Maidford River and Floodplain Restoration Alternatives Work Plan Phase 2 River Restoration



Maidford River

Middletown, Rhode Island

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SNEP NETWORK

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1 Executive Summary

This report summarizes the analysis of proposed flood mitigation improvements along the Maidford River in Middletown, Rhode Island. Specifically, this report presents hydraulic modeling results for improvements along the Maidford River in the vicinity of the Berkeley Avenue culvert crossing (Project Site). *Figure 1* shows the limit of study, which starts just downstream of Wyatt Road and terminates approximately one mile downstream of Green End Avenue.

A detailed hydrologic model was performed using HEC-HMS with the rainfall data from NOAA Atlas-14. FEMA's hydraulic model from the published Flood Insurance Study (FIS, effective July 6, 2021) was used as a basis for comparison to assess the hydraulic impacts of the proposed activities on the Maidford River at the Project Site. A new hydraulic model was creating utilizing HEC-RAS 2-dimensional (2D).

The updated hydraulic model was used to assess existing conditions and evaluate a series of alternatives to mitigate flooding and improve the ecological conditions within the Project Site.

The undersized culverts at Berkeley Avenue and Berkeley Avenue Extension are primarily responsible for flooding in this area. To address this flooding, the following three alternatives were assessed:

1. Raise Berkeley Avenue, install a berm, and increase the culvert capacity at Berkeley Avenue Extension
2. Raise Berkeley Avenue, install a berm, increase the culvert capacity at Berkeley Avenue Extension, and add flood storage on Sweet Berry Farm
3. Raise Berkeley Avenue, install a berm, increase the culvert capacity at Berkeley Avenue Extension, add flood storage on Sweet Berry Farm, and increase the culvert capacity at Berkeley Avenue

Alternative 3 was selected as the preferred solution, which is hydraulically adequate to pass the present-day 100-year flood without causing adverse impacts to the regulatory floodplain. Alternative 3 included the following design parameters:

- Raise Berkeley Avenue by 2.5-feet
- Create a 3.5-foot fall berm perpendicular to Berkeley Avenue
- Increase the culvert capacity at Berkeley Avenue Extension (35-foot span)
- Optional: add 4 acres of storage on Sweet Berry Farm
- Increase the culvert capacity at Berkeley Avenue (35-foot span)
- Floodplain restoration of the Maidford River from downstream of Berkeley Avenue to Green End Avenue

A climate change analysis was performed for the preferred alternative by scaling existing flows by a 1.21 magnification factor. The results indicated that the proposed design is resilient between the 50-year and 100-year projected storm; the modeling shows no overtopping of the Berkeley Avenue or Berkeley Avenue Extension roadways.

During future phases of this project, it will be necessary to evaluate impacts to the FEMA regulatory floodway on the Maidford River within the project reach. The proposed road raise at Berkeley Avenue causes an increase in Water Surface Elevation (WSEL) in the floodway for all alternatives. The design for this project focused on restoration alternatives downstream of Berkeley Avenue. Therefore, for future phases of this

project, it will be necessary to develop engineering controls to mitigate floodway impacts upstream of Berkeley Avenue.

2 Hydrology

2.1 Drainage Basin

The watershed for the Maidford River analysis was delineated using the StreamStats online webtool developed by the United States Geological Survey (USGS). The outlet point was selected at Green End Avenue to capture the full flow through the project site. The total contributing watershed area is 1.38 square miles and is located within the Narragansett Bay HUC 12 watershed (No. 010900040910). There are no significant tributaries upstream of Green End Avenue. The Maidford River Watershed is shown in *Figure 2*.

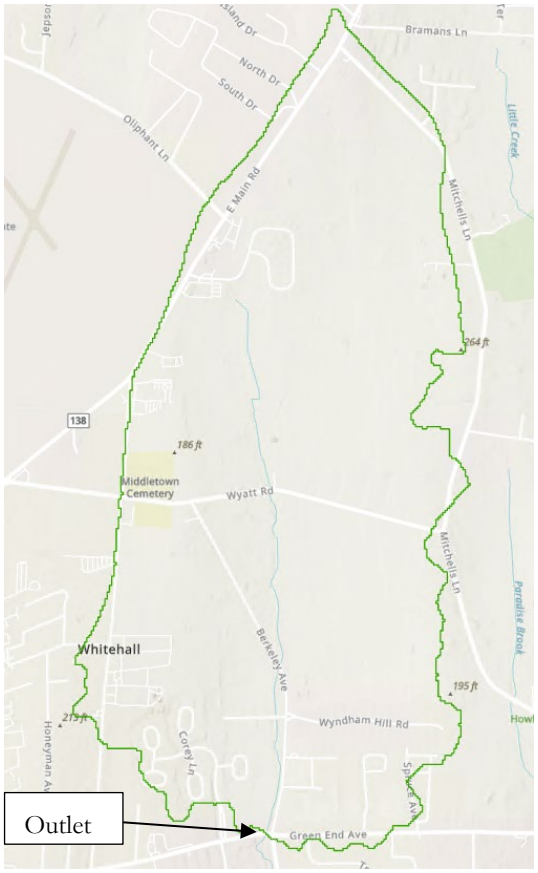


Figure 2
Maidford River Watershed Delineated at Green End Avenue

2.2 FEMA Model Data

The detailed FEMA flood study for the Maidford river was completed in November 1979. The most recent FIS for Newport County is dated July 6, 2021. The detailed flood study on the Maidford River, however, has not been updated since it was completed in 1979. Information provided in the Newport County FIS indicates that the peak discharges for the Maidford River were calculated using TR-20 methodology and the hydraulics were calculated using HEC-2. Peak discharges at two locations along the Maidford river are published in the FIS for a range of storm return intervals: at the mouth of the Maidford River, and at Prospect Avenue (approximately 0.5 miles downstream of Green End Avenue).

The published FEMA discharges for the Maidford River are provided in *Table 1*. Copies of pertinent sections of the FEMA FIS are provided in *Appendix A*.

Table 1
FEMA Flood Discharges

Sub-watershed	Drainage Area (sq mi)	Peak Discharge (cfs)		
		10-year	50-year	100-year
Maidford River (at mouth)	2.25	624	929	1,119
Maidford River (Prospect Avenue)	1.32	651	970	1,168

2.3 Hydrologic Model

To verify the discharges provided in the FEMA FIS, a new hydrologic model utilizing recent data was developed. Recent datasets used to update the hydrology include land use, soil, rainfall, and LiDAR. Additionally, new methodologies provide a more accurate analysis than those available when the study was completed in 1979.

A hydrologic model for the Maidford River was developed using the U.S Army Corps of Engineers HEC-HMS version 4.7.1 software. The Soil Conservation Service (SCS) Curve Number (CN) methodology was used to represent the hydrologic losses for the watershed. The Snyder Unit Hydrograph method was used to simulate the excess rainfall-runoff response of the watershed. Details of the development of the hydrologic model are presented in the following sections.

2.3.1 Design Storms

The meteorological model in HEC-HMS was set up for a hypothetical storm using an SCS Type 3 distribution. Five (5) design storms were selected for the analysis: 2-, 10-, 25-, 50-, and 100-year. Precipitation depth values were obtained from NOAA Atlas-14 for the 24-hour storm event and are shown in *Table 2*.

Table 2
Design Storm Normal Depths

Design Storm	Precipitation Depth (in)
2-year	3.41
10-year	5.04
25-year	6.06
50-year	6.81
100-year	7.63

2.3.2 Curve Number (CN) Development

To determine the composite Curve Number for the watershed, soil and land use data were obtained from the USDA Natural Resources Conservation Service (NRCS) Web Soil Survey (WSS) Database (SSURGO 2.2) and the Land Use data (2011) was obtained from the USDA National Land Cover Data Set (NLCD).

The Natural Resources Conservation Service (NRCS) classifies soils into four hydrologic groups represented as Type A, B, C, and D soils. Type A soils have high infiltration capacity and typically consist of coarse sands, while Type D soils have very low infiltration capacity, typically due to a restrictive layer or clay content. For this watershed, approximately 2/3 of the soils are classified as Type C and the remaining 1/3 is classified as type D. A small area along the western edge of the watershed contained Type A soils (< 1% by area). *Figure 3* displays the Hydrologic Soil Groups within the Maidford River Watershed.

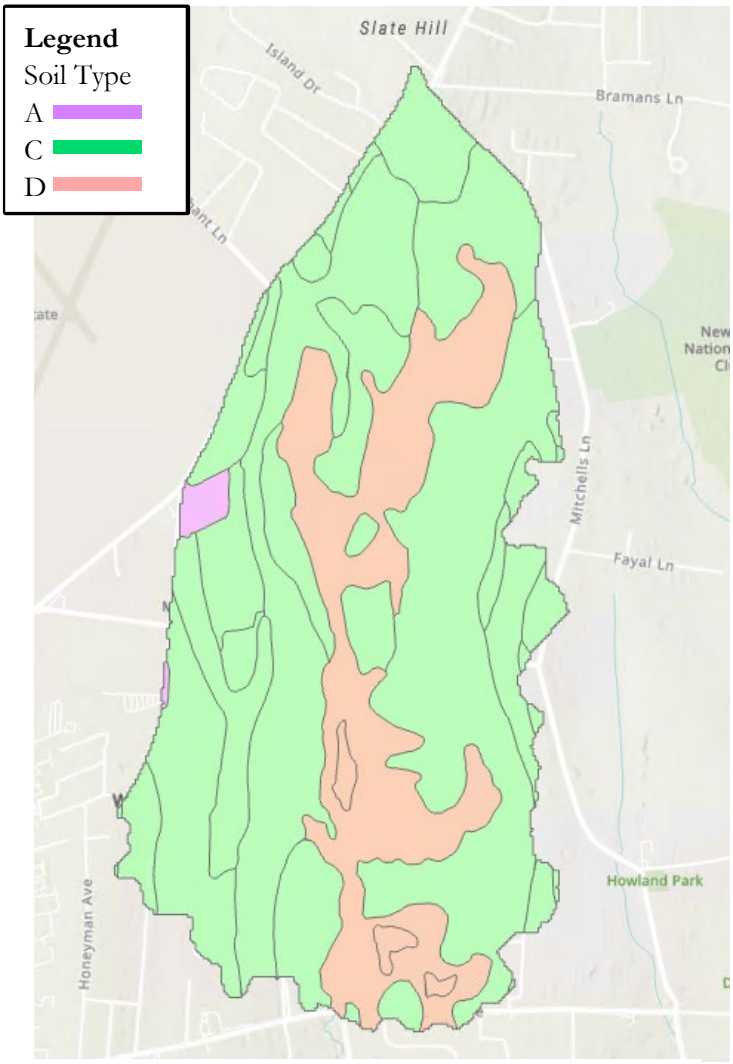


Figure 3
Hydrologic Soil Groups

The primary Land Uses in the watershed are hay/pasture, cultivated crops, and low/medium density residential. Curve numbers were assigned to each of the land uses using guidance from Table 2-2a in the *USDA Urban Hydrology for Small Watersheds TR-55* document. A composite curve number of 80.4 was calculated based on the combined land use and soil types.

2.4 Snyder Methodology

The HEC-HMS model uses two parameters to define the runoff characteristics of a watershed when using the Snyder Unit Hydrograph methodology: Standard Lag (T_L) and the Peaking Coefficient (C_P).

The Standard Lag Time (T_L) was computed using the Snyder watershed lag equation:

$$T_L = C_T(L * L_{ca})^{0.3}$$

Where:
C_T = Coefficient representing variations in watershed topography
L = Longest Flow Path along main stream to basin divide (mi)
L_{ca} = Centroidal Flow Path Length along main stream to watershed centroid (mi)

C_T and C_P are not physically based parameters, and therefore are better determined through calibration. However, there are no stream gages near the Maidford River watershed to calibrate the hydrologic parameters. Based on guidance from the HEC-HMS technical manual, which presents typical ranges for C_T to be from 1.8 to 2.2, a value of 2.0 was used as an average typical value for C_T. The longest flow path and centroidal flow path were calculated in GIS.

The HEC-HMS technical manual indicates typical values for C_P ranging from 0.4 to 0.8. Without calibration data, there is limited justification for varying this parameter. Therefore, a C_P value of 0.6 was used as an average representation for the parameter's feasible range. *Table 3* presents a summary of the hydrologic parameters.

