US Army Corps
of Engineers
Baltimore District

FINAL FLOOD DAMAGE REDUCTION ANALYSIS FOR BELLE HAVEN WATERSHED, FAIRFAX COUNTY, VIRGINIA

Prepared for: **Fairfax County Storm Water Planning Division**
Department of Public Works and Environmental Services
12000 Government Center Parkway, Suite 449
Fairfax, Virginia 22035-0052

Prepared by: **U.S. Army Corps of Engineers, Baltimore District**
P.O. Box 1715
Baltimore, Maryland 21203-1715

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TABLE OF CONTENTS

1.0 INTRODUCTION 1-1

1.1 BACKGROUND 1-1

1.2 STUDY PURPOSE 1-1

1.3 STUDY AUTHORITY 1-1

1.4 STUDY AREA 1-1

1.5 PROBLEM IDENTIFICATION 1-4

1.6 GOALS AND OBJECTIVES 1-6

2.0 WATERSHED DESCRIPTION AND PREVIOUS STUDIES 2-1

2.1 WATERSHED DESCRIPTION 2-1

2.1.1 Belle Haven Tributary 2-2
2.1.2 Belle Haven East Channel 2-2
2.1.3 Belle Haven West Channel 2-3
2.1.4 Belle Haven West Channel North 2-4

2.2 PREVIOUS STUDIES 2-6

3.0 DATA COLLECTION AND FIELD INVESTIGATION 3-1

4.0 TYPES OF FLOOD DAMAGE REDUCTION MEASURES 4-1

4.1 STRUCTURAL TECHNIQUES 4-1

4.1.1 Levees 4-2
4.1.2 Floodwalls 4-2
4.1.3 Closure Structures for Levees and Floodwalls 4-2

4.2 NON-STRUCTURAL TECHNIQUES 4-5

4.2.1 Elevation 4-5
4.2.2 Flood Proofing 4-5
4.2.3 Flood Warning System 4-5

5.0 FLOOD DAMAGE REDUCTION ALTERNATIVES 5-1

5.1 DEVELOPMENT OF PRELIMINARY ALTERNATIVES 5-1

5.2 EVALUATION AND COMPARISON OF ALTERNATIVES 5-19

6.0 FINDINGS AND CONCLUSIONS 6-1

7.0 REFERENCES 7-1

List of Tables

Table 2.1 - Summary of Frequency of Hurricane Tidal Flooding for the Potomac Estuary near Washington D.C. used in the 1980 Urban Engineering, Inc. Study 2-8

Table 2.2 - Results of the Flood-Frequency Analysis for Select Cross-Sections 2-10

Table 3.1 - Data Sources 3-1

Table 3.2 - Summary of Frequency of Hurricane Tidal Flooding for the Potomac Estuary near Washington D.C. determined by Statistical Analysis completed by Fairfax County Stormwater Planning Division, 2005 3-3

Table 5.1 – Concept Plan Alternatives Analysis 5-20

List of Figures

Figure 1.1 – Vicinity Map 1-2

Figure 1.2 – Study Area Map 1-3

Figure 1.3 – Hurricane Isabel Flooding 1-5

Figure 2.1 - Drainage Channels within the Belle Haven Watershed 2-1

Figure 2.2 - Culvert under George Washington Memorial Highway on Belle Haven Tributary 2-2

Figure 2.3 - Location and Photograph of I Street Tide Gate 2-2

Figure 2.4 - Belle Haven East Channel Downstream of Belle Haven Road 2-3

Figure 2.5 - Belle Haven West Channel Downstream of Fort Hunt Road Culvert 2-4

Figure 2.6 - Inlet to and Location of 13th Street Pump Station 2-5

Figure 2.7 - Belle Haven West Channel North Downstream of Belle Haven Road 2-6

Figure 2.8 - Flood-Frequency Cross-Sections 2-9

Figure 3-1: 100-Year storm surge (Based on County Statistical Analysis) 3-4

Figure 4-1: Typical Swing Gate Closure Structure 4-3

Figure 4-2: Typical Roller Gate Closure Structure 4-3

Figure 4-3: Typical Stop Log Closure Structure 4-4

Figure 5.1 – Plan 1a Concept Plans 5-2

Figure 5.2 – Plan 1b Concept Plans 5-7

Figure 5.3 – Plan 2a Concept Plans 5-10

Figure 5.4 – Plan 2b Concept Plans 5-13

Figure 5.5: Schematic Showing Plan 3b 5-15

Figure 5.6 - Photos of Belle View Condominium 5-16

Figure 5.7: Photographs of the Belle View Shopping Center 5-17

Figure 5.8 –Shopping Center Ring Wall Alternative Plan 5-18

APPENDICES

APPENDIX A – INTERIOR DRAINAGE ANALYSIS

APPENDIX B – COST ESTIMATES FOR CONCEPT PLANS

APPENDIX C – ECONOMIC ANALYSIS

APPENDIX D – SOIL BORINGS

1.0 INTRODUCTION

1.1 BACKGROUND

The Belle Haven Watershed, as defined by Fairfax County, contains two subdivisions which experienced severe flooding from storm surge during Hurricane Isabel in September 2003: New Alexandria and Belle View. It is estimated that over 200 structures were damaged by flooding during that storm event. The majority of both subdivisions lies within the 100-year floodplain and are vulnerable to future flooding.

1.2 STUDY PURPOSE

The purpose of this study was to determine if there are potential flood damage reduction alternatives for the Belle Haven watershed that are technically feasible and cost-effective. The study evaluated alternatives such as levees and flood walls, and flood proofing alternatives such as raising and modifying structures. Two heights of protection were evaluated: just above the 50-year water surface elevation and just above the 100-year water surface elevation. As part of the study, the county requested that a preliminary economic analysis be conducted to determine if a project might meet the federal economic justification requirements. Concept level designs were developed and economic costs and benefits were determined. This was a reconnaissance-level study to identify potential alternatives and approximate construction cost estimates and further design is necessary before proceeding with any of these plans.

1.3 STUDY AUTHORITY

This study was conducted by the U.S. Army Corps of Engineers, Baltimore District (Corps), for Fairfax County under the authority of the Floodplain Management Services (FPMS) Program. This program provides authority for the Corps of Engineers to assist county governments with flood plain information and planning assistance. This study, which was funded by Fairfax County and the Corps of Engineers, was a planning-level study and did not include detailed designs.

1.4 STUDY AREA

The study area is a portion of the Belle Haven Watershed, located in Fairfax County, Virginia The Belle Haven Watershed, which encompasses approximately 1154 acres (1.8 square miles), is located in the eastern portion of Fairfax County along the westbank of the Potomac River. Figure 1.1 is a vicinity map. Fairfax County contains approximately 356 square miles, has a population of roughly 1 million people (2004 census). Fairfax County has experienced rapid development over the last 25 years and the growth is expected to continue.

The study area consists of the New Alexandria and Belle View communities, which lie within the Belle Haven watershed. The study area includes the portion of the communities within the 100-year floodplain. Figure 1.2 is a study area map. The actual study area is approximately 204 acres (0.32 square miles) within the watershed.

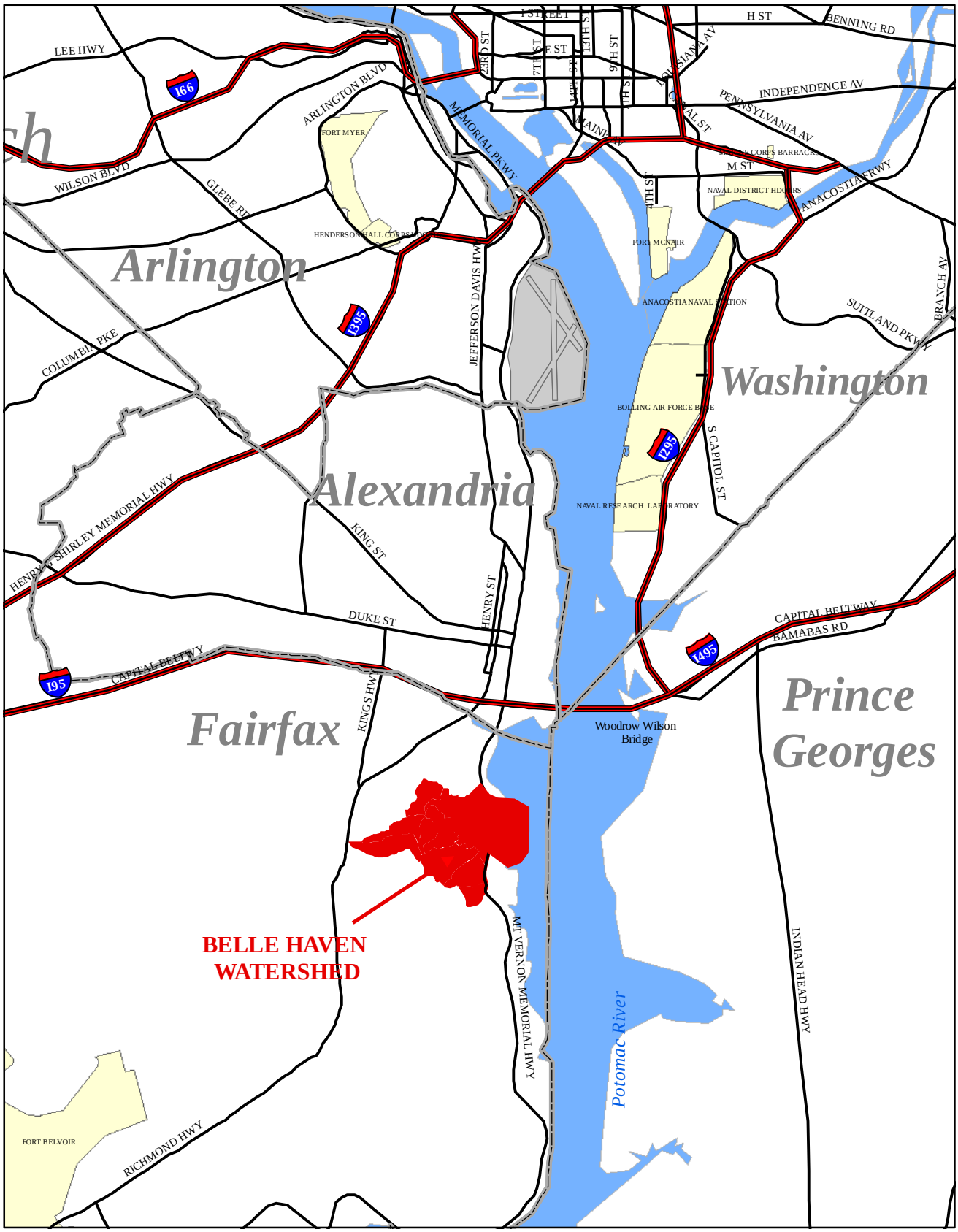

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Figure 1.1

Vicinity Map - Belle Haven Watershed

N
W E
S

0 2,000 4,000 8,000 Feet

1 inch equals 8,000 feet

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N
W E
S

0 130 260 520 Feet

1 inch equals 500 feet

Figure 1.2: Study Area Map

Legend

Waterways

The study area is located within the boundaries of the Mount Vernon Magisterial District. The Mount Vernon Magisterial District has a population density of approximately 19 people per square mile, and contains a mix of single family homes, townhouses, duplexes, multiplexes, apartments, mobile homes, and commercial structures.

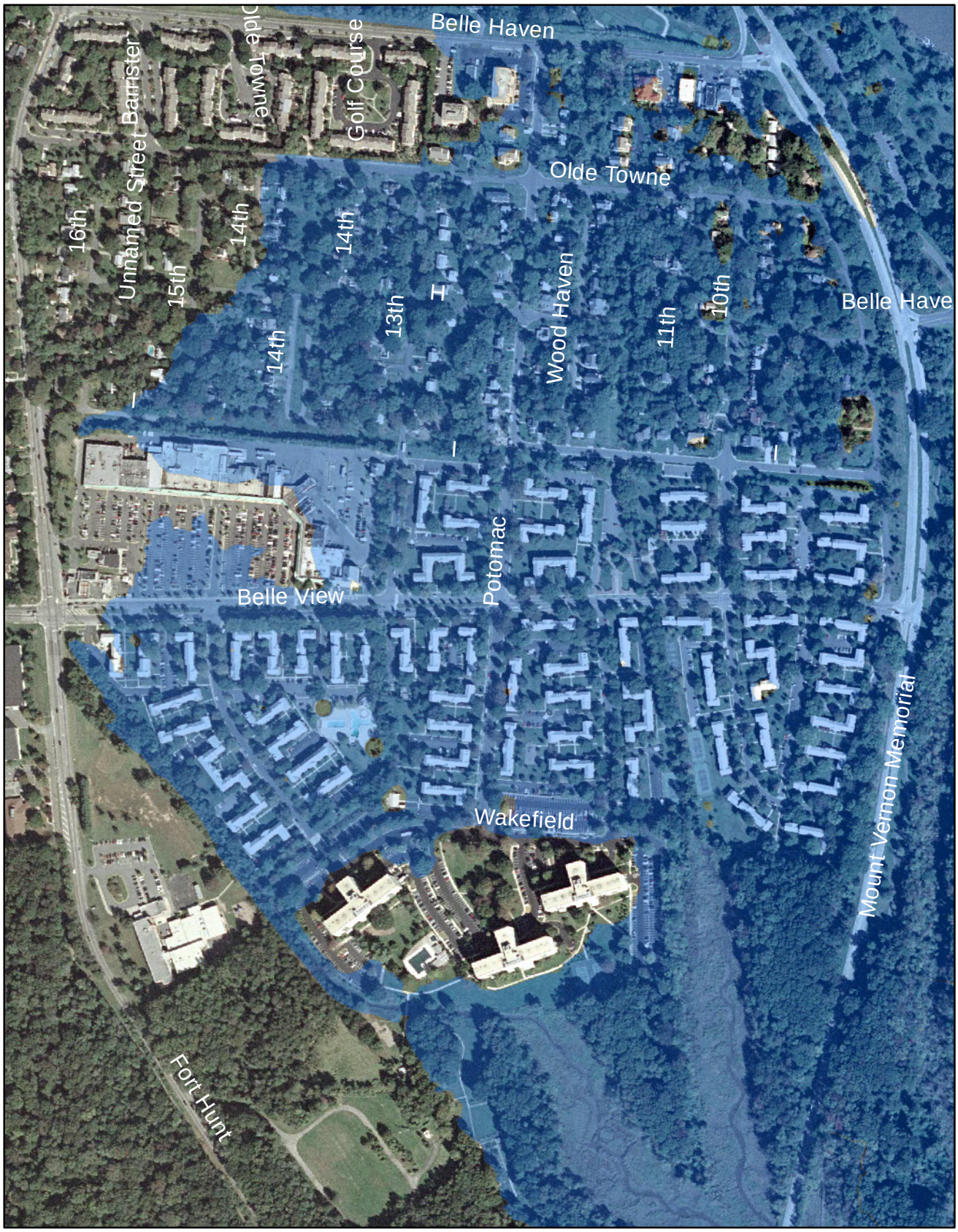
New Alexandria is in the northern section of the watershed above I Street and contains mostly single-family houses (approximately 180). There are a few commercial structures along Belle Haven Road and a townhouse development that is outside of the 100-year floodplain. Belle View contains the Belle View Condominiums (65 separate buildings), the Belle View shopping center, and the River Towers high-rise apartment complex (which is located outside of the 100-year floodplain).

Since the late 1970's, Fairfax County, per their Floodplain Management Ordinance, has required any new development to elevate the first floor to a minimum of 18 inches above the 100-year (base flood). The 100-year (base flood) is defined as the flood that has a 1% chance of occurring in any given year and is the standard flood used by the Federal Emergency Management Agency (FEMA) for regulatory purposes. In the Mount Vernon Planning District and Belle Haven Watershed, however, approximately 80% of the structures in the area were built prior to 1980. Therefore, many of the structures in the area may be subject to damages from floods. Because of this scenario, the Belle Haven watershed is one of the highest flood risk priority areas within Fairfax County for the Fairfax County Stormwater Planning Division.

Other than flash flooding from a sudden rainstorm in the Belle Haven Watershed, there is ample flood warning time for the residents of the area from major tropical systems that cause tidal surges along the Potomac River. Fairfax County uses the Community Emergency Alert Network, or CEAN, to deliver important emergency alerts, notifications and updates during a major crisis or emergency, such as flooding. When an incident or emergency occurs, authorized senders will notify residents using this alert network via email, cell phone, telephone, or other means.

1.5 PROBLEM IDENTIFICATION

As shown in Figure 1.3, the Belle Haven watershed experienced severe flooding from storm surge during Hurricane Isabel in September 2003. The storm surge reached an elevation of approximately 9.6 feet (National Geotedetic Vertical Datum), which is the projected 50-year storm surge elevation as calculated by Fairfax County Stormwater Planning Division using a statistical analysis. Many of the structures have first floor elevations or openings into their basements between elevations 6 and 9 feet. The current Flood Insurance Rate Map (FIRM) for Fairfax County, VA (Panel Number 515525 0137 D), dated March 5, 1990, shows that the 100-year flood plain elevation is 10.0 feet for this study area. However, based on the County's 2005 statistical analysis, the 100-year surge tide elevation is 11.2 feet, which is consistent with a data letter sent to Fairfax County by FEMA recommending revisions to the local floodplain ordinance to require new construction to build to elevation 11.0 feet rather than 10.0 feet for areas north of Olde Town Road (as shown on the FIRM). There is some risk of riverine flooding from heavy rainfall, however, the County's main concern is flooding from Potomac River storm surge during



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N W E S

0 125 250 500 Feet

1 inch equals 500 feet

Figure 1.3: Belle Haven Watershed Hurricane Isabel Flooding Elevation 9.6 ft (NGVD29)

Legend

Hurricane Isabel Flooding

tropical events. Reducing flood damages from storm surge flooding was the primary focus of this study.

1.6 GOALS AND OBJECTIVES

At the initiation of the study, Fairfax County established a goal for the project. The goal is to provide adequate flood damage reduction measures that are technically feasible and financially prudent to ensure the safety of the New Alexandria and Belle View Communities without increased flood damage to neighboring communities and infrastructure.

To meet this goal, several objectives were established by Fairfax County:

- Examine alternatives above the 50 and 100 year water surface elevations
- Minimize risk to the community
- Reduce damages from storm surge flooding

Although they were outside the scope of this current study, Fairfax County also established the following objectives.

- Incorporate needs/desires of the community for flood damage reduction as much as possible;
- Minimize environmental impacts

Due to the preliminary nature of this study, public meetings were not held. However, if any flood damage reduction alternatives are pursued further, the County plans to coordinate with the community for their input. The County will also identify any critical environmental resources that may be affected by a project and minimize impacts to the resources. Although the scope of study did not include the identification of critical environmental resources, the team was aware of Dyke Marsh on the south and east sides of the study area and aligned the floodwall alternative to avoid/minimize any impacts to the valuable wetlands.

2.0 WATERSHED DESCRIPTION AND PREVIOUS STUDIES

2.1 WATERSHED DESCRIPTION

The Belle Haven Watershed contains 2 unnamed tributaries that drain southeasterly into the Potomac River. The outlets of these tributaries occur under the George Washington Memorial Highway. For the purposes of this investigation, the tributaries are named Belle Haven East Channel, Belle Haven West Channel, and Belle Haven West Channel North. The segment where the East Channel and West Channel converge and flow under the George Washington Memorial Highway is referred to as the Belle Haven Tributary (Figure 2.1).

FIGURE 2.1 - DRAINAGE CHANNELS WITHIN THE BELLE HAVEN WATERSHED

To the east and south of the study area are tidal wetlands known as Dyke Marsh, which is one of the last remaining natural wetland areas in Fairfax County (Urban Engineering, Inc. 1980). The

wetlands are excellent habitat for wildlife and the area is widely used by tourists and local residents for recreational purposes (biking, hiking, etc…). Thus, this area is a high priority for preservation by State and Federal agencies. Any proposed development in these areas would undergo a rigorous review process by regulating agencies, and also, any proposed development would certainly have negative environmental and recreational effects.

2.1.1 Belle Haven Tributary

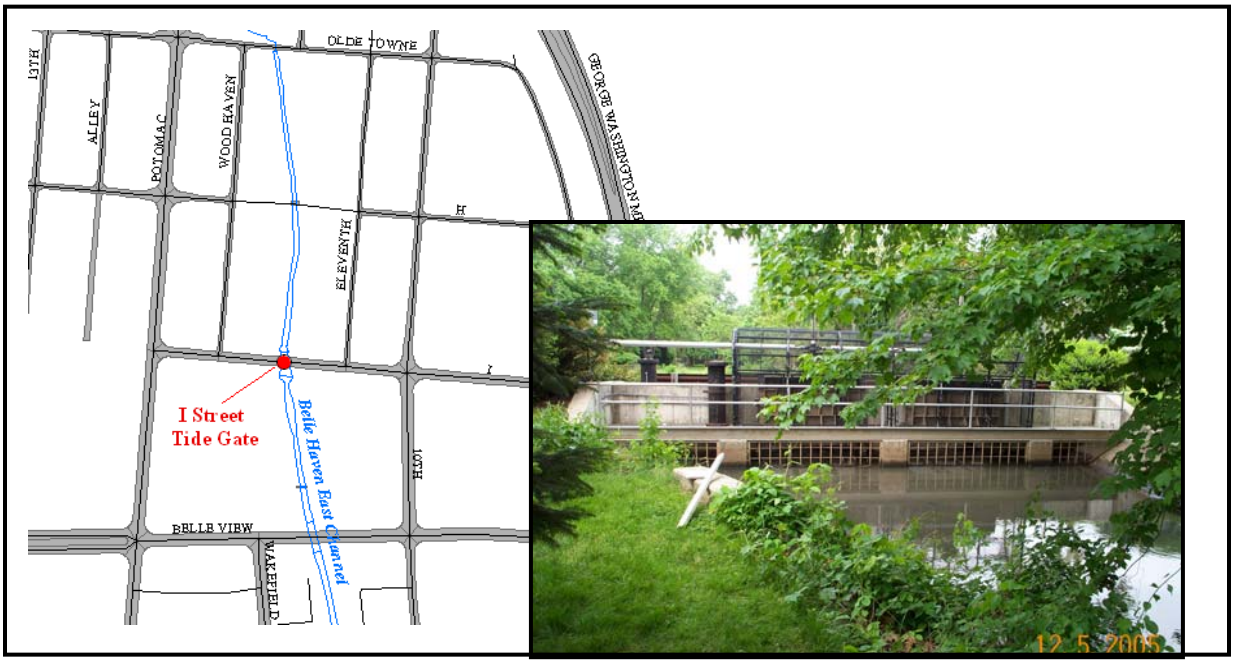
The Belle Haven Tributary is a marshy area that contains one road crossing, the George Washington Memorial Highway. This crossing is the primary outlet point of all flow from the Belle Haven Watershed to the Potomac River (Figure 2.2). In addition, a footbridge is located approximately 160 feet downstream of the George Washington Memorial Highway. The channel in this area is broad and wide and the over bank areas resemble a typical tidal marsh ecosystem.

FIGURE 2.2 - CULVERT UNDER GEORGE WASHINGTON MEMORIAL HIGHWAY ON BELLE HAVEN TRIBUTARY

2.1.2 Belle Haven East Channel

The Belle Haven East Channel contains three road crossings at Belle View Boulevard, I Street, and Olde Towne Road. There are also several footbridges crossing the East Channel. In addition, a tide gate is located at the I Street crossing in order to control the backflow of flood waters to the areas above I Street (Figure 2.3). The I Street Tide Gate protects the residential area upstream of I Street when the tide is above 4 feet in elevation (NGVD29 Datum). If the tide elevation is greater than 4 feet, the tide gate closes. It will stay closed as long as the downstream water surface elevation is above 4 feet unless it senses a 6" differential between upstream and downstream of the gate. It will open until that difference equalizes and will close again.

