FLOOD MITIGATION AND STORMWATER INFRASTRUCTURE IMPROVEMENTS FEASIBILITY STUDY

EPHESUS CHURCH ROAD/FORDHAM BOULEVARD SMALL AREA PLAN (SAP), PHASE 3

TOWN OF CHAPEL HILL, ORANGE COUNTY, NORTH CAROLINA

PREPARED BY:

KIMLEY-HORN AND ASSOCIATES, INC.

2000 SOUTH BLVD. STE. 440

CHARLOTTE, NORTH CAROLINA 28203

(704) 333 5131

KHA FILE # 011159009

PREPARED FOR:

THE TOWN OF CHAPEL HILL, NORTH CAROLINA

JUNE 19, 2013

Contents

I. GENERAL DESCRIPTION 1

II. ELLIOTT ROAD CULVERT EXTENSION / REPLACEMENT 1

III. FLOOD MITIGATION AND STORMWATER INFRASTRUCTURE IMPROVEMENTS 2

Primary Drainage Systems 2

Drainage System 1 2

Drainage System 2 3

Drainage System 3 3

Drainage System 4 3

XPSWMM Hydrologic and Hydraulic Modeling 3

Existing Conditions Analysis 3

Improvement Alternatives Analysis 5

Results 7

Tables

Table 1 – Alternatives Cost Comparison
Table 2 – Calibration Storm Events Analysis
Table 3 – SCS Type II 24-Hour 2- and 5-Year Storm Events Analysis
Table 4 – SCS Type II 24-Hour 10- and 25-Year Storm Events Analysis
Table 5 – SCS Type II 24-Hour 50- and 100-Year Storm Events Analysis

Figures

Figure 1 – Drainage Area Map
Figure 2 – XPSWMM Existing Conditions Network
Figure 3 – XPSWMM Proposed Conditions Network
Figure 4 – 100-Year Floodplain Map – Existing Conditions
Figure 5 – 100-Year Floodplain Map – Alternative A
Figure 6 – 100-Year Floodplain Map – Alternative B
Figure 7 – 100-Year Floodplain Map – Alternative C

I. GENERAL DESCRIPTION

The Town of Chapel Hill developed the 'Ephesus Church Road/Fordham Boulevard Small Area Plan (SAP) and Traffic Analysis' project in seeking to define future land uses and determine transportation solutions to encourage reinvestment within the areas surrounding the Ephesus Church Road/Fordham Boulevard intersection. Kimley-Horn and Associates, Inc. (KHA) has been part of the consultant team assembled to help the Town develop the project. As a part of Phase 3 of this project, Kimley-Horn has prepared this Flood Mitigation and Stormwater Infrastructure Improvements Feasibility Study in order to first, assist the Town in identifying potential limitations in extending the existing Elliott Road culvert based on proposed roadway improvements; and second, identify options that could potentially reduce flooding within the Ephesus Church – Fordham area (study area). This study determined that a culvert extension or replacement could be constructed at Elliott Road which would meet FEMA and local floodplain regulations. This study also resulted in the development of three improvement alternatives that have the potential to decrease flood risk and more efficiently transport stormwater within the study area.

II. ELLIOTT ROAD CULVERT EXTENSION / REPLACEMENT

The extension of Elliott Road eastward to Ephesus Church Road was identified to help provide congestion relief at this intersection as one of several key elements of the SAP. This extension would include the addition of a lane to Elliott Road and would consequently require an extension or replacement of the existing culvert that carries Booker Creek under Elliott Road. Because Booker Creek is a FEMA-regulated detailed study stream with a regulated floodway, the proposed culvert option must meet local and national floodplain regulations. These regulations require that a hydraulic analysis demonstrate that the proposed culvert will have no impact to flood levels during the occurrence of the base flood or meet the requirements for a Conditional Letter of Map Revision (CLOMR). It is important to note that, although the application for a CLOMR may be possible, the results of the hydraulic analysis must be certified as not impacting insurable structures. Within the study area, there are many structures located within the effective base flood hazard areas, so for purposes of this feasibility study, Kimley-Horn assumed that the selection of a proposed culvert option would be based on the limitation that no increase in base flood elevation would be allowed as a result of the proposed project.

In order to develop and analyze Elliott Road culvert options, Kimley-Horn obtained the effective FEMA hydraulic modeling files (HEC-RAS format) for Booker Creek, and from these files, created duplicate effective, corrected effective, and revised conditions HEC-RAS modeling plans. The duplicate effective HEC-RAS plan, duplicated the effective base flood and floodway elevations to within 0.1 ft except for at locations at Eastwood Lake, where differences between the duplicate effective and effective base flood and floodway elevations differed by up to 0.8 ft. These discrepancies were not investigated or corrected in the corrected effective plan, because of the fact that this is a feasibility level analysis and most importantly because this reach of Booker Creek is outside of the study area. The corrected effective plan incorporated corrections related to cross section layouts and topographic data at Elliott Road and Fordham Boulevard. Corrections were also made to the Elliott Road culvert type and size based on field measurements.

Two revised conditions plans, one for the simulation of a culvert extension at Elliott Road and one for the simulation of a culvert replacement at Elliott Road, were developed as a part of this study. The culvert extension plan simulated a 38-ft extension based on current preliminary design plans for the Elliott Road improvements. This analysis demonstrated that no-impact conditions could not be met if this culvert were extended with corrugated metal elements. If the Elliott Road culvert is extended, resulting increases in base flood elevations would need to be countered by reducing culvert friction losses by lining the culvert after extension. Based on the HEC-RAS steady flow analysis results, an extended and lined culvert would meet no impact requirements and result in a maximum decrease in base flood elevation of 0.2 ft upstream of Elliott Road. The culvert replacement plan simulated a quadruple barrel 20-ft by 10-ft reinforced concrete box culvert (RCBC) with a headwall and flared wing walls. This replacement option meets no impact requirements based on the HEC-RAS steady flow analysis results, and demonstrated a maximum decrease in base flood elevation of 1.4 ft upstream of Elliott Road.

III. FLOOD MITIGATION AND STORMWATER INFRASTRUCTURE IMPROVEMENTS

The Ephesus Church-Fordham area is significantly impacted by drainage inefficiencies and high water levels within Booker Creek, which currently passes directly under Eastgate Shopping Center (Eastgate). The Ephesus Church-Fordham area represents the most urbanized sub-watershed along Booker Creek. Redevelopment or sustained vitality of this commercial area is not only dependent upon transportation improvements but also upon the reduction of flood risk to the commercial tenants as well as the consumers they serve.

The flood mitigation and stormwater infrastructure improvements portion of this study focused on the interaction of Booker Creek flood levels and study area stormwater system levels. Investigation and simulation of this interaction was important in determining what improvements could potentially be useful for flood risk reduction. For this study, multiple site investigations were performed during dry and wet weather conditions to gather information that was critical in developing a general understanding of existing drainage patterns and stormwater infrastructure connections within the study area.

Primary Drainage Systems

Rainfall runoff within the study area occurs along four major drainage systems, comprised of a combination of stream channels, pipes and ditches. These four systems were analyzed using a dynamic, one-dimensional hydrologic and hydraulic analysis model (XPSWMM). Only the most downstream components of the four primary drainage systems were included within the model, and their selection was based on whether a component had been or was likely affected by flooding or whether the component was within a likely location for a potential infrastructure improvement. The four systems are shown in Figures 2 and 3 of this report and are described as follows:

Drainage System 1

The first of the four analyzed drainage systems includes drainage to and through a Booker Creek tributary which originates between East Franklin Street and Elliott Road, adjacent to Chapel Hill Rehab & Healthcare, and flows to a 24" RCP which passes under Elliott Drive and Village Plaza Shopping Center until it daylights into an open channel which flows between Squid's Restaurant and Burger King and then turns sharply to parallel Fordham Boulevard and confluences with Booker Creek just upstream of Fordham Boulevard.

Drainage System 2

The second of the four analyzed drainage systems includes drainage to and through a Booker Creek tributary which originates approximately 0.3 mi upstream of East Franklin Street and flows into an open end pipe storm system at the Chapel Hill Fire Department driveway and continues through a stormwater system that crosses under East Franklin Street, then makes a 90-degree turn to the East and passes parallel to East Franklin Street and through the Village Plaza parking lot. This system then connects to a junction box within the rear access driveway for Eastgate Shopping Center (adjacent to the Exxon Station) and then turns sharply to pass under the Eastgate rear access driveway until it daylights and confluences with Booker Creek just downstream of the Eastgate culvert outfall.

Drainage System 3

The third of the four analyzed drainage systems includes Booker Creek, which collects and transports rainfall runoff from approximately 5.5 sq mi of land upstream of East Franklin Street. The creek then moves this flow through a triple 12-ft by 12-ft box culvert under East Franklin Street and then immediately flows into a single 35-ft by 10.5-ft box culvert which runs for approximately 700 ft under the Eastgate Shopping Center until it daylights downstream of the shopping center. Booker Creek then runs for approximately 900 ft until it passes through a triple barrel 15.6-ft by 9.5-ft corrugated metal pipe arch under Elliott Road. The creek then flows for approximately 130 ft before it enters a triple 11-ft by 11-ft box culvert under Fordham Boulevard. Booker Creek then continues from Fordham Boulevard to its confluence with Little Creek approximately 0.6 mi downstream.

Drainage System 4

The fourth of the four analyzed drainage systems includes the stream feature and pipe system which runs along the eastern side of Fordham Boulevard. This system receives runoff from Ram's Plaza and Fordham Boulevard as well as flows from a tributary to Booker Creek which originates at a pond upstream of Clover Drive and flows into a pipe system which passes under Hamlin Park Condominiums and outlets downstream of Ephesus Church Road, runs adjacent to this road and then turns sharply to continue alongside the Chapel Hill University Inn until it discharges into the Fordham Boulevard roadside stream feature.

XPSWMM Hydrologic and Hydraulic Modeling

Existing Conditions Analysis

An existing conditions hydrologic and hydraulic analysis was prepared using XPSWMM software and included the combination of the effective FEMA-studied reach of Booker Creek combined with the three confluencing drainage systems previously described. Booker Creek channel cross-section and hydraulic crossing data was imported into XPSWMM from the effective Booker Creek HEC-RAS model, as no supplementary survey data was collected for this feasibility study. The Booker Creek FEMA study was prepared using detailed methods, so it was assumed that the HEC-RAS geometric data is based on updated LIDAR and supplemental survey, and the quality of the data was assumed satisfactory for this feasibility-level study. Field measurements of the Booker Creek structures were compared with the HEC-RAS structure sizes from East Franklin Street downstream to Willow Avenue. From this comparison, the structure dimensions measured in the field were only found to be slightly different from the HEC-RAS data only at the Elliott Road culvert. Stormwater infrastructure information for the study area drainage

components was developed using a combination of the Town's GIS stormwater layers and field investigation data. Pipe sizes were measured in the field if accessible. Typical channel and ditch dimensions were also field-measured. Inlet, pipe, channel and ditch inverts were estimated based on existing topographic data in combination with field measurements and/or visual estimates. The XPSWMM modeling links and nodes are shown in Figures 2 and 3 of this report.

A fully revised hydrologic analysis of Booker Creek was not performed for this study. Hydrologic data was only updated for the reach of the Creek that passes through the study area. Hydrologic data for the Booker Creek drainage areas upstream and downstream of the small area were generated using the drainage areas reported in the effective Flood Insurance Study (FIS). SCS curve numbers were estimated for each of these drainage areas and time of concentration was used as a variable for calibrating the hydrograph peaks to the effective FEMA 100-year discharge values. Study area drainage sub-basins were delineated based on Town GIS contours in conjunction with North Carolina Floodplain Mapping Program LIDAR data and field tracing of and connection of stormwater structures, flow paths and drainage divides. These sub-basins were characterized using SCS curve numbers selected based on the ESRI's Bing aerial base mapping. Time of concentrations were calculated using the TR55 method and evaluated by comparison to values calculated using the FAA and Kirpich equations. The study area sub-basin delineations are shown in Figure 1 of this report.

