Table 6-7: Acquisition for Jones Point Benefit-Cost Results

Total Cost (FMV) of Land + Building	$10,951,000
Other Costs	$329,000
Total Costs	$11,280,000
Total Benefit for Acquisition	$198,000
Benefit-Cost Ratio (BCR)	**0.02**

King Street

The King Street focus area is a commercial area predominantly composed of shops, restaurants, and boutiques with some row houses. In the King Street focus area, 23 commercial and five residential structures are prone to flooding. One residential unit was excluded from this analysis; the unit excluded is attached to a separate row of houses that is not susceptible to flooding. The estimated financial benefit for acquisition of these 28 properties is $4,230,000.

The total estimated cost FMV of land and buildings in the King Street focus area is $85,320,000. The total other costs for residential and commercial properties were an estimated $5,507,000.

The BCA for the King Street focus area is presented in Table 6-8, resulting in a BCR of 0.05. This BCA indicates that property acquisition in King Street would not be cost effective, because the costs outweigh the benefits.

Table 6-8: Acquisition for King Street Benefit-Cost Results

Total Cost (FMV) of Land + Building	$85,320,000
Other Costs	$5,507,000
Total Costs	$90,872,000
Total Benefit for Acquisition	$4,230,000
Benefit-Cost Ratio (BCR)	**0.05**

Waterfront Commercial

The Waterfront Commercial focus area is composed of various commercial buildings including warehouses, parking garages, shops, an office complex, and a gallery. Based on the assumptions outlined in Section 6.5.1, our benefit calculations consider only four properties during the intermediate flood event and 28 properties during the extreme event. The estimated financial benefit for acquisition of these properties is $7,336,000.

The total estimated cost FMV of land and buildings in the Waterfront Commercial focus area is $99,000,000. Because of the variance in average building square footage price, the FMV was determined for each of the 22 commercial properties. The total other costs were an estimated $5,375,000

The BCA for the Waterfront Commercial focus area is presented in Table 6-9, resulting in a BCR of 0.07. This BCA indicates that property acquisition in Waterfront Commercial would not be cost-effective because the costs substantially outweigh the benefits.

Table 6-9: Acquisition for Waterfront Commercial Benefit-Cost Results

Total Cost (FMV) of Land + Building	$99,000,000
Other Costs	$5,375,000
Total Costs	$104,375,000
Total Benefit for Acquisition	$7,336,000
Benefit-Cost Ratio (BCR)	**0.07**

North Union

The North Union focus area is a residential community containing only residential row houses. Thirty-four residential properties were considered feasible for acquisition. The estimated financial benefit for acquisition of these 34 properties is $610,000.

The total estimated cost FMV of land and buildings in the North Union focus area is $18,500,000. The total other costs were an estimated $1,360,000.

The BCA for the North Union focus area is presented in Table 6-10, resulting in a BCR of 0.03. This BCA indicates that property acquisition in North Union would not be cost-effective because the costs substantially outweigh the benefits.

Table 6-10: Acquisition for North Union Benefit-Cost Results

Total Cost (FMV) of Land + Building	$18,500,000
Other Costs for North Union	$1,360,000
Total Costs	$19,860,000
Total Benefit for Acquisition	$610,000
Benefit-Cost Ratio (BCR)	**0.03**

6.6 FLOODPROOFING

Floodproofing provides a variety of methods to protect structures from flood waters. As described in Section 3.1.3, dry floodproofing was selected as the mitigation measure to be assessed further. This section presents the analysis of the dry floodproofing assessment including the assumptions, the potential impacts imposed by this alternative, and the associated permit requirements.

6.6.1 Assumptions

The following assumptions were used to assess floodproofing as a mitigation measure for the four focus areas.

- Only dry floodproofing measures were considered.
- Floodproof membranes and window shields were not included due to the historic nature of the area.

- Not all structures were evaluated for construction elements, such as height of windows, size of doorways, materials used, or the presence of basements.

6.6.2 Potential Impacts

Floodproofing has several potential impacts. Positive impacts include protection of structures and contents from flood damages and improving the communities standing in FEMA's CRS. As discussed in Section 3, the historic structures in Alexandria present significant limitations to the selection of some floodproofing options. Elements such as floodproof doors and windows use materials that are not historically accurate. More discussion related to the historic effects is contained in the permit review below.

6.6.3 Permitting/Approval Requirements

Dependent upon the floodproofing alternatives selected by the property owner, the permitting requirements for floodproofing are only anticipated to cause a moderate level of review effort. Given the historic sensitivity, the local review schedule could take between 4 and 12 months, and any federal review is anticipated to take 12 to 24 months.

