Blind Brook Watershed Management Plan

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1.0 INTRODUCTION

The Blind Brook Watershed Management Plan is being performed under Section 206 of the 1960 Flood Control Act (PL 86-645), as amended. The objective of the act is to foster public understanding of the options for dealing with flood hazards and to promote prudent use and management of the nation's floodplains. The purpose of this study is to develop a flood mitigation plan for the Blind Brook Watershed, which includes the following objectives: review of existing hydrologic and hydraulic models of the Blind Brook Watershed, completion of an overall assessment of flood impacts within the Blind Brook Watershed, identification and evaluation of specific flood mitigation alternatives for the Blind Brook Watershed, and formulation of a comprehensive plan for short and long term flood mitigation improvements within the Blind Brook Watershed. Even though the hydrologic and hydraulic assessment considers the entire watershed, the economic assessment focuses on the structural flood damages located within the municipal limits of the City of Rye (City). A Summary Review of Existing Information for the Blind Brook Watershed Management Plan was completed and delivered as a part of the first phase of the project in April 2007. The second phase of the project addresses the Flood Hazard Assessment and Development of Flood Mitigation Goals. As a part of this technical memorandum report, results from the Flood Hazard Assessment task are presented along with Flood Mitigation Goals developed based on the meeting with USACE and the City held on May 16th, 2008.

1.1 Description of the Study Area

The Blind Brook Watershed drains approximately 10.91 square miles into the Long Island Sound and contains several municipalities including the City, Village of Rye Brook, Village of Port Chester, and Town/Village of Harrison (see Figure 1). Blind Brook itself forms portions of the municipal border between Town/Village of Harrison and Village of Rye Brook. The length of the Blind Brook Watershed is approximately 9 miles and its width varies from 0.5 mile to 2.0 miles. Approximately 96.7 percent of the watershed is within Westchester County, New York and 3.3 percent is within Fairfield County, Connecticut. Please refer to the Summary Review of Existing Information for the Blind Brook Watershed Management Plan completed March 2007 for detailed description of the study area.

2.0 EXISTING DATA

As a part of this study, data from various government agencies was acquired. The following sections describe the type of data and the government agency from which it was acquired.

2.1 Existing Condition Topography and Digital Elevation Model (DEM)

The primary data sources for existing topography were USGS topographic data and the 2 foot elevation contours provided by Westchester County GIS Department. Figure 2 shows the extent of the contour dataset covering the municipal limits of the City within the Blind Brook Watershed that was used in this study. The elevation contours were converted to a seamless girded dataset using ArcGIS 9.2 tools. Existing sub-basin delineations based on USGS topography were used in updating the TR-20 hydrologic model. The elevation-area-volume curves required for the hydrologic and hydraulic modeling tasks were derived using the 2 foot topographic data from Westchester County.

2.2 Depth – Damage Curves

Residential depth-damage curve information for structures and contents was obtained from "*EGM04-01*: *Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements"*. Non-residential depth-damage curve information for structures and contents was obtained from "*IWR Report 96-R-12: Analysis of Non-Residential Content Value and Depth-Damage Data for Flood Damage Reduction Studies"*. This data was used in conjunction with topographic data, hydraulic model results and property valuation data in the flood damage assessment.

2.3 Tax Assessment Information

Tax Assessors Data obtained from the City contains property valuation information. Valuation information contains parcel ID, legal address of each parcel, 2007 Land Value and 2007 Total Value of each parcel. Valuation data also includes "Improvement Value 2007" as the difference between 2007 Total Value and 2007 Land Value. An equalization value of 0.018 was applied for residential structures and 0.0197 was applied for commercial and public structures and included as "Improved Market Value 2007" in the valuation information. As per the City's guidance, "Improved Market Value 2007" obtained from the tax assessors data was used as the representative structure value per parcel in the flood damage assessment. It is essential to note that valuation was based on individual tax parcels and in some cases an individual tax parcel contains multiple structures. In cases where a tax parcel contains multiple structures, the value of that parcel was assumed to be representative of the value of all the structures contained within the parcel.

2.4 Structure Elevation

First floor and low opening elevations of structures were used in the flood damage assessment. As the survey information representing the elevations of the structures was not readily available, elevations of structures were extracted based on the existing topographic contour information obtained from the City.

2.5 Hydrologic and Hydraulic Models

Hard copies of various NRCS notes and hand-written documentation containing partial TR-20 model parameters were obtained and refined as needed as a part of hydrologic analysis. TR-20 model was calibrated to match 2006 FEMA hydrologic discharges. Detailed description of the hydrologic analysis was described under the existing conditions hydrologic and hydraulic analysis. Readily available 2006 FEMA hydraulic models were used and refined as needed as a part of hydraulic analysis.

2.6 Bowman Avenue Survey

Survey information at Bowman Avenue was obtained from the City. This information was used in developing stage-storage-discharge relations at Bowman Avenue.

3.0 EXISTING CONDITIONS HYDROLOGY AND HYDRAULICS

3.1 Hydrologic Modeling

In support of a comprehensive flood mitigation plan for the Blind Brook Watershed, a runoff hydrograph model is necessary to develop flood depth / frequency characteristics so that flood mitigation measures can be analyzed. The model will support the analysis and evaluation of potential detention storage structures and other structural measures during alternatives development.

Originally it was reported that existing hydrologic and hydraulic models (TR-20 and WSP2) performed for previous studies would be available in electronic format. Following a Freedom of Information Act (FOIA) request to the Natural Resources Conservation Society (NRCS), it was determined that limited information was available consisting of hard copies of various NRCS notes and hand-written documentation (dated 1975) containing partial TR-20 model parameters for the Blind Brook Watershed as follows:

- TR-20 model schematic drawing;
- Drainage area parameters for each sub-basin;
- Curve number calculations for each sub-basin;
- Time of concentration parameters for each sub-basin;
- Reach routing lengths;
- Three storage structure locations, including Anderson Hill Road, Bowman Avenue Dam, and Interstate 95; and
- Rainfall parameters (24-Hour, AMC-2, Type III rainfall distribution).

The following information was not available from the NRCS documentation, and was determined to be necessary to assemble a complete TR-20 hydrologic model:

- Routing parameters for each reach [e.g., stage-area-discharge functions or Modified Attenuation-Kinematic (Att-Kin) routing coefficients]; and
- Stage-storage-discharge functions for structures, including the Bowman Avenue Dam.

For the purposes of developing a hydrologic model, a TR-20 model input file was generated using the available 1975 NRCS documentation. Sub-basins within the watershed modeled within TR-20 model are shown in Figure 3. Since no routing parameters were provided in the NRCS documentation, these parameters were computed from an available HEC-RAS model. The Att-Kin method was selected for reach routing, and Att-Kin routing coefficients “x” and “m” parameters computed from HEC-RAS data were entered into the TR-20 model input file.

Stage-storage-discharge relationships for three flood storage areas were computed from existing topographic mapping and HEC-RAS models. These stage-storage-discharge relationships were developed along Blind Brook at Anderson Hill Road (Table 1), Bowman Avenue Dam (Table 2), and Interstate 95 (Table 3), and then entered into the TR-20 model input file.

The TR-20 model was then operated to generate runoff hydrographs for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year return period events. The 100-year peak discharges from the TR-20 model hydrographs were compared to the 2006 FEMA Flood Insurance Study discharges for Westchester County. These FEMA discharges were developed from Log-Pearson Type III analysis based on 46 years of record available at USGS stream gage 01300000 on Blind Brook at Rye from 1944 to 1989. Drainage area transposition was then utilized to determine peak discharges for selected recurrence intervals at other locations of interest including at Bowman Avenue, at Mouth, at Hutchinson Parkway and at Purchase Street within the watershed. Four (4) coincidental locations (including the USGS gage location) are identified based on 2006 FEMA drainage area delineations and 1975 NRCS drainage area delineations (used in TR-20 model) to compare hydrologic output. Table 4 compares the TR-20 generated peak discharges to the FEMA discharges at several locations (Figure 3) along Blind Brook.

As shown in Table 4, the TR-20 100-year peak discharges are considerably higher than the FEMA discharges. At USGS gage location uncalibrated flows are approximately 55% higher compared to the 2006 FEMA peak discharges. In efforts to calibrate the TR-20 model to match the FEMA discharges, the TR-20 hydrologic parameters were adjusted until the TR-20 model generated peak discharges which reasonably agreed with the FEMA discharges. The Att-Kin routing coefficients were used to calibrate the model.

The Att-Kin routing parameter “m” has an effect on the calculation of travel time of the hydrograph through a reach, and is dependent on stream channel depth, width, and side slope. For a triangular stream channel with uniform roughness and normal flow, “m” is equal to 1.33. Since the HEC-RAS geometry data shows a triangular stream channel at most locations along Blind Brook, the “m” parameter was held constant at 1.33.

The Att-Kin routing parameter “x” is proportionately constant relating cross sectional flow area and velocity. Lower values of “x” result in lower velocities and higher flood attenuation, whereas higher values of “x” result in higher velocities and lower flood attenuation. The un-calibrated (computed from HEC-RAS) “x” parameters ranged from 0.5 to 1.6. In order to calibrate the 100-year peak discharges, the “x” parameters ranged from 0.16 to 0.53. These lower “x” values resulted in increased flood attenuation recognized in the TR-20 model, and brought the TR-20 peak discharges into agreement with the FEMA published discharges. Table 4 compares the FEMA, un-calibrated TR-20, and calibrated TR-20 peak discharges at several locations along Blind Brook. At USGS gage location, calibrated peak flows from TR-20 model match very close to the 2006 FRMA peak flow discharges. Calibrated TR-20 models were developed for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year return period events. The calibrated TR-20 model input and output data is provided in Appendix A.

The City Planning Department and Westchester County GIS departments were contacted to obtain any future land use mapping for the Blind Brook Watershed. Future land use mapping was not available, as the watershed is nearly fully developed. Thus, the development of a future land-use conditions hydrologic model was determined to be unwarranted at this time.

The calibrated TR-20 model discharges will be used as the basis for hydrologic computations in support of the comprehensive flood mitigation plan for the Blind Brook Watershed. This TR-20 model is capable of generating runoff hydrographs necessary to analyze flood mitigation measures. The model will support the analysis, evaluation, and effectiveness of potential detention storage structures and other structural measures during alternatives development.

The existing conditions HEC-RAS model has more flow change locations including the ones used for comparison. In order to maintain the level of detail of the 2006 FEMA HEC-RAS model for flow change locations, peak flows at the intermediate locations were interpolated for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year return periods using the calibrated peak flows from TR-20 model and 500-year peak flows from the 2006 FEMA study were directly used at all flow change locations in the updated hydraulic model. Drainage area transposition using USGS (WRIR90-4197) methodology was used to obtain the peak flow rates at selected locations where TR-20 peak flows are not directly available. Peak flows from the immediate down stream cross section were used in the drainage area transposition method to obtain the intermediate peak flows. This method produced few inconsistent results such as decreasing peak flows with increasing drainage areas at few intermediate locations for specific flood events. At those locations, linear interpolation replaced the drainage area transposition method in obtaining the peak flows. Since no published exponent was available from USAGS published data for drainage area transposition method for 1-year event, linear interpolation and extrapolation was used to obtain the peak flows at all the locations where peak flow results are unavailable from TR-20 model. Table 5 lists the summary of peak flows used in the updated HEC-RAS model.

3.2 Hydraulic Analysis and Modeling

3.2.1 Existing Channel

Blind Brook is approximately nine (9) miles in length flowing through several municipalities in Westchester County including the City, City of White Plains, Village of Rye Brook, Village of Port Chester, and Town/Village of Harrison. Cross section locations from 2006 FEMA hydraulic study are shown in Figure 4.

Review of previous studies indicates that overall flooding problems within the watershed are caused by 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. Upper reaches of the Blind Brook Watershed are subject to riverine flooding while the middle and lower reaches are subject to tidal and riverine flood events.

3.2.2 Existing Conditions Hydraulic Model

The existing conditions hydraulic model obtained from 2006 FEMA study was used in this analysis. The following descriptions regarding the existing conditions hydraulic model were obtained from the “Flood Insurance Study (FIS) for Westchester County, New York (All Jurisdictions) dated September 28, 2007”.

“A hydraulic model for Blind Brook was developed using field survey data for stream cross sections as well as for hydraulic obstructions such as bridges, culverts, dams and weirs. This information was combined with topographic data provided by the Westchester County GIS in the form of bare earth mass points and break lines to create a bare earth surface for the stream corridor.

A starting water surface elevation of 3.71 (ft, NAVD 88) was used for all events modeled. This value represents the mean high water elevation on the Long Island Sound, as determined from tidal gage analysis. Roughness factors (Manning’s n) used in the hydraulic computations for the FEMA FIS were based on field observations of the streams and floodplain areas. Expansion and contraction coefficients were used to account for energy losses due to turbulence caused by changes in cross-sectional area along the channel. The coefficients ranged from 0.1 (contraction) and 0.3 (expansion) for fairly uniform flow, to 0.3 and 0.5 for more abrupt changes in channel geometry, such as constrictions through bridges.”

4.0 FLOOD DAMAGE ASSESSMENT

Flood damage assessment was focused on quantifying the extent and severity of surface water flood hazards within the Blind Brook Watershed. While the hydrologic and hydraulic assessment considers the entire watershed, the economic assessment focuses on the structural flood damages located within the municipal limits of the City. Flood damage assessment was based on riverine flooding along the main stem of Blind Brook and it does not include the flood damages due to coastal flooding. The feasibility and evaluation of structural flood controls including levees and floodwalls within the coastal flood zone could require additional analysis. The results of the hydrologic and hydraulic models, topographic data, building valuations, and depth-damage functions were used as the basis for the development of flood damage-frequency curves for structures within the 100-year floodplain of Blind Brook. The goal of the damage assessment was to quantify the damages associated with various flood events from riverine flooding and to establish "baseline" average annual flood damages for existing conditions. The baseline flood damage assessment will support the determination of flood damage reduction benefits associated with potential flood mitigation alternatives.

Input data used in flood damage assessment includes:

1. 2006 FEMA Floodplain Delineations.
2. Water Surface Elevation Data: Hydraulic model (HEC-RAS) results for 1, 2, 5, 10, 25, 50, 100, and 500-year events.
3. Depth-Damage Curve Information: Residential depth-damage curve information for structures and contents was obtained from "EMG04-01: Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements". Non-residential depth-damage curve information for structures and contents was obtained from "IWR Report 96-R-12: Analysis of Non-Residential Content Value and Depth-Damage Data for Flood Damage Reduction Studies."
4. Structure Value: Value of all the structures within each parcel was obtained from the City Tax Assessors office.
5. Structure Classification: Based on the GIS information from Westchester County, structures within the 100-year floodplain within the municipal limits of the City were grouped into residential, commercial and public categories. The parcels containing these structures are shown in Figures 5 & 6.

6. Elevation of Structures: Highest and lowest adjacent grades of each structure were obtained from the topographic information. These grades were used to estimate structure first floor and low opening elevations.

Using the 2006 FEMA 100-year floodplain delineation, 467 unique structures were identified (Figure 7) within the municipal limits of the City. It was noted that approximately one third of these structures were affected by the coastal flood event. It was observed that 368 unique tax parcels contain the structures within the 100-year floodplain within the City. It was also found that 90 of those parcels contain multiple structures. The value of each tax parcel was obtained from tax assessor's data, damage assessment calculations were performed for each structure within a parcel within the 100-year floodplain. In the case of a parcel having multiple structures, professional judgment was used in assigning the structure elevation and water surface elevation values. As an example, based on the aerial photography, if it was determined that one of the structures represented a residence and the other structure(s) within the same parcel represented a garage or a shed, elevation values of the residence were used as the representative elevations in the damage computations.

Based on the available topographic information, each structure was assigned with a first floor elevation and a low opening elevation for flood damage computations. Highest adjacent grade of the structure that falls within the parcel was taken as the representative first floor elevation, and lowest adjacent grade was taken as the representative low opening elevation for that parcel. As the damage assessment focuses on damages due to surface water flooding, damage computations start only when the water surface elevation for a particular flood event exceeds the lowest adjacent grade.

Based on the hydraulic model results, each structure was associated with a water surface elevation for each flood event modeled. Even though the existing flood plain delineates flooding due to coastal and riverine flooding, water surface elevations are obtained based on the riverine flooding. Water surface elevation for each structure was derived using linear interpolation based on the water surface elevations for the upstream and the downstream cross sections from the hydraulic model.

The hydraulic analysis results were then integrated with the structure elevations, property valuations, depth-damage relationships, and probability data to calculate economic damages. Flood damages were computed for the 1-year through 500-year flood events, and then translated to a probability-weighted estimate of average annual flood damages.

The following assumptions were made in performing the flood damage assessment:

1. Contents valuations were assumed to be 50% of the structure valuations.
2. As the depth-damage curves for multi-family residential homes are not included in Economic Guidance Memorandum (EGM) 04-01:
   - Multi-family residential one story buildings and contents were assumed to have the same depth-damage function as single-family residential one story buildings and contents.
   - Multi-family residential buildings and contents with two or more stories were assumed to have the same depth-damage function as single-family residential buildings and contents with two or more stories.
3. The *IWR Report 96-R-12* containing depth-damage information for non-residential structures provides a generic depth-damage function for non-residential structures, as well as several depth-damage functions based on Standard Industrial Classifications (SIC) as presented in Table 6. Even though North American Industry Classification System (NAICS) classification supersedes SIC classification, SIC data were used because depth-damage functions for SIC data were readily available. Each non-residential structure in this analysis was matched to the most appropriate SIC depth-damage function. A generic non-residential depth-damage function was used for non-residential structures types that did not have an specific SIC depth damage relationship identified in the report.
4. The number of stories for non-residential structures was not available from the City. Therefore, the following assumptions were made:
   - The following occupant descriptions were assumed to be single-story buildings: auto body, restaurant, and service and gas station.
   - The following occupant descriptions were assumed to be multi-story buildings: equipment storage, hospital, recreation facility, library, school, waste disposal facility, government, and police and fire protection.
5. Parcels listed as “vacant lot” in the tax assessor’s data received from the City were assumed to be vacant, and not included in the analysis.

6. In the average annual flood damage calculation, the ½-year event was assumed to have $0.00 damage.

7. Tables 7, & 8 and Figures 8 & 9 summarize the results from the assumption that all of the structures (residential, commercial and public) analyzed for flood damage assessment have basements.

5.0 DEVELOPMENT OF FLOOD MITIGATION GOALS

The following flood mitigation goals were proposed based on the meetings held on May 16, 2008 and on October 27, 2008 with USACE, and the City of Rye. The Village of Rye Brook also participated on the meeting on May 16, 2008.

5.1 Structural Solutions

Both the City of Rye and the Village of Rye Brook have indicated that structural solutions at the Bowman Avenue Dam, Anderson Hill Road, and the County Airport are possibilities to help alleviate some of the flooding problems within the Blind Brook watershed. The City indicated that they have various considered alternatives at Bowman Avenue Dam including ponds upstream and downstream of the dam. The proposed improvements at Bowman Avenue Dam also include a sluice gate to operate the uncontrolled opening at the bottom of the existing structure. Another suggestion included a storage area upstream of Anderson Hill Road so that the peak flow entering the Blind Brook is reduced. Two (2) locations for potential structural measures were recommended for further evaluation in this study and were identified as Anderson Hill Road and Bowman Avenue Dam (Figure 10).

5.2 Non-Structural Solutions

The City of Rye has indicated that they are working on implementing various non-structural measures such as such as regulation of the existing land use and future development in the floodplain, advance flood-warning systems, and emergency response planning. The City of Rye has also said that elevating the buildings above the 100-year water surface elevation is being considered to avoid future flooding problems. It was also noted that all municipalities should meet NYSDEC regulations for any proposed development within the floodplain.

6.0 PROPOSED CONDITIONS FLOOD MITIGATION ANALYSIS

The proposed conditions alternative analysis evaluated both structural and non-structural measures that are technically sound, economically feasible and environmentally acceptable. The preferred alternative(s) should provide the greatest amount of protection for an area, and the benefits received from flood damage reduction must be greater than the project costs including construction operation and maintenance. The alternative(s) should achieve the City's planning objectives and adequately address social, environmental and economic impacts.

6.1 Identification of Structural Flood Damage Reduction Alternatives

Structural measures are those physical barriers or features that prevent floodwaters from entering the community or inhabited areas. These measures include levees, floodwalls, reservoirs, watershed dams, and channel modifications. Based on the meetings with the City and USACE, improvements at Anderson Hill Road and at Bowman Avenue were studied for potential structural solutions. A stormwater pond upstream of Anderson Hill Road, improvements to the low flow opening at the Bowman Avenue Dam and increasing storage capacity upstream of Bowman Dam were identified for further study and evaluation. First, each structural measure was studied to evaluate the flood damage reduction potential within the City. Later, individual structural alternatives were combined to study the cumulative impacts of the structural measures on the flood damage reduction potential within the City.

6.2 Evaluation of Structural Alternatives

6.2.1 Improvements at Anderson Hill Road

Upstream detention structures are man-made physical barriers that provide protection from damages by limiting or delaying excessive runoff during flood events to reduce downstream flows and flood stages. The intent of the upstream detention alternative presented in this report is to provide a stormwater pond upstream of Anderson Hill Road with sufficient storage capacity to store peak flows above the 1-year flood event up to the 100-year flood event and to design an outlet structure to release the detained flow back to Blindbrook at a reduced rate to decrease the existing flood damages within the City. The area upstream of Anderson Hill Road, adjacent to State University of New York (SUNY) – Purchase Campus (Figure 11) was selected for potential structural improvements because of the potential to acquire the undeveloped land and the potential to capture the flow in the watershed at an upstream location.

6.2.1.1 Stormwater Pond Upstream of Anderson Hill Road

A stormwater pond 17.5 acres in area with a depth of 13 feet is proposed upstream of Anderson Hill Road (AH) as shown in Figure 11. The pond will function as an off-channel detention basin that collects and detains flood flows in the Blind Brook Watershed. It was determined that approximately 1.53 square miles of drainage area contributes to the flow at the intake point to the pond. It is also proposed to divert the flows above the 1-year peak flow using a concrete diversion structure with a low flow opening and a diversion channel to the pond.

