Project Report
Flood Mitigation Study
Bowman Avenue Dam Site

City of Rye and Village of Rye Brook
Westchester County, N.Y.

Flood Control Improvements
Blind Brook at Bowman Avenue Dam Site

Prepared By:
CHAS. H. SELLS, INC.
Consulting Engineers, Surveyors & Photogrammetrists
555 Pleasantville Road
Briarcliff Manor, NY 10510

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EXECUTIVE SUMMARY

This project involves a feasibility analysis of various flood damage reduction measures at the Bowman Avenue Dam site and Lower Pond. This initiative is consistent with the City of Rye's (City) Flood Mitigation Plan dated November 2001 to which the City identified conceptual level improvements at the Bowman Avenue Dam site and Lower Pond as being part of a comprehensive plan to provide downstream flood control. This study will assess the feasibility, costs and benefits associated with these conceptual flood control alternatives. It is the intent of this report to aid the City in implementing meaningful flood mitigation measures and to provide documentation necessary for securing Hazard Mitigation Grant Program (HMGP) funding.

The Bowman Avenue Dam property is located within the Village of Rye Brook immediately upstream of I-287. The site is the only regional flood control facility owned and operated by the City. Originally constructed in the 1900's, the dam and the Upper Pond were used for ice production. In 1941, the dam collapsed and was rebuilt. The existing dam is a reinforced concrete gravity dam founded on ledge rock. Currently the dam has low-level outlet with a fixed orifice opening of 15-feet wide by 2.5-foot high.

Based on aerial photographs from 1925, the Bowman Avenue Dam site has changed considerably. Over the past 75-years, the Upper Pond has been significantly reduced in size due to siltation. It has been estimated that the Upper Pond is approximately one-quarter its original size. Up until 1976, the Lower Pond did not exist. It was formed as a result of the abandonment of a quarry operation at the site. The Lower Pond was not designed nor does it currently function as a flood control measure.

Several alternatives were investigated as part of this analysis. Each alternative was compared based on its benefit in terms of relative flow reduction and lowering of downstream water surface elevations versus overall cost and impacts.

The preferred alternative, from a short-term perspective, consists of the installation of an automated sluice gate at the Bowman Avenue Dam. An automated sluice gate has the ability to vary the outlet opening, thus providing the optimum orifice size for the flow rate in the stream. The sluice gate would be automatically controlled based on water surface elevations measured at a gauge mounted at the dam. Based on our analysis, this alternative provides the most cost-effective means to reduce water surface elevations downstream. For example, during the 100-year design storm, it has been determined that the water surface elevation at Highland Road would be reduced by approximately 1-foot. The budgetary construction cost for this alternative is estimated at $1 - $2 million. This alternative will not result in upstream impacts.

Other alternatives, including maximizing the storage potential of the Upper Pond in conjunction with the sluice gate, resulted in a further reduction of downstream water surface elevations. The budgetary construction cost for this alternative is estimated at $10 - $15 million. However, it should be noted that the cost/benefit of this alternative heavily relies on the limit of rock excavation and the presence of contaminated material. Further subsurface investigation including rock probes and soil testing is necessary.

INTRODUCTION

Pursuant to the request of the City of Rye and the Village of Rye Brook, Chas. H. Sells, Inc. (Sells) has prepared this Flood Mitigation Study for Blind Brook. The scope of this study is to evaluate various flood damage reduction measures at the Bowman Avenue Dam Site and Lower Pond so as to reduce downstream flooding specifically in the reach between I-287 and I-95.

The proposed project, Bowman Avenue Dam site and Lower Pond, is located in the northern portion of the City of Rye and at the southern limit of the Village of Rye Brook, Westchester County, New York (see Figure 1). The project site is bounded by Bowman Avenue to the north; I-287 to the south; and the Rye Ridge Plaza and Roanoke Avenue to the east (Latitude 41° 00'10" North by Longitude 73° 41'16" West). The total project area, including the Upper and Lower Ponds, is approximately 35-acres.

DESCRIPTION OF EXISTING CONDITIONS

The watershed of Blind Brook is located within the corporate entities of the Town of Greenwich in Connecticut, the City of Rye, the Town/Village of Harrison, and the Villages of Rye Brook and Portchester in New York.

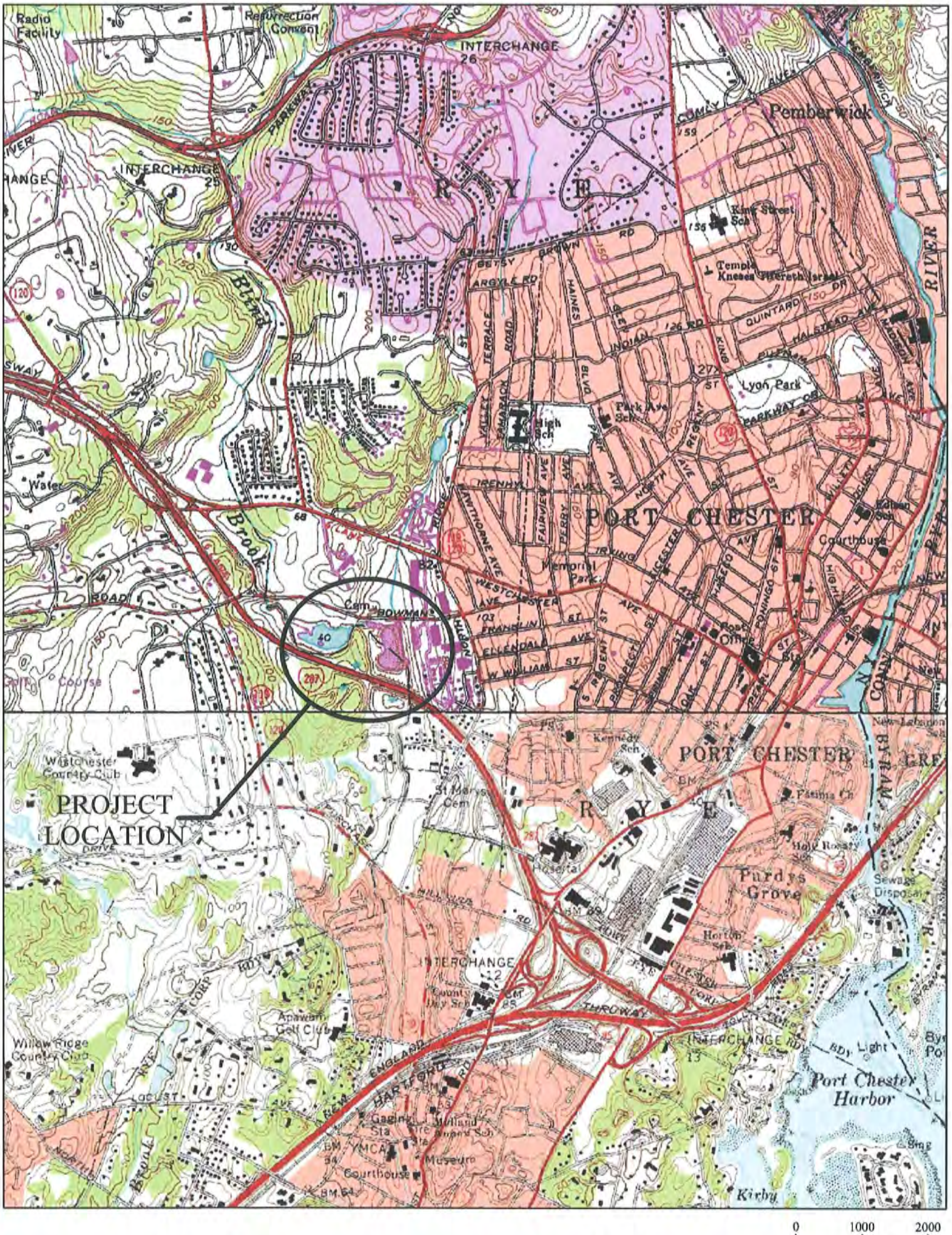
The watershed area of Blind Brook was delineated on and measured from the USGS quadrangle sheets for Glenville, CT –NY and Mamaroneck, NY-CT as shown in Appendix A. The measured area at the downstream end of the study area, the U.S.G.S. Gauge 01300000 just downstream of I-95, is 9.6 mi^2.

Examination of the quadrangle sheets indicates that the streambed is moderately sloping, with an average slope of 0.7 percent upstream of the Bowman Avenue Dam and 0.12 percent upstream of I-95.

The quadrangle sheet also shows that the watershed is suburban in the upper and middle third, and urbanized in the lower third and eastern part of the watershed. The topography of the watershed is gently rolling and lightly wooded hills in the upper portion, and less hilly and partially cleared in the lower part. For the most part, between Westchester Avenue and I-95, the floodplain is wide when compared to the stream channel. Most of the development presently in the floodplain is comprised of low to medium density residential and office uses.

As documented in numerous previous studies, (see Bibliography for listing), the Blind Brook Watershed is subject to frequent flooding throughout its entire length. A combination of a narrow channel, obstructed flows, vegetative growth in stream banks, constricted bridge openings, low banks, sedimentation in tidal reaches, years of wetland filling, and floodplain encroachment are considered the primary cause of the flooding.[1]

[1] USACOE, *Summary Review of Existing Information for the Blind Brook Watershed Management Plan – Final Report,* April 2007, p. 4



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CITY OF RYE FLOOD MITIGATION MEASURES
PROJECT LOCATION MAP

FIGURE NO.
1

There are estimated to be approximately 1,500 structures located within the entire Blind Brook 100-year floodplain. It is estimated that 20% of the properties in the City of Rye are within a FEMA designated flood zone.[2] This study will focus on flooding conditions occurring within the segment of Blind Brook south of I-287 and north of I-95. This segment is roughly 135-acres in size with approximately 140 structures located within the 100-year floodplain. See Figure 2 for the Study Area.

There are known records quantifying extreme floods events on Blind Brook. Hurricane Agnes in June 1972 produced the largest flow (2,320 cfs) ever recorded at the gauge and the September 1975, Hurricane Eloise, discharge was slightly smaller (2,280 cfs). These storms produced extensive damage to buildings, yards, and streets. Flooding in the Blind Brook watershed resulted in substantial damage especially between Purchase Street and Highland Road. According to the preliminary 2006 Flood Insurance Study, "the areas subject to flooding are immediately upstream of road culverts where constrictions cause backwater. The most severe problems on Blind Brook occur at Bowman Avenue, Westchester Avenue, Lincoln Avenue and Brookside Way culverts".

Indian Village is documented as having a high concentration of repetitive loss claims. According to National Flood Insurance Program (NFIP) data there have been 273 repetitive loss claims in the City of Rye since 1978. The total of these claims exceeds $4.5 million with an average claim exceeding $16,000,[3] according to the Army Corps of Engineers (ACOE) approximately 1/3 of these claims occur within Indian Village.

The most recent storm event was the April 15, 2007 Nor'easter. This storm yielded roughly 8" of rain over a 24-hour period and was classified as a 100-year event. The City of Rye incurred severe damage to both private property and public facilities. A summary of damages is provided in Table 1.

[2] Ibid., p. 4
[3] Ibid., p. 19

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CITY OF RYE FLOOD MITIGATION MEASURES
STUDY LOCATION MAP

FIGURE NO. 2

TABLE 1 April 15, 2007 Nor'easter Summary of Damages	
Damage Description	Total Cost
Private Property[1]	
Minor Damage	$4,691,670
Moderate Damage	$20,863,350
Major Damage	$57,675,620
Total Private Property Damage	**$83,230,640**
Public Property[2]	
Debris Removal	$24,560
Elm Place Retaining Wall	$1,032,000
Emergency Services	$128,160
Theodore Fremd Retaining Wall	$880,000
Locust Avenue Firehouse	$153,840
Parking Paystation	$12,490
Total Public Property Damages	**$2,231,050**
Grand Total	**$85,461,690**

[1] According to CEDAR damage report for Westchester County. Damage amounts are based on building assessed values (minor – 15%, moderate – 40%, major – 63%)
[2] According to FEMA PA FA forms prepared by the City of Rye

Bowman Avenue Dam Site and Lower Pond

The Bowman Avenue Dam represents the only flood control structure on Blind Brook and is owned and operated by the City of Rye. Originally constructed in the early 1900's, the dam and the upstream pond were used for ice production. In 1941, the dam collapsed and was rebuilt. The existing dam is a reinforced concrete gravity dam founded on ledge rock. The dam is 119 feet long by 13 feet high (measured to the spillway). The dam was constructed with a 15-foot wide by 11.5-foot high outlet at the bottom of the dam and a 20-foot wide by 2-foot high spillway at the top. Currently the dam has an orifice opening of 15-feet wide by 2.5-foot high due the presence of a fixed timber gate. Based on a visual inspection, the dam appears to be in overall fair condition with fine random cracks with efflorescent stains. The dam is not listed on the New York State Department of Environmental Conservation Dam Safety Inventory list.