FIGURE 2.3 - LOCATION AND PHOTOGRAPH OF I STREET TIDE GATE



The East Channel is approximately 4400 feet in length from its origin downstream of Belle Haven Road to its confluence with the West Channel. The channel is a natural channel that is rather straight and contains a narrow vegetated buffer (Figure 2.4).

FIGURE 2.4 - BELLE HAVEN EAST CHANNEL DOWNSTREAM OF BELLE HAVEN ROAD

2.1.3 Belle Haven West Channel

The Belle Haven West Channel begins at the outflow of a 48” and 36” round concrete culvert under Fort Hunt Road. The West Channel is approximately 3400 feet in length from this point to its confluence with the East Channel. Like the East Channel, the West Channel is fairly straight

and contains a vegetated buffer. However, the buffer for the West Channel is wider with more trees (Figure 2.5). There are two footbridges located on the West Channel, one just upstream of the confluence with the West Channel North, and one approximately 710 feet downstream of the confluence with West Channel North.

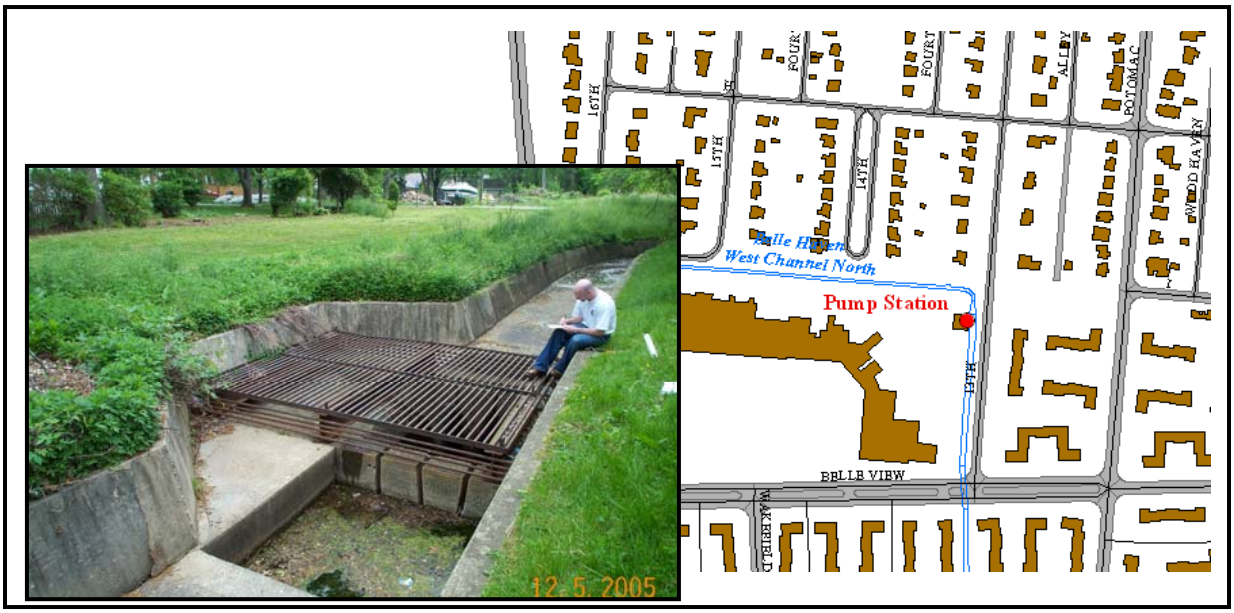
FIGURE 2.5 - BELLE HAVEN WEST CHANNEL DOWNSTREAM OF FORT HUNT ROAD CULVERT

2.1.4 Belle Haven West Channel North

The Belle Haven West Channel North begins at an outfall from the stormwater infrastructure of a nearby shopping plaza. The channel is a concrete, trapezoidal channel for approximately 1100 feet until it reaches a grate inlet that is the inflow pipe to a pump station at 13th Street (Figure 2.6). The pump station was constructed in the late 1980s to alleviate flooding issues during tidal surges. The purpose of the pump station is to pump storm water runoff from the drainage basin upstream into the drainage channel downstream where it can flow by gravity to the Potomac River.

All surface drainage which does not evaporate or percolate into the soil is eventually collected in a concrete channel upstream of the pump station. A slide gate on the culvert pipe at the 13th street entrance to the shopping center isolates the pump station's drainage channel inlet structure from the discharge receiving channel. This gated culvert isolates the drainage area upstream from tidal flows in the receiving channel and also prevents the pump station discharge from recirculating to the drainage inlet structure. The drainage channel structure upstream from the slide gate receives all collected water and directs it to the pump station wetwell. The pumps then lift the water to the level of the downstream channel and discharge it into the drainage channel where it flows by gravity to the Potomac River. There is a culvert slide gate for emergency use. In the event of a pump station failure, the slide gate can be manually opened to permit gravity flow of water from the drainage channel to the receiving channel (Black & Veatch, 1989).

FIGURE 2.6 - INLET TO AND LOCATION OF 13TH STREET PUMP STATION



The station has two 7,200 gallons per minute (gpm) (which is 16 cubic feet per second (cfs)) and two 39,000 gpm (87 cfs) electric motor driven pumps providing a maximum pumping capacity of 93,000 gpm (206 cfs) at minimum static head. A diesel engine driven generator provides back-up electric power for the pumps.

From the pump station, the West Channel North is an approximately 1700 feet, rather straight channel that has the same characteristics as the East Channel (Figure 2.7). There are 4 footbridges and road crossings at Belle View Boulevard and Wakefield Drive from the pump station to the confluence with the West Channel.

FIGURE 2.7 - BELLE HAVEN WEST CHANNEL NORTH DOWNSTREAM OF BELLE HAVEN ROAD

2.2 PREVIOUS STUDIES

The Belle Haven watershed has had a long history of flooding problems. The average elevation of this generally flat area is less than 3 feet above mean high tide, and the soils offer poor drainage (Urban Engineering, Inc. 1980). Since the majority of the community was constructed prior to floodplain regulations taking effect, the area has been a primary concern of the mostly newer, suburban Fairfax County. Thus, the area has been studied extensively throughout the last 45 years.

15 May 1963- Hurricane Survey, Washington D.C. Metropolitan Area, Survey Report, completed by the U.S. Army Corps of Engineers Baltimore District

This investigation concentrated on the hurricane effects that are subject to modification by protective works, zoning, and evacuation. The investigation included the determination of the extent of hurricane induced tides, evaluation of damages for various levels of flooding, the engineering and economic feasibility of protective works, and the need for zoning and evacuation plans.

The Belle Haven Watershed is located in Reach 12 identified in this report. It was proposed as part of the investigation to construct a levee along the east side of the George Washington Parkway to protect the area against the design hurricane tide (elevation 15.0 NGVD29). This would require about 12,400 feet of earth levee, 400 feet of reinforced concrete floodwall, a pumping station for interior drainage, and several other drainage structures at a 1960 cost of $1,500,000. The benefit cost ratio of such a project was calculated to be 0.8. To protect the area against damages from a recurrence of flooding to 10.6 feet, the cost would be $1,200,000 in 1960 dollars, and would have a benefit cost ratio of 0.6. Because of the benefit-cost ratio being below 1.0, the construction of this levee/floodwall structure was not recommended.

December 1978- Immediate Action Plan for New Alexandria Area, completed by Parsons. Brinckerhoff, Quade, and Douglas (PBQ&D)

This preliminary investigation into flooding issues in the New Alexandria/Belle Haven area identified the most significant problems in the Belle Haven Watershed as an inadequate road crossing at Belle View Boulevard, flooding of residences, high tidal stages in the Potomac River, and a degraded aquatic environment. The investigation recommended two primary projects: the addition of a culvert at Belle View Boulevard and the installation of a floodwall, tidal gates, and pumping station near the George Washington Memorial Highway. The approximate cost for the culvert addition, in 1978 dollars, was $41,000. The approximate cost of the floodwall system, which entails approximately 1400 linear feet of floodwall on the river side of the parkway, would be $1,856,000 in 1978 dollars (roughly $5,500,000 in 2004 dollars). This floodwall would protect against flooding from a 25-year Potomac storm surge. The investigation also concluded that more detailed analysis is required prior to the construction of any such projects.

August 1980- New Alexandria Flood Relief Feasibility Study, completed by Urban Engineering & Associates, Inc.

As a result of the recommendations made in the PBQ&D study, Fairfax County contracted Urban Engineering & Associates to provide a detailed study of the drainage problems in the Belle Haven Watershed, propose several alternative solutions with cost estimates, and recommend the most cost effective solution. This investigation is the most comprehensive to date for the Belle Haven Watershed. Several key points were made in the investigation, including:

- A major contributor to the flooding issues in the Belle Haven Watershed is inadequate culverts, inadequate channel area, inadequate storm drain system, and no protection of homes.
- Zoning and building code restrictions on development in the floodplain are being practiced by Fairfax County.
- Floodproofing is a viable alternative for protecting homes, however, it skirts the major problems associated with the existing channels and storm drain system.
- Permanent evacuation of homes, or “buyouts”, is not a feasible option because of prohibitive costs and adverse effects on the community.
- A dike or levee along the Potomac River is the optimal method of mitigating disastrous effects of tidal flooding, but the costs and environmental issues of such a plan render it infeasible.
- Protection in excess of the 50-year tide is infeasible (at the time of the study, the 50-year tide was calculated to be 7.4 feet NGVD29).

The proposed solution outlined in the study was a combination of protection against the 50-yr frequency tide and the 100-yr rainfall. The solution included improvements to the channels in the watershed, the installation of a tide gate and a pump station, as well as the installation of an extensive storm sewer network in the areas North of I Street. The estimated cost of the solution was $8,900,000 in 1980 dollars. Subsequently, as a result of this study, Fairfax County

implemented the recommendations and the pumping station and storm sewer improvements were constructed, as well as the tide gate, though its location was shifted upstream from Belle View Boulevard to I Street.

Note that the storm surge tide elevations for the Potomac River used in the study were from the USACE 1961 Hurricane Survey. A summary of the storm surge elevations used for the Potomac River in the 1980 Urban Engineering, Inc. study is listed in Table 2.1.

TABLE 2.1 - SUMMARY OF FREQUENCY OF HURRICANE TIDAL FLOODING FOR THE POTOMAC ESTUARY NEAR WASHINGTON D.C. USED IN THE 1980 URBAN ENGINEERING, INC. STUDY

Frequency (Years)	Surge Tide Elevation (Feet, NGVD29)
2	3.8
5	4.2
10	5.2
25	5.9
50	7.4
100	9.6
Standard Project Hurricane (Approximately the 500-year storm)	13.6
Maximum Probable Tide	18.6

Since 1961, there have been 44 years of additional data on tides and Hurricanes in the Chesapeake Bay area, and there have been several studies and computations completed to assist local planners and communities for revising and administering their floodplain regulations. However, the Urban Engineering, Inc. investigation was the last to review potential solutions to the flooding issues in the Belle Haven Watershed.

February 2006 – Floodplain Mapping for the Belle Haven Watershed, Fairfax County, VA, completed by the U.S. Army Corps of Engineers, Baltimore District for Fairfax County Stormwater Planning Division

The purpose of this investigation was to complete an existing-conditions hydrologic and hydraulic evaluation of the Belle Haven Watershed and produce floodplain mapping based on the results. The objective of the study was to determine the floodplain limits for various return periods taking into account the timing of overland flooding directly from the Belle Haven watershed with the tidal and non-tidal flooding influences of the Potomac River ("joint

probability”). The results of this 2006 study were used in developing and evaluating some of the flood damage reduction alternatives as part of this current study.

Figure 2.8 shows the cross sections used for the 2006 Floodplain Mapping study.

FIGURE 2.8 - FLOOD-FREQUENCY CROSS-SECTIONS

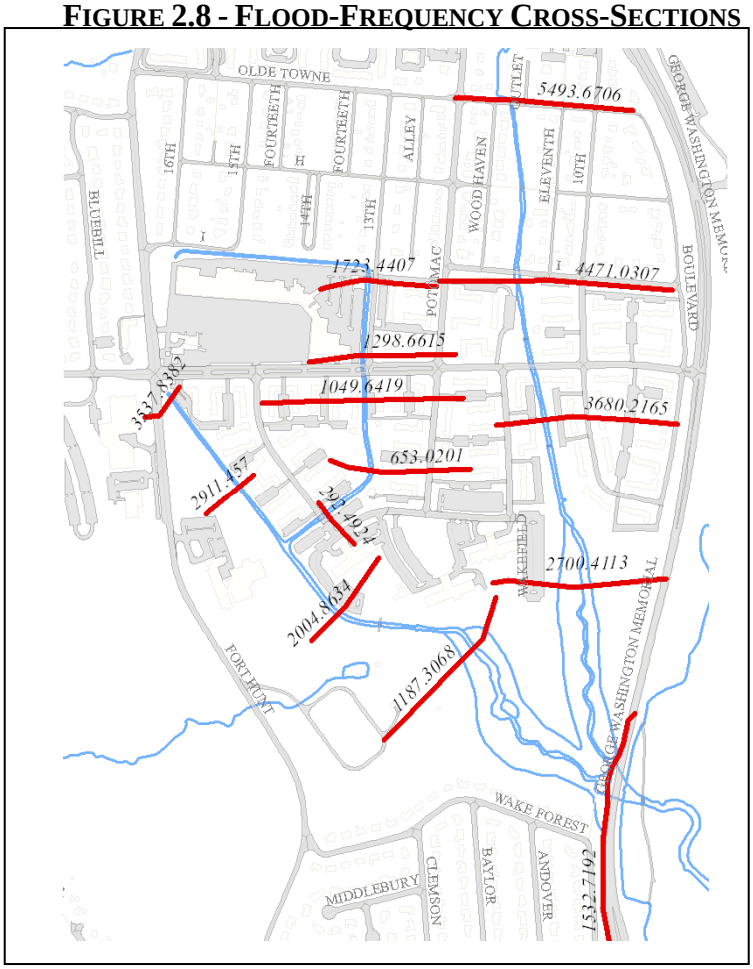


TABLE 2.2 - RESULTS OF THE FLOOD-FREQUENCY ANALYSIS FOR SELECT CROSS-SECTIONS

Reach	Station	Flood Elevations (feet NGVD 29)						
		2-year	5-year	10-year	25-year	50-year	100-year	500-year
East Channel	5493	5.0	6.1	7.4	8.5	9.8	11.4	16.0
	4471	4.8	5.9	7.4	8.5	9.8	11.3	16.0
	3680	4.8	5.7	6.8	8.2	9.6	11.2	16.0
	2700	4.8	5.7	6.7	8.2	9.5	11.2	16.0
West Channel	3537	5.4	7.2	8.1	9.1	10.4	11.6	16.0
	2911	5.2	6.7	7.8	8.8	10.1	11.5	16.0
	2004	5.2	6.3	7.5	8.6	9.9	11.4	16.0
	1187	4.8	5.6	6.8	8.2	9.5	11.2	16.0
West Channel North	1723	6.6	8.0	8.5	9.8	10.8	11.9	16.0
	1298	6.5	8.0	8.5	9.7	10.8	11.9	16.0
	1049	5.5	7.5	8.1	9.1	10.4	11.6	16.0
	653	5.4	6.7	7.8	8.8	10.2	11.5	16.0
	292	5.2	6.5	7.7	8.7	10.1	11.4	16.0
Belle Haven Tributary	1532	4.8	5.6	6.7	8.2	9.5	11.1	16.0

3.0 DATA COLLECTION AND FIELD INVESTIGATION

This study was conducted using existing data pertaining to stormwater management, topography, soils, floodplains, and flood damages. Table 3-1 outlines the data sources used for this study.

TABLE 3.1 - DATA SOURCES

Data Type	Source	Use/Comments
Surveys and Mapping	Base mapping layers, including topography and utility mapping, were provided by Fairfax County.	
Soils	Soil borings that were taken as part of Fairfax County Sewer Sags Project; few borings at I Street and Belle View Blvd; Nov 06	No new borings were taken as part of this study. These previous borings were used to help determine potential soil conditions in and around potential project area
Floodplain Elevations	FEMA's Flood Insurance Study (FIS) for Fairfax County, VA, Panel No. 515525 0137 D dated March 5, 1990.	Current FIRM shows 100-yr elevation to be 10.0 feet, NGVD 29. However, FEMA sent letter to Fairfax County recommending that new construction be built to elevation 11.0 feet instead of 10.0 feet north of Olde Towne Road.
	Statistical analysis conducted by Fairfax County to determine frequency of hurricane tidal flooding for Potomac Estuary near Washington D.C.	County statistical analysis shows 100-yr elevation to be 11.2 feet, NGVD 29
	Joint probability flood frequency analysis conducted by Army Corps of Engineers (Floodplain Mapping for the Belle Haven Watershed, Fairfax Co, VA, February 2006)	Joint probability analysis shows 100-yr elevation to range between 11.2 feet and 11.9 feet (varies for each tributary)

The following provides additional information regarding the field investigation and data collection phase of the study.

Surveys & Mapping:

Surveys and mapping were provided by Fairfax County in GIS format, with the exception of field run-cross-sections which were provided in autocad format. For use in the concept drawings, all GIS data was imported to Autocad.

One-foot contours were provided for the study area. Information about the survey method, datums, target scale, targeted contour interval, accuracy, etc. was requested, but only partial information was provided (July 29, 2004 letter from Baker Engineering). The contours appear to have been targeted for a map scale of 1"=100' or so, and a contour interval greater than one-foot (for example, the contours do not indicate curbs along the roads). A text file was provided stating "one-foot contours, interpolated from 5-ft contour data".

Utility mapping was provided in GIS format for storm drains, sanitary sewer pipes, and water mains. As-built record plans were requested for all storm drains and sanitary sewer pipes that cross through the line of protection. The USACE requested assistance from Fairfax County in determining any other utilities that may exist.

The horizontal control datum is NAD 83, State Plane Virginia. The vertical control datum is NGVD29.

A digital terrain model of the area was not provided. The team prepared an approximate digital terrain model using the 1-foot contour data.

Based on the accuracy of the mapping data, multiple sources of the data, and the above mentioned discrepancies, new topographic mapping should be done during the preconstruction engineering and design phase if a project will be constructed.

Soils

No soil borings were taken as part of this concept study. Borings in the study area were taken in 2006 as part of the Fairfax County Sewer Sags Project. Two holes (B9 and B10) are located near I Street at 13th Street and along Belle View Boulevard near Boulevard View. Logs are presented in Appendix D. In general, soils are clays, silts and sand.

Floodplain Mapping

The current FEMA Flood Insurance Rate Map (FIRM) shows the 100-year floodplain elevation to be 10.0 feet for the Belle Haven area. However, the Fairfax County Stormwater Planning Division completed a statistical analysis of tidal data for a period of record from 1933 to 2005 for the Potomac River, using a Log-Pearson Type III distribution, as outlined in *Guidelines for Determining Flood Flow Frequency, Bulletin 17B*, produced by the United States Geological Survey in 1981. Tidal data from previous investigations and the National Oceanic and Atmospheric Administration (NOAA) tidal gages were used as the basis for the analysis to determine the estimated storm surge elevation for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year events. The revised analysis was completed due to the occurrence of two major tropical events (Agnes and Isabel), as well as other smaller tidal events, since the last published analysis completed by USACE in 1961. The results of the statistical analysis completed by the Fairfax County Stormwater Planning Division, shown in Table 3.2, are considered more accurate than the 1961 data, due to the addition of 45 years of data and it is consistent with a data letter sent to Fairfax County by FEMA recommending revisions to the local floodplain ordinance to require new construction to build to elevation 11.0 feet rather than 10.0 feet for areas north of Olde Town Road. This surge tide data was used for this current study. Figure 3-1 shows the 100-year

storm surge as determined by the County's statistical analysis.

TABLE 3.2 - SUMMARY OF FREQUENCY OF HURRICANE TIDAL FLOODING FOR THE POTOMAC ESTUARY NEAR WASHINGTON D.C. DETERMINED BY STATISTICAL ANALYSIS COMPLETED BY FAIRFAX COUNTY STORMWATER PLANNING DIVISION, 2005

Frequency (Years)	Surge Tide Elevation (Feet, NGVD29)
2	4.4
5	5.5
10	6.5
25	7.7
50	9.6
100	11.2
500	16.2

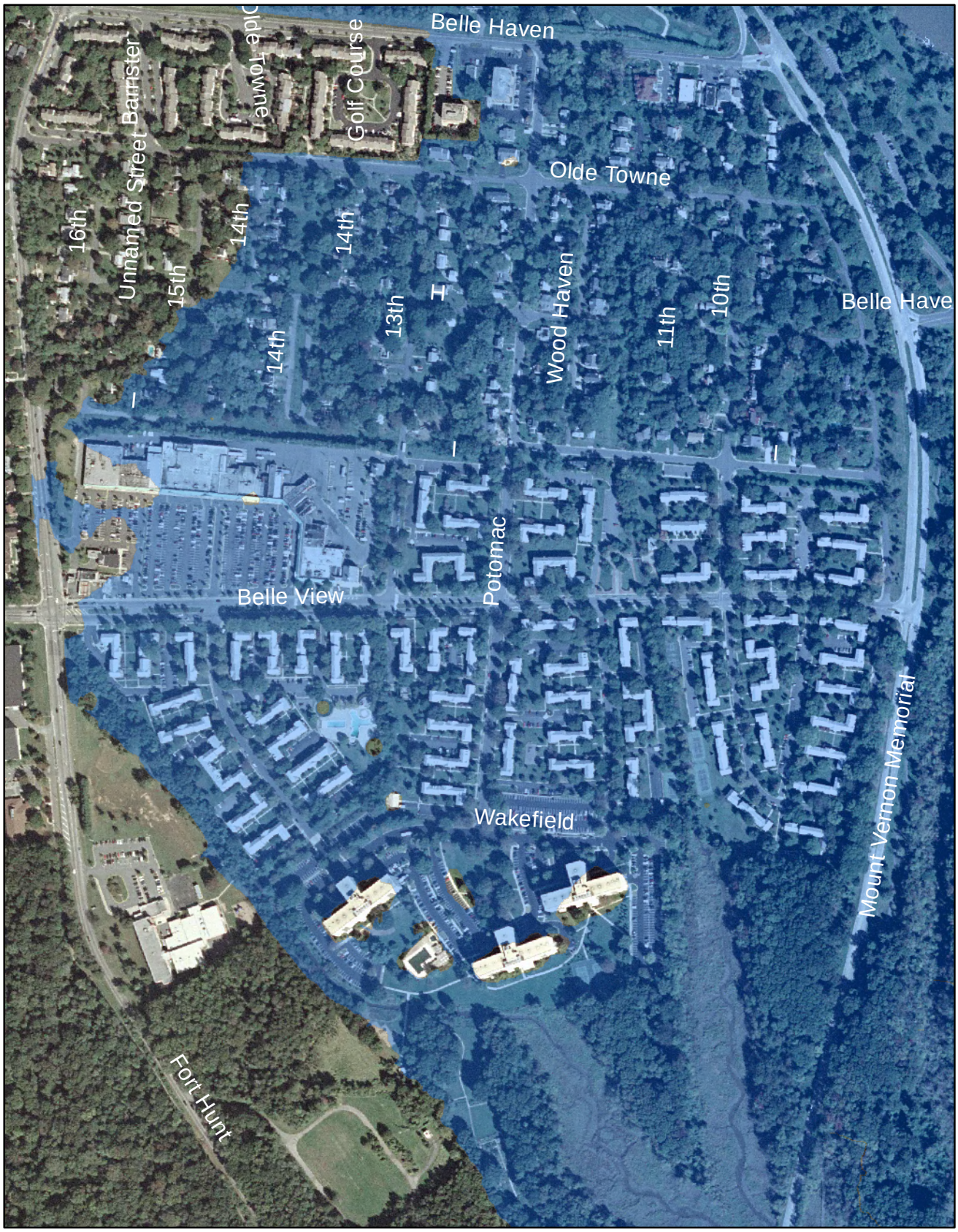
As part of this current study, the 200-year surge tide elevation was required to conduct the economic analysis. Fairfax County plotted these seven flood frequencies on a stage-frequency curve and determined that the 200-year surge elevation is 12.6 feet.

