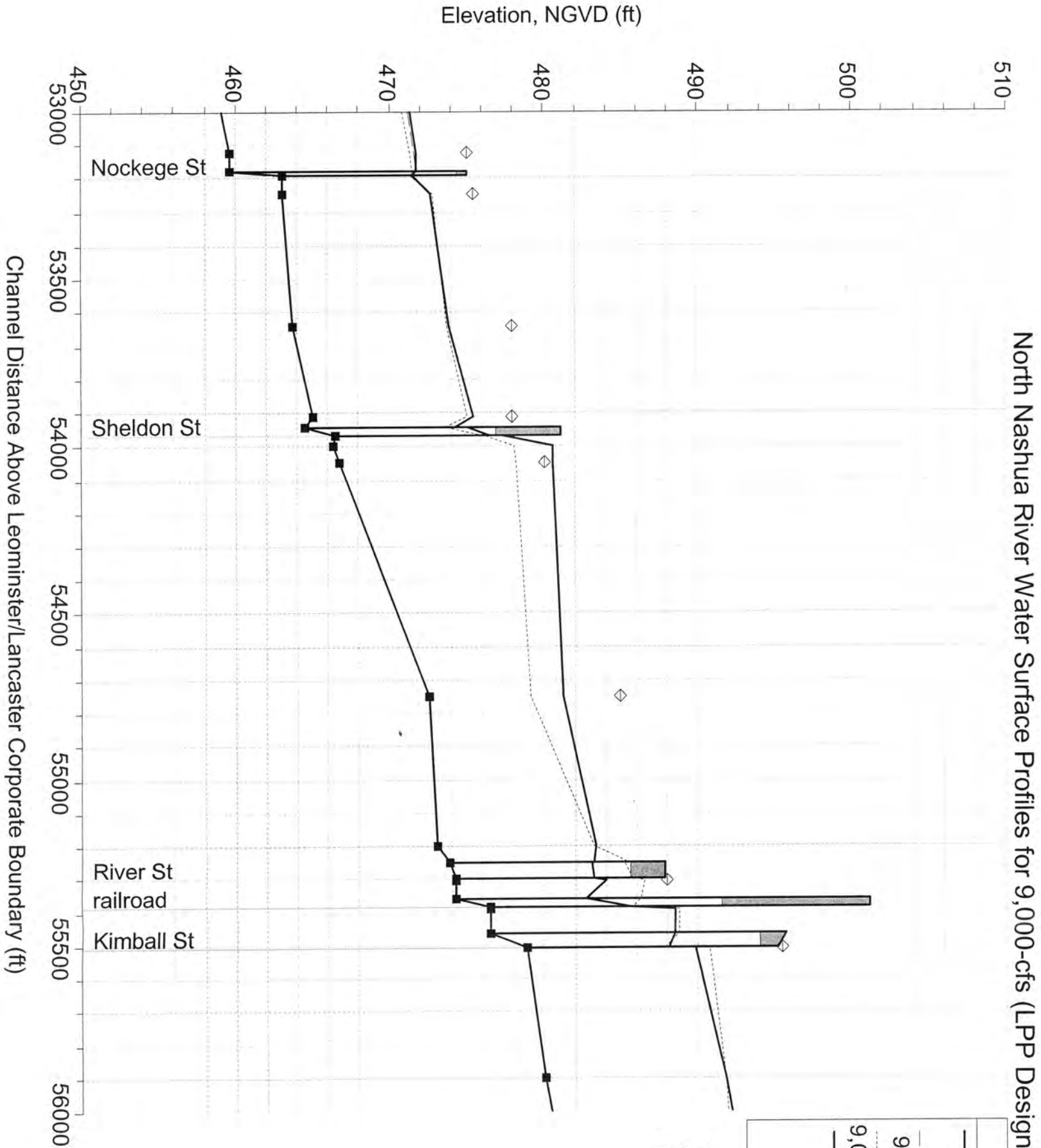
| Legend |                                              |
|--------|----------------------------------------------|
|        | Existing 9,000-cfs Water Surface (WS)        |
|        | 9,000-cfs WS with New Recommendations        |
|        | 9,000-cfs WS Goal of Previous Rehabilitation |
|        | Channel Minimum                              |
|        | Approximate Low Bank                         |

Shaded areas of bridge cross-sections represent the approximate range of the high low chord to the low top of road.