As noted in previous reports, the upstream pond, referred to in this report as the Upper Pond, has decreased in size over the years due to heavy siltation. It is difficult to accurately determine the overall reduction in storage capacity. Sells surveyed the Upper Pond and determined that its existing reservoir capacity is 145 acre-feet as measured from the normal pool elevation to the crest of the dam at elevation 57.3 feet. The datum used for the field survey was NAVD-88. See Figure 3 for existing topography of Upper Pond.

Downstream of the dam is the Lower Pond of Blind Brook, which also serves as the confluence with East Branch Blind Brook. The Lower Pond, originally used as a quarry, was abandoned in 1976 and subsequently flooded to form the pond. The 1-acre peninsula along the northern shore

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CITY OF RYE FLOOD MITIGATION MEASURES
BOWMAN AVENUE DAM RESERVOIR - EXISTING CONDITIONS

FIGURE NO.
3

of the pond has been formed as a result of dumping within the last 25-years. The maximum depth of the pond is 30-feet as determined by soundings performed by Sells.

The Lower Pond provides minimal storage capacity for flood control purposes; it was not designed to do so. There is no man-made outlet control at this location. The water level in the pond is controlled by a "natural" overflow located immediately downstream of the Lower Pond approximately 300 feet upstream from the I-287 bridge.

ALTERNATIVES ANALYSIS

An initial evaluation was made for 24 different alternatives plus the no-build scenario. This evaluation was based on whether the alternative could provide meaningful flood mitigation in terms of flow reduction. Flow rates were computed at the following three locations for each of the alternatives:

- Downstream of the Bowman Avenue Dam
- Downstream of the I-287 Bridge
- Downstream of the I-95 Bridge

From this evaluation, four preferred alternatives (including the no-build) were identified. The preferred alternatives, discussed later in the report, are evaluated based on the level of mitigation they could achieve in terms of water surface elevation reduction.

The initial alternatives can be divided into six general categories of work:

1. No-build – existing conditions
2. Resizing the Upper Pond
3. Modifying the Opening of the Outlet Orifice on the Bowman Avenue Dam
4. Raising the Top of the Bowman Avenue Dam
5. A Combination of Resizing the Upper Pond and Modifying the Orifice
6. Modifications to the Lower Pond

Methodology

Within each of the six above-referenced general categories, sub-alternates were analyzed for potential mitigation. In the initial evaluation each of the alternatives was compared using flood routing calculations. Flood routing calculations are used to establish inflow/outflow rates for a variety of reservoir volumes and outlet openings. The results are discharge rates for the stream. Even though this methodology only provides for rates and not water surface elevations, it was selected for the initial calculations since it does provide a means to evaluate the magnitude of mitigation an alternative could provide with a relatively simple calculation. From these results a short list of alternatives that show meaningful mitigation potential can be established for more detailed analysis. The detailed analysis, which is described in the "Preferred Alternatives" section, produces water surface elevations on Blind Brook within the study area.

The Bowman Avenue Dam is a flood control structure and its efficiency during various frequency storms depends on the difference between rates of inflow and outflow. As the water level at a control structure rise, so does its flow rate through the structure. To analyze the effects of a control structure a stage/discharge curve is established that computes the outgoing flow rate for various water levels (stages). For a given reservoir site the reservoir storage capacity is constant and the spillway stage/discharge curve is variable depending on the type and size of the spillway and outlet and how they are operated. Stage/discharge curves (attached in the Appendix B) were developed at the dam based on topographical field survey performed by Sells in August 2007.

The hydraulic features of the Bowman Avenue Dam site contain several components, where depending upon the water level, flow can occur. The manner in which each of these features handle flow and interaction between them in different flow conditions makes it a complex system. In our analysis we took into consideration a number of factors that included:

- Irregular stream bed was approximated as a weir (allows the discharge of normal flow),
- An approximately 15 foot orifice with a varying height of 2.5 feet to 11.5 feet,
- 12-foot long principal spillway at elevation 55.3,
- An approximately 99 foot long dam crest at elevation 57.3, and
- Overflow channel extending north east towards Bowman Road (consisting mostly of processed asphalt fill).

It should be noted that not all of the outlet area is effective (i.e. controls the amount of flow). There is a substantial amount of bedrock extending into the upstream and downstream channel. Therefore, smaller effective areas were used in the stage/discharge calculations for a variety of outlet openings.

During storm events where flows start to exceed approximately 1,450 cfs (between the 2- and 5-year design storm), the water overtops the crest of the dam and starts to flow in the overflow channel. It then rejoins the main channel of Blind Brook just downstream of the dam. Thus in the majority of the storm events (under existing conditions) the dam and the overflow combination control the discharge downstream of Bowman Dam.

The flood routing was performed using the National Resources Center's (NRC) WinTR-20, Version 1 software. This software is the windows version of the original DOS based TR-20 model developed by the NRC, formerly known as the Soil Conservation Center.

The software forecasts the rate of surface water runoff and watercourse flow rates based on several factors. The input data includes information on land use, soil types, vegetation, watershed areas, times of concentration, rainfall data, storage volumes, and hydraulic capacities of the hydraulic structures. The computer model predicts the amount of runoff as a function of time, including the attenuation effect due to dams, lakes, large wetlands, and floodplains. Runoff rates during specific rainstorms may vary due to different assumptions concerning soil moisture, water levels in ponds, snowmelt, and rainfall patterns. The input data for rainfalls with statistical recurrence frequencies of 2, 5, 10, 25, 50 and 100-years were obtained from the U.S. Weather Bureau Technical Papers. The National Weather Service developed four synthetic storms to simulate rainfall patterns around the country. For analysis in Westchester County, the Type III rainfall pattern with 24-hour duration is valid. Typically, the TR-20 methodology overestimates the peak discharges for all storm events.

The available TR-20 model data is included in the 1979 Flood Insurance Study backup information that Sells obtained from FEMA, c/o Michael Baker, Jr., Inc. The backup data includes drainage area delineations, Runoff Curve Numbers and times of concentration for each sub watershed, and the model schematic. Although this data is from the 1970's and might not represent existing conditions, including the extent of natural and manmade changes that have occurred in the watershed, in our professional opinion for the purpose of determining inflow/outflow rate at the Bowman Avenue Dam, the available data is valid. This is the same data that was used in the April 2007 ACOE report.

In order to calibrate our results, a few modifications of the old model were performed. These include:

- To analyze the effect of storage at the Lower Pond site, the subbasin located north of I-287 was divided into sub-watersheds representing smaller portions of the total area. Based on Sells field survey data in the vicinity of the dam, the structure data was also updated.
- The entry of routing coefficients x and m (in the Att-Kin routing procedure) in lieu of reach cross-section rating data is no longer accepted by the newest version of WinTR-20. All reaches in the old data used cross sections instead of routing coefficients. Therefore, the analysis is based on cross section ratings developed for the 2007 FEMA Flood Insurance Study (FIS) model were used.
- The East Tributary located north of Hutchinson Parkway was not studied in detail and cross section data was not available in the new FIS. Therefore, the FEMA cross-section information was supplemented with Sells field survey in this area.

Output generated by WinTR-20 models for each alternate studied in detail are attached in the Appendix B.

Alternative Descriptions and Initial Calculation Results

No-Build Alternative

The no-build alternative reflects current topographic conditions in the Upper and Lower Ponds, as well as the current outflow configurations. Additionally, flow rates were computed using the existing topography with the dam removed so as to show the effect of the existing detention and flood control provided by the dam. As shown in Table 2, the flow rates in the condition where the dam is removed increase the greatest in the lower design year storms. However, as the design storm frequency decreases from 25-year to 100-year the difference in discharge rates with and without the dam approach each other. This occurs since the dam is greatly overtopped with higher flows and looses its effect as a control structure. The flow rates generated under the no-build alternative (See Table 2) will be used as a basis for comparison with the other alternatives to provide an indication of the mitigation potential of the proposal.

TABLE 2: Discharges - No-Build (cfs)			
Storm Event/Location	**Existing Conditions**	**Existing Condition with No Dam**	**Difference**
2-Year Storm			
D/S Bowman Dam	397	854	457
D/S I-287	565	1106	541
D/S I-95	681	1148	467
5-Year Storm			
D/S Bowman Dam	1253	1592	339
D/S I-287	1473	1999	526
D/S I-95	1413	2061	648
10-Year Storm			
D/S Bowman Dam	1768	1984	216
D/S I-287	2088	2479	391
D/S I-95	2012	2564	552
25-Year Storm			
D/S Bowman Dam	2800	2805	5
D/S I-287	3396	3495	99
D/S I-95	2994	3410	416
50-Year Storm			
D/S Bowman Dam	3755	3663	-92
D/S I-287	4506	4498	-8
D/S I-95	4844	4906	62
100-Year Storm			
D/S Bowman Dam	4322	4215	-107
D/S I-287	5162	5118	-44
D/S I-95	5621	5646	25

Upper Pond Resizing Alternatives

The alternatives analyzed under this general category examined the effects of increasing the storage volume of the Upper Pond. This would be accomplished by excavating along the banks of the pond, in particular the north side, combined in some instances with dredging of the pond bottom to remove siltation. The bottom of the pond itself was taken as an average elevation of approximately 39.0. Due to the softness of the siltation and muck present in the bottom of the pond area, a field survey with exact elevations could not be performed. Four scenarios of increasing the storage were examined.

Alt. 1. The Upper Pond was created the early 1900's when the Bowman Avenue Dam was constructed. Since that time the pond has silted up and been filled in. The extent to which the volume has changed is difficult to determine since there are no record plans for the original dam and pond area. However, an estimate of the original limits of the pond was taken from Figure B-1 of the *Technical Memorandum Evaluation of the Bowman Avenue Dam Site,* prepared by Harza Engineering Company, October 2000. This alternative considers excavating around the pond to the 1925 configuration without any dredging of any material in the pond itself, keeping the bottom elevation at approximately 39.0. The total volume of material to be removed is 36,000 cubic yards (CY).

Alt. 2. The second alternative includes excavating to the 1925 configuration and dredging the bottom of the pond area by 2 feet to elevation 37.0. The total volume of material to be removed is 53,000 CY.

Alt. 3. This alternative looked at maximizing the volume behind the pond by excavating up to Bowman Avenue without any dredging of the pond. The total volume of material to be removed is 160,000 CY.

Alt. 4. The last alternative in this category used the maximized volume in Alternative 3 and included the dredging of 2 feet of the pond area. The total volume of material to be removed is 190,000 CY.

Flow rates for the four locations listed above were computed for each of the design storms and compared to the existing conditions flow rates. Table 3 shows the outcome of those computations and the resulting difference in flow rate.

TABLE 3: Discharges - Alternatives 1 - 4 (cfs)

Storm Event/Location	Existing Cond.	Alt. 1	Diff.	Alt. 2	Diff.	Alt. 3	Diff.	Alt. 4	Diff.
2-Year Storm									
D/S Bowman Dam	397	383	-14	380	-17	341	-56	332	-65
D/S I-287	565	544	-21	535	-30	526	-39	503	-62
D/S I-95	681	658	-23	637	-44	655	-26	592	-89
5-Year Storm									
D/S Bowman Dam	1253	1114	-139	1085	-168	678	-575	605	-648
D/S I-287	1473	1303	-170	1269	-204	803	-670	729	-744
D/S I-95	1413	1272	-141	1243	-170	1100	-313	1037	-376
10-Year Storm									
D/S Bowman Dam	1768	1665	-103	1644	-124	1288	-480	1230	-538
D/S I-287	2088	1958	-130	1934	-154	1508	-580	1440	-648
D/S I-95	2012	1878	-134	1852	-160	1454	-558	1395	-617
25-Year Storm									
D/S Bowman Dam	2800	2755	-45	2745	-55	2509	-291	2474	-326
D/S I-287	3396	3319	-77	3306	-90	2967	-429	2918	-478
D/S I-95	2994	2922	-72	2907	-87	2625	-369	2587	-407
50-Year Storm									
D/S Bowman Dam	3755	3749	-6	3747	-8	3645	-110	3627	-128
D/S I-287	4506	4489	-17	4485	-21	4293	-213	4262	-244
D/S I-95	4844	4798	-46	4795	-49	4497	-347	4442	-402
100-Year Storm									
D/S Bowman Dam	4322	4320	-2	4319	-3	4255	-67	4245	-77
D/S I-287	5162	5140	-22	5134	-28	4990	-172	4967	-195
D/S I-95	5621	5585	-36	5577	-44	5370	-251	5341	-280

As can be seen the peak flow reductions resulting from excavating to the 1925 contours are relatively small when compared to the total flow and are therefore Alternative 1 and 2 were dismissed from further consideration. As shown in Table 4, Alternatives 3 and 4 produce the largest percent reductions at the I-287 and I-95 culverts for the 5- to 10-year storms.