Based on the topographic information, it is estimated that the bottom of the stream is at an elevation of 252.25 feet at the intake point. In order to divert the flows above the 1-year peak flow, the top of the low flow opening in the diversion structure is proposed at 254.25 feet. The auxiliary spillway of the diversion structure is proposed at 261.55 feet, 0.05 feet above the calculated 100-year water surface elevation within the proposed pond. As per New York State Department of Environmental Conservation regulations (part 608.3 – Dams [and impoundment structures]), an impoundment capacity equal to or greater than three million gallons will be classified as a dam. Since the maximum storage within the pond is approximately 40 million gallons and for a 100-year event, both the diversion structure and the pond berm will be classified as dams under NYSDEC regulations. A diversion channel of approximately 160 feet in length, and at approximately 1.4% slope is proposed to capture the diverted flows into the pond. The top of the banks for the diversion channel are proposed at 265 feet, approximately 3.5 feet of freeboard above the projected pond water surface elevation of 261.5 feet for the 100 year elevation.

A 7 foot diameter concrete pipe is proposed to convey outflows from the pond to the Blind Brook. Table 9 lists the stage, storage, and discharge relation for the proposed pond. The stormwater pond requires excavation to achieve the required storage capacity. It also requires construction of an embankment of compacted earthen fill material at elevation 265 feet, a concrete headwall for the outlet pipe and an emergency spillway at elevation 261.6 feet through the earthen embankment. The emergency spillway provides for flows above the 100 year event and directs discharges to a channel lined with articulated concrete blocks before reconnecting with the Blind Brook.

6.2.2 Improvements at Bowman Avenue

The City previously identified several flood mitigation options in their Flood Mitigation Plan including improvements at Bowman Avenue Dam. Alternatives studied as a part of this analysis include a storage area upstream of the Bowman Dam (Upper Pond - UP) and modifying the orifice opening at the Bowman Dam (Sluice Gate - SG) as shown in the figure 12, which was obtained directly from the City of Rye. These proposed alternatives are consistent with the City's Flood Mitigation Plan.

The report titled "Project Report Flood Mitigation Study Bowman Avenue Dam Site, October 16, 2007" obtained from the City of Rye contains relevant data, graphics, and assumptions for alternatives at Bowman Avenue. Descriptions of the proposed alternatives at Bowman Avenue in the following sections in quotes ("") are directly taken from the above mentioned report.

6.2.2.1 Sluice Gate Modifications

"The existing Bowman Avenue Dam has a low flow orifice at the bottom of the structure with an effective area of approximately 20.2 square feet (sf). Flow through this orifice is restricted by timber railroad ties. Four alternatives examined the effects of increasing the size of the opening without modifying the storage volume behind the dam. The four orifice opening sizes analyzed include: Orifice Area = 45.6 sf, 72.1 sf, 105.6 sf and 139.1 sf. For each design storm frequency, the orifice size that would create the greatest reduction in flow rate at selected down stream points varies. The orifice opening size that creates the optimum flow rate reduction for each flow event was selected. Implementation of orifice optimization 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 will be automatically controlled based on water surface elevations measured by an actuator and level control at the Bowman Avenue Dam. The sluice gate would have remote control capabilities via a SCADA system, however manual overrides will also be provided at the installation."

Due to the differences in the hydrologic methodologies and results between the current study and the study conducted by the City, optimum orifice sizes were recomputed for each flood event. For each design storm frequency, each orifice size at selected stream points (at which the existing conditions TR-20 model was calibrated) within the watershed was analyzed. The orifice opening size that creates the optimum flow rate reduction for each flow event was selected. Table 10 presents the peak flow results and the percent reduction in proposed conditions peak flows compared to existing conditions peak flows (Table 5) at selected locations. Table 11 presents the selected orifice configuration for each flood event.

The October 16, 2007 report results are based on five unique sluice gate orifice configurations for each storm event and an optimum opening size for each event. This implies that full orifice opening will be available for the entire duration of inflow hydrograph for each event was selected. If it were to operate as an "automated sluice gate" as described in the report, the full orifice would not be available for the duration of almost all inflow hydrographs. The orifice opening would increase in size as the water surface level in the pond goes up. The result is that a greater portion of the rising limb inflow hydrographs would be captured than what was reflected in the October 16, 2007 report calculations. Therefore, there will not be as much pond storage available as the flood crest enters the area and the flood will not be attenuated to the extent currently modeled.

TR-20 hydrologic models developed as a part of the current study and used to determine flood damage reduction benefits included the relevant data from the October 16, 2007 report. These computations and modeling methodologies need to be further optimized during the subsequent study phases to reflect the actual operations of the automated sluice gate that is selected. This recalculation will further affect flood damage computations benefit to cost ratios.

6.2.2.2 Sluice Gate combined with Upper Pond

One of the preferred alternatives from the October 16, 2007 Chas Sells report is “Optimizing the orifice opening, maximizing the storage area upstream of the Bowman Avenue Dam (Upper Pond) and dredging 2 feet of sediment material. This alternative includes sluice gate optimization in conjunction with maximizing the storage of the upper pond. Maximizing the storage includes removal of in-situ soils along the northern side of the pond and removal of dumped material through excavation. It is estimated to remove 190,000 cubic yards of material in this process”.

The orifice opening size that created the optimum flow reduction for each flow event was established using a similar procedure as described under “Sluice Gate Modification” option. The four orifice sizes were analyzed with the modified storage volume (proposed Upper Pond volume) behind the Bowman Avenue Dam.

For each design storm frequency, flows at selected stream locations (at which the existing conditions TR-20 model was calibrated) were examined to determine the impacts of changes in orifice size. The orifice opening size that creates the optimum flow rate reduction for each flow event was selected. Table 12 presents the peak flow results and the percent reduction in proposed conditions peak flows compared to existing conditions peak flows (Table 5) at selected locations based on use of the sluice gate combined with the upper pond structural measure. Table 13 presents the selected orifice configuration for each flood event.

6.2.3 Combined Improvements at Anderson Hill Road and at Bowman Avenue

Two different alternatives were analyzed combining proposed alternatives at Anderson Hill Road and at Bowman Avenue.

6.2.3.1 Storage Area Upstream of Anderson Hill Road combined with Sluice Gate Modifications at Bowman Avenue

The proposed stormwater pond upstream of Anderson Hill Road was combined with the proposed Sluice Gate alternative at Bowman Avenue Dam.

The four orifice opening sizes (Orifice Area = 45.6 sf, 72.1 sf, 105.6 sf and 139.1 sf) were analyzed to study the effects of increasing the size of the opening with the proposed pond storage volume upstream of Anderson Hill road. For each design storm frequency, flows at selected stream locations (at which the existing conditions TR-20 model was calibrated) were examined to determine the impacts of changes in orifice size. The orifice opening size that creates the optimum flow rate reduction for each flow event was selected. Table 14 presents the peak flow results and the percent reduction in proposed conditions peak flows compared to existing conditions peak flows at selected locations based on the use of the sluice gate combined with the Anderson Hill Road structural measure. Table 14 presents the selected orifice configuration for each flood event.

6.2.3.2 Storage Area Upstream of Anderson Hill Road combined with Sluice Gate Modifications and Upper Pond at Bowman Avenue

The proposed stormwater pond upstream of Anderson Hill Road was combined with the proposed Sluice Gate and Upper Pond alternatives at Bowman Avenue.

The four orifice opening sizes (Orifice Area = 45.6 sf, 72.1 sf, 105.6 sf and 139.1 sf) were analyzed to study the effects of increasing the size of the opening with the proposed pond storage volumes upstream of Anderson Hill Road and Upper Pond. For each design storm frequency, flows at selected stream locations (at which the existing conditions TR-20 model was calibrated) were examined to determine the impacts of changes in orifice size. . The orifice opening size that creates the optimum flow rate reduction for each flow event was selected. Table 16 presents the peak flow results and the percent reduction in proposed conditions peak flows compared to existing conditions peak flows at selected locations based on the use of the sluice gate combined with both the upper pond at Bowman Avenue and the Anderson Hill road structural measures. Table 17 presents the selected orifice configuration for each flood event.

6.3 Proposed Conditions Hydrology and Hydraulics Analysis

6.3.1 Hydrologic Analysis

Stage-storage-discharge relations were updated in the proposed conditions TR-20 input file for each proposed structural alternative and runoff hydrographs for 1-, 2-, 5-, 10-, 25-, 50-, and 100-year return period events were generated. Peak flows at selected locations within the watershed were calculated using the same approach as described in existing conditions hydrology Section 3.1. Table 18 to 22 present the peak flow results within the watershed based on the proposed structural solutions. Table 23 provides a comparison of proposed conditions peak flows to the existing conditions peak flows within the City.

6.3.2 Hydraulic Analysis

Peak flows from the proposed conditions TR-20 model were used as input in the proposed conditions hydraulic analysis. Water surface elevations were generated for the 1-, 2-, 5-, 10-, 25-, 50-, and 100-year return period events using the HEC-RAS model. Table 24 presents the water surface elevations at selected locations within the City.

6.4 Preliminary Economic Analysis

6.4.1 Proposed Conditions Flood Damage Assessment

Excel based flood damage computations were used as the basis for proposed conditions flood damage analysis. Assumptions used for proposed conditions flood damage assessment are consistent with the assumptions used for existing conditions flood damage assessment. Water surface elevation results derived from proposed conditions HEC-RAS models were used as input into the flood damage assessments. Table 25 to 34 present both total and average annual damage amounts for different proposed structural alternatives. Figures 13 to 22 show the average annual damages by parcel within the municipal limits of the City. It is important to note the flood damage assessment was only conducted for structures within the City of Rye. For further evaluation of flood damage benefits, additional flood damage assessment should be performed for other parts of the watershed which may be affected by any structural measures. It is also noted that the flood damage amounts need to be refined based on additional modeling and optimization of the automated sluice gate modification. This modification most likely will reduce the estimated preliminary benefit to cost ratio results in the report.

6.4.2 Preliminary Cost Estimate

Average annual cost estimates for each structural alternative were estimated using construction costs, operations and maintenance costs, interest during construction and contingency. Average annual costs were calculated using the procedures described in “USACE Economic and Environmental Principles and Guidelines for Water and Related and Resources Implementation Studies – March 10, 1983”.

6.4.2.1 Alternative Upstream of Anderson Hill Road

Construction and Operation and Maintenance costs for the proposed pond upstream of Anderson Hill Road (AH) were developed as a part of this study. Detailed cost estimate breakdown is presented in Appendix C.

6.4.2.2 Alternatives at Bowman Avenue

Construction costs for the proposed Sluice Gate (SG) and Upper Pond (UP) were obtained from the report titled “Project Report Flood Mitigation Study Bowman Avenue Dam Site, October 16, 2007”. In the report a range in construction costs for each alternative was presented. The mid point in the range was used as the representative construction cost in the study. Operations and Maintenance (O&M) costs for both SG and UP alternatives were estimated in this study. Table 35 tabulates the construction and O&M costs for each structural improvement and a detailed cost estimate breakdown for selected alternatives was presented in Appendix C.

6.4.3 Benefit – Cost Analysis

Table 36 shows the project economic analysis summary for the structural measures studied within the watershed. Based on the analysis, the benefit to cost ratio (BCR) for implementing the sluice gate is significantly high compared to other alternatives. It can also be noted that the combined benefits of the pond upstream of AH and SG yield a benefit to cost ratio more than one. In this analysis flood damage reduction benefits are calculated only within the City. When the benefits are computed within the entire watershed, including the Town/Village of Harrison and the Village of Rye Brook, BCR for structural measures will likely increase.

Average annual costs are computed using an interest rate of 4.875%, (source: USACE Economic Guidance Memorandum #08-01). A 50-year period of analysis was used in the performing this analysis. Construction costs for improvements upstream of AH were computed in this study whereas the construction costs for SG and UP were obtained from the City. Operations and Maintenance Costs (O&M) for all the structural alternatives were estimated in this study. Project costs for the combined alternatives were computed using the individual project costs for each alternative. For example, total project costs for the proposed pond upstream of AH and SG are estimated to be $522,100 and $84, 600 respectively. Hence, for the combined alternative (AH and UP), the total project cost is estimated to be $606,700.

Average annual benefits for each proposed alternative are computed as the decrease in average annual damages between existing conditions and proposed conditions alternatives. For example, average annual damages for existing conditions are estimated to be $7,720,000 and the average annual damages for the SG alternative are estimated to be $7,250,000. Hence, the average annual benefit for this alternative would be $469,000. Average annual damages are initially computed using 2007 tax assessors data. Hence, the damage amounts were adjusted to the 2008 dollars using a Consumer Price Index of 3.021%.

Based on the results from Table 36, it can be concluded that the SG modifications alternative provides the maximum benefit to cost ratio of 5.54. The pond upstream of AH provides the minimum BCR of 0.56, but this result is likely to change when the flood damage assessment is performed for the entire watershed. Additionally, BCR are listed below for the following combinations of alternatives:

- BCR for UP and SG is estimated to be 0.86
- BCR for AH and SG is estimated to be 1.49
- BCR for AH, UP and SG is estimated to be 0.92

Since the City of Rye did not identify improvements to UP alone as a viable option, BCR for that option was not analyzed as a part of this study.

6.5 Potential Land Acquisition and Permitting Issues

The proposed location for the pond upstream of AH, within the State University of New York (SUNY) - Purchase campus, was selected based on the communications with the City and the Village of Rye Brook. During the next phase of this study, coordination with the officials from SUNY – Purchase and possibly the Town/Village of Harrison and the Village of Rye Brook may be required to further establish the feasibility of the land acquisition.

Construction of a stormwater pond and the design of the embankment should comply with the New York State Department of Environmental Conservation (NYSDEC) and USACE requirements including all dam safety regulations. From the report titled "Project Report Flood Mitigation Study Bowman Avenue Dam Site, October 16, 2007" it is also noted that dredging the UP at BA may involve removing and disposing contaminated materials. All necessary environmental permits for dredging including USACE Wetlands Permit and NYSDEC Stream Permit should be obtained during the subsequent permitting and design phases.

6.6 Identification and Evaluation of Non-Structural Alternatives

Non-structural flood reduction measures generally do not restrict or alter the path of floodwaters. As a means of protecting structures from flood damages, these measures can involve modifying structures within the floodplain to withstand flooding with minimal damages. Generally, non-structural flood damage reduction measures can include flood-proofing, relocation of structures, regulation of existing land use and future development in the floodplain, advance flood-warning systems, and emergency response planning. These measures can be used to decrease potential future flood damages.

A sensitivity analysis was also performed for the structures within the existing 100-year floodplain to determine the change in the average annual damages within the municipal limits of the City assuming that the first floor of the structures was elevated by one foot. Table 37 shows the average annual damages within the municipal limits of the City for the existing condition and for the proposed structural solutions when the first floor was elevated by one foot. The cost for raising structures one foot would need to be further studied in order to understand the economic impacts of this non structural measure. Also, costs for non-structural solutions were not analyzed as a part of this study scope and they can be analyzed in a future study phase.

7.0 SUMMARY AND RECOMMENDATIONS

The City is subjected to flood damages due to the riverine flooding as well as coastal flooding. As a part of this analysis, existing flood damages due to the riverine flooding from Blind Brook are evaluated. Several alternatives to reduce flood damage have been studied to determine the technical and economic feasibility. Based on the results presented in this report, several alternatives having a BCR of more than one have been identified. Furthermore, these BCR will likely increase once all benefits within the watershed are quantified.

Based on the estimated benefit-cost analysis, SG modifications provide a BCR of 5.54. Therefore, this alternative is recommended for further study. Estimated BCR for the proposed alternative SG combined with increase in storage capacity at UP at Bowman Avenue is 0.86. Hence this alternative may not be economically justified at this time, but may warrant further study depending on extent of additional potential benefits not currently studied that can be identified in the watershed.

Based on the results presented in table 36, estimated BCR for the proposed pond upstream of AH is 0.56. Even though the BCR for this structural alternative is less than one, it is important to note that the flood damage assessment was conducted only for structures within the City of Rye. In order to better understand the feasibility of these alternatives, additional flood damage assessment should be performed within the other parts of the watershed. Similarly, BCR for the other structural alternatives, which combine the alternatives at AH and at Bowman Avenue, are likely to change based on the flood damage assessment within the entire watershed. Hence, it is recommended to conduct a comprehensive flood damage assessment for the entire watershed for consideration of these alternatives.

APPENDIX A

TABLES

Table 1: Existing Conditions: Stage – Storage – Discharge relationship for area upstream of Anderson Hill Road

Stage (ft, NAVD 88)	Storage (ac-ft)	Discharge (cfs)
234.5	0.0	0
239.4	0.1	305
241.4	0.2	490
243.4	3.3	640
245.4	15.8	775
247.4	41.3	1000
249.4	81.5	2050
251.4	139.6	4385
253.4	213.9	7450
255.4	310.7	17500

Table 2: Existing Conditions: Stage – Storage – Discharge relationship for area upstream of Bowman Avenue

Stage (ft, NAVD 88)	Storage (ac-ft)	Discharge (cfs)
35.9	0.0	0
36.2	0.0	10
36.5	0.0	25
37.4	0.0	100
39.3	0.2	200
44.4	1.3	300
51.2	21.1	400
55.4	73.3	500
56.6	112.6	750
57.2	124.0	1000
57.7	131.0	1317
57.9	135.9	1500
58.5	138.2	2160
58.8	144.5	2580
59.3	148.3	3500
59.3	154.4	3490
60.0	163.8	5000

Table 3: Existing Conditions: Stage – Storage – Discharge relationship for area upstream of Interstate 95

Stage (ft, NAVD 88)	Storage (ac-ft)	Discharge (cfs)
12.0	0.0	0
18.0	0.2	30
20.0	0.3	40
22.0	2.4	580
24.0	6.9	1695
26.0	25.5	2330
28.0	61.1	2680
30.0	137.0	2935
32.0	242.5	3520
34.0	386.7	3950
36.0	556.3	4300
38.0	764.0	4605
40.0	1000.4	4865
42.0	1274.8	5115
44.0	1576.1	5350
46.0	1905.1	5590
48.0	2259.3	5830
50.0	2649.4	6380
52.0	3070.1	8495
54.0	3519.5	12090
56.0	3991.4	18570

Table 4: Existing Conditions: Comparison of 100-Year Peak Discharges

Location	Drainage Area (sm)	100-Year Peak Discharges FEMA (cfs)	TR-20 Un-Calibrated (cfs)	TR-20 Calibrated (cfs)
Hutchinson Parkway	3.0	1535	1792	1545
Upstream of Confluence with East Branch	7.8	2580	3698	2591
At USGS gage 01300000 (US of Interstate 95)	9.6	2984	4597	2983
Mouth	10.9	3265	3675	3265

Table 5: Existing Conditions: Summary of Discharges Used in HEC-RAS Model (cfs)

FLOODING SOURCE AND LOCATION	RECURRENCE INTERVAL						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
<u>BLIND BROOK</u>							
At mouth	635	888	1465	1884	2400	2856	3265
At USGS Gage: US of I-95	353	505	909	1332	1956	2487	2983
At Purchase Street[b]	314[a]	475	891[a]	1305[a]	1843	2342	2809
At upstream corporate limit[b]	291[a]	457	881[a]	1289[a]	1836[a]	2253	2702
US of Conf. with East Branch	266	353	869	1271	1787	2204	2591
At Bowman Avenue[b]	328[a]	566[a]	1101	1378	1978	2420	2747
At Cross-Section O[b]	290[a]	513[a]	1000	1252	1797	2197	2494
At cross section Z: At Hutchinson Pkwy	217	316	621	778	1116	1363	1545
At cross section AH (upstream of New Blind Brook CC dam)[b]	137[a]	270	533	668	957	1169	1324
At cross section AM (upstream of Anderson Hill Road)[b]	112[a]	221	437	548	786	959	1086

<u>Notes:</u>

a. Peak flows are obtained from linear interpolation/extrapolation using the TR-20 results.
b. Locations where TR-20 results are not directly available.