Table 3
Hydrologic Parameters

Sub-watershed	Drainage Area (sq mi)	Longest Flow Path, L (mi)	Centroidal Flow Length, L_{ca} (mi)	C_T	Peaking Coefficient (C_P)	Lag Time, T_L (hours)
Green End Avenue	1.38	2.76	0.89	2.0	0.6	2.6

2.5 FEMA Comparison to HEC-HMS

To directly compare the HEC-HMS model to the FEMA FIS, the peak flows were scaled based on drainage area. The FEMA FIS peak discharges were divided by the contributing watershed area to calculate peak flow in cubic feet per second (cfs) per square mile. Scaled peak flows are shown in *Table 4*.

Table 4
FEMA and HEC-HMS Comparison of Scaled Peak Flows

Sub-watershed	Scaled Peak flow (cfs/sq. mi)		
	10-year	50-year	100-year
Maidford River (at mouth) FEMA	277	413	497
Green End Avenue (HEC-HMS)	289	448	523

The comparison between the FEMA model peak flows to HEC-HMS when the flows are scaled by the drainage area are similar for the 10-, 50-, and 100-year storms (less than 8% variance). Therefore, the HEC-HMS model is providing a reasonable prediction for peak flows for the revised hydrologic model. The hydraulic analysis presented in the following sections uses the updated hydrology developed with HEC-HMS.

3 Hydraulics

3.1 Hydraulic Model

A 2D HEC-RAS (version 6.0) hydraulic model was developed to evaluate existing and proposed conditions for the Maidford River at the Project Site.

The Flood Insurance Rate Map (FIRM panel 44005C0094H) developed for the Maidford River has an effective date of April 5, 2010 (*Figure 4*). As discussed in Section 2.2, the inundation boundary and water surface elevations presented in the FIRM were developed using a HEC-2 model (1974). It is expected that there will be differences between the published FEMA FIRM and the current HEC-RAS results due to the use of current software, datasets, and revised hydrology. Details of the development of the hydraulic model are presented in the following sections.

3.2 Existing Conditions

To evaluate existing conditions for the Maidford River, a surface terrain was created for the project reach. The terrain was created from 1-meter LiDAR based Digital Elevation Model (DEM) downloaded from NOAA Coastal Data Viewer (2016 USGS CoNED Topobathymetric Model). A point survey was performed by Interfluve on May 14, 2021, which included the channel and bridge crossings. The surveyed points were merged with the LiDAR for the project reach.

The 2D mesh was developed using an average of 50-foot by 50-foot grid cells. The mesh was refined using breaklines along the channel and major roads using 25-foot by 25-foot cells. Cells as small as 10-foot by 10-foot cells were used in areas that required further refinement, such as steep slopes.

The model starts just downstream of Wyatt Road and terminates approximately one mile downstream of Green End Avenue (*Figure 1*). The updated discharge values for the 2-, 10-, 25-, 50-, and 100-year storms developed in HEC-HMS were used as upstream boundary conditions to the model. The updated flows from HEC-HMS are developed as a hydrograph, and therefore the models were run as unsteady flow rather than assuming peak flows for the storm duration.

3.3 FEMA Cross Sections

The detailed FEMA FIS completed for the Maidford River contains four (4) lettered cross sections in the reach subject to this project. The first lettered cross section shown on the FIRM (lettered Section M) is located approximately 1,200 feet upstream of Berkeley Avenue (the start of the Project Site). The last lettered cross section subject to this project (lettered section J) is located approximately 70 feet downstream of Green End Avenue. The cross-section locations are shown on the FIRM (*Figure 4*).

These four lettered cross sections serve as comparison points between the newly developed HEC-RAS 2D hydraulic model, and the results published in the FEMA FIS.

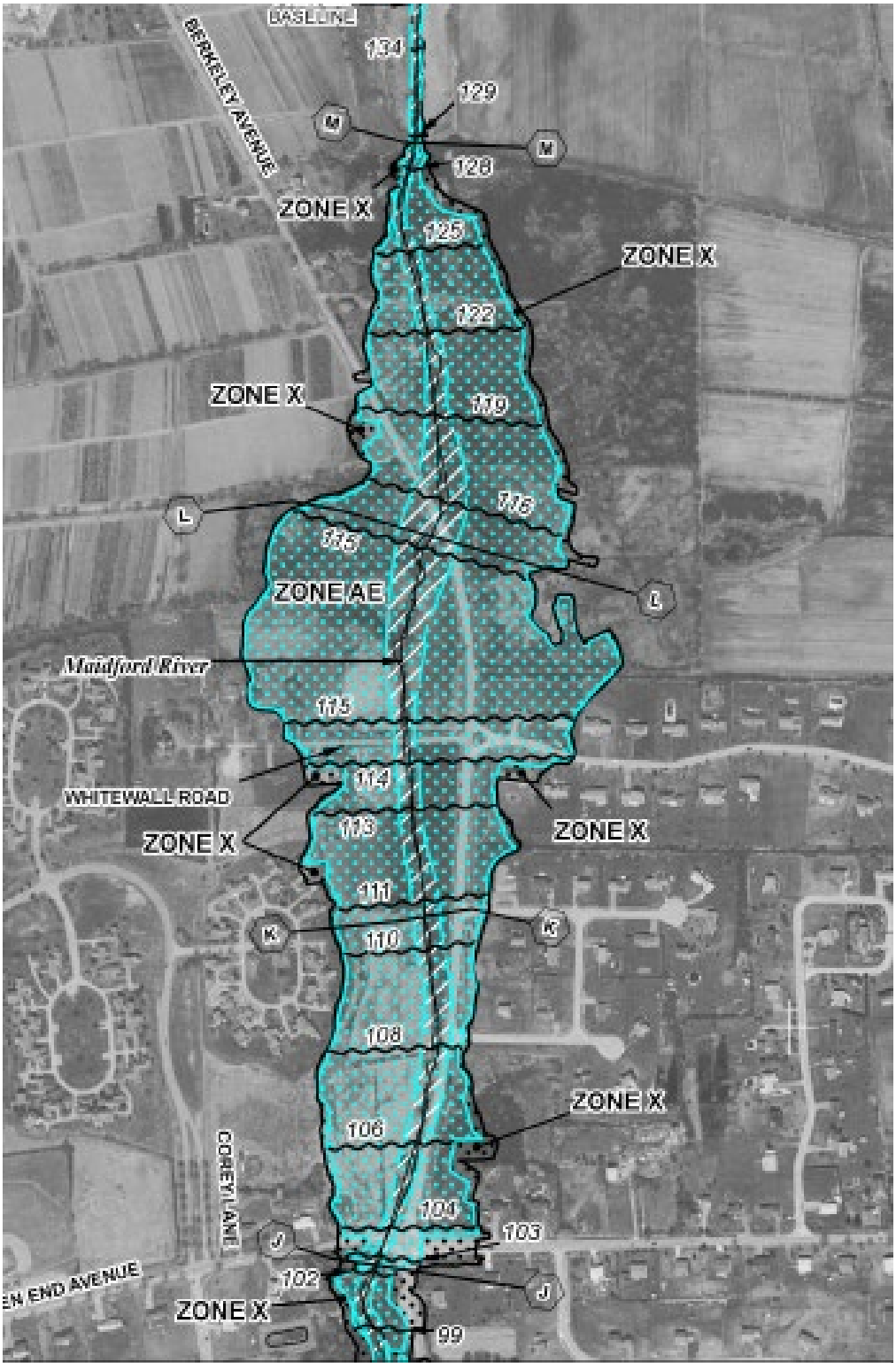


Figure 4
FEMA FIRM and Cross Section Locations

3.4 Elevation Datum

The FEMA flood profiles, and water surface elevations presented in the effective FIS July 6, 2021, report are referenced to the NAVD 88 datum. The 2016 LiDAR utilized to develop the HEC-RAS model terrain is also referenced to the NAVD 88 datum. Therefore, no datum convection was necessary, and all elevations listed in this report refer to the NAVD 88 datum.

3.4.1 Bridge Modeling Approach

There are three (3) box culverts within the Project Site: Berkeley Avenue, Berkeley Avenue Extension, and Green End Avenue. The culvert openings, inverts, and top of road measurements were surveyed in the field by Interfluve on May 14, 2021 and were incorporated into the HEC-RAS model as SA/2D area connections. The surveyed hydraulic openings for each of the culverts is presented in *Table 5*.

Table 5
Culvert Opening Dimensions

Crossing	Span (ft)	Rise (ft)
Berkeley Avenue	8	4
Berkeley Avenue Extension	8.9	4
Green End Avenue	15	5

In a 1D HEC-RAS model, expansion and contraction values are specified by the user. A 2D model internally calculates these parameters, thereby eliminating the subjectivity required in the parameter estimation. Therefore, contraction and expansion coefficients are not defined for this model.

3.4.2 Roughness (n) Values

HEC-RAS 2D incorporates Manning's n values as a layer underneath the 2D mesh so that roughness values are spatially varied throughout the extent of the terrain. The layer is created by uploading a land cover layer and assigning roughness values to each land use type. For this project, the National Land Cover Database (NLCD, 2011) was selected as the land use layer. The NLCD layer is a raster dataset with 30-meter spatial resolution. Since the resolution of land use datasets can be too course over smaller transitional areas with different land uses, it is often necessary to refine the Manning's layer with override regions, particularly for the channel. The roughness values were assigned typical values for each land use provided from the HEC-RAS technical manual (*Table 6*). The override region for the channel was assigned a roughness value of 0.035.

Table 6
Roughness Values Assigned Based on Land Cover in the HEC-RAS Model

ID	Name	ManningsN
0	NoData	0.04
15	Palustrine Emergent Wetland	0.08
14	Palustrine Scrub/Shrub Wetla...	0.08
6	Cultivated Crops	0.05
4	Developed - Low Intensity	0.1
13	Palustrine Forested Wetland	0.08
11	Mixed Forest	0.15
16	Estuarine Forested Wetland	0.08
7	Pasture/Hay	0.05
10	Evergreen Forest	0.12
12	Scrub/Shrub	0.12
5	Developed - Open Space	0.05
8	Grassland/Herbaceous	0.05
3	Developed - Medium Intensity	0.12
2	Developed - High Intensity	0.15
9	Deciduous Forest	0.15

3.4.3 Model Results - Existing Conditions

A comparison of the 100-year water surface elevations (WSELs) calculated using the HEC-RAS existing condition model to the published FEMA FIS is provided in *Table 7*. The 100-year inundation boundary depicted on the FEMA FIRM is shown in *Figure 5*. Differences between the published FEMA results and the computed HEC-RAS results are attributed to the computational differences between the HEC-2 and HEC-RAS software, updated hydrology, and the use of updated 1 meter LiDAR and site-specific survey data.

Table 7
Existing Conditions Water Surface Elevations Compared to FEMA FIS at Lettered Cross Sections

FEMA Lettered Cross Section	100-year FEMA WSEL (ft)	100-year HEC-RAS WSEL (average, ft)	Δ WSEL (ft)
M	128.9	129.6	+0.7
L	115.3	113.4	-1.9
K	110.6	109.1	-1.5
J	102.1	102.0	-0.1

In addition to analyzing the 100-year storm, more frequent design storms were also analyzed. Anecdotal data suggests that Berkeley Avenue overtops frequently; the hydraulic model confirms that this is mainly due to the limited culvert capacity at Berkeley Avenue and Berkeley Avenue Extension.

The HEC-RAS model predicts that both Berkeley Avenue and Berkeley Avenue Extension will overtop during the 2-year storm under existing conditions. Berkeley Avenue is predicted to overtop by up to 1.3-feet and Berkeley Avenue Extension overtops by up to 0.3-feet during the 2-year storm. The model predicts flooding up to 0.5 feet deep for several residential properties on Wyndham Hill Road; however, the residential structures themselves are not shown to be impacted. Several residences located just upstream and downstream of Green End Avenue are predicted to experience flooding for storms greater than or equal to the 10-year event (flood depths between 0.4 and 1-foot). *Figure 6* presents the existing conditions 2-year and 100-year inundation boundary extents for comparison.



Figure 6
Existing Conditions 2- and 100-year

3.4.4 Existing Conditions Floodway Analysis

The FEMA requirements for proposed developments in a regulatory floodway states that the community shall "prohibit encroachments, including fill, new construction, substantial improvements and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base (100-year) flood discharge." Newport County participates in the National Flood Insurance Program (NFIP) program and follows the same guidance as FEMA (§1003(B)(1)).