The costs associated with the Upper Pond resizing mainly stem from excavation and will be discussed later in the report. The area designated for excavation, between the pond and Bowman Avenue, will include both unclassified excavation and rock excavation. City officials have indicated that portions of this area had been filled in with construction material in the past. It is also evident that ledge rock is present throughout the area, which can be costly to remove. A second consideration is the removal of contaminated material. There is the potential for a low level of contamination, mainly what would be associated with untreated runoff from impervious surfaces such as roads and parking facilities, in any dredged materials. Cost estimates for the excavation are based on conservative assumptions for the amount of rock and contaminated material.

TABLE 4: Reduction in Discharges - Alternatives 1 - 4

Storm Event/Location	Alt. 1 % Red.	Alt. 2 % Red.	Alt. 3 % Red.	Alt. 4 % Red.
2-Year Storm				
D/S I-287	3.7%	5.3%	6.9%	11.0%
D/S I-95	3.4%	6.5%	3.8%	13.1%
5-Year Storm				
D/S I-287	11.5%	13.8%	45.5%	50.5%
D/S I-95	10.0%	12.0%	22.2%	26.6%
10-Year Storm				
D/S I-287	6.2%	7.4%	27.8%	31.0%
D/S I-95	6.7%	8.0%	27.7%	30.7%
25-Year Storm				
D/S I-287	2.3%	2.7%	12.6%	14.1%
D/S I-95	2.4%	2.9%	12.3%	13.6%
50-Year Storm				
D/S I-287	0.4%	0.5%	4.7%	5.4%
D/S I-95	0.9%	1.0%	7.2%	8.3%
100-Year Storm				
D/S I-287	0.4%	0.5%	3.3%	3.8%
D/S I-95	0.6%	0.8%	4.5%	5.0%

Orifice Optimization Alternatives

The existing Bowman Avenue Dam outlet consists of a concrete structure with a 20- foot long by 2-foot high principal spillway along the top. Normal (low) stream flows pass beneath the structure through a 15-foot wide by 11.5-foot high opening at the base of the dam that has its flow restricted on the upstream side by timber railroad ties, creating an opening of approximately 20.2 square feet (sf). As the Blind Brook's flow increases and stream level goes above the top of that opening the structure acts as an orifice. Flow rates that can pass through an orifice depend upon two factors – the size of the orifice opening and the head or water level above the opening. Increasing the size of an orifice will result in a higher flow rate that can pass through. Likewise, increasing the head above an orifice will also increase the exiting flow rate. The four alternatives under this general category examined the effects of increasing the size of the opening without modifying the storage volume behind the dam (i.e. existing conditions). The four orifice opening sizes analyzed include:

Alt. 5. Orifice Area = 45.6 sf
Alt. 6. Orifice Area = 72.1 sf

Alt. 7. Orifice Area = 105.6 sf
Alt. 8. Orifice Area = 139.1 sf

For any fixed opening size, as the incoming stream flow increases and starts to exceed the flow rate that can pass through, the water will build up behind the dam. As the water level increases it creates a larger head on the opening, which will result in a larger flow through the orifice. At the Bowman Avenue Dam there are not only the dynamics of the size of the orifice opening versus the water level behind the dam, but also the fact that at some point the water level will overtop the dam at its weir, thus creating an additional flow area. The amount of storage volume in the pond also impacts the way in which a particular size orifice opening will increase or decrease the flow through the dam when compared to existing conditions.

The orifice optimization alternatives took into account each of these factors. As a result, for each design storm frequency, the orifice size that would create the greatest reduction in flow rate varies. Table 5 contains the results of the analysis of the four orifice openings for each design storm. The orifice opening size that creates the optimum flow rate reduction has been highlighted.

TABLE 5: Discharges - Alternatives 5 - 8 (cfs)

Storm Event/Location	Existing Cond.	Alt. 5	Diff.	Alt. 6	Diff.	Alt. 7	Diff.	Alt. 8	Diff.
2-Year Storm									
D/S Bowman Dam	397	625	228	798	401	828	431	816	419
D/S I-287	565	783	218	994	429	1014	449	1004	439
D/S I-95	681	873	192	1066	385	1070	389	1068	387
5-Year Storm									
D/S Bowman Dam	1253	969	-284	1200	-53	1377	124	1565	312
D/S I-287	1473	1154	-319	1458	-15	1669	196	1909	436
D/S I-95	1413	1238	-175	1564	151	1760	347	1928	515
10-Year Storm									
D/S Bowman Dam	2006	1593	-413	1387	-619	1632	-374	1822	-184
D/S I-287	2006	1870	-136	1687	-319	1967	-39	2218	212
D/S I-95	2006	1838	-168	1816	-190	2087	81	2319	313
25-Year Storm									
D/S Bowman Dam	2800	2730	-70	2535	-265	2266	-534	2388	-412
D/S I-287	3396	3279	-117	3010	-386	2676	-720	2888	-508
D/S I-95	2994	2946	-48	2848	-146	2773	-221	2975	-19
50-Year Storm									
D/S Bowman Dam	3755	3722	-33	3673	-82	3570	-185	3381	-374
D/S I-287	4506	4455	-51	4370	-136	4233	-273	4002	-504
D/S I-95	4844	4750	-94	4616	-228	4407	-437	3873	-971
100-Year Storm									
D/S Bowman Dam	4322	4315	-7	4261	-61	4210	-112	4078	-244
D/S I-287	5162	5126	-36	5047	-115	4971	-191	4809	-353
D/S I-95	5621	5561	-60	5443	-178	5341	-280	5136	-485

As can be seen in Table 5, this option produces more significant decreases in peak flow for the 25-, 50-, and 100-year design frequency storms when compared to the pond resizing alternatives.

Implementation of the orifice optimization alternative can be accomplished by retrofitting the Bowman Avenue Dam with an automated sluice gate. An automated sluice gate has the ability to vary the opening size, thus providing the optimum orifice size for the flow rate in the stream. The sluice gate would be automatically controlled based on water surface elevations measured at a gauge mounted behind the Bowman Avenue Dam. The percent reductions for the optimum orifice opening for the 5- through 100-year storms are shown in Table 6.

TABLE 6: Reduction in Discharges - Alternatives 5 - 8

Storm Event/Location	Alt. 5-8 % Red.
5-Year Storm	
Orifice Opening (sf)	**45.6**
D/S Bowman Dam	22.7%
D/S I-287	21.7%
D/S I-95	12.4%
10-Year Storm	
Orifice Opening (sf)	**72.1**
D/S Bowman Dam	30.9%
D/S I-287	15.9%
D/S I-95	9.5%
25-Year Storm	
Orifice Opening (sf)	**105.6**
D/S Bowman Dam	19.1%
D/S I-287	21.2%
D/S I-95	7.4%
50-Year Storm	
Orifice Opening (sf)	**139.1**
D/S Bowman Dam	10.0%
D/S I-287	11.2%
D/S I-95	20.0%
100-Year Storm	
Orifice Opening (sf)	**139.1**
D/S Bowman Dam	5.6%
D/S I-287	6.8%
D/S I-95	8.6%

The positive results for peak flow mitigation achieved by optimizing the orifice opening together with the ability to provide an automatic means of accomplishing it warrants a more detailed analysis of this alternative.

Raising the Bowman Avenue Dam Alternatives

The third alternative category considered was to raise the height of the Bowman Avenue Dam. As part of the analysis the storage volume for the pond was also increased in the same manner as was considered under the pond resizing alternatives – to the 1925 configuration and to one that maximizes the area, plus the option of with and without dredging (Alternative 1 through 4). The four alternatives considered include:

- Alt. 9. Raising the dam two feet and excavating the Upper Pond to the 1925 configuration without the dredging of any material in the pond itself, keeping the bottom elevation at 39.0.
- Alt. 10. Raising the dam two feet, excavating to the 1925 configuration, and dredging the bottom of the pond area by 2 feet to elevation 37.0.
- Alt. 11. Raising the dam two feet and maximizing the volume behind the pond by excavating up to Bowman Avenue without the dredging of any material in the pond itself, keeping the bottom elevation at 39.0.
- Alt. 12. Raising the dam two feet, using the maximized the volume in Alternative 11, and dredging of 2 feet of the pond area to elevation 37.0.

The flow rates resulting from these alternatives are shown in Table 7.

TABLE 7: Discharges - Alternatives 9 - 12 (cfs)

Storm Event/Location	Existing Cond.	Alt. 9	Diff.	Alt. 10	Diff.	Alt. 11	Diff.	Alt. 12	Diff.
2-Year Storm									
D/S Bowman Dam	397	380	-17	376	-21	345	-52	337	-60
D/S I-287	565	547	-18	536	-29	513	-52	490	-75
D/S I-95	681	651	-30	635	-46	646	-35	601	-80
5-Year Storm									
D/S Bowman Dam	1253	894	-359	873	-380	558	-695	527	-726
D/S I-287	1473	1058	-415	1034	-439	750	-723	736	-737
D/S I-95	1413	1090	-323	1069	-344	1096	-317	1032	-381
10-Year Storm									
D/S Bowman Dam	1768	1508	-260	1486	-282	1122	-646	1059	-709
D/S I-287	2088	1769	-319	1743	-345	1312	-776	1238	-850
D/S I-95	2012	1702	-310	1676	-336	1302	-710	1239	-773
25-Year Storm									
D/S Bowman Dam	2800	2641	-159	2630	-170	2382	-418	2340	-460
D/S I-287	3396	3150	-246	3135	-261	2801	-595	2751	-645
D/S I-95	2994	2797	-197	2782	-212	2560	-434	2516	-478
50-Year Storm									
D/S Bowman Dam	3755	3695	-60	3692	-63	3554	-201	3533	-222
D/S I-287	4506	4391	-115	4384	-122	4167	-339	4136	-370
D/S I-95	4844	4650	-194	4638	-206	4253	-591	4194	-650
100-Year Storm									
D/S Bowman Dam	4322	4282	-40	4281	-41	4187	-135	4171	-151
D/S I-287	5162	5062	-100	5055	-107	4890	-272	4864	-298
D/S I-95	5621	5467	-154	5458	-163	5239	-382	5207	-414

Raising the top of the Bowman Avenue Dam by two feet, particularly when coupled with maximizing the storage potential in the Upper Pond does result in sizeable reductions in peak flow rates. However, this alternative does result in negative impacts to the stability of the dam and upstream properties.

Stability Analysis

The stability of the dam was assessed according to criteria set forth by NYSDEC in the publication "*Guidelines for Design of Dams*." The functions of the NYSDEC's dam safety unit include: safety inspection of dams; technical review of proposed dam construction or modification; monitoring of remedial work for compliance with dam safety criteria; and emergency preparedness. Although the Bowman Avenue Dam is not on the state's inventory, rehabilitation and/or modification to the dam is considered a permitted activity due to its size and impoundment volume; hence subject to NYSDEC approval.

The dam was analyzed under the 100-year flood condition, with headwater elevation of 59.70' and tailwater elevation at 42.64'. This represents roughly a 2-foot increase in elevation. The dam was analyzed to determine its resistance to sliding and overturning.

A dam's resistance to sliding is said to meet the guideline requirements if the factor of safety is greater than or equal to 1.25 for 100-year flood conditions. Resistance to overturning is measured in terms of the eccentricity of the resultant force acting on the base. A dam's resistance to overturning is said to meet the guideline requirements if the resultant force acts within the middle third of the base for normal conditions and within the middle half for 100-year flood conditions.