Table 6: Standard Industrial Classifications

Property Description	Damage Curve Code	SIC #
Office Building, Professional Building	OFS	86
Service & Gas Station	SGS	55
Auto Body, Tire Shops, Etc.	AUS	75
Restaurants, Bars	RNS	58
Other Storage, Whse./Dist. Facility	EQS	GEN
All Other Health Facilities	HOS	GEN
YMCA,YWCA	RFS	GEN
Libraries	LIB	GEN
Schools	SPS	GEN
Waste Disposal	WDF	GEN
Athletic Fields	RFS	GEN
Government	GOV	GEN
Police & Fire Protection	PFP	GEN

* GEN – Generic non-residential damage curve

Table 7: Existing Conditions: Total Flood Damages (w/ Basements)

Reach	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Blind Brook	$2,381,000	$3,232,000	$6,781,000	$13,630,000	$26,954,000	$38,683,000	$61,936,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 8: Existing Conditions: Cumulative Average Annual Flood Damages by Structure Classification for 100-yr Event (w/ Basements)

Reach	Residential	Commercial	Public	Total
Blind Brook	$7,473,000	$17,000	$3,000	$7,493,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 9: Stage – Storage – Discharge relation for the Proposed pond Upstream of Anderson Hill Road

Stage (ft, NAVD 88)	Storage (ac-ft)	Discharge (cfs)
252	0.0	0.0
253	11.6	3.0
254	23.6	25.0
255	35.8	66.0
256	48.4	123.0
257	61.2	189.0
258	74.4	259.0
259	87.9	323.0
260	101.8	370.0
261	115.9	414.0
262	130.4	453.0

Table 10: Peak Flows and Percent Reduction – Bowman Sluice Gate Modifications

FLOODING SOURCE AND LOCATION	Proposed Conditions Peak Flows (cfs)							% Reduction						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Sluice Gate Area = 20.2 sq.ft (Existing Conditions Opening)														
At mouth	634	885	1454	1872	2385	2837	3249	0	0	1	1	1	1	0
At USGS gage:US of I-95	352	502	844	1284	1917	2452	2948	0	1	7	4	2	1	1
US of Conf. with East Branch	252	332	818	1267	1785	2203	2588	5	6	6	0	0	0	0
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0
Sluice Gate Area = 45.6 sq ft														
At mouth	628	876	1489	1823	2398	2912	3314	1	1	-2	3	0	-2	-2
At USGS gage:US of I-95	371	541	892	1141	1846	2411	2918	-5	-7	2	14	6	3	2
US of Conf. with East Branch	299	445	757	1017	1762	2200	2588	-12	-26	13	20	1	0	0
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0
Sluice Gate Area = 72.1 sq ft														
At mouth	637	896	1538	1915	2272	2893	3364	0	-1	-5	-2	5	-1	-3
At USGS gage:US of I-95	371	573	1078	1333	1705	2301	2858	-5	-13	-19	0	13	7	4
US of Conf. with East Branch	298	473	912	1141	1500	2141	2581	-12	-34	-5	10	16	3	0
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0
Sluice Gate Area = 105.6 sq ft														
At mouth	637	883	1539	1880	2462	2818	3301	0	1	-5	0	-3	1	-1
At USGS gage:US of I-95	365	568	1136	1443	1901	2259	2763	-3	-12	-25	-8	3	9	7

FLOODING SOURCE AND LOCATION	Proposed Conditions Peak Flows (cfs)							% Reduction						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	1-year	2-year	5-year	10-year	25-year	50-year	100-year
US of Conf. with East Branch	294	473	968	1239	1638	1968	2474	-11	-34	-11	3	8	11	5
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0
Sluice Gate Area = 139.1 sq ft														
At mouth	637	897	1489	1895	2482	2946	3369	0	-1	-2	-1	-3	-3	-3
At USGS gage:US of I-95	373	571	1118	1490	2033	2445	2814	-6	-13	-23	-12	-4	2	6
US of Conf. with East Branch	299	470	966	1285	1734	2095	2411	-12	-33	-11	-1	3	5	7
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0

Note: Shaded areas represent maximum flow reductions and associated sluice gate dimension for each recurrence interval

Table 11: Selected Orifice Openings– Sluice Gate

Flood Event	Orifice Area (Sq. ft)
1-year	20.2
2-year	20.2
5-year	20.2
10-year	45.6
25-year	72.1
50-year	105.6
100-year	105.6

Table 12: Peak Flows and Percent Reduction – Bowman Avenue Dam Sluice Gate Modifications and Upper Pond

FLOODING SOURCE AND LOCATION	Proposed Conditions Peak Flows (cfs)							% Reduction						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Sluice Gate Area A = 20.2 sq.ft (Existing Conditions Opening)														
At mouth	618	857	1441	1768	2305	2758	3189	3	3	2	6	4	3	2
At USGS gage:US of I-95	333	466	800	979	1660	2240	2763	6	8	12	27	15	10	7
US of Conf. with East Branch	215	281	469	998	1703	2177	2579	19	20	46	21	5	1	0
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0
Sluice Gate Area = 45.6 sq ft														
At mouth	620	860	1442	1785	2231	2772	3207	2	3	2	5	7	3	2
At USGS gage:US of I-95	334	476	801	996	1526	2169	2717	5	6	12	25	22	13	9
US of Conf. with East Branch	274	405	665	811	1525	2132	2564	-3	-15	23	36	15	3	1
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0
Sluice Gate Area = 72.1 sq ft														
At mouth	621	845	1466	1816	2308	2612	3223	2	5	0	4	4	9	1
At USGS gage:US of I-95	335	506	995	1227	1550	1976	2610	5	0	-9	8	21	21	13
US of Conf. with East Branch	269	444	861	1063	1339	1829	2486	-1	-26	1	16	25	17	4
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0
Sluice Gate Area = 105.6 sq ft														

FLOODING SOURCE AND LOCATION	Proposed Conditions Peak Flows (cfs)							% Reduction						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	1-year	2-year	5-year	10-year	25-year	50-year	100-year
At mouth	621	838	1474	1829	2325	2779	3170	2	6	-1	3	3	3	3
At USGS gage:US of I-95	336	496	1053	1352	1770	2103	2474	5	2	-16	-2	10	15	17
US of Conf. with East Branch	254	439	930	1183	1545	1832	2203	5	-24	-7	7	14	17	15
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0
Sluice Gate Area = 139.1 sq ft														
At mouth	616	850	1452	1835	2345	2806	3230	3	4	1	3	2	2	1
At USGS gage:US of I-95	329	504	1024	1401	1938	2318	2662	7	0	-13	-5	1	7	11
US of Conf. with East Branch	274	437	902	1254	1693	2016	2310	-3	-24	-4	1	5	9	11
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545	3	0	0	0	0	0	0

Note: Shaded areas represent maximum flow reductions and associated sluice gate dimension for each recurrence interval

Table 13: Selected Orifice Openings – Bowman Avenue Sluice Gate Modifications and Upper Pond

Flood Event	Orifice Area (Sq. ft)
1-year	20.2
2-year	20.2
5-year	20.2
10-year	45.6
25-year	72.1
50-year	72.1
100-year	105.6

Table 14: Peak Flows and Percent Reduction – Pond U/S of Anderson Hill Road and Bowman Avenue Sluice Gate Modifications

FLOODING SOURCE AND LOCATION	Proposed Conditions Peak Flows (cfs)							% Reduction						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Sluice Gate Area = 20.2 sq.ft (Existing Conditions Opening)														
At mouth	634	885	1429	1860	2340	2826	3244	0	0	2	1	3	1	1
At USGS gage:US of I-95	352	502	787	1150	1712	2222	2752	0	1	13	14	12	11	8
US of Conf. with East Branch	252	326	682	1102	1567	1965	2375	5	8	22	13	12	11	8
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416	0	-9	1	0	10	12	8
Sluice Gate Area = 45.6 sq ft														
At mouth	636	892	1514	1881	2415	2896	3307	0	0	-3	0	-1	-1	-1
At USGS gage:US of I-95	373	544	886	1112	1618	2166	2710	-6	-8	3	17	17	13	9
US of Conf. with East Branch	300	438	715	880	1489	1947	2371	-13	-24	18	31	17	12	8
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416	0	-9	1	0	10	12	8
Sluice Gate Area = 72.1 sq ft														
At mouth	629	897	1537	1915	2446	2754	3353	1	-1	-5	-2	-2	4	-3
At USGS gage:US of I-95	371	573	1052	1302	1628	2005	2623	-5	-13	-16	2	17	19	12
US of Conf. with East Branch	299	463	849	1059	1334	1757	2328	-12	-31	2	17	25	20	10
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416	0	-9	1	0	10	12	8
Sluice Gate Area = 105.6 sq ft														

FLOODING SOURCE AND LOCATION	Proposed Conditions Peak Flows (cfs)							% Reduction						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	1-year	2-year	5-year	10-year	25-year	50-year	100-year
At mouth	637	897	1536	1919	2456	2924	3418	0	-1	-5	-2	-2	-2	-5
At USGS gage:US of I-95	366	570	1088	1398	1806	2156	2765	-4	-13	-20	-5	8	13	7
US of Conf. with East Branch	295	463	883	1133	1478	1778	2385	-11	-31	-2	11	17	19	8
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1508	0	-9	1	0	10	12	2
Sluice Gate Area = 139.1 sq ft														
At mouth	638	898	1542	1931	2475	2924	3368	0	-1	-5	-2	-3	-2	-3
At USGS gage:US of I-95	375	573	1072	1423	1929	2326	2719	-6	-13	-18	-7	1	6	9
US of Conf. with East Branch	299	460	873	1166	1573	1893	2229	-12	-30	0	8	12	14	14
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416	0	-9	1	0	10	12	8

Note: Shaded areas represent maximum flow reductions and associated sluice gate dimension for each recurrence interval

Table 15: Selected Orifice Openings - Pond U/S of Anderson Hill Road and Bowman Avenue Sluice Gate Modifications

Flood Event	Orifice Area (Sq. ft)
1-year	20.2
2-year	20.2
5-year	20.2
10-year	45.6
25-year	72.1
50-year	72.1
100-year	139.1

Table 16: Peak Flows and Percent Reduction – Pond U/S of Anderson Hill Road and Bowman, Sluice Gate Modifications and Upper Pond

FLOODING SOURCE AND LOCATION	Proposed Conditions Peak Flows (cfs)							% Reduction						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Sluice Gate Area = 20.2 sq.ft (Existing Conditions Opening)														
At mouth	618	857	1441	1743	2287	2741	3180	3	3	2	7	5	4	3
At USGS gage:US of I-95	333	466	800	947	1431	1967	2512	6	8	12	29	27	21	16
US of Conf. with East Branch	215	279	411	791	1425	1890	2335	19	21	53	38	20	14	10
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416	0	-9	1	0	10	12	8
Sluice Gate Area = 45.6 sq ft														
At mouth	620	859	1442	1786	2211	2751	3197	2	3	2	5	8	4	2
At USGS gage:US of I-95	334	473	801	997	1281	1876	2453	5	6	12	25	35	25	18
US of Conf. with East Branch	274	397	623	768	1166	1798	2295	-3	-12	28	40	35	18	11
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416	0	-9	1	0	10	12	8
Sluice Gate Area = 72.1 sq ft														
At mouth	615	838	1463	1813	2303	2713	3128	3	6	0	4	4	5	4
At USGS gage:US of I-95	328	499	955	1185	1482	1736	2288	7	1	-5	11	24	30	23
US of Conf. with East Branch	269	432	799	989	1235	1480	2110	-1	-22	8	22	31	33	19
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416	0	-9	1	0	10	12	8
Sluice Gate Area = 105.6 sq ft														
At mouth	621	856	1469	1825	2319	2771	3205	2	4	0	3	3	3	2

FLOODING SOURCE AND LOCATION	Proposed Conditions Peak Flows (cfs)							% Reduction						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year	1-year	2-year	5-year	10-year	25-year	50-year	100-year
At USGS gage:US of I-95	336	490	990	1289	1667	1992	2306	5	3	-9	3	15	20	23
US of Conf. with East Branch	255	427	844	1085	1400	1671	1941	4	-21	3	15	22	24	25
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416	0	-9	1	0	10	12	8
Sluice Gate Area = 139.1 sq ft														
At mouth	622	857	1467	1828	2337	2799	3227	2	3	0	3	3	2	1
At USGS gage:US of I-95	336	501	967	1303	1809	2192	2557	5	1	-6	2	8	12	14
US of Conf. with East Branch	275	426	821	1121	1538	1831	2134	-3	-21	6	12	14	17	18
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416	0	-9	1	0	10	12	8

Note: Shaded areas represent maximum flow reductions and associated sluice gate dimension for each recurrence interval

Table 17: Selected Orifice Openings-
Pond U/S of Anderson Hill Road, and Bowman Avenue Sluice Gate Modifications and Upper Pond

Flood Event	Orifice Area (Sq. ft)
1-year	20.2
2-year	20.2
5-year	20.2
10-year	45.6
25-year	45.6
50-year	72.1
100-year	105.6

Table 18: Peak discharges with the pond upstream of Anderson Hill Road

FLOODING SOURCE AND LOCATION	RECURRENCE INTERVAL						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
BLIND BROOK							
At mouth	635	888	1455	1874	2387	2846	3261
At USGS Gage: US of I-95	353	505	819	1206	1757	2267	2797
At Purchase Street[b]	314[a]	475	771	1166[a]	1676[a]	2135	2634
At upstream corporate limit[b]	290[a]	457	742	1142[a]	1592	2054	2534
US of Conf. with East Branch	265	349	738	1116	1575	1969	2378
At Bowman Avenue[b]	328[a]	618	1093	1374	1770	2137	2518
At Cross-Section O[b]	289[a]	560	993	1248	1608	1941	2286
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416
At cross section AH (upstream of New Blind Brook CC dam)[b]	136[a]	295	529	666	857	1032	1214
At cross section AM (upstream of Anderson Hill Road)[b]	110[a]	241	434	547	703	847	995

Notes:

a. Peak flows are obtained from linear interpolation/extrapolation using the TR-20 results.
b. Locations where TR-20 results are not directly available.

Table 19: Peak discharges with the Sluice Gate Modifications at Bowman Avenue Dam

FLOODING SOURCE AND LOCATION	RECURRENCE INTERVAL						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
BLIND BROOK							
At mouth	634	885	1454	1823	2272	2818	3301
At USGS Gage: US of I-95	352	502	844	1141	1705	2259	2763
At Purchase Street[b]	308[a]	472	832[a]	1075	1606	2128	2602
At upstream corporate limit[b]	281[a]	454	826[a]	1034	1545	2047	2503
US of Conf. with East Branch	252	332	818	1017	1500	1968	2474
At Bowman Avenue[b]	322[a]	566	1101	1378	1978	2420	2747
At Cross-Section O[b]	283[a]	513	1000	1252	1797	2197	2494
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545
At cross section AH (upstream of New Blind Brook CC dam)[b]	127[a]	270	533	668	957	1169	1324
At cross section AM (upstream of Anderson Hill Road)[b]	101[a]	221	437	548	786	959	1086

Notes:

a. Peak flows are obtained from linear interpolation/extrapolation using the TR-20 results.
b. Locations where TR-20 results are not directly available.

Table 20: Peak discharges with the Sluice Gate Modifications and Upper Pond at Bowman Avenue Dam

FLOODING SOURCE AND LOCATION	RECURRENCE INTERVAL						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
BLIND BROOK							
At mouth	618	857	1441	1785	2308	2612	3170
At USGS Gage: US of I-95	333	466	800	996	1550	1976	2474
At Purchase Street[b]	281[a]	438	754	938	1460	1911[a]	2330
At upstream corporate limit[b]	249[a]	422	725	903	1405	1871[a]	2241
US of Conf. with East Branch	215	281	469	811	1339	1829	2203
At Bowman Avenue[b]	306[a]	566	1101	1378	1978	2420	2747
At Cross-Section O[b]	269[a]	513	1000	1252	1797	2197	2494
At cross section Z: At Hutchinson Pkwy	210	316	621	778	1116	1363	1545
At cross section AH (upstream of New Blind Brook CC dam)[b]	121[a]	270	533	668	957	1169	1324
At cross section AM (upstream of Anderson Hill Road)[b]	97[a]	221	437	548	786	959	1086

Notes:

a. Peak flows are obtained from linear interpolation/extrapolation using the TR-20 results.
b. Locations where TR-20 results are not directly available.

Table 21: Peak discharges with the pond upstream of Anderson Hill Road combined with Sluice Gate Modifications at Bowman Avenue Dam

FLOODING SOURCE AND LOCATION	RECURRENCE INTERVAL						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
BLIND BROOK							
At mouth	634	885	1429	1881	2446	2754	3368
At USGS Gage: US of I-95	352	502	787	1112	1628	2005	2719
At Purchase Street[b]	308[a]	472	741	1048	1534	1888	2560
At upstream corporate limit[b]	281[a]	454	713	1008	1476	1817	2463
US of Conf. with East Branch	252	326	682	880	1334	1757	2229
At Bowman Avenue[b]	324[a]	618	1093	1374	1770	2137	2518
At Cross-Section O[b]	286[a]	560	993	1248	1608	1941	2286
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416
At cross section AH (upstream of New Blind Brook CC dam)[b]	133[a]	295	529	666	857	1032	1214
At cross section AM (upstream of Anderson Hill Road)[b]	107[a]	241	434	547	703	847	995

Notes:

a. Peak flows are obtained from linear interpolation/extrapolation using the TR-20 results.
b. Locations where TR-20 results are not directly available.

Table 22: Peak discharges with the pond upstream of Anderson Hill Road combined with Sluice Gate Modifications and Upper Pond at Bowman Avenue

FLOODING SOURCE AND LOCATION	RECURRENCE INTERVAL						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
BLIND BROOK							
At mouth	618	857	1441	1786	2211	2713	3205
At USGS Gage: US of I-95	333	466	800	997	1281	1736	2306
At Purchase Street[b]	281[a]	438	754	939	1207	1635	2171
At upstream corporate limit[b]	249[a]	422	725	904	1161	1573	2089
US of Conf. with East Branch	215	279	411	768	1166	1480	1941
At Bowman Avenue[b]	308[a]	618	1093	1374	1770	2137	2518
At Cross-Section O[b]	272[a]	560	993	1248	1608	1941	2286
At cross section Z: At Hutchinson Pkwy	216	345	617	776	999	1204	1416
At cross section AH (upstream of New Blind Brook CC dam)[b]	127[a]	295	529	666	857	1032	1214
At cross section AM (upstream of Anderson Hill Road)[b]	103[a]	241	434	547	703	847	995

Notes:

a. Peak flows are obtained from linear interpolation/extrapolation using the TR-20 results.
b. Locations where TR-20 results are not directly available.

Table 23: Comparison of peak flows at selected locations within the City

Storm Event / Location	Existing Cond.	AHR	Flow Reduction	SG	Flow Reduction	UP_SG	Flow Reduction	AHR_SG	Flow Reduction	AHR_ UP_ SG	Flow Reduction
1 - year storm											
At mouth	636	635	1	634	2	618	18	634	2	618	18
At USGS gage: US of I-95	353	353	0	352	1	333	20	352	1	333	20
At Purchase Street	314	314	0	308	6	281	33	308	6	281	33
At Upstream Corporate Limit	291	290	1	281	10	249	42	281	10	249	42
U/S of Confluence with East Branch	266	265	1	252	14	215	51	252	14	215	51
2 - year storm											
At mouth	888	888	0	885	3	857	31	885	3	857	31
At USGS gage: US of I-95	505	505	0	502	3	466	39	502	3	466	39
At Purchase Street	475	475	0	472	3	438	37	472	3	438	37
At Upstream Corporate Limit	457	457	0	454	3	422	35	454	3	422	35
U/S of Confluence with East Branch	353	349	4	332	21	281	72	326	27	279	74
5 - year storm											
At mouth	1465	1455	10	1454	11	1441	24	1429	36	1441	24
At USGS gage: US of I-95	909	819	90	844	65	800	109	787	122	800	109
At Purchase Street	891	771	120	832	59	754	138	741	150	754	138
At Upstream Corporate Limit	881	742	138	826	55	725	155	713	167	725	155
U/S of Confluence with East Branch	869	738	131	818	51	469	400	682	187	411	458
10 - year storm											
At mouth	1884	1874	10	1823	61	1785	99	1881	3	1786	98

Notes:

a. AHR – Pond Upstream of Anderson Hill Road
b. SG – Sluice Gate
c. UP – Upper Pond

Table 23: Comparison of peak flows at selected locations within the City (Continued)

Storm Event / Location	Existing Cond.	AHR	Flow Reduction	SG	Flow Reduction	UP_SG	Flow Reduction	AHR_SG	Flow Reduction	AHR_ UP_ SG	Flow Reduction
At USGS gage: US of I-95	1332	1206	126	1141	191	996	336	1112	220	997	335
At Purchase Street	1305	1166	139	1075	230	938	367	1048	257	939	366
At Upstream Corporate Limit	1289	1142	147	1034	254	903	386	1008	281	904	385
U/S of Confluence with East Branch	1271	1116	155	1017	254	811	460	880	391	768	503
25 - year storm											
At mouth	2400	2387	13	2272	128	2308	92	2446	-46	2211	189
At USGS gage: US of I-95	1956	1757	199	1705	251	1550	406	1628	328	1281	675
At Purchase Street	1843	1676	166	1606	236	1460	382	1534	309	1207	636
At Upstream Corporate Limit	1836	1592	243	1545	290	1405	431	1476	360	1161	675
U/S of Confluence with East Branch	1787	1575	212	1500	287	1339	448	1334	453	1166	621
50 - year storm											
At mouth	2856	2846	10	2818	38	2612	244	2754	102	2713	143
At USGS gage: US of I-95	2487	2267	220	2259	228	1976	511	2005	482	1736	751
At Purchase Street	2342	2135	207	2128	215	1911	432	1888	454	1635	707
At Upstream Corporate Limit	2253	2054	199	2047	207	1871	382	1817	437	1573	680
U/S of Confluence with East Branch	2204	1969	235	1968	236	1829	375	1757	447	1480	724
100 - year storm											
At mouth	3265	3261	4	3301	-36	3170	95	3368	-103	3205	60
At USGS gage: US of I-95	2983	2797	186	2763	220	2474	509	2719	264	2306	677
At Purchase Street	2809	2634	175	2602	207	2330	479	2560	249	2171	637
At Upstream Corporate Limit	2702	2534	168	2503	199	2241	461	2463	239	2089	613
U/S of Confluence with East Branch	2591	2378	213	2474	117	2203	388	2229	362	1941	650

Notes:

a. AHR – Pond Upstream of Anderson Hill Road
b. SG – Sluice Gate
c. UP – Upper Pond

Table 24: Water Surface Elevations (ft) at selected locations within the City

HEC-RAS Station	Locations	Existing Conditions	Proposed Conditions									
			Pond U/S of AH Rd	Reduction in WSEL	SG Only	Reduction in WSEL	UP & SG	Reduction in WSEL	Pond AH Rd & SG	Reduction in WSEL	Pond AH Rd & UP & SG	Reduction in WSEL
1-year Storm												
19434.98	U/S of I-287	29.81	29.8	0.01	29.76	0.05	29.61	0.2	29.76	0.05	29.61	0.2
19109.74	D/S of I-287	29.28	29.28	0	29.24	0.04	29.07	0.21	29.24	0.04	29.07	0.21
16593.28	U/S of Purchase Street	23.49	23.49	0	23.48	0.01	23.48	0.01	23.48	0.01	23.38	0.11
16442.38	D/S of Purchase Street	23.2	23.2	0	23.19	0.01	23.09	0.11	23.19	0.01	23.09	0.11
13040.06	U/S of I-95	17.04	17.04	0	17.03	0.01	16.92	0.12	17.03	0.01	16.92	0.12
12698.45	D/S of I-95	16.74	16.74	0	16.74	0	16.64	0.1	16.74	0	16.64	0.1
2-year Storm												
19434.98	U/S of I-287	30.45	30.45	0	30.44	0.01	30.33	0.12	30.44	0.01	30.33	0.12
19109.74	D/S of I-287	29.99	29.99	0	29.98	0.01	29.86	0.13	29.98	0.01	29.86	0.13
16593.28	U/S of Purchase Street	24.36	24.36	0	24.35	0.01	24.21	0.15	24.35	0.01	24.21	0.15
16442.38	D/S of Purchase Street	23.84	23.84	0	23.83	0.01	23.7	0.14	23.83	0.01	23.7	0.14
13040.06	U/S of I-95	18.52	18.52	0	18.5	0.02	17.97	0.55	18.5	0.02	17.97	0.55
12698.45	D/S of I-95	17.8	17.8	0	17.79	0.01	17.67	0.13	17.79	0.01	17.67	0.13
	5-year Storm											
19434.98	U/S of I-287	31.8	31.39	0.41	31.64	0.16	31.33	0.47	31.34	0.46	31.33	0.47
19109.74	D/S of I-287	31.34	30.96	0.38	31.19	0.15	30.9	0.44	30.9	0.44	30.9	0.44
16593.28	U/S of Purchase Street	25.78	25.44	0.34	25.59	0.19	25.38	0.4	25.38	0.4	25.38	0.4
16442.38	D/S of Purchase Street	25.08	24.81	0.27	24.9	0.18	24.76	0.32	24.76	0.32	24.76	0.32
13040.06	U/S of I-95	20.82	20.54	0.28	20.61	0.21	20.46	0.36	20.47	0.35	20.46	0.36
12698.45	D/S of I-95	19.81	19.69	0.12	19.72	0.09	19.64	0.17	19.64	0.17	19.64	0.17
10-year Storm												
19434.98	U/S of I-287	32.72	32.43	0.29	32.19	0.53	31.87	0.85	31.87	0.85	31.87	0.85
19109.74	D/S of I-287	32.18	31.91	0.27	31.7	0.48	31.4	0.78	31.4	0.78	31.4	0.78