Site Plan Approval

Site plan preparation and grading plan approval not is likely to be required for any floodproofing project. However, for patio improvements, if the area of disturbance is greater than 2,500 square feet, a grading plan will be required to be submitted to the City's TES group. Other site plan permits/approvals are not anticipated for floodproofing activities.

Natural Resources

This alternative creates no anticipated natural resource impacts. However, if soil disturbance is required, a permit review should be performed.

Cultural Resources

Aboveground Resources

Each building requires independent review with an exact scope of work to assess the impacts of the specific floodproofing measures proposed for that building. Typically, exterior alterations that replace original fabric and design may adversely affect the look of the building. This can be interpreted to result in a cumulative adverse effect on the physical setting and character of the historic district as a whole. As the historic fabric and integrity of multiple buildings are altered and replaced with historically uncharacteristic materials, the overall integrity of the historic district is diminished.

Archaeological Resources

An archaeological survey would likely not be triggered by this alternative. However, if the process requires access to the area around the foundations or basements of historic structures, this could trigger a Phase I Identification focus (background research and shovel testing of the area of direct effect). If archaeological features were identified as a result of this focus, then a

Phase II (National Register Evaluation) focus would follow. If the archaeological features were found eligible for listing in the National Register and would be adversely affected by floodproofing, then Phase III (Treatment) would be required and would likely involve recordation and data recovery excavations. Since membranes and window shields are not proposed, this review process is unlikely to be required for any of the floodproofing recommendations

6.6.4 Floodproofing Applicability/Benefit-Cost Analysis

This section defines the solutions included in the BCA for floodproofing in each of the four focus areas (Jones Point, King Street, Waterfront Commercial, and North Union) and presents the benefits, costs, and resultant BCR. Note that the King Street Focus Area discussion was separated into commercial and residential areas. For purposes of the BCA, it was assumed that any structure susceptible to the nuisance, intermediate or extreme flood event would need a floodproof option. Secondary glazing of windows and window shields are less expensive than replacement windows, and flood gates are less expensive than custom doors. However, given the historic nature of the study area and the variety of construction styles, cost estimates were inflated to allow for the cost variations seen in custom construction. The costs used to determine BCR for each focus area are shown in Table 6-11. The method for computing the cost for each floodproofing method is described in Appendix K.

Table 6-11: Estimated Costs for Various Floodproofing Methods

Method	Cost/Structure
Flood Gate	$900
Custom Floodproof Door	$10,000
Custom Floodproof Window (residential)	$3,000
Custom Floodproof Window (commercial)	$6,000
Raise Patio/Fill	$8,000
Internal Elevation	Based on Average Square Footage Per Focus Area

Where floodproof doors are practical, they are considered. Flood gates are indicated where a door is not practical. Flood gates could be used in place of floodproof doors throughout, but they are an active system and not as aesthetically appealing. The cost estimate for windows assumes replacement windows with suitable historic features. A less expensive flood barrier could be used for the window, but that would require placement of a product before the flood event occurs, and is not as aesthetically acceptable.

Jones Point

Approximately 17 structures in the Jones Point focus area are at risk of flooding from the extreme flood event. All of these buildings are residential. In some cases, field reconnaissance provided limited access because residents were not home.

Table 6-12 shows the different dry floodproofing options and the approximate number of structures within the Jones Point focus area that might benefit from each. Approximately 15 structures could potentially benefit from a floodproof gate or door. Eight structures have

windows that require protection. In addition, eight structures may benefit from raising the ground elevation at the point of floodwater entry. The recommended floodproofing measure for each structure in the Jones Point focus area, as well as the level of protection it would provide, is shown on Figure 6-9.

Table 6-12: Floodproofing Options for Jones Point: 17 Residential Structures

Method	Cost / Structure	Number of Structures
Flood Gate	$900	15
Floodproof Openings		
Door	$10,000	14
Window	$3,000	8
Raise Patio/Fill	$8,000	8

For purposes of determining the benefit cost ratio, the most expensive dry floodproofing plan for Jones Point was considered. The most expensive floodproofing option considered is replacing all doors and windows that are below the flood elevation with floodproof doors and windows.

As shown in Table 6-13, the floodproofing BCA results in a BCR of 1.0. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used in the Jones Point focus area will also be cost effective.