The storm surge elevations have increased with the addition of 44 years of data to the statistical analysis. The 50-year storm surge elevation calculated in this study, 9.6 feet, is equivalent to what a 100-year storm surge was calculated in 1961.

Field Investigation

In December 2006, part of the study team (Corps and County representatives) conducted a field reconnaissance to understand the layout of the Belle Haven watershed and how it floods. The team reviewed the topography and the storm drain system. The team primarily looked at the potential for structural solutions, such as levees, berms and floodwalls. The team identified preliminary alignments for structural measures.

In March 2007, another part of the study team, comprised of members of the Corps' National Non-Structural/Flood Proofing Committee and a representative of the County, conducted a field reconnaissance. Their focus was to evaluate a sample of individual houses and structures within the 100-year floodplain to determine the feasibility of using non-structural measures for protection. The committee investigated the possibility of raising or modifying the flood-prone structures.



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N
W E
S

0 125 250 500 Feet

1 inch equals 500 feet

Figure 3.1: Belle Haven Watershed 100-year Storm Surge Elevation 11.2 ft (NGVD29)

Legend

100-year Storm Surge

4.0 TYPES OF FLOOD DAMAGE REDUCTION MEASURES

Flood damage reduction consists of two basic techniques – structural and non-structural. Structural methods modify the flood and "take the flood away from people" by measures such as levees, floodwalls, and dams. Non-structural flood damage reduction techniques basically "take the people away from the floods" leaving the flood to pass unmodified. Non-structural techniques consist of measures such as relocation, flood proofing individual structures, acquisition, and flood preparedness. The following structural and non-structural flood damage reduction techniques were evaluated for this study. To familiarize the reader with these flood damage reduction measures, general descriptions are presented below.

- Structural Techniques
  - Levees
  - Floodwalls
- Non-Structural Techniques
  - Elevation
  - Flood Proofing
  - Flood Warning

4.1 STRUCTURAL TECHNIQUES

The types of structural measures that were investigated include levees and floodwalls. Floodwalls and levees are freestanding structures located adjacent to or away from the building that prevent the encroachment of floodwaters. They may completely surround the building or buildings, or protect only the low side of the property. Unlike other flood proofing measures, a well designed and constructed freestanding floodwall or levee results in no water pressure on the structure itself. Consequently, as long as the floodwall or levee holds or is not overtopped, the protected area should not be exposed to flood waters. Another advantage with this technique is that there is no need to make major structural alterations to the existing buildings.

When constructing a floodwall or levee around buildings, pumping stations must be incorporated to provide proper interior drainage from groundwater seepage and rainwater from the building side of the protection.

Floodwalls and levees require periodic maintenance, including removing debris from any check valves on pump discharge pipes after each storm, inspecting the pumps for proper operation, and maintenance of the flap gates. In addition, the project owner will have to inspect levees for signs of erosion, settlement, animal burrows, and trees. Floodwalls need inspection for signs of cracking and spalling. Construction of floodwalls and levees may require local, state and/or Federal permits.

Floodwalls or levees can create a false sense of security about property protection. Every flood is different, and one could exceed the design height and overtop the floodwall or levee at anytime. For this reason, the protected area should always be evacuated prior to flooding.

If a floodwall or levee fails due to overtopping or other reasons, damage to the protected

structure will be as great or greater than if no protection was provided. Additional damage could result because it takes longer to remove the flood water from the inside of the floodwall or levee once flood levels subside.

4.1.1 Levees

Typically, levees are constructed of compacted fill taken from locally available impervious soils. Depending upon the availability of suitable local soil, levees may be one of the least expensive flood damage reduction measures. Levees, which are planted with grass to help prevent erosion, have the advantage of being compatible with the landscape.

Although levees may be attractive in terms of economics and appearance, one potential drawback is the amount of property space required. To minimize erosion and to provide adequate stability, their embankment slopes must be fairly gentle, usually a ratio of one vertical to two or three horizontal. A levee's width will be several times its height.

4.1.2 Floodwalls

Similar to levees, floodwalls also keep water away from the building. However, floodwalls are constructed of stronger materials, are thinner, take less space, and generally require less maintenance than levees. Floodwalls can be constructed using a variety of designs and materials, such as sheetpiles and concrete. They can be constructed in a way that is aesthetically pleasing.

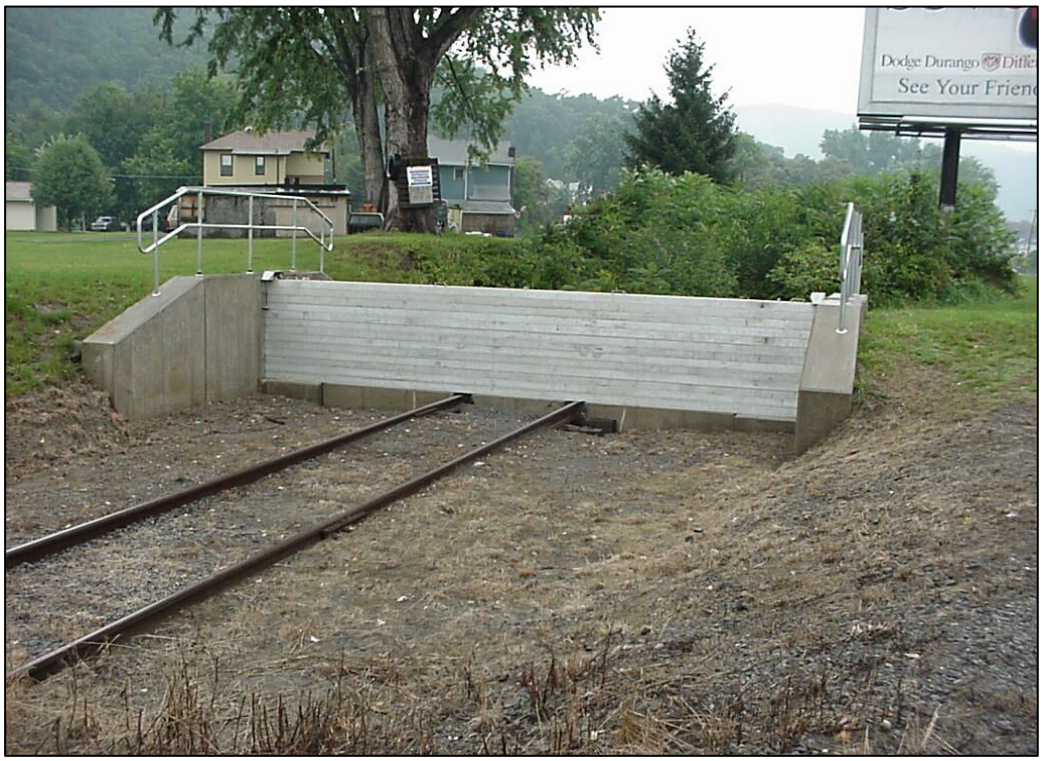
4.1.3 Closure Structures for Levees and Floodwalls

Closure structures must be provided for roads, sidewalks, driveways, and other openings left in a floodwall or levee. Closures act to close the openings in floodwalls and levees and prevent water from entering. They can be of a variety of shapes, sizes, and materials. In some cases closures are permanently attached to the closure structure abutments using hinges so that they can remain open when there is no flood threat, such as a swing gate (Figure 4-1). Another type of closure is a roller gate that slides into place along a track (Figure 4-2). There are also stop log closures which are portable, normally stored in a convenient location, and put into place when a flood threatens (Figure 4-3). Typically, sandbags must be placed at the bottom of most closure structures to prevent leakage.

FIGURE 4-1: TYPICAL SWING GATE CLOSURE STRUCTURE

FIGURE 4-2: TYPICAL ROLLER GATE CLOSURE STRUCTURE

FIGURE 4-3: TYPICAL STOP LOG CLOSURE STRUCTURE



Closures can be considered as an option only if a flooding situation provides sufficient warning time to properly install them. The need for both sufficient warning time and human action is critical, since all closure systems require personnel to install them and make certain they are properly sealed. Closures that are stored between floods must be readily accessible. Swing gates and roller gates take less time to install than stop log structures, which must be transported to the site and put in place. Typically, swing and roller gates can be installed in less than two hours. Most swing (or mitre) gates can be closed in about 15 minutes which would effectively close the opening. However, it will take approximately another 30 minutes to an hour to install sandbags to seal the closure. Roller gates may take about 15-30 minutes to set the winch (if needed) in place and another 5 minutes to pull the gates closed. Small pedestrian stop log closure structures can take 2-3 hours to install and roughly 3-6 hours are required for a larger vehicular stop log closure structure. The effectiveness of an entire system will be compromised if the closure materials are stored such that flooding renders them inaccessible, or if even one closure is improperly installed. Closure systems are most effective where there are a limited number of openings. If there are too many, leakage could overwhelm and defeat the system.

In addition to closure structures for roads, sidewalks, etc., closures need to be provided for any storm pipe to prevent back flow. Any sewers or drain pipes passing through or under a floodwall or levee will generally require a flap gate or tideflex valve at the outfall plus sluice gates as backup at the line of protection to prevent backup and flooding inside the protected area.

Because there will likely be ample warning time for the study area prior to a flood event,

closures were evaluated as potential options for use with the levee and floodwall alternatives, as discussed in Section 5.

4.2 NON-STRUCTURAL TECHNIQUES

4.2.1 Elevation

Elevation involves raising the flood-prone building in place so that the lowest floor is above the flood level for which flood protection is required. The building is jacked up and set on a new or extended foundation above the level of protection. Elevating houses in New Alexandria is a viable option. For houses that include basements, the basements can be filled in, the house raised, and additional living space can be added to compensate for the lost basement space.

4.2.2 Flood Proofing

Structures can also be flood proofed to keep the interior of the structure dry. In the Belle Haven watershed, there are many residential structures with basements and only the basements were flooded during Hurricane Isabel. One flood proofing option is to fill the basement and add more living space that is above the 100-year flood elevation to the side or rear of the structure if adequate space is available. Flood proofing the houses in New Alexandria and the Belle View Condominiums was evaluated as part of this study.

4.2.3 Flood Warning System

The implementation of a flood warning system is also a non-structural technique for reducing damages and protecting lives. Fairfax County already uses the Community Emergency Alert Network, or CEAN, to deliver important emergency alerts, notifications and updates during an emergency, such as flooding to the Belle Haven watershed residents and others. The County is also installing river gages in areas throughout the region to better understand the risk of potential flood events. Therefore, a flood warning system was not investigated as part of this study.

5.0 FLOOD DAMAGE REDUCTION ALTERNATIVES

5.1 DEVELOPMENT OF PRELIMINARY ALTERNATIVES

As part of this concept-level study, Fairfax County and the Corps decided to select two heights of protection to evaluate for the levee and floodwall alternatives; one above the 50-year flood elevation and one above the 100-year flood elevation. Since the levee/wall would protect against tidal storm surge, and not riverine flooding (i.e. flooding produced by runoff from the Belle Haven watershed itself), the team used Fairfax County's storm surge elevations as determined through a statistical analysis in 2005 (refer to Table 3.2). The 50-year storm surge elevation is 9.6 feet so the team selected 11 feet as a top of protection elevation. The 100-year storm surge elevation is 11.2 feet so the team selected 12 feet as the second top of protection elevation. Since this is a preliminary level study, a risk and uncertainty analysis was not conducted, but should be considered in the future if the County decides to implement any of the plans. Typically, when a levee is designed to protect against a certain event, say the 100-year flood, a risk and uncertainty analysis is conducted to determine how much higher than the design event elevation the levee should be constructed to in order to ensure a high probability that it will not be overtopped (typically it can be 2-4 feet higher than the design flood elevation). For FEMA to certify a levee or floodwall, which would preclude the residents behind the levee from being required to own flood insurance, it must be designed for the 100-year flood event with risk and uncertainty included. There must be a 90% probability that the levee/wall will not be exceeded by the 100-year flood. In order to meet this standard, higher tops of protection would likely be needed for the Belle Haven watershed.

The team decided to evaluate plans that would provide protection to the entire study area as well as plans that would provide protection to each of the two subdivisions. Plan 1 would reduce flood damages for the entire study area. Plans 2 and 3 only reduce damages to the New Alexandria area. Plan 4 only reduces flood damages to the Belle View area. Plans 2 or 3 could be combined with Plan 4 to provide protection to the entire study area.

Plan 1a – A combination levee and floodwall would be constructed surrounding the entire study area to elevation 11 feet (1.4 feet above the 50-year water surface elevation). See Figure 5.1 for plan view and cross sections. The levee would be an earthen berm and for this preliminary analysis, it was assumed that the floodwall would be a concrete T-wall since it is less expensive than a sheetpile wall. The levee/wall would be approximately 6600 feet long; the levee would be approximately 3000 feet and the floodwall would be approximately 3600 feet. Along the northern side, the alignment would parallel the North side of Belle Haven Road. It appears that sufficient room exists for a levee. Along the east side, the alignment would hug the east side of Boulevard View to minimize impacts to the large trees along the George Washington Parkway. For the same reasons, a floodwall is recommended here. Along the South side, the alignment would hug the marsh. It appears that sufficient room exists for a levee along a portion of this side. A floodwall is recommended along the parking lot to minimize marsh impacts. The Southern tie-out was located to avoid crossing the sanitary force main.

Sheet Number: W101

BELLE HAVEN
FAIRFAX COUNTY, VIRGINIA
LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.1, PLAN 1a, ELEV. 11.0

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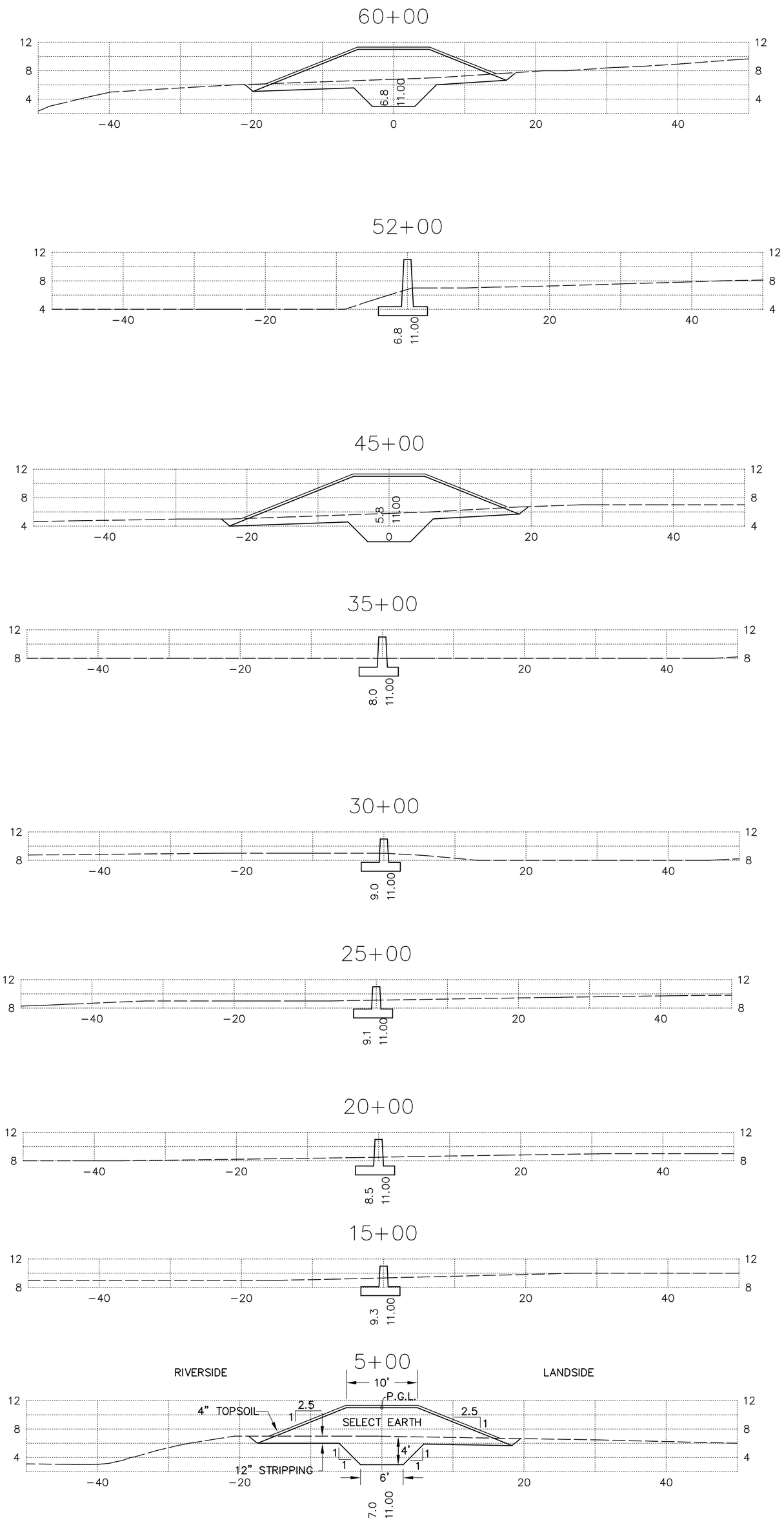
LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.1, PLAN 1a, ELEV. 11.0

Sheet Number:
W102



Sheet Number: W301

BELLE HAVEN
FAIRFAX COUNTY, VIRGINIA
LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.1
CONCEPT SECTIONS, PLAN 1a, EL. 11.0

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The height of the protection above ground would vary due to the variation in ground elevations, however, it would range from approximately 3 to 5 feet high. Closure structures would be needed at Belle Haven Road and Belle View Boulevard. For cost estimating purposes, it was assumed that stop log closure structures would be used since there should be ample warning time to install them.

According to soil borings that were taken in 2006 as part of another project (Appendix D), from about 8 to 17 feet in depth, the material consists of low blow count clay, silts, and sands. This may not be a factor if lower heights of levee/floodwalls are considered, as is for this study, but should be further investigated during any design phase. To be conservative, since poor soils have been an issue for other projects in the area, the excavation and fill amounts for all of the levee/floodwall alternatives were increased by 20% for cost estimating purposes.

As part of this plan, one pumping station would be constructed at the downstream end of the West Channel near the River Towers apartments. A preliminary interior drainage analysis was conducted which showed that a 144 cfs capacity pump would be needed during the 50-year rainfall to maintain a peak elevation of 7.4 feet The County's goal was to select a pump that would keep the water level below elevation 7.5 feet for Plan 1 for a 50-year rainfall event. No pump would be needed for the East Channel since the 50-year rainfall has a peak elevation of 7.4 feet; however, the County may want to consider having a portable pump available. The existing tide gate and pump station along I Street would have to be activated to keep the interior runoff from backing up into the New Alexandria area, which has houses with low opening elevations lower than 7.5 feet. The interior drainage analysis conducted as part of this study is preliminary and further analysis would be needed during detailed design, specifically to look at how the existing tide gate and pump station along I Street would have to function in conjunction with any new pump stations. Accurate low opening elevations for each of the structures will also be necessary. Information regarding the interior drainage analysis can be found in Appendix A.

For conceptual design purposes, drainage structures were located at every drainage channel and storm drain pipe that crossed the line of protection. Pipe sizes were chosen without the benefit of hydraulic analysis so 24" size was assumed for this concept plan. Flap gates and sluice gates are recommended, so these are included in the concept plan. Self-regulating tide gates are recommended on the two tidal channels, as well as back-up sluice gates.

To alleviate nuisance ponding caused by the levee/floodwalls, drainage swales and modifications to the storm drain system may be needed.

Based on the GIS mapping, the Belle Haven area is served by a gravity collector sanitary sewer system that outfalls to a sanitary pumping station. This pumping station discharges into a force main that bisects the site. Where the line of protection crosses the force main, the pipe should be relocated around the levee or the pipe should be upgraded and provided with shutoff valves as shown.

Utility locations shown on the drawings are based on County GIS data only, and it is limited to storm drains, sanitary sewers, and water mains. Other utilities may be present. Gas valves were noted during the field visit. Utility designation and location services should be requested for the next phase of design. Based on a site visit, some overhead utilities will need to be relocated.

Based on the GIS data, the line of protection crosses some water mains. These pipes should be upgraded at the crossing, and shutoff valves should be added.

Construction would affect existing streams, tidal waters, trees, and maybe wetlands.

Plan 1b – Plan 1b is similar to Plan 1a but the height of protection is one foot higher. A combination levee and floodwall would be constructed surrounding the entire study area to elevation 12 feet (0.8 feet above the 100-year water surface elevation). See Figure 5.2 for plan view and cross sections. The levee/wall would be the same length as Plan 1a, but would be approximately 4 to 6 feet high. As in Plan 1a, one pumping station (144 cfs capacity) would be constructed at the downstream end of the West Channel near the high-rise apartments. The drainage structures, utility impacts, and impacts to wetlands, streams, tidal waters and trees are the same as Plan 1a.

Plan 2a – A combination levee and floodwall would be constructed surrounding the New Alexandria section to elevation 11 feet (1.4 feet above the 50-year water surface elevation). See Figure 5.3. The levee/wall would be approximately 5700 feet long the levee would be approximately 2400 feet and the floodwall would be approximately 3300 feet. Along the northern and eastern sides, the alignment would follow the same route described above. Along the southern side, the alignment would parallel the southern side of I Street and the northern side of the shopping center parking lot, similar to the existing line of protection. It appears that sufficient room exists for a levee along a portion of this side. An abandoned house is recommended to be demolished, and a parking lot would need to be relocated. A floodwall is recommended along the shopping center lot to minimize impacts to the loading areas. The height of protection would range from 3 to 5 feet.

A preliminary interior drainage analysis was conducted which showed that two pumping stations would be needed; a 26 cfs capacity pump would be needed for the East Channel and a 66 cfs capacity pump would be needed for the West Channel. During the 50-year rainfall, these pumps would maintain a peak elevation between 5.6 and 5.9 feet in New Alexandria. The County's goal was to select a pump that would keep the water level below elevation 6 feet for Plan 2 for a 50-year rainfall event. (Low opening elevations of all of the houses in New Alexandria should be surveyed to confirm that no houses would be flooded at elevations less than 6 feet). The East Channel pumping station would be located where the existing tide gate is along I Street. The West Channel pump would be located at or near the existing pump station on I Street. The existing pumping station has a capacity of 206 cfs, which is greater than the capacity determined to be necessary to handle the 50-year flow. The study team did not have documentation stating why the existing pump station was designed with such a high capacity, but it could have been designed to handle the 100-year flow, to keep the ponding at a lower elevation, and/or because the County was considering diverting some of the east flows into the west channel pump station. As part of Plan 2, either the existing pump station would need to be flood proofed, the line of protection would have to be realigned to protect the pump station, or a new pump station would need to be constructed. The existing pump station would have to be further analyzed to determine how it could be incorporated into this plan and what modifications might be required. To be conservative, the cost of a new pump station along the West Channel with a capacity of 66 cfs.