Notes:

a. AHR – Pond Upstream of Anderson Hill Road
b. SG – Sluice Gate
c. UP – Upper Pond

Table 24: Water Surface Elevations (ft) at selected locations within the City (Continued)

HEC-RAS Station	Locations	Existing Conditions	Proposed Conditions									
			Pond U/S of AH Rd	Reduction in WSEL	SG Only	Reduction in WSEL	UP & SG	Reduction in WSEL	Pond AH Rd & SG	Reduction in WSEL	Pond AH Rd & UP & SG	Reduction in WSEL
16593.28	U/S of Purchase Street	26.94	26.59	0.35	26.37	0.57	25.97	0.97	25.97	0.97	25.97	0.97
16442.38	D/S of Purchase Street	26.11	25.82	0.29	25.66	0.45	25.29	0.82	25.3	0.81	25.3	0.81
13040.06	U/S of I-95	22.38	22	0.38	21.79	0.59	21.41	0.97	21.41	0.97	21.41	0.97
12698.45	D/S of I-95	20.7	20.59	0.11	20.5	0.2	20.4	0.3	20.4	0.3	20.4	0.3
25-year Storm												
19434.98	U/S of I-287	33.58	33.25	0.33	33.17	0.41	32.94	0.64	32.82	0.76	31.33	2.25
19109.74	D/S of I-287	32.94	32.64	0.3	32.57	0.37	32.37	0.57	32.27	0.67	30.9	2.04
16593.28	U/S of Purchase Street	28.45	27.99	0.46	27.83	0.62	27.44	1.01	27.26	1.19	25.38	3.07
16442.38	D/S of Purchase Street	27.6	27.14	0.46	27.01	0.59	26.64	0.96	26.47	1.13	24.76	2.84
13040.06	U/S of I-95	24.53	23.85	0.68	23.66	0.87	23.17	1.36	22.97	1.56	20.46	4.07
12698.45	D/S of I-95	21.52	21.35	0.17	21.24	0.28	21.14	0.38	21.1	0.42	19.64	1.88
50-year Storm												
19434.98	U/S of I-287	34.26	33.94	0.32	33.93	0.33	33.64	0.62	33.83	0.43	33.21	1.05
19109.74	D/S of I-287	33.44	33.21	0.23	33.2	0.24	32.99	0.45	33.13	0.31	32.61	0.83
16593.28	U/S of Purchase Street	30.11	29.22	0.89	29.2	0.91	28.56	1.55	29.04	1.07	27.92	2.19
16442.38	D/S of Purchase Street	28.89	28.35	0.54	28.33	0.56	27.66	1.23	28.17	0.72	27.1	1.79
13040.06	U/S of I-95	26.51	25.68	0.83	25.65	0.86	24.63	1.88	25.4	1.11	23.87	2.64
12698.45	D/S of I-95	22.19	22	0.19	21.98	0.21	21.65	0.54	21.92	0.27	21.55	0.64
100-year Storm												
19434.98	U/S of I-287	35.02	34.74	0.28	34.69	0.33	34.24	0.78	34.59	0.43	34	1.02
19109.74	D/S of I-287	34.02	33.81	0.21	33.77	0.25	33.43	0.59	33.68	0.34	33.25	0.77
16593.28	U/S of Purchase Street	31.7	31.4	0.3	31.35	0.35	30.1	1.6	30.52	1.18	29.32	2.38
16442.38	D/S of Purchase Street	31.5	31.07	0.43	31	0.5	28.86	2.64	29.51	1.99	28.45	3.05
13040.06	U/S of I-95	30.31	29.91	0.4	29.84	0.47	26.46	3.85	27.49	2.82	25.82	4.49
12698.45	D/S of I-95	22.42	22.32	0.1	22.3	0.12	22.15	0.27	22.27	0.15	22.05	0.37

Notes:

a. AHR – Pond Upstream of Anderson Hill Road
b. SG – Sluice Gate
c. UP – Upper Pond

Table 25: Total Flood Damages (w/ Basements) in 2007 dollars with Pond U/S of Anderson Hill Road

Reach	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Blind Brook	$2,381,000	$3,232,000	$6,723,000	$12,364,000	$24,526,000	$35,246,000	$57,566,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 26: Cumulative Average Annual Flood Damages in 2007 dollars by Structure Classification for 100-yr Event (w/ Basements) with Pond U/S of Anderson Hill Road

Reach	Residential	Commercial	Public	Total
Blind Brook	$7,196,000	$11,000	$3,000	$7,210,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 27: Total Flood Damages (w/ Basements) in 2007 dollars with Sluice Gate Modifications at Bowman Dam

Reach	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Blind Brook	$2,381,000	$3,232,000	$6,723,000	$11,264,000	$22,646,000	$34,780,000	$57,060,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 28: Cumulative Average Annual Flood Damages in 2007 dollars by Structure Classification for 100-yr Event (w/ Basements) with Sluice Gate Modifications at Bowman Dam

Reach	Residential	Commercial	Public	Total
Blind Brook	$7,023,000	$11,000	$3,000	$7,037,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 29: Total Flood Damages (w/ Basements) in 2007 dollars with Sluice Gate Modifications and Upper Pond at Bowman Avenue

Reach	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Blind Brook	$2,381,000	$3,130,000	$6,538,000	$9,718,000	$19,630,000	$28,522,000	$39,979,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 30: Cumulative Average Annual Flood Damages in 2007 dollars by Structure Classification for 100-yr Event (w/ Basements) with Sluice Gate Modifications and Upper Pond at Bowman Avenue

Reach	Residential	Commercial	Public	Total
Blind Brook	$6,533,000	$3,000	$0	$6,536,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 31: Total Flood Damages (w/ Basements) in 2007 dollars with Pond U/S of Anderson Hill Road and Sluice Gate Modifications at Bowman Dam

Reach	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Blind Brook	$2,381,000	$3,232,000	$6,538,000	$9,718,000	$18,104,000	$33,202,000	$45,274,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 32: Cumulative Average Annual Flood Damages in 2007 dollars by Structure Classification for 100-yr Event (w/ Basements) with Pond U/S of Anderson Hill Road and Sluice Gate Modifications at Bowman Dam

Reach	Residential	Commercial	Public	Total
Blind Brook	$6,607,000	$4,000	$1,000	$6,612,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 33: Total Flood Damages (w/ Basements) in 2007 dollars with Pond U/S of Anderson Hill Road and Sluice Gate Modifications and Upper Pond at Bowman Avenue

Reach	1-year	2-year	5-year	10-year	25-year	50-year	100-year
Blind Brook	$2,381,000	$3,232,000	$6,538,000	$9,718,000	$6,538,000	$26,145,000	$37,230,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 34: Cumulative Average Annual Flood Damages in 2007 dollars by Structure Classification for 100-yr Event (w/ Basements) with Pond U/S of Anderson Hill Road and Sluice Gate Modifications and Upper Pond at Bowman Avenue

Reach	Residential	Commercial	Public	Total
Blind Brook	$6,002,000	$1,000	$0	$6,003,000

(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

Table 35: Structural Improvements - Cost Summary

			Construction Cost	O&M Cost
Existing Conditions				
Proposed Conditions	Anderson Hill Road (AH)	Pond U/S of the Road (AH)	$ 9,100,00	$42,000
	Bowman Ave (BA)	Sluice Gate (SG)	$1,500,000[a]	$5,000
		Upper Pond (UP) & SG	$20,000,000[a]	$103,000
	Combined (AH & BA)	AH & SG	$10,600,000	$47,000
		AH & UP & SG	$29,100,000	$145,000

a: Obtained from the City of Rye.

Table 36: Benefit to Cost Ratio Results

			Average Annual Damages (2007 Dollars)	Adjusted Average Annual Damages (2008 dollars)	Average Annual Costs (C)	Average Annual Benefits (B)	B/C Ratio
Existing Conditions			$7,493,000	$7,720,000			
Proposed Conditions	Anderson Hill Road (AH)	Pond U/S of the Road (AH)	$7,210,000	$7,428,000	$522,100	$291,000	0.56
	Bowman Ave (BA)	Sluice Gate (SG)	$7,037,000	$7,250,000	$84,600	$469,000	5.54
		Upper Pond (UP) & SG	$6,536,000	$6,733,000	$1,153,000	$986,000	0.86
	Combined (AH & BA)	AH & SG	$6,612,000	$6,812,000	$606,700	$907,000	1.49
		AH & UP & SG	$6,003,000	$6,185,000	$1,675,100	$1,535,000	0.92

Notes:

a. Average annual costs are computed using an interest rate of 4.875%, (source: USACE Economic Guidance Memorandum #08-01) period of analysis of 50 years.
b. Construction and O&M costs for proposed pond upstream of AH are computed by HDR.
c. Construction costs for SG, and UP&SG are obtained from the City of Rye. HDR estimated the average annual O&M costs.
d. Project costs for combined alternatives (ex: AH & SG) are obtained by adding project costs for individual alternatives.
e. Benefits are computed as the decrease in average annual damages between existing conditions and conditions with proposed alternatives.
f. Average annual damages are computed based on 2007 tax assessors data.
g. Adjusted Average Annual Damages are computed using a Consumer Price Index of 3.021%.
h. Average annual benefits are calculated only within the City.

Table 37: Total Flood Damages (w/ Basements) – Elevate Structures by One Foot

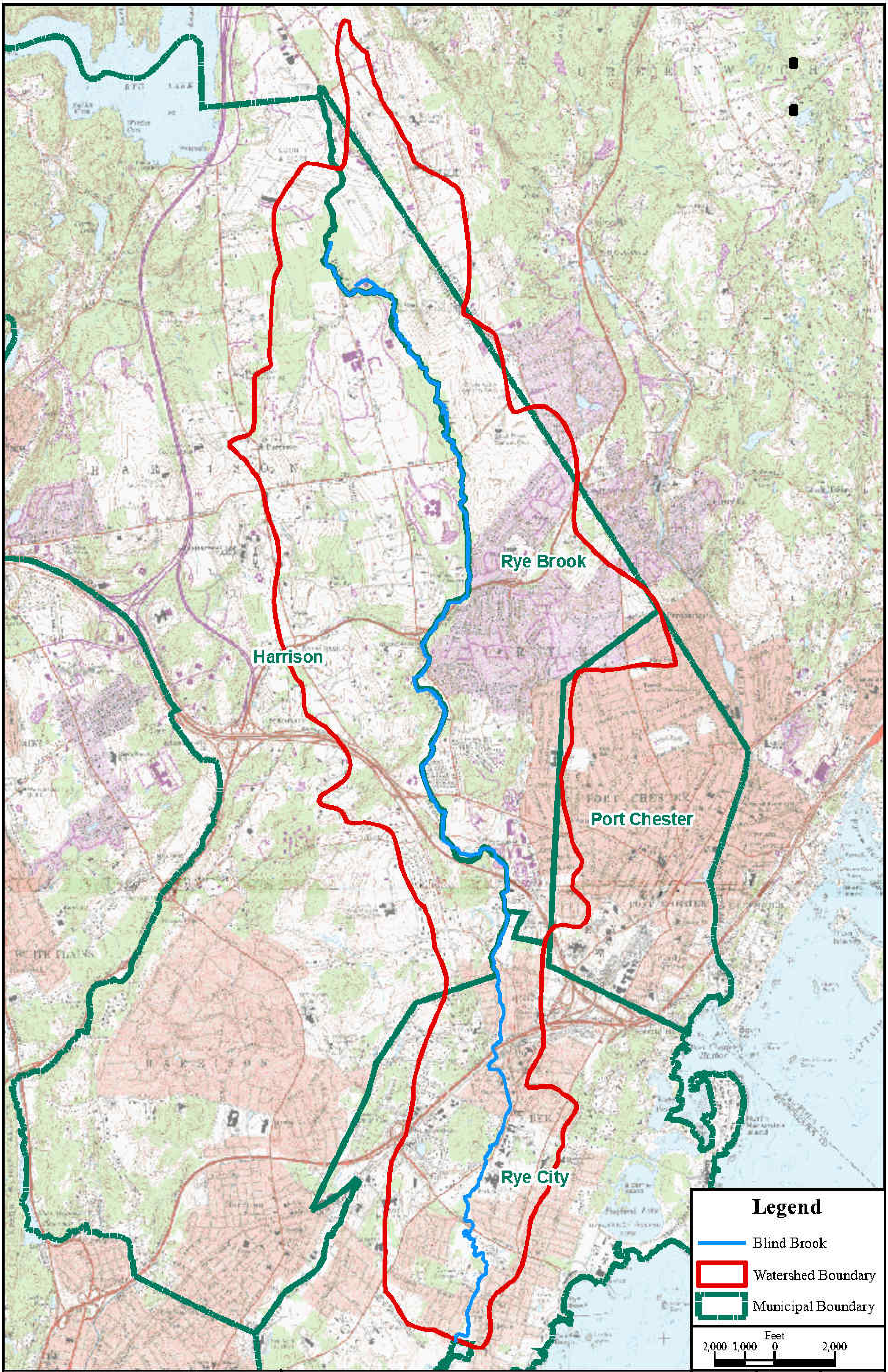
Condition	Residential	Commercial	Public	Total
Existing	$6,001,958	$1,293	$0	$6,003,000
Anderson Hill Rd	$5,585,397	$5,959	$2,113	$5,593,000
Sluice Gate	$5,450,310	$5,959	$2,113	$5,458,000
Upper Pond & Sluice Gate	$5,056,345	$491	$0	$5,057,000
Anderson Hill Rd & Sluice Gate	$5,119,324	$1,388	$0	$5,121,000
Anderson Hill Rd, Upper Pond, & Sluice Gate	$4,631,409	$410	$0	$4,632,000

a. Average annual damages are computed based on 2007 tax assessors data.

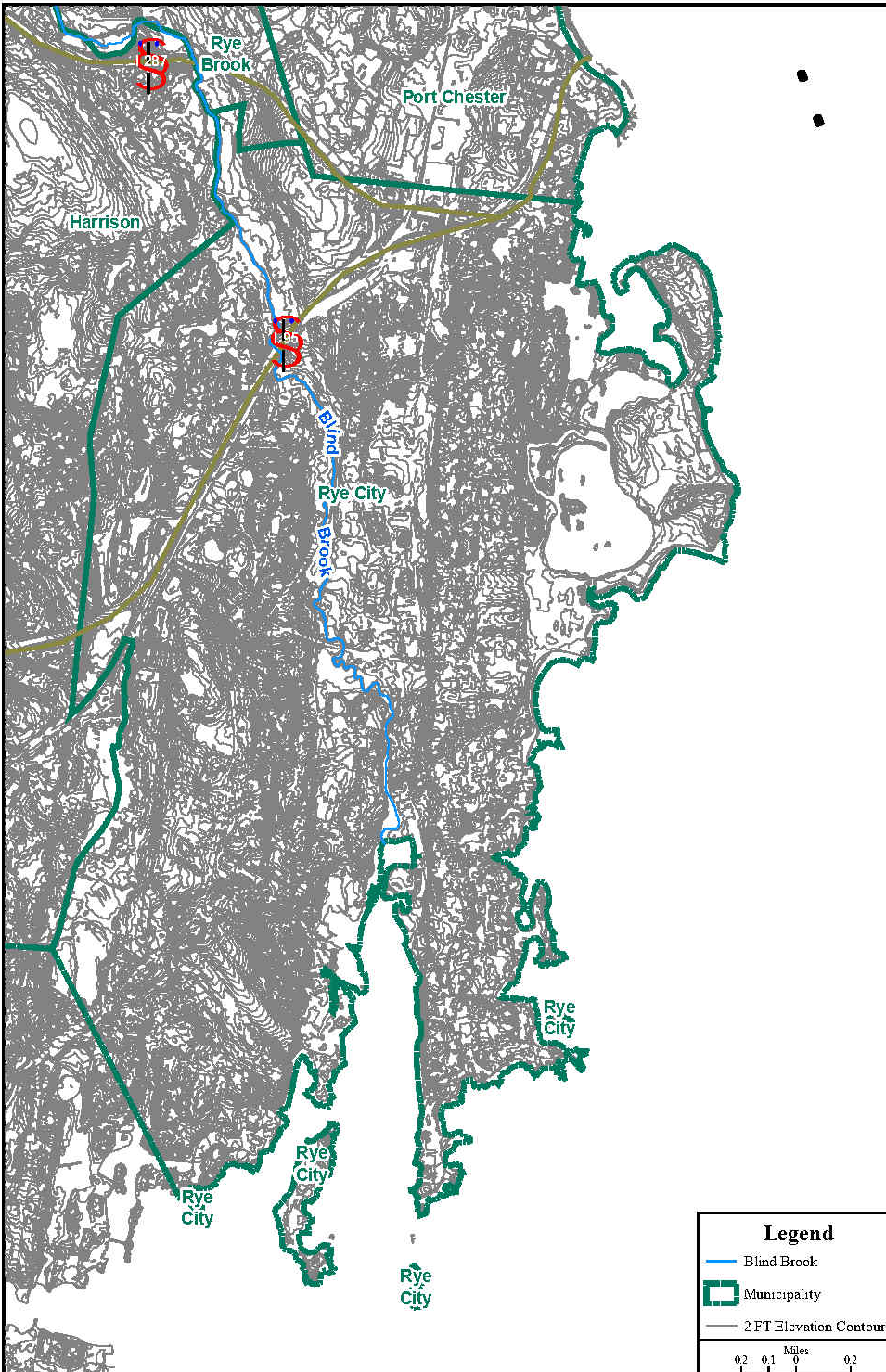
(Analysis is limited to structures within 100 year floodplain and City municipal limits based on riverine flooding.)

APPENDIX B

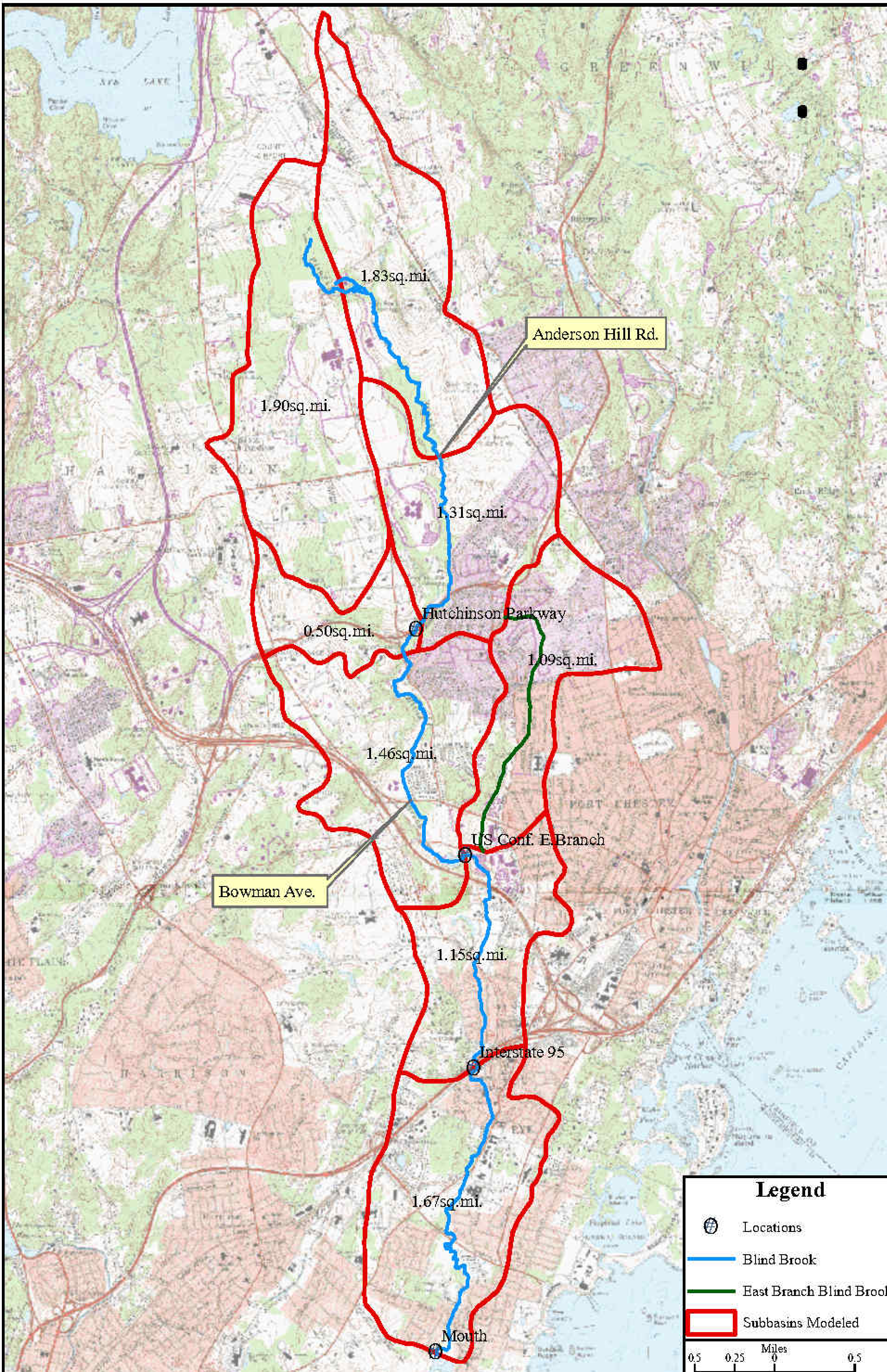
FIGURES



U.S. Army Corps of Engineers New York District	Blind Brook Watershed Municipalities	Job No.	Date	Figure No.
		66905	Mar 2009	1