In the absence of a detailed geotechnical investigation, uplift pressures (caused by seepage beneath the spillway) were calculated using full hydrostatic head values. Uplift pressures were included in the spillway calculations for both normal and 100-year flood loading conditions.

The results of the analysis indicate a factor of safety for sliding equal to 1.04 which does not meet the minimum guideline requirements of 1.25. With regard to overturning, the eccentricity of the resultant force for the 100-year flood was calculated to be 0.71 feet which is within the minimum guideline requirements.

In summary, due to minimum sliding criteria, modification to the dam by raising the elevation of its crest will require extensive rehabilitation/reconstruction in order to satisfy the minimum dam safety requirements.

Upstream Impacts

An analysis was performed to determine the effects on upstream properties and facilities should the water surface elevation in the Upper Pond was raised by two-feet. The results indicate that the backwater effect would raise the 100-year base flood elevation for a distance of approximately ½ mile upstream of the dam. At the Bowman Avenue Bridge the water surface elevation is raised by an additional 1.87 feet. The additional flooding on Bowman Avenue would further impede emergency access thus creating a public safety issue. Additionally, the increase in water surface elevation would result in additional flooding on private properties within the ½ mile influence.

Although the impacts in this area might be perceived as limited to additional flooding in parking areas and other non-residential facilities, they still present significant issues based on the flood study status of the stream. Having been studied by detailed methods, the stream has a regulatory floodplain, floodway, and base flood elevations. Any proposed increase to the flood elevation at any point along the stream would require coordination through the Federal Emergency Management Agency (FEMA) for conditional approval and for a follow-up physical revision to the regulatory flood hazard information. This process includes a detailed review of increased impacts as they relate to potential increased risk to public safety and private and public property.

For a conditional request to be considered, FEMA needs documented proof that the local government and all impacted property owners have been made aware of the proposed increased flood hazards and that they would accept the increases upon completion of the proposed project. Typically, conditional request for proposed projects that might result in an increase between 0.00' and 1.00' are considered acceptable given that all technical data supporting the increase has been certified by a Professional Engineer and reviewed by an independent party for full compliance with regulatory requirements including the previously mentioned property owner notification. For conditional request where the increase would be greater than 1.00', FEMA takes into consideration a greater level of detail due to the higher degree of increased risk.

In the case of raising the elevation of this dam, for example, consideration would be given to the decreased level of service on Bowman Avenue, potential for significant property damage to cars parked in areas of inundation, and an evaluation of alternatives. In this case, there are feasible alternatives to provide a decrease in flooding downstream of the dam without resulting in increases upstream of the dam. Finally, the review process for a conditional request to increase flood hazards, especially when a flood control device is involved, can be lengthy, ranging from a 3 month period to in excess of a full year of ongoing coordination. The time that would likely lapse in the process to implement solutions to flooding problems might create an added burden should flood conditions persist while no action if being taken.

Based on these issues, this alternative is removed from further consideration.

Combined Upper Pond Resizing and Orifice Optimization Alternatives

These alternatives combine Alternatives 3 and 4 that increase the volume of storage behind the Bowman Avenue Dam to the maximum with Alternatives 5 through 8 that vary the size of the orifice (opening) at the dam. A total of eight alternative configurations were considered:

- Alt. 13. Maximizing the volume behind the pond, no dredging of the pond (bottom elevation at 39.00) and an orifice area = 45.6 sf.
- Alt. 14. Maximizing the volume behind the pond, no dredging of the pond (bottom elevation at 39.00) and an orifice area = 72.1 sf
- Alt. 15. Maximizing the volume behind the pond, no dredging of the pond (bottom elevation at 39.00) and an orifice area = 105.6 sf
- Alt. 16. Maximizing the volume behind the pond, no dredging of the pond (bottom elevation at 39.00) and an orifice area = 139.1 sf
- Alt. 17. Maximizing the volume behind the pond, dredge the pond two feet (bottom elevation at 37.00) and an orifice area = 45.6 sf.
- Alt. 18. Maximizing the volume behind the pond, dredge the pond two feet (bottom elevation at 37.00) and an orifice area = 72.1 sf

Alt. 19. Maximizing the volume behind the pond, dredge the pond two feet (bottom elevation at 37.00) and an orifice area = 105.6 sf

Alt. 20. Maximizing the volume behind the pond, dredge the pond two feet (bottom elevation at 37.00) and an orifice area = 139.1 sf

Tables 9 and 10 contain the results of the analysis of Alternatives 13 through 20. As discussed in the section on optimizing the orifice opening, the orifice size that would create the greatest reduction in flow rate varies with the design storm frequency and the orifice opening size that creates the optimum flow rate reduction has been highlighted.

oth the resizing of the Upper Pond and the optimization of its outlet produce flow reductions that warrant more detailed analysis. As part of that analysis the combination of the alternatives will be included. The optimum percent reduction of flows for these alternatives is as follows:

TABLE 8: Discharges - Alternatives 13 - 16 (cfs)									
Storm Event/Location	Existing Cond.	Alt. 13	Diff.	Alt. 14	Diff.	Alt. 15	Diff.	Alt. 16	Diff.
2-Year Storm									
D/S Bowman Dam	397	550	153	731	334	710	313	713	316
D/S I-287	565	690	125	902	337	865	300	869	304
D/S I-95	681	782	101	964	283	932	251	935	254
5-Year Storm									
D/S Bowman Dam	1253	778	-475	1083	-170	1257	4	1418	165
D/S I-287	1473	1000	-473	1317	-156	1515	42	1693	220
D/S I-95	1413	1128	-285	1421	8	1597	184	1711	298
10-Year Storm									
D/S Bowman Dam	1768	983	-785	1250	-518	1486	-282	1719	-49
D/S I-287	2088	1172	-916	1524	-564	1789	-299	2080	-8
D/S I-95	2012	1309	-703	1649	-363	1900	-112	2154	142
25-Year Storm									
D/S Bowman Dam	2800	2314	-486	1925	-875	1922	-878	2220	-580
D/S I-287	3396	2719	-677	2261	-1135	2317	-1079	2674	-722
D/S I-95	2994	2576	-418	2332	-662	2484	-510	2777	-217
50-Year Storm									
D/S Bowman Dam	3755	3535	-220	3360	-395	3163	-592	2824	-931
D/S I-287	4506	4156	-350	3965	-541	3716	-790	3337	-1169
D/S I-95	4844	4235	-609	3564	-1280	3502	-1342	3424	-1420
100-Year Storm									
D/S Bowman Dam	4322	4190	-132	4035	-287	3897	-425	3659	-663
D/S I-287	5162	4890	-272	4716	-446	4564	-598	4317	-845
D/S I-95	5621	5239	-382	5020	-601	4832	-789	4513	-1108

TABLE 9: Discharges - Alternatives 17 - 20 (cfs)									
Storm Event/Location	Existing Cond.	Alt. 17	Diff.	Alt. 18	Diff.	Alt. 19	Diff.	Alt. 20	Diff.
2-Year Storm									
D/S Bowman Dam	397	536	139	717	320	854	457	690	293
D/S I-287	565	669	104	879	314	1106	541	839	274
D/S I-95	681	749	68	935	254	1148	467	902	221
5-Year Storm									
D/S Bowman Dam	1253	768	-485	1071	-182	1244	-9	1392	139
D/S I-287	1473	981	-492	1300	-173	1496	23	1658	185
D/S I-95	1413	1106	-307	1401	-12	1574	161	1673	260
10-Year Storm									
D/S Bowman Dam	1768	957	-811	1240	-528	1475	-293	1709	-59
D/S I-287	2088	1140	-948	1509	-579	1772	-316	2064	-24
D/S I-95	2012	1129	-883	1631	-381	1880	-132	2132	120
25-Year Storm									
D/S Bowman Dam	2800	2268	-532	1894	-906	1913	-887	2212	-588
D/S I-287	3396	2665	-731	2225	-1171	2305	-1091	2663	-733
D/S I-95	2994	2539	-455	2299	-695	2470	-524	2763	-231
50-Year Storm									
D/S Bowman Dam	3755	3518	-237	3342	-413	3144	-611	2815	-940
D/S I-287	4506	4131	-375	3940	-566	3693	-813	3326	-1180
D/S I-95	4844	4186	-658	3540	-1304	3481	-1363	3411	-1433
100-Year Storm									
D/S Bowman Dam	4322	4177	-145	4020	-302	3883	-439	3646	-676
D/S I-287	5162	4869	-293	4698	-464	4549	-613	4300	-862
D/S I-95	5621	5213	-408	4998	-623	4814	-807	4489	-1132

Table 10 - Reduction in Discharges - Alternates 13 - 20		
	Alt. 13-16 % Red.	Alt. 17-20 % Red.
5-Year Storm		
Orifice Opening (sf)	**45.6**	**45.6**
D/S Bowman Dam	37.9%	38.7%
D/S I-287	32.1%	33.4%
D/S I-95	20.2%	21.7%
10-Year Storm		
Orifice Opening (sf)	**45.6**	**45.6**
D/S Bowman Dam	44.4%	45.9%
D/S I-287	43.9%	45.4%
D/S I-95	34.9%	43.9%
25-Year Storm		
Orifice Opening (sf)	**72.1**	**72.1**
D/S Bowman Dam	31.3%	32.4%
D/S I-287	33.4%	34.5%
D/S I-95	22.1%	23.2%
50-Year Storm		
Orifice Opening (sf)	**139.1**	**139.1**
D/S Bowman Dam	24.8%	25.0%
D/S I-287	25.9%	26.2%
D/S I-95	29.3%	29.6%
100-Year Storm		
Orifice Opening (sf)	**139.1**	**139.1**
D/S Bowman Dam	15.3%	15.6%
D/S I-287	16.4%	16.7%
D/S I-95	19.7%	20.1%

Modifications to the Lower Pond Alternatives

The final category of alternatives involves modifications to the Lower Pond. The modifications to the Lower Pond that were considered contained two components. The first was the removal of the 1-acre "peninsula" adjacent to Bowman Avenue at the northwest side of the pond so as to create additional storage and the second was modifications to the outlet from the pond.

The outlet modifications involved three scenarios. The first resulted from an evaluation of the streambed profile between the pond and I-287 that was field surveyed by Sells. There is an apparent "bump" in the profile approximately 300 feet from I-287 where an 80 foot section of the streambed rises up about 1.5 feet. The first outlet modification involves the removal of that material. The second and third outlet modifications involve the creation of a spillway section for the Lower Pond, one of which is 75 feet and the other 120 feet, together with the downstream streambed change and the removal of the peninsula.

- Alt. 21. Removal of Lower Pond peninsula.
- Alt. 22. Removal of Lower Pond peninsula and lowering the downstream overflow section to elevation 27.5.
- Alt. 23. Removal of Lower Pond peninsula, lowering the downstream overflow section to elevation 27.5, and providing a 75 foot spillway at elevation 33.0.
- Alt. 24. Removal of Lower Pond peninsula, lowering the downstream overflow section to elevation 27.5, and providing a 120 foot spillway at elevation 33.0.

The peak flow rates are shown in Table 11.

Removal of the peninsula adjacent to Bowman Avenue at the northern side of the Lower Pond and modifications to the overflow section have negligible effects in reducing the peak flow rates. Based on these results these alternatives were not carried forward for more detailed analysis.

It should be noted that in order for the Lower Pond to function as a flood control measure, the pond would need to exist in a pre-drained condition. This can be accomplished via gravity-based and mechanical-based means. The study of these alternatives is beyond the scope of this project.