The floodway is the portion of the floodplain that conveys most of the floodwaters and is defined as a channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more 1.0 foot. Preserving the floodway prevents development from occurring in the floodplain that will increase water surface elevations and damage to upstream properties. FEMA requires a less that 1.0-foot raise in WSEL for the floodway analysis for existing conditions and a "no-rise" in the floodway due to proposed conditions.

A regulatory floodway has been defined for the Maidford River which is shown on the FEMA FIRM (*Figure 4*). For existing conditions, the floodway analysis should demonstrate less than a 1.0-foot rise over base flood elevations when introducing encroachments along the floodway. A floodway analysis was performed using the updated HEC-RAS 2D hydraulic model for existing conditions to verify that the updated model will show less than 1.0-foot rise over base flood elevations.

The floodway boundaries were replicated in GIS to match the extent of the FEMA floodway depicted on the FIRM. These boundaries were imported into HEC-RAS as SA/2D area connections. The heights were artificially raised to an infinite height, effectively creating a "flood wall" obstruction where water will be confined to the floodway. *Figure 7* shows the floodway model setup in the HEC-RAS 2D model.

Table 8 shows that for each FEMA lettered cross section the floodway analysis is showing less than a 1.0-foot rise over the base flood elevation for the HEC-RAS existing conditions model.

Table 8
100-year Floodway Analysis for Existing Conditions

FEMA Lettered Cross Section	FEMA Floodway WSEL (ft)	HEC-RAS Floodway Existing WSEL (average, ft)	HEC-RAS Existing WSEL (average, ft)	HEC-RAS Δ WSEL (ft)
M	129.9	129.6	129.6	0.0
L	116.3	114.3	113.4	+0.9
K	111.6	109.4	109.1	+0.3
J	102.4	101.6	102	-0.4



Figure 7
Overview of Floodway Model in HEC-RAS

3.4.5 Existing Conditions with Future Flows

According to USGS Scientific Investigations Report 2012-5109, average flood magnification factors of 1.06, 1.13, and 1.21 were computed from local stream gauge data for 10-, 20-, and 30-year projections, respectively, out from 2010. To assess the impacts for existing conditions that projected increases in precipitation caused by climate change would have on flooding experienced through the project reach, a flood magnification factor of 1.21 was applied to each flood event in the existing conditions model, reflecting future conditions for the year 2040.

To quantify the change in runoff as a result of increased precipitation due to climate change, the existing conditions were also run in the HEC-RAS model with the 1.21 magnification factor applied to the rainfall runoff hydrographs generated for each analyzed flood event. This comparison demonstrates what the flooding conditions will look like under future precipitation conditions if no action is taken at the Project Site. A depiction of existing conditions with existing flow versus existing conditions with projected flows at the Project Site for the 100-year storm is provided on *Figure 8*. If no site improvements are made, the biggest impacts under future flood conditions are predicted at Berkeley Avenue Extension as water encroaches on the surrounding houses at the condo association to the west and Wyndham Hill Road to the east. Under future conditions, flooding depths at each of the road crossings is predicted to increase an average 0.2-ft.

The alternatives considered for this project were also analyzed using projected flows and are explained in more detail in the following sections.

4 Alternatives Analysis

4.1 Design Elements

The design elements that were considered to mitigate flooding at the Project Site include:

- Raise Berkeley Avenue
- Increase the culvert size at Berkely Avenue
- Increase the culvert size at Berkely Avenue Extension
- Introduce flood storage on Sweet Berry Farm
- Install a berm adjacent to Berkley Avenue

The design elements are broken into five (5) elements shown in *Figure 9*. Three alternatives were evaluated to determine the impact of flood mitigation of the five proposed design elements as outline in *Table 9*. A summary description of each alternative is provided in the following paragraphs.

Table 9
Summary of Design Elements Included in Each Alternative

	Berkeley Ave Road Raise	Berm Perpendicular to Berkeley Ave	Berkeley Ave Extension Culvert Expansion	Sweet Berry Farm Flood Storage	Berkeley Ave Culvert Expansion
Alternative 1	Yes	Yes	Yes	No	No
Alternative 2	Yes	Yes	Yes	Yes	No
Alternative 3	Yes	Yes	Yes	Yes	Yes

Alternative 1 assesses the road raise necessary at Berkeley Avenue to prevent overtopping while only increasing culvert capacity at Berkeley Avenue Extension. A proposed berm is to be installed perpendicularly to Berkeley Avenue to prevent water from reaching the downstream residences by Windham Hill Road.

Alternative 2 incorporates the same elements as Alternative 1, but also adds storage on Sweet Berry Farm (upstream of Berkeley Avenue) to act like a detention basin. The goal of the storage on Sweet Berry Farm is to offset the road raise required for Berkeley Avenue to not overtop.

Alternative 3 incorporates the same elements as Alternative 2 but also assesses the impacts of expanding the Berkeley Avenue culvert.

In addition to the design elements presented above, floodplain restoration and the addition of sinuosity to the Maidford River between Berkeley Avenue and Green End Avenue are included in all alternatives (*Figure 10*).



Figure 10
Existing Conditions (left) and Floodplain Restoration with Added Sinuosity (right)

4.2 Results of Alternatives Analysis

The inundation mapping for the full model extents for each Alternative are provided in *Appendix B*.

Alternative 1 demonstrated the impacts of the limited culvert size at Berkeley Avenue. The iterative solution determined the following sizes for the design elements:

- Raise Berkeley Avenue by 9-feet, culvert size remains the same
- Create an 8-foot fall berm perpendicular to Berkeley Avenue
- Increase the culvert capacity at Berkeley Avenue Extension (35-foot width)

Despite the 9-foot road raise, Berkley Avenue is still predicted to overtop for the 100-year storm. *Figure 11* demonstrates the water surface elevation (WSEL) of the proposed conditions, as viewed looking downstream.

For comparison, the 10-year storm was analyzed. While the results show some improvements downstream during the 10-year storm, Berkeley Avenue would have to be raised more than 5-feet (*Figure 12*). While Berkeley Avenue could theoretically be raised 5-feet, the costs associated with such a significant road raise would likely outweigh the benefits this solution provides. When performing a road raise, the proposed elevation must tie into existing grade and ensure that the slopes are reasonable for vehicles to traverse. The larger the road raise, the linear distance required to meet existing grade also increases which translates into larger costs. Additionally, Berkeley Avenue intersects with other side streets; these roads would also require a road raise to tie into the new elevations proposed for Berkeley Avenue, further increasing the expense of the project.

The results of Alternative 1 highlighted the sensitivity of the hydraulics compared to the road height at Berkeley Avenue. In existing conditions, Berkeley Avenue overtops and therefore most of the water travels downstream. In this alternative, instead of water overtopping Berkeley Avenue, water is stored behind the road. Both the 10-year and 100-year results show that the predicted flood boundaries upstream of Berkeley Avenue extend beyond existing conditions. Therefore, Alternative 1 is not a feasible solution on its own.

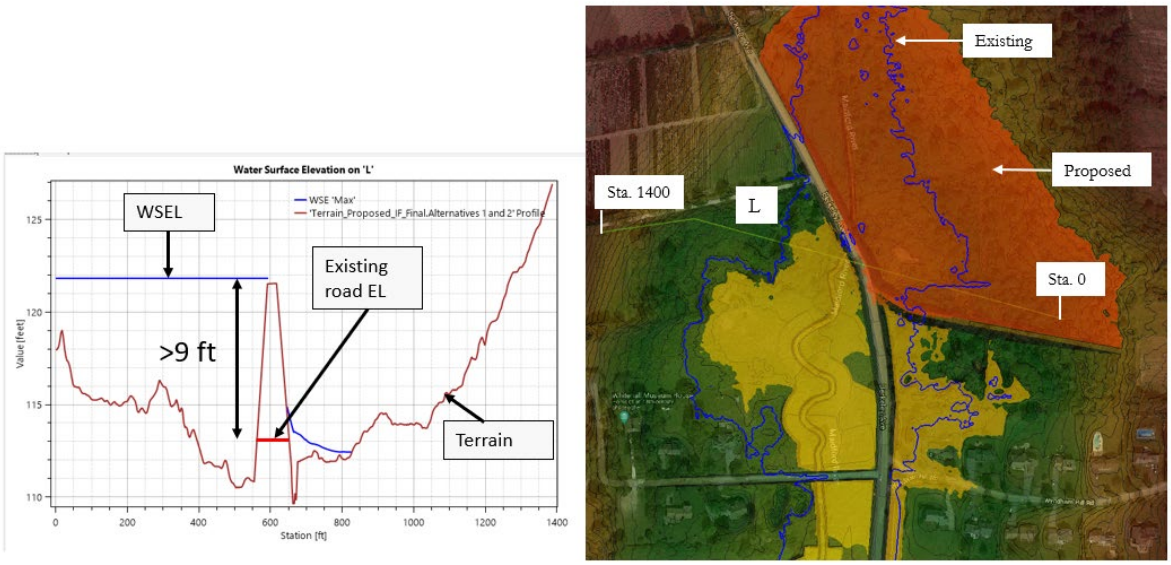


Figure 11
Alternative 1 – 100-year Results

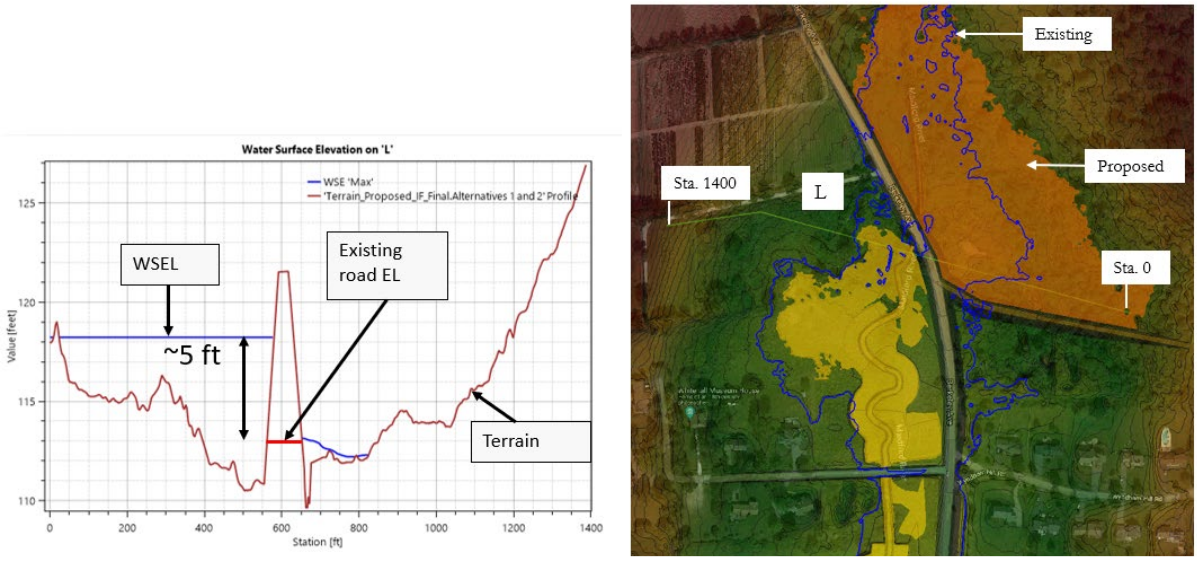


Figure 12
Alternative 1 – 10-year Results

Alternative 2 incorporates the same design elements as Alternative 1, with the addition of storage on Sweet Berry Farm. The iterative solution determined the following sizes for the design elements:

- Raise Berkeley Avenue by 9-feet
- Create an 8-foot fall berm perpendicular to Berkeley Avenue
- Increase culvert capacity at Berkeley Avenue Extension (35-foot width)
- Add 4 acres of storage on Sweet Berry Farm

In Alternative 1, it was determined that the road raise required to prevent Berkeley Avenue from overtopping is significant (greater than 5-feet). The proposed solution of adding storage on Sweet Berry Farm is to attempt to offset the required road raise at Berkeley Avenue. A 4-acre area was used for floodplain restoration. The results from the 10-year storm are shown as an example in *Figure 13*.

The results of Alternative 2 showed that the additional storage on Sweet Berry Farm did not impact the required dimensions for the road raise, berm, or culvert width at Berkeley Avenue Extension; they are the same as Alternative 1. While it might be possible to achieve a reduced road raise using flood storage on Sweet Berry Farm, the area to be excavated would have to be considerably greater than 4 acres, and therefore the construction costs would likely outweigh the benefits. Further analysis was not performed to determine the flood storage necessary to achieve a road reduction, however it was apparent that it is not feasible to achieve appreciable results without significant excavation. Alternative 2 determined that floodplain restoration on Sweet Berry Farm will be useful for providing ecological benefits but does not provide flood reduction benefits.