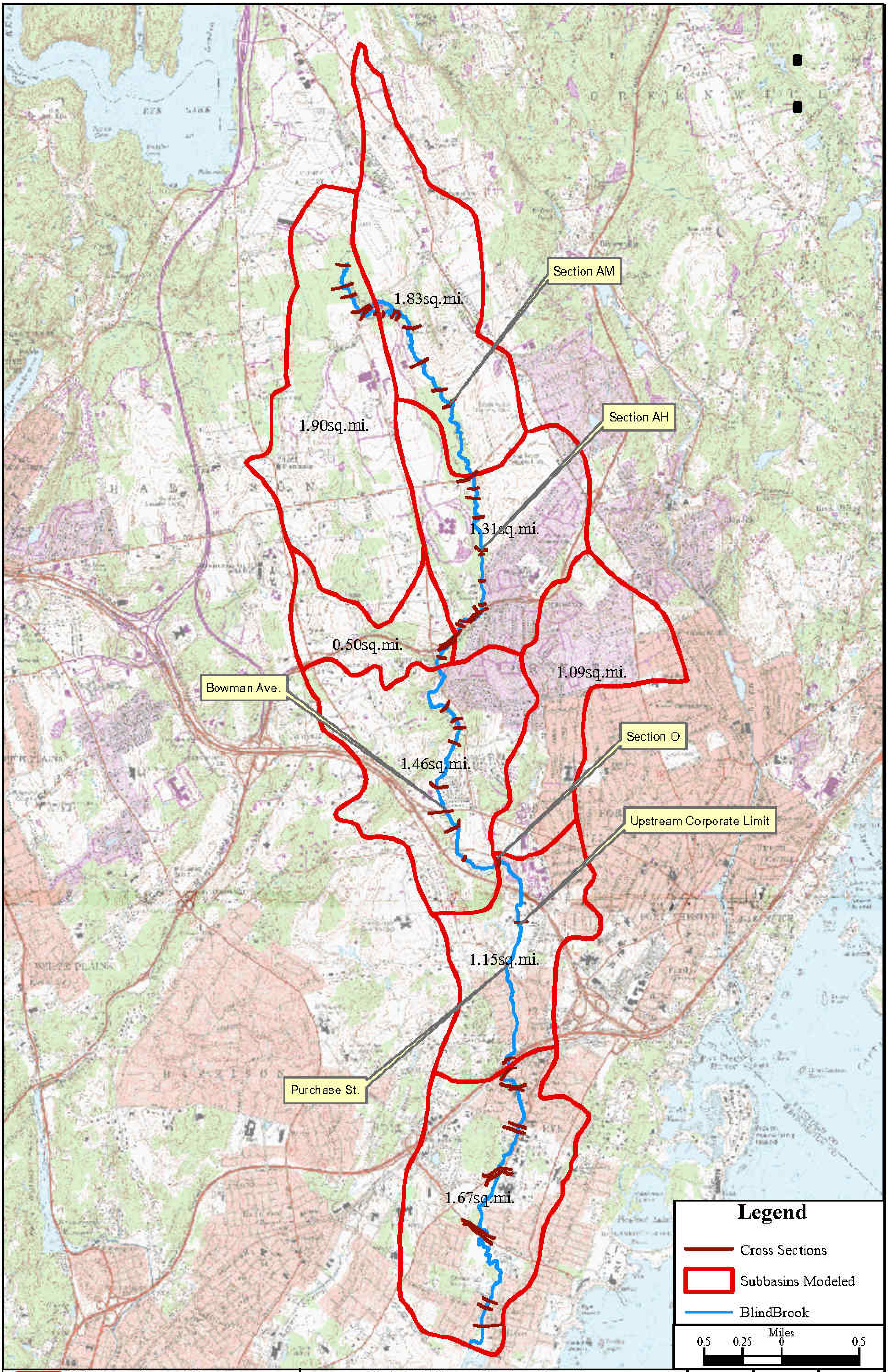
U.S. Army Corps of Engineers New York District	Existing Topography (2ft Contours)	Job No.	Date	Figure No.
		66905	Mar 2009	2



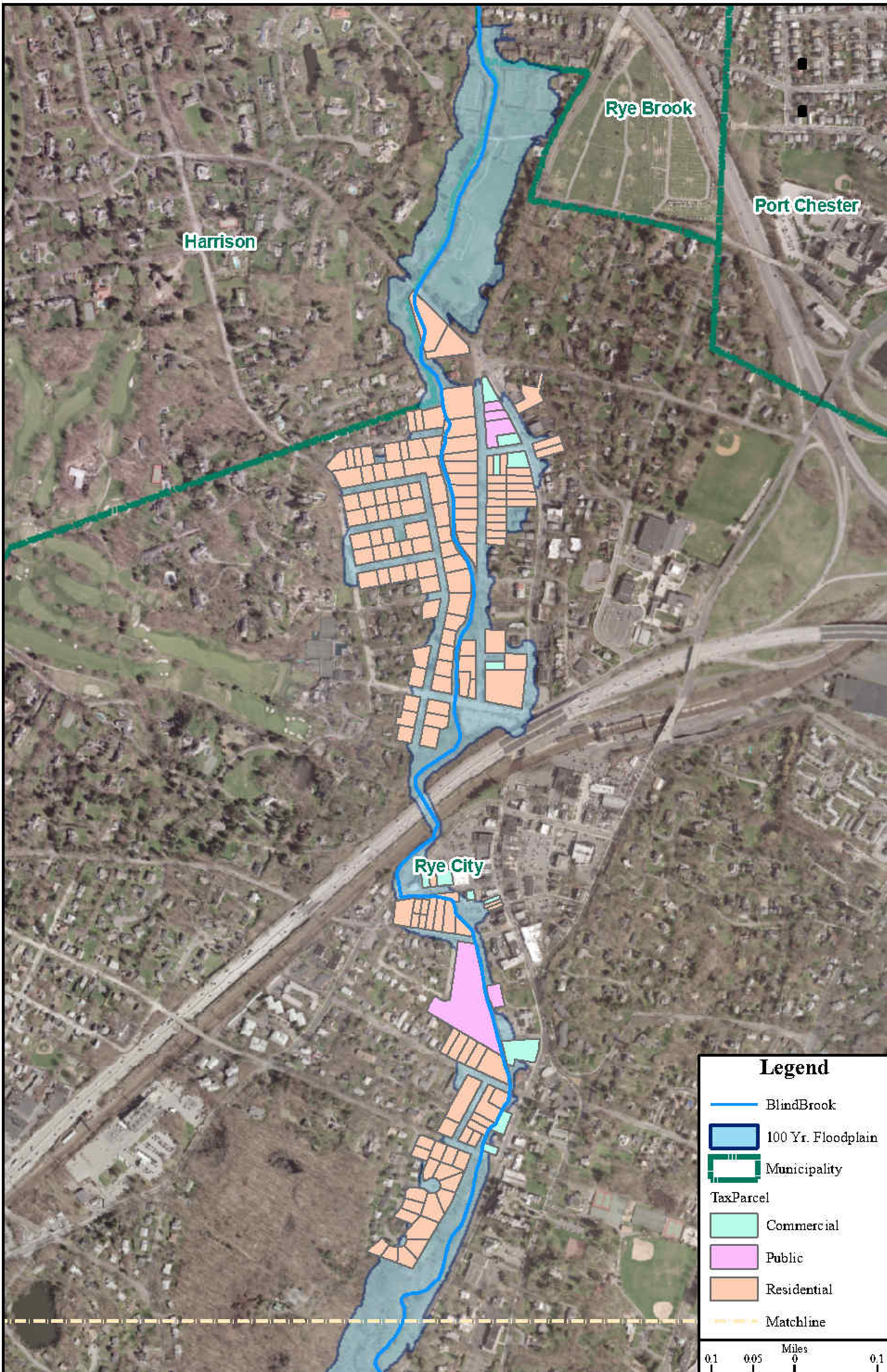
U.S. Army Corps of Engineers
New York District

Locations Where TR-20 Peak Discharges Are Compared to 2006 FEMA FIS Peak Discharges

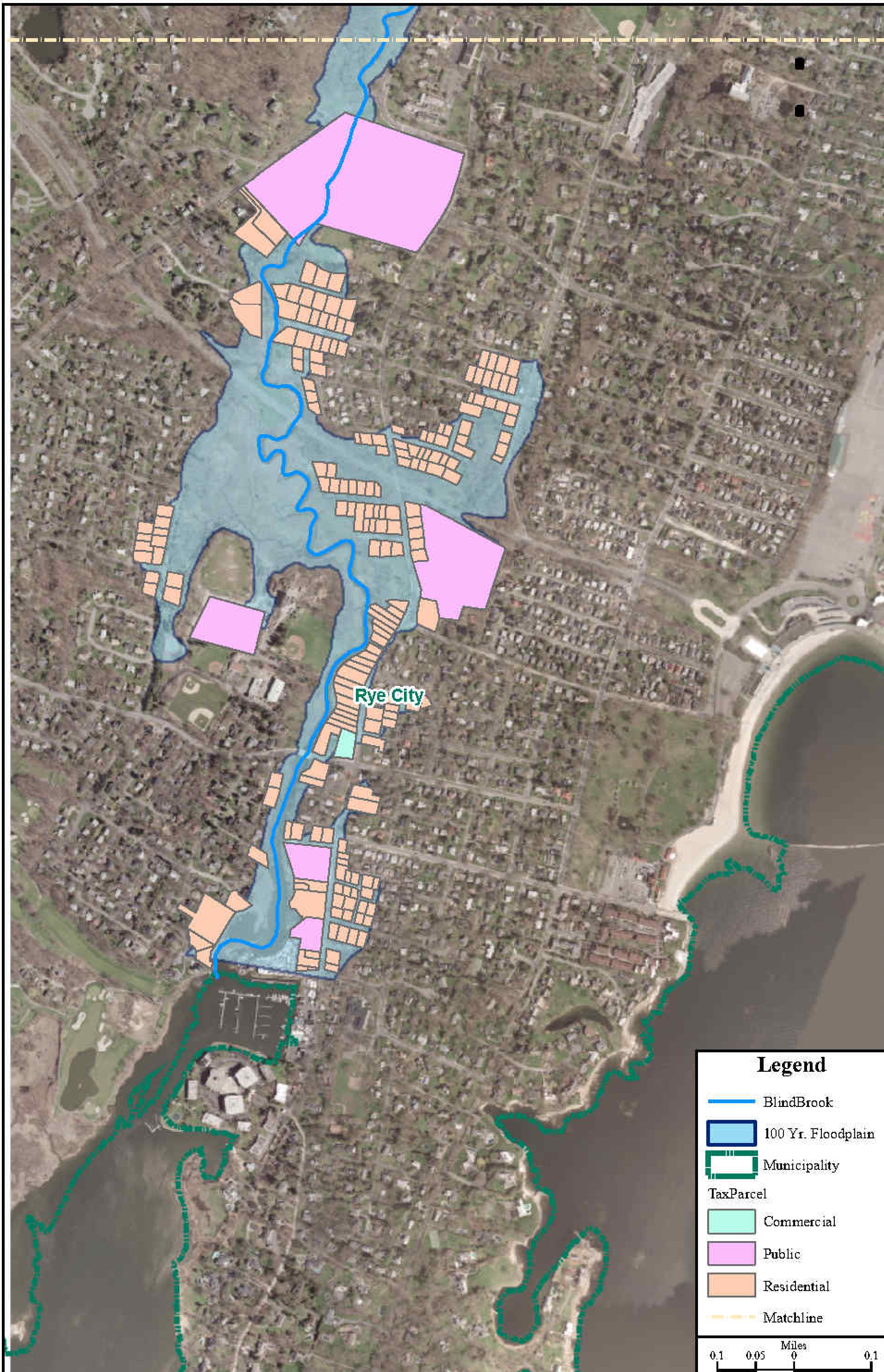
Job No.	Date	Figure No.
66905	Mar 2009	3



U.S. Army Corps of Engineers New York District	Labeled Cross Section Locations (2006 FEMA Study)	Job No.	Date	Figure No.
		66905	Mar 2009	4

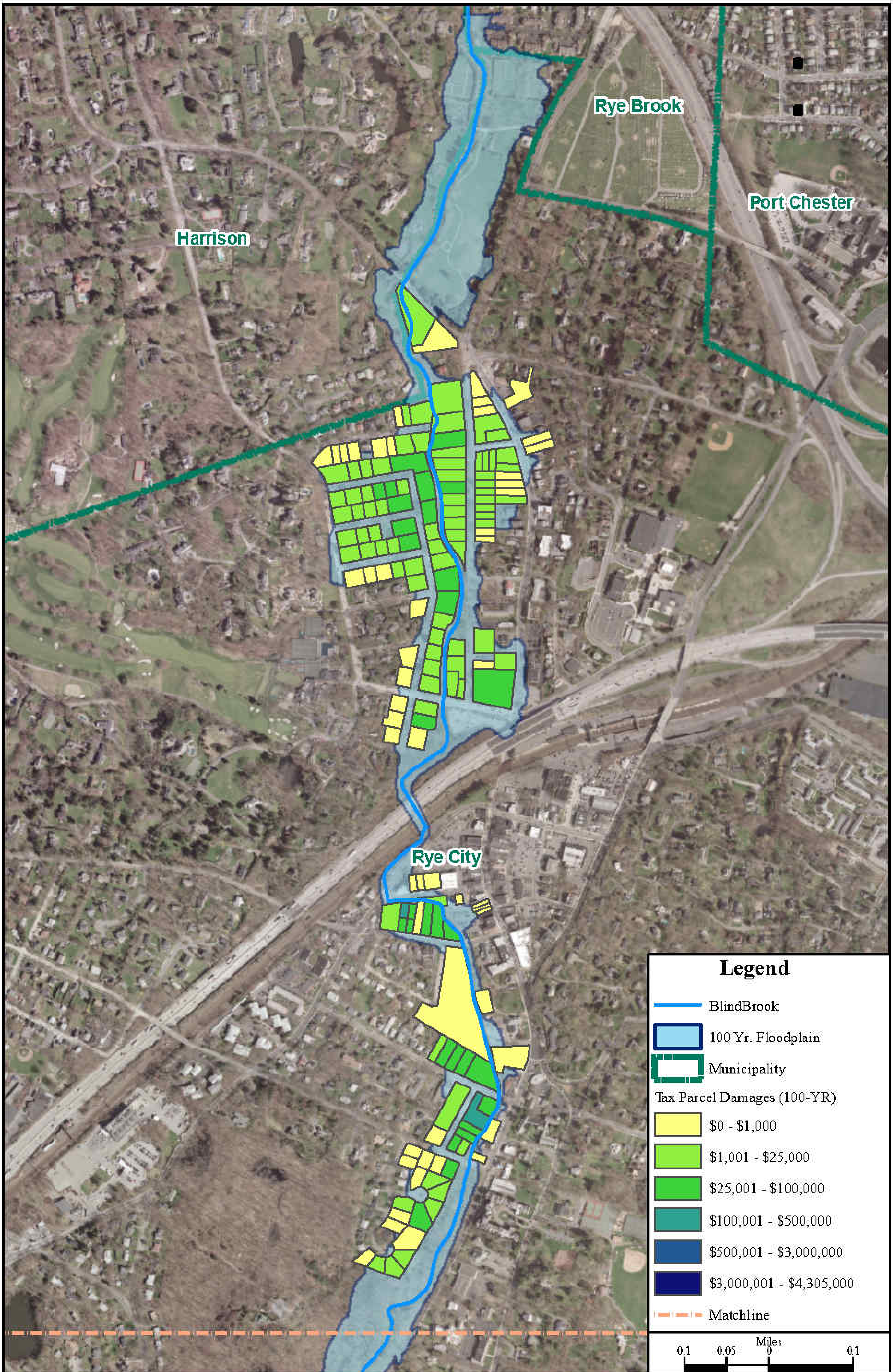


U.S. Army Corps of Engineers New York District	Classification of Parcels within 100 Yr. Floodplain within City of Rye-1	Job No.	Date	Figure No.
		66905	Mar 2009	5

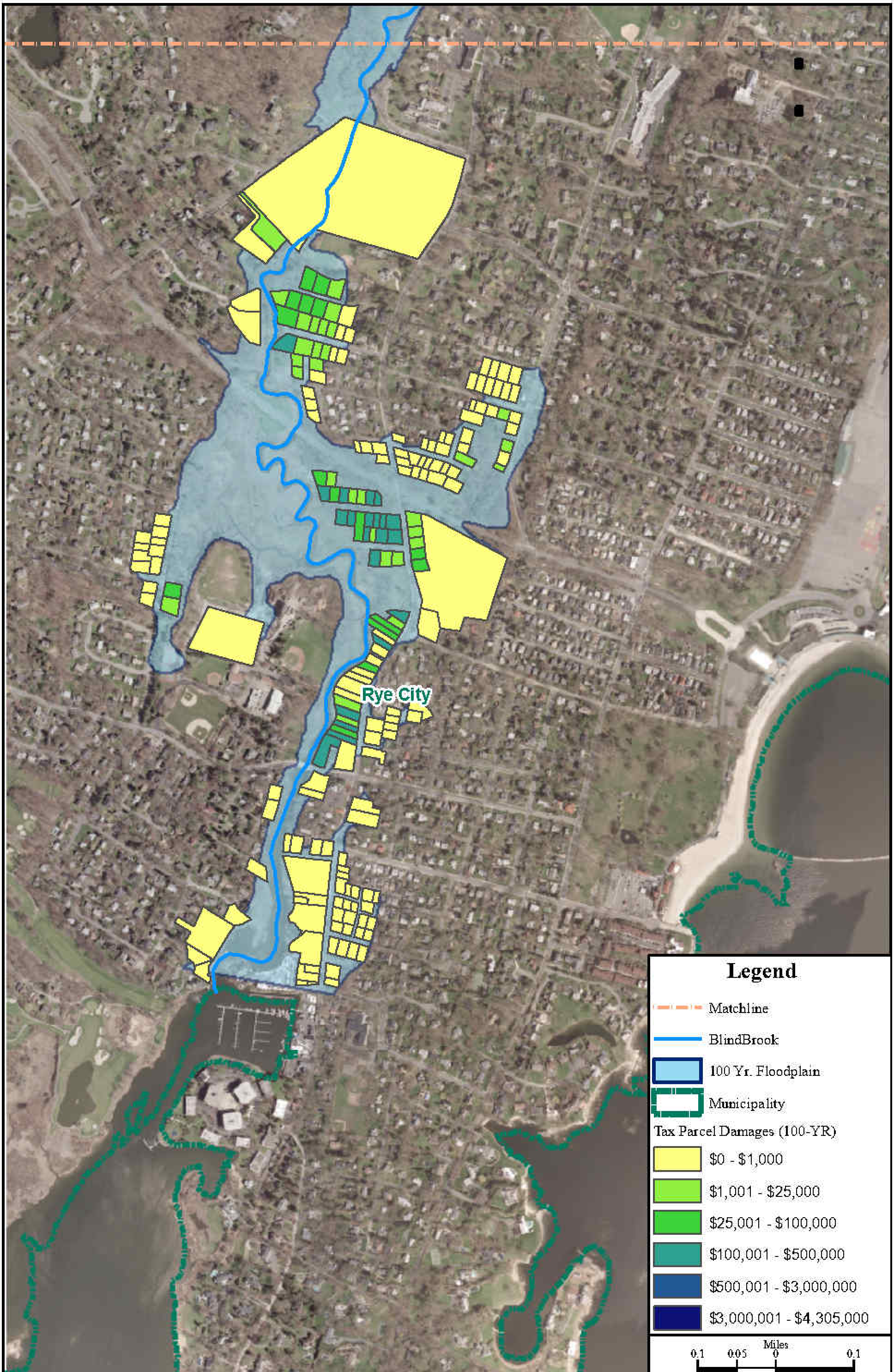


U.S. Army Corps of Engineers New York District	Classification of Parcels within 100 Yr. Floodplain within City of Rye-2	Job No.	Date	Figure No.
		66905	Mar 2009	6

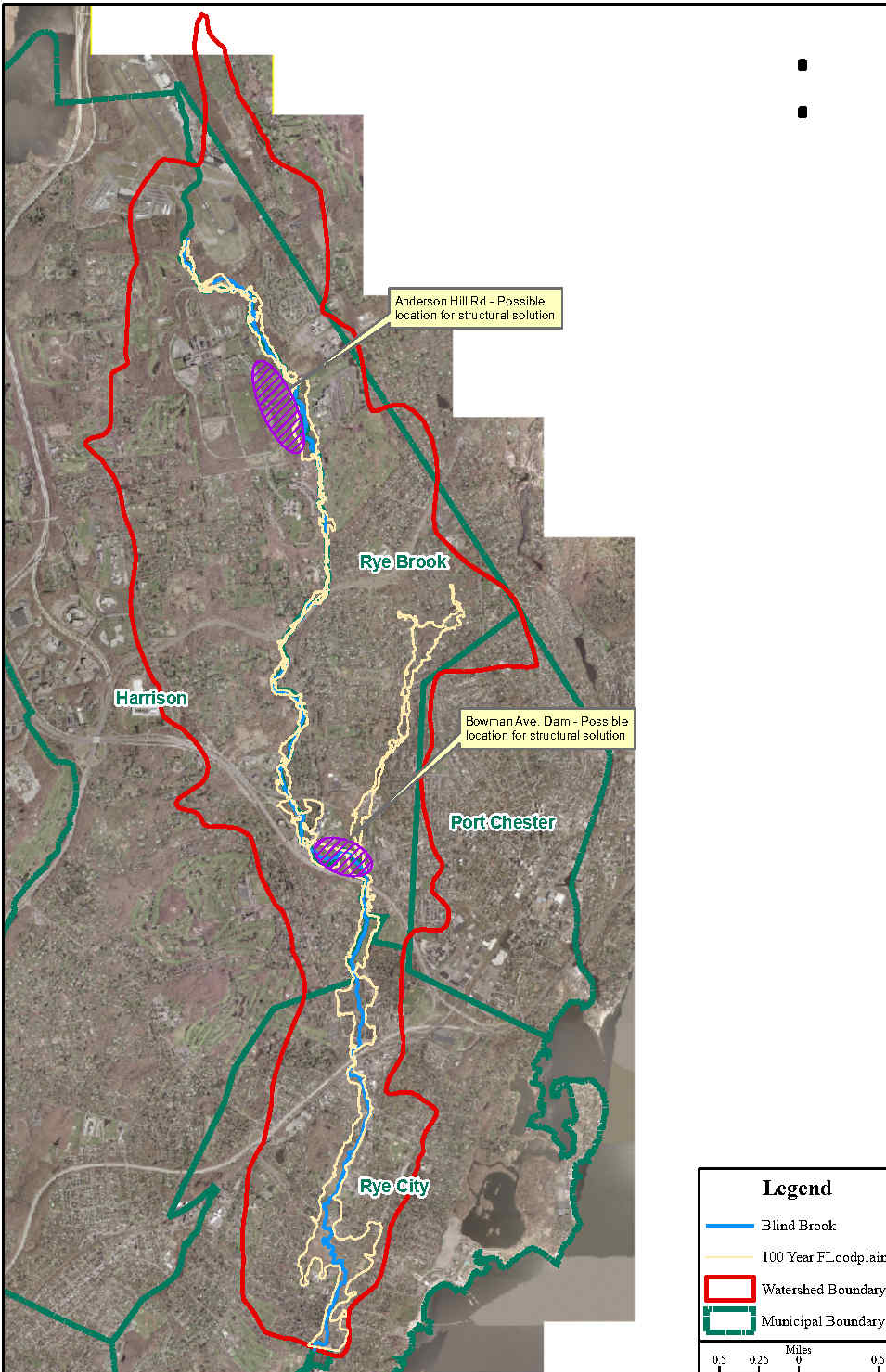
U.S. Army Corps of Engineers New York District	Structures within 100 Yr. Floodplain within City of Rye Municipal Limits	Job No.	Date	Figure No.
		66905	Mar 2009	7