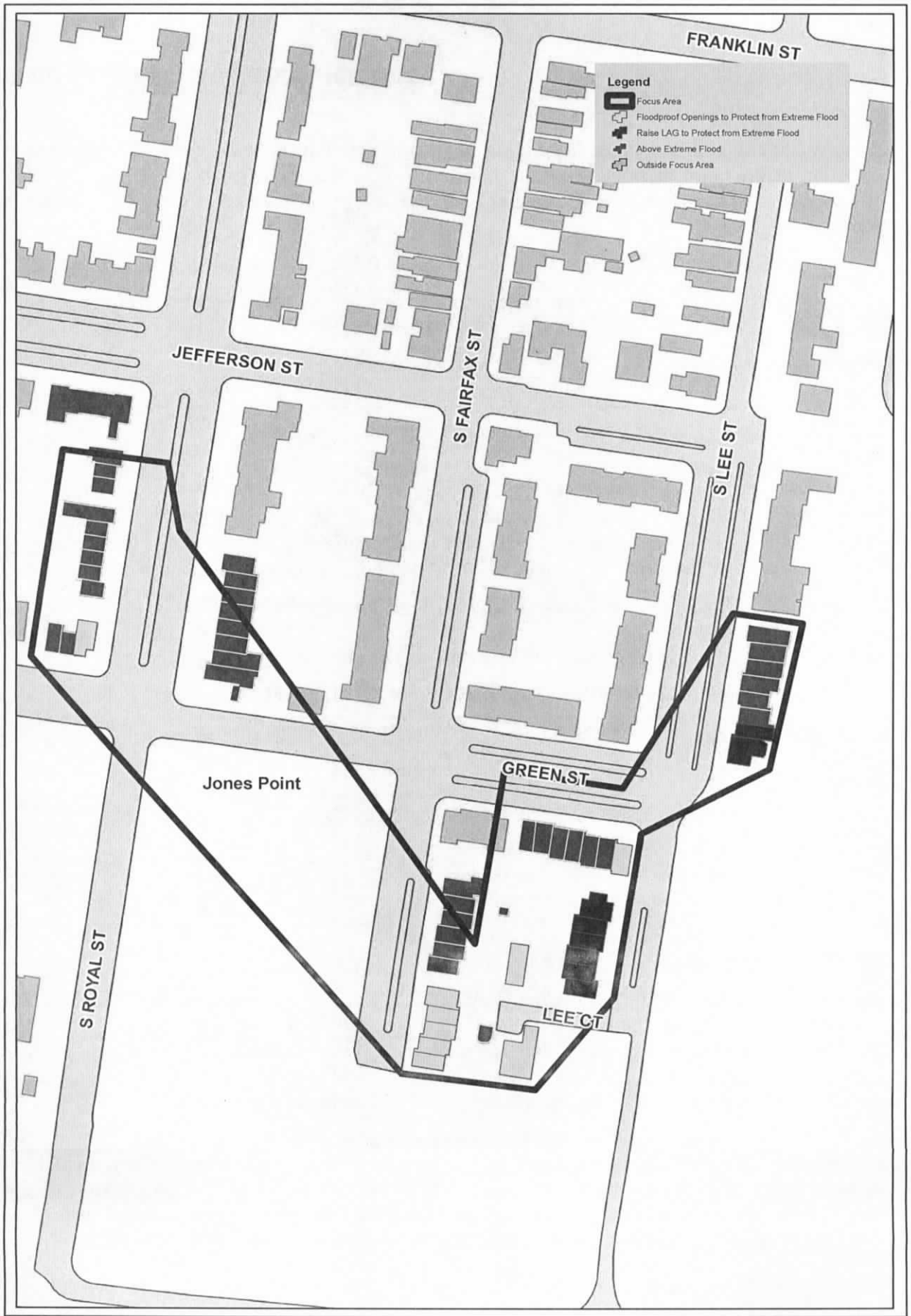
Table 6-13: Cost Ratio for Jones Point: 17 Residential Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Flood Gate	$900	3	1.5	$4,000
Floodproof Openings				
Door	$10,000	14	1.5	$210,000
Window	$3,000	8	1	$24,000
			Total Cost =	**$238,000**
			Total Benefit =	**$231,000**
			BCR =	**1.0**

King Street Commercial

Approximately 29 structures within the King Street focus area are predicted to flood from the extreme flood event. Of these 29 structures, 23 are commercial structures. About 13 of these structures experience extreme flood depths greater than 3 feet. Therefore, dry floodproofing will not protect these structures from the extreme flood event. However, the depth of flooding from the intermediate flood event is less than 3 feet for all 23 commercial structures.

Table 6-14 shows the different dry floodproofing options and the approximate number of commercial structures within the King Street focus area that might benefit from each. It is estimated that all 23 structures could benefit from floodproof doors and windows. Most of the structures could make use of a flood gate, but floodproof doors are recommended instead of floodgates for commercial properties because they are a passive system of flood protections.