Two calibration storm events were simulated within the existing conditions XPSWMM model to check the results of the model against factual flooding information. The September 6, 2008 rainfall event was simulated using rainfall data from NOAA climatological data collected at Horace Williams Airport. The existing conditions XPSWMM model was calibrated based on this simulation using post-storm photographs of the Eastgate Shopping Center provided by Town stormwater staff. During this rainfall event, the Eastgate culvert flowed full but did not overtop and stormwater inlets within the Eastgate parking lot became surcharged and submerged to a depth of approximately 1.5 ft. The July 23, 2000 rainfall event was also simulated and the existing conditions model was calibrated for this event based on high water levels reported in local newspaper articles provided by Town stormwater staff.

In addition to the calibration events, the 2-, 5-, 10-, 25-, 50-, and 100-year SCS Type II 24-hour storm events were also simulated within the existing conditions XPSWMM model. The existing conditions analysis shows that for events greater than the 5-year, the Eastgate stormwater system becomes controlled by the water level within the Eastgate culvert and the stormwater inlets, if at an elevation lower than the overtopping elevation of the Eastgate culvert (assumed at elevation 260 ft) will surcharge and flood the Eastgate parking lot even though the culvert has not overtopped. The existing conditions model shows that the Eastgate culvert reaches capacity and overtops, flooding the Eastgate Shopping Center during any event greater than the 50-year. The existing conditions analysis shows that during the 100-year storm event, Eastgate floods with approximately 2 ft of water near the buildings and approximately 4 ft of water above the lowest parking lot inlets. The existing conditions model shows that the 100-year event does not overtop East Franklin Street, Elliott Road or Fordham Boulevard. In addition, the ratio of headwater to diameter for these structures during even the 100-year event is less than 1.2, which indicates that these structures, based on NCDOT culvert sizing standards, are of adequate capacity. The existing conditions model shows that drainage systems 1, 2 and 4 operate at or below capacity during the 10-year event,

which signifies no significant need for improvement, aside from aesthetics where the system 4 Fordham Boulevard roadside stream feature is concerned. These results indicate that flooding issues within the study area (primarily Eastgate) are not necessarily a factor of undersized pipe systems, but more a factor of site location (within the Booker Creek floodplain) and elevation (below the Booker Creek base flood elevation). As is proven by the proposed alternatives analysis discussed in the next section, to offset the disadvantages Eastgate has in terms of location and elevation, an increase in capacity of the Eastgate stormwater system infrastructure in combination with an increase in capacity of the downstream culvert crossings is required. Otherwise the Booker Creek stream between the downstream side of the Eastgate culvert and Fordham Boulevard will continue to be characterized by adverse gradients, slower moving flows and persistent sediment accumulation within the Eastgate culvert.

Improvement Alternatives Analysis

Once the existing conditions model was calibrated and the existing conditions SCS storm events were simulated, a combination of major and minor stormwater infrastructure improvements geared toward flood reduction potential were developed and analyzed. These analyzed improvement options included the following:

- Widening of the Eastgate culvert. This option showed negligible reduction in water levels even with a culvert width three times as wide as the existing culvert.

- Increase in floodplain storage downstream of the Eastgate culvert outfall and/or upstream of East Franklin Street. Increased floodplain storage showed no noticeable reduction in water levels due the relative magnitude of Booker Creek flows compared to the area available for implementing increased storage.

- Redirection of the Fordham Boulevard roadside stream feature to a location further downstream of Fordham Boulevard. This option was analyzed to determine if it would lower water surface levels directly downstream of the Fordham Boulevard culvert and hence reduce Booker Creek elevations upstream of the Fordham culvert; however, this option showed no improvement.

- Improvement to the Eastgate culvert entrance through the integration of a side- or slope-tapered inlet. This option showed no improvement.

- Disconnection of the Eastgate stormwater system from the Eastgate culvert and redirection of the Eastgate drainage through a designated stormwater system to the Eastgate culvert outfall. This option in itself would not provide substantial improvement unless the tail water at the Eastgate culvert outfall is lowered through the replacement of the Elliott Road and/or Fordham Boulevard culverts.

- Replacement of the Elliott Road culvert

- Replacement of the Fordham Boulevard culvert

- Replacement of the Fordham Boulevard roadside stream feature with a pipe system. This would aesthetically enhance the study area and provides increased system capacity.

- Extension of the Eastgate culvert upstream and connection to the downstream side of the East Franklin Street culvert. This connection would create a continuous culvert from upstream of East Franklin Street to downstream of Eastgate.

From these options a set of three alternatives were developed, wherein each alternative builds upon a combination of selected improvement options that demonstrated the most significant potential for flood risk reduction within the study area. The proposed improvement alternatives are as follows:

Alternative A

This alternative includes the replacement of the Elliott Road culvert with a structure comparable in capacity to a quadruple barrel 20-ft by 10-ft box culvert. This structural opening area was set based on a sensitivity analysis resulted in the selection of a culvert capacity that would offer the best performance at the lowest required area. The dimensions of the culvert were also set based on assumed construction limitations. This alternative also includes the disconnection and redirection of the Eastgate stormwater system. This would require the construction of a new stormwater system trunk line within Eastgate that would receive flows from the ditch behind Trader Joes and True Value Hardware and flows from the Eastgate parking lot. This new stormwater trunk line could be designed to provide more capacity for transferring runoff to Booker Creek more quickly before Booker Creek crests flood wave and to provide increased storage for parking lot runoff until Booker Creek flood levels fall, at which point the stored flows can discharge from the system.

Alternative B

This alternative includes the alternative A options and adds the option for the connection of the Eastgate and East Franklin Street culverts.

Alternative C

This alternative includes the alternative B options and adds the option for the replacement of the Fordham Boulevard culvert with a structure which is comparable in capacity to a quadruple barrel 20-ft by 10-ft box culvert. This structural opening area was set based on a sensitivity analysis resulted in the selection of a culvert capacity that would offer the best performance at the lowest required area. The dimensions of the culvert were also set based on assumed construction limitations.

Each of the three alternatives includes the proposed option of increased floodplain storage downstream of the Eastgate culvert, because it is anticipated that a stormwater wetland will be constructed here based on preliminary stormwater management planning described in the SAP and verified by stormwater wetland calculations prepared by Kimley-Horn as a part of the Phase 3 Potential BMP Location Analysis submitted to the Town under separate cover. The three alternatives also include the replacement of the

Fordham Boulevard roadside stream feature with a pipe system. Detailed results of the proposed alternatives analysis are included in Tables 1-4 of this report.

Results

The results of this study are based on a feasibility-level analysis. Site survey data was not collected for this study, and limited field evaluation was performed. A revised Booker Creek hydrologic evaluation was not performed for areas outside of the reach of Booker Creek within the SAP. The hydraulic modeling performed for this study included a one-dimensional hydrodynamic analysis. Based on the length of the Eastgate culvert and the limitations of a one-dimensional model in simulating shallow flooding through the Eastgate shopping center, it is believed that a two-dimensional model would better simulate the conditions in this area if a design-level hydraulic analysis were performed in the future. This feasibility study shows that all three proposed alternatives reduce or eliminate surcharging of the Eastgate parking lot inlets and reduce water surface elevations upstream of East Franklin Street, up- and downstream of the Eastgate culvert, and upstream of Elliott Road. Further reduction in water surface levels is achieved as you move from Alternative A to C. Alternative C also provides reduction in water surface elevations up- and downstream of Fordham Boulevard. The major differences between the alternatives are as follows:

Alternative A

The strategy for Alternative A was to reduce water surfaces downstream of the Eastgate shopping center and direct the Eastgate stormwater drainage system to this location where a lower tail water condition would have less impact on causing surcharged inlets. This study shows that this could be achieved through increasing the capacity of the Elliott Road culvert crossing downstream. This alternative reduces water levels up and downstream of Eastgate, and reduces the flood risk of Eastgate to a level where the Eastgate culvert would not overtop until a 50-year event as opposed to a 25-year under existing conditions. Because the condition of the Elliott Road culvert is degrading and because the SAP transportation improvements will require lengthening of this culvert, it becomes an obvious choice to replace the existing culvert with one of increased capacity. Taking the Eastgate parking lot drainage offline from the Eastgate culvert and connecting it to a new stormwater trunk line would be a choice to be made by Fidelity Realty. If this choice is not made, the existing parking lot stormwater system would show reductions of approximately 0.4 ft. However, if a new stormwater system which outfalls downstream of the Eastgate culvert is put online, parking lot system elevations can be reduced by approximately 1.5 ft for storm events less than the 50-year.

Alternative B

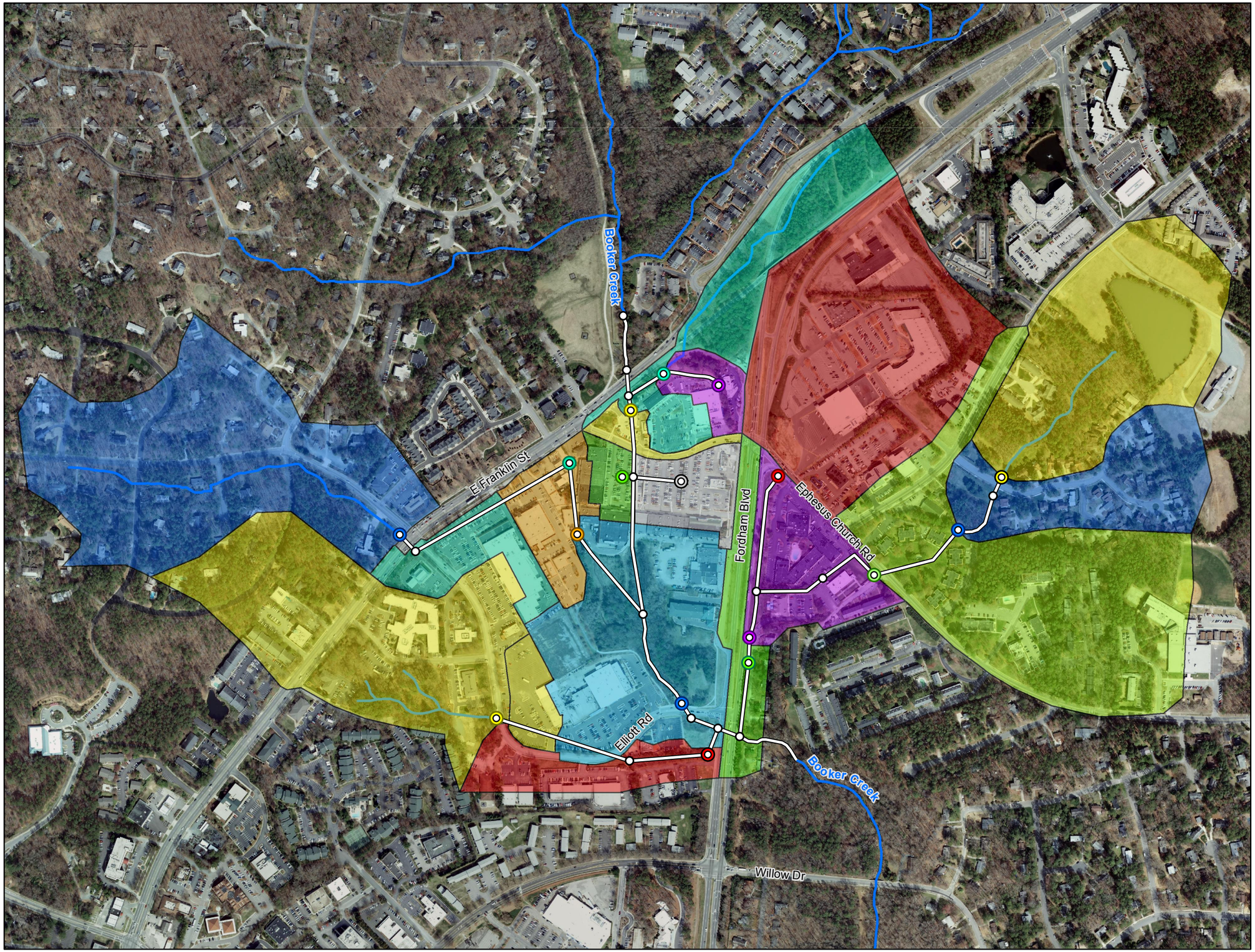
This alternative provides further improvement from Alternative A by utilizing the high elevations of East Franklin Street to restrict the flooding of Eastgate shopping center. This study shows that for this alternative, Eastgate would not flood from flows upstream overtopping the site until East Franklin Street overtops, which was shown not to occur for storm events less than the 500-year. Despite this reduction in flood risk upstream, the downstream tail water on the Eastgate culvert will rise to above elevation 260 ft, which would result in the flooding of Eastgate from the downstream side during the 100-year event.