Sheet Number: W101

BELLE HAVEN
FAIRFAX COUNTY, VIRGINIA
LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.2, PLAN 1b, ELEV. 12.0

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LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.2, PLAN 1b, ELEV. 12.0

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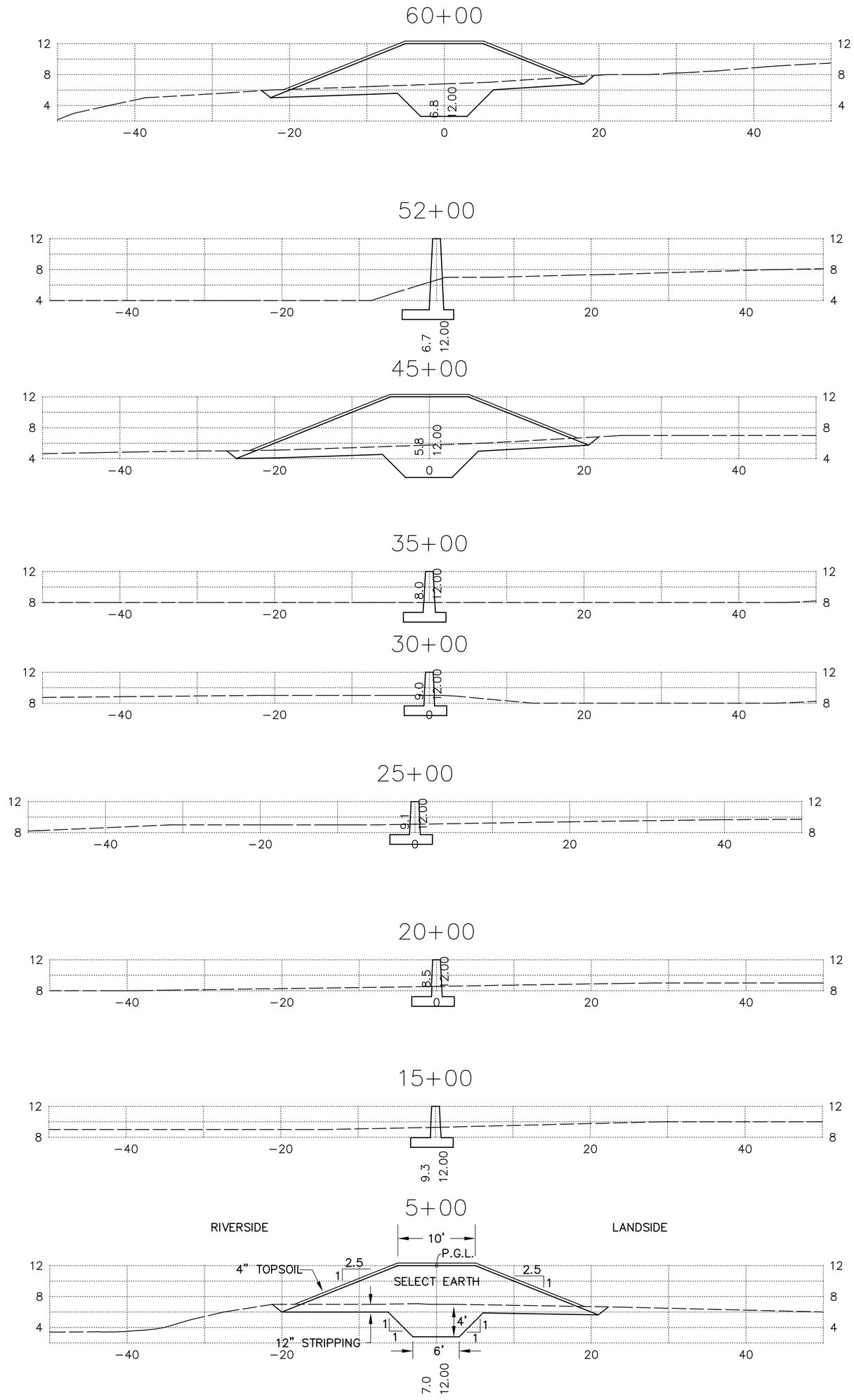

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BELLE HAVEN
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LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.2
CONCEPT SECTIONS, PLAN 1b, EL. 12.0

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BELLE HAVEN
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LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.3, PLAN 2a, ELEV. 11.0

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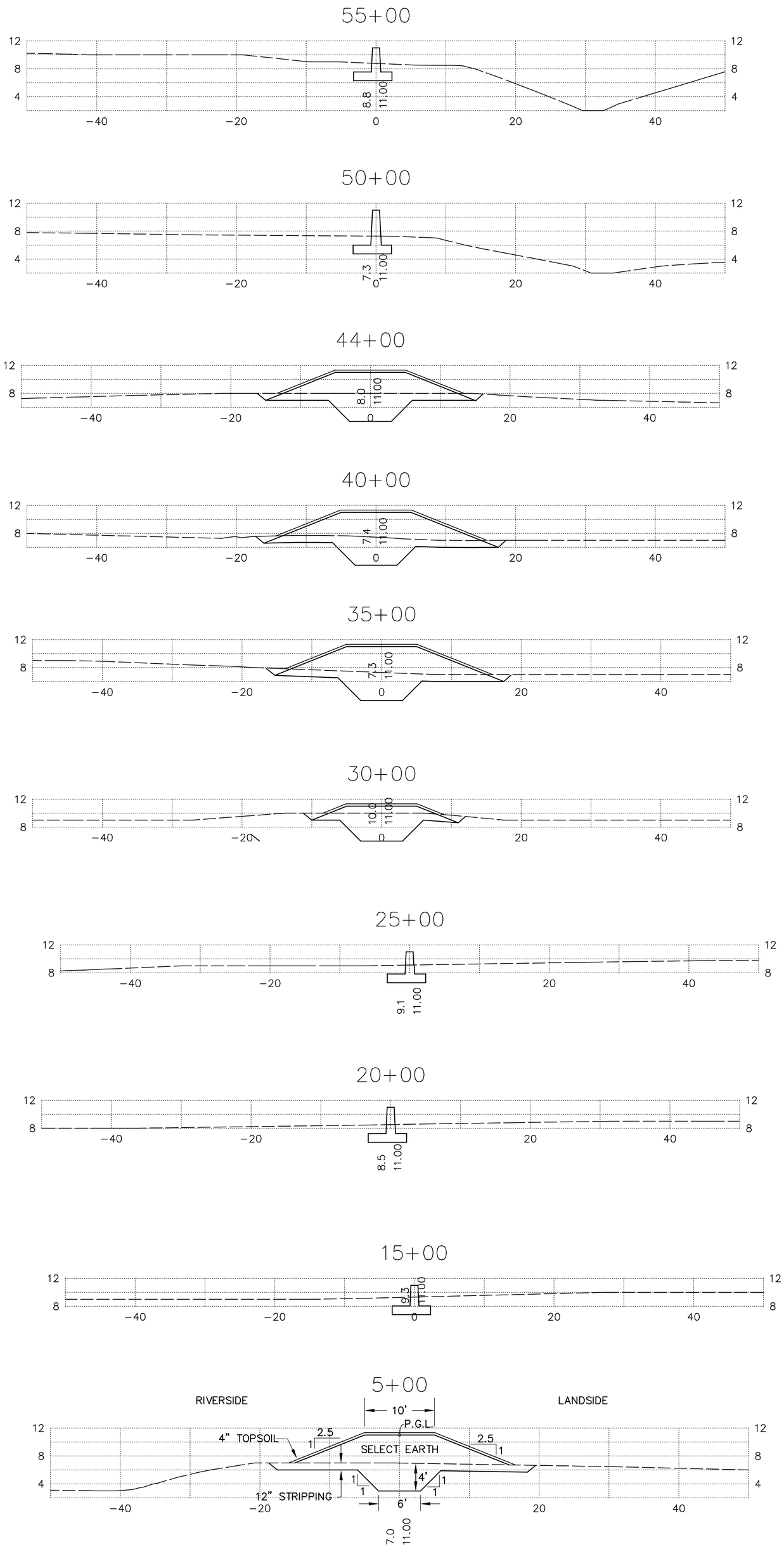

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BELLE HAVEN
FAIRFAX COUNTY, VIRGINIA
LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.3
CONCEPT SECTIONS, PLAN 2a, EL. 11.0

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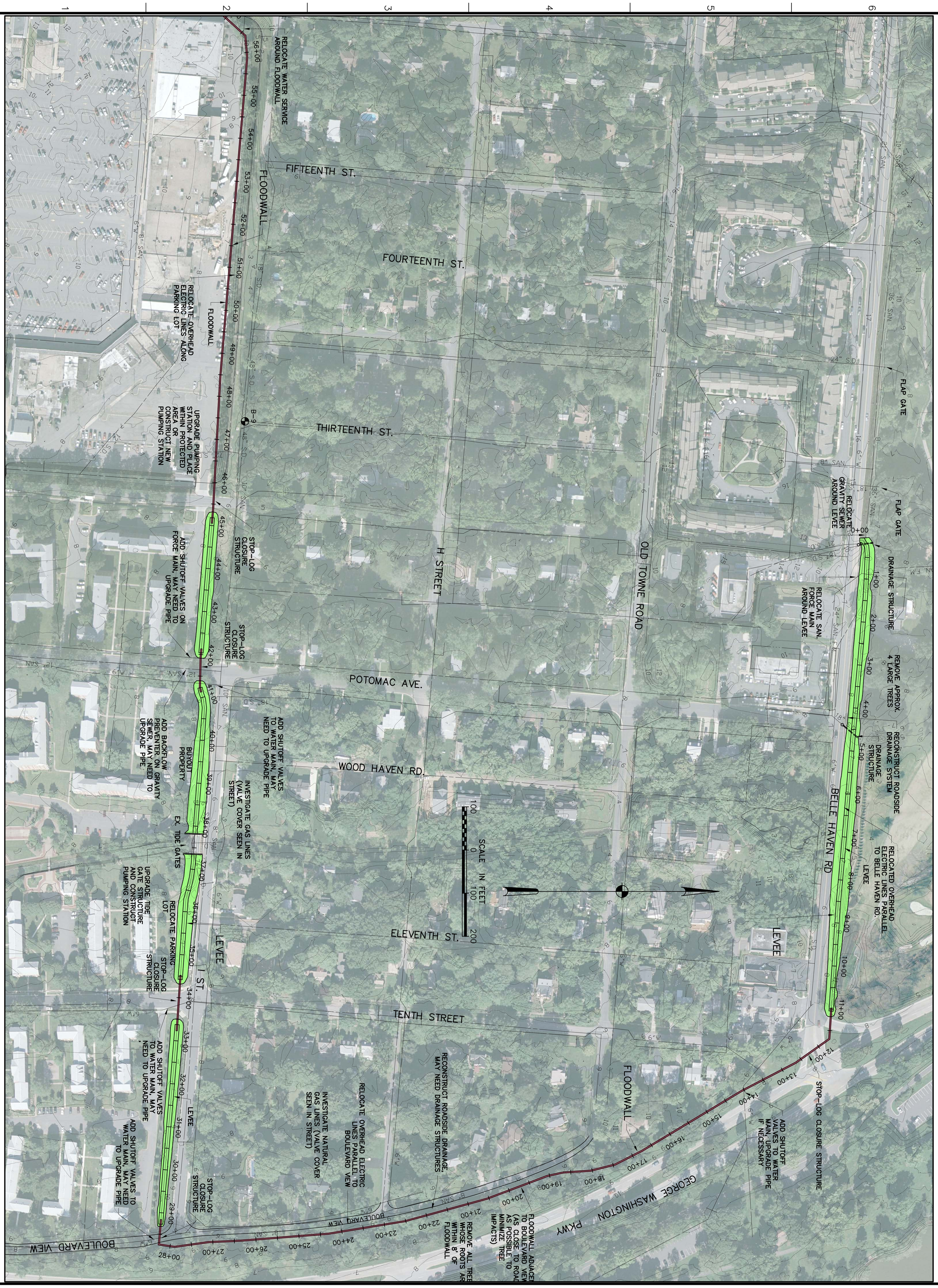
was included in the cost estimate.

The drainage structures, utility impacts, and impacts to wetlands, streams, tidal waters and trees are similar to Plan 1a. The line of protection for Plan 2 crosses one gravity sewer. This pipe should be upgraded where it crosses, and a backflow preventer should be considered.

Plan 2b – Plan 2b is similar to Plan 2a but the height of protection is one foot higher. A combination levee and floodwall would be constructed surrounding the New Alexandria section to elevation 12 feet (0.8 feet above the 100-year flood elevation). See Figure 5.4. The levee/wall would be the same length as Plan 2a, but would be approximately 4 to 6 feet high. As in Plan 2a, two pumping stations would be constructed along the East and West Channels to handle the 50-year rainfall.

Plan 3a – This plan would involve flood proofing all of the New Alexandria houses that have basements, which is estimated to be 53 structures. During Hurricane Isabel, only the basements flooded in some houses; the floodwaters did not reach the first floor. For Plan 3a, each of the basements would be filled in and new living space would be added to the first floor (18" above the 100-year "joint probability" flood elevation) to compensate for the lost basement space. The utilities would be moved from the basement to the first floor also. The level of protection provided by this alternative would vary for each house. There would be no basements to be flooded, so the houses would not start to incur damages until the flood level reached the first floor. During a flood event, vehicles would incur damages unless they were moved prior to the flood. In addition, any other exterior buildings, such as sheds, would still incur damages. During the construction modification of each house, the residents would need to be relocated for approximately three weeks.



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BELLE HAVEN
FAIRFAX COUNTY, VIRGINIA
LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.4, PLAN 2b, ELEV. 12.0

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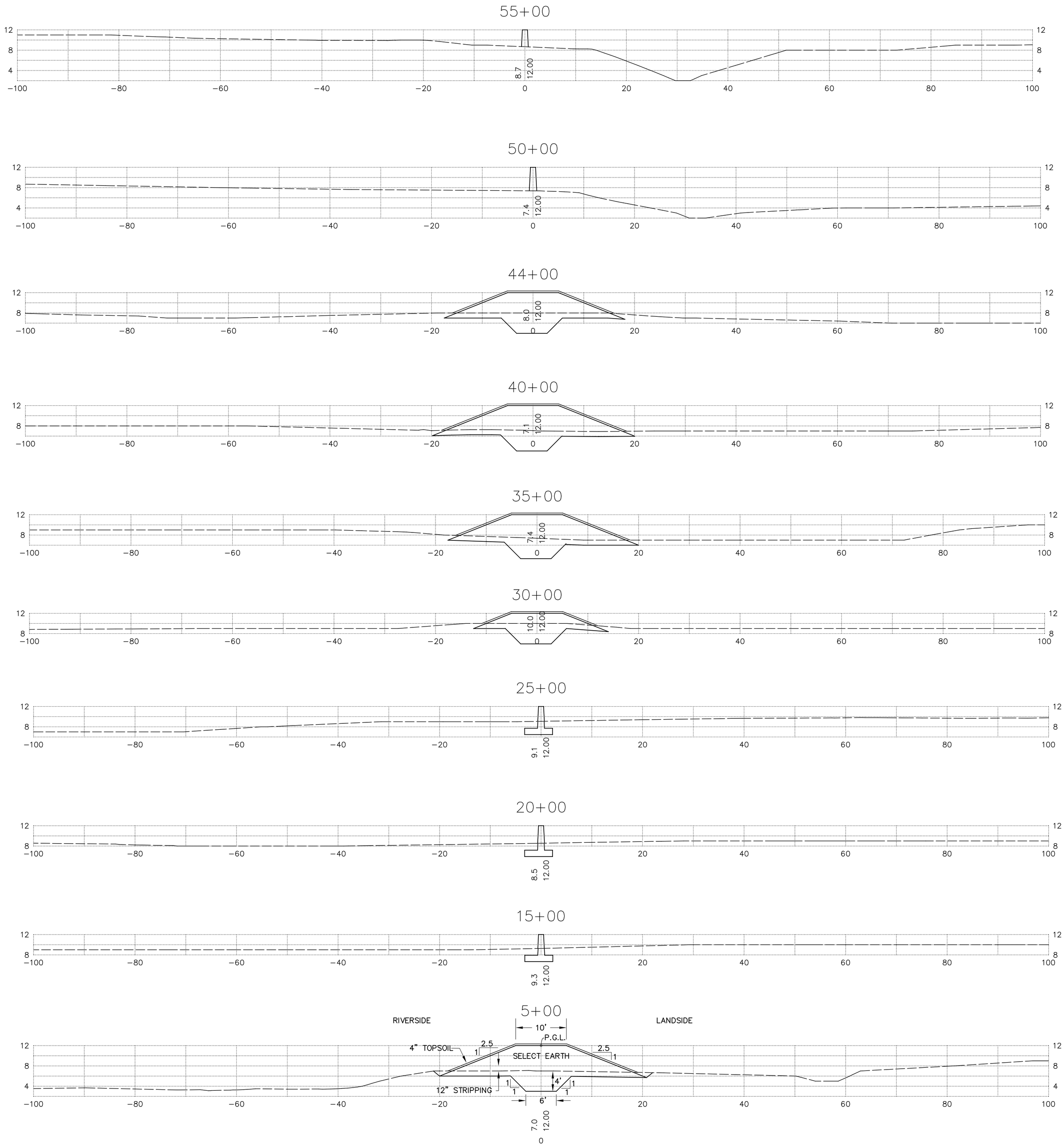

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BELLE HAVEN
FAIRFAX COUNTY, VIRGINIA
LOCAL FLOOD PROTECTION PROJECT

FIGURE 5.4
CONCEPT SECTIONS, PLAN 2b, EL. 12.0

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Plan 3b – This plan would involve flood proofing all of the New Alexandria houses by filling in all basements, raising all of the houses, and adding living space to the new first floor to compensate for the lost basement space. This plan would elevate all of the New Alexandria homes, estimated to be 183 structures, to 18" above the 100-year "joint probability" water surface elevation. The utilities would be moved up to the first floor also. As in Plan 3a, during a flood event, vehicles would incur damages unless they were moved prior to the flood and any other exterior buildings, such as sheds, would still incur damages. During the raising of each house, the residents would need to be relocated for approximately 12 weeks. See Figure 5.5 for a schematic showing a house that has been flood proofed by this method.

FIGURE 5.5: SCHEMATIC SHOWING PLAN 3B

Existing House

House after Being Elevated

Plan 4 – This plan would be to flood proof the Belle View section of the study area by implementing the following actions:

Belle View Condominiums – During Hurricane Isabel, only the lower units (J-units) of the Belle View Condominiums were flooded. Currently, the basements begin to flood when the water surface elevations reach approximately 8 feet. See Figure 5.6 for photos of the condominiums. This flood proofing plan would include buying out the J-units (there are 17 total), filling in the basements of the condo buildings, and moving the utilities to above the 100-year flood elevation. A new separate building would be constructed adjacent to a set of the condominium buildings, above the 100-year flood elevation, to house the utilities. The first floor elevation of each of the buildings is approximately elevation 11 feet. The buildings would not incur damages until the flood level reached that elevation, which is close to the 100-year storm surge elevation (11.2 feet).

FIGURE 5.6 - PHOTOS OF BELLE VIEW CONDOMINIUM

Front Entrance

Rear Entrance to Basement

Belle View Townhouses – The two sets of Belle View townhouses would be flood proofed in a similar manner to the condominiums. The basement levels would be filled in and additional living space above the 100-year flood level would be added to the rear of the first floor. A new separate building would be constructed for the townhouses above the 100-year elevation for utilities and storage. As in the condominiums, the townhouse units would not incur damages until the flood level reached the first floor elevation (approximately 11 feet). The new living space and the new utility/storage building would be 18" above the 100-year flood elevation.

Belle View Shopping Center – A number of the tenants in the shopping center have basements that were flooded during Hurricane Isabel. The low openings into the basements are at approximately elevation 7.0 feet. Many of the first floor elevations are approximately 10.8 feet. See Figure 5.7 for photographs of the shopping center. This flood proofing plan would include constructing a 1400 linear foot partial ring wall to elevation 10.8 feet around the north and east sides of the shopping center. See Figure 5.8 for schematic of ring wall. Two stop log closures would be included in the wall for access. It is estimated that two sump pumps would be needed to handle interior rainfall. The storm sewer would need to be modified and backflow preventers would be required on the sanitary sewer lines. At the southeast end of the shopping center, the roadway would have to be elevated to 10.8 feet, where the ring wall would tie into. The purpose of the wall would be to prevent basement flooding; it would not be high enough to prevent first floor flooding. The elevation of the wall, 10.8 feet, is equivalent to the 50-year "joint probability" (rainfall and surge) elevation and is above the 50-year storm surge elevation of 9.6 feet. In order to reduce flood damages from the 100-year storm, the ring-wall would need to completely surround the shopping center since there is no high ground to tie into.

FIGURE 5.7: PHOTOGRAPHS OF THE BELLE VIEW SHOPPING CENTER

Front of Belle View Shopping Center

Rear Showing Basement Windows and Door

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N
W E
S

0 80 160 320 Feet

1 inch equals 200 feet

Figure 5.8: Belle Haven Watershed
Belle Haven Shopping Center
Ring Wall Alternative Plan (Part of Plan 4)

Legend
- Closure Structure
- Elevated Road
- Ring Wall

5.2 EVALUATION AND COMPARISON OF ALTERNATIVES

As part of the study, Fairfax County requested that the Corps conduct an economic analysis of the alternative plans to determine if any of the plans would meet the requirements for federal funding. A reconnaissance-level analysis was conducted to compare the costs and economic benefits of each of the alternative plans. Costs were based on the 5% concept plans and are preliminary. Project costs include the construction cost, design cost, construction management costs, and 30-40% contingency. Due to uncertainty in the soils conditions, the excavation and fill volumes for the levee and floodwall were increased by 20 percent. Real estate costs to acquire the necessary property to construct the alternative plans were not included, however, the cost does include an estimate to buy-out necessary structures (such as one abandoned property along I Street for Plans 2a and 2b, and the J-units of the condominiums for Plan 4). A breakdown of the estimated project costs is included in Appendix B.

The economic benefits of each alternative plan were estimated. The economic benefit of each plan is the estimated reduction in future damage costs. The calculation takes into account the reduction in damages to structures (both residential and commercial), vehicles, utilities, as well as the reduction of costs related to emergency services during and following a flood event. Using various models, future flood elevations are predicted and the amount of flood damages that would occur are estimated for each of the flood events. These damages are then translated into an estimated annual damages figure. The estimated future without-project damages are compared to the future with-project damages (compare damages without a levee/wall against damages with a levee/wall). The difference between these two figures is the annual economic benefit of the project.

The details of the economic analysis are included in Appendix C. A summary table showing the costs and benefits for each alternative plan is shown in Table 5.1. The table includes the construction cost without escalation (using 2007 prices) that was used in the economic analysis.

It also includes the construction cost with escalation, assuming that construction will begin in FY10. A very rough annual cost for operation and maintenance has been estimated, for items such as mowing the levee, repairing and replacing parts of the pump stations and drainage structures, and repairing any damaged portion of the levee/wall after a flood event. The costs and benefits were estimated during a 50-year duration, and then were translated into annualized costs and benefits. The annualized net benefits for the alternative are the annualized benefits minus the annualized costs. The benefit-cost-ratio is the annualized benefits divided by the annualized costs. For a project to meet the requirements for federal funding, the annualized benefits must be larger than the annualized costs, and the benefit-to-cost ratio must be greater than 1.0. The summary table also includes the height of protection, a description of the main risks associated with each plan, and some additional notes of interest.