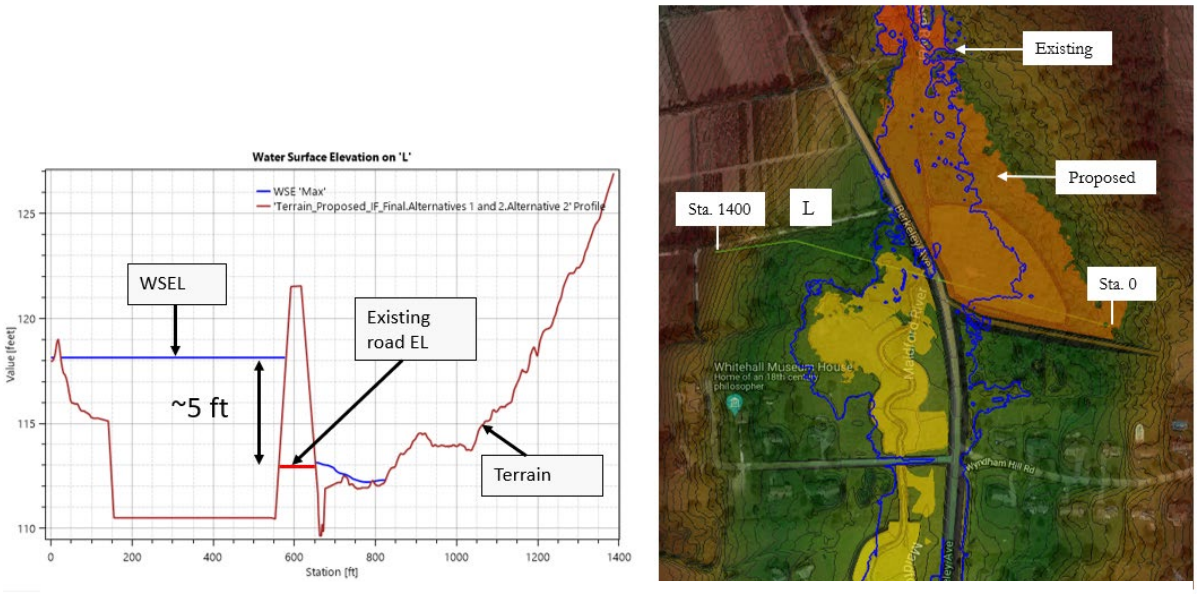


Figure 13
Alternative 2 – 10-year Results

Alternative 3, which uses all five design elements showed the best results for flood mitigation at the Project Site. The iterative solution determined the following sizes for the design elements:

- Raise Berkeley Avenue by 2.5-feet (including 0.5 feet of freeboard)
- Create a 3.5-foot-tall berm perpendicular to Berkeley Avenue
- Increase the culvert capacity at Berkeley Avenue Extension (35-foot width)
- Optional: add 4 acres of storage on Sweet Berry Farm
- Increase the culvert capacity at Berkeley Avenue (35-foot width)

As shown in *Figure 14*, Alternative 3 removes several areas from the 100-year floodplain. Both Berkeley Avenue and Berkeley Avenue Extension are no longer overtopping. The berm adjacent to Berkeley Avenue is preventing water from reaching Wyndham Hill Road, removing the downstream houses and roadways from the floodplain. As discussed in Alterative 2, the 4-acres on Sweet Berry Farm did not improve flood reductions for this alternative.

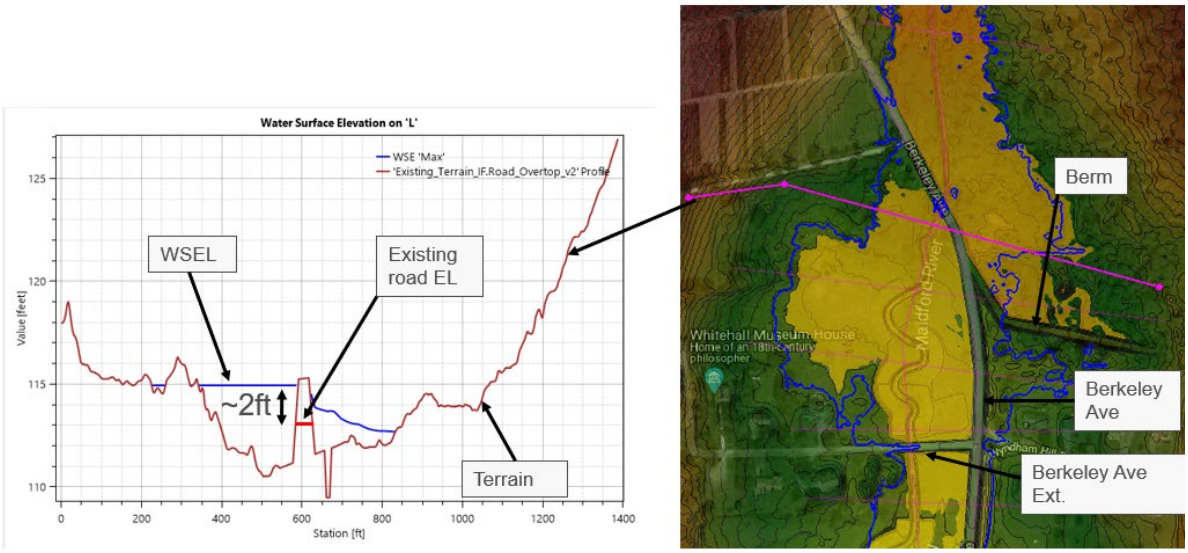


Figure 14
Alternative 3 – 100-year Results

A fourth alternative was developed to assess the minimum design width for the culverts based on 1.2 times the bankfull width (the minimum requirement for culvert size). The field measurements indicated a bankfull width of 18 feet, resulting in Berkeley Avenue and Berkeley Avenue Extension culverts to be widened to at least 22-ft.

Alternative 4 is an extension of Alternative 3. The design elements incorporated in Alternative 4 are:

- Raise Berkeley Avenue by 2.5-feet (including 0.5 feet of freeboard)
- Create a 3.5-foot fall berm perpendicular to Berkeley Avenue
- Increase the culvert capacity at Berkeley Avenue Extension (22-foot width)
- Increase the culvert capacity at Berkeley Avenue (22-foot width)
- Add 4 acres of storage on Sweet Berry Farm

Alternative 4 is a less expensive solution compared to Alternative 3 but does not provide as much flood protection. This solution can provide flooding protection up to the 25-year present day storm (*Figure 15*).

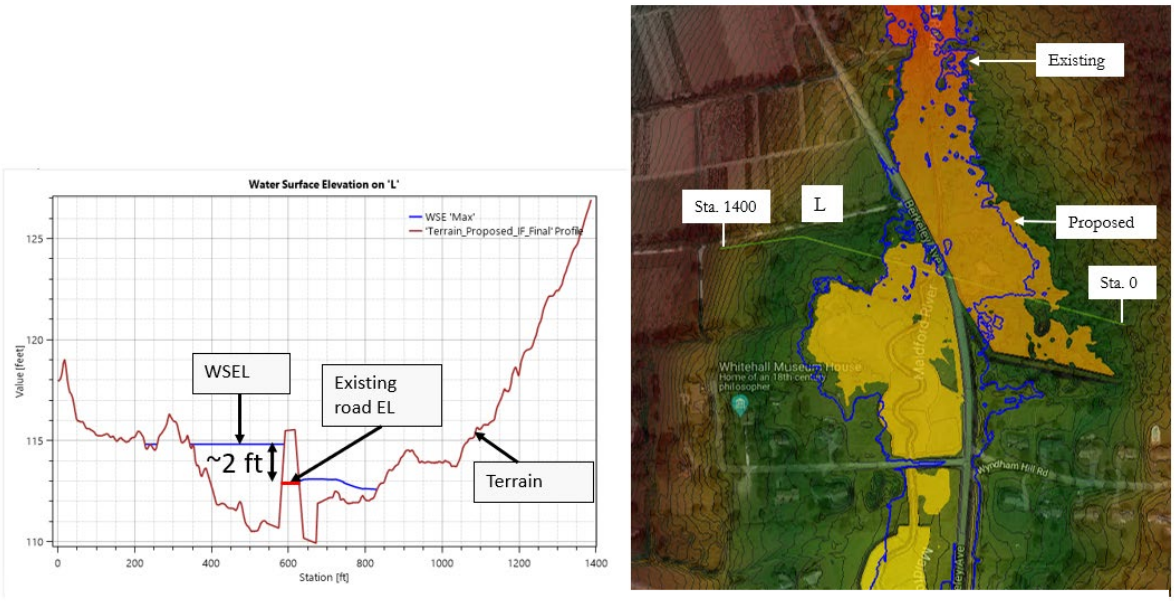


Figure 15
Alternative 4 – 25-year Results

4.3 Alternatives Floodway Analysis

As discussed in Section 3.2.6, FEMA and the NFIP regulations for Newport County require a "no-rise" in the floodway for proposed projects. Each of the proposed alternatives was run using the floodway model to determine the proposed changes in water surface elevation at each of the FEMA lettered cross sections (*Table 10*). Each Alternative currently shows a net rise at cross section M which is located upstream of Berkeley Avenue. The downstream cross sections are all showing a WSEL reduction in the floodway model for each alternative.

Table 10
100-year HEC-RAS Floodway Analysis for Each Alternative Compared to Existing Conditions

FEMA Lettered Cross Section	Floodway Existing Conditions WSEL (average, ft)	Alternative 1 WSEL (average, ft)	Δ WSEL (ft)	Alternative 2 WSEL (average, ft)	Δ WSEL (ft)	Alternative 3 WSEL (average, ft)	Δ WSEL (ft)	Alternative 4 WSEL (average, ft)	Δ WSEL (ft)
M	129.6	130.3	+0.7	130.3	+0.7	130.3	+0.7	130.3	+0.7
L	114.3	113.5	-0.8	113.5	-0.8	113.5	-0.8	113.6	-0.7
K	109.4	109.2	-0.2	109.2	-0.2	109.2	-0.2	109.2	-0.2
J	101.6	101.4	-0.2	101.4	-0.2	101.4	-0.2	101.4	-0.2

The road raise at Berkeley Avenue will impact the floodway elevation at cross section M. For this phase of the project, restoration alternatives were not developed at the upstream end of the model. For future phases of the project, it will be necessary to develop engineering controls to offset the backwater effects from raising Berkeley Avenue.

5 Design Analysis

5.1 Recommended Alternative

A summary of the results from the Alternatives Analysis is presented in *Table 11* below. The initial screening of the Alternatives showed that Alternatives 1 and 2 are not sufficient on their own to mitigate flooding in this area and the cost associated with the massive road raise at Berkeley Avenue are significant compared to the limited flood benefits these alternatives provide. Both Alternatives 3 and 4 meet the project objectives in terms of ecological restoration and flood mitigation downstream of Berkeley Avenue. However, additional analysis will need to be completed to address the rise in floodway upstream of Berkeley Avenue.

Table 11
Summary of Design Elements for Alternatives Analysis

Alternative	Design Storm	Berkeley Ave Road Raise	Berkeley Ave Ext. Culvert (width)	Berkeley Ave Culvert (width)	Additional Floodplain Storage on Sweet Berry Farm	Rise in Floodway
1	100-year	>9 ft	35 ft	N/A	N/A	Yes
	10-year	>5 ft	35 ft	N/A	N/A	Yes
2	10-year	>5 ft	35 ft	N/A	Yes (~4 acres)*	Yes
3	100-year	~2.5 ft	35 ft	35 ft	Yes (~4 acres)*	Yes
	10-year	~1 ft	35 ft	35 ft	Yes (~4 acres)*	Yes
4	25-year	~2.5 ft	22 ft	22 ft	N/A	Yes

* Not required to obtain similar results

To determine the preferred alternative, a meeting was conducted with the Town of Middletown on September 8, 2021. It was decided that Alternative 3 is the preferred solution as it provides flood benefits for larger storm events. While Alternative 4 is a viable option, the Town decided to design for flood protection for a larger design storm (present day 100-year).

One of the objectives for the preferred alternative was to avoid increasing flows downstream due to the proposed conditions. The hydrographs for the existing and proposed conditions at the downstream extent of the model are presented in *Figure 16*. The existing conditions show a peak flow of 717 cfs and a proposed peak flow of 707 cfs. The results show that flow increases are not expected downstream for the preferred alternative.