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	JEA	09/22/09
SCALE	1 inch = 100 feet	DR BY	JEA	09/24/09
W:\City of Alexandria\15298470 - Lower King St\Task 3 Report Final\Figures\MXDs\F6-9 Jones_Point_Area.mxd		CHK BY	MER	10/04/09

TITLE: Jones Point Focus Area Floodproofing Options

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO: 15298592

FIGURE: 6-9

There are approximately eight commercial structures within this focus area where internal elevation appears to be feasible. These include the following: 100 King Street, Windsor Studio, Ben & Jerry's, Firehook Bakery, Art Craft, Old Town Trading Post, The Small Mall, and Christmas Attic.

For those structures where internal elevation is not feasible, floodproofing of the doors and windows is recommended. The commercial structures in the King Street focus area typically have two doors and two or three windows that need flood protection.

Table 6-14: Floodproofing Options for King Street: 23 Commercial Structures

Method	Cost/Structure	Structures for Benefits
Flood Gate	$900	23
Floodproof Openings		
Door	$10,000	23
Window	$6,000	23
Internal Elevation	$105,000	8

Internal elevation is recommended for eight properties. The remaining 15 properties are estimated with floodproof doors and windows. Although dry floodproofing is generally recommended for up to a depth of 3 feet of flooding, it is usually not possible to internally elevate a structure 3 feet. The height of the ceiling will limit how far the floor can be raised. Therefore, the recommendation assumes that internal elevation can raise the first floor elevation by 1 foot. The recommended floodproofing measure for each structure in the King Street focus area, as well as the level of protection it would provide, is shown on Figure 6-10. It is important to note that floodproofing of the doors and windows can be used instead of internal elevation and could provide up to 2 more feet of protection in conjunction with internal elevation. However, internal elevation is more reliable because it does not require maintenance.

As shown in Table 6-15, the floodproofing BCA results in a BCR of 4.7. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used in the commercial structures in the King Street focus area will also be cost effective.

Table 6-15: Benefit Cost Ratio for King Street: 23 Commercial Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Floodproof Openings				
Door	$10,000	15	2	$300,000
Window	$6,000	15	2.5	$225,000
Internal Elevation	$105,000	8	1	$837,000
			Total Cost =	**$1,362,000**
			Total Benefit =	**$6,337,000**
			BCR =	**4.7**

King Street Residential

Of the 29 structures within the King Street focus area described above, six are residential. These are along Prince Street, near the intersection with South Union Street. Only one of these, 100 Prince Street, has an extreme flood depth greater than 3 feet. Therefore, all the rest can be floodproofed to protect from the extreme storm.

Table 6-16 below shows the different dry floodproofing options and the approximate number of residential structures within the King Street focus area that might benefit from each. For example, approximately two structures could benefit from raising the lowest adjacent grade, which is estimated to cost about $8,000 per building. Our topography indicates that these structures may be at risk of flooding from the back of the buildings. However, our field reconnaissance team did not have access to the back of these buildings to determine if there are any points of entry there. It is assumed that placing fill to raise a back patio may be an option for some of the structures.

Two of these structures had low front windows that would need floodproofing. The other four structures would only need the doors floodproofed. Also, it was assumed that some of the structures have back doors and windows that are low points of entry. The recommended floodproofing measure for each structure in the King Street focus area, as well as the level of protection it would provide, is shown on Figure 6-10.