TABLE 5.1
Belle Haven Flood Damage Reduction Analysis
5% Concept Plan Alternatives Analysis

Alternative	Cost without escalation used for economic analysis (w/design, const mgmt)	Escalation Cost	Construction Year	Total Project Cost	Annual O&M Cost	Annualized Costs	Annualized Benefits	Annualixed Net Benefits (Benefits-Costs)	Benefit to Cost Ratio (BCR)	Height of Protection	Main Risk	NOTES
Plan 1a (with pumps) - Levee/floodwall surrounding entire study area to elevation 11' (above 50 yr profile) with pumps	$10,640,000	$1,030,000	FY10	$11,670,000	$150,000	$722,000	$1,688,000	$966,000	2.34	elevation 11'; 1.4' above 50 yr storm surge elevation	Higher flood event could overtop levee/wall and cause more catastrophic damages; closures must be installed prior to flood event	Assumes 144 cfs pump on west channel (will reduce 50-yr rainfall ponding from elev. 8.43' to 7.38'); no pump needed on east channel (50-yr ponding elev will be 7.36'); assumed no damages for the 50-yr and below rainfall events - will need to operate tide gate and ex. pump station to keep water from backing up into New Alexandria
Plan 1a (without pumps)	$6,440,000	$630,000	FY10	$7,070,000	$75,000	$421,000	$0	($421,000)	0.00	elevation 11'; 1.4' above 50 yr storm surge elevation	Flooding from interior drainage	Zero benefits because for the lower flood frequencies, there would be a higher flood elevation with the levee and no pump than the without project plan (no levee)
Plan 1b (with pumps) - Levee/floodwall surrounding entire study area to elevation 12' (above 100 yr profile) with pumps	$11,570,000	$1,120,000	FY10	$12,690,000	$150,000	$772,000	$1,943,000	$1,171,000	2.52	elevation 12'; 0.8' above 100 yr storm surge elevation	Higher flood event could overtop levee/wall and cause more catastrophic damages; closures must be installed prior to flood event	Assumes 144 cfs pump on west channel (will reduce 50-yr rainfall ponding from elev. 8.43' to 7.38'); no pump needed on east channel (50-yr ponding elev will be 7.36'); assumed no damages for the 50-yr and below rainfall events - will need to operate tide gate and ex. pump station to keep water from backing up into New Alexandria
Plan 1b (without pumps)	$6,870,000	$1,110,000	FY10	$7,980,000	$75,000	$444,000	$0	($444,000)	0.00	elevation 12'; 0.8' above 100 yr storm surge elevation	Flooding from interior drainage	Zero benefits because for the lower flood frequencies, there would be a higher flood elevation with the levee and no pump than the without project plan (no levee)
Plan 2a (with pumps) - Levee/floodwall surrounding New Alexandria to elevation 11' (above 50 yr profile) with pumps	$11,990,000	$1,160,000	FY10	$13,150,000	$150,000	$794,000	$919,000	$125,000	1.16	elevation 11' for New Alexandria; 1.4' above 50 yr storm surge elevation	Higher flood event could overtop levee/wall and cause more catastrophic damages; closures must be installed prior to flood event	Assumes 66 cfs pump on west channel (will reduce 50-yr rainfall ponding from elev. 6.85' to 5.62'); 54 cfs pump on east channel (will reduce 50-yr rainfall ponding from elev. 7.01' to 5.43'); assumed no damages for the 50-yr and below rainfall events
Plan 2a (without pumps)	$5,400,000	$520,000	FY10	$5,920,000	$75,000	$365,000	$627,000	$262,000	1.72	elevation 11' for New Alexandria; 1.4' above 50 yr storm surge elevation	Flooding from interior drainage	
Plan 2b (with pumps) - Levee/floodwall surrounding New Alexandria to elevation 12' (above 100 yr profile) with pumps	$13,470,000	$1,300,000	FY10	$14,770,000	$150,000	$874,000	$1,004,000	$130,000	1.15	elevation 12' for New Alexandria; 0.8' above 100 yr storm surge elevation	Higher flood event could overtop levee/wall and cause more catastrophic damages; closures must be installed prior to flood event	
Plan 2b (without pumps)	$6,040,000	$580,000	FY10	$6,620,000	$75,000	$399,000	$735,000	$336,000	1.84	elevation 12' for New Alexandria; 0.8' above 100 yr storm surge elevation	Flooding from interior drainage	
Plan 3a - Flood proof New Alexandria houses by filling basements and adding living space above 100-year	$4,425,000	$443,000	FY10	$4,868,000	$0	$238,000	$228,000	($10,000)	0.96	Varies - New Alex houses protected up to first floor	Exterior items, vehicles are not protected	Houses are protected up to first floor elevation (no basements to be flooded); vehicles, other exterior items are not protected; residents must relocate for approx 6 wks during construction;
Plan 3b - Flood proof New Alexandria houses by filling basements, raising houses above 100-yr elev and adding living space	$23,150,000	$2,310,000	FY10	$25,460,000	$0	$1,244,000	$1,026,000	($218,000)	0.82	100 yr elevation + 18" for New Alexandria	Exterior items, vehicles are not protected	Houses are elevated to 18 inches above the 100-year flood elevation; vehicles, other exterior items are not protected; residents must relocate for approx 12 wks during construction
Plan 4 - Flood proof Belle View area (flood proof condos and townhouses by filling basements; construct ring wall around shopping ctr)	$6,590,000	$660,000	FY10	$7,250,000	$0	$354,000	$37,000	($317,000)	0.10	Varies - Belle View Condos/townhomes protected up to first floor; shopping ctr protection to elev. 10.8'	Belle View Condos and Townhouses are only protected up to first floor elevation; Shopping Ctr only protected to elev. 10.8'	

Notes:
- Project costs are based on 5% concept-level plans and are subject to change
- To meet Corps economic justification requirements, the benefit-to-cost ratio must be greater than 1.0; however, due to limited funding, the Corps is prioritizing projects and only the projects with the highest BCR's are being included in the budget

As part of the economic analysis, each of the levee/floodwall plans were evaluated with pumping stations and without pumping stations. If pumping stations are not constructed, residual flooding would likely occur on the interior of the levee from rain falling within the levee.

As shown on the table, Plans 1a and 1b with pumps and Plans 2a and 2b with and without pumps are the only plans that have economic benefits that outweigh the costs. None of the flood proofing plans are cost-effective.

For the preliminary alternative plans that were evaluated during this study, Plan 1b, a levee/floodwall surrounding the entire study area to elevation 12' with a pumping station, is the most cost-effective solution. The annualized net benefits are $1,171,000 and the benefit-to-cost ratio (BCR) is 2.52. If Fairfax County further pursues this type of plan as a solution to the Belle Haven watershed flooding problem, it is recommended that various heights of protection be considered (specifically higher levels) and that a risk and uncertainty analysis be conducted to determine the optimal solution.

6.0 FINDINGS AND CONCLUSIONS

The purpose of this study was to determine if there are potential flood damage reduction alternatives for the Belle Haven watershed that are technically feasible and cost-effective. A preliminary investigation was performed and 5% concept-level plans were developed. The study evaluated levee and floodwall alignments, as well as flood proofing techniques.

To reduce flood damages throughout the entire study area, it was determined that a floodwall/levee combination, with a pumping station for interior drainage, would be technically feasible and cost-effective. Two top of protection elevations were evaluated, 11 feet (1.4 feet above the 50-year storm surge elevation) and 12 feet (0.8 feet above the 100-year storm surge elevation), and for both plans, the annualized economic benefits were greater than the annualized project costs. A levee/floodwall with a top of protection to elevation 12 feet is estimated to cost $12.7 million (escalated to FY10 dollars).

If Fairfax County decides to pursue this type of project further for implementation, the Corps recommends that various heights of protection be considered (specifically higher levels) and that a risk and uncertainty analysis be conducted to determine the optimal height of protection. This analysis would be required if federal funding is provided. Since this was a reconnaissance level study, a risk and uncertainty analysis was not conducted. Typically, when a levee is designed to protect against a certain event, say the 100-year flood, a risk and uncertainty analysis is conducted to determine how much higher than the design event elevation the levee should be constructed to in order to ensure a high probability that it will not be overtopped (typically it can be 2-4 feet higher than the design flood elevation). For FEMA to certify a levee or floodwall, which would preclude the residents behind the levee from being required to own flood insurance, it must be designed for the 100-year flood event with risk and uncertainty included. There must be a 90% probability that the levee/wall will not be exceeded by the 100-year flood. In order to meet this standard, higher tops of protection would likely be needed for the Belle Haven watershed.

One of the requirements to obtain federal funding for flood damage reduction projects is that the economic benefits must outweigh the project costs. A few of the preliminary alternatives evaluated during this study currently meet this requirement, so the Corps of Engineers could further investigate these alternatives as part of the Civil Works Program if authorized and funded to do so. During further study, the Corps could complete additional tasks and conduct a more thorough economic analysis of the plans to confirm that there is a project that would meet the federal requirements for construction.

This study was preliminary and used existing data. If Fairfax County pursues this type of levee/floodwall project, numerous additional tasks would need to be completed before a project could be built. Below is a list of some of the tasks that should be completed:

- Select a plan for implementation and prepare the design
- Conduct foundation investigations
- Survey elevation data for all structures (low opening/first floor)
- Conduct topographical surveys and prepare mapping suitable for design and construction

drawings
- Conduct risk and uncertainty analysis related to top of protection elevation
- Complete surveys and mapping of existing utilities
- Select type of closure structures to be used
- Conduct more detailed interior drainage analysis to determine pumping capacities and needs
- Prior to construction, acquire necessary permits (may include erosion and sediment control, NPDES, possible forest conservation (if applicable), and authorization to work in streams and wetlands)
- Coordinate with the public regarding the various alternative plans
- Evaluate environmental resources and impacts, including wetlands
- Coordinate with National Park Service, who own property along George Washington Memorial Parkway
- Evaluate cultural and historical resources and impacts
- Determine necessary real estate to be acquired and cost

The County has a few options on how they could proceed with this potential project. The County could conduct further studies, select a final plan, and design and construct the project using County funds, or possibly request the Commonwealth of Virginia for funding assistance. The County could voluntarily contribute funds to the Corps to assist in the further studies, as was done for this study through the Floodplain Management Services Program. The County could also request that a feasibility study be conducted as part of the Corps' Civil Works Program, which is cost-shared 50/50 between the non-federal sponsor and the Corps. During this type of study, all of the tasks listed above would be accomplished and a determination would be made regarding whether or not a project meets the requirements for federal funding for construction. However, due to the federal budget process, it could take more than a year to begin a feasibility study and there is no guarantee that if the project meets the federal requirements, that federal funding would be available to cost-share the design and construction of the project.

7.0 REFERENCES

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Appendix A – Interior Drainage Analysis

Appendix A

BELLE HAVEN FLOOD DAMAGE REDUCTION STUDY
INTERIOR DRAINAGE ANALYSIS

INTRODUCTION

This interior drainage analysis is part of a Flood Damage Reduction Study for the Belle Haven Watershed, Fairfax County. The goal of the overall study is to evaluate alternatives for reducing flood damages. The Corps has prepared concept plans for various alternatives. Measures for reducing flood damages included floodwalls, levees, floodproofing, and combinations of these. The interior drainage analysis was needed as part of the floodwall/levee plans. This analysis was completed in order to determine the locations, capacities, and costs of pumping stations required to release interior drainage behind the line of protection.

WITH-PROJECT CONDITIONS

Two alignments of the levee/wall combination were evaluated. Plan 1 includes a levee/wall surrounding the entire study area. Plan 2 includes a levee/wall only around the New Alexandria subdivision. Two different heights of protection were evaluated as part of the study, 11 feet and 12 feet. However, for the interior drainage analysis, it was assumed that the height of protection would be 12 feet.

LIKELY STORM/RAINFALL SCENARIO

The "worst-case" scenario storm event would be a tropical system where the outfalls are closed by flap gates and are not releasing runoff from the interior areas, and the peak rainfall occurs during this time. Also, rainfall duration of 24 hours is appropriate given the long duration of the oufalls being non-functioning.

OUTFALL/LOW POINT IDENTIFICATION

Major outfall locations and low points where the with-project conditions will cause likely ponding of water were identified using existing Fairfax County mapping. The outfalls were named by their locations within the Belle Haven Community (Plan 1 West and East Outfalls as well as Plan 2 West and East Outfalls).

HYDROLOGIC MODEL

Hydrologic Engineering Center – Hydrologic Modeling Software (HEC-HMS) Version 3.0.1 was used in order to calculate the interior drainage (peak runoff, peak discharge, peak storage, and peak elevation) within Plan 1 and Plan 2 for various rainfall events.

HEC-HMS is a public domain software package for hydrologic modeling developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC). It is designed to simulate the precipitation-runoff process in branched watershed systems. It is designed to be applicable in a wide range of geographic areas for solving the widest possible range of problems. This includes large river basin water sypply and flood hydrology, and small urban or natural watershed runoff. Hydrographs produced by the program are typically used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation. HEC-HMS was used in this study to determine the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year storm event's peak runoff, peak storage, peak discharge, and peak elevation.

Design Interior Pumping Storm

With-project interior flooding conditions can be determined using HEC-HMS model for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year rainfall events. However, when designing pumping facilities, judgment must be used in determining which event to design for. Fairfax County determined that the 50-year rainfall would be used in order to determine the size pump needed for the Belle Haven area. In this scenario, there would be a significant storm surge that would block the drainage structures through the levee/floodwall and a 50-year rainfall occurring concurrently. Pumps designed for this event would remove a majority of the 50-year rainfall flooding from the interior areas, and would also reduce the overall impact of larger events by reducing the volume of water and the flood stage.

Modeling Strategy

HEC-HMS was used to simulate the interior drainage peak flows, volumes, and stages for the outfalls/low points along the line of protection. Existing Fairfax County topographic mapping was used to calculate the storage volume between different elevations at each outfall point. Each outfall point was modeled as a reservoir in the HEC-HMS model, with no outlet, no spillway, and no overflow. This was done to simulate the likely storm event. In the storm event, the flap gates would prevent any water release from the interior areas, as well as any storm surge intrusion. The model was used to identify areas where interior drainage is an issue with the project and to preliminarily size potential pumps stations. Note that the model does not account for any flow from seepage under the project. It is likely that the seepage volume will be minor compared to the volume of water being generated from a significant rainfall event.

Basin Data

Data collection - Topographic data was provided by the Fairfax County, Virginia. The data was in the form of a Geographic Information System (GIS) shape file format and utilized in ArcMap 9.0. Fairfax County also provided mapping for stormwater infrastructure. The data was provided in shape file format which was used to delineate the inundation of interior flooding.

Drainage Basins

Contributing watersheds to each of the outfall points were delineated using existing Fairfax County data. The delineation assumed that the stormwater piping system was fully surcharged and that all flow is overland flow. Using the County's topographic data (1-ft. contour interval) in ArcView GIS 9.0, the areas for each contour were calculated. These numbers were then input into HEC-HMS under the elevation-areas function of paired data. This function allows for the modeling software to calculate the storage volume. As the model runs, HEC-HMS will calculate the elevation and water volume collected from a particular storm event.

Figures A.1 and A.2 show the drainage areas for Plan 1 and Plan 2. To the west of the study area, there is a 0.29 square mile area that drains north to a 66" culvert under Fort Hunt Road. During very low flows (less than 2-year), this area drains into the golf course. However, during any rain events higher than approximately the 2-year event, the culvert cannot handle the flow and Fort Hunt Road is overtopped. This 0.29 square mile area then flows into the West Channel. Due to the expense that would be incurred in pumping the additional runoff diverted from this 0.29 square mile area into the West Channel, it was agreed that the county would first attempt to increase the capacity of the system under Fort Hunt Road so that the flow would be conveyed to the golf course area. The pump calculations in this study, therefore, assume no diversion from this 0.29 square mile watershed into the West Channel watershed.

Soils and Land Use

Fairfax County provided the land use and soils data in a TR-20 model that they provided the Corps of Engineers. The Corps modified the data from the TR-20 model in order for it to be used in HEC-HMS.

Runoff Curve Numbers

Runoff Curve Numbers (CN) are commonly used as hydrologic models to convert mass rainfall into mass runoff. CN is based upon soils, plant cover, amount of impervious area, interception, and surface storage. CN's generally range from 30-98, with 30 having the least amount of runoff and 98 being impervious area, with the most amount of runoff. For Commercial, industrial, and residential areas, the amount of impervious area is factored into the CN.

Time of Concentration and SCS Lag Time

The time of concentration is defined as the time it takes for stormwater to flow from the most hydrologic remote point in the watershed to the point of interest. Lengths and slopes of flow paths were calculated using existing topographic mapping. Existing Fairfax County data for time of concentration was extracted from the County's TR-20 model. The data was then adjusted to a lag time for the HEC-HMS model. Lag time is calculated as 0.6 * Tc. The time of concentration calculations assumed that all stormwater piping is fully surcharged and that all flow to the outlet point is overland flow.

Table 1 lists the data input for each outfall point.

Table 1: HEC-HMS Input Data

Belle Haven Areas	Drainage Area (sq mile)	SCS Lag Time (minutes)	Runoff Curve Number
Plan 1 Flows West	0.4600	17.14	87
Plan 1 Flows East	0.1400	18.54	86
Plan 2 Flows West	0.0970	9.936	88
Plan 2 Flows East	0.0682	18.54	87

Precipitation Data

Rainfall data for the HEC-HMS model is that of the SCS Hypothetical Storm. The NRCS developed four synthetic 24-hour rainfall duration distributions (Type I, IA, II, and III) from available National Weather Service (NWS) duration frequency data or local storm data. Belle Haven watershed, Fairfax County is located in a Type II distribution, which is characterized by intense, short duration rainfall. Table 2 shows the precipitation data for the location of the Belle Haven watershed that was used for the HEC-HMS model.

Table 2: Precipitation Data for the Belle Haven Watershed, Fairfax County

Rainfall Event	24-hour Rainfall (inches
2-year	3.2
5-year	4.1
10-year	4.9
25-year	6.1
50-year	7.2
100-year	8.5
500-year	11.9

Reaches and Routing

The runoff was routed through the system using the HEC-HMS model. Each outfall point had two components associated with it, a reservoir and a sub-basin. The reservoir represents the interior areas (volume) that will collect the runoff. The sub-basin represents the upland areas where contributing runoff will be coming from.

Hydrologic Model Parameters

Below lists the methods and options used in the HEC-HMS model:

Sub-Basin Loss Method: SCS Curve Number
Sub-Basin Transform Method: SCS Unit Hydrograph
Sub-Basin Baseflow Method: N/A
Reach: Lag

Precipitation Method: SCS Hypothetical Storm
Control Specification: 24-hour duration, 1-minute time interval

Results

Data collected was input into the HEC-HMS model to determine the peak discharges, volumes, and stages for the 50-year storm of the outlet areas. Table 3 lists the results.

Table 3: 50-year HEC-HMS Results for Interior Areas of the Belle Haven Watershed, Fairfax County

50-year Peak	Plan 1 West Outfall	Plan 1 East Outfall	Plan 2 West Outfall	Plan 2 East Outfall
Peak In-Flow (cfs)	1527	437	427	216
Peak Elevation (feet, NGVD)	8.4	7.4	6.9	7.0
Peak Volume (acre-feet)	138.5	41.3	29.9	20.5

PUMPING NEEDS

From the interior drainage results from HEC-HMS, the Corps simulated pumps within the modeling software by using the orifice feature. An orifice can be defined as a hole created to discharge a tank of water. The orifice simulated is sharp edged with a coefficient of 0.62. Orifice diameters ranged from 1-8 feet. This was an iterative process with which HEC-HMS calculated results for each diameter orifice for each plan, outfall, and storm event. Based upon the low opening elevations into the residential structures, the County determined that the level of water needs to stay below 7.5 feet for Plan 1 and 6.0 feet for Plan 2 for the 50-year storm event (low opening elevations to all structures should be confirmed in the future). The HEC-HMS generated the following data to show the discharge requirements needed in order to keep the water elevation below the County's goals as stated above for Plan 1 and 2. As a reference point, the current pump station located near the Belle Haven shopping center has a discharge capacity of 206 cubic feet per second.

Table 4: 50-year HEC-HMS Results for Discharge (Pumps) for the Belle Haven Watershed, Fairfax County

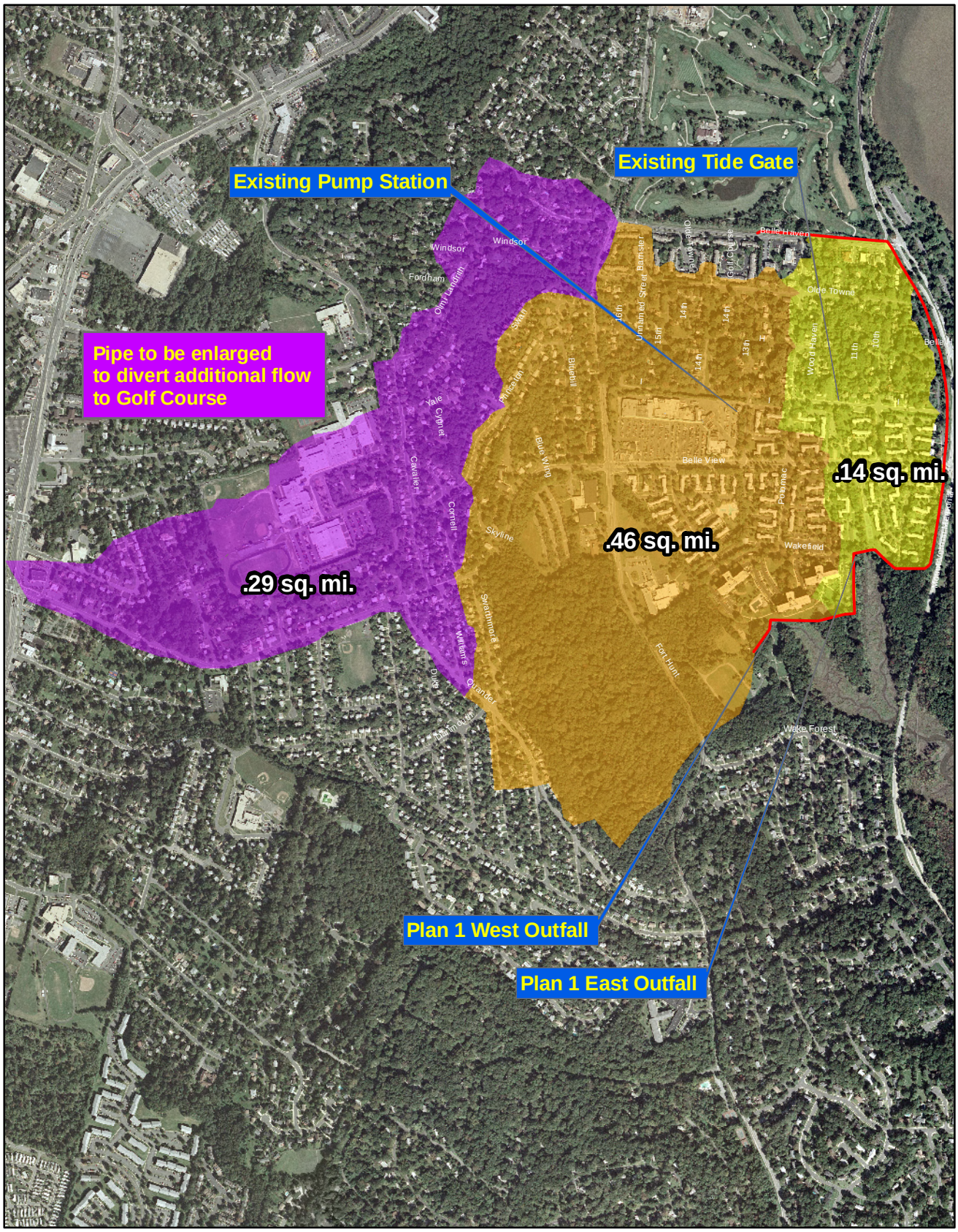
50-year Peak Discharge /Elevation/Volume	Plan 1 West Outfall	Plan 1 East Outfall	Plan 2 West Outfall	Plan 2 East Outfall
Peak Discharge (cfs)	144	No pump req.	66	26
Peak Elevation (ft)*	7.4	No pump req.	5.6	5.9
Peak Volume (acre-ft)	66.7	No pump req.	10.7	9.7

* Peak elevation will be the elevation of the ponded water behind the pump station; the elevation will be the same along the entire channel

Based upon the results of this interior drainage analysis, it is estimated that two permanent pump stations would be required for Plan 2 (66 cfs at the West outfall and 26 cfs at the East outfall) and one pump station for Plan 1 (144 cfs at the West outfall). These pumping stations are required to prevent flooding of structures in the Belle Haven watershed. Note that for Plan 2, the pumping capacity required at the West outfall is 66 cfs; the existing pumping station has a current capacity of 206 cfs. Therefore, it is likely that a new pumping station would not be needed on the West outfall, but some modifications may be needed to the existing station such as flood proofing the station or realigning the floodwall to include the pumping station on the protected side of the wall, along with other modifications.