U.S. Army Corps of Engineers New York District	Average Annual Flood Damages within 100 Yr. Floodplain w/Basements-1	Job No.	Date	Figure No.
		66905	Mar 2009	8



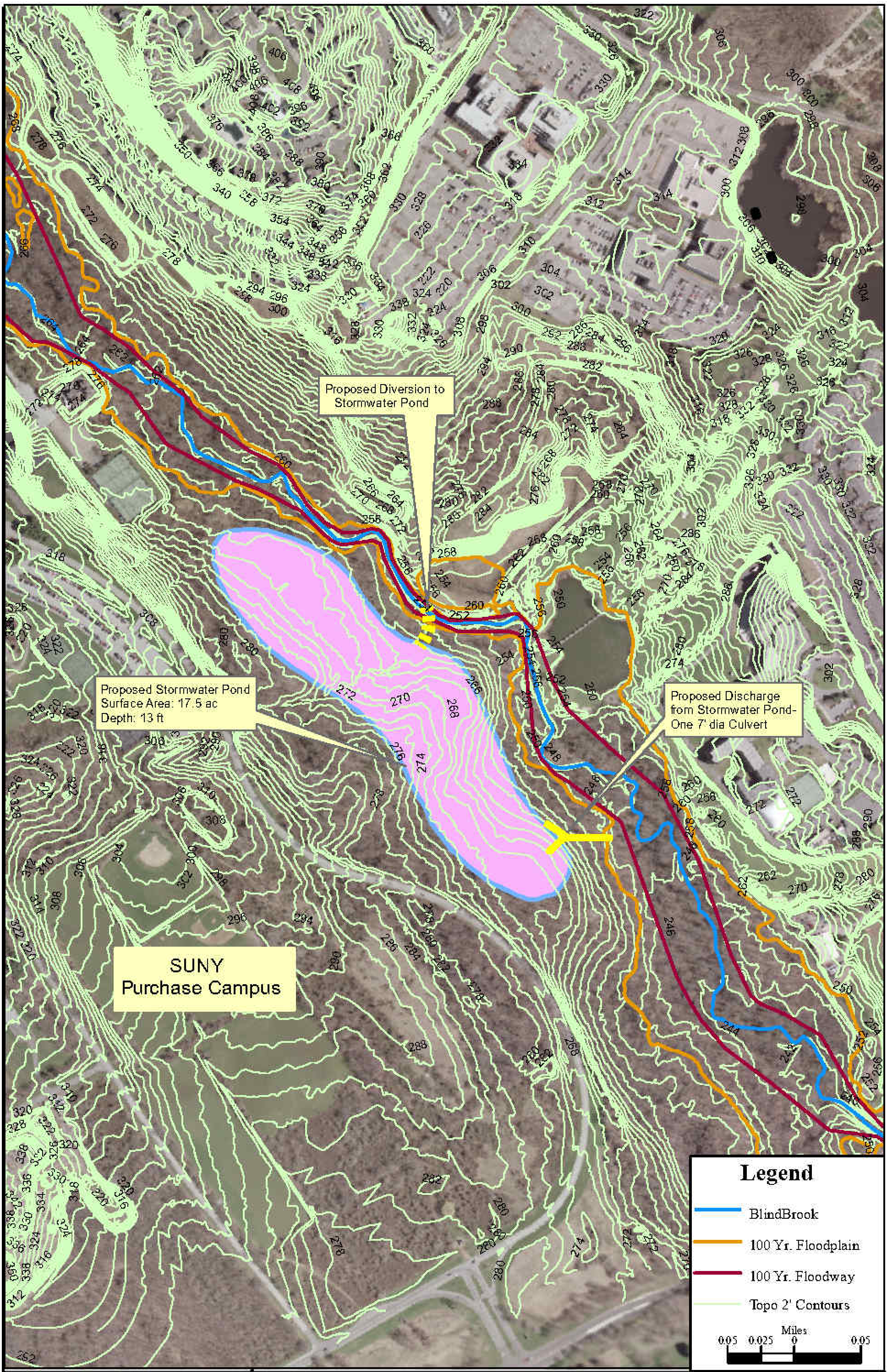
U.S. Army Corps of Engineers New York District	Average Annual Flood Damages within 100Yr. Floodplain w/Basements-2	Job No.	Date	Figure No.
		66905	Mar 2009	9



U.S. Army Corps of Engineers
New York District

Locations of Potential Structural and Non-Structural Solutions

Job No.	Date	Figure No.
66905	Mar 2009	10

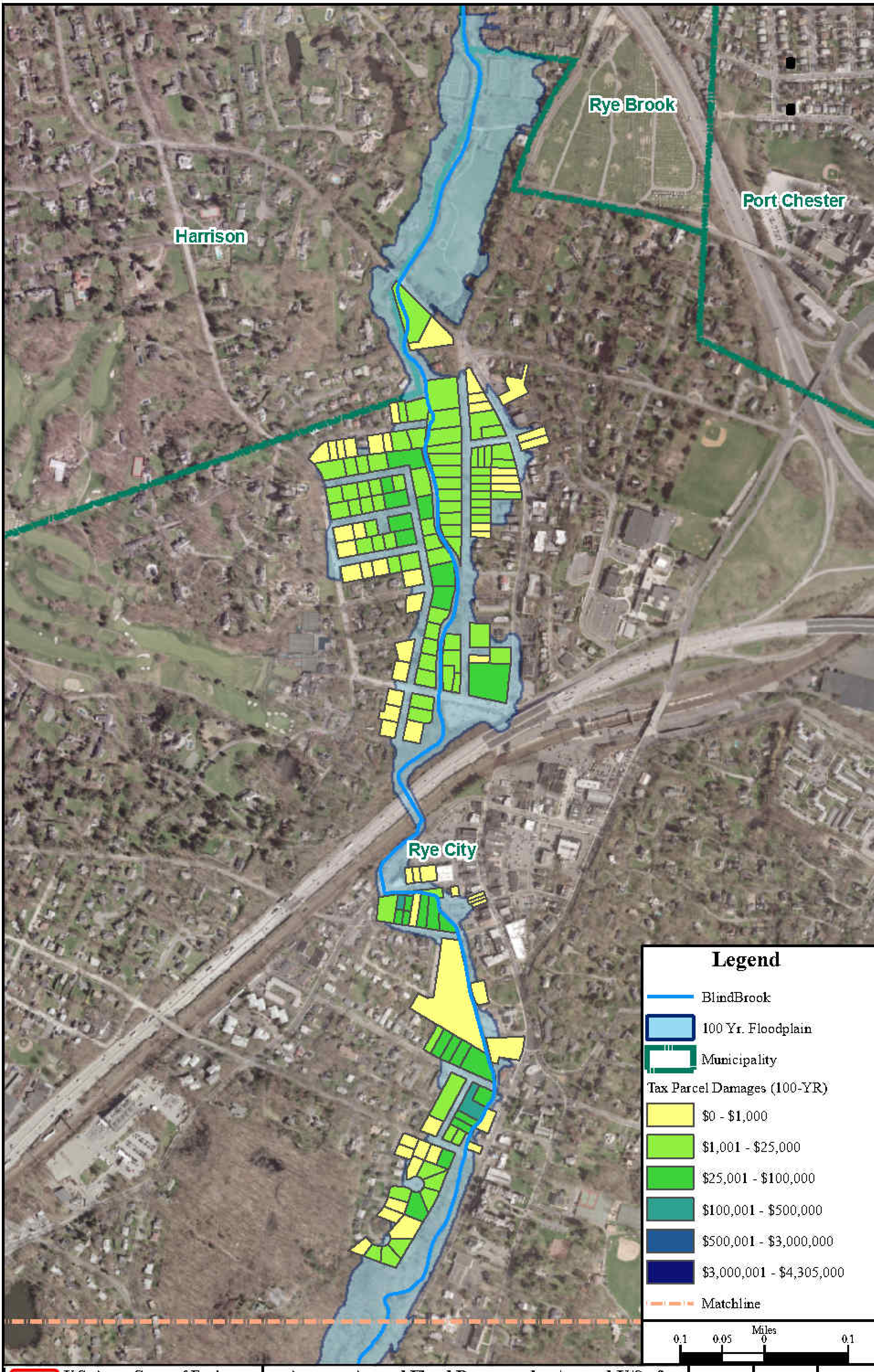


U.S. Army Corps of Engineers New York District	Proposed Pond Upstream of Anderson Hill Rd	Job No.	Date	Figure No.
		66905	Mar 2009	11

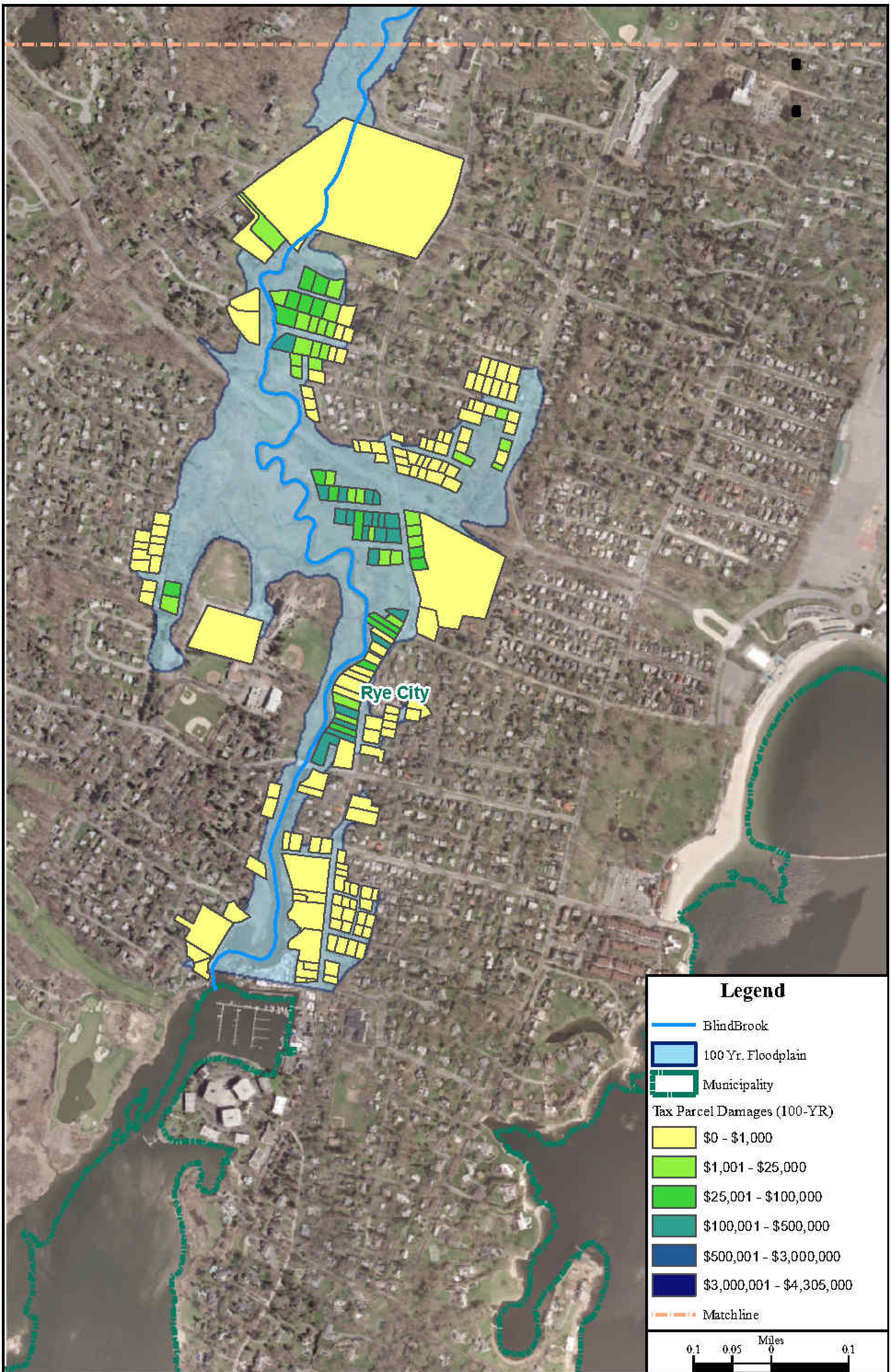
CHAS. H. SELLS, INC
Consulting Engineers, Surveyors & Photogrammetrists

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

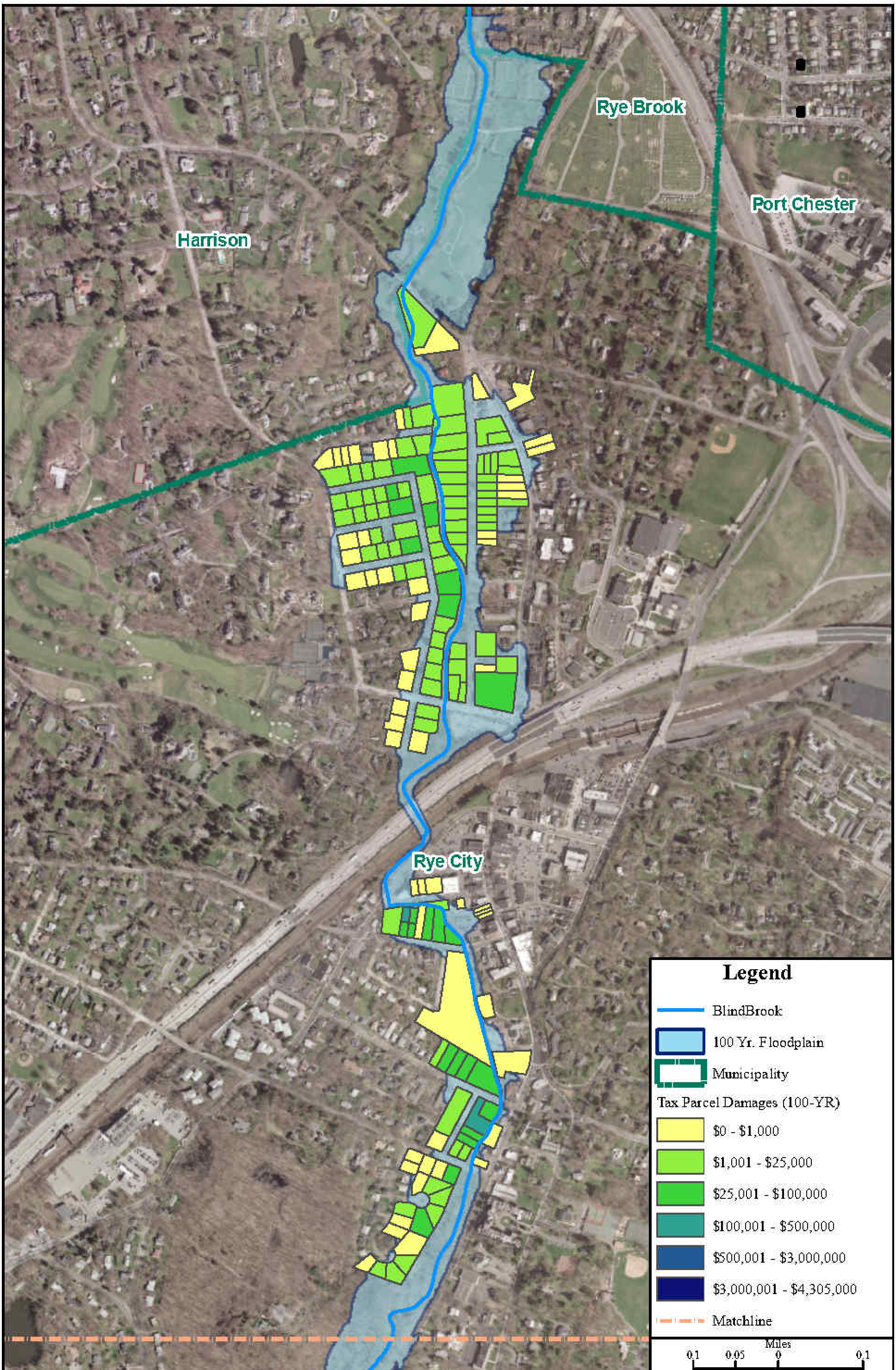
FIGURE NO.
12



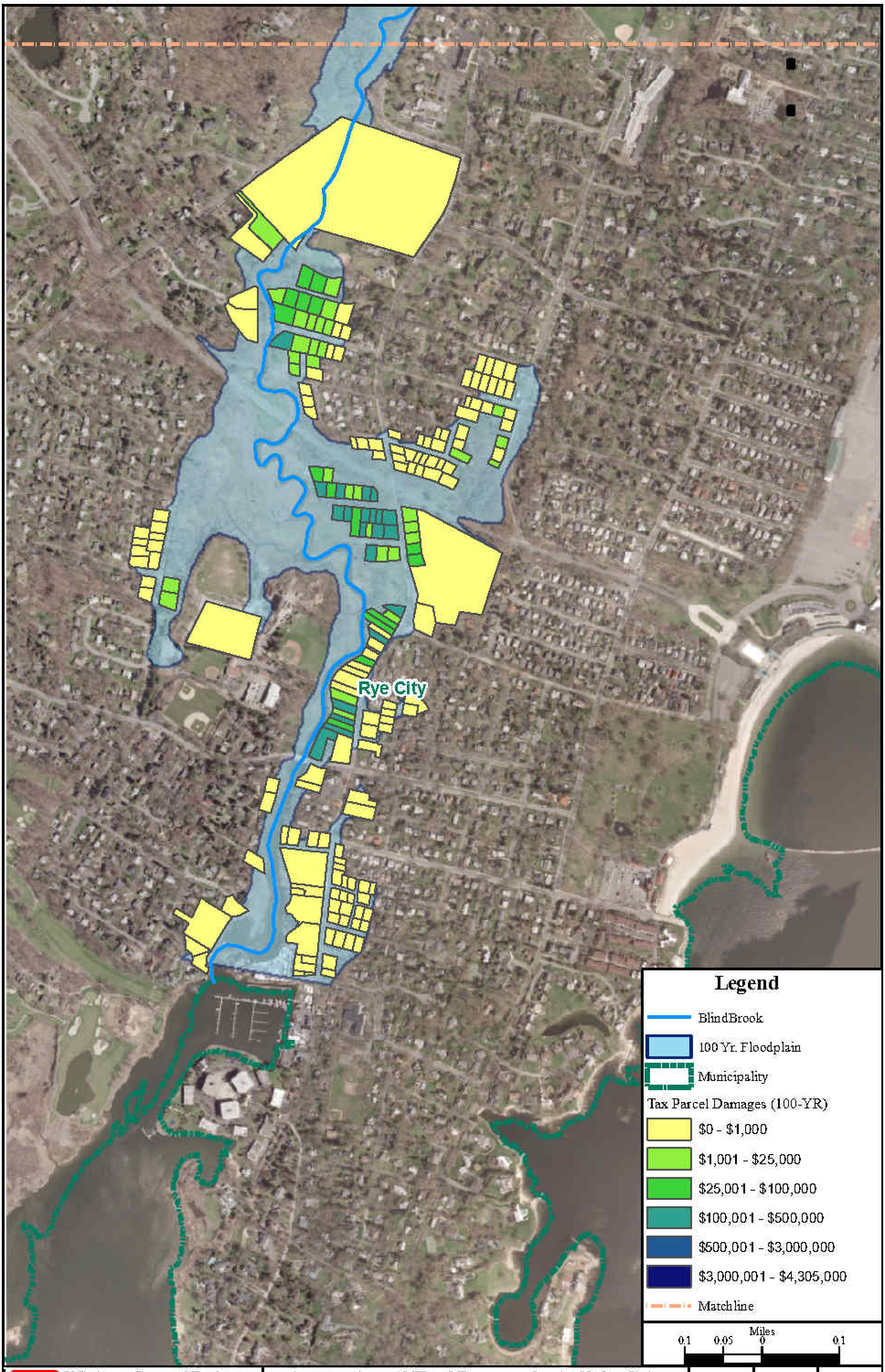
U.S. Army Corps of Engineers New York District	Average Annual Flood Damages due to pond U/S of Anderson Hill Road within 100 Yr. Floodplain - 1	Job No.	Date	Figure No.
		66905	Mar 2009	13