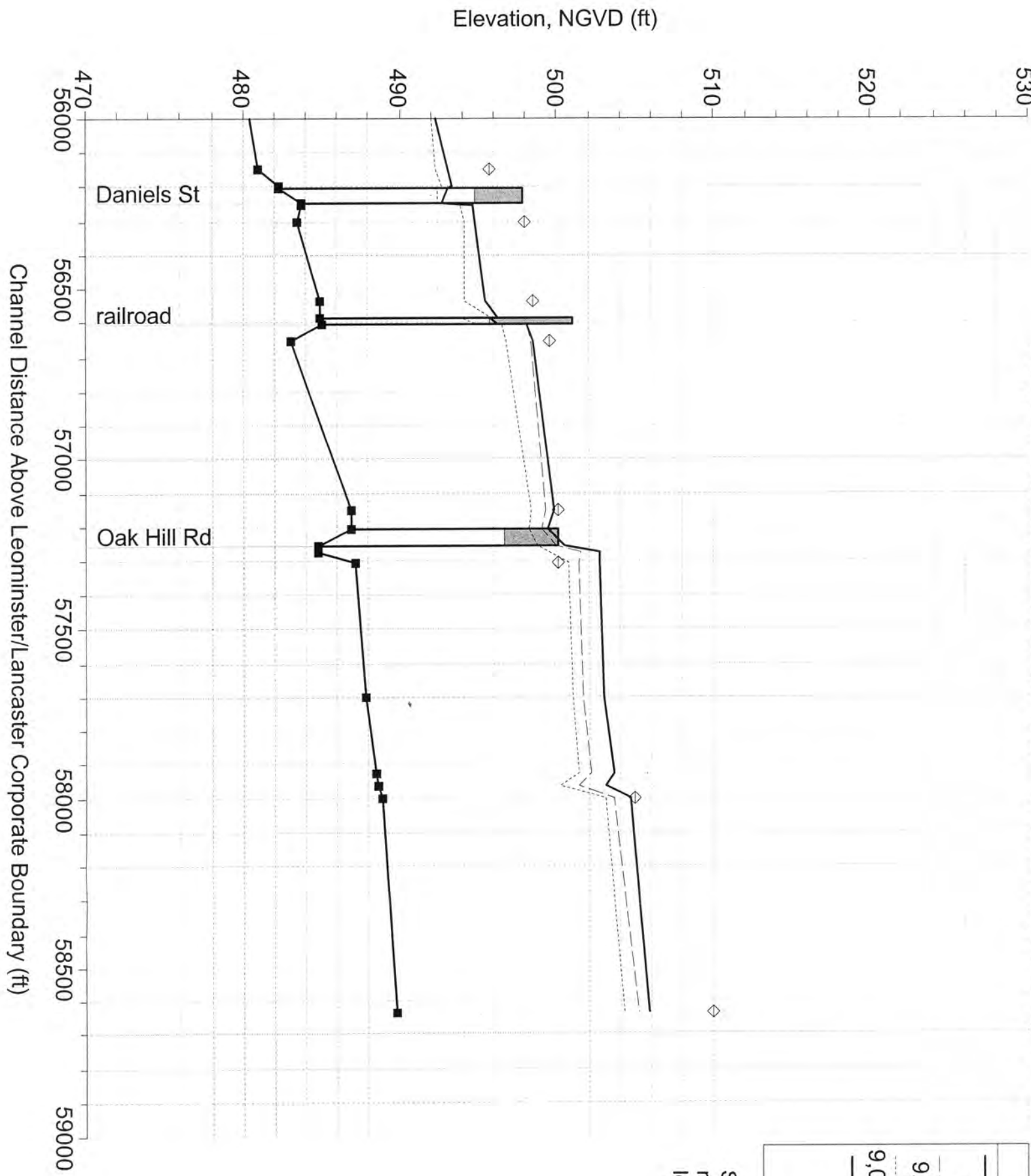
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PROFILE 3





North Nashua River Water Surface Profiles for 9,000-cfs (LPP Design Capacity)



| Legend                                       |  |
|----------------------------------------------|--|
| Existing 9,000-cfs Water Surface (WS)        |  |
| 9,000-cfs WS with New Recommendations        |  |
| 9,000-cfs WS Goal of Previous Rehabilitation |  |
| Channel Minimum                              |  |
| Approximate Low Bank                         |  |

Shaded areas of bridge cross-sections represent the approximate range of the high low chord to the low top of road.