Figure A.3 shows the interior flooding for Plan 1 assuming a 144 cfs pump at the West outfall. Flood levels would reach elevation 7.4 feet. Although the figure shows flooding in New Alexandria since portions of the subdivision are below elevation 7.4 feet, the existing pump station and tide gate would need to be operated to prevent the flood waters from reaching this level on the upstream side and entering the structures. If this plan is pursued further, a more detailed analysis of the interior drainage would be required, specifically to investigate how the existing tide gate and pump station would need to function in conjunction with a levee/wall and new pump station.

Figure A.4 shows the interior flooding for Plan 2 assuming two pumping stations with 66 cfs and 26 cfs capacities. Flood levels would reach near 5.6 feet on the West channel and 5.9 feet on the East channel. Although the figure shows many structures within the flooded area, the partial data provided by the County shows no low openings into structures less than 6 feet in this area. If a project is pursued, low opening elevations for each structure in the study area would be needed. If is determined that there are lower openings, more pumping capacity would be required to lower the flood levels.



US Army Corps of Engineers
Baltimore District

N
W E
S

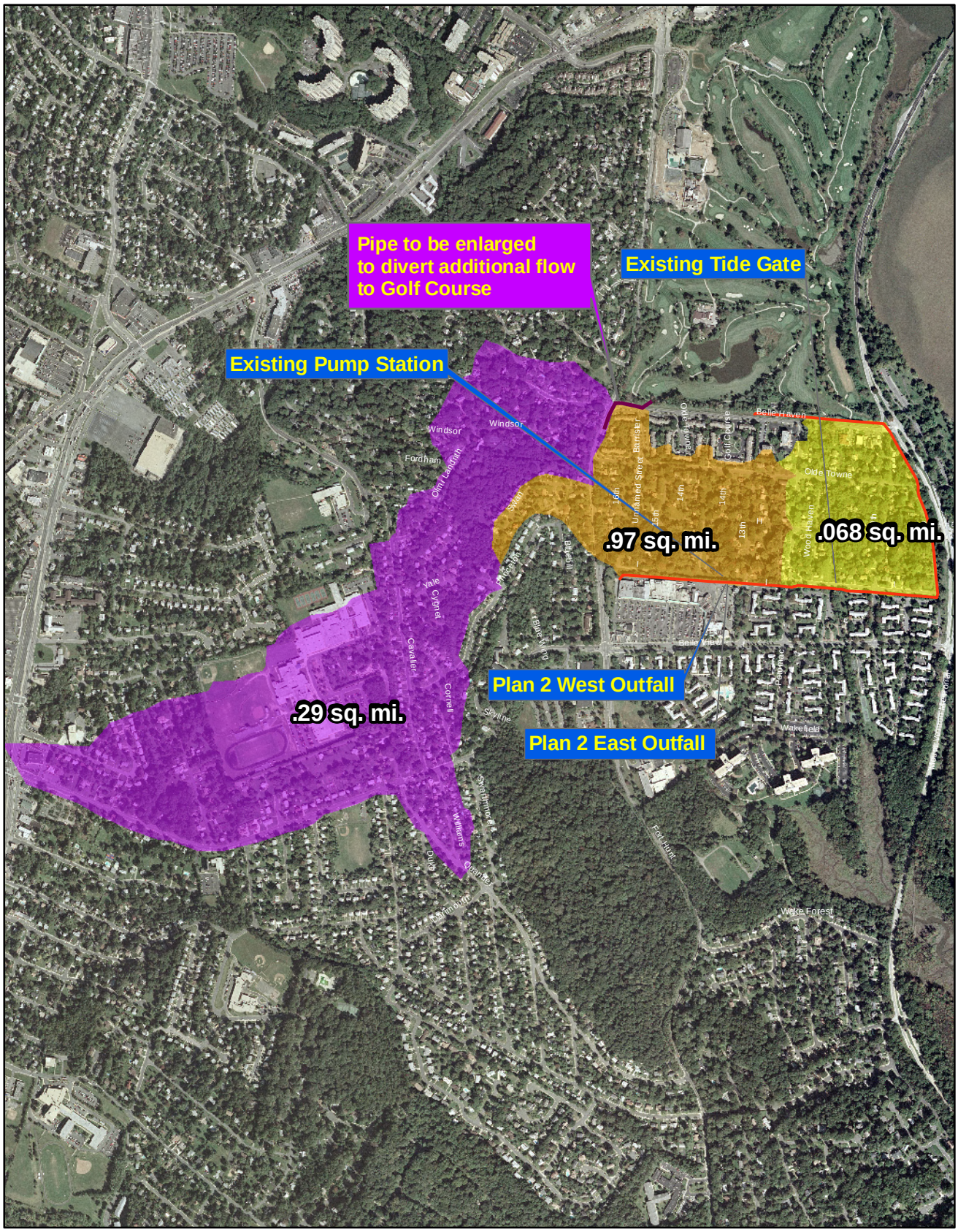
0 300 600 1,200 feet

1 inch equals 1,000 feet

Figure A.1: Belle Haven Watershed Plan 1 Map Showing Interior Flooding Drainage Areas

Legend

- Plan 1 Levee/Floodwall
- West Outfall Drainage Area
- East Outfall Drainage Area
- Diverted West Outfall Drainage Area



US Army Corps
of Engineers
Baltimore District

N
W E
S

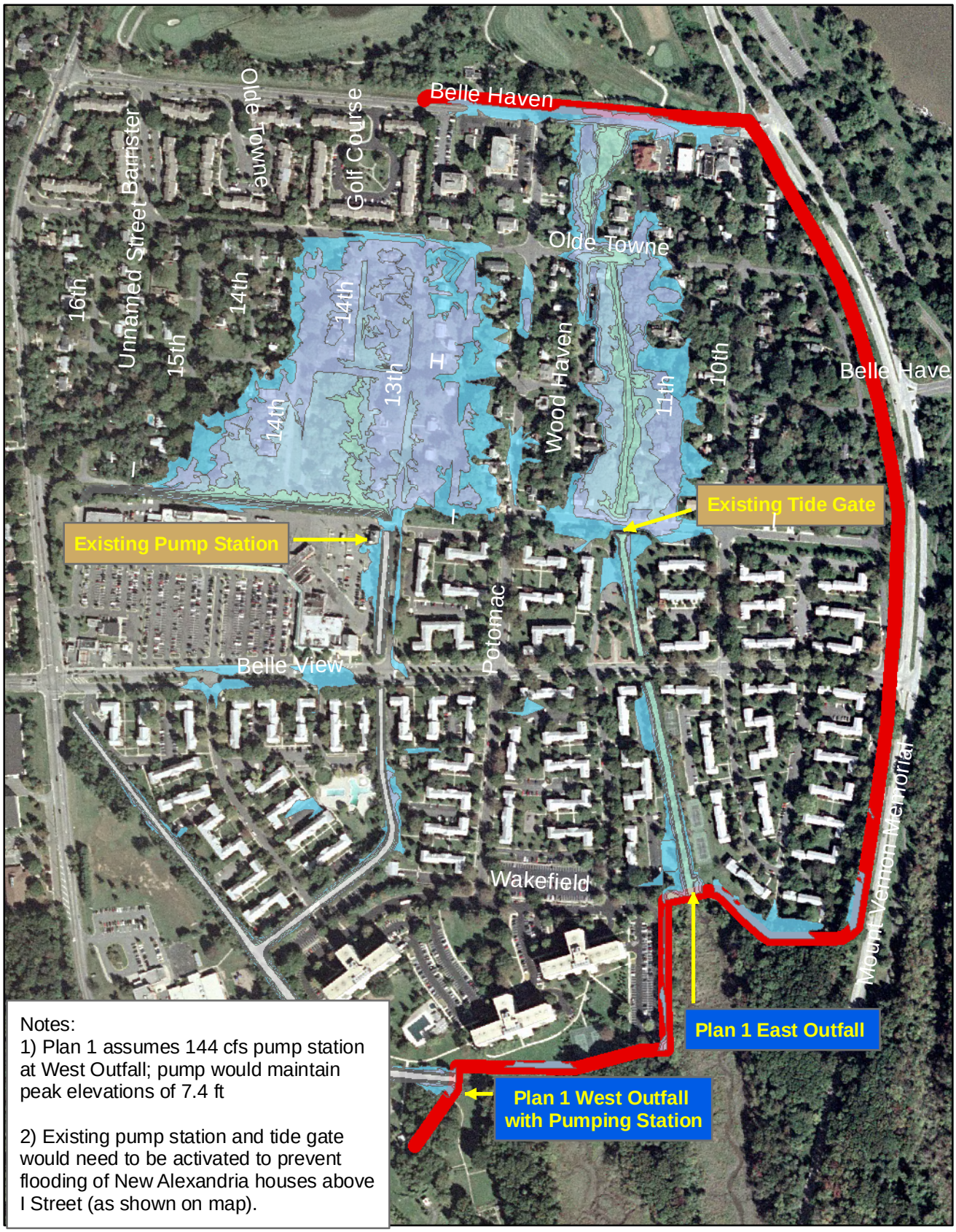
0 300 600 1,200 Feet

1 inch equals 1,000 feet

Figure A.2: Belle Haven Watershed Plan 2 Map Showing Interior Flooding Drainage Areas

Legend

- Plan 2 Levee/Floodwall
- West Outfall Drainage Area
- East Outfall Drainage Area
- Diverted West Outfall Drainage Area



Notes:
1) Plan 1 assumes 144 cfs pump station at West Outfall; pump would maintain peak elevations of 7.4 ft

2) Existing pump station and tide gate would need to be activated to prevent flooding of New Alexandria houses above I Street (as shown on map).

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Baltimore District

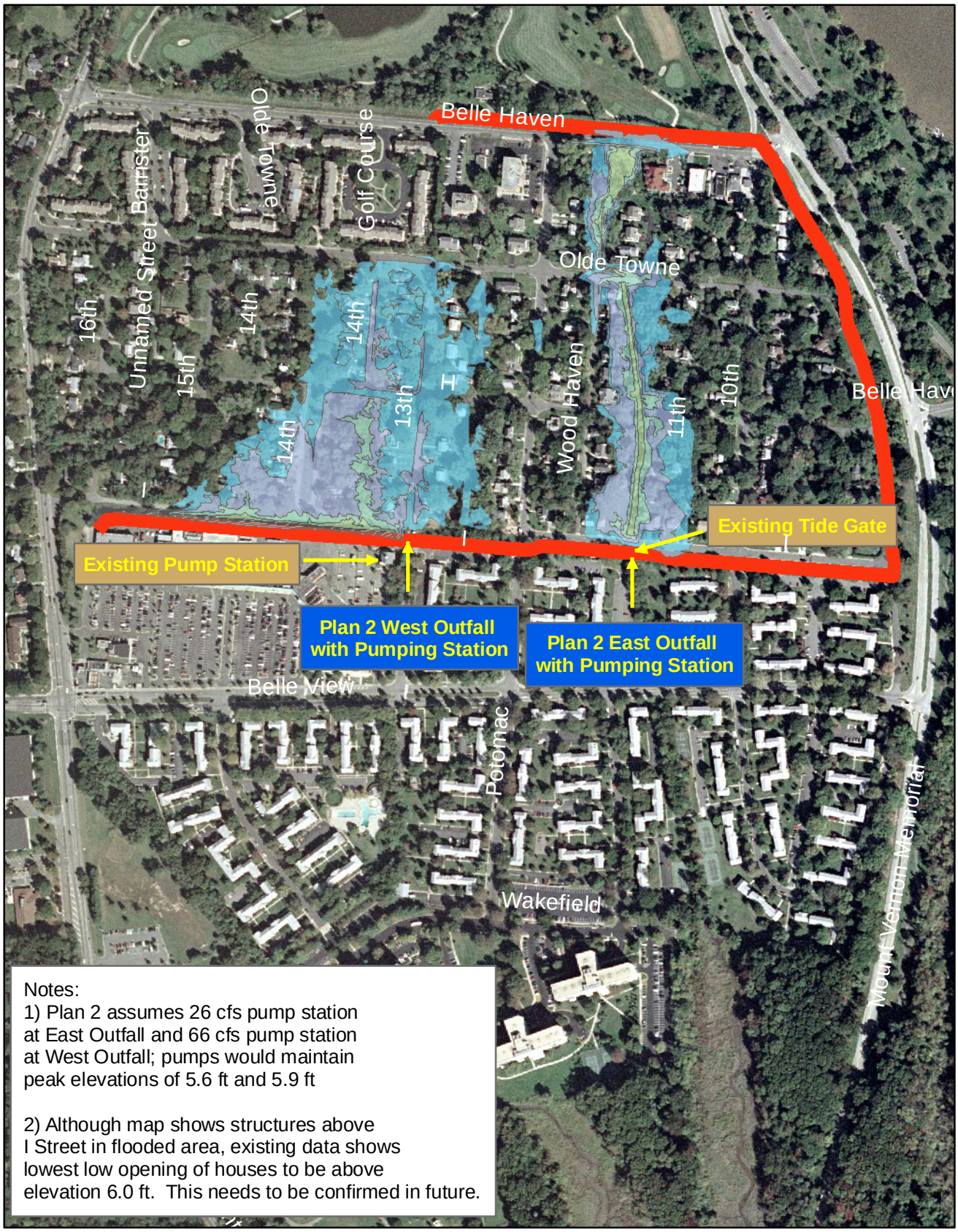
N
W E
S

0 125 250 500 Feet

1 inch equals 500 feet

Figure A.3: Belle Haven Watershed Plan 1 Map Showing Interior Flood Levels for 50-year Rainfall with a Pump

Legend
- 2 FEET
- 3 FEET
- 4 FEET
- 5 FEET
- 6 FEET
- 7 FEET
- Plan 1 Levee/Floodwall



Notes:
1) Plan 2 assumes 26 cfs pump station at East Outfall and 66 cfs pump station at West Outfall; pumps would maintain peak elevations of 5.6 ft and 5.9 ft

2) Although map shows structures above I Street in flooded area, existing data shows lowest low opening of houses to be above elevation 6.0 ft. This needs to be confirmed in future.

US Army Corps of Engineers
Baltimore District

N W E S

0 125 250 500 Feet

1 inch equals 500 feet

Figure A.4: Belle Haven Watershed Plan 2 Map Showing Interior Flood Levels for 50-year Rainfall with 2 Pumps

Legend
- 2 FEET
- 3 FEET
- 4 FEET
- 5 FEET
- 6 FEET
- Plan 2 Levee/Floodwall

Appendix B – Cost Estimates for Concept Plans

Note: The cost estimates in this report are preliminary and are based on the 5% concept plans.

Belle Haven Non-Structural Alternatives
5% Concept Plan Cost Estimates
Prepared December 2007

			Plan 4		
	Plan 3a - New Alexandria Fill Basements (53 houses)	Plan 3b - New Alexandria Raise Houses (183 houses)	Residential - Fill Condo J units and Townhouse Basements	Shopping Center - Ring wall	Plan 4 Total
Construction	$2,548,379	$10,941,600	$984,147	$261,021	$1,245,168
Engineering and Design (15-20%)	$382,257	$1,641,240	$147,622	$52,204	$199,826
Supervision and Admin (4-5%)	$127,418	$437,660	$49,207	$13,051	$62,258
Subtotal	$3,058,054	$13,020,500	$1,180,976	$326,276	$1,507,252
Contingency (30-40%)	$917,416	$3,906,150	$354,293	$130,510	$484,803
Relocation housing cost ($405/day - 3wks for 3a/12 wks for 3b)	$450,765	$6,225,660	$0	$0	$0
Buyout J units (17 units @$270k)	$0	$0	$4,590,000	$0	$4,590,000
Total Plan Cost	$4,426,235	$23,152,310	$6,125,269	$456,786	$6,582,055

Total Plan Cost (Rounded)	$4,425,000	$23,150,000	$6,590,000

Estimated by CENAB-EN-DT
Designed by Baltimore District, COE
Prepared by Luan Ngo
Preparation Date 12/3/2007
Effective Date of Pricing 12/3/2007
Estimated Construction Time Days

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Date	Author	Note
5/23/2007	Luan Ngo	Assume Planning, Engineering, and Design occurs in FY09. Assume midpoint of construction is FY11. Start of construction is assumed to be in FY10. Estimated construction duration is 18 months.
5/23/2007	Luan Ngo	The Direct Cost includes sales tax on materials and labor burden The Cost To Prime includes the Direct Cost and sub-contractor mark-ups. The Contract Cost includes the Cost To Prime and the Prime Contractor mark-ups. The Project Cost includes the Contract Cost, Contingency and Escalation to the mid-point of construction.

Description	Quantity	UOM	ContractCost	Contingency	Escalation	ProjectCost
Project Cost			8,183,558	2,455,067	1,029,692	11,668,317
02 Relocations	1	EA	314,737	94,421	38,870	448,028
11 Levees and Floodwalls	1	EA	6,764,466	2,029,340	835,412	9,629,218
30 Planning, Engineering and Design	1	EA	644,207	193,262	60,298	897,767
31 Construction Management	1	EA	460,148	138,044	95,113	693,305

Description	Quantity	UOM	DirectCost	JOOH	HOOH	Profit	Bond	ContractCost
Cost To Owner			5,519,440	287,035	224,413	525,761	53,991	8,183,558
02 Relocations	1	EA	*179,692.27* 179,692	0	8,194	21,304	0	*314,736.63* 314,737
0201 Roads, Construction Activities (Access Ramp)	1	EA	*20,422.40* 20,422	0	931	2,421	0	*35,770.46* 35,770
020139 Road Surfacing	1	EA	*15,487.19* 15,487	0	706	1,836	0	*27,126.30* 27,126
020199 Associated General Items	1	EA	*4,935.20* 4,935	0	225	585	0	*8,644.16* 8,644
0203 Cemetery, Utilities, & Structure	1	EA	*159,269.88* 159,270	0	7,263	18,883	0	*278,966.16* 278,966
020318 Utilities	1	EA	*159,269.88* 159,270	0	7,263	18,883	0	*278,966.16* 278,966
11 Levees and Floodwalls	1	EA	*4,235,392.50* 4,235,393	287,035	216,219	504,457	53,991	*6,764,466.38* 6,764,466
1101 Levees	1	EA	*3,077,872.94* 3,077,873	277,346	162,647	367,142	52,169	*4,692,701.68* 4,692,702
110101 Mob, Demob & Preparatory Work	1	EA	*110,588.51* 110,589	15,482	6,304	13,237	2,912	*148,524.13* 148,524
110102 Drainage	1	EA	*2,082,504.44* 2,082,504	139,761	106,343	248,040	26,289	*3,351,158.42* 3,351,158
110199 Associated General Items	1	EA	*884,779.99* 884,780	122,103	50,001	105,865	22,968	*1,193,019.13* 1,193,019
1102 Floodwalls	1	EA	*1,157,519.56* 1,157,520	9,689	53,572	137,314	1,822	*2,071,764.70* 2,071,765
110202 Drainage	1	EA	*99,153.49* 99,153	0	4,521	11,756	0	*173,670.43* 173,670
110299 Associated General Items	1	EA	*1,058,366.08* 1,058,366	9,689	49,050	125,559	1,822	*1,898,094.27* 1,898,094
30 Planning, Engineering and Design	1	EA	*644,207.00* 644,207	0	0	0	0	*644,207.00* 644,207
31 Construction Management	1	EA	*460,148.00* 460,148	0	0	0	0	*460,148.00* 460,148

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Description	Quantity	UOM	ContractCost	Contingency	Escalation	ProjectCost
Project Cost			9,223,406	2,767,022	1,160,530	13,150,958
02 Relocations	1	EA	724,452	217,336	89,470	1,031,258
11 Levees and Floodwalls	1	EA	7,254,273	2,176,282	895,903	10,326,458
30 Planning, Engineering and Design	1	EA	726,064	217,819	67,960	1,011,843
31 Construction Management	1	EA	518,617	155,585	107,198	781,400

Description	Quantity	UOM	DirectCost	JOOH	HOOH	Profit	Bond	ContractCost
Cost To Owner			6,134,888	235,054	231,094	553,583	44,214	9,223,406
02 Relocations	1	EA	*531,130.04* 531,130	9,521	14,191	34,958	1,791	*724,452.15* 724,452
0201 Roads, Construction Activities (Access Ramp)	1	EA	*325,591.20* 325,591	9,521	4,819	10,590	1,791	*364,444.46* 364,444
020139 Road Surfacing	1	EA	*15,582.90* 15,583	0	711	1,848	0	*27,293.93* 27,294
020199 Associated General Items	1	EA	*310,008.31* 310,008	9,521	4,108	8,742	1,791	*337,150.52* 337,151
0203 Cemetery, Utilities, & Structure	1	EA	*205,538.84* 205,539	0	9,373	24,369	0	*360,007.69* 360,008
020318 Utilities	1	EA	*205,538.84* 205,539	0	9,373	24,369	0	*360,007.69* 360,008
11 Levees and Floodwalls	1	EA	*4,359,076.52* 4,359,077	225,533	216,903	518,625	42,423	*7,254,273.04* 7,254,273
1101 Levees	1	EA	*3,426,198.65* 3,426,199	217,954	173,746	407,961	40,997	*5,587,565.37* 5,587,565
110101 Mob, Demob & Preparatory Work	1	EA	*111,712.43* 111,712	15,640	6,368	13,372	2,942	*150,033.60* 150,034
110102 Drainage	1	EA	*2,596,982.92* 2,596,983	103,313	126,835	308,740	19,433	*4,470,022.36* 4,470,022
110199 Associated General Items	1	EA	*717,503.30* 717,503	99,002	40,544	85,850	18,622	*967,509.41* 967,509
1102 Floodwalls	1	EA	*932,877.87* 932,878	7,578	43,156	110,664	1,425	*1,666,707.67* 1,666,708
110202 Drainage	1	EA	*65,703.16* 65,703	0	2,996	7,790	0	*115,081.13* 115,081
110299 Associated General Items	1	EA	*867,174.71* 867,175	7,578	40,160	102,874	1,425	*1,551,626.54* 1,551,627
30 Planning, Engineering and Design	1	EA	*726,064.00* 726,064	0	0	0	0	*726,064.00* 726,064
31 Construction Management	1	EA	*518,617.00* 518,617	0	0	0	0	*518,617.00* 518,617