Table 11 - Discharges - Alternatives 21 - 24 (cfs)									
	Existing Cond.	Alt. 21	Diff.	Alt. 22	Diff.	Alt. 23	Diff.	Alt. 24	Diff.
2-Year Storm									
D/S Bowman Dam	397	397	0	397	0	397	0	397	0
D/S I-287	558	557	-1	555	-3	553	-5	555	-3
D/S I-95	681	678	-3	668	-13	671	-10	687	6
5-Year Storm									
D/S Bowman Dam	1253	1253	0	1253	0	1253	0	1253	0
D/S I-287	1467	1464	-3	1463	-4	1434	-33	1459	-8
D/S I-95	1413	1412	-1	1413	0	1403	-10	1412	-1
10-Year Storm									
D/S Bowman Dam	1768	1768	0	1768	0	1768	0	1768	0
D/S I-287	2079	2077	-2	2077	-2	2032	-47	2068	-11
D/S I-95	2012	2010	-2	2010	-2	1989	-23	2008	-4
25-Year Storm									
D/S Bowman Dam	2800	2800	0	2800	0	2800	0	2800	0
D/S I-287	3384	3390	6	3378	-6	3335	-49	3347	-37
D/S I-95	2994	2987	-7	2995	1	2987	-7	2993	-1
50-Year Storm									
D/S Bowman Dam	3755	3755	0	3755	0	3755	0	3755	0
D/S I-287	4490	4489	-1	4503	13	4487	-3	4472	-18
D/S I-95	4844	4857	13	4855	11	4819	-25	4792	-52
100-Year Storm									
D/S Bowman Dam	4322	4322	0	4322	0	4322	0	4322	0
D/S I-287	5144	5100	-44	5206	62	5192	48	5175	31
D/S I-95	5621	5554	-67	5749	128	5708	87	5673	52

PREFERRED ALTERNATIVES

Based on the results of the Alternatives Analysis, three preferred alternatives were developed and further analyzed to determine water surface elevations. Selection of the preferred alternatives was based on several factors: cost, anticipated level of mitigation, and potential impacts on upstream neighborhoods. The three alternatives are:

Alternative A: Optimizing the orifice opening at the dam

Alternative B: Optimizing the orifice opening and maximizing the Upper Pond

Alternative C: Optimizing the orifice opening, maximizing the Upper Pond area and dredging 2 feet of sediment material (bottom elevation 37.0)

Methodology

Blind Brook and East Branch Blind Brook were studied by detailed hydrologic and hydraulic methods for FEMA's preliminary FIS for Westchester County. Backup data was made available to Sells through Michael Baker, Jr., Inc. The area studied in this report on Blind Brook is from I-

95 (south) to Interstate I-287 (north). For this study of this reach of Blind Brook, base data from the FIS model was used as presented with the exception of flow rates. For our analysis we used the discharges developed in our August 2007 Hydrologic Report (see Appendix A). All other data including cross sections, distances between cross sections, Manning's n values, bridge geometry, ineffective flow areas, etc. was applied as represented in the FEMA study. The model created was used as the baseline model for this report.

The software used for the FIS for developing water surface profiles for Blind Brook and East Branch Blind Brook is the ACOE's HEC-RAS software. HEC-RAS is an improved windows version of the DOS based HEC-2. The program is designed to perform one-dimensional hydraulic calculations of natural and manmade channels. Water surface profiles are computed using an iterative procedure called the standard step method. The water surface elevations are calculated from section to section by solving the Energy equation. The bridge modeling approach chosen in the FIS is the "momentum" for low flows and "pressure and/or weir" for high flows.

To take into account the peak discharge reduction at Bowman Dam site for each alternative, the computed discharges were adjusted by an inflow/outflow ratio developed by the WinTR-20 software. The boundary condition (starting point of the backflow analysis) for each alternative was determined from a rating curve (included in Appendix C) developed from the existing FIS HEC-RAS water surface elevations at a section located approximately 850 feet downstream of Interstate I-95. The water surface elevations for the existing and three alternatives of improvements at Bowman Avenue Dam site were computed and presented in the following sections. Copies of the HEC-RAS outputs are also included in the Appendix C.

Table 12 provides a comparison of the discharge rates and water surface elevations arrived at by the FIS and those presented in this report. Since Sells' August 2007 Hydrological Report determined that the discharge rates in this reach of Blind Brook are greater than those used by FEMA for the existing conditions our results are larger. For the alternative analyses differences in the results stem from not only the variation in discharge rates but also from the manner in which the outlet system at the Bowman Avenue Dam was modeled. In Sells' analysis we took into account the ability of varying the orifice opening at the base of the dam as well as the other outflow features such as the weir and dam site overflow. In the FEMA model the dam was modeled as an "in-line structure". Input for this feature is a single weir and a single orifice, a much simpler configuration than the existing conditions that Sells modeled. The differences in the manner in which the actual dam, pond, overflow, and outlet work depending upon the water surface elevation leads to the variations between our values and FEMA's. In some instances our flow rates in the Alternatives will be greater than FEMA's and in others less.

Table 12 - Comparison Between the FIS and Sells Anayses

	Existing Conditions				Alternate A Optimize Orifice Opening			
	FIS		Sells		FIS		Sells	
	Discharge (cfs)	WS Elev. (ft.)	Discharge (cfs)	WS Elev. (ft.)	Discharge (cfs)	WS Elev. (ft.)	Discharge (cfs)	WS Elev. (ft.)
10-Year Storm								
I-95 (U/S)	1,521	22.93	1,982	24.59	1,521	22.93	1,789	23.79
Highland Rd. (U/S)	1,521	24.15	1,982	25.88	1,521	24.15	1,789	25.24
Purchase St. (U/S)	1,434	27.35	1,663	28.33	1,434	27.35	1,344	27.73
I-287 (D/S)	1,374	32.32	1,663	32.73	1,374	32.32	1,344	32.27
50-Year Storm								
I-95 (U/S)	2,497	26.55	3,078	30.56	2,497	26.55	2,461	26.41
Highland Rd. (U/S)	2,497	27.49	3,078	31.01	2,497	27.49	2,461	27.39
Purchase St. (U/S)	2,353	30.12	2,767	31.91	2,353	30.12	2,458	30.18
I-287 (D/S)	2,255	33.45	2,767	34.11	2,255	33.45	2,458	33.66
100-Year Storm								
I-95 (U/S)	2,984	30.33	3,583	32.17	2,984	30.33	3,274	31.12
Highland Rd. (U/S)	2,984	30.78	3,583	32.60	2,984	30.78	3,274	31.57
Purchase St. (U/S)	2,812	31.71	3,346	33.44	2,812	31.71	3,117	32.55
I-287 (D/S)	2,694	34.01	3,346	34.97	2,694	34.01	3,117	34.54
	Alternate B Opt. Orifice Opening, Maz. Vol. with Bottom				Alternate C Opt. Orifice Opening, Maz. Vol. with Bottom			
	FIS		Sells		FIS		Sells	
	Discharge (cfs)	WS Elev. (ft.)	Discharge (cfs)	WS Elev. (ft.)	Discharge (cfs)	WS Elev. (ft.)	Discharge (cfs)	WS Elev. (ft.)
10-Year Storm								
I-95 (U/S)	1,521	22.93	1,289	22.12	1,521	22.93	1,112	21.48
Highland Rd. (U/S)	1,521	24.15	1,289	23.04	1,521	24.15	1,112	21.72
Purchase St. (U/S)	1,434	27.35	933	26.45	1,434	27.35	908	26.14
I-287 (D/S)	1,374	32.32	933	31.47	1,374	32.32	908	31.41
50-Year Storm								
I-95 (U/S)	2,497	26.55	2,176	25.32	2,497	26.55	2,167	25.29
Highland Rd. (U/S)	2,497	27.49	2,176	26.51	2,497	27.49	2,167	25.41
Purchase St. (U/S)	2,353	30.12	2,049	29.00	2,353	30.12	2,042	28.98
I-287 (D/S)	2,255	33.45	2,049	33.20	2,255	33.45	2,042	33.19
100-Year Storm								
I-95 (U/S)	2,984	30.33	2,877	30.07	2,984	30.33	2,861	30.04
Highland Rd. (U/S)	2,984	30.78	2,877	30.52	2,984	30.78	2,861	30.08
Purchase St. (U/S)	2,812	31.71	2,798	31.54	2,812	31.71	2,787	31.51
I-287 (D/S)	2,694	34.01	2,798	34.08	2,694	34.01	2,787	34.06

The upstream impact of each flood control improvement alternative was also determined for areas upstream of the Bowman Avenue Dam and on East Branch Blind Brook. The water surface calculations were performed using the FIS HEC-RAS model with Sells, discharges and boundary conditions. The calculations were extended only to Long Ledge Court since most of the flooding experienced on East Branch Blind Brook is occurring south of Avon Circle located approximately 500 feet south of Long Ledge Court.

The discharges used for East Branch Blind Brook were New York regression discharges for unregulated streams as presented in the July 2007 Hydrologic Report. The starting water surface elevations for each run were interpolated from rating curves developed at the Lower Pond just downstream of the East Branch Blind Brook. The rating curves were derived from WinTR-20 computed water surface elevations at the Lower Pond for each alternative.

The rating curves at the Lower Pond for each alternative are included in Appendix E. The water surface elevations for the existing and the impact of the three alternatives of improvements at Bowman Avenue Dam Site are presented below.

For each of the alternatives the water surface elevation for existing and improved conditions was computed at the downstream face of the I-287 culvert and upstream face of the I-95 culvert, the extents of the Indian Village neighborhood, as well as two intermediate locations (Purchase Street and Highland Road).

Analysis Results

Alternative A: Optimizing the Orifice Opening at the Dam

As previously described in the Alternatives Analysis section of this report, this alternative consists of retrofitting the Bowman Avenue Dam with an automated sluice gate. An automated sluice gate has the ability to vary the opening size, thus providing the optimum orifice size for the flow rate in the stream. The sluice gate would be automatically controlled based on water surface elevations measured at a gauge mounted behind the Bowman Avenue Dam. The results of this alternative are provided in Table 13.

As can be seen, the reduction in water surface elevation, measured in feet, is particularly notable during the 50-year storm event. The 4.15-foot reduction in water surface elevation upstream of I-95 is attributed to the fact that the flow is passing through the I-95 bridge with little backwater effect. During the 100-year event, the stream flow does not pass the structure thus creating backwater. See Figures 6 through 8 for water surface elevation of 10-, 5-, and 100-year design storms.

Slight modification to the upstream dam face would be required to accommodate the sluice gate. A detailed inspection and analysis including dam cores would be required during subsequent design phases. Additionally, upstream channel work and clearing and grubbing would be required. The budgetary cost for this alternative is **$1 - 2 million**.

Table 13: Alternative A - Optimizing Orifice Opening				
		Water Surface Elevation (ft-NAVD)		
	Orifice Size	Existing Cond.	Proposed Cond.	Difference
2-Year Storm	**20.2**			
D/S I-287		31.07	31.07	0.00
Purchase Street		25.65	25.65	0.00
Highland Road		21.41	21.43	0.02
U/S I-95		20.77	20.80	0.03
5-Year Storm	**45.6**			
D/S I-287		32.15	31.62	-0.53
Purchase Street		27.20	26.61	-0.59
Highland Road		24.19	23.35	-0.84
U/S I-95		22.95	22.36	-0.59
10-Year Storm	**72.1**			
D/S I-287		32.73	32.27	-0.46
Purchase Street		28.33	27.73	-0.60
Highland Road		25.88	25.24	-0.64
U/S I-95		24.59	23.89	-0.70
25-Year Storm	**105.6**			
D/S I-287		33.44	32.87	-0.57
Purchase Street		30.06	29.21	-0.85
Highland Road		27.78	27.20	-0.58
U/S I-95		26.93	26.19	-0.74
50-Year Storm	**139.1**			
D/S I-287		34.11	33.66	-0.45
Purchase Street		31.91	30.18	-1.73
Highland Road		31.01	27.39	-3.62
U/S I-95		30.56	26.41	-4.15
100-Year Storm	**139.1**			
D/S I-287		34.97	34.54	-0.43
Purchase Street		33.44	32.55	-0.89
Highland Road		32.60	31.57	-1.03
U/S I-95		32.17	31.12	-1.05

Alternative B: Optimizing the Orifice Opening and Maximizing the Upper Pond

This alternative includes the work described in Alternative A above in conjunction with maximizing the area of the Upper Pond. Maximizing the pond size will include removal of in-situ soils along the northern side of the pond, removal of previously dumped material and rock excavation (see Figure 4). The results of this alternative are provided in Table 14 below. As can be seen, the water surface elevations are further reduced. See Figures 6 through 8 for water surface elevation of 10-, 5-, and 100-year design storms.

The budgetary construction cost for this alternative is **\$10 - \$15 million**. This includes the removal of approximately 160,000 CY of material. For estimating purposes, it is assumed that approximately 50% of this material is rock. Soil borings would be required during subsequent design phases to accurately determine the extent of rock removal.