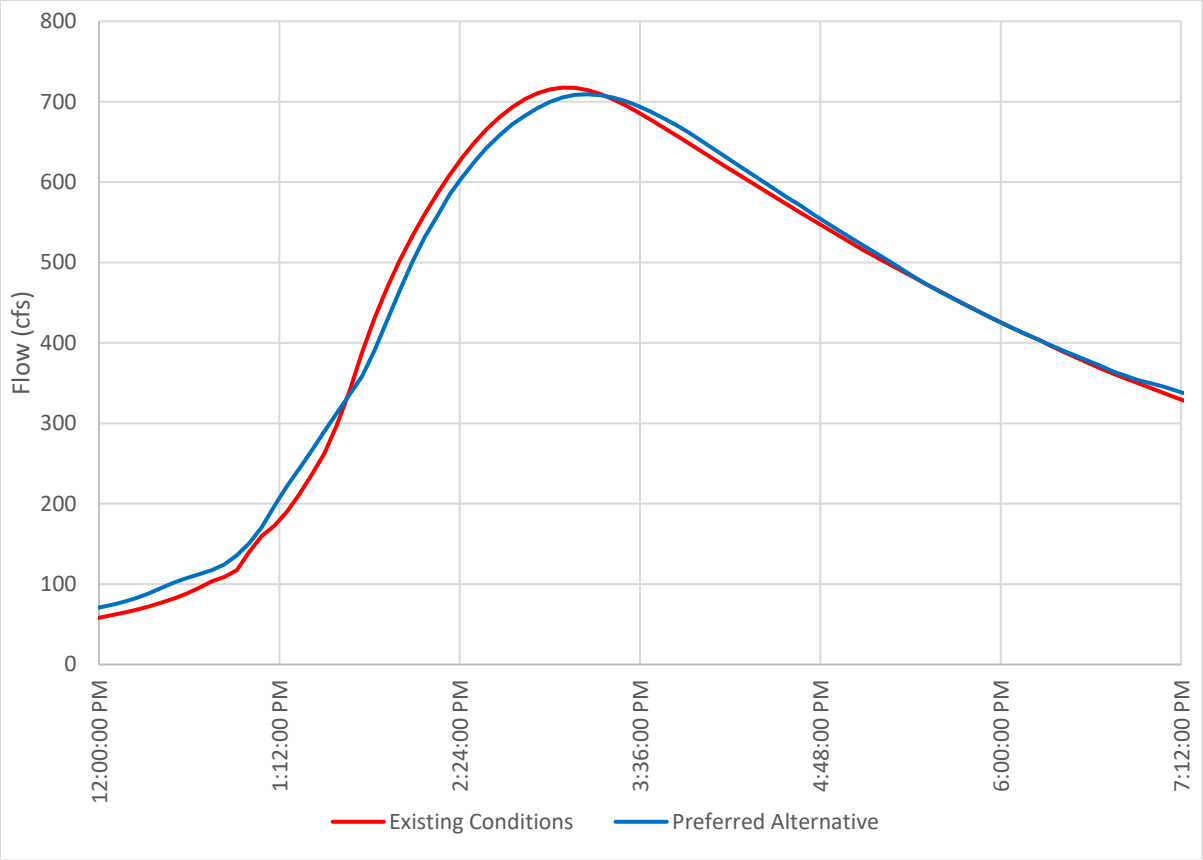


Figure 16
Existing and Proposed Discharge of Preferred Alternative at Downstream Extent of Model

5.2 Recommended Alternative with Projected Flows

As discussed in Section 3.2.6, a flood magnification factor of 1.21 was applied to assess the impacts of future conditions on the preferred alternative. Since the present day 100-year storm was used as the design storm for the preferred alternative, an analysis was conducted to determine which design storm the preferred alternative can withstand under future conditions. The 100-year projected storm was run first which showed Berkeley Avenue overtopping by 0.1 feet. The 50-year was the next largest storm that was analyzed, and the results showed no overtopping for Berkeley Avenue or Berkeley Avenue Extension (*Figure 17*). The results indicate that the preferred alternative is resilient to a future design storm between the 50- and 100-year. The exact return interval was not calculated as a part of this study.

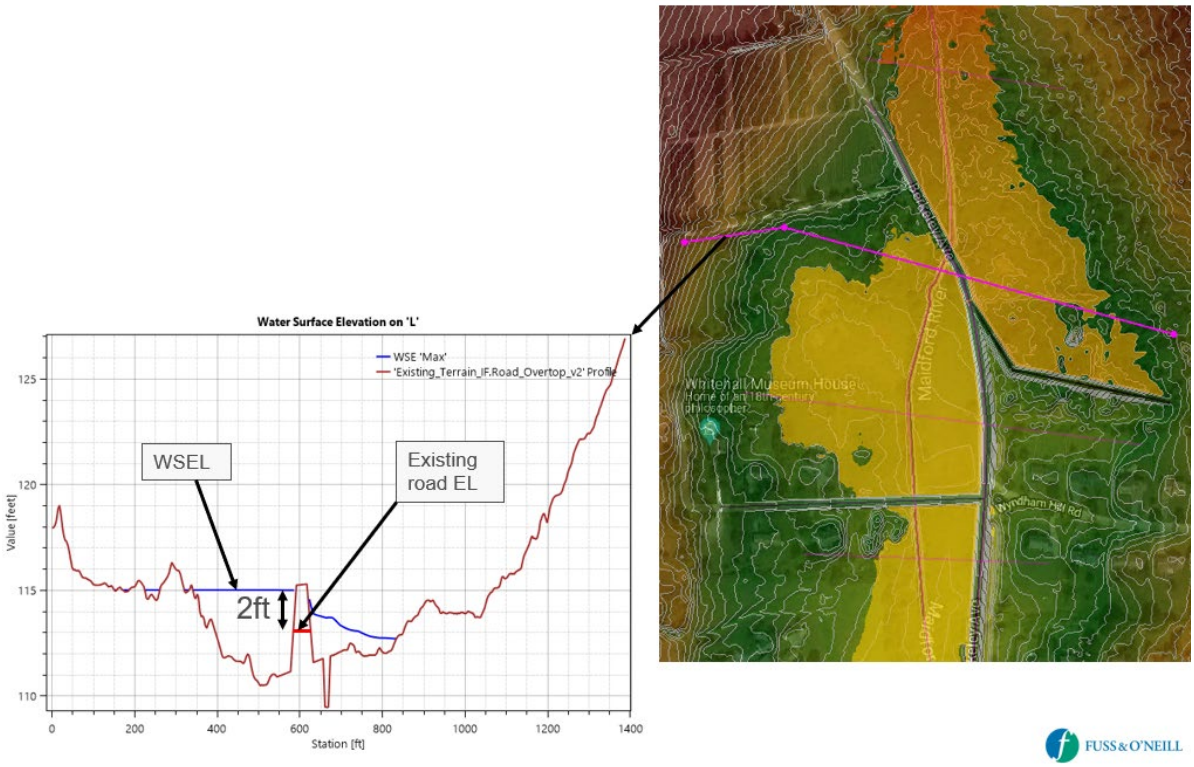


Figure 17
Alternative 3 – 50-year Projected Results

5.3 Recommended Alternative Compared to FEMA Lettered Cross Sections

A comparison of the 100-year WSELs from the HEC-RAS existing condition model to the proposed recommended alternative at the FEMA lettered cross sections is provided in *Table 12*. All FEMA lettered cross sections show values below the maximum allowable 1.0-foot increase in the floodplain.

Table 12
Comparison of 100-year WSEL for HEC-RAS Existing and Proposed Conditions at FEMA Lettered Cross Sections

FEMA Lettered Cross Section	100-year HEC-RAS Existing WSEL (average, ft)	100-year HEC-RAS Proposed WSEL (average, ft)	Δ WSEL (ft)
M	129.6	129.4	-0.2
L	113.4	114.0	+0.6
K	109.1	105.9	-3.2
J	102.0	102.3	+0.3

Note that while cross section L is showing an increase in WSEL for proposed conditions, this can be misleading. Since HEC-RAS 2D calculates WSEL on a grid cell by grid cell basis, an average of the WSEL must be taken across the lettered cross sections in order to compare the values to the published FEMA FIS.

Cross section L overlaps both the upstream and downstream side of Berkeley Avenue (*Figure 18*). Since the proposed conditions contain a road raise at Berkeley Avenue, the upstream side on Sweet Berry Farm shows a higher WSEL of 114.6 (water is being stored behind the road). The downstream side heading towards the condo association is at elevation 113.1, which is 0.9 feet below existing conditions. When averaged across the entire cross section at L, that is showing an overall increase of 0.6 feet as presented in *Table 13*. The results are showing more water being stored on open space (Sweet Berry Farm) and less that is moving downstream.

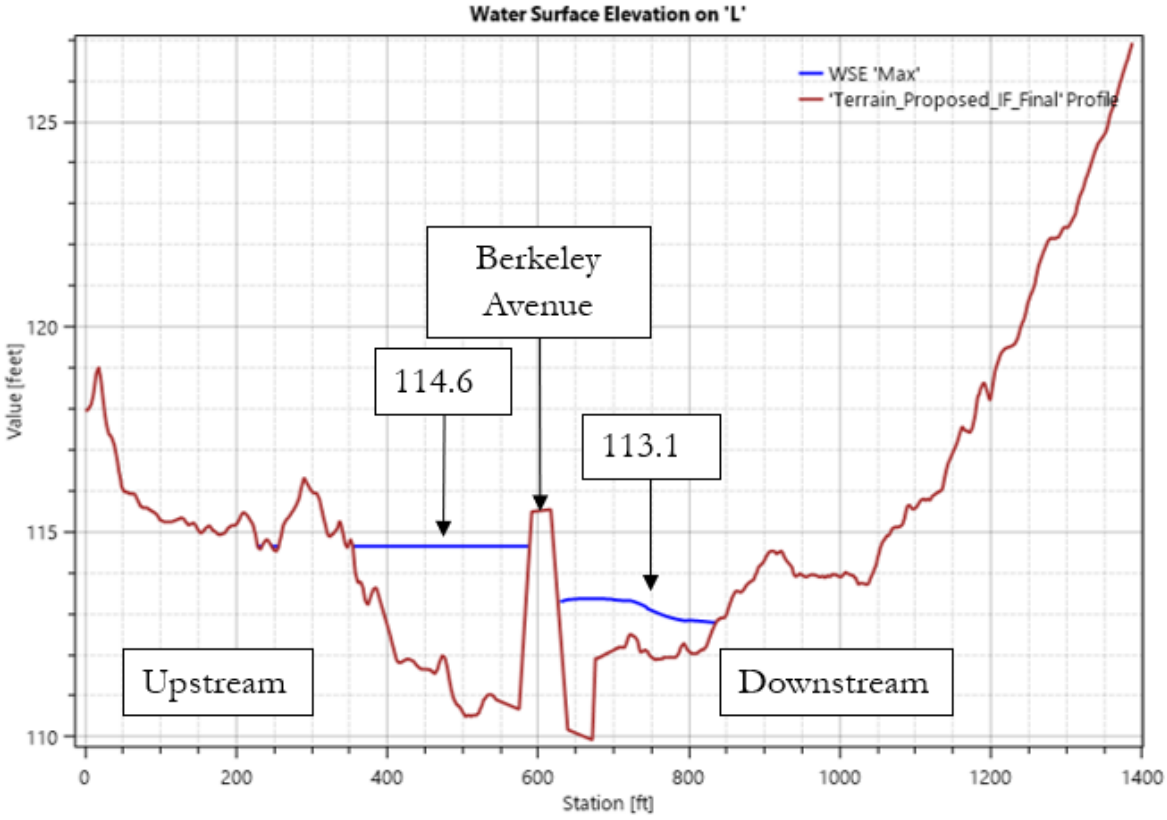


Figure 18
WSEL Across FEMA Section L for Preferred Alternative

A comparison of the 100-year WSELs calculated from the HEC-RAS proposed recommended alternative compared to the published FEMA FIS is provided in *Table 13*. Note that while these values are not a direct comparison due to differences in the modeling approach, the HEC-RAS results are showing a less than 1.0-foot rise in the floodplain compared to the published FEMA FIS at the lettered cross sections.