Alternative C

This alternative provides further improvement from Alternative B by decreasing the tail water from the outlet of the Eastgate culvert by approximately one foot more. This decrease in tail water would prevent the flooding of Eastgate from the downstream side during the 100-year event. As shown in Figure 7, Alternative C improvements could reduce the FEMA base flood mapping significantly and remove many properties from the currently effective floodplain and floodway if the results of this feasibility study were to be duplicated in a future design-level study and used as a basis for a FEMA Conditional Letter of Map Revision.

Table 1. Alternatives Cost Comparison

Improvement Option	Cost Range (Million Dollars)	**Alternative A**	**Alternative B**	**Alternative C**
Replace Elliott Road Culvert	1 to 1.5	1.5	1.5	1.5
Eastgate and Franklin Culvert Connection	1.5 to 2.0	X	2.0	2.0
Replace Fordham Boulevard Culvert	1.5 to 2.5	X	X	2.5
Total Cost (Million Dollars)		**1.5**	**3.5**	**6.0**



Ephesus Church Road/Fordham Boulevard Small Area Plan (SAP), Phase 3

Legend

- XPSWMM Nodes
- XPSWMM Nodes Receiving Flow
- XPSWMM Links
- Streams
- Drainage Areas

0 250 500 Feet

N

Figure 1
Drainage Area Map

Town of Chapel Hill
Orange County, NC

Ephesus Church Road/Fordham Boulevard Small Area Plan (SAP), Phase 3

Legend

XPSWMM Analysis Points

XPSWMM Nodes

- Drainage System 1
- Drainage System 2
- Drainage System 3
- Drainage System 4

XPSWMM Links

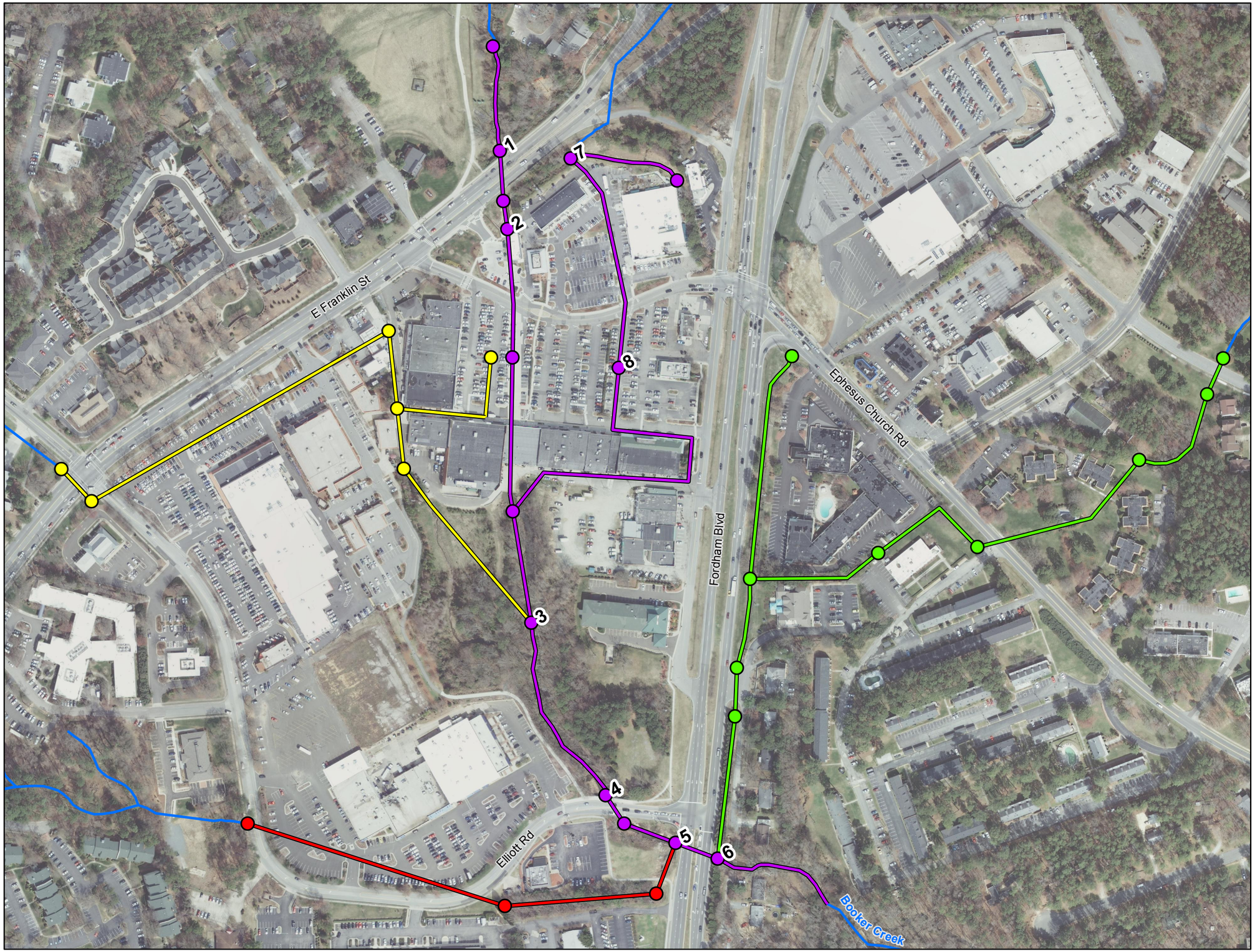
- Drainage System 1
- Drainage System 2
- Drainage System 3
- Drainage System 4
- Streams

0 150 300 Feet

N

Figure 2
XPSWMM Existing Conditions Network

Town of Chapel Hill
Orange County, NC



Ephesus Church Road/Fordham Boulevard Small Area Plan (SAP), Phase 3

Legend

XPSWMM Analysis Points

XPSWMM Nodes

- Drainage System 1
- Drainage System 2
- Drainage System 3
- Drainage System 4

XPSWMM Links

- Drainage System 1
- Drainage System 2
- Drainage System 3
- Drainage System 4
- Streams

0 150 300 Feet

N

Figure 3
XPSWMM Proposed Conditions Network

Town of Chapel Hill
Orange County, NC

TABLE 2. CALIBRATION STORM EVENTS ANALYSIS
Ephesus-Fordham Small Area Plan Flood and Stormwater Alternatives

Storm Events [1]		September 6, 2008								July 23-24, 2000							
		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Analysis Location		Upstream Franklin Street	Upstream Eastgate Culvert	Downstream Eastgate Culvert	Upstream Elliott Road	Upstream Fordham Boulevard	Downstream Fordham Boulevard	Eastgate Parking Lot North of Ephesus Church Road	Eastgate Parking Lot South of Ephesus Church Road	Upstream Franklin Street	Upstream Eastgate Culvert	Downstream Eastgate Culvert	Upstream Elliott Road	Upstream Fordham Boulevard	Downstream Fordham Boulevard	Eastgate Parking Lot North of Ephesus Church Road	Eastgate Parking Lot South of Ephesus Church Road
Alternatives	**Description**	Computed Water Surface Elevations (FT NAVD) ***And Differences Compared to Existing Conditions***															
EX	Existing Conditions	259.9	259.3	258.7	258.5	257.4	256.7	259.3	259.2	264.2	262.7	262.4	262.2	259.5	257.9	262.7	262.7
A	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater	259.6 ***-0.3***	258.9 ***-0.4***	258.0 ***-0.7***	257.7 ***-0.8***	257.4 ***0.0***	256.8 ***+0.1***	258.0 ***-1.3***	258.0 ***-1.2***	263.5 ***-0.7***	261.8 ***-0.9***	261.0 ***-1.4***	260.6 ***-1.6***	260.0 ***+0.5***	258.1 ***+0.2***	261.0 ***-1.7***	261.0 ***-1.7***
B	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater *Connect Franklin Street and Eastgate Culverts	259.2 ***-0.7***	**N/A [2]**	258.0 ***-0.7***	257.7 ***-0.8***	257.4 ***0.0***	256.8 ***+0.1***	258.0 ***-1.3***	258.0 ***-1.2***	264.3 ***+0.1***	**N/A [2]**	260.9 ***-1.5***	260.5 ***-1.7***	259.9 ***+0.4***	258.1 ***+0.2***	260.9 ***-1.8***	260.9 ***-1.8***
C	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater *Connect Franklin Street and Eastgate Culverts *Replace Fordham Boulevard Culvert	258.7 ***-1.2***	**N/A [2]**	257.1 ***-1.6***	256.8 ***-1.7***	256.3 ***-1.1***	256.2 ***-0.5***	257.2 ***-2.1***	257.2 ***-2.0***	263.2 ***-1.0***	**N/A [2]**	259.7 ***-2.7***	259.1 ***-3.1***	258.2 ***-1.3***	257.6 ***-0.3***	259.7 ***-3.0***	259.7 ***-3.0***

[1] Storm event hyetographs were developed from NOAA NCDC Local Climatological Data collected at Horace Williams Airport (IGX) Chapel Hill, NC. September 6, 2008 and July 24, 2000 events were used to calibrate the XPSWMM hydrologic/hydraulic model used to compute the reported water surface elevations

[2] For this alternative the Eastgate Culvert has been extended upstream and connected to the Franklin Street Culvert. This connection prevents Booker Creek flows from spilling over into the Eastgate Shopping Center for all flows that do not overtop Franklin Street