Table 6-16: Floodproofing Options for King Street: 6 Residential Structures

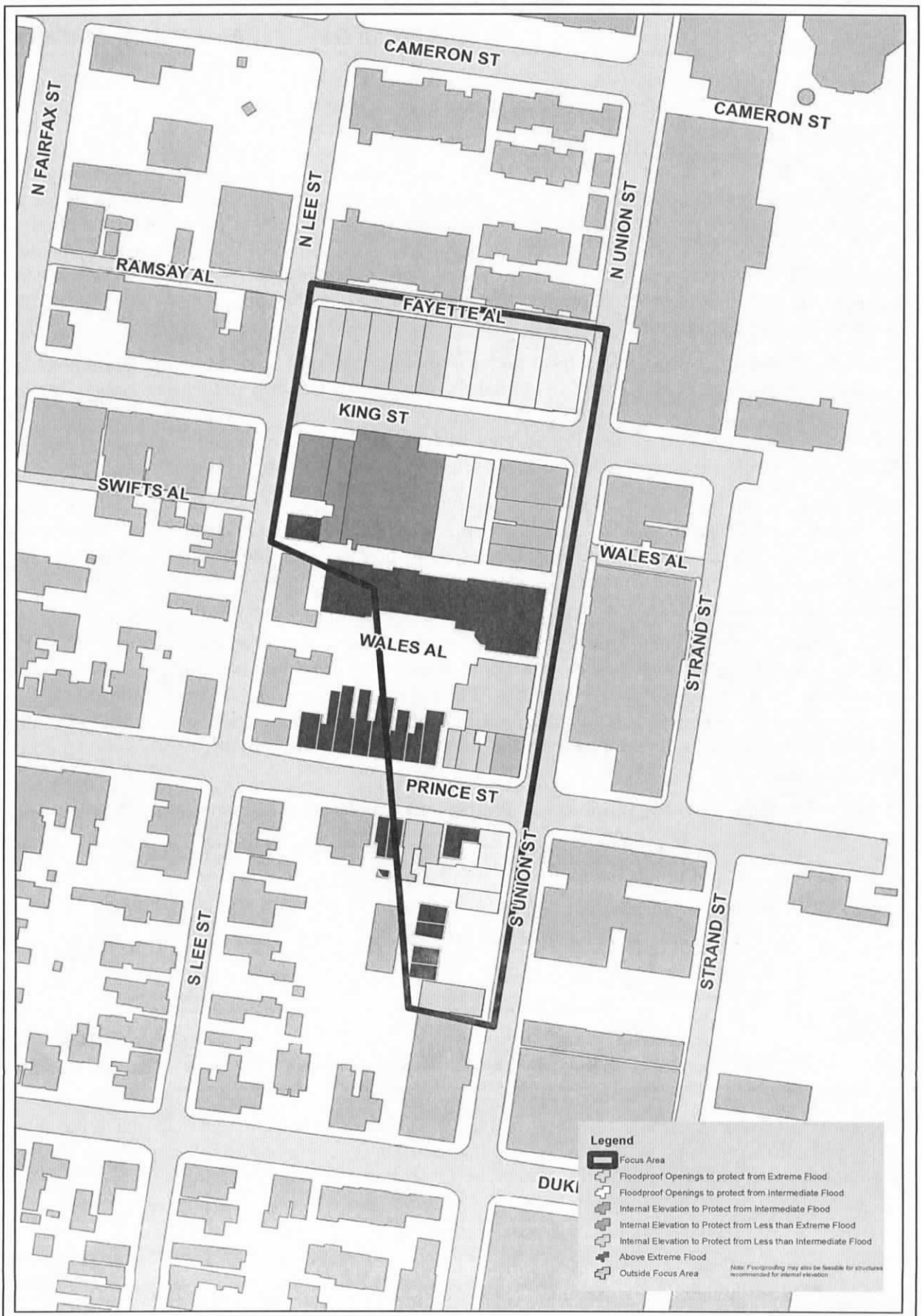
Method	Cost/Structure	Structures That Could Benefit
Flood Gate	$900	6
Floodproof Openings		
Door	$10,000	6
Window	$3,000	2
Raise Patio/Fill	$8,000	2

Because the most expensive floodproofing scenario is to floodproof the doors and windows, it was assumed that this technique would be used whenever feasible.

As shown in Table 6-17, the floodproofing BCA results in a BCR of 11.6. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used for residential structures in the King Street focus area will also be cost effective.

Table 6-17: Benefit Cost Ratio King Street: 6 Residential Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Floodproof Openings				
Door	$10,000	6	1.33	$80,000
Window	$3,000	2	3.00	$18,000
			Total Cost =	**$98,000**
			Total Benefit =	**$1,134,000**
			BCR =	**11.6**



CLIENT	City of Alexandria				
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	JEA	09/22/09	
SCALE	1 inch = 100 feet	DR BY	xxx	00/00/00	
W:\City of Alexandria\15298470 - Lower King St\Task 3\Report Final Figures\MXDs\F6-10 King Street Area.mxd		CHK BY	xxx	00/00/00	

0 25 50 100 Feet

TITLE: King Street Focus Area Floodproofing Options

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 6-10

Waterfront Commercial

Approximately 22 structures in the Waterfront Commercial focus area would flood during the extreme storm. About 16 of these have an extreme flood depth greater than 3 feet and thus can not be floodproofed from the extreme flood. However, approximately 14 of the 18 structures that are susceptible to the intermediate flood can be floodproofed from this flood event. Only two structures in this focus area are impacted by nuisance flooding, and both can be floodproofed. None of these structures have basements, and it is assumed that they do not have openings below the first floor elevation.

Table 6-18 shows the different dry floodproofing options and the approximate number of structures within the Waterfront Commercial focus area that might benefit from each measure. Approximately 22 structures could benefit from floodproofing the doors and windows. Most of the structures could use a flood gate, but floodproof doors are recommended instead of floodgates for commercial properties because they are a passive system of flood protection.

Eight buildings in the Waterfront Commercial focus area that are at risk of flooding appear to be candidates for internal elevation. These include Alexandria Marine, Art League, Robinson South Terminal, the street level shops on Union Street, and Chadwicks. In addition, the shops on Strand Street (Potomac Riverboat/chiropractor/Idea Sciences) appear to have suspended ceilings. They may be candidates for internal elevation if the suspended ceiling height can be raised.