Table 13
Comparison of 100-year WSEL for HEC-RAS Proposed Conditions and FEMA FIS at FEMA Lettered Cross Sections

FEMA Lettered Cross Section	100-year FEMA WSEL (ft)	100-year HEC-RAS Proposed WSEL (average, ft)	Δ WSEL (ft)
M	128.9	129.4	+0.5
L	115.3	114.0	-1.3
K	110.6	105.9	-4.7
J	102.1	102.3	+0.2

6 Conclusions and Recommendations

This report presents the hydrologic and hydraulic analyses performed to assess the potential impacts to regulatory FEMA floodplain on the Maidford River. The published flows from the FEMA FIS showed inconsistences between the magnitude of the flows and the drainage areas. Therefore, an updated hydrologic analysis was performed using the most up to date land use, soil, and rainfall data. The published hydraulic model was created in 1974 using HEC-2 and has not been updated since its creation. An updated 2D HEC-RAS model was created to evaluate existing conditions. The 2D model utilizes 1-meter LiDAR providing higher accuracy of the existing terrain compared to interpolation between cross sections that is required of 1D models.

An alternatives analysis was performed to address the frequent flooding issues in the vicinity of Berkeley Avenue. Alternative 3 was selected as the preferred solution, which is hydraulically adequate to pass the present-day 100-year flood without causing adverse impacts to the regulatory floodplain. Alternative 3 included the following design parameters:

- Raise Berkeley Avenue by 2.5-feet (including 0.5 feet of freeboard)
- Create a 3.5-foot fall berm perpendicular to Berkeley Avenue
- Increase the culvert capacity at Berkeley Avenue Extension (35-foot width)
- Optional: add 4 acres of storage on Sweet Berry Farm
- Increase the culvert capacity at Berkeley Avenue (35-foot width)
- Floodplain restoration and added sinuosity of the Maidford River downstream of Berkeley Avenue to Green End Avenue

A climate change analysis was performed for the preferred alternative by scaling existing flows by a 1.21 magnification factor. The results indicated that the proposed design is resilient between the 50-year and 100-year projected storm (Berkeley Avenue and Berkeley Avenue Extension do not overtop).

There is a regulatory floodway on the Maidford River reach within the Project Site. The proposed road raise at Berkeley Avenue causes an increase in WSEL in the floodway model at cross section M for all alternatives. The design for this project only focused on restoration alternatives downstream of Berkeley Avenue. Therefore, for future phases of this project, it will be necessary to develop engineering controls to address the increase in the floodway upstream of Berkeley Avenue.

A potential solution for addressing the WSEL increase in the floodway is to incorporate floodplain restoration within the floodway upstream of Berkeley Avenue. Adding additional flood storage within the floodway should offset the raise in WSEL created from raising Berkley Avenue. This solution will require additional buy-in from the surrounding land owners.

Figures

Figure 1 - Model Extent
Figure 5 – FEMA Boundary Comparison
Figure 8 – Existing Conditions under Future Climate Change
Figure 9 – Design Elements