TABLE 3. SCS TYPE II 24-HOUR 2- AND 5-YEAR STORM EVENTS ANALYSIS

Ephesus-Fordham Small Area Plan Flood and Stormwater Alternatives

Storm Events (Total Rainfall [1])		2-Year (3.58 inches)								5-Year (4.47 inches)							
		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Analysis Location		Upstream Franklin Street	Upstream Eastgate Culvert	Downstream Eastgate Culvert	Upstream Elliott Road	Upstream Fordham Boulevard	Downstream Fordham Boulevard	Eastgate Parking Lot North of Ephesus Church Road	Eastgate Parking Lot South of Ephesus Church Road	Upstream Franklin Street	Upstream Eastgate Culvert	Downstream Eastgate Culvert	Upstream Elliott Road	Upstream Fordham Boulevard	Downstream Fordham Boulevard	Eastgate Parking Lot North of Ephesus Church Road	Eastgate Parking Lot South of Ephesus Church Road
Alternatives	**Description**	Computed Water Surface Elevations (FT NAVD) ***And Differences Compared to Existing Conditions***															
EX	Existing Conditions	255.9	255.8	255.7	255.6	255.4	255.3	257.5	255.9	257.5	257.2	256.8	256.7	256.2	256.0	257.7	257.2
A	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater	255.7 ***-0.2***	255.6 ***-0.2***	255.4 ***-0.3***	255.4 ***-0.2***	255.4 ***0.0***	255.3 ***0.0***	257.3 ***-0.2***	255.4 ***-0.5***	257.3 ***-0.2***	256.9 ***-0.3***	256.5 ***-0.3***	256.4 ***-0.3***	256.2 ***0.0***	256.0 ***0.0***	257.7 ***0.0***	256.5 ***-0.7***
B	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater *Connect Franklin Street and Eastgate Culverts	255.6 ***-0.3***	**N/A [2]**	255.5 ***-0.2***	255.4 ***-0.2***	255.4 ***0.0***	255.3 ***0.0***	257.3 ***-0.2***	255.5 ***-0.4***	257.0 ***-0.5***	**N/A [2]**	256.5 ***-0.3***	256.4 ***-0.3***	256.2 ***0.0***	256.0 ***0.0***	257.7 ***0.0***	256.5 ***-0.7***
C	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater *Connect Franklin Street and Eastgate Culverts *Replace Fordham Boulevard Culvert	255.2 ***-0.7***	**N/A [2]**	255.0 ***-0.7***	254.9 ***-0.7***	254.8 ***-0.6***	254.8 ***-0.5***	257.3 ***-0.2***	255.0 ***-0.9***	256.6 ***-0.9***	**N/A [2]**	255.9 ***-0.9***	255.7 ***-1.0***	255.6 ***-0.6***	255.5 ***-0.5***	257.7 ***0.0***	255.9 ***-1.3***

[1] Total rainfall depths obtained from NOAA Atlas 14 Precipitation Frequency Data Server (PFDS)

[2] For this alternative the Eastgate Culvert has been extended upstream and connected to the Franklin Street Culvert. This connection prevents Booker Creek flows from spilling over into the Eastgate Shopping Center for all flows that do not overtop Franklin Street

TABLE 4. SCS TYPE II 24-HOUR 10- AND 25-YEAR STORM EVENTS ANALYSIS

Ephesus-Fordham Small Area Plan Flood and Stormwater Alternatives

Storm Events (Total Rainfall [1])		10-Year (5.17 inches)								25-Year (6.11 inches)							
		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Analysis Location		Upstream Franklin Street	Upstream Eastgate Culvert	Downstream Eastgate Culvert	Upstream Elliott Road	Upstream Fordham Boulevard	Downstream Fordham Boulevard	Eastgate Parking Lot North of Ephesus Church Road	Eastgate Parking Lot South of Ephesus Church Road	Upstream Franklin Street	Upstream Eastgate Culvert	Downstream Eastgate Culvert	Upstream Elliott Road	Upstream Fordham Boulevard	Downstream Fordham Boulevard	Eastgate Parking Lot North of Ephesus Church Road	Eastgate Parking Lot South of Ephesus Church Road
Alternatives	**Description**	Computed Water Surface Elevations (FT NAVD) ***And Differences Compared to Existing Conditions***															
EX	Existing Conditions	259.0	258.5	258.0	257.8	256.9	256.4	258.5	258.5	261.0	260.2	259.5	259.3	257.9	257.1	260.2	260.2
A	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater	258.7 ***-0.3***	258.1 ***-0.4***	257.4 ***-0.6***	257.2 ***-0.6***	256.9 ***0.0***	256.5 ***0.1***	258.0 ***-0.5***	257.4 ***-1.1***	260.6 ***-0.4***	259.8 ***-0.4***	258.7 ***-0.8***	258.4 ***-0.9***	258.0 ***0.1***	257.1 ***0.0***	258.7 ***-1.5***	258.7 ***-1.5***
B	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater *Connect Franklin Street and Eastgate Culverts	258.4 ***-0.6***	**N/A [2]**	257.4 ***-0.6***	257.2 ***-0.6***	256.9 ***0.0***	256.5 ***0.1***	258.0 ***-0.5***	257.4 ***-1.1***	260.3 ***-0.7***	**N/A [2]**	258.7 ***-0.8***	258.4 ***-0.9***	258.0 ***0.1***	257.1 ***0.0***	258.7 ***-1.5***	258.7 ***-1.5***
C	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater *Connect Franklin Street and Eastgate Culverts *Replace Fordham Boulevard Culvert	257.9 ***-1.1***	**N/A [2]**	256.6 ***-1.4***	256.3 ***-1.5***	256.0 ***-0.9***	255.8 ***-0.6***	258.0 ***-0.5***	256.6 ***-1.9***	259.7 ***-1.3***	**N/A [2]**	257.8 ***-1.7***	257.4 ***-1.9***	256.8 ***-1.1***	256.5 ***-0.6***	258.4 ***-1.8***	257.8 ***-2.4***

[1] Total rainfall depths obtained from NOAA Atlas 14 Precipitation Frequency Data Server (PFDS)

[2] For this alternative the Eastgate Culvert has been extended upstream and connected to the Franklin Street Culvert. This connection prevents Booker Creek flows from spilling over into the Eastgate Shopping Center for all flows that do not overtop Franklin Street

TABLE 5. SCS TYPE II 24-HOUR 50- AND 100-YEAR STORM EVENTS ANALYSIS

Ephesus-Fordham Small Area Plan Flood and Stormwater Alternatives

Storm Events (Total Rainfall [1])		50-Year (6.86 inches)								100-Year (7.62 inches)							
		1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Analysis Location		Upstream Franklin Street	Upstream Eastgate Culvert	Downstream Eastgate Culvert	Upstream Elliott Road	Upstream Fordham Boulevard	Downstream Fordham Boulevard	Eastgate Parking Lot North of Ephesus Church Road	Eastgate Parking Lot South of Ephesus Church Road	Upstream Franklin Street	Upstream Eastgate Culvert	Downstream Eastgate Culvert	Upstream Elliott Road	Upstream Fordham Boulevard	Downstream Fordham Boulevard	Eastgate Parking Lot North of Ephesus Church Road	Eastgate Parking Lot South of Ephesus Church Road
Alternatives	**Description**	Computed Water Surface Elevations (FT NAVD) ***And Differences Compared to Existing Conditions***															
EX	Existing Conditions	262.1	261.1	260.5	260.3	258.5	257.4	261.1	261.1	263.0	261.9	261.4	261.2	259.1	257.7	261.9	261.9
A	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater	261.7 ***-0.4***	260.7 ***-0.4***	259.4 ***-1.1***	259.1 ***-1.2***	258.6 ***0.1***	257.5 ***0.1***	260.7 ***-0.4***	260.7 ***-0.4***	262.7 ***-0.3***	261.3 ***-0.6***	260.3 ***-1.1***	259.9 ***-1.3***	259.4 ***0.3***	257.9 ***0.2***	261.3 ***-0.6***	261.3 ***-0.6***
B	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater *Connect Franklin Street and Eastgate Culverts	261.4 ***-0.7***	**N/A [2]**	259.4 ***-1.1***	259.1 ***-1.2***	258.7 ***0.2***	257.5 ***0.1***	259.4 ***-1.7***	259.4 ***-1.7***	262.8 ***-0.2***	**N/A [2]**	260.3 ***-1.1***	259.9 ***-1.3***	259.4 ***0.3***	257.8 ***0.1***	260.3 ***-1.6***	260.3 ***-1.6***
C	*Replace Elliott Road Culvert *Redirect Eastgate Parking Lot Stormwater *Connect Franklin Street and Eastgate Culverts *Replace Fordham Boulevard Culvert	260.7 ***-1.4***	**N/A [2]**	258.4 ***-2.1***	257.9 ***-2.4***	257.2 ***-1.3***	256.9 ***-0.5***	258.7 ***-2.4***	258.4 ***-2.7***	262.0 ***-1.0***	**N/A [2]**	259.2 ***-2.2***	258.6 ***-2.6***	257.8 ***-1.3***	257.3 ***-0.4***	259.2 ***-2.7***	259.2 ***-2.7***

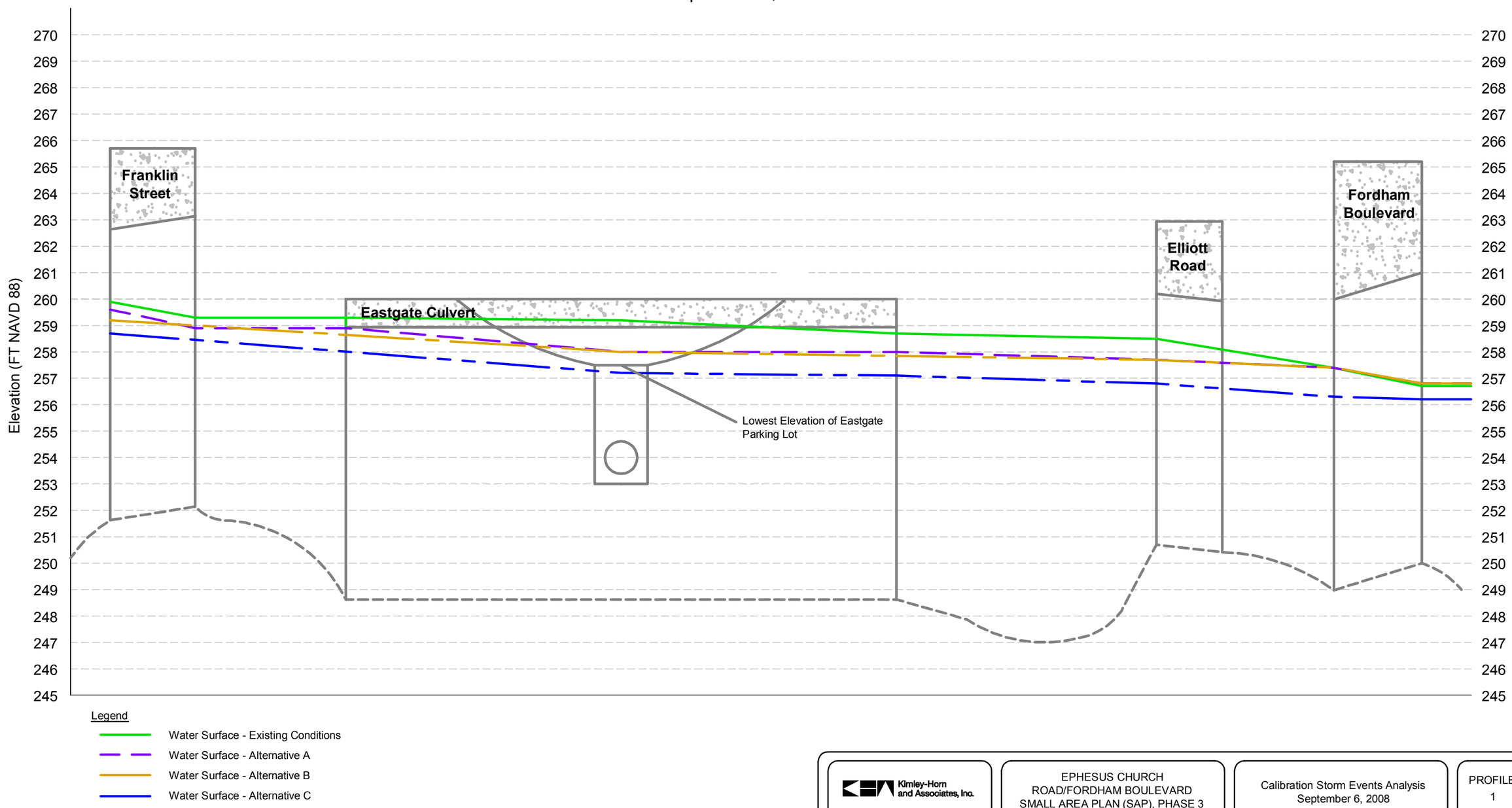
[1] Total rainfall depths obtained from NOAA Atlas 14 Precipitation Frequency Data Server (PFDS)

[2] For this alternative the Eastgate Culvert has been extended upstream and connected to the Franklin Street Culvert. This connection prevents Booker Creek flows from spilling over into the Eastgate Shopping Center for all flows that do not overtop Franklin Street

Booker Creek Flood Profile

Calibration Storm Events Analysis

September 6, 2008



Kimley-Horn and Associates, Inc.