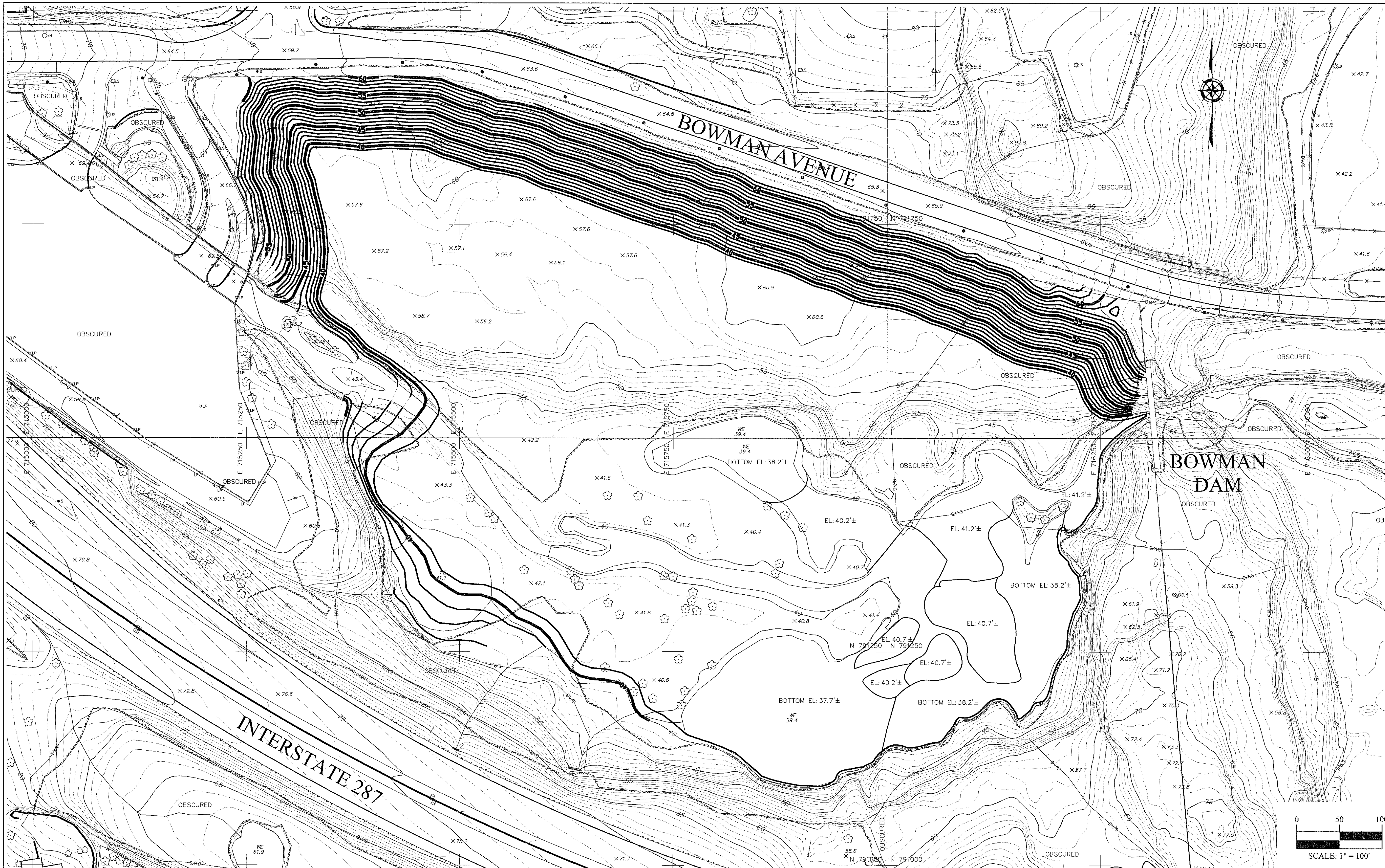
Table 14: Alternative B - Optimizing Orifice and Maximizing Upper Pond w/o Dredging (El. = 39.0)

		Water Surface Elevation (ft-NAVD)		
	Orifice Size	Existing Cond.	Proposed Cond.	Difference
2-Year Storm	**20.2**			
D/S I-287		31.07	30.90	-0.17
Purchase Street		25.65	25.52	-0.13
Highland Road		21.41	21.29	-0.12
U/S I-95		20.77	20.66	-0.11
5-Year Storm	**45.6**			
D/S I-287		32.15	31.29	-0.86
Purchase Street		27.20	26.27	-0.93
Highland Road		24.19	22.72	-1.47
U/S I-95		22.95	21.89	-1.06
10-Year Storm	**45.6**			
D/S I-287		32.73	31.47	-1.26
Purchase Street		28.33	26.45	-1.88
Highland Road		25.88	23.04	-2.84
U/S I-95		24.59	22.12	-2.47
25-Year Storm	**72.1**			
D/S I-287		33.44	32.51	-0.93
Purchase Street		30.06	28.28	-1.78
Highland Road		27.78	26.01	-1.77
U/S I-95		26.93	24.73	-2.20
50-Year Storm	**139.1**			
D/S I-287		34.11	33.20	-0.91
Purchase Street		31.91	29.00	-2.91
Highland Road		31.01	26.51	-4.50
U/S I-95		30.56	25.32	-5.24
100-Year Storm	**139.1**			
D/S I-287		34.97	34.08	-0.89
Purchase Street		33.44	31.54	-1.90
Highland Road		32.60	30.52	-2.08
U/S I-95		32.17	30.07	-2.10

Alternative C: Optimizing the Orifice Opening, Maximizing the Upper Pond and Dredging 2-feet of Sediment Material from Upper Pond

This alternative includes the work described in Alternative A and B above in conjunction with dredging up to 2 feet of sediment accumulated in the Upper Pond (see Figure 5). As previously stated, the sediment is likely contaminated with typical roadway pollutants, such as lead, oil, copper, zinc, iron and chromium. Soil sampling and testing would be required during subsequent design phases. The results of this alternative are provided in Table 15 below. As compared to Alternate B, this alternative only provides benefit during the lower intensity storm events (2-year or less). During more intense storms, this alternative provides virtually the same water surface elevations as compared to Alternative B. See Figures 6 through 8 for water surface elevation of 10-, 5-, and 100-year design storms. The budgetary construction cost for this alternative is **$18 - $22 million**. This includes the removal of approximately 30,000 CY of contaminated material.

Table 15: Alternative C - Optimizing Orifice and Maximizing Upper Pond with Dredging (El. = 37.0)				
		Water Surface Elevation (ft-NAVD)		
	Orifice Size	Existing Cond.	Proposed Cond.	Difference
2-Year Storm	**20.2**			
D/S I-287		31.07	30.79	-0.28
Purchase Street		25.65	25.32	-0.33
Highland Road		21.41	20.93	-0.48
U/S I-95		20.77	20.32	-0.45
5-Year Storm	**45.6**			
D/S I-287		32.15	31.25	-0.90
Purchase Street		27.20	26.22	-0.98
Highland Road		24.19	22.70	-1.49
U/S I-95		22.95	21.79	-1.16
10-Year Storm	**45.6**			
D/S I-287		32.73	31.41	-1.32
Purchase Street		28.33	26.14	-2.19
Highland Road		25.88	22.62	-3.26
U/S I-95		24.59	21.48	-3.11
25-Year Storm	**72.1**			
D/S I-287		33.44	32.47	-0.97
Purchase Street		30.06	28.20	-1.86
Highland Road		27.78	25.92	-1.86
U/S I-95		26.93	24.62	-2.31
50-Year Storm	**139.1**			
D/S I-287		34.11	33.19	-0.92
Purchase Street		31.91	28.98	-2.93
Highland Road		31.01	26.48	-4.53
U/S I-95		30.56	25.29	-5.27
100-Year Storm	**139.1**			
D/S I-287		34.97	34.06	-0.91
Purchase Street		33.44	31.51	-1.93
Highland Road		32.60	30.48	-2.12
U/S I-95		32.17	30.04	-2.13



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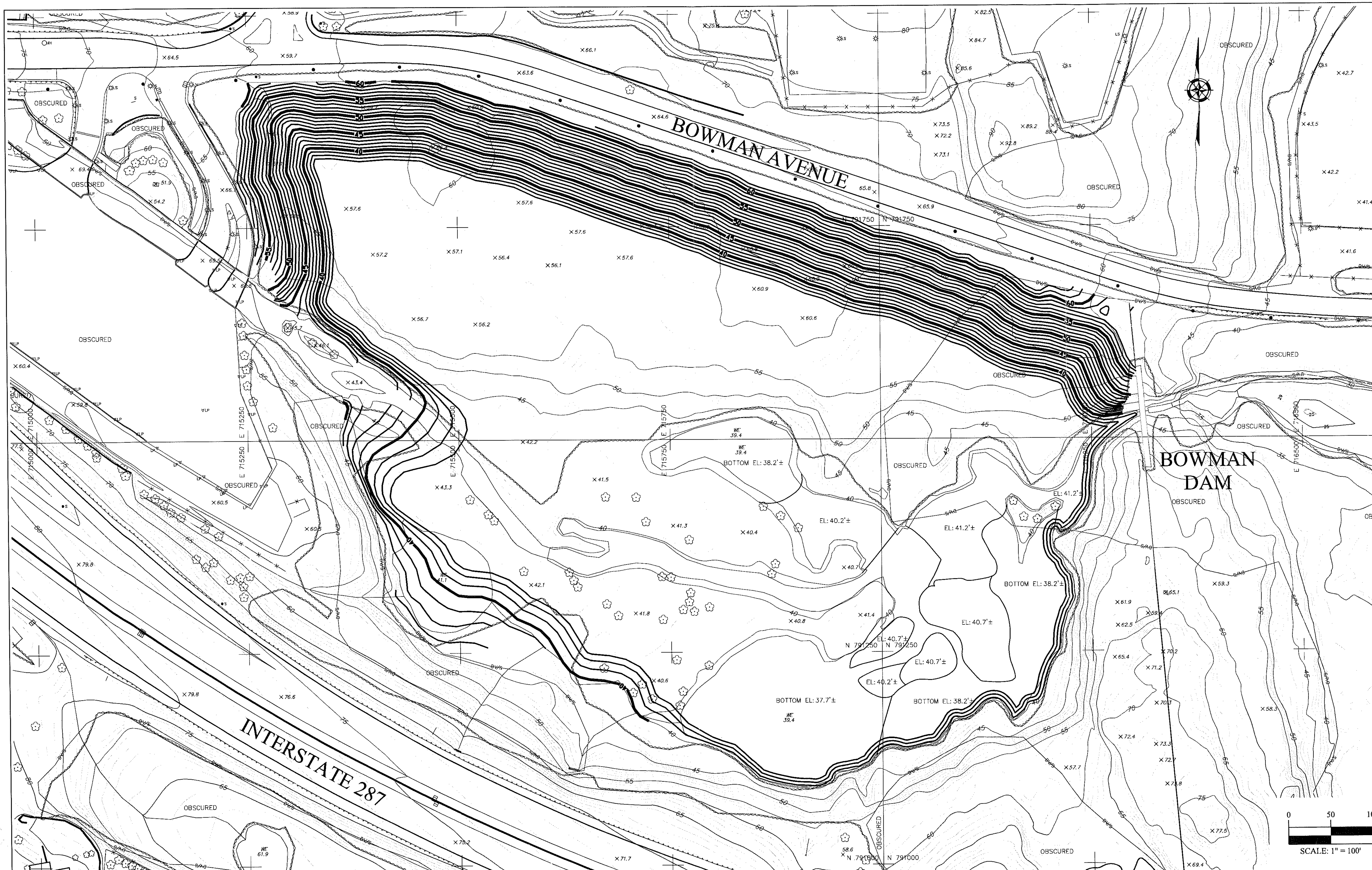
CITY OF RYE FLOOD MITIGATION MEASURES
BOWMAN AVENUE DAM RESERVOIR - MAXIMIZED RESERVOIR AREA - BOTTOM ELEVATION 39.0