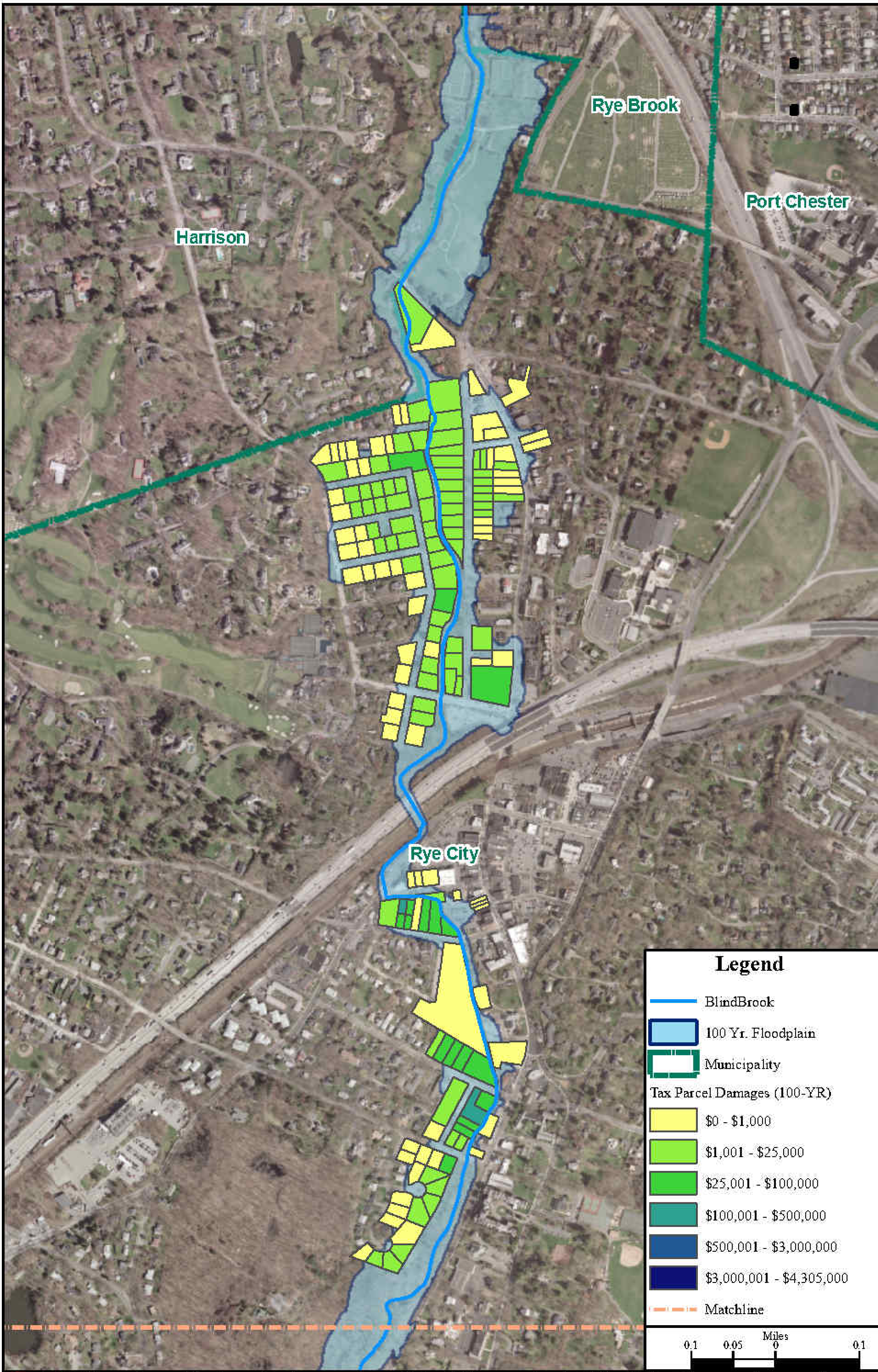
U.S. Army Corps of Engineers New York District	Average Annual Flood Damages due to pond U/S of Anderson Hill Road within 100 Yr. Floodplain - 2	Job No.	Date	Figure No.
		66905	Mar 2009	14



U.S. Army Corps of Engineers New York District	Average Annual Flood Damages due to Sluice Gate at Bowman Avenue Dam within 100 Yr. Floodplain - 1	Job No.	Date	Figure No.
		66905	Mar 2009	15



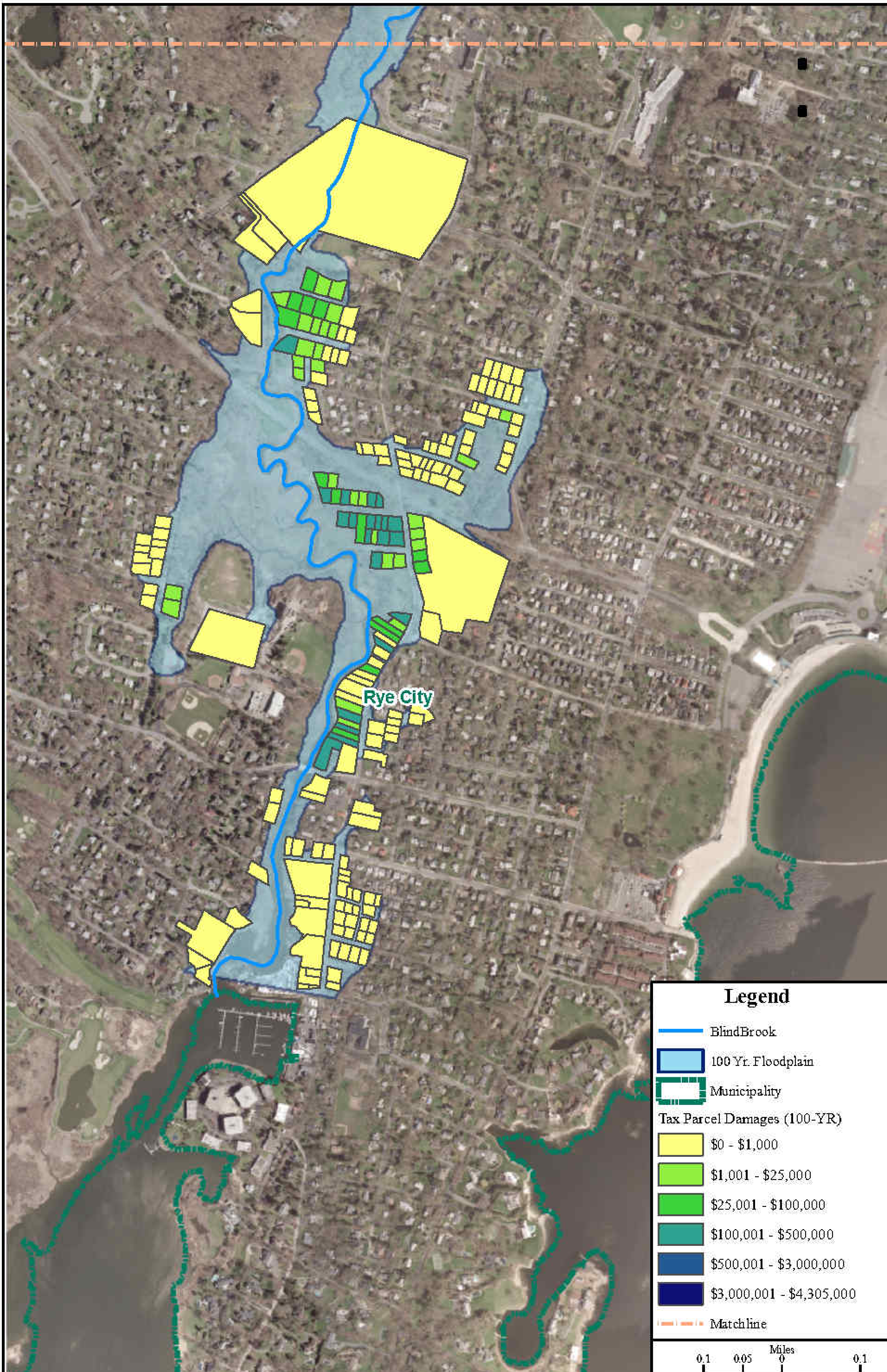
U.S. Army Corps of Engineers New York District	Average Annual Flood Damages due to Sluice Gate at Bowman Avenue Dam within 100 Yr. Floodplain - 2	Job No.	Date	Figure No.
		66905	Mar 2009	16



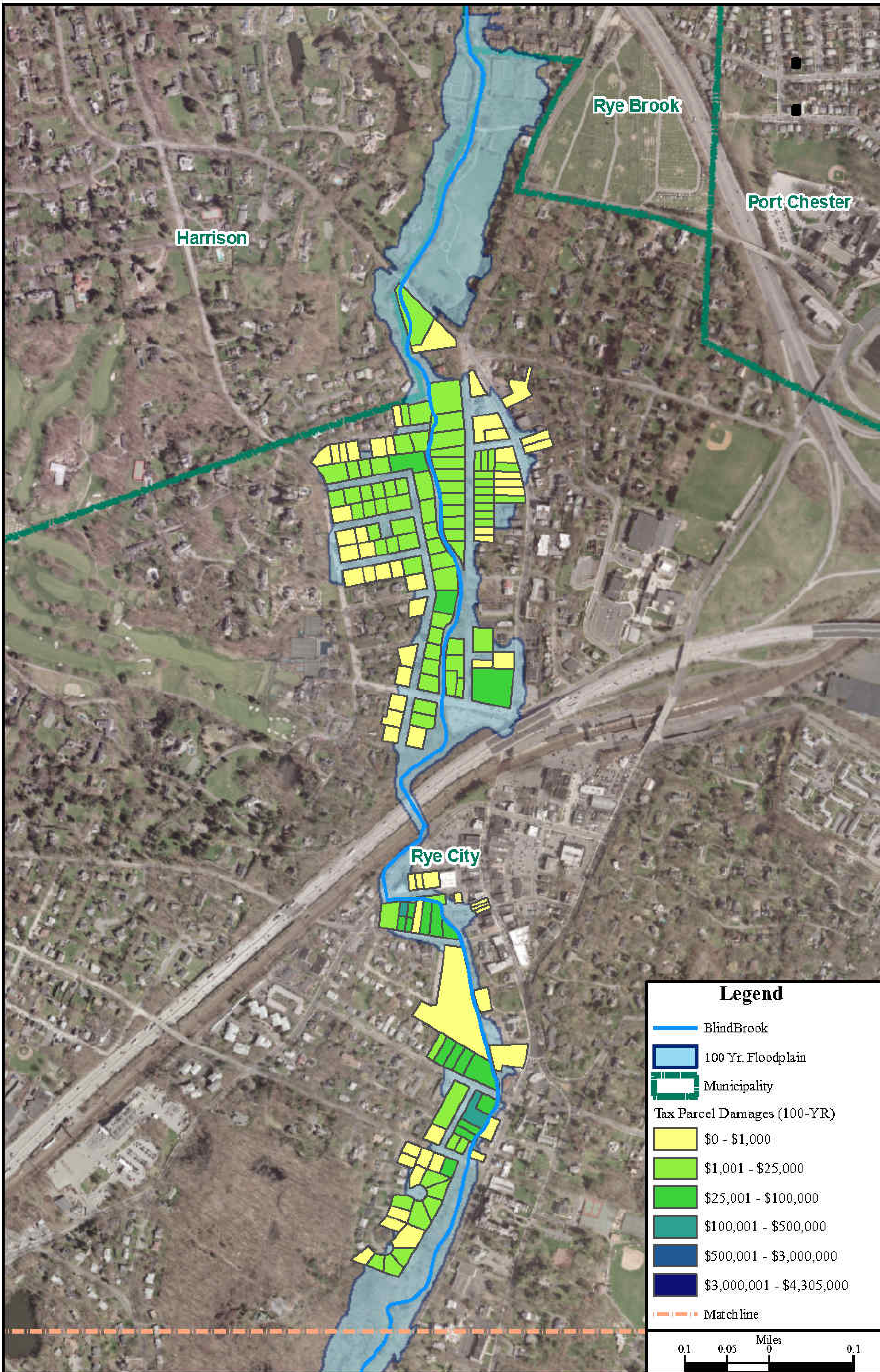
U.S. Army Corps of Engineers
New York District

Average Annual Flood Damages due to Sluice Gate and Upper Pond at Bowman Ave within 100 Yr. FP - 1

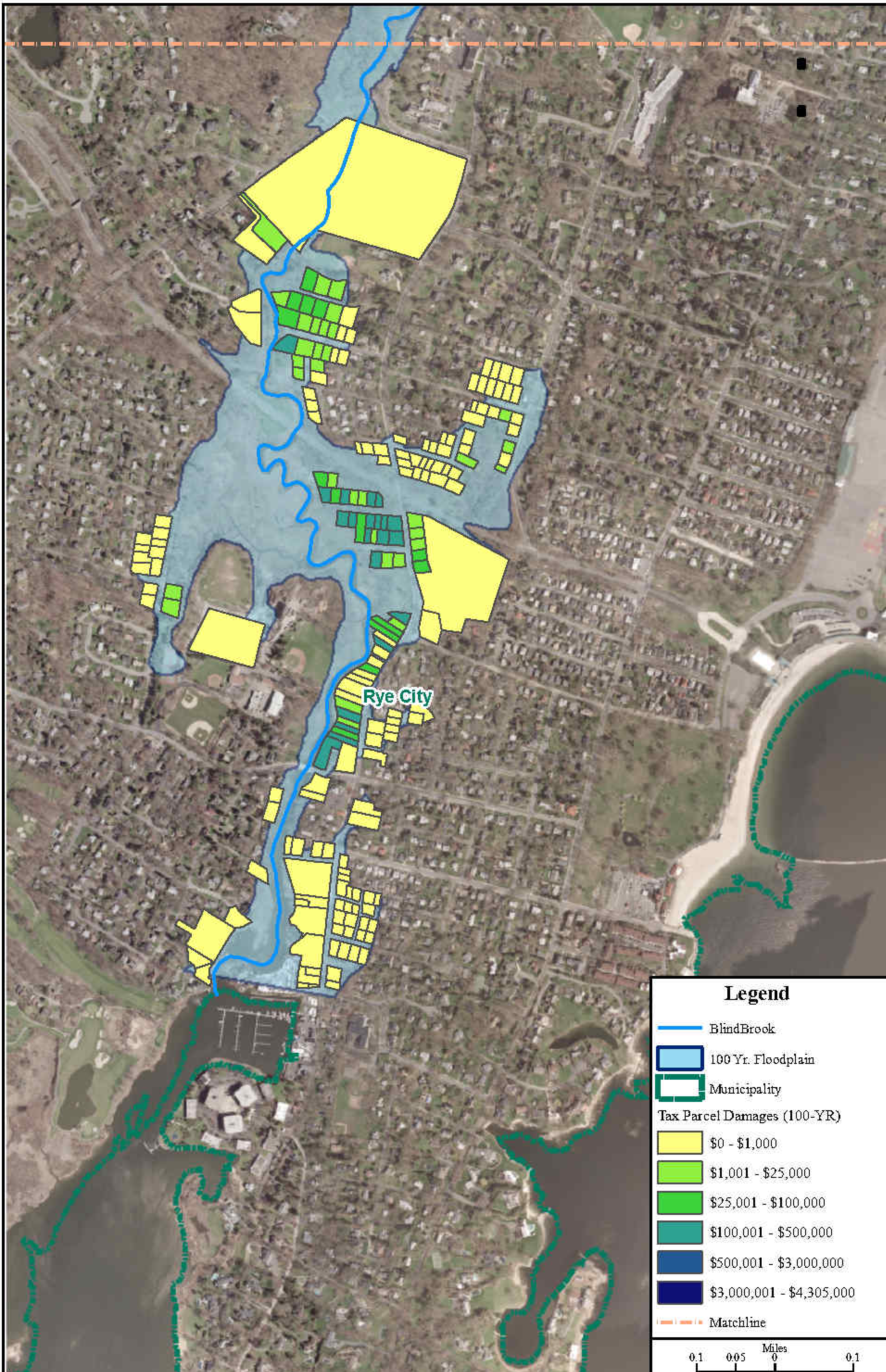
Job No.	Date	Figure No.
66905	Mar 2009	17



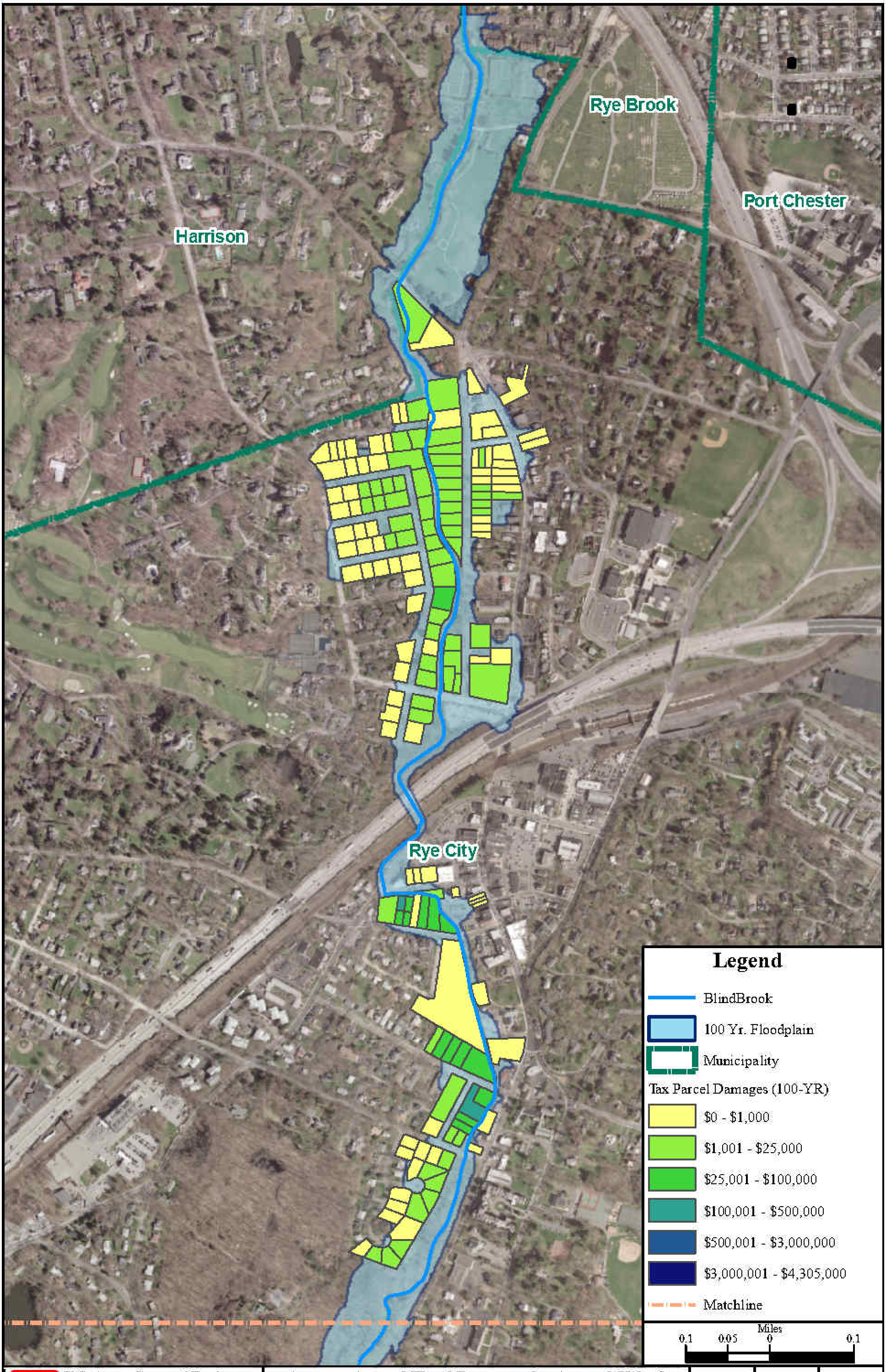
U.S. Army Corps of Engineers New York District	Average Annual Flood Damages due to Sluice Gate and Upper Pond at Bowman Ave Dam within 100 Yr. FP - 2	Job No.	Date	Figure No.
		66905	Mar 2009	18



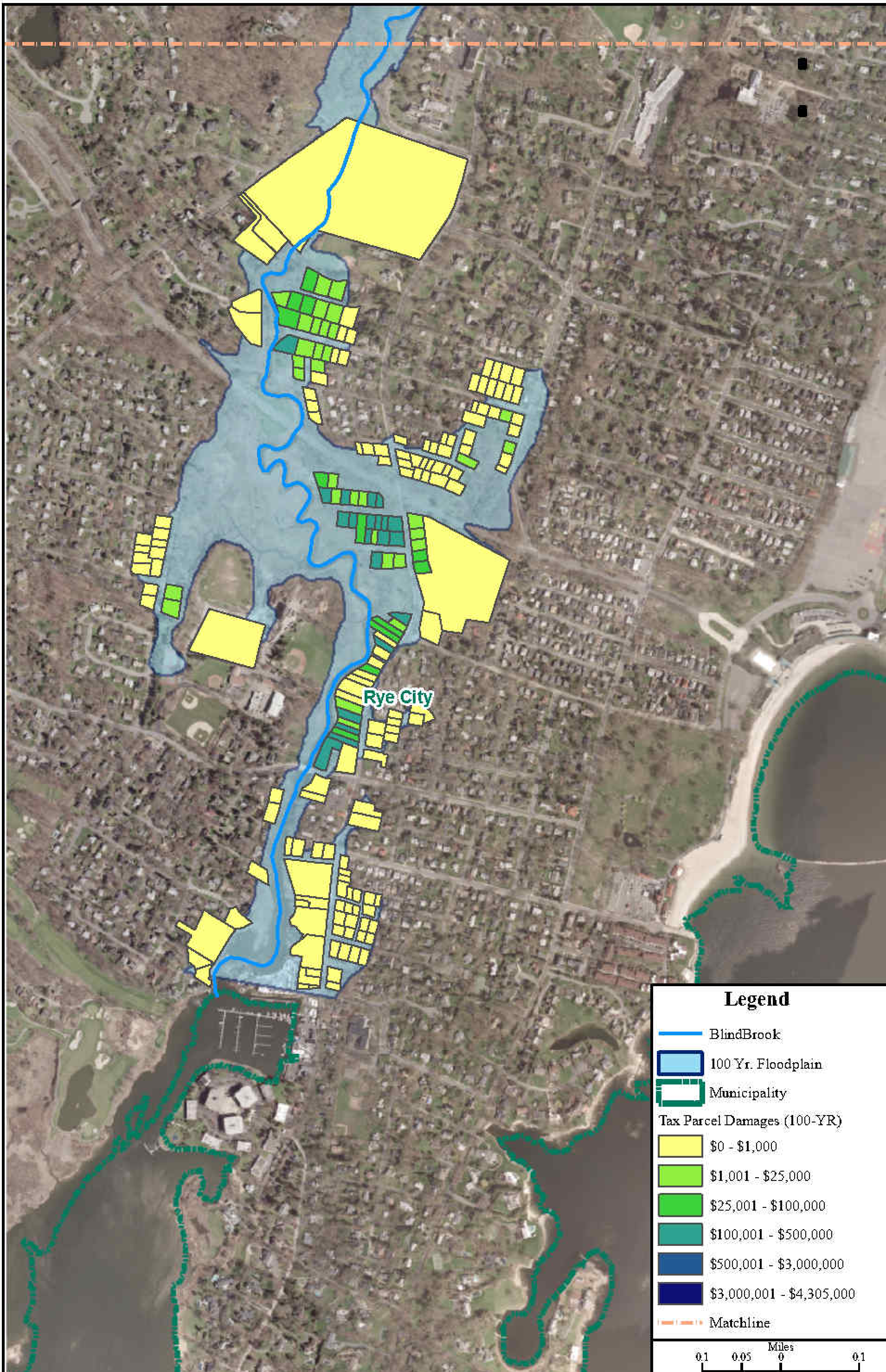
U.S. Army Corps of Engineers New York District	Average Annual Flood Damages due to pond U/S of AH Rd and SG at BA within 100Yr. FP - 1	Job No.	Date	Figure No.
		66905	Mar 2009	19