EPHESUS CHURCH ROAD/FORDHAM BOULEVARD SMALL AREA PLAN (SAP), PHASE 3

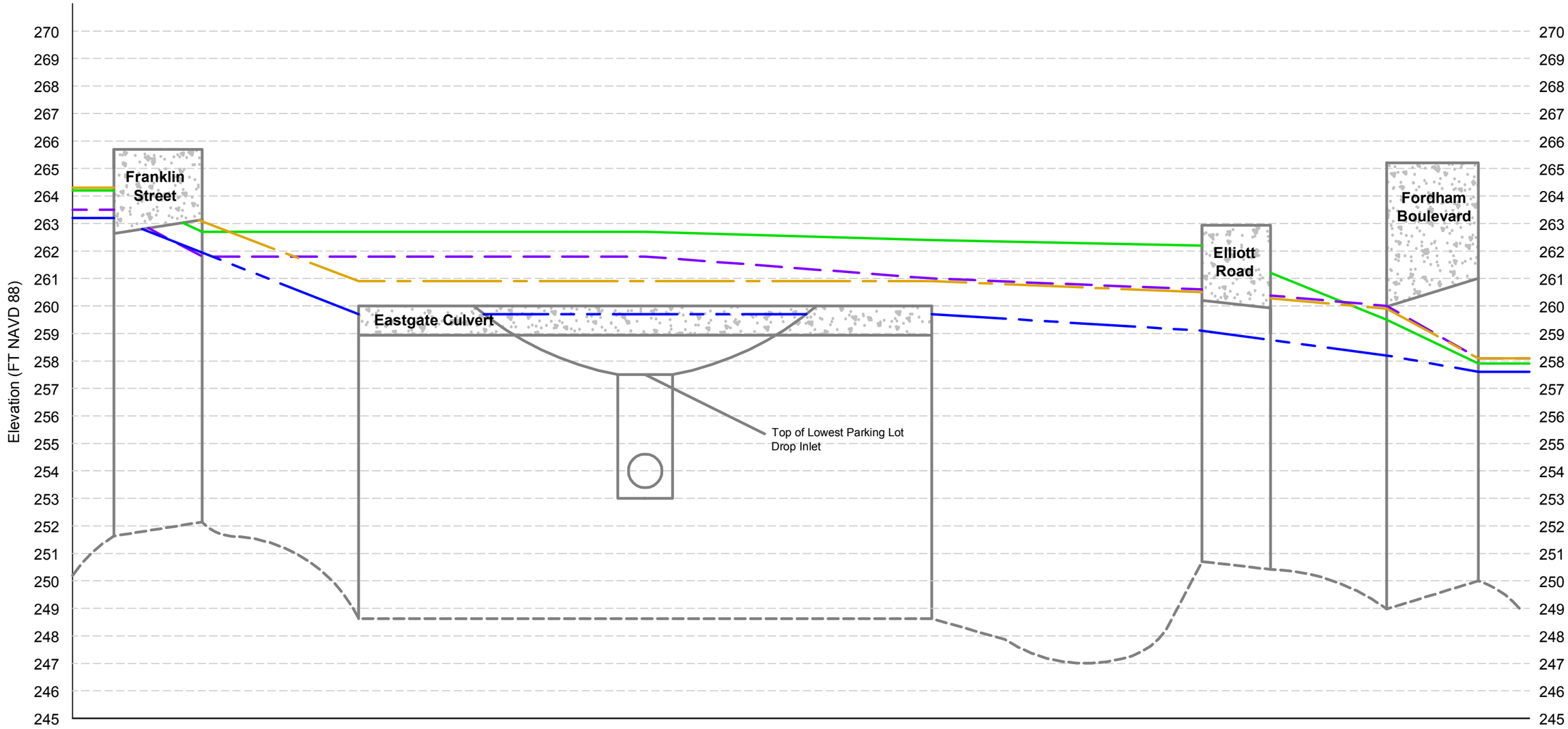
Calibration Storm Events Analysis
September 6, 2008

PROFILE 1

Booker Creek Flood Profile

Calibration Storm Events Analysis

July 23-24, 2000



Legend

- Water Surface - Existing Conditions
- Water Surface - Alternative A
- Water Surface - Alternative B
- Water Surface - Alternative C

Kimley-Horn and Associates, Inc.

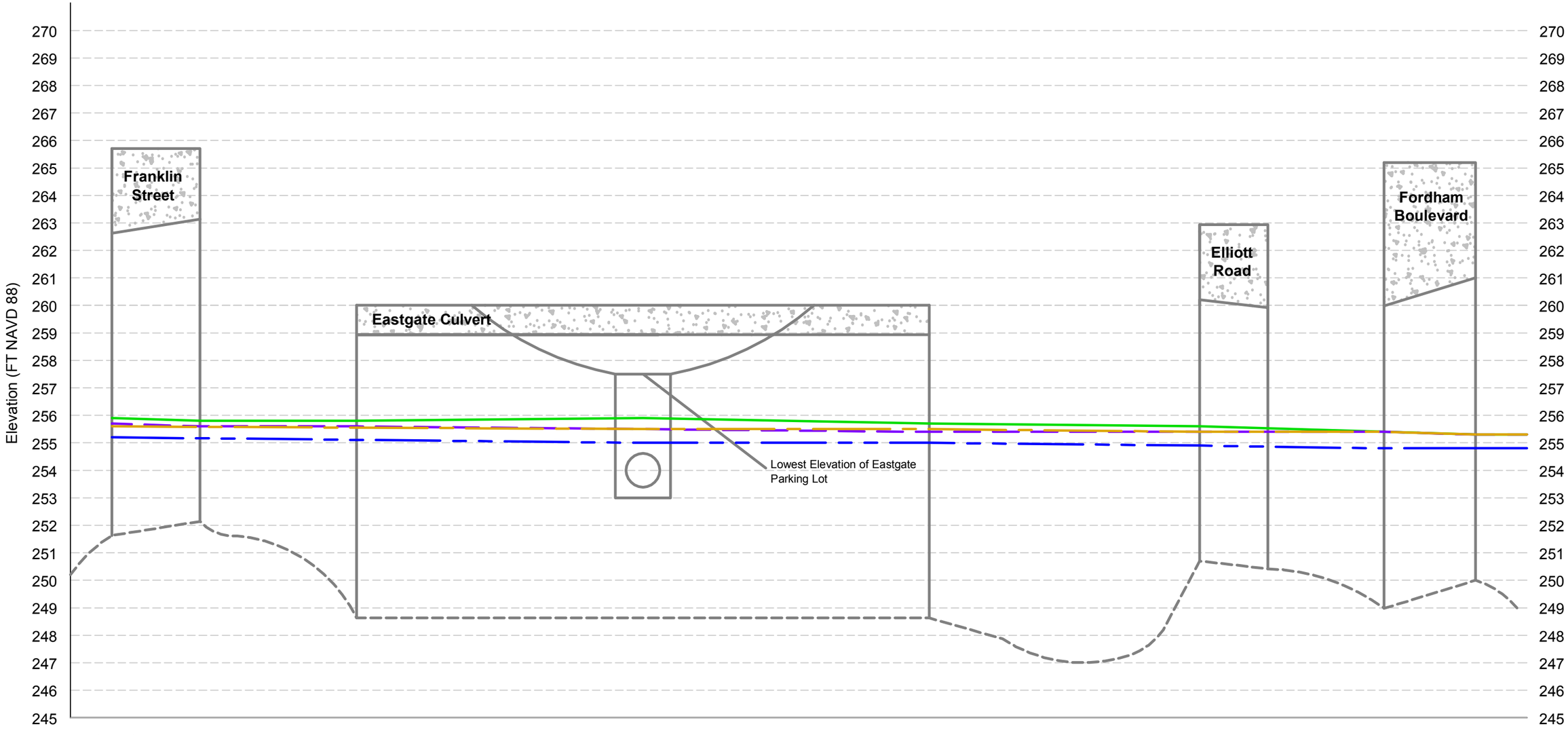
EPHESUS CHURCH ROAD/FORDHAM BOULEVARD SMALL AREA PLAN (SAP), PHASE 3

Booker Creek Flood Profile
Calibration Storm Events Analysis
July 23-24, 2000

PROFILE 2

Booker Creek Flood Profile

SCS Type II 24-Hour 2-Year Storm Event Analysis



Kimley-Horn and Associates, Inc.

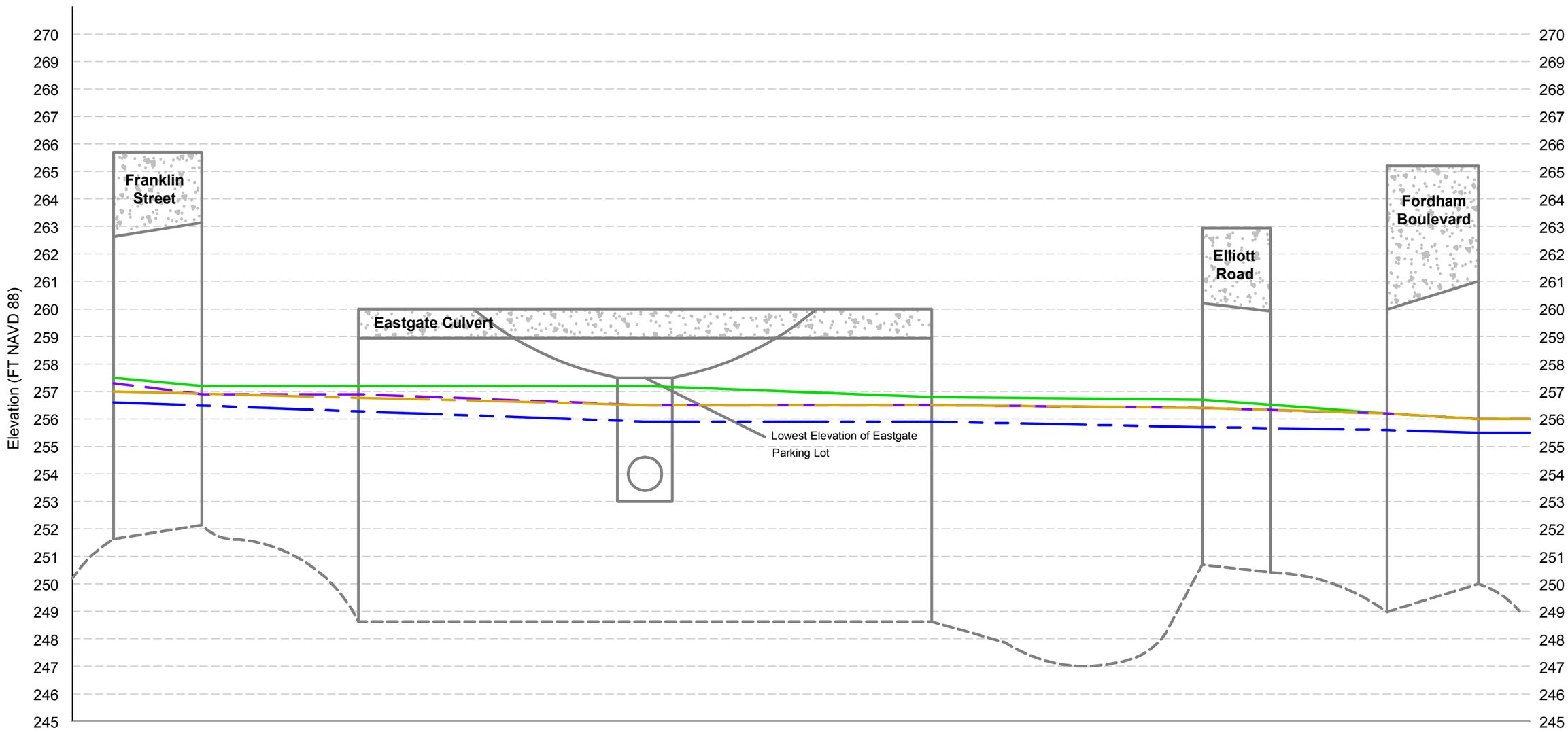
EPHESUS CHURCH ROAD/FORDHAM BOULEVARD SMALL AREA PLAN (SAP), PHASE 3

SCS Type II 24-Hour 2-Year Storm Event Analysis

PROFILE 3

Booker Creek Flood Profile

SCS Type II 24-Hour 5-Year Storm Event Analysis



Legend

- Water Surface - Existing Conditions
- Water Surface - Alternative A
- Water Surface - Alternative B
- Water Surface - Alternative C

Kimley-Horn and Associates, Inc.