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Description	Quantity	UOM	ContractCost	Contingency	Escalation	ProjectCost
Project Cost			8,899,462	2,669,838	1,119,770	12,689,070
02 Relocations	1	EA	319,293	95,788	39,433	454,514
11 Levees and Floodwalls	1	EA	7,379,203	2,213,761	911,332	10,504,296
30 Planning, Engineering and Design	1	EA	700,563	210,169	65,573	976,305
31 Construction Management	1	EA	500,402	150,121	103,433	753,956

Description	Quantity	UOM	DirectCost	JOOH	HOOH	Profit	Bond	ContractCost
Cost To Owner			6,009,514	314,698	244,577	572,632	59,195	8,899,462
02 Relocations	1	EA	*182,293.78* 182,294	0	8,313	21,613	0	*319,293.24* 319,293
0201 Roads, Construction Activities (Access Ramp)	1	EA	*20,604.16* 20,604	0	940	2,443	0	*36,088.82* 36,089
020139 Road Surfacing	1	EA	*15,542.98* 15,543	0	709	1,843	0	*27,224.02* 27,224
020199 Associated General Items	1	EA	*5,061.17* 5,061	0	231	600	0	*8,864.80* 8,865
0203 Cemetery, Utilities, & Structure	1	EA	*161,689.62* 161,690	0	7,373	19,170	0	*283,204.42* 283,204
020318 Utilities	1	EA	*161,689.62* 161,690	0	7,373	19,170	0	*283,204.42* 283,204
11 Levees and Floodwalls	1	EA	*4,626,255.62* 4,626,256	314,698	236,264	551,020	59,195	*7,379,203.30* 7,379,203
1101 Levees	1	EA	*3,322,164.47* 3,322,164	304,854	175,996	396,326	57,343	*5,040,278.69* 5,040,279
110101 Mob, Demob & Preparatory Work	1	EA	*111,602.86* 111,603	15,624	6,361	13,359	2,939	*149,886.44* 149,886
110102 Drainage	1	EA	*2,130,010.05* 2,130,010	139,906	108,521	253,673	26,316	*3,433,943.08* 3,433,943
110199 Associated General Items	1	EA	*1,080,551.55* 1,080,552	149,323	61,114	129,294	28,088	*1,456,449.17* 1,456,449
1102 Floodwalls	1	EA	*1,304,091.15* 1,304,091	9,845	60,268	154,693	1,852	*2,338,924.61* 2,338,925
110202 Drainage	1	EA	*97,505.92* 97,506	0	4,446	11,560	0	*170,784.67* 170,785
110299 Associated General Items	1	EA	*1,206,585.23* 1,206,585	9,845	55,822	143,133	1,852	*2,168,139.94* 2,168,140
30 Planning, Engineering and Design	1	EA	*700,563.00* 700,563	0	0	0	0	*700,563.00* 700,563
31 Construction Management	1	EA	*500,402.00* 500,402	0	0	0	0	*500,402.00* 500,402

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Description	Quantity	UOM	ContractCost	Contingency	Escalation	ProjectCost
Project Cost			10,358,815	3,107,645	1,303,393	14,769,853
02 Relocations	1	EA	723,926	217,178	89,405	1,030,508
11 Levees and Floodwalls	1	EA	8,236,988	2,471,096	1,017,268	11,725,352
30 Planning, Engineering and Design	1	EA	815,443	244,633	76,325	1,136,401
31 Construction Management	1	EA	582,459	174,738	120,394	877,591

Description	Quantity	UOM	DirectCost	JOOH	HOOH	Profit	Bond	ContractCost
Cost To Owner			6,977,733	315,165	269,045	635,996	59,282	10,358,815
02 Relocations	1	EA	*530,818.83* 530,819	9,515	14,176	34,922	1,790	*723,925.75* 723,926
0201 Roads, Construction Activities (Access Ramp)	1	EA	*325,498.20* 325,498	9,515	4,814	10,579	1,790	*364,300.27* 364,300
020139 Road Surfacing	1	EA	*15,547.16* 15,547	0	709	1,843	0	*27,231.34* 27,231
020199 Associated General Items	1	EA	*309,951.04* 309,951	9,515	4,105	8,735	1,790	*337,068.93* 337,069
0203 Cemetery, Utilities, & Structure	1	EA	*205,320.63* 205,321	0	9,363	24,343	0	*359,625.49* 359,625
020318 Utilities	1	EA	*205,320.63* 205,321	0	9,363	24,343	0	*359,625.49* 359,625
11 Levees and Floodwalls	1	EA	*5,049,012.51* 5,049,013	305,650	254,868	601,074	57,493	*8,236,987.68* 8,236,988
1101 Levees	1	EA	*4,004,253.51* 4,004,254	298,113	206,613	477,146	56,075	*6,366,127.73* 6,366,128
110101 Mob, Demob & Preparatory Work	1	EA	*111,636.33* 111,636	15,629	6,363	13,363	2,940	*149,931.39* 149,931
110102 Drainage	1	EA	*3,012,805.86* 3,012,806	160,879	150,484	358,508	30,261	*5,030,381.34* 5,030,381
110199 Associated General Items	1	EA	*879,811.32* 879,811	121,605	49,766	105,275	22,874	*1,185,814.99* 1,185,815
1102 Floodwalls	1	EA	*1,044,759.00* 1,044,759	7,537	48,255	123,928	1,418	*1,870,859.96* 1,870,860
110202 Drainage	1	EA	*65,639.51* 65,640	0	2,993	7,782	0	*114,969.66* 114,970
110299 Associated General Items	1	EA	*979,119.48* 979,119	7,537	45,262	116,146	1,418	*1,755,890.30* 1,755,890
30 Planning, Engineering and Design	1	EA	*815,443.00* 815,443	0	0	0	0	*815,443.00* 815,443
31 Construction Management	1	EA	*582,459.00* 582,459	0	0	0	0	*582,459.00* 582,459

Appendix C – Economic Analysis

BELLE HAVEN WATERSHED FLOOD DAMAGE REDUCTION STUDY

FAIRFAX COUNTY, VIRGINIA

ECONOMIC APPENDIX

PREPARED BY:
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

January 10, 2008

ECONOMIC APPENDIX
TABLE OF CONTENTS

ITEM	Page No.
INTRODUCTION	1
METHODOLOGY	1
FLOOD DAMAGE ESTIMATES	1
AFFECTED AREA	2
FLOOD DAMAGE COMPUTATION	2
FLOOD DAMAGES	2
RECURRING LOSSES	3
ANNUAL LOSSES	3
IMPROVEMENT PLANS	3
PLANS COST	5
ECONOMIC BENEFIT ESTIMATION	6
PLAN JUSTIFICATION	6

List of Tables

Table No.	Description	Page No.
1	Recurring Damages All Damage Reaches Belle Haven Watershed	3
2	Plan Costs Belle Haven Watershed	5
3	Plan Benefit-Cost Summary Belle Haven Watershed	7

INTRODUCTION

Fairfax County requested that the Corps conduct an economic analysis of various flood damage reduction alternatives to determine if any of the plans would meet the requirements for federal funding. The Corps conducted a reconnaissance-level analysis for the Belle Haven watershed.

Expected annual damages are calculated for both the natural and modified conditions. The difference in these magnitudes is a measure of flood damage reduction. Plans to reduce flooding damages are evaluated. For each plan annual benefit is divided by annual cost to determine a benefit cost ratio. This ratio must be equal to or greater than one to one for federal participation in water resource improvement projects. If a plan is found with a benefit to cost ratio greater than one, the study proceeds to the feasibility phase.

METHODOLOGY

Benefits and costs are made comparable by conversion to average annual equivalents. An interest rate of 4-7/8% as specified in the Federal Register is to be used by Federal agencies in the formulation and evaluation of water and land resource plans for the period 1 October 2007 to 30 September 2008. All costs and benefits are stated at the 2007 price level. The project period of analysis is considered to be 50 years. The analysis of costs and benefits follows standard U.S. Army Corps of Engineers procedures. The reference documents used in the benefit estimation process are ER 1105-2-100, Chapter 6, Section IV, NED Benefit Evaluation Procedures: Urban Flood Damage and ER 1105-2-101.

FLOOD DAMAGE ESTIMATES

Flood damage estimates were developed using depth damage relationships developed by the Institute for Water Resources (IWR) and the National Flood Insurance Administration (NFIA). The IWR depth damage curves were developed for residential structures. They were developed from an analysis of actual flooding events and relate damages to building structure and contents at various flooding depths to the value of the structure. These curves are supplemented with the NFIA curves for and nonresidential structures, such as commercial, industrial and public buildings.

These depth damage relationships are used to develop a stage damage function for each structure in the floodplain for each possible flood stage. The floodplain includes residential and commercial structures. The stage or elevation at which flood damage begins was determined for each property. For structures without surveyed data estimates were made based on topographic maps with two-foot contours. Estimates of potential damages were then made from the starting point, in one-foot increments of stage, to a level of at least 6 feet above the first floor. Dollar value estimates were made for physical damages to structure and contents. Damages were assumed to start in a building when water reached the first opening. Seepage through the bottom of the foundation was not assumed as the start of damage. Separate damage functions were entered for

automobiles. It is assumed that 50 percent of the vehicles that could be damaged would be damaged by a flood. Estimates of income losses to businesses and wage losses to employees resulting from a disruption of normal activities were not determined. These nonphysical losses were not estimated because of the difficulty of documentation given the limited scope of study. Estimates for temporary housing and food were made for residential occupants.

Emergency cost, or flood fighting cost was estimated. Emergency cost is defined as the cost that results from emergency activities prior to, during, and after a flood. Emergency cost includes expenses for flood emergency centers, communication facilities not otherwise needed, temporary evacuation assistance, flood fighting materials and personnel, additional police and fire protection, and public cleanup.

AFFECTED AREA

The Belle Haven watershed consists of two unnamed tributaries that drain into the Potomac River. They are referred to as Belle Haven East Channel and Belle Haven West Channel. Structures in the flood plain were assigned to the cross section within the appropriate channel. There are 254 structures in the 500-year floodplain. The Belle View section is to the south and the New Alexandria section to the north.

FLOOD DAMAGE COMPUTATION

Flood damage estimates were developed using the Hydrologic Engineering Center Flood Damage Analysis (HEC-FDA) computer program. The program develops stage-damage information for each structure based on the structure value and generic stage-damage functions along with the elevation of the first floor and the elevation at which damage starts. Stage damage functions were aggregated by structure type such as residential and commercial. Stage-frequency data for each cross section in the hydrologic zone were then input. The computer model combined stage-frequency data and stage-damage information to compute damage frequency distributions and expected annual damage by damage reaches. Single flood event damage was determined for several events.

FLOOD DAMAGES

Recurring damages are those that are estimated for each event. Expected annual damage is recurring damage weighted by its probability of occurrence.

Recurring Damages

Recurring flood losses are those potential damages that are estimated to occur at various flood stages. Recurring losses by event are presented in Table 1.

Table 1 Recurring Damages All Damage Reaches Belle Haven Watershed				
Return Interval	No. Structures			
(years)	With Damage	W/ FF Damage	Damage	Ave Dam
			($000)	($000)
2	5	0	123.9	24.8
5	16	10	798.4	49.9
10	76	61	4,469.2	58.8
25	150	111	12,474.7	83.2
50	227	173	27,263.3	120.1
100	252	245	43,720.6	173.5
200	253	253	53,985.4	213.4
500	254	254	79,915.8	314.6

Column two shows the number of structures that receive damage during events from the 2-year return interval to the 500-year return interval. In Column three are the number of structures that had damage above the first floor. Total damages for each event is shown in Column four and the average damage per structure is displayed in Column five.

Annual Losses

Expected annual damages for the entire Belle Haven Watershed are estimated to be $2,357,000.

IMPROVEMENT PLANS

Improvement plans are of two types, structural and nonstructural. Structural plans include floodwalls and levees. Nonstructural plans include raising first floors and floodproofing structures. The plans under consideration are briefly described below.

Plan 1a – Levee/floodwall (T-wall) surrounding entire study area to elevation 11'(above 50-year protection); 1 pumping station at downstream end of West Channel near high-rise apartments

Plan 1b - Levee/floodwall (T-wall) surrounding entire study area to elevation 12'(above 100-year protection); 1 pumping station at downstream end of West Channel near high-rise apartments

Plan 2a – Levee/floodwall (T-wall) surrounding New Alexandria section to elevation 11' (above 50-year protection); 2 pumping stations near where existing pump station and tide gate are currently located

Plan 2b – Levee/floodwall (T-wall) surrounding New Alexandria section to elevation 12' (above 100-year protection); 2 pumping stations near where existing pump station and tide gate are currently located

Plan 3a – Flood proof New Alexandria houses by filling in basements and adding living space to first floor (18" above 100-year flood elevation); houses will only be protected up the first floor elevation

Plan 3b – Flood proof New Alexandria houses by filling in basements, raising houses to 18" above 100-year flood level, and adding living space to new first floor; 100-year level of protection

Plan 4 – Flood proof Belle View section of the study area by doing the following:

- flood proof Belle View Condos by filling in the basement units (buyouts), moving utilities to above 100-year elevation; will be protected up to existing first floor elevation
- flood proof townhouses by filling in basement storage/utility area and adding storage space/moving utilities to area above 100-year elevation; will be protected up to existing first floor elevation
- Construct ring wall around the shopping center to elevation 10.8

PLANS COST

The estimated plan costs are shown in Table 2.

Table 2 Plan Costs Belle Haven Watershed							
Plan	Construction Cost ($000)	Construction Period	idc	Implementation Cost ($000)	Annual Implementation Cost ($000)	Annual O&M Cost ($000)	Annual Project Cost ($000)
1a	10,640	1	0	10,640	572	150	722
w/pumps							
1a							
wo/pumps	6,440	1	0	6,440	346	75	421
1b							
w/pumps	11,570	1	0	11,570	622	150	772
1b							
wo/pumps	6,870	1	0	6,870	369	75	444
2a							
w/pumps	11,990	1	0	11,990	644	150	794
2a							
wo/pumps	5,400	1	0	5,400	290	75	365
2b							
w/pumps	13,470	1	0	13,470	724	150	874
2b							
wo/pumps	6,040	1	0	6,040	324	75	399
3a	4,425	1	0	4,425	238	0	238
3b	23,150	1	0	23,150	1,244	0	1,244
4	6,590	1	0	6,590	354	0	354

Alternatives 1 and 2 are evaluated with and without pumping stations. Columns three and four can be ignored as it is not necessary to calculate this cost for a reconnaissance level study. IDC is an acronym for interest during construction. It is an economic cost and not a financial cost. It represents the opportunity cost of funds committed to the project, but not yielding benefit. The cost disappears when the project is complete and yielding benefit. Flood damage reduction plans range in construction cost from $4,425,000 for Plan 3a to $23,150,000 for Plan 3b.

ECONOMIC BENEFIT ESTIMATION

Economic benefit is measured as a reduction in inundation damages and in emergency cost. Inundation reduction refers to physical damages to buildings and contents including furnishings, equipment, materials and products. Inundation reduction benefit is shown in Table. Total annual inundation reduction benefit for the Belle Haven Watershed is estimated to range from $37,000 annually for Plan 4 to $1,943,000 for Plan 1b with pumping stations.

PLAN JUSTIFICATION

A plan must have a benefit cost ratio greater than one, or net benefit greater than zero, to justify federal funding. Table 3 displays plan benefit and cost. Net benefit for Plans 1a with pumps, 1b with pumps, 2a with and without pumps, and 2b with and without pumps are estimated to have net benefits greater than zero and benefit-cost ratios greater than one to one. Net benefits for these plans range from $125,000 for Plan 2a with pumps to $1,171,000 for Plan 1b with pumps. There are no estimated benefits for Plans 1a and 1b without pumps as interior stages are not reduced with these plans. Levees prevent the drainage of water into the river resulting in ponding behind them. Benefit-cost ratios vary from 1.15 for Plan 2b with pumps to 2.52 for Plan 1b with pumps. Since at least one plan has been identified with positive net benefit, or a benefit-to-cost ratio greater than 1.0, the Corps' planning process can proceed to the feasibility phase if the Corps is authorized and funded to do so.

Table 3
Plan Benefit-Cost Summary
Belle Haven

Plan	Annual Benefit	Annual Cost	Annual Net Benefit	Benefit/Cost Ratio
	($000)	($000)	($000)	
1a				
w/pumps	1,688.0	722.0	966.0	2.34
1a				
wo/pumps	0.0	421.0	-421.0	0.00
1b				
w/pumps	1,943.0	772.0	1,171.0	2.52
1b				
wo/pumps	0.0	444.0	-444.0	0.00
2a				
w/pumps	919.0	794.0	125.0	1.16
2a				
wo/pumps	627.0	365.0	262.0	1.72
2b				
w/pumps	1,004.0	874.0	130.0	1.15
2b				
wo/pumps	735.0	399.0	336.0	1.84
3a	228.0	238.0	-10.0	0.96
3b	1,026.0	1,244.0	-218.0	0.82
4	37.0	354.0	-317.0	0.10

Appendix D – Soil Borings

CLIENT	JOB #	BORING #	SHEET
FAIRFAX COUNTY	10252B	B-9A	1 OF 2

PROJECT NAME: FAIRFAX COUNTY SEWER SAGS

ARCHITECT-ENGINEER: HAZEN AND SAWYER, P.C.

ECS LLC MID-ATLANTIC

SITE LOCATION: FAIRFAX COUNTY, VA. I STREET @ 13TH STREET

CALIBRATED PENETROMETER TONS/FT.^{2} (1, 2, 3, 4, 5+)

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % △

ROCK QUALITY DESIGNATION & RECOVERY: RQD% — — — REC.% — 20% 40% 60% 80% 100%

STANDARD PENETRATION BLOWS/FT. (10, 20, 30, 40, 50+)

DESCRIPTION OF MATERIAL — ENGLISH UNITS

BOTTOM OF CASING ▶ — LOSS OF CIRCULATION 100%

SURFACE ELEVATION 5

SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL
1	SS	18	18	Topsoil Depth 2"
2	SS	18	16	Clayey SAND, With Gravel, Trace Roots, Dark Brown to Gray, Moist, Very Loose to Loose, (SC-FILL)
3	SS	18	16	
4	SS	18	14	CLAY, Trace Sand and Roots, Orangish Brown, Moist to Wet, Very Soft to Soft, (CL-Possible Fill)
5	SS	18	8	Silty SAND, Trace Mica, Light Brown, Moist to Wet, Very Loose, (SM)
6	SS	18	14	SAND, Trace Fine Gravel, Brown, Moist, Loose to Medium Dense, (SP)
7	SS	18	16	
8	SS	18	16	

DEPTH (FT): 0, 5, 10, 15, 20, 25, 30

WATER LEVELS ELEVATION (FT): 0, -5, -10, -15, -20

Sample	Blows	Penetrometer (tons/ft.^{2})
1	7	19.0
2	4	5.1
3	4	25.2
4	2	31.4
5	WOH	31.2
6	7	29.5
7	12	18.7
8	10	21.3

CONTINUED ON NEXT PAGE.

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

▽WL 6.5' WS OR WD	BORING STARTED 11-17-06	
▽WL(BCR) 25.0' ▽WL(ACR)	BORING COMPLETED 11-17-06	CAVE IN DEPTH ● 50.0'
▽WL	RIG CME45C FOREMAN CONNELLY	DRILLING METHOD HOLLOW STEM AUGER

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RC (11-22-06) RC (11-28-06) RC (12-01-06) RC (12-12-06)
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CLIENT	JOB #	BORING #	SHEET
FAIRFAX COUNTY	10252B	B-9A	2 OF 2

PROJECT NAME: FAIRFAX COUNTY SEWER SAGS

ARCHITECT-ENGINEER: HAZEN AND SAWYER, P.C.

ECS LLC MID-ATLANTIC

SITE LOCATION: FAIRFAX COUNTY, VA. I STREET @ 13TH STREET

CALIBRATED PENETROMETER TONS/FT.^{2} 1 2 3 4 5+

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % Δ

ROCK QUALITY DESIGNATION & RECOVERY RQD% — — — REC.% 20% 40% 60% 80% 100%

⊗ STANDARD PENETRATION BLOWS/FT. 10 20 30 40 50+

BOTTOM OF CASING ▶ LOSS OF CIRCULATION 100%

SURFACE ELEVATION 5

DEPTH (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL (ENGLISH UNITS)	WATER LEVELS	ELEVATION (FT)	STANDARD PENETRATION BLOWS/FT.	WATER CONTENT %
30					SAND, Trace Fine Gravel, Brown, Moist, Loose to Medium Dense, (SP)				
	9	SS	18	16				11	21.3
35							30		
					Silty SAND, With Gravel, Orangish Brown, Moist, Medium Dense, (SM)				
	10	SS	18	16				12	9.8
40							35		
	11	SS	18	12				23	10.4
45							40		
	12	SS	18	12				28	8.2
50					END OF BORING @ 50.00'		45		
55							50		
60									

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

▽WL 6.5' WS OR FD	BORING STARTED 11-17-06	
▽WL(BCR) 25.0' ▽WL(ACR)	BORING COMPLETED 11-17-06	CAVE IN DEPTH ● 50.0'
▽WL	RIG CME45C FOREMAN CONNELLY	DRILLING METHOD HOLLOW STEM AUGER

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dbcenter(11/20/2006)

CLIENT	JOB #	BORING #	SHEET
FAIRFAX COUNTY	10252B	B-10A	1 OF 2

PROJECT NAME: FAIRFAX COUNTY SEWER SAGS

ARCHITECT-ENGINEER: HAZEN AND SAWYER, P.C.

ECS LLC MID-ATLANTIC

SITE LOCATION: FAIRFAX COUNTY, VA. BELLE VIEW BLVD.