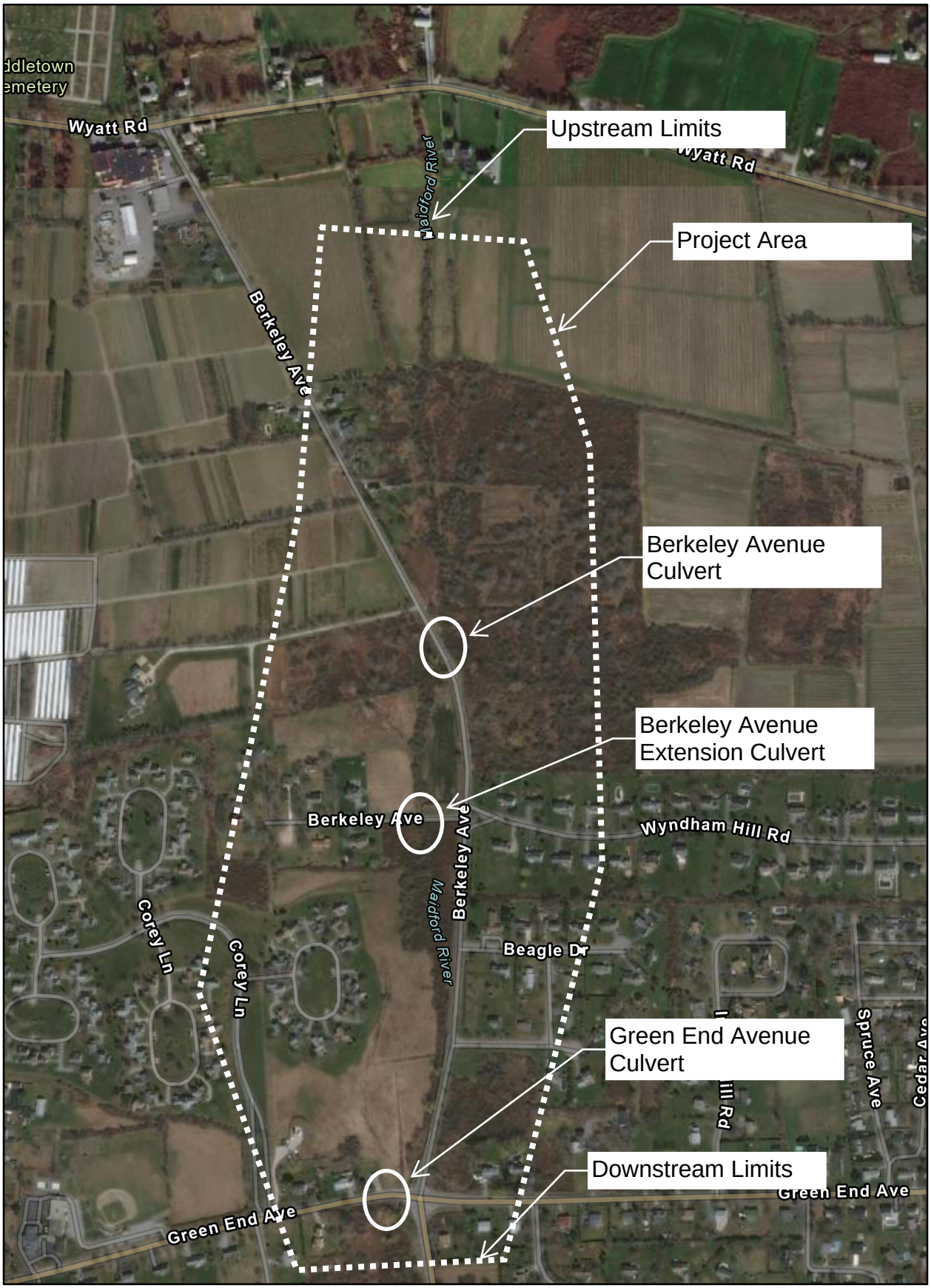


Figure 1
Model Extent



Figure 5
FEMA Boundary Comparison

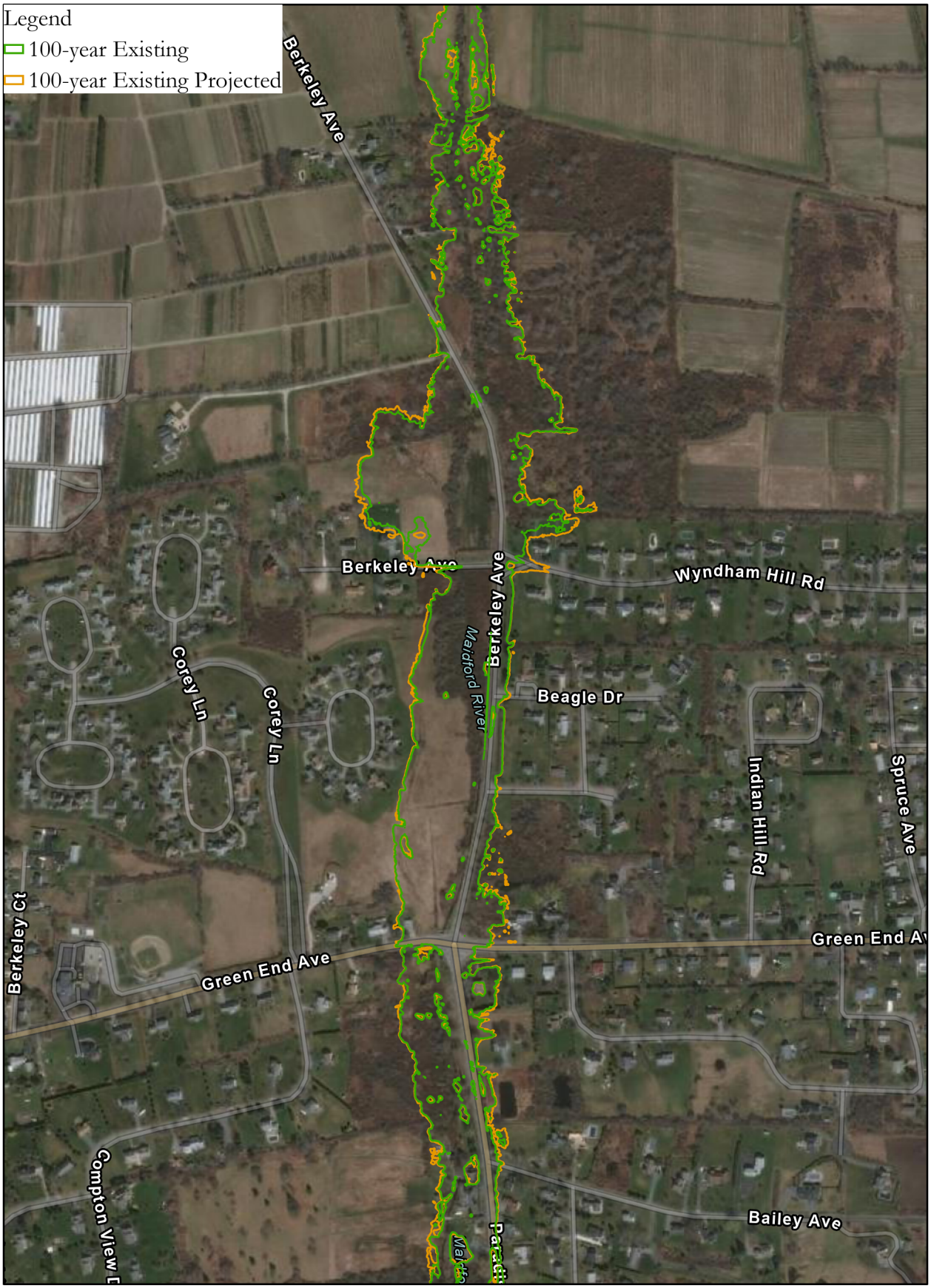


Figure 8
Existing Conditions under Future Climate Change

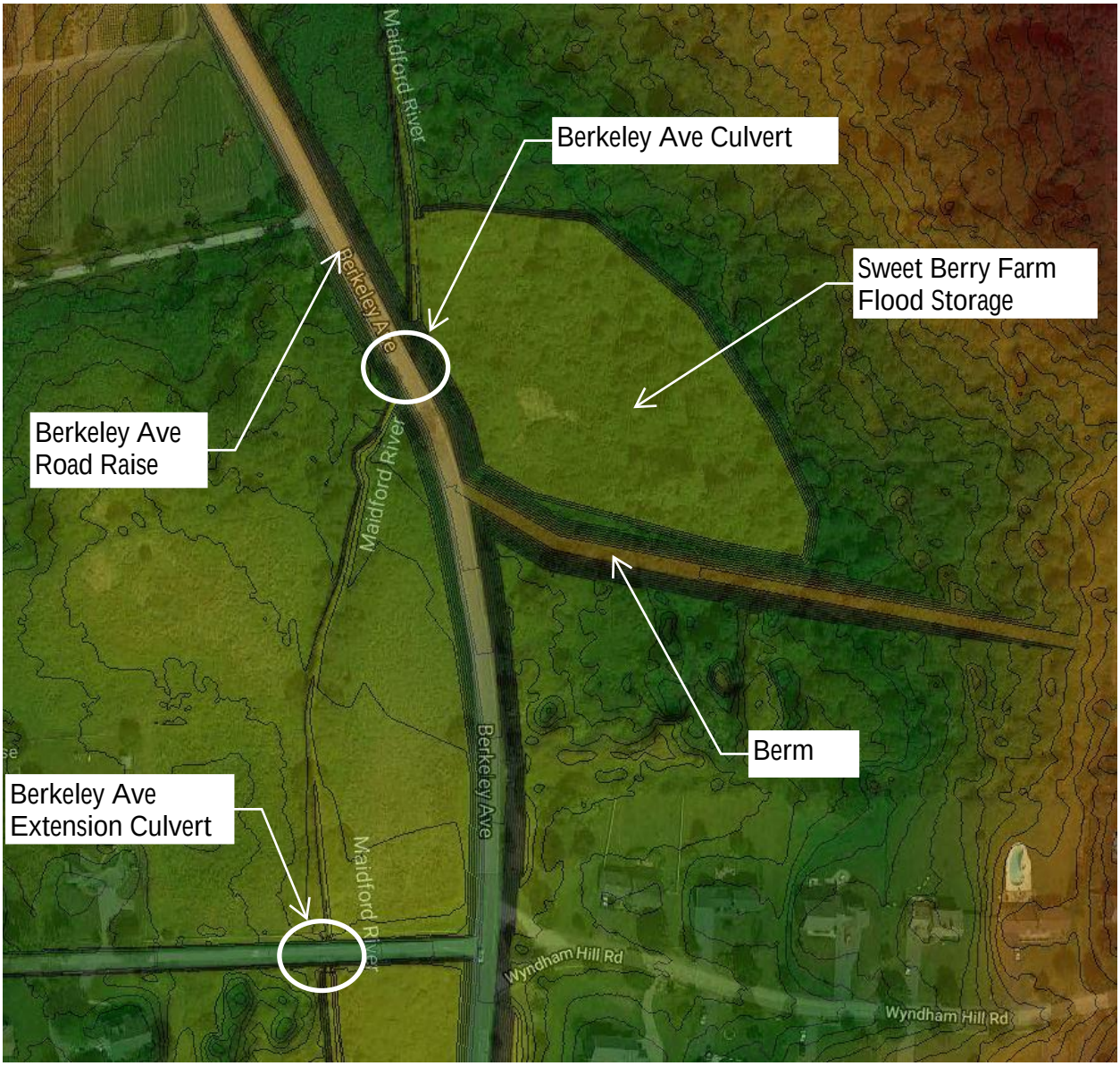


Figure 9
Design Elements

Appendix A

Relevant Pages from FEMA FIS

Table 9: Summary of Discharges

Flooding Source	Location	Drainage Area (Square Miles)	Peak Discharge (cfs)				
			10% Annual Chance	4% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Bailey Brook	At the mouth	2.79	370	*	625	710	1,055
Bailey Brook	At State Route 214	1.18	215	*	370	415	619
Beacon Avenue Tributary	At the mouth	*	69	*	114	136	216
Conanicut Brook	At the mouth	*	106	*	164	222	295
Jamestown Brook	At the mouth	1.1	451	*	724	919	1,319
Maidford River	At the mouth	2.25	624	*	929	1,119	1,567
Maidford River	At Prospect Avenue	1.32	651	*	970	1,168	1,696
Paradise Brook	A the mouth	1.08	200	*	350	395	597
Paradise Brook	At Private Drive	0.41	115	*	190	215	314
Sheffield Cove Brook	At the mouth	*	264	*	434	496	639

*Not calculated for this Flood Risk Project

Figure 7: Frequency Discharge-Drainage Area Curves

[Not Applicable to this Flood Risk Project]

Table 10: Summary of Non-Coastal Stillwater Elevations

[Not Applicable to this Flood Risk Project]

Table 12: Summary of Hydrologic and Hydraulic Analyses

Flooding Source	Study Limits Downstream Limit	Study Limits Upstream Limit	Hydrologic Model or Method Used	Hydraulic Model or Method Used	Date Analyses Completed	Flood Zone on FIRM	Special Considerations
Maidford River	Paradise Avenue	Above Wyatt Road	TR-20 (SCS 1965)	HEC-2 (USACE 1974)	11/1/1979	AE w/Floodway	Starting water-surface elevations were from mean high tide on Sakonnet River. Hydraulic model was calibrated to historical records from local residents and officials. Recent modifications were taken into account in the use of historical records.
Paradise Brook	Mouth at Nelson Pond	Above Third Beach Road	TR-55 (SCS 1974)	HEC-2 (USACE 1974)	11/1/1979	AE w/Floodway	TR-55 was used to compute 10-, 2-, and 1-percent-annual-chance floods. 0.2-percent-annual-chance flood was extrapolated based on log-Pearson type III distribution (WRC 1976). Starting water-surface elevations were from bankfull analysis of Nelson Pond. Hydraulic model was calibrated to historical records from local residents and officials. Recent modifications were taken into account in the use of historical records.
Sheffield Cove Brook	Maple Avenue	Narragansett Avenue	Time of concentration-flow relationships	WSP-2 (SCS 1976)	2/1/1984	AE	Discharges were determined using the relationship between time of concentration and flow in cubic feet per second per square mile per inch of runoff. Time of concentration was calculated from the physical characteristics of each basin. Flow was calculated using rainfall data (USWB 1961) and SCS runoff curves, in turn based on soils and land-use data.

LOCATION		FLOODWAY			1% ANNUAL CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD88)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQ. FEET)	MEAN VELOCITY (FEET/SEC)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
A	6,930	197	764	1.5	10.7[2]	11.0[3]	12.0	1.0
B	7,390	51	253	4.6	14.6	14.6	15.6	1.0
C	8,075	39	155	7.6	25.3	25.3	25.5	0.2
D	8,595	20	137	8.5	34.8	34.8	35.8	1.0
E	9,020	49	159	7.4	44.4	44.4	44.7	0.3
F	10,340	42	190	6.1	60.3	60.3	61.3	1.0
G	10,770	132	179	6.5	69.9	69.9	70.2	0.3
H	11,690	26	144	8.1	82.2	82.2	83.2	1.0
I	12,615	22	177	6.6	86.6	86.6	87.6	1.0
J	13,640	43	160	7.3	102.1	102.1	102.4	0.3
K	14,765	85	317	3.2	110.6	110.6	111.6	1.0
L	16,040	185	872	1.0	115.3	115.3	116.3	1.0
M	17,285	24	118	6.5	128.9	128.9	129.9	1.0
N	18,380	21	97	7.4	147.8	147.8	148.8	1.0
O	19,055	55	201	2.8	152.6	152.6	153.6	1.0

[1]Feet above confluence with Sakonnet River
[2]Elevation computed without consideration of wave effects
[3]Elevation computed without consideration of tidal flooding from Rhode Island Sound

TABLE 23

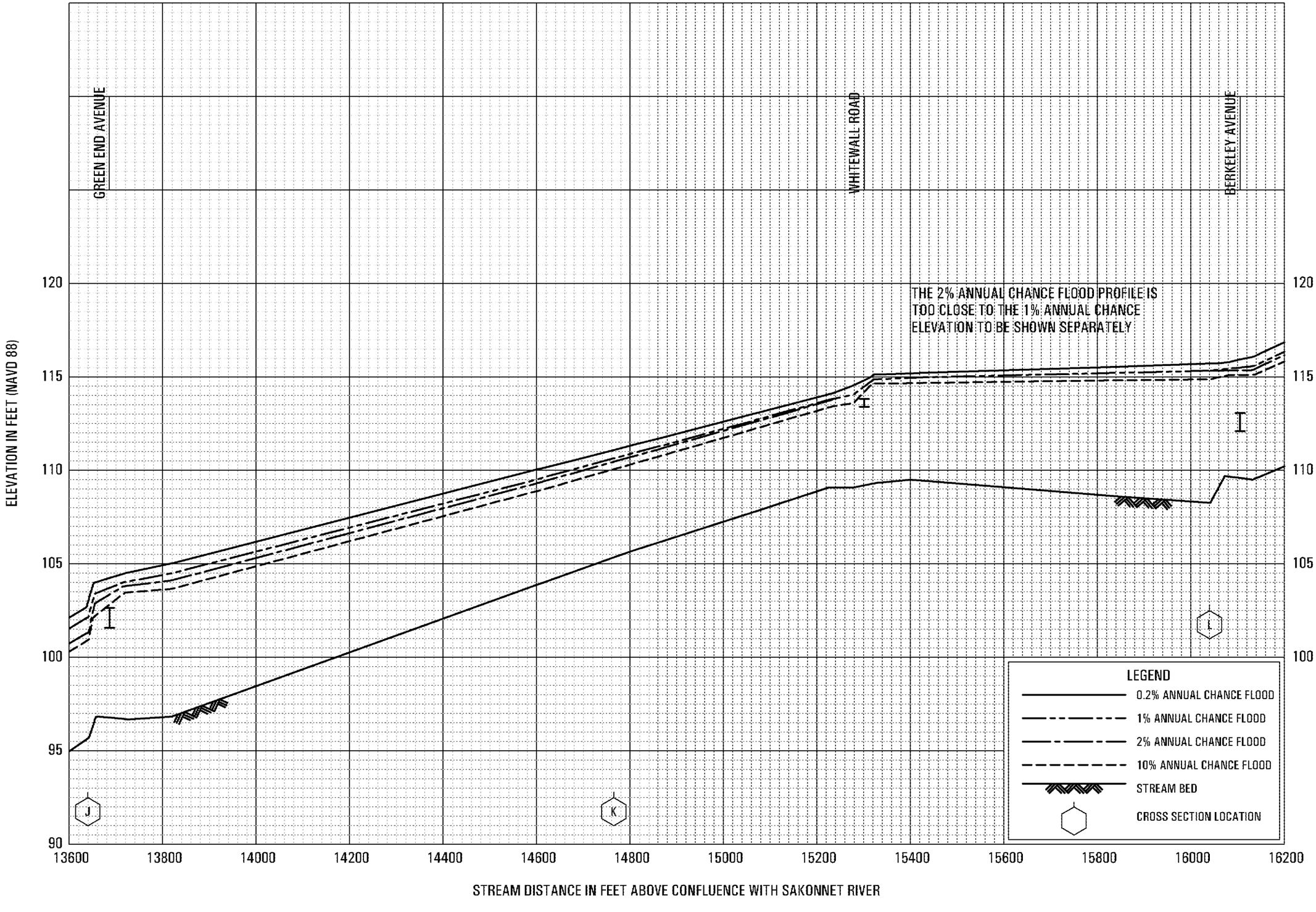
FEDERAL EMERGENCY MANAGEMENT AGENCY

NEWPORT COUNTY, RHODE ISLAND

(ALL JURISDICTIONS)