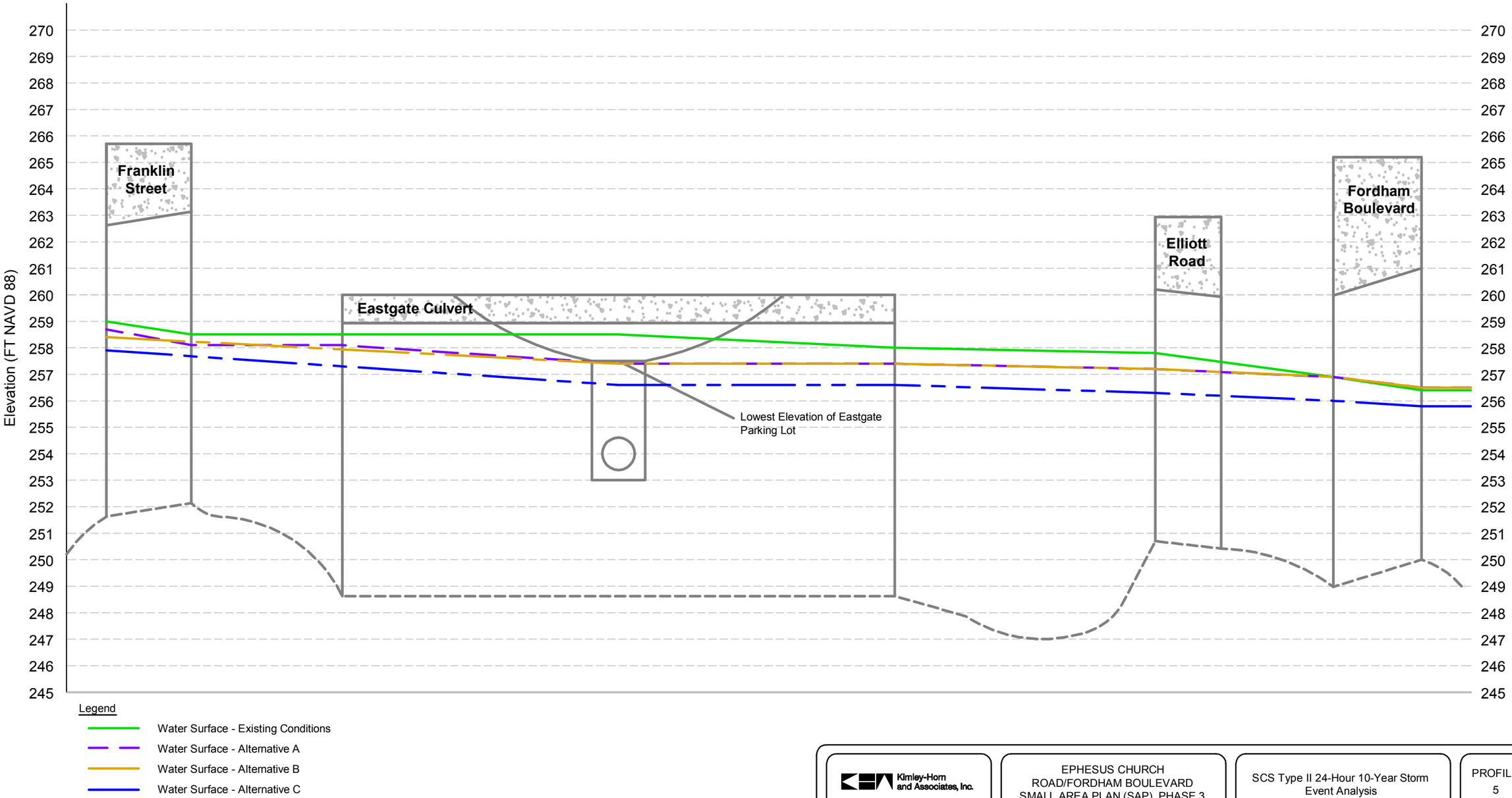
EPHESUS CHURCH ROAD/FORDHAM BOULEVARD SMALL AREA PLAN (SAP), PHASE 3

SCS Type II 24-Hour 5-Year Storm Event Analysis

PROFILE 4

Booker Creek Flood Profile

SCS Type II 24-Hour 10-Year Storm Event Analysis



Kimley-Horn and Associates, Inc.

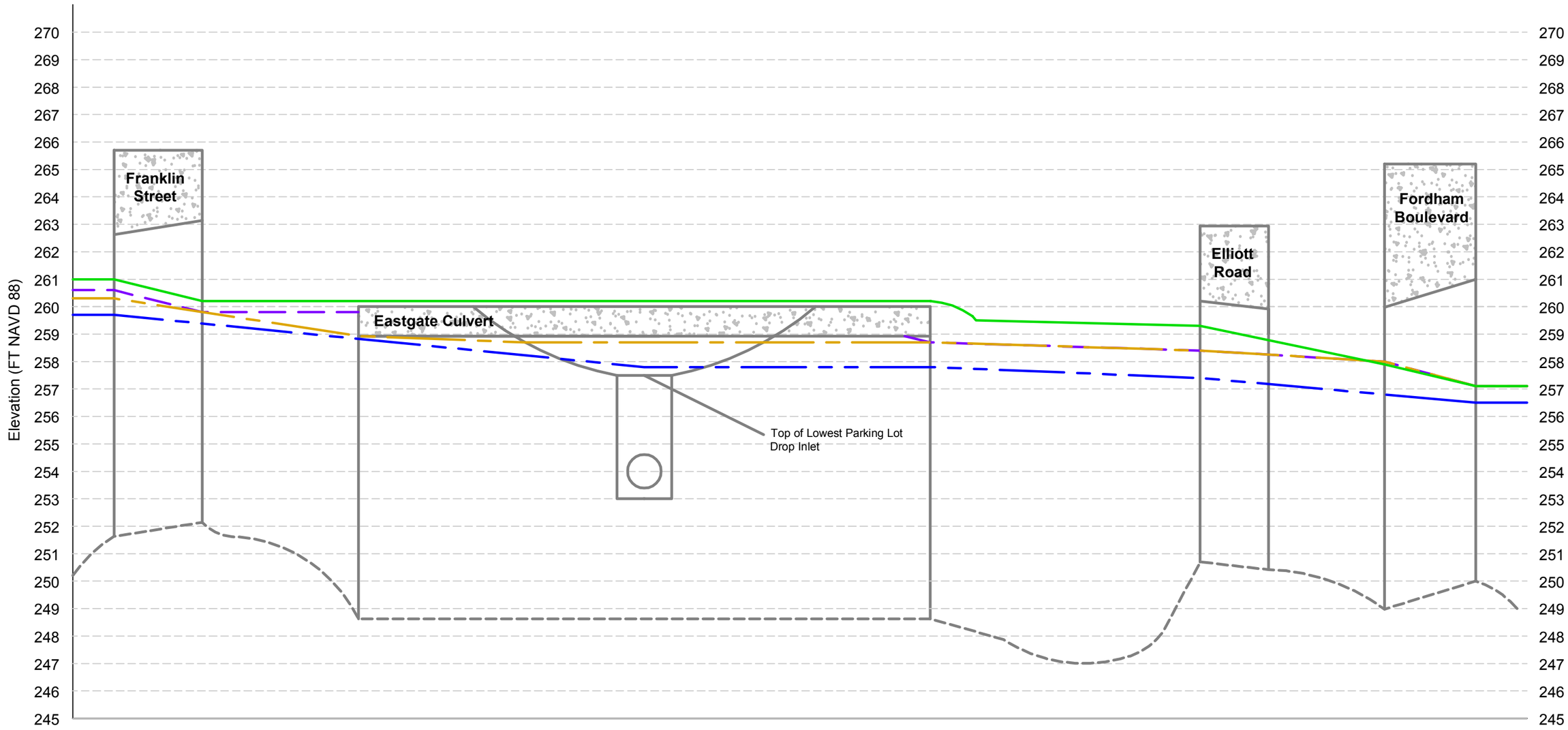
EPHESUS CHURCH ROAD/FORDHAM BOULEVARD SMALL AREA PLAN (SAP), PHASE 3

SCS Type II 24-Hour 10-Year Storm Event Analysis

PROFILE 5

Booker Creek Flood Profile

SCS Type II 24-Hour 25-Year Storm Event Analysis



Legend

- Water Surface - Existing Conditions
- Water Surface - Alternative A
- Water Surface - Alternative B
- Water Surface - Alternative C

Kimley-Horn and Associates, Inc.