CALIBRATED PENETROMETER TONS/FT.^{2} (1, 2, 3, 4, 5+)

PLASTIC LIMIT % — WATER CONTENT % — LIQUID LIMIT %

ROCK QUALITY DESIGNATION & RECOVERY: RQD% — REC.% (20%, 40%, 60%, 80%, 100%)

STANDARD PENETRATION BLOWS/FT. (10, 20, 30, 40, 50+)

DESCRIPTION OF MATERIAL — ENGLISH UNITS

BOTTOM OF CASING — LOSS OF CIRCULATION 100%

SURFACE ELEVATION 10

SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)
1	SS	18	12
2	SS	18	18
3	SS	18	18
4	SS	18	14
5	SS	18	10
6	SS	18	16
7	SS	18	16
8	SS	18	18

DEPTH (FT): 0, 5, 10, 15, 20, 25, 30

WATER LEVELS — ELEVATION (FT): 5, 0, -5, -10, -15

Asphalt Depth 3"

Gravel Depth 6"

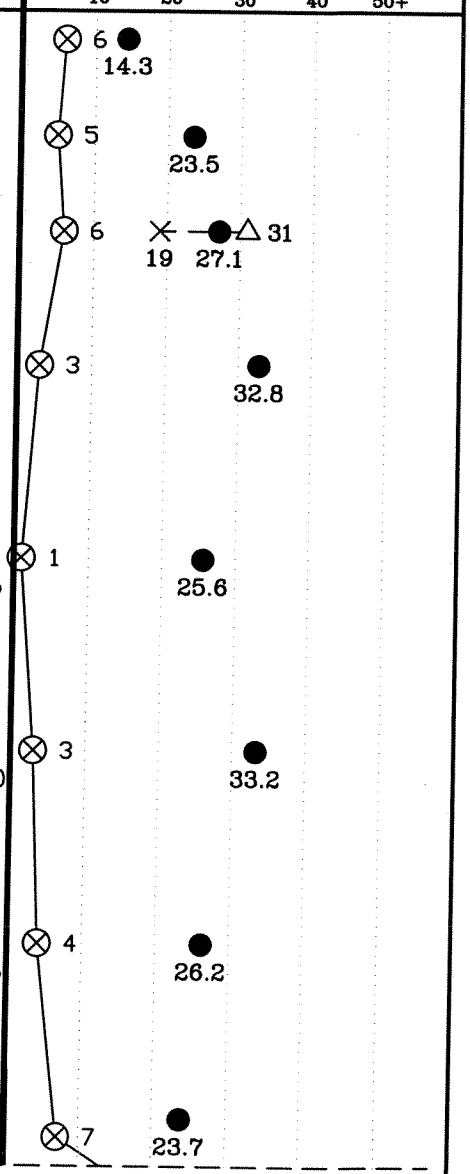
Fine Sandy SILT, With Gravel, Trace Asphalt, Brown to Dark Brown, Moist, Loose, (ML-FILL)

Lean CLAY, With Sand, Trace Mica, Brown, Moist to Wet, Soft to Medium Stiff, (CL)

Silty SAND, Trace Clay, Brown, Moist to Wet, Very Loose, (SM)

Fine Sandy SILT, Light Brown, Moist to Wet, Very Loose, (ML)

SAND, Trace Clay, Brown, Moist to Wet, Very Loose to Loose, (SP)



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THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

WL 7.5'	WS OR WD	BORING STARTED 11-14-06	
WL(BCR) 38.0' WL(ACR)		BORING COMPLETED 11-14-06	CAVE IN DEPTH @ 50.0'
WL		RIG CME45C FOREMAN CONNELLY	DRILLING METHOD HOLLOW STEM AUGER

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dbosenter(11/17/2006)

CLIENT	JOB #	BORING #	SHEET
FAIRFAX COUNTY	10252B	B-10A	2 OF 2

PROJECT NAME: FAIRFAX COUNTY SEWER SAGS

ARCHITECT-ENGINEER: HAZEN AND SAWYER, P.C.

ECS LLC MID-ATLANTIC

SITE LOCATION: FAIRFAX COUNTY, VA. BELLE VIEW BLVD.

CALIBRATED PENETROMETER TONS/FT.^{2} 1 2 3 4 5+

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % △

ROCK QUALITY DESIGNATION & RECOVERY RQD% — — — REC.% 20% 40% 60% 80% 100%

⊗ STANDARD PENETRATION BLOWS/FT. 10 20 30 40 50+

DESCRIPTION OF MATERIAL — ENGLISH UNITS

BOTTOM OF CASING ▶ — LOSS OF CIRCULATION 100%

SURFACE ELEVATION 10

DEPTH (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS	ELEVATION (FT)	STANDARD PENETRATION BLOWS/FT.	WATER CONTENT %
30					SAND, Trace Clay, Brown, Moist to Wet, Very Loose to Loose, (SP)				
	9	SS	18	16	SAND, With Fine Gravel, Brown to Dark Brown, Moist to Wet, Medium Dense, (SP)		25	13	17.2
35						▽			
	10	SS	18	14			30	15	16.2
40					Gravelly SAND, Trace Clay, Light Brown, Moist, Medium Dense, (SP)				
	11	SS	18	16			35	16	13.1
45									
	12	SS	18	14			40	19	17.7
50					END OF BORING @ 50.00'				
55							45		
60									

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

▽WL 7.5' WS OR WD	BORING STARTED 11-14-06	
▽WL(BCR) 38.0' ▽WL(ACR)	BORING COMPLETED 11-14-06	CAVE IN DEPTH ● 50.0'
▽WL	RIG CME45C FOREMAN CONNELLY	DRILLING METHOD HOLLOW STEM AUGER

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RC (11-22-06) RC (11-28-06) RC (12-01-06) RC (12-12-06)
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Temporary Piezometer No.	Date	Approx. Elevation of Temporary Piezometer (ft)	Water Level (ft)	Approx. Water Elevation (ft)
B6-2A	11/21/2006	5	1.7	3.3
B8-1A	11/21/2006	6.6	1.9	4.7
B8-2A	11/21/2006	12.6	10.3	2.3
B9-A	11/21/2006	5	1.3	3.7
B10-A	11/21/2006	10	6.0	4.1
B6-2A	11/29/2006	5	1.2	3.8
B8-1A	11/29/2006	6.6	1.2	5.4
B8-2A	11/29/2006	12.6	9.9	2.7
B9-A	11/29/2006	5	1.2	3.8
B10-A	11/29/2006	10	5.7	4.4

ECS Mid-Atlantic, LLC
Chantilly, Virginia
Laboratory Testing Summary

Project Number: 10252-B

Project Name: Fairfax County Sewer Sags

Date: 11/27/06

Project Engineer: TKM

Principal Engineer: KAH

Summary By: HNT

Boring Number	Sample Number	Depth (feet)	Moisture Content (%)	USCS	Liquid Limit	Plastic Limit	Plasticity Index	Percent Passing No. 200 Sieve	Compaction		CBR Value	Other
									Maximum Density (pcf)	Optimum Moisture (%)		
B-10A	S-1	0-1.5	14.3									
B-10A	S-2	2.5-4.0	23.5									
B-10A	S-3	5.0 - 6.5	27.1	CL	31	19	12	77.0				
B-10A	S-4	8.5 - 10.0	32.8									
B-10A	S-5	13.5 - 15.0	25.6									
B-10A	S-6	18.5 - 20.0	33.2									
B-10A	S-7	23.5 - 25.0	26.2									
B-10A	S-8	28.5 - 30.0	23.7									
B-10A	S-9	33.5 - 35.0	17.2									
B-10A	S-10	38.5 - 40.0	16.2									
B-10A	S-11	43.5 - 45.0	13.1									
B-10A	S-12	48.5 - 50.0	17.7									
B9-A	S-1	0-1.5	19.0									
B9-A	S-2	2.5-4.0	5.1									
B9-A	S-3	5.0 - 6.5	25.2									
B9-A	S-4	8.5 - 10.0	31.4									
B9-A	S-5	13.5 - 15.0	31.2	SM	NP	NP	NP	33.6				
B9-A	S-6	18.5 - 20.0	29.5									
B9-A	S-7	23.5 - 25.0	18.7									
B9-A	S-8	28.5 - 30.0	21.3									
B9-A	S-9	33.5 - 35.0	21.3									

Summary Key:

SA = See Attached
S = Standard Proctor
M= Modified Proctor
V = Virginia Test Method
OC = Organic Content

Hyd = Hydrometer
Con = Consolidation
DS = Direct Shear
GS = Specific Gravity

UCS = Unconfined Compression Soil
UCR = Unconfined Compression Rock
LS = Lime Stabilization
CS = Cement Staibilization

ECS Mid-Atlantic, LLC
Chantilly, Virginia
Laboratory Testing Summary

Date: 11/27/06

Project Number: 10252-B **Project Name: Fairfax County Sewer Sags**

Project Engineer: TKM **Principal Engineer: KAH** **Summary By: HNT**

Boring Number	Sample Number	Depth (feet)	Moisture Content (%)	USCS	Liquid Limit	Plastic Limit	Plasticity Index	Percent Passing No. 200 Sieve	Compaction		CBR Value	Other
									Maximum Density (pcf)	Optimum Moisture (%)		
B9-A	S-10	38.5 - 40.0	9.8									
B9-A	S-11	43.5 - 45.0	10.4									
B9-A	S-12	48.5 - 50.0	8.2									
B6-2A	S-1	0-1.5	12.2									
B6-2A	S-2	2.5-4.0	19.9									
B6-2A	S-3	5.0 - 6.5	23.4									
B6-2A	S-4	8.5 - 10.0	14.5									
B6-2A	S-5	13.5 - 15.0	25.8									
B6-2A	S-6	18.5 - 20.0	26.8	SM	NP	NP	NP	31.1				
B6-2A	S-7	23.5 - 25.0	38.3									
B6-2A	S-8	28.5 - 30.0	35.6									
B6-2A	S-9	33.5 - 35.0	37.8									
B6-2A	S-10	38.5 - 40.0	36.6									
B6-2A	S-11	43.5 - 45.0	44.2									
B6-2A	S-12	48.5 - 50.0	34.2									

Summary Key:

SA = See Attached
S = Standard Proctor
M= Modified Proctor
V = Virginia Test Method
OC = Organic Content

Hyd = Hydrometer
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GS = Specific Gravity

UCS = Unconfined Compression Soil
UCR = Unconfined Compression Rock
LS = Lime Stabilization
CS = Cement Staibilization

ECS Mid-Atlantic, LLC
Chantilly, Virginia
Laboratory Testing Summary

Completed Date: 11/29/06

Project Number: 10252-B

Project Name: Fairfax County Sewer Sags

Project Engineer: TKM

Principal Engineer: KAH

Summary By: HNT

Boring Number	Sample Number	Depth (feet)	Moisture Content (%)	USCS	Liquid Limit	Plastic Limit	Plasticity Index	Percent Passing No. 200 Sieve	Compaction		CBR Value	Other
									Maximum Density (pcf)	Optimum Moisture (%)		
8A-2A	S-10	38.5 - 40.0	46.0									
8A-2A	S-11	43.5 - 45.0	43.3									
8A-2A	S-12	48.5 - 50.0	258.8									

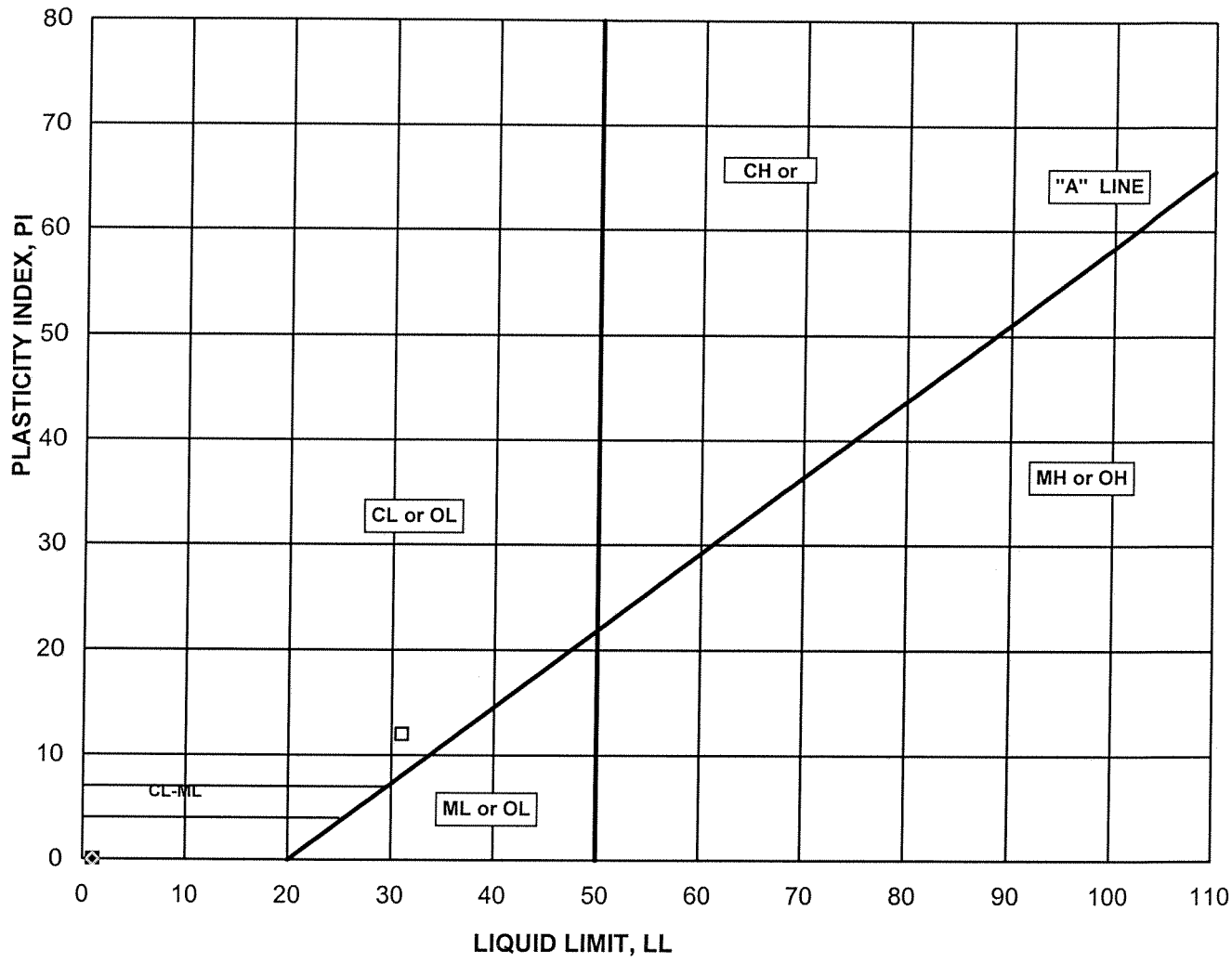
Summary Key:

SA = See Attached
S = Standard Proctor
M= Modified Proctor
V = Virginia Test Method
OC = Organic Content

Hyd = Hydrometer
Con = Consolidation
DS = Direct Shear
GS = Specific Gravity

UCS = Unconfined Compression Soil
UCR = Unconfined Compression Rock
LS = Lime Stabilization
CS = Cement Stabilization

NP = Non Plastic

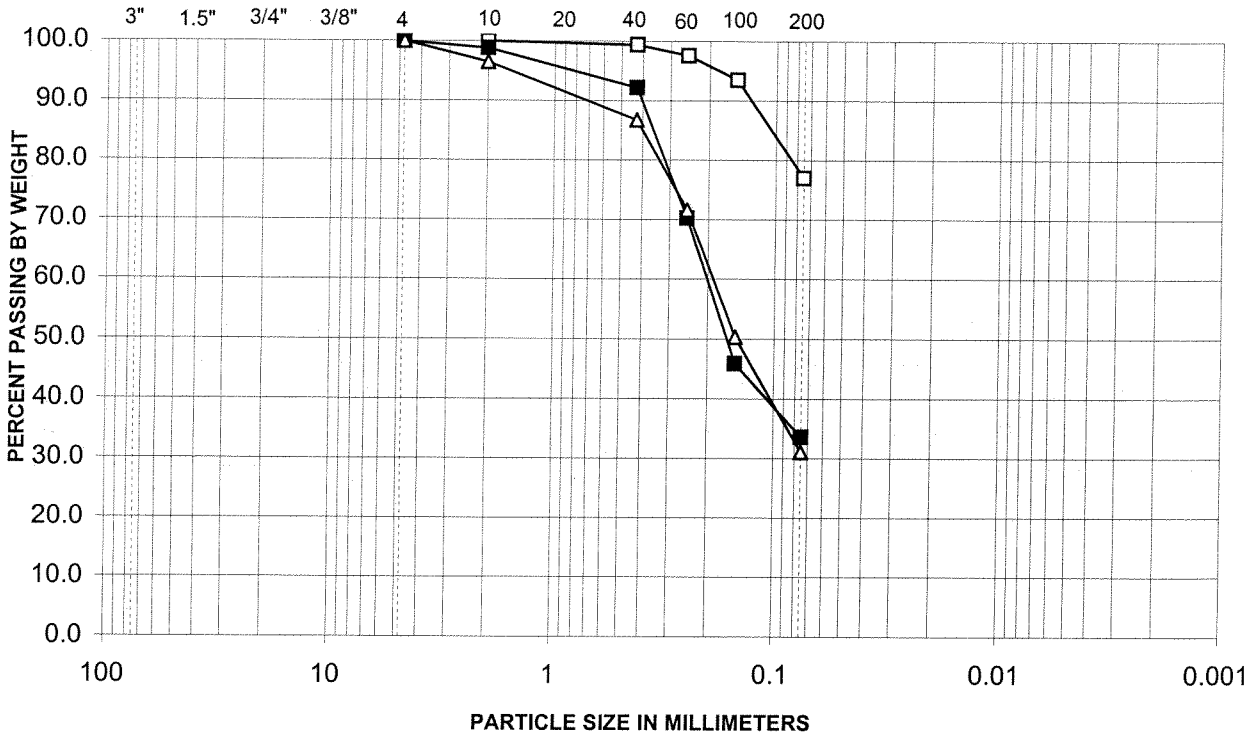


BORING/ SAMPLE No.	DEPTH (feet)	TEST SYMBOL	DESCRIPTION	WATER CONTENT (%)	LL	PL	PI
B-10A / S-3	5.0-6.5	□	Lean Clay w/Sand Tr/Mica Yellowish Brown (CL)	27.1	31	19	12
B9-A / S-5	13.5-15.0	■	Silty Sand Tr/Mica Yellow Brown (SM)	31.2	NP	NP	NP
B6-2A / S-6	18.5-20.0	△	Silty Sand Tr/Mica Grayish Brown (SM)	26.8	NP	NP	NP
/		▲			-	-	-
/		X			-	-	-
/		○			-	-	-
/		●			-	-	-
/		◇			-	-	-
/		◆			-	-	-
/		+			-	-	-
		X|					

Project: Fairfax County Sewer Sags	**ECS Mid-Atlantic, LLC**
Project No.: 10252-B	**Chantilly, Virginia**
Date: 11/22/06	**Plasticity Chart**

COBBLE	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

U.S. STANDARD SIEVE OPENING IN INCHES	U.S. STANDARD SIEVE NUMBERS	HYDROMETER



Boring/ Sample No.	Depth (feet)	Symbol	LL	PI	Description
B-10A S-3	5.0-6.5	□	31	12	Lean Clay w/Sand Tr/Mica Yellowish Brown (CL)
B-9A S-5	13.5-15.0	■	NP	NP	Silty Sand Tr/Mica Yellow L/Brown (SM)
B6-2A S-6	18.5-20.0	△	NP	NP	Silty Sand Grayish Brown (SM)
		▲			

Applicable ASTM: D-422

Project: Fairfax County Sewer Sags

Project No: 10252-B

Performed Date: 11/22/06

ECS MID-ATLANTIC, LLC

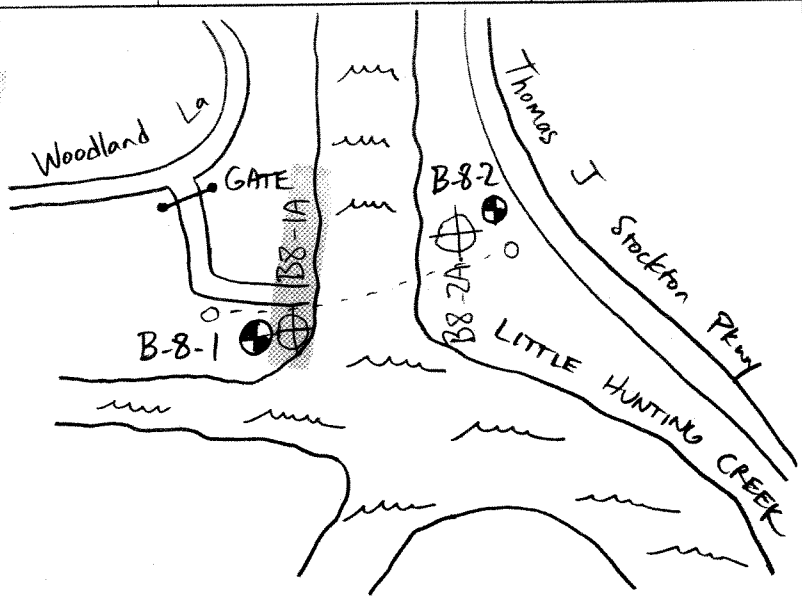
Chantilly, Virginia

Grain Size Analysis

ENGINEERING CONSULTING SERVICES, LTD. CALCULATION SHEET	PROJECT: Fairfax Co Sewer Sags			FIGURE NO.
	TITLE: BLD - Sites 8, 9, 10, 12			JOB NO.
				SCALE:
	BY:	DATE:	APPROVED BY:	DATE

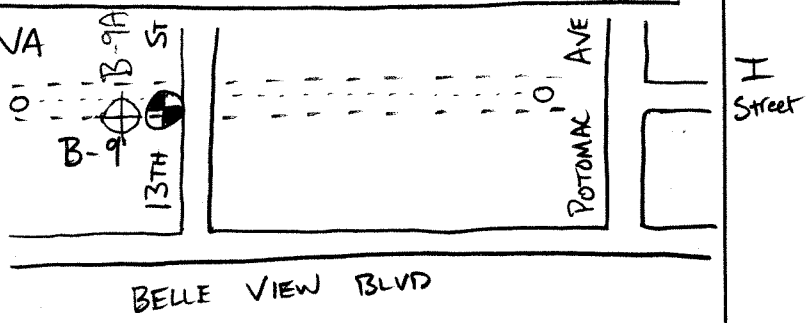
SITE 8: Little Hunting Creek between Woodland Lane + Thomas J. Stockton Parkway

2 Borings: B-8-1
B-8-2



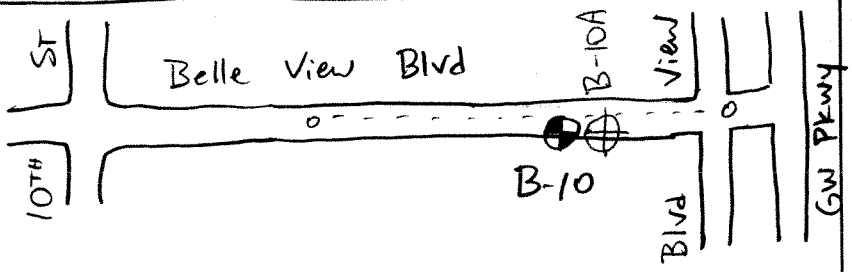
SITE 9: 13th + I Streets, Huntington VA

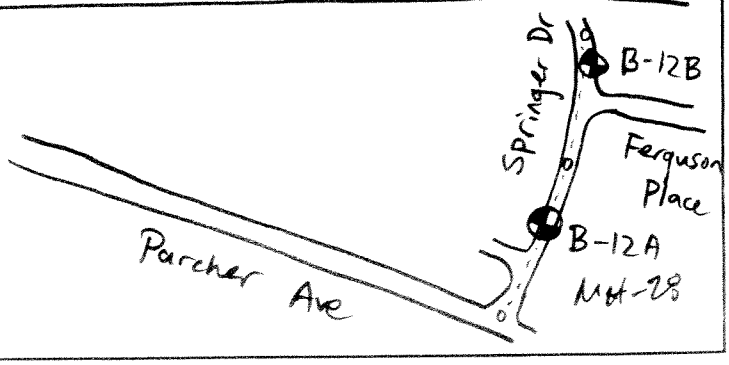
1 Boring: B-9



SITE 10: Belle View Blvd

1 Boring: B-10



SITE 12: Springer Dr, Herndon VA

2 Borings: B-12A
B-12B