FIGURE NO.
4



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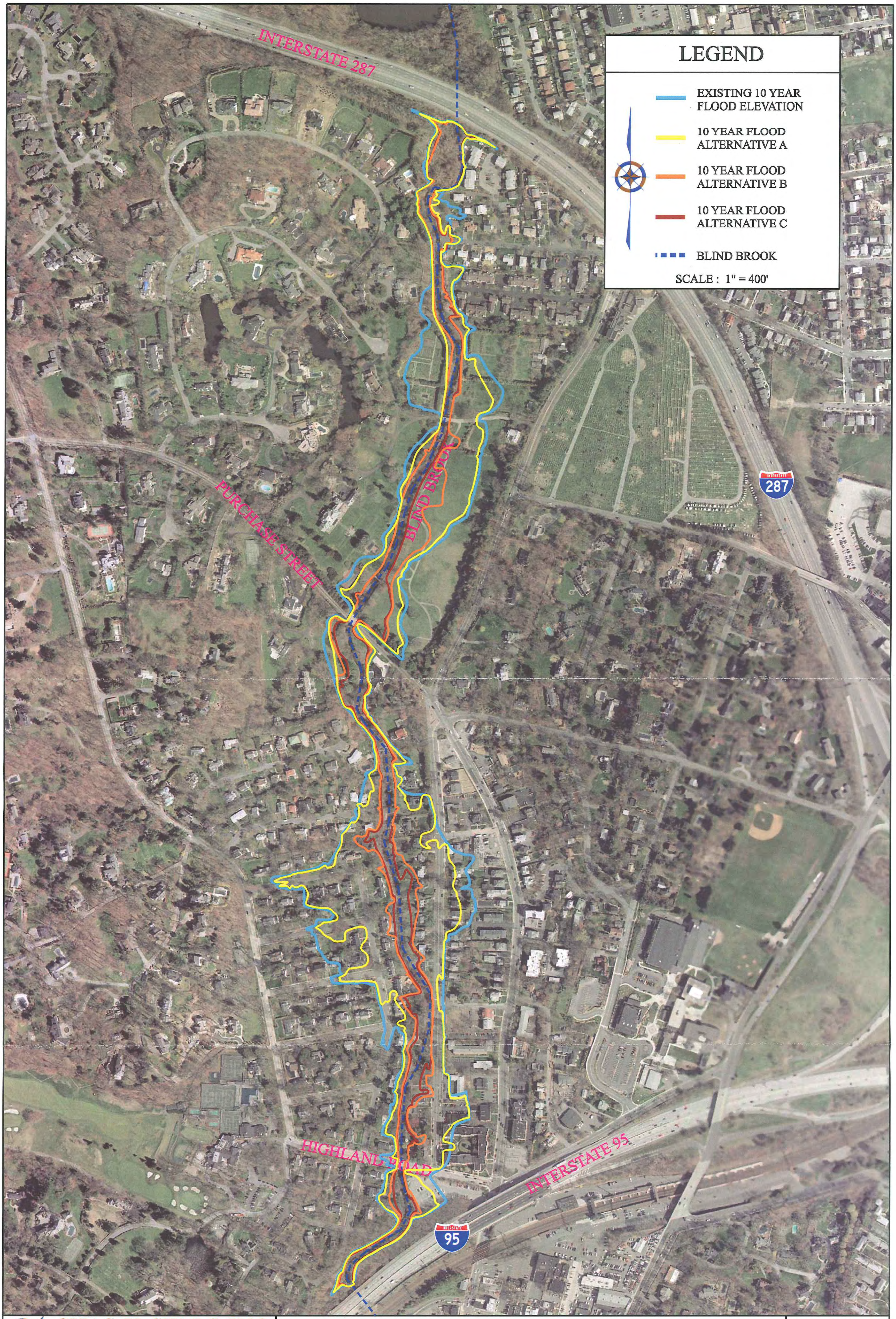
CITY OF RYE FLOOD MITIGATION MEASURES
BOWMAN AVENUE DAM RESERVOIR - MAXIMIZED RESERVOIR AREA - BOTTOM ELEVATION 37.0

FIGURE NO.
5



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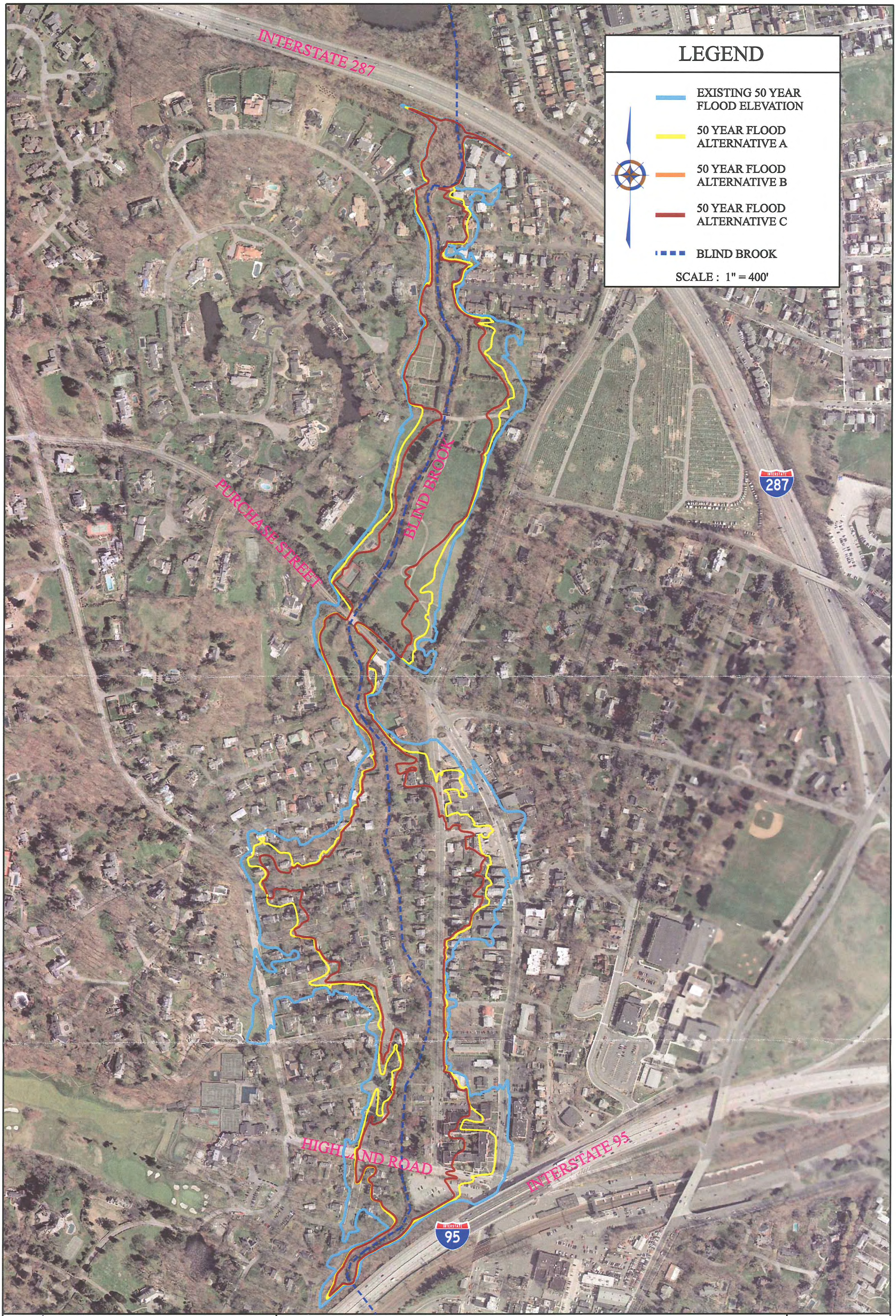
CITY OF RYE FLOOD MITIGATION MEASURES
10 YEAR STORM LIMITS - EXISTING CONDITIONS AND ALTERNATIVES

FIGURE NO. 6



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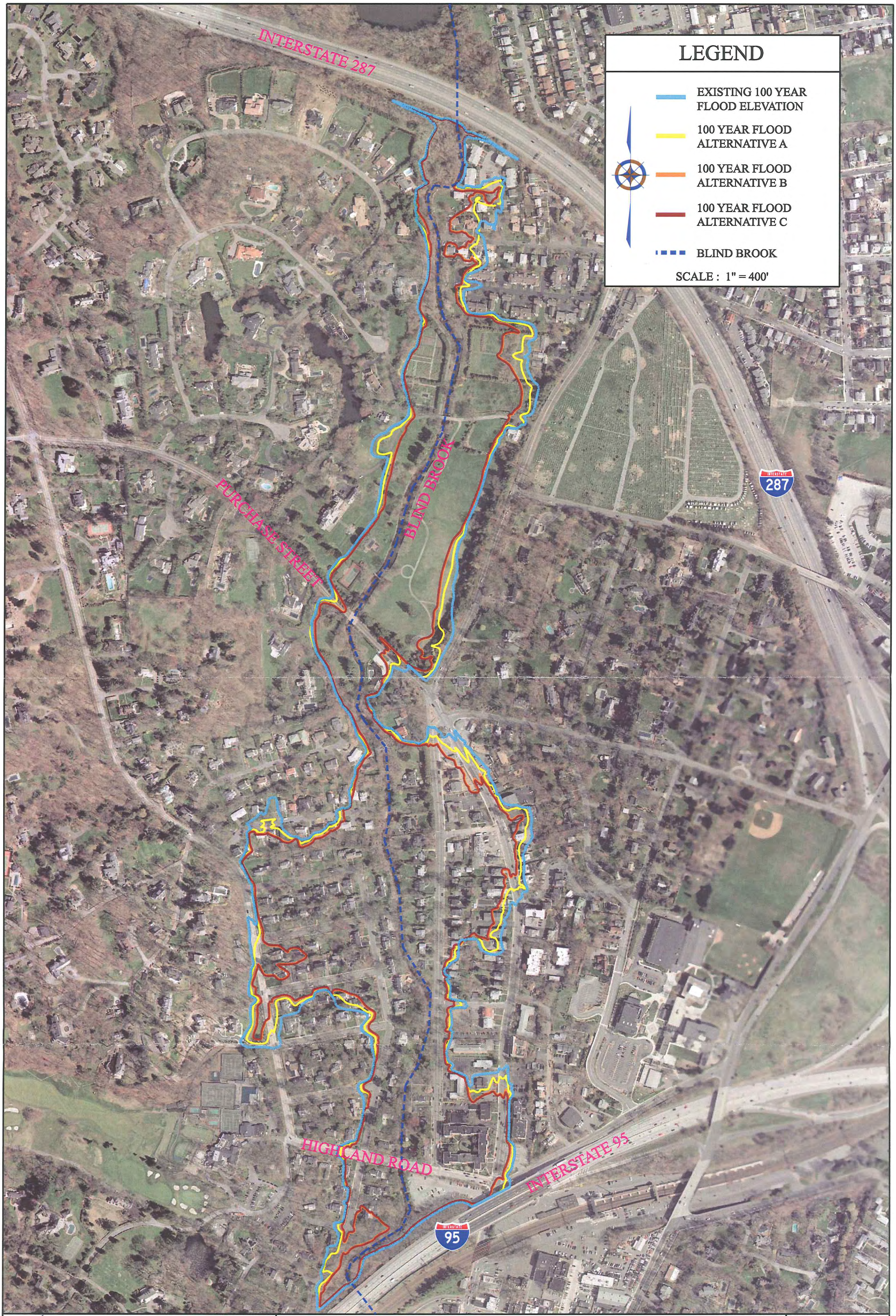
CITY OF RYE FLOOD MITIGATION MEASURES
50 YEAR STORM LIMITS - EXISTING CONDITIONS AND ALTERNATIVES

FIGURE NO.
7



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CITY OF RYE FLOOD MITIGATION MEASURES
100 YEAR STORM LIMITS - EXISTING CONDITIONS AND ALTERNATIVES

FIGURE NO. 8

Upstream Impacts

Although the goal of making improvements to the Upper Pond area is to alleviate flood conditions downstream of I-287, it is equally important to ensure that there are no negative effects to upstream neighborhoods. Additional analyses were performed along a portion of Blind