U.S. Army Corps of Engineers New York District	Average Annual Flood Damages due to pond U/S of AH Rd and SG at BA within 100 Yr. FP - 2	Job No.	Date	Figure No.
		66905	Mar 2009	20



U.S. Army Corps of Engineers New York District	Average Annual Flood Damages due to pond U/S of AH Rd and UP and SG at BA within 100 Yr. FP - 1	Job No.	Date	Figure No.
		66905	Mar 2009	21



U.S. Army Corps of Engineers New York District	Average Annual Flood Damages due to pond U/S of AH Rd and UP and SG at BA within 100 Yr. FP - 2	Job No.	Date	Figure No.
		66905	Mar 2009	22

APPENDIX C

COST ANALYSIS

Blind Brook Watershed Management Plan

Opinion of Probable Cost - Anderson Hill Road

11/26/2008

Prepared by: HDR Engineering, Inc,

Item	Quantity	Unit Cost	Unit	Cost
Civil Estimate				
Clearing, Grubbing, etc.	20.2	$3,500	AC	$ 70,700.00
Temporary Site Fence	5,000	$10	LF	$ 50,000.00
Erosion Control Silt Fence	2,125	$3	LF	$ 6,375.00
Construction Entrance/Exit	1	$2,500	EA.	$ 2,500.00
Excavation and Disposal[1]	365,200	$12	CY	$ 4,382,400.00
84" RCP Pipe (material)	180	$600	LF	$ 108,000.00
84" RCP Pipe (install)	5	$2,750	Day	$ 13,750.00
Diversion Structure[2]	1	See Below	See Below	$ 208,175.00
Headwall	2	$10,000	EA.	$ 20,000.00
Rip Rap (Stone Revetment)	1,000	$100	SY	$ 100,000.00
Articulated Concrete Block	2,285	$450	SY	$ 1,028,250.00
Permanent Stabilization	879.9	$22	MSF	$ 19,358.06
Lands, Easements, Right-of-Ways, Relocations, Demolition (LEERD)[3]				$ 36,250.00
			Subtotal	$ 6,045,758.06
			Total	$ 6,045,760.00
Design	10%			$ 604,576.00
Permitting	5%			$ 302,288.00
CM	5%			$ 302,288.00
Subtotal				**$ 7,254,912.00**
Contingency - conceptual	25%			**$ 9,068,640.00**

1)Rock excavation and other unforeseen conditions not considered. Loading and transpiration of material assumed on-site. NYSDEC freeboard regulations require further analysis of fill quantities.

2)Sub Item Costs:				
Diversion Stream	2,165	$12	CY	$ 25,980.00
Coffer Dam	2,880	$24	SF	$ 67,680.00
Dewatering	21	$175	Day	$ 3,675.00
Excavation and disposal	1,500	$12	CY	$ 18,000.00
Backfill	11	$40	CY	$ 440.00
Cast-in-place Concrete	116	$800	CY	$ 92,400.00
			Total	$ 208,175.00

3)LEERDS - Value only includes estimated management and administrative fees associated with acquisition of property. Cost estimate does not include land acquisition and easement values.

Operations and Maintenance Costs - Pond U/S of Anderson Hill Road

Data	Proposed Pond Area	17.5	acres
	Period of Analysis (years)	50	years
	Esclation used in converting 2006 RSMeans estimates to 2008 estimates	4%	
1	Inspection: It is assumed that two men crew for 2days is necessary for annual inspection.		
	Hourly Rate	$120.00	per hour
	Average Annual Cost	$3,840.00	in 2008 dollars
2	Standard Maintenance: It is assumed that bi-weekly maintenance is required for summar months (May - August)		
	Mowing, Debris Removal and Repair	$60.00	per acre
	Average Annual Cost	$1,100.00	in 2008 dollars
3	Removal of Sediment from Forebay: It is assumed that sediment removal is necessary once in every 5 years		
	Two laborers, 1 equipment operator an I backhoe loader is assumed necessary to remove sediment.		
	Crew Cost	$1,356.00	per day
	Escalation to 2008 rates	$1,410.24	
	Total Cost of Sediment Removal	$14,102.40	
	Average Annual Cost	$300.00	in 2008 dollars
4	Dredging Costs: It is assumed that the pond needs to be dredged once in the life time (50 years);		
	Dredging is necessary when the sediment reduces the pond volume by 25% or more.		
	Total Pond Volume	130.4	acres-ft
	25% of Pond Volume	52595	CY
	Unit Cost of dredging	28.41	per CY
	Total dredging cost	$1,494,223.95	
	Average Annual Cost	$29,900.00	in 2008 dollars
	Average Annual O&M Cost	$35,100.00	
	Contingency	20%	
	Average Annual O&M Costs	$42,100.00	in 2008 dollars

Operations and Maintenance Costs - Sluice Gate at Bowman Avenue			
1	Inspection: It is assumed that two man crew for 2days is necessary for annual inspection and maintenance.		
	Hourly Rate	$120.00	per hour
	Average Annual Cost	$3,840.00	in 2008 dollars
	Contingency	20%	
	Average Annual O&M Costs	$4,600.00	in 2008 dollars

Operations and Maintenance Costs - Upper Pond at Bowman Avenue

Data	Proposed Pond Area	18.5	acres
	Period of Analysis (years)	50	years
	Esclation used in converting 2006 RSMeans estimates to 2008 estimates	4%	
1	Inspection: It is assumed that two men crew for 2days is necessary for annual inspection.		
	Hourly Rate	$120.00	per hour
	Average Annual Cost	$3,840.00	in 2008 dollars
2	Standard Maintenance: It is assumed that bi-weekly maintenance is required for summar months (May - August)		
	Mowing, Debris Removal and Repair	$60.00	per acre
	Average Annual Cost	$1,100.00	in 2008 dollars
3	Removal of Sediment from Forebay: It is assumed that sediment removal is necessary once in every 5 years		
	Two laborers, 1 equipment operator an I backhoe loader is assumed necessary to remove sediment.		
	Crew Cost	$1,356.00	per day
	Escalation to 2008 rates	$1,410.24	
	Total Cost of Sediment Removal	$14,102.40	
	Average Annual Cost	$300.00	in 2008 dollars
4	Dredging Costs: It is assumed that the pond needs to be dredged once in the life time (50 years);		
	Dredging is necessary when the sediment reduces the pond volume by 25% or more.		
	Total Pond Volume	335	acres-ft
	25% of Pond Volume	135117	CY
	Unit Cost of dredging	28.41	per CY
	Total dredging cost	$3,838,673.97	
	Average Annual Cost	$76,800.00	in 2008 dollars
	Average Annual O&M Cost	$82,000.00	
	Contingency	20%	
	Average Annual O&M Costs	$98,400.00	in 2008 dollars

Average Annual Cost - Pond Upstream of Anderson Hill Road

Inputs				Summary	
Interest Rate*	4.875%			Present Value Construction Cost	$ 8,650,000
Period of Analysis (years)	50			Interest During Construction (IDC)	$ 221,081
Project Estimate	$9,070,000			Subtotal	$ 8,871,081
Annual O&M	$42,100			Annual Equivalent (AE) Construction Cost	$ 480,000
* Source: USACE Economic Guidance Memo #08-01				Annual O&M	$ 42,100
				Total Annual Cost	$ 522,100

Calculations

Year	*Discount Factor*	*Construction Cost*	*Present Value Construction Cost*	1/2 annual expense	All Previous years Expenses
0		*0*	*0*	-	-
1	0.953516091	$ 9,070,000.00	$ 8,648,390.94	4,535,000	-
2	0.909192935		$ -	-	9,070,000
3	0.866930093		$ -	-	-
4	0.826631793		$ -	-	-
5	0.788206716		$ -	-	-
6	0.751567786		$ -	-	-
7	0.716631977		$ -	-	-
8	0.683320121		$ -	-	-
9	0.651556731		$ -	-	-
10	0.621269827		$ -	-	-
11	0.592390776		$ -	-	-
12	0.564854137		$ -	-	-
13	0.538597509		$ -	-	-
14	0.513561391		$ -	-	-
15	0.48968905		$ -	-	-
16	0.466926388		$ -	-	-
17	0.445221824		$ -	-	-
18	0.424526173		$ -	-	-
19	0.404792537		$ -	-	-
20	0.385976197		$ -	-	-
21	0.368034515		$ -	-	-
22	0.350926832		$ -	-	-
23	0.334614381		$ -	-	-
24	0.319060196		$ -	-	-
25	0.304229031		$ -	-	-
26	0.290087276		$ -	-	-
27	0.276602886		$ -	-	-
28	0.263745302		$ -	-	-
29	0.251485389		$ -	-	-
30	0.239795365		$ -	-	-
31	0.228648739		$ -	-	-
32	0.218020252		$ -	-	-
33	0.207885818		$ -	-	-
34	0.198222473		$ -	-	-
35	0.189008317		$ -	-	-
36	0.180222472		$ -	-	-
37	0.171845027		$ -	-	-
38	0.163856998		$ -	-	-
39	0.156240284		$ -	-	-
40	0.148977625		$ -	-	-
41	0.142052563		$ -	-	-
42	0.135449404		$ -	-	-
43	0.129153186		$ -	-	-
44	0.123149641		$ -	-	-
45	0.117425165		$ -	-	-
46	0.111966784		$ -	-	-
47	0.10676213		$ -	-	-
48	0.101799409		$ -	-	-
49	0.097067374		$ -	-	-
50	0.092555303		$ -	-	-
		9070000	$ 8,648,390.94		

Average Annual Cost - Pond Upstream of Anderson Hill Road - Contd					
Alternative in Service	Previous Interest	Interest Bearing Amount	IDC Compund Interest		
-	-	-	-		
1	-	4,535,000	221,081		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
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			221,081		

Average Annual Cost - Sluice Gate

Inputs		Summary	
Interest Rate*	4.875%	Present Value Construction Cost	$ 1,430,000
Period of Analysis (years)	50	Interest During Construction (IDC)	$ 36,563
Project Estimate	$1,500,000	Subtotal	$ 1,466,563
Annual O&M	$4,600	Annual Equivalent (AE) Construction Cost	$ 80,000
* Source: USACE Economic Guidance Memo #08-01		Annual O&M	$ 4,600
		Total Annual Cost	$ 84,600

Calculations

Year	*Discount Factor*	*Construction Cost*	*Present Value Construction Cost*	1/2 annual expense	All Previous years Expenses
0		*0*	*0*	-	-
1	0.953516091	$ 1,500,000.00	$ 1,430,274.14	750,000	-
2	0.909192935		$ -	-	1,500,000
3	0.866930093		$ -	-	-
4	0.826631793		$ -	-	-
5	0.788206716		$ -	-	-
6	0.751567786		$ -	-	-
7	0.716631977		$ -	-	-
8	0.683320121		$ -	-	-
9	0.651556731		$ -	-	-
10	0.621269827		$ -	-	-
11	0.592390776		$ -	-	-
12	0.564854137		$ -	-	-
13	0.538597509		$ -	-	-
14	0.513561391		$ -	-	-
15	0.48968905		$ -	-	-
16	0.466926388		$ -	-	-
17	0.445221824		$ -	-	-
18	0.424526173		$ -	-	-
19	0.404792537		$ -	-	-
20	0.385976197		$ -	-	-
21	0.368034515		$ -	-	-
22	0.350926832		$ -	-	-
23	0.334614381		$ -	-	-
24	0.319060196		$ -	-	-
25	0.304229031		$ -	-	-
26	0.290087276		$ -	-	-
27	0.276602886		$ -	-	-
28	0.263745302		$ -	-	-
29	0.251485389		$ -	-	-
30	0.239795365		$ -	-	-
31	0.228648739		$ -	-	-
32	0.218020252		$ -	-	-
33	0.207885818		$ -	-	-
34	0.198222473		$ -	-	-
35	0.189008317		$ -	-	-
36	0.180222472		$ -	-	-
37	0.171845027		$ -	-	-
38	0.163856998		$ -	-	-
39	0.156240284		$ -	-	-
40	0.148977625		$ -	-	-
41	0.142052563		$ -	-	-
42	0.135449404		$ -	-	-
43	0.129153186		$ -	-	-
44	0.123149641		$ -	-	-
45	0.117425165		$ -	-	-
46	0.111966784		$ -	-	-
47	0.10676213		$ -	-	-
48	0.101799409		$ -	-	-
49	0.097067374		$ -	-	-
50	0.092555303		$ -	-	-
		1500000	$ 1,430,274.14		

Average Annual Cost - Sluice Gate

Alternative in Service	Previous Interest	Interest Bearing Amount	IDC Compund Interest		
-	-	-	-		
1	-	750,000	36,563		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
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1	-	-	-		
			36,563		

Average Annual Cost - Upper Pond and Sluice Gate					
Inputs				Summary	
Interest Rate*	4.875%			Present Value Construction Cost	$ 19,070,000
Period of Analysis (years)	50			Interest During Construction (IDC)	$ 487,500
Project Estimate	$20,000,000			Subtotal	$ 19,557,500
Annual O&M	$103,000			Annual Equivalent (AE) Construction Cost	$ 1,050,000
* Source: USACE Economic Guidance Memo #08-01				Annual O&M	$ 103,000
				Total Annual Cost	$ 1,153,000
Calculations					
Year	*Discount Factor*	*Construction Cost*	*Present Value Construction Cost*	1/2 annual expense	All Previous years Expenses
0		*0*	*0*	-	-
1	0.953516091	$ 20,000,000.00	$ 19,070,321.81	10,000,000	-
2	0.909192935		$ -	-	20,000,000
3	0.866930093		$ -	-	-
4	0.826631793		$ -	-	-
5	0.788206716		$ -	-	-
6	0.751567786		$ -	-	-
7	0.716631977		$ -	-	-
8	0.683320121		$ -	-	-
9	0.651556731		$ -	-	-
10	0.621269827		$ -	-	-
11	0.592390776		$ -	-	-
12	0.564854137		$ -	-	-
13	0.538597509		$ -	-	-
14	0.513561391		$ -	-	-
15	0.48968905		$ -	-	-
16	0.466926388		$ -	-	-
17	0.445221824		$ -	-	-
18	0.424526173		$ -	-	-
19	0.404792537		$ -	-	-
20	0.385976197		$ -	-	-
21	0.368034515		$ -	-	-
22	0.350926832		$ -	-	-
23	0.334614381		$ -	-	-
24	0.319060196		$ -	-	-
25	0.304229031		$ -	-	-
26	0.290087276		$ -	-	-
27	0.276602886		$ -	-	-
28	0.263745302		$ -	-	-
29	0.251485389		$ -	-	-
30	0.239795365		$ -	-	-
31	0.228648739		$ -	-	-
32	0.218020252		$ -	-	-
33	0.207885818		$ -	-	-
34	0.198222473		$ -	-	-
35	0.189008317		$ -	-	-
36	0.180222472		$ -	-	-
37	0.171845027		$ -	-	-
38	0.163856998		$ -	-	-
39	0.156240284		$ -	-	-
40	0.148977625		$ -	-	-
41	0.142052563		$ -	-	-
42	0.135449404		$ -	-	-
43	0.129153186		$ -	-	-
44	0.123149641		$ -	-	-
45	0.117425165		$ -	-	-
46	0.111966784		$ -	-	-
47	0.10676213		$ -	-	-
48	0.101799409		$ -	-	-
49	0.097067374		$ -	-	-
50	0.092555303		$ -	-	-
		20000000	$ 19,070,321.81		

Average Annual Cost - Upper Pond and Sluice Gate (contd)

Alternative in Service	Previous Interest	Interest Bearing Amount	IDC Compund Interest		
-	-	-	-		
1	-	10,000,000	487,500		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
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1	-	-	-		
			487,500		

Average Annual Cost - Pond Upstream of Anderson Hill Road and SluiceGate

Inputs	
Interest Rate*	4.875%
Period of Analysis (years)	50
Project Estimate	$10,570,000
Annual O&M	$46,700

* Source: USACE Economic Guidance Memo #08-01

Summary	
Present Value Construction Cost	$ 10,080,000
Interest During Construction (IDC)	$ 257,644
Subtotal	$ 10,337,644
Annual Equivalent (AE) Construction Cost	$ 560,000
Annual O&M	$ 46,700
Total Annual Cost	$ 606,700

Calculations

Year	*Discount Factor*	*Construction Cost*	*Present Value Construction Cost*	1/2 annual expense	All Previous years Expenses
0		0	0	-	-
1	0.953516091	$ 10,570,000.00	$ 10,078,665.08	5,285,000	-
2	0.909192935		$ -	-	10,570,000
3	0.866930093		$ -	-	-
4	0.826631793		$ -	-	-
5	0.788206716		$ -	-	-
6	0.751567786		$ -	-	-
7	0.716631977		$ -	-	-
8	0.683320121		$ -	-	-
9	0.651556731		$ -	-	-
10	0.621269827		$ -	-	-
11	0.592390776		$ -	-	-
12	0.564854137		$ -	-	-
13	0.538597509		$ -	-	-
14	0.513561391		$ -	-	-
15	0.48968905		$ -	-	-
16	0.466926388		$ -	-	-
17	0.445221824		$ -	-	-
18	0.424526173		$ -	-	-
19	0.404792537		$ -	-	-
20	0.385976197		$ -	-	-
21	0.368034515		$ -	-	-
22	0.350926832		$ -	-	-
23	0.334614381		$ -	-	-
24	0.319060196		$ -	-	-
25	0.304229031		$ -	-	-
26	0.290087276		$ -	-	-
27	0.276602886		$ -	-	-
28	0.263745302		$ -	-	-
29	0.251485389		$ -	-	-
30	0.239795365		$ -	-	-
31	0.228648739		$ -	-	-
32	0.218020252		$ -	-	-
33	0.207885818		$ -	-	-
34	0.198222473		$ -	-	-
35	0.189008317		$ -	-	-
36	0.180222472		$ -	-	-
37	0.171845027		$ -	-	-
38	0.163856998		$ -	-	-
39	0.156240284		$ -	-	-
40	0.148977625		$ -	-	-
41	0.142052563		$ -	-	-
42	0.135449404		$ -	-	-
43	0.129153186		$ -	-	-
44	0.123149641		$ -	-	-
45	0.117425165		$ -	-	-
46	0.111966784		$ -	-	-
47	0.10676213		$ -	-	-
48	0.101799409		$ -	-	-
49	0.097067374		$ -	-	-
50	0.092555303		$ -	-	-
		10570000	$ 10,078,665.08		

Average Annual Cost - Pond Upstream of Anderson Hill Road and SluiceGate (contd)					
Alternative in Service	Previous Interest	Interest Bearing Amount	IDC Compund Interest		
-	-	-	-		
1	-	5,285,000	257,644		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
1	-	-	-		
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1	-	-	-		
			257,644		

Average Annual Cost - Pond Upstream of Anderson Hill Road, Upper Pond and Sluice Gate					
Inputs				Summary	
Interest Rate*	4.875%			Present Value Construction Cost	$ 27,720,000
Period of Analysis (years)	50			Interest During Construction (IDC)	$ 708,581
Project Estimate	$29,070,000			Subtotal	$ 28,428,581
Annual O&M	$145,100			Annual Equivalent (AE) Construction Cost	$ 1,530,000
* Source: USACE Economic Guidance Memo #08-01				Annual O&M	$ 145,100
				Total Annual Cost	$ 1,675,100
Calculations					
Year	*Discount Factor*	*Construction Cost*	*Present Value Construction Cost*	1/2 annual expense	All Previous years Expenses
0		*0*	*0*	-	-
1	0.953516091	$ 29,070,000.00	$ 27,718,712.75	14,535,000	-
2	0.909192935		$ -	-	29,070,000
3	0.866930093		$ -	-	-
4	0.826631793		$ -	-	-
5	0.788206716		$ -	-	-
6	0.751567786		$ -	-	-
7	0.716631977		$ -	-	-
8	0.683320121		$ -	-	-
9	0.651556731		$ -	-	-
10	0.621269827		$ -	-	-
11	0.592390776		$ -	-	-
12	0.564854137		$ -	-	-
13	0.538597509		$ -	-	-
14	0.513561391		$ -	-	-
15	0.48968905		$ -	-	-
16	0.466926388		$ -	-	-
17	0.445221824		$ -	-	-
18	0.424526173		$ -	-	-
19	0.404792537		$ -	-	-
20	0.385976197		$ -	-	-
21	0.368034515		$ -	-	-
22	0.350926832		$ -	-	-
23	0.334614381		$ -	-	-
24	0.319060196		$ -	-	-
25	0.304229031		$ -	-	-
26	0.290087276		$ -	-	-
27	0.276602886		$ -	-	-
28	0.263745302		$ -	-	-
29	0.251485389		$ -	-	-
30	0.239795365		$ -	-	-
31	0.228648739		$ -	-	-
32	0.218020252		$ -	-	-
33	0.207885818		$ -	-	-
34	0.198222473		$ -	-	-
35	0.189008317		$ -	-	-
36	0.180222472		$ -	-	-
37	0.171845027		$ -	-	-
38	0.163856998		$ -	-	-
39	0.156240284		$ -	-	-
40	0.148977625		$ -	-	-
41	0.142052563		$ -	-	-
42	0.135449404		$ -	-	-
43	0.129153186		$ -	-	-
44	0.123149641		$ -	-	-
45	0.117425165		$ -	-	-
46	0.111966784		$ -	-	-
47	0.10676213		$ -	-	-
48	0.101799409		$ -	-	-
49	0.097067374		$ -	-	-
50	0.092555303		$ -	-	-
		29070000	$ 27,718,712.75		