FLOODWAY DATA

FLOODING SOURCE: MAIDFORD RIVER



FLOOD PROFILES

MAIDFORD RIVER

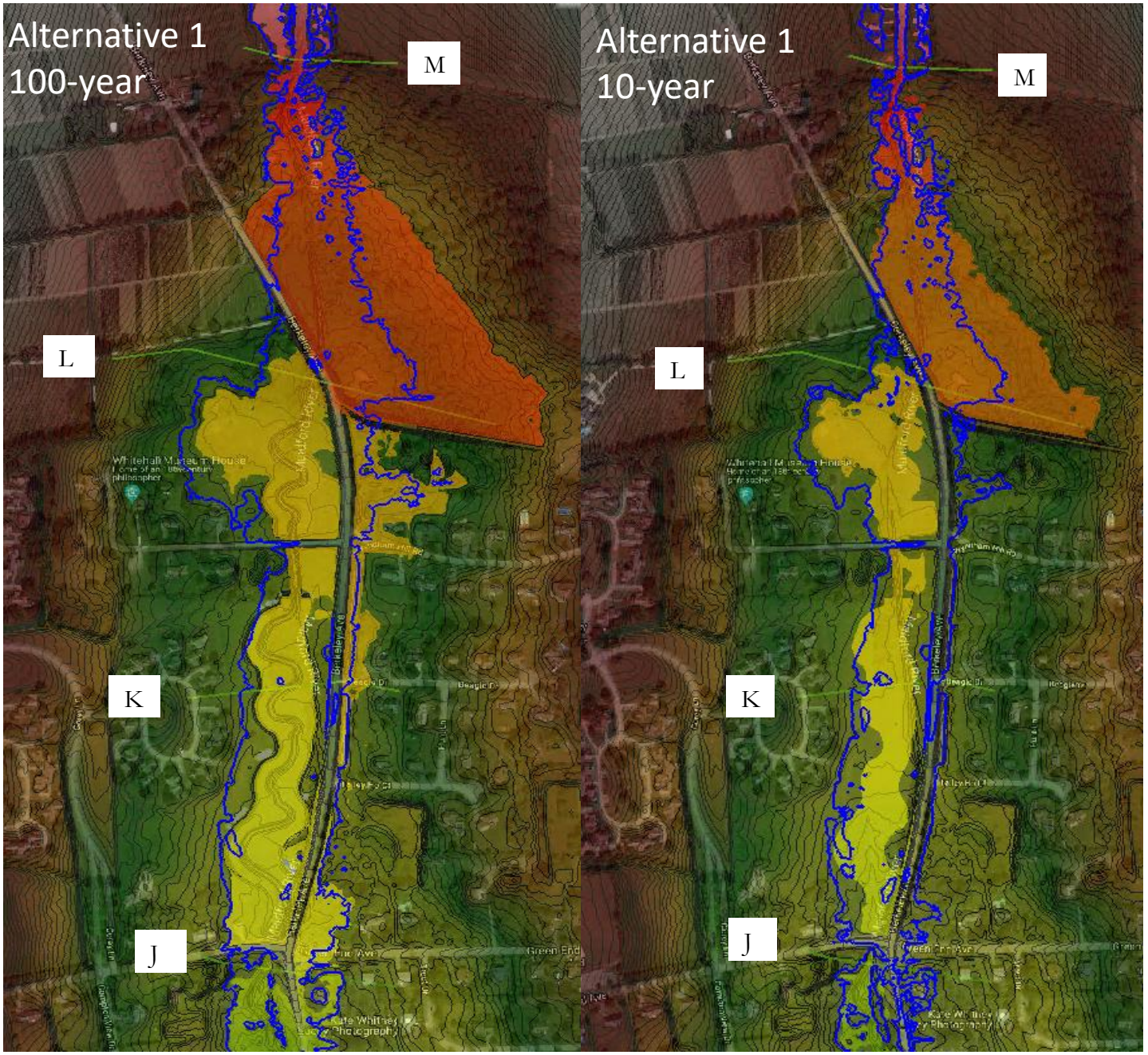
FEDERAL EMERGENCY MANAGEMENT AGENCY

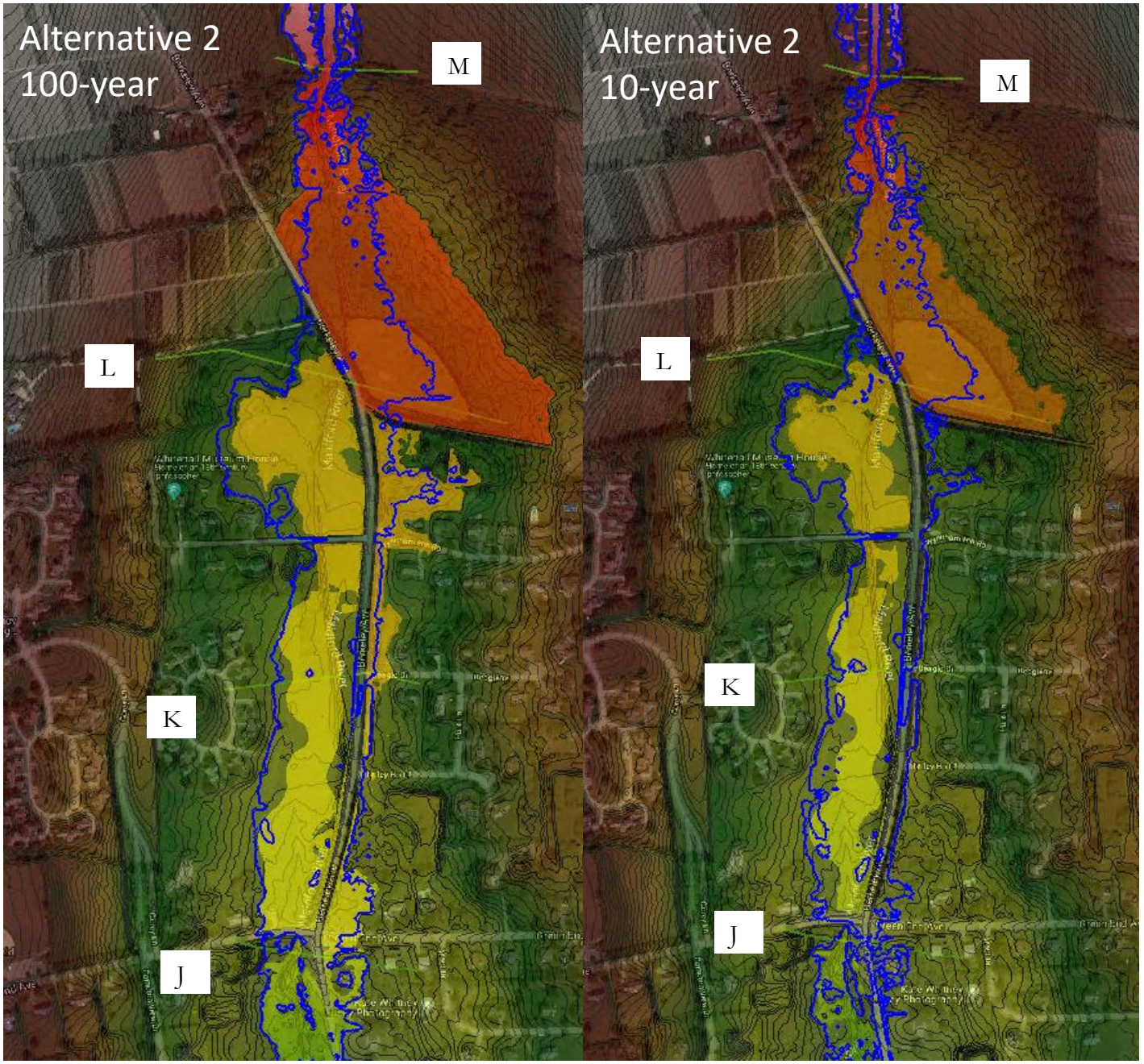
NEWPORT COUNTY, RI

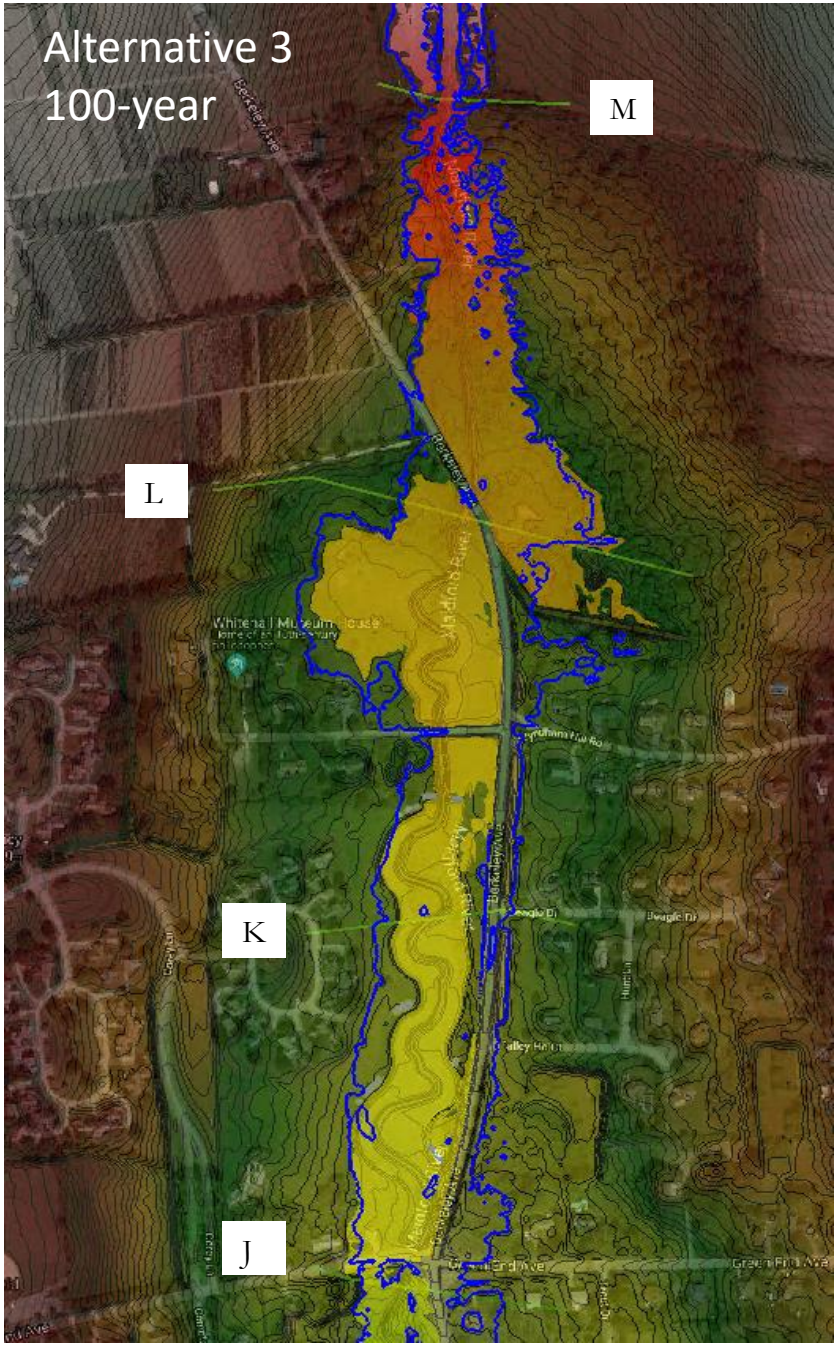
(ALL JURISDICTIONS)

Appendix B

Alternatives Analysis Inundation Mapping


Alternative 1
100-year
M
L
K
J
Alternative 1
10-year
M
L
K
J


Alternative 2
100-year
M
L
K
J
Alternative 2
10-year
M
L
K
J


Alternative 3
100-year
M
L
K
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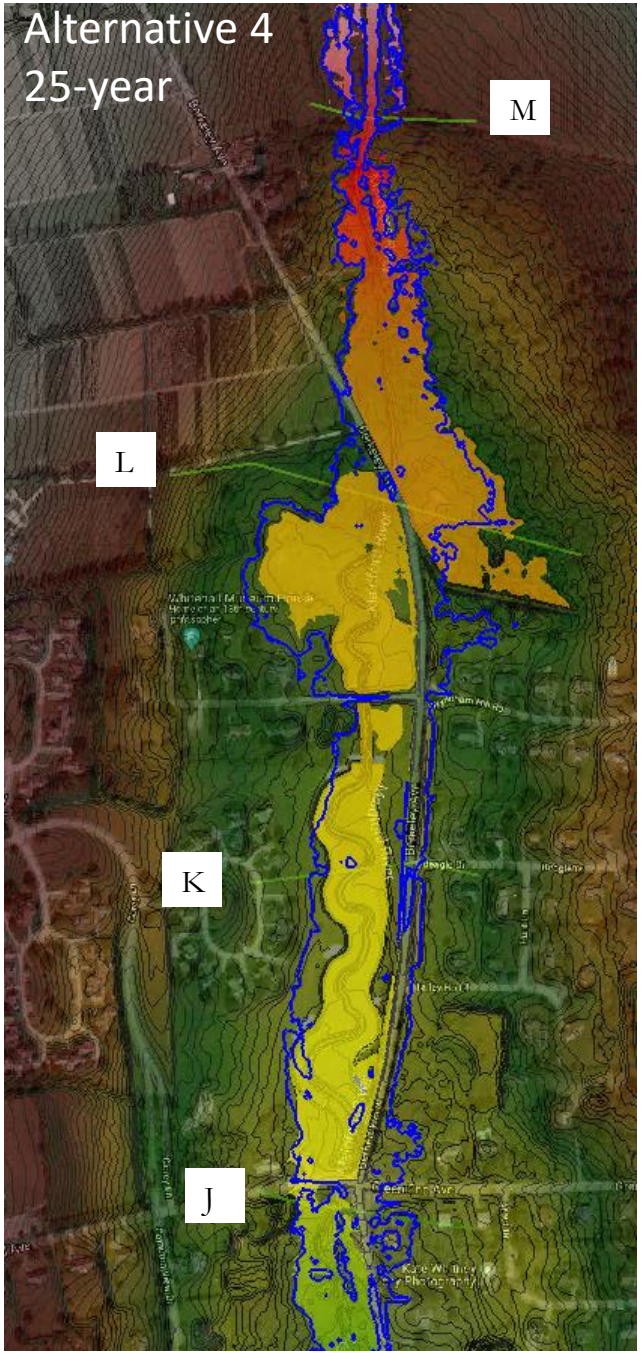
Alternative 4
25-year
M
L
K
J