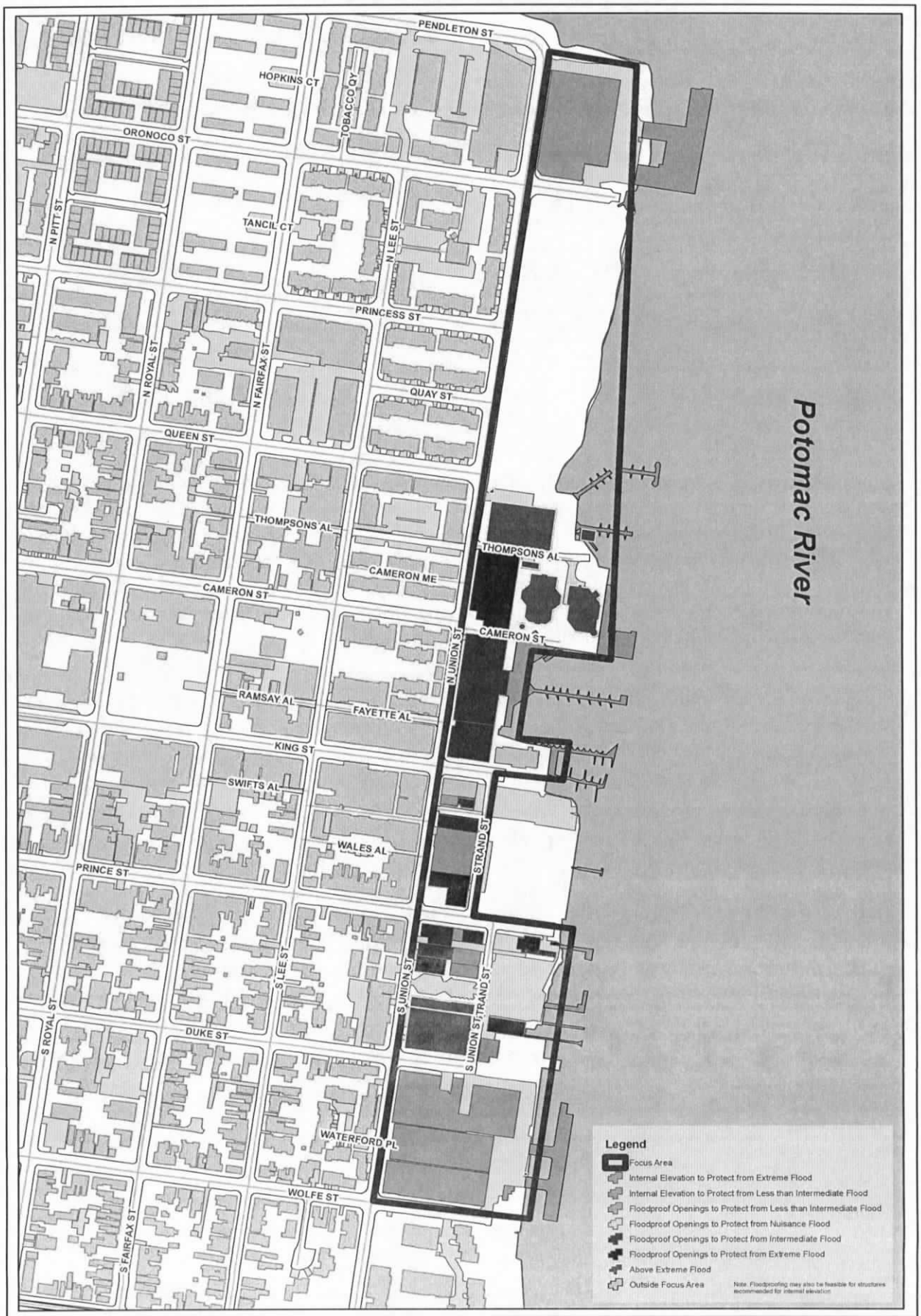
Raising the lowest adjacent grade is not feasible in this focus area, because most of these structures would be inundated by floodwater on all sides. The remaining structures tend to have two doors and several windows close to the FFE; therefore, those openings are recommended for floodproofing. The recommended floodproofing measure for each structure in the Waterfront Commercial focus area, as well as the level of protection it would provide, is shown on Figure 6-11.

Table 6-18: Floodproofing Options for Waterfront Commercial: 22 Commercial Structures

Method	Cost/Structure	Structures That Could Benefit
Flood Gate	$900	22
Floodproof Openings		
Door	$10,000	22
Window	$6,000	22
Internal Elevation	$646,000	6

Because the most expensive floodproofing scenario is internal elevation, it was assumed that this technique would be used whenever feasible.