Table 16 - Elevations in Feet-NAVD

		Alternate A Optimize Orifice Opening			Alternate B Opt. Orifice Opening, Maz. Vol. with Bottom Elevation of 39.0			Alternate C Opt. Orifice Opening, Maz. Vol. with Bottom Elevation of 37.0		
	Orifice Size	Existing Cond.	Proposed Cond.	Difference	Existing Cond.	Proposed Cond.	Difference	Existing Cond.	Proposed Cond.	Difference
2-Year Storm	20.2									
Bowman Avenue Dam		51.75	51.75	0.00	51.75	48.00	-3.75	51.75	47.20	-4.55
Bowman Avenue (U/S)		55.91	55.91	0.00	55.91	55.91	0.00	55.91	55.91	0.00
Westchester Ave. Culvert (U/S)		67.11	67.11	0.00	67.11	67.11	0.00	67.11	67.11	0.00
Deer Run Area		84.25	84.25	0.00	84.25	84.25	0.00	84.25	84.25	0.00
5-Year Storm	45.6									
Bowman Avenue Dam		53.90	53.85	-0.05	53.90	49.80	-4.10	53.90	49.20	-4.70
Bowman Avenue (U/S)		58.06	58.06	0.00	58.06	58.06	0.00	58.06	58.06	0.00
Westchester Ave. Culvert (U/S)		68.30	68.30	0.00	68.30	68.29	-0.01	68.30	68.29	-0.01
Deer Run Area		85.05	85.05	0.00	85.05	85.05	0.00	85.05	85.05	0.00
10-Year Storm	72.1									
Bowman Avenue Dam		56.40	55.30	-1.10	56.40	51.40	-5.00	56.40	51.00	-5.40
Bowman Avenue (U/S)		59.37	59.18	-0.19	59.37	59.23	-0.14	59.37	59.23	-0.14
Westchester Ave. Culvert (U/S)		68.83	68.83	0.00	68.83	68.83	0.00	68.83	68.83	0.00
Deer Run Area		85.49	85.49	0.00	85.49	85.49	0.00	85.49	85.49	0.00
25-Year Storm	105.6									
Bowman Avenue Dam		58.95	57.80	-1.15	58.95	55.20	-3.75	58.95	54.95	-4.00
Bowman Avenue (U/S)		62.03	61.24	-0.79	62.03	60.89	-1.14	62.03	60.89	-1.14
Westchester Ave. Culvert (U/S)		70.45	70.45	0.00	70.45	70.45	0.00	70.45	70.45	0.00
Deer Run Area		86.01	86.01	0.00	86.01	86.01	0.00	86.01	86.01	0.00
50-Year Storm	139.1									
Bowman Avenue Dam		59.20	58.45	-0.75	59.20	57.45	-1.75	59.20	57.25	-1.95
Bowman Avenue (U/S)		62.92	62.50	-0.42	62.92	62.14	-0.78	62.92	62.11	-0.81
Westchester Ave. Culvert (U/S)		70.90	70.90	0.00	70.90	70.90	0.00	70.90	70.90	0.00
Deer Run Area		86.41	86.41	0.00	86.41	86.41	0.00	86.41	86.41	0.00
100-Year Storm	139.1									
Bowman Avenue Dam		59.60	58.55	-1.05	59.60	57.90	-1.70	59.60	57.79	-1.81
Bowman Avenue (U/S)		63.54	63.66	0.12	63.54	63.53	-0.01	63.54	63.53	-0.01
Westchester Ave. Culvert (U/S)		71.84	71.84	0.00	71.84	71.84	0.00	71.84	71.84	0.00
Deer Run Area		86.82	86.82	0.00	86.82	86.82	0.00	86.82	86.82	0.00

Brook above the Upper Pond and East Branch Blind Brook. Upstream of the Upper Pond along Blind Brook, water surface elevations were computed at Bowman Avenue, Westchester Avenue, and the Deer Run (Brook Lane) area. Along East Branch Blind Brook, elevations were computed at Bowman Avenue, Westchester Avenue, and Long Edge Drive. Tables 16 and 17 provide water surface elevations for Alternates A, B and C.

In all instances none of the alternatives will create any impacts on the upstream areas.

Table 17 - Elevations in Feet-NAVD

		Alternate A Optimize Orifice Opening			Alternate B Opt. Orifice Opening, Maz. Vol. with Bottom Elevation of 39.0			Alternate C Opt. Orifice Opening, Maz. Vol. with Bottom Elevation of 37.0		
	Orifice Size	Existing Cond.	Proposed Cond.	Difference	Existing Cond.	Proposed Cond.	Difference	Existing Cond.	Proposed Cond.	Difference
2-Year Storm	**20.2**									
I-287		31.35	31.15	-0.20	31.35	31.30	-0.05	31.35	31.25	-0.10
Bowman Avenue (U/S)		33.68	33.68	0.00	33.68	33.68	0.00	33.68	33.68	0.00
Westchester Ave. Culvert (D/S)		39.94	39.94	0.00	39.94	39.94	0.00	39.94	39.94	0.00
Long Edge Drive (D/S)		62.07	62.07	0.00	62.07	62.07	0.00	62.07	62.07	0.00
5-Year Storm	**45.6**									
I-287		31.90	31.72	-0.18	31.90	31.42	-0.48	31.90	31.40	-0.50
Bowman Avenue (U/S)		34.54	34.54	0.00	34.54	34.54	0.00	34.54	34.54	0.00
Westchester Ave. Culvert (D/S)		40.49	40.49	0.00	40.49	40.49	0.00	40.49	40.49	0.00
Long Edge Drive (D/S)		62.88	62.88	0.00	62.88	62.88	0.00	62.88	62.88	0.00
10-Year Storm	**72.1**									
I-287		32.35	32.05	-0.30	32.35	31.60	-0.75	32.35	31.50	-0.85
Bowman Avenue (U/S)		36.09	36.09	0.00	36.09	36.09	0.00	36.09	36.09	0.00
Westchester Ave. Culvert (D/S)		40.67	40.67	0.00	40.67	40.67	0.00	40.67	40.67	0.00
Long Edge Drive (D/S)		63.25	63.25	0.00	63.25	63.25	0.00	63.25	63.25	0.00
25-Year Storm	**105.6**									
I-287		32.35	32.05	-0.30	32.35	31.60	-0.75	32.35	31.50	-0.85
Bowman Avenue (U/S)		37.35	37.35	0.00	37.35	37.35	0.00	37.35	37.35	0.00
Westchester Ave. Culvert (D/S)		40.90	40.90	0.00	40.90	40.90	0.00	40.90	40.90	0.00
Long Edge Drive (D/S)		63.65	63.65	0.00	63.65	63.65	0.00	63.65	63.65	0.00
50-Year Storm	**139.1**									
I-287		32.75	32.35	-0.40	32.75	32.20	-0.55	32.75	32.13	-0.62
Bowman Avenue (U/S)		38.47	38.47	0.00	38.47	38.47	0.00	38.47	38.47	0.00
Westchester Ave. Culvert (D/S)		42.09	42.09	0.00	42.09	42.09	0.00	42.09	42.09	0.00
Long Edge Drive (D/S)		64.90	64.90	0.00	64.90	64.90	0.00	64.90	64.90	0.00
100-Year Storm	**139.1**									
I-287		33.10	32.90	-0.20	33.10	32.65	-0.45	33.10	32.64	-0.46
Bowman Avenue (U/S)		40.06	40.06	0.00	40.06	40.06	0.00	40.06	40.06	0.00
Westchester Ave. Culvert (D/S)		41.31	41.31	0.00	41.31	41.31	0.00	41.31	41.31	0.00
Long Edge Drive (D/S)		64.27	64.27	0.00	64.27	64.27	0.00	64.27	64.27	0.00

CONCLUSION AND RECOMMENDATIONS

1. **Orifice Optimization:** It is our recommendation to move forward with detailed design for the installation of the automated sluice gate as this option presents the most cost-effective solution for mitigating downstream flooding. As previously stated, the automated sluice gate has the ability to vary the outlet opening, thus providing the optimum orifice size for the flow rate in the stream. The sluice gate would be automatically controlled based on water surface elevations measured by an actuator and level control at the dam. The sluice gate would have remote control abilities via a SCADA system, however manual overrides will also be provided at the installation. The budgetary construction cost for this alternative is estimated at $1 - $2 million. This alternative will not result in upstream impacts.

2. **Maximizing Storage at Upper Pond:** Immediately conduct subsurface investigation at the upper pond so as to determine location and condition of underlying bedrock. Additionally, soil sampling and testing is necessary to determine level of contamination. We believe this information is necessary to further evaluate the feasibility and cost-effectiveness of maximizing the storage capacity of the upper pond. In conjunction with this, the City should evaluate means in which to provide maintenance access to the upper pond.

3. **Lower Pond Alternatives:** Additional studies should be performed to investigate the feasibility of modifying the Lower Pond so as to allow for it to function as a flood control measure. These options include pre-draining via gravity-based and/or mechanical-based means.

4. **Revise FIS and FIRM Mapping:** We feel the City should prepare a revised version of the FIS and FIRM mapping incorporating the discharge values determined as part of this study. We believe the discharge values developed as part of Sells' August 2007 Hydrologic Report are a more accurate representation of actual flood events based on methodology, calibration, and historical information. In a community where there are so many houses within and immediately adjacent to the floodplain, the difference in water surface elevation could be the difference of dozens of houses being flooded or susceptible to deeper flooding and more damage.

5. **Hydraulic Improvements at Avon Circle:** The available FEMA HEC-RAS model was used to assess possibilities of improving the flood conditions during various storm events in two areas located in the Village of Rye Brook: the Avon Circle area situated on the left bank of East Branch Blind Brook between Westchester Avenue and Long Ledge Drive, and the Brook Lane area located on the left bank of Blind Brook between Westchester Avenue and Deer Run.

   A few models were developed using lower tailwater depths that resulted from the reduction of the peak discharges downstream of the Bowman Dam and from lowering the overflow just upstream of I-275 from elevation 29.0 to elevation 27.5. Although the Bowman Avenue Bridge on East Branch Blind Brook seems to be undersized, the bridge backwater does not carry over to Westchester Avenue. Preliminary calculations suggest that increasing the size of the existing Westchester Avenue culvert unit from 5 feet in diameter to a 12-foot by 6-foot box culvert will lower the water surface elevations between 0.8 and 4.0 feet during various storm events (Appendix F). In order to provide a final sizing, the existing FEMA model should be supplemented with a topographical survey and the model updated. Water surface profiles and cross sections are included in Appendix F.

6. **Evaluation of Brook Lane:** The FEMA hydraulic model was also used in assessing flood improvements in the Brook Lane area. It seems that the flooding in this area is in connection with a relatively wide flood plain in some sections. The condition of the Bowman Avenue bridge on Blind Brook seems similar to the one on East Branch Blind Brook; it is undersized but its backwater does not carry over to Westchester Avenue. In order to lower the water surface elevations in the Brook Lane area, various bridge opening sizes were analyzed; widening the bridge by as much as 10 feet and increasing the bridge height be 2 feet, respectively. These changes in bridge openings resulted in minimal water surface elevation reductions (Appendix F). To help determine the influence the Westchester Avenue bridge has on the Brook Lane area, a model where there is no bridge at this location was developed. The HEC-RAS output results showed that during various storm events, the backwater created by the existing Westchester Avenue bridge is lower than 6 inches. Therefore, it was concluded that the existing bridge opening is basically adequate and the flooding in this area is connected with a wider floodplain rather than an undersized structure. Water surface profiles and cross sections are included in Appendix F.

BIBLIOGRAPHY

1. *Survey Report for Flood Control.* Army Corps of Engineers (1968)
2. *Flood Insurance Study.* Federal Emergency Management Agency (1979)
3. *Watershed Plan and Environmental Impact Statement Blind Brook Watershed.* U.S.D.A. – Soil Conservation Service (1979)
4. *City of Rye Development Plan.* City of Rye (1985)
5. *Long Island Sound Study – The Comprehensive Conservation and Management Plan.* (1994)
6. *Controlling Non-*point *Source Pollution in Long Island Sound.* Westchester Advisory Committee 3 and Westchester County Department of Planning (1998)
7. *Flood Mitigation Plan.* City of Rye (2001)
8. *Technical Memorandum Evaluation of the Bowman Avenue Dam Site Blind Brook Watershed.* City of Rye (2000)
9. *Draft Hazard Mitigation Plan.* City of Rye (2004)
10. *Update on Preliminary Hydrologic Analysis for the Blind Brook Watershed Management Plan.* Army Corps of Engineers (2007)
11. *Summary Review of Existing Information for the Blind Brook Watershed Management Plan.* Army Corps of Engineers (2007)