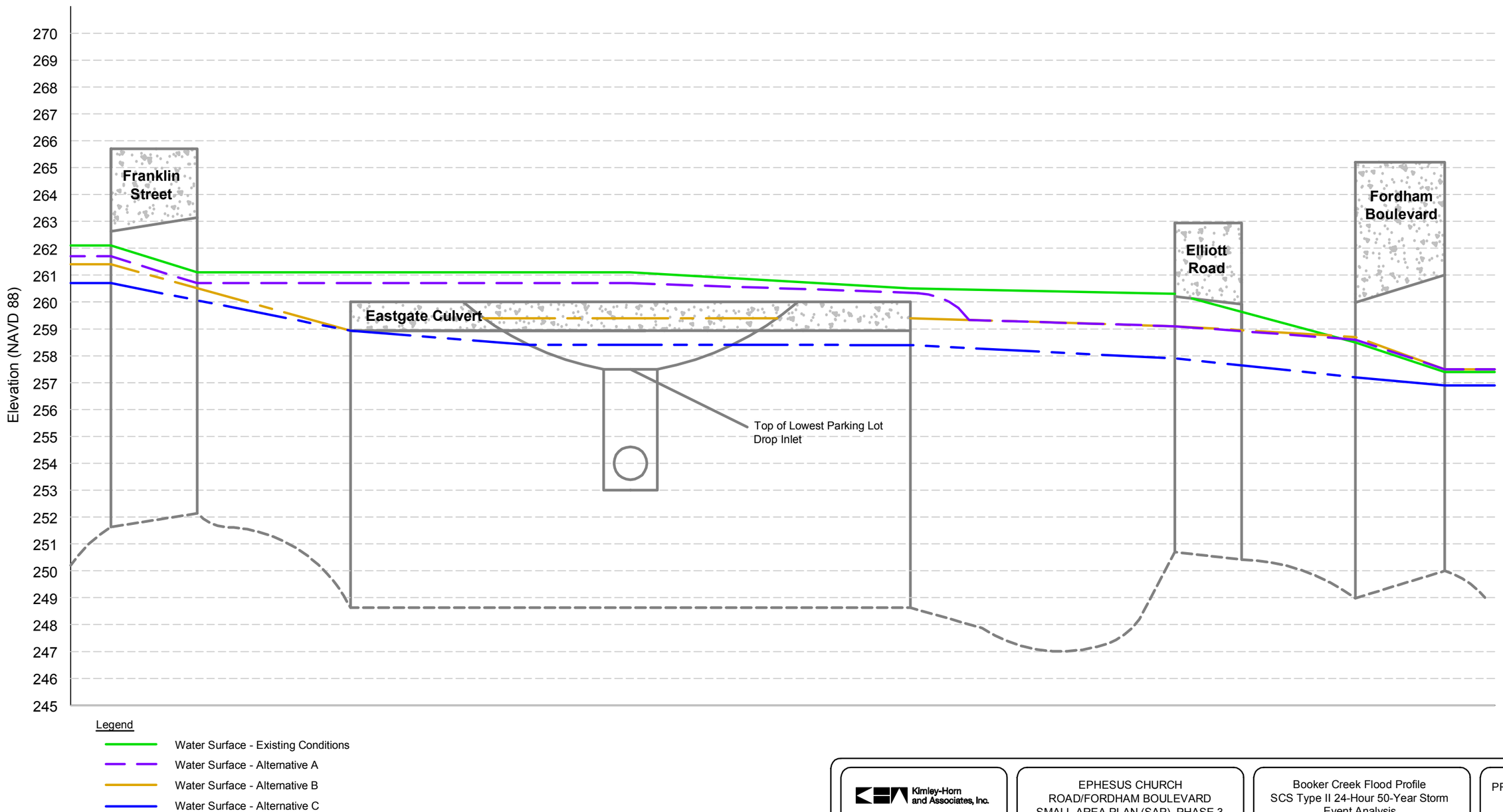
EPHESUS CHURCH ROAD/FORDHAM BOULEVARD SMALL AREA PLAN (SAP), PHASE 3

SCS Type II 24-Hour 25-Year Storm Event Analysis

PROFILE 6

Booker Creek Flood Profile

SCS Type II 24-Hour 50-Year Storm Event Analysis



Kimley-Horn and Associates, Inc.

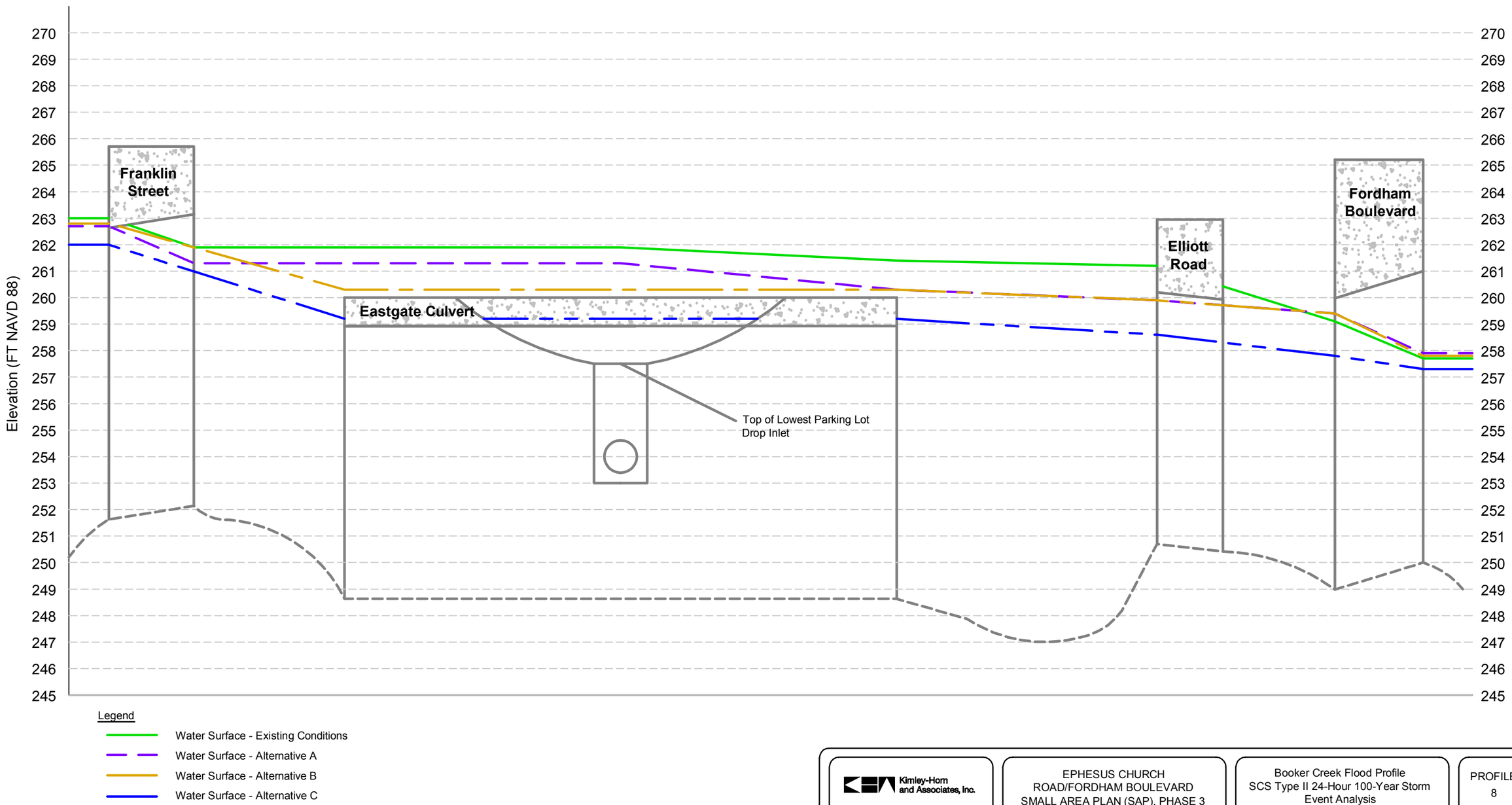
EPHESUS CHURCH ROAD/FORDHAM BOULEVARD SMALL AREA PLAN (SAP), PHASE 3

Booker Creek Flood Profile
SCS Type II 24-Hour 50-Year Storm Event Analysis

PROFILE 7

Booker Creek Flood Profile

SCS Type II 24-Hour 100-Year Storm Event Analysis

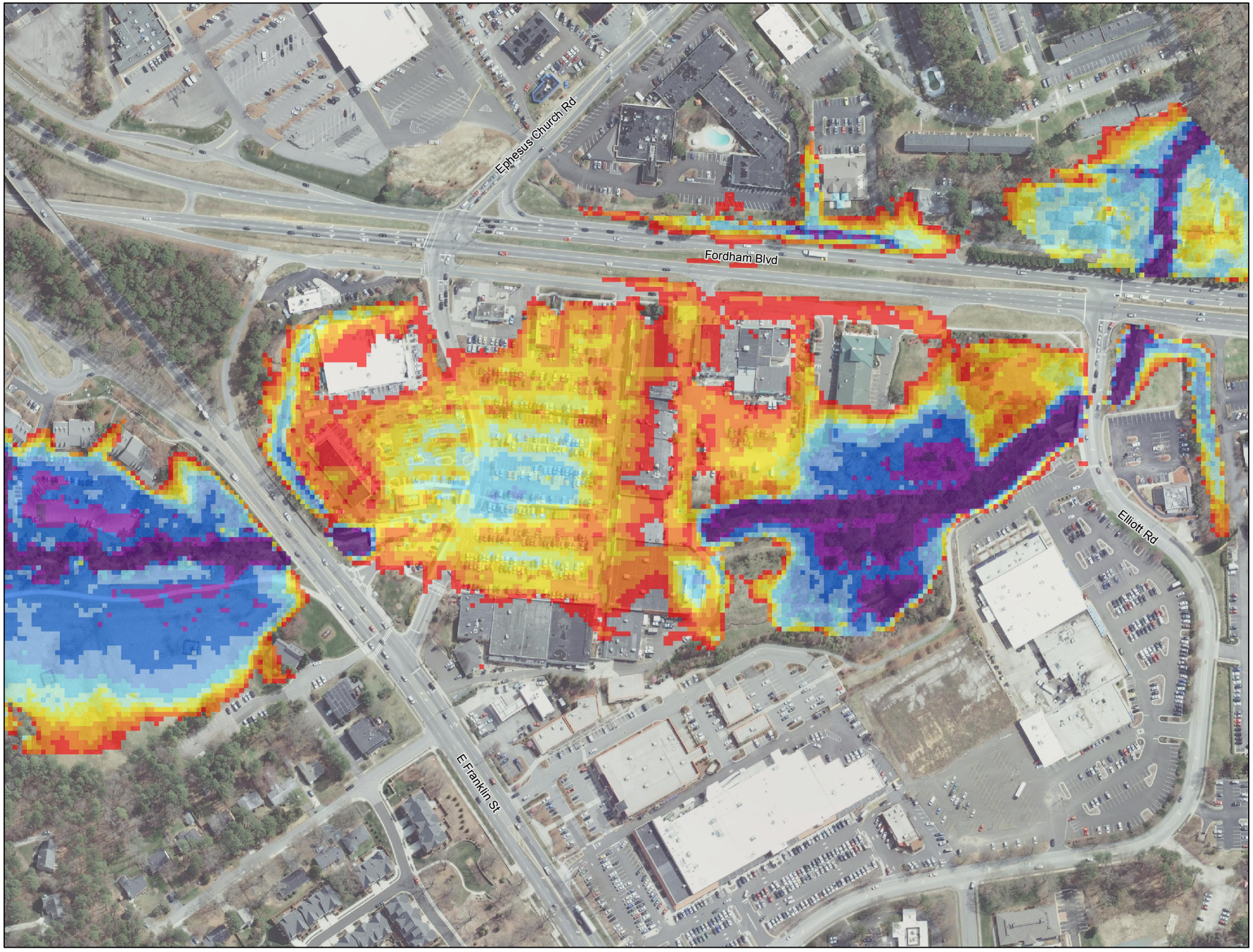


Kimley-Horn and Associates, Inc.