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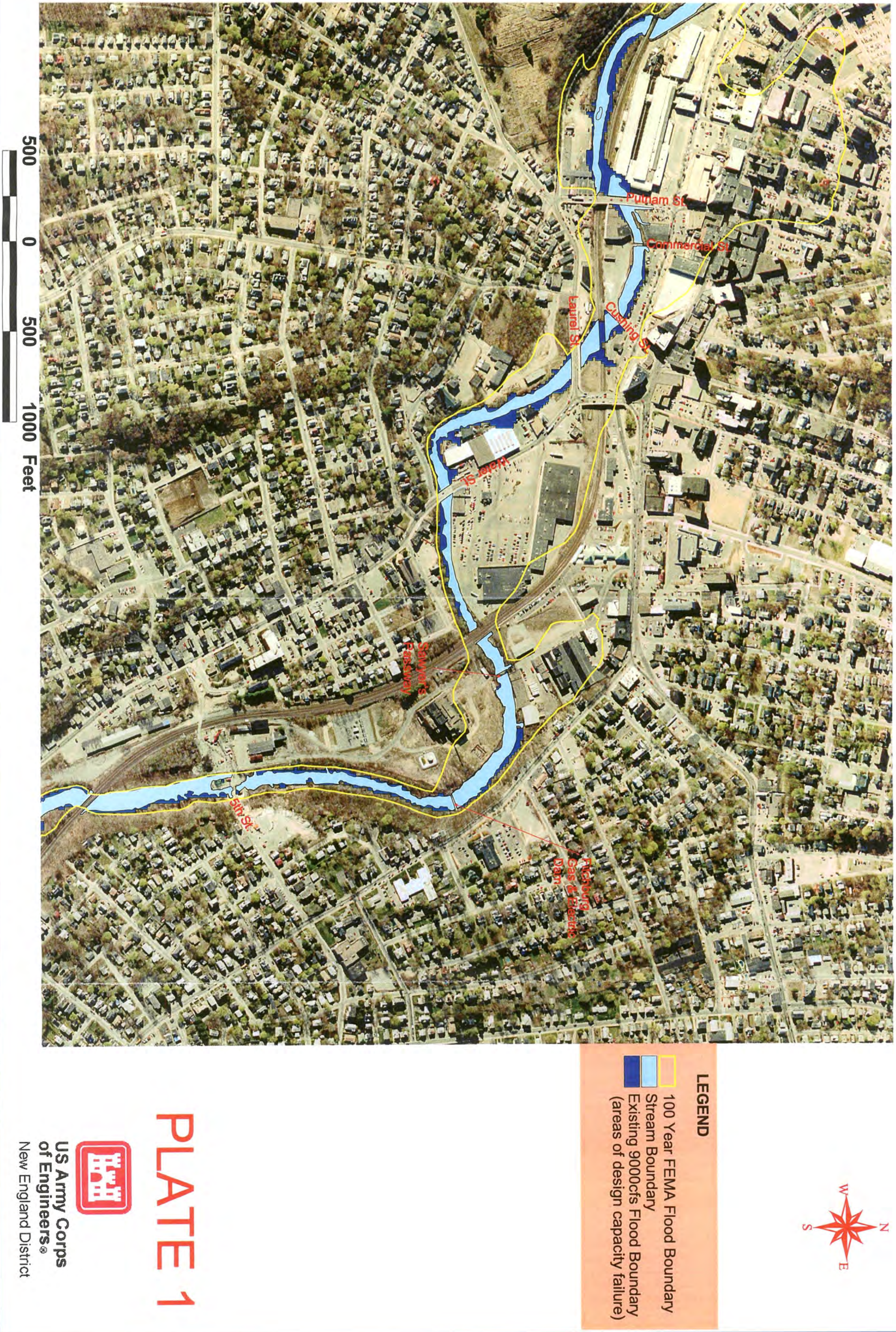
PROFILE 5

## APPENDIX C

### PLATES



North Nashua River (Fitchburg) Existing 9000 cfs Flood Boundary



LEGEND

- 100 Year FEMA Flood Boundary
- Stream Boundary
- Existing 9000cfs Flood Boundary (areas of design capacity failure)

PLATE 1



North Nashua River (Fitchburg) Existing 9000 cfs Flood Boundary



PLATE 2



North Nashua River (Fitchburg) Existing 9000 cfs Flood Boundary