As shown in Table 6-19, the floodproofing BCA results in a BCR of 2.41. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used for the Waterfront Commercial focus area will also be cost effective.



CLIENT	City of Alexandria		
PROJ	Potomac River Waterfront Flood Mitigation Study		
REVISION NO	0	DES BY	CJL
SCALE	1 inch = 250 feet	DR BY	CJL
W:\City of Alexandria\15298470 - Lower King St\Task 3 Report Final\Figures\MXDs\F6-11 Waterfront_Area.mxd		CHK BY	MER
		09/11/09	
		09/24/09	
		10/04/09	

0 65 130 260 Feet

TITLE: Waterfront Focus Area Floodproofing Options

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO: 15298592

FIGURE: 6-11

Table 6-19: Benefit Cost Ratio for Waterfront Commercial: 22 Commercial Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Floodproof Openings				
Door	$10,000	16	2	$160,000
Window	$6,000	16	3	$96,000
Internal Elevation	$646,000	6	1	$3,874,000
			Total Cost =	**$2,790,000**
			Total Benefit =	**$6,728,000**
			BCR =	**2.41**

North Union Street

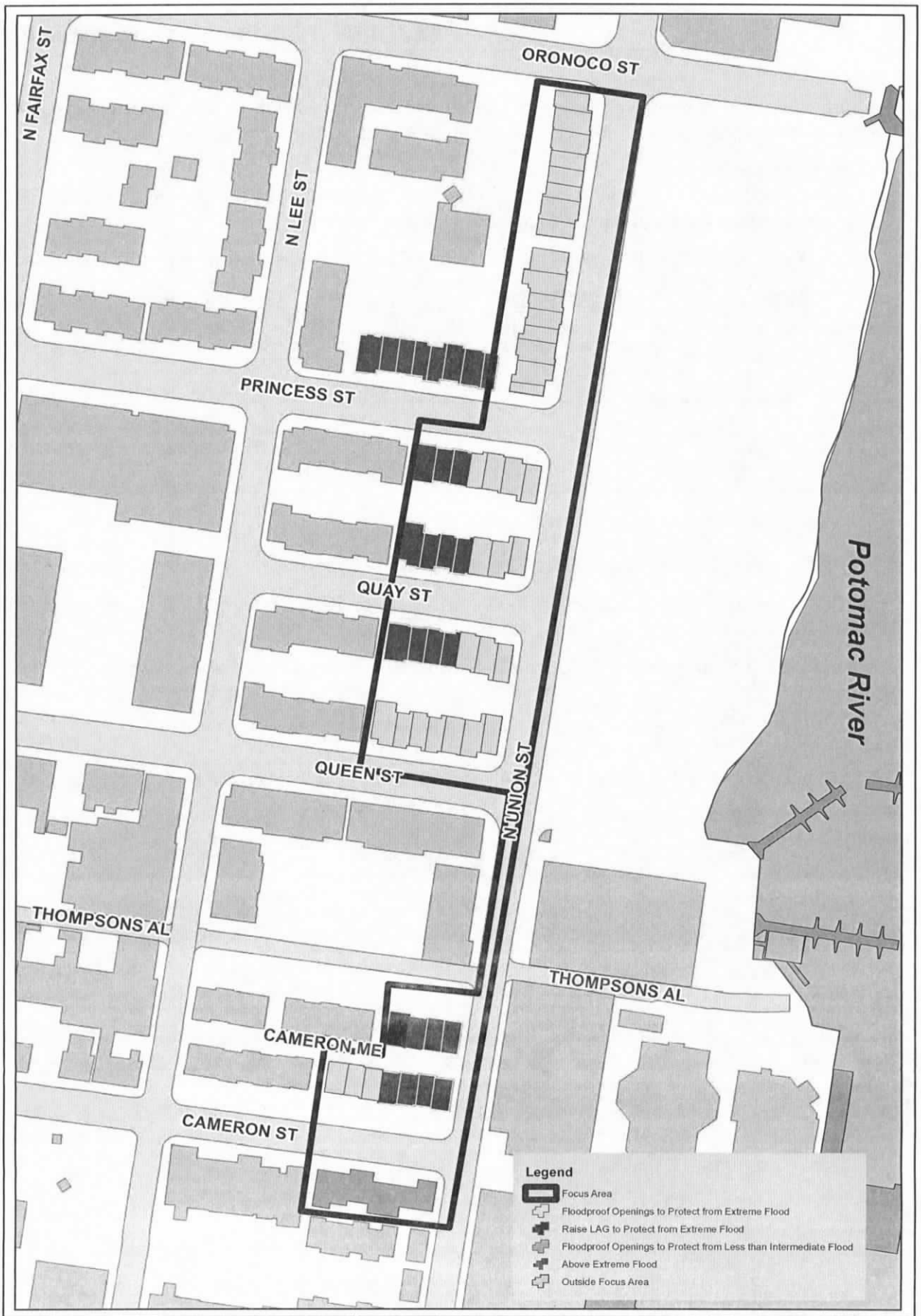
Approximately 37 structures (including 9 apartments) within the North Union Street focus area would flood during the extreme storm. Many of these have basements; however, as noted previously, floodproofing for structures with basements is recommended on a case-by-case basis. Most of these buildings have extreme flood depths less than 3 feet and can be protected from the extreme flood by dry floodproofing. The only exceptions are the Torpedo Factory Apartments. The apartments themselves are above the extreme flood elevation. However, there is storage space at ground level that is susceptible to the intermediate and extreme floods.