EPHESUS CHURCH ROAD/FORDHAM BOULEVARD SMALL AREA PLAN (SAP), PHASE 3

Booker Creek Flood Profile
SCS Type II 24-Hour 100-Year Storm Event Analysis

PROFILE 8



Ephesus Church Road/Fordham Boulevard Small Area Plan (SAP), Phase 3

Legend

Flood Depths (feet)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- > 7

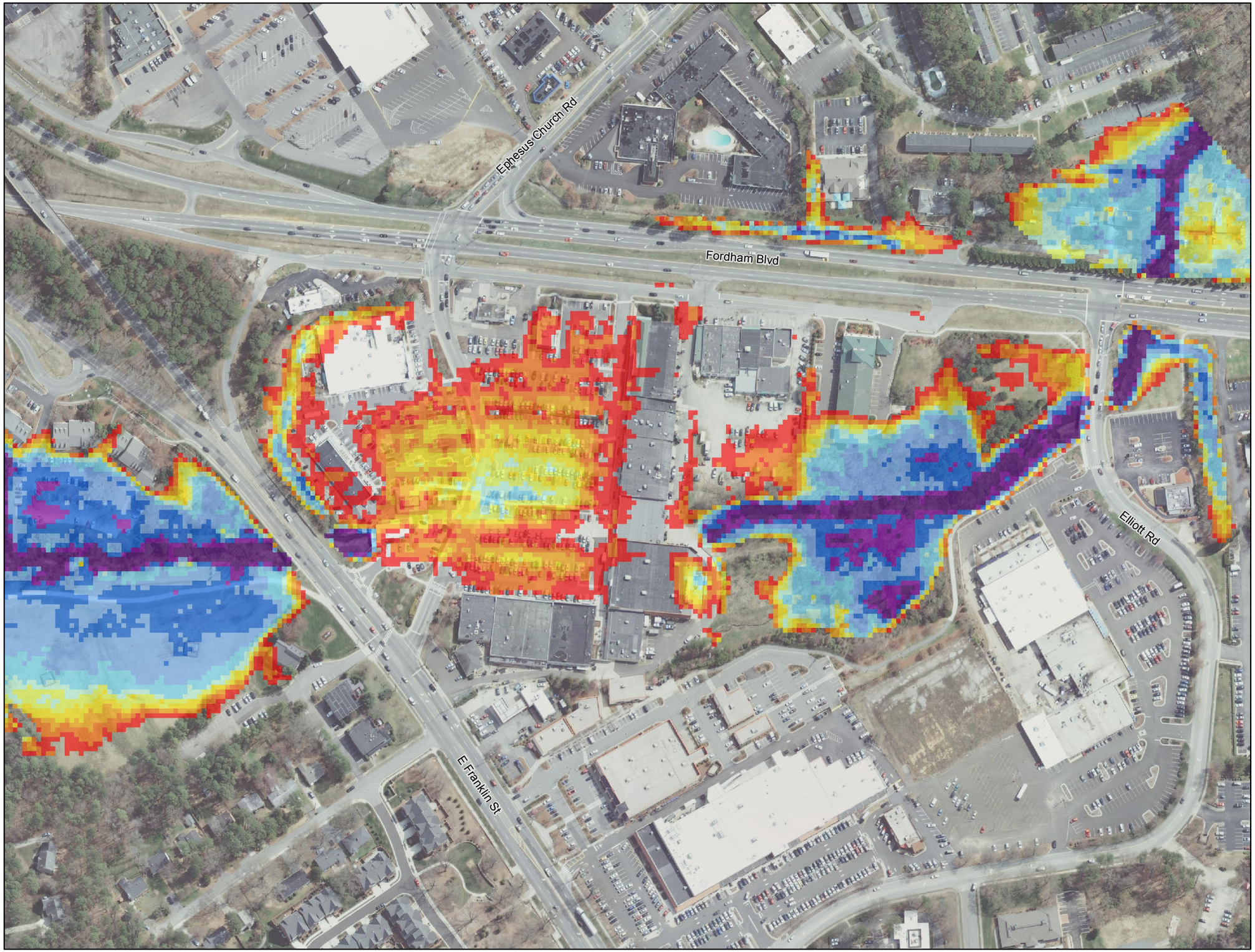
0 100 200 Feet

N

Figure 4
100-Year Floodplain Map

Existing Conditions

Town of Chapel Hill
Orange County, NC



Ephesus Church Road/Fordham Boulevard Small Area Plan (SAP), Phase 3

Legend

Flood Depths (feet)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- > 7

Alternative A Improvements:

1. Replace Elliott Rd Culvert
2. Redirect Eastgate Stormwater

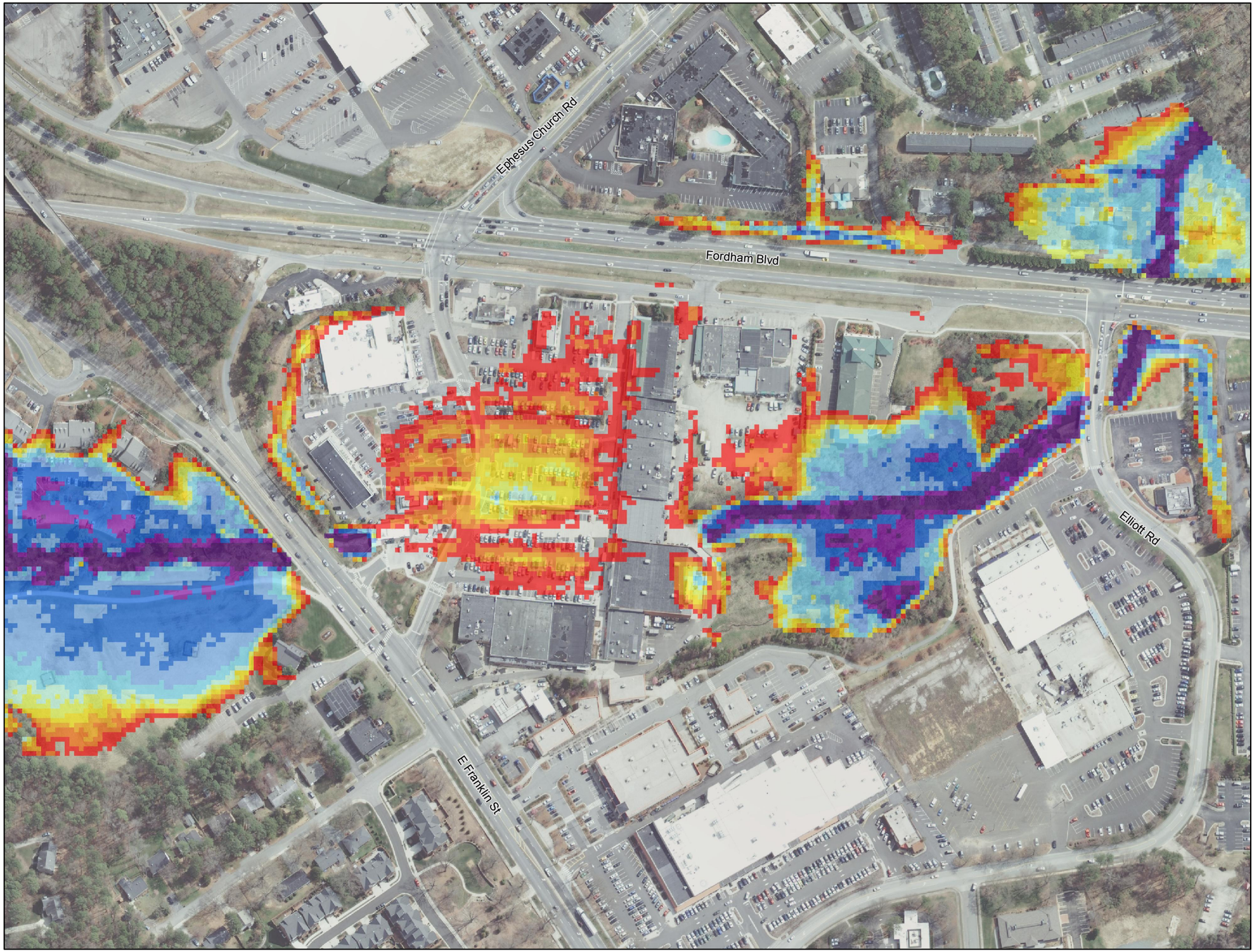
0 100 200 Feet

N

Figure 5
100-Year Floodplain Map

Alternative A

Town of Chapel Hill
Orange County, NC



Ephesus Church Road/Fordham Boulevard Small Area Plan (SAP), Phase 3

Legend

Flood Depths (feet)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- > 7

Alternative B Improvements:

1. Replace Elliott Rd Culvert
2. Redirect Eastgate Stormwater
3. Connect Franklin St and Eastgate Culverts

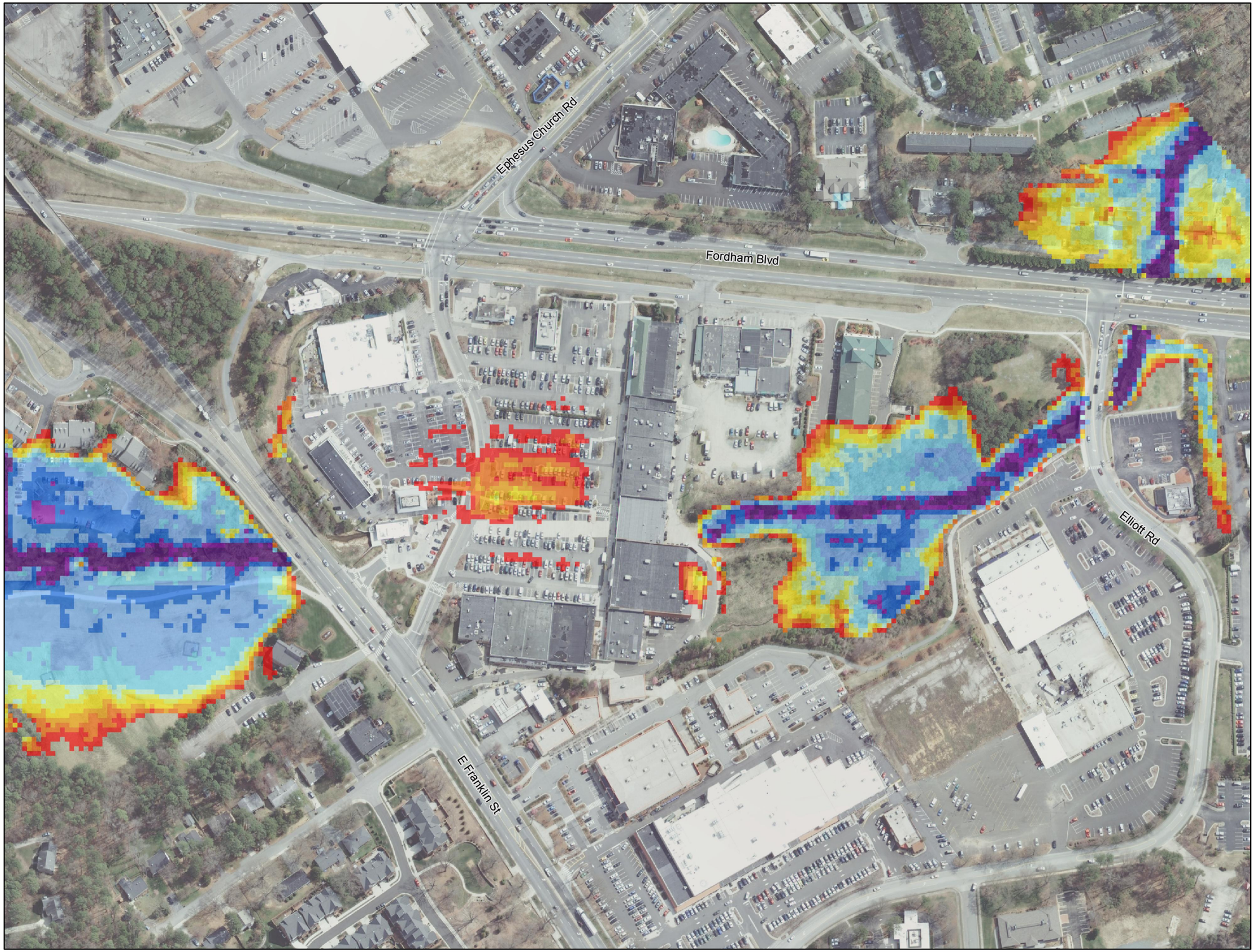
0 100 200 Feet

N

Figure 6
100-Year Floodplain Map

Alternative B

Town of Chapel Hill
Orange County, NC



Ephesus Church Road/Fordham Boulevard Small Area Plan (SAP), Phase 3

Legend

Flood Depths (feet)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- > 7

Alternative C Improvements:

1. Replace Elliott Rd Culvert
2. Redirect Eastgate Stormwater
3. Connect Franklin St and Eastgate Culverts
4. Replace Fordham Blvd Culvert

Feet
0 100 200

N

Figure 7
100-Year Floodplain Map

Alternative C

Town of Chapel Hill
Orange County, NC