Based on the available topographic data, it appears that the structures in this focus area would flood from water coming off the street. Therefore, it is not necessary to consider floodproofing the back of the structures. A potential exceptions to this are the houses along Cameron Mews, because these structures are vulnerable to flooding from Cameron Street and Thompsons Alley. Many of the structures in the North Union Street focus area have garages that would flood. Floodgates are likely the only available option for floodproofing garage doors.

Table 6-20 provides the different dry floodproofing options and the approximate number of structures within the North Union Street focus area that might benefit from each. Most of the structures could make use of a flood gate for the garage. All of these buildings are row houses. Therefore, all units that are at risk of flooding within the row need to be floodproofed. The only unit in its row to be at risk of flooding is 107 Cameron Mews. Therefore, both floodproofing the points of entry or raising the lowest adjacent grade are reasonable options for this unit. The recommended floodproofing measure for each structure in the North Union Street focus area, as well as the level of protection it would provide, is shown on Figure 6-12.

Table 6-20: Dry Floodproofing Options for North Union: 37 Residential Structures

Method	Cost/Structure	Structures That Could Benefit
Flood Gate	$900	37
Floodproof Openings		
Door	$10,000	37
Raise Patio/Fill	$8,000	1



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	JEA	09/22/09
SCALE	1 inch = 100 feet	DR BY	xxx	00/00/00
W:\City of Alexandria\15298670 - Lower Eng 30\Task 8 Report\Final Figures\MXD\8-F6-12 North Union Area.mxd		CHK BY	xxx	00/00/00

0 25 50 100 Feet

TITLE: North Union Focus Area Floodproofing Options

URS 200 Orchard Ridge Drive Gaithersburg, MD 20878

PROJ NO 15298592

FIGURE 6-12

Because the most expensive floodproofing scenario is to install floodproofed doors and windows, it was assumed that this technique would be used whenever feasible.

As shown in Table 6-21, the floodproofing BCA results in a BCR of 1.29. Because the most expensive floodproofing scenario is cost effective, any combination of dry floodproofing techniques used for the North Union focus area will also be cost effective.

Table 6-21: Benefit Cost Ratio for North Union: 37 Residential Structures

Method	Cost/Structure	# Structures	Units/Structure	Total Cost
Flood Gate	$900	25	2	$34,000
Floodproof Openings				
Door	$10,000	40	1.33	$532,000
			Total Cost =	$568,000
			Total Benefit =	**$734,000**
			BCR =	**1.29**

6.6.5 Floodproofing Applicability for Repetitive Loss Properties

Specific information for application of floodproofing for repetitive loss properties is summarized in Table 6-22 below.

Table 6-22: Summary of Floodproofing Applicability for Repetitive Loss Properties

Repetitive Loss Property	First floor Elevation (NAVD88)	Internal Elevation	Raise the LAG	Floodproof Openings
1 King Street (Boat Club)	3.75 feet	Not applicable due to ceiling height	Not applicable as the structure is susceptible to flooding on all sides	Potential option
6 King Street (Mai Thai / Starbucks)	3.51 feet	Not applicable due to ceiling height	Not applicable as the structure is susceptible to flooding on all sides	Potential option
101 King Street (Conrad's Furniture)	5.01 feet	Not applicable due to ceiling height	Not applicable because FFE is above sidewalk	Potential option
104 South Union	4.50 feet	Not applicable due to ceiling height	Not applicable as the structure is susceptible to flooding on all sides	Potential option
120 Cameron Street	4.6 feet	Not applicable as the lowest finished floor is above the extreme flood elevation	Not applicable as the lowest finished floor is above the extreme flood elevation	Potential option

SECTION SEVEN: RECOMMENDATIONS

7.1 OVERVIEW OF RECOMMENDATIONS

Ten flood mitigation measures were analyzed in detail. Because no clear single measure provides flood protection for the entire project area and is technically feasible without extensive resulting impacts, this section recommends a series of options for each of the focus areas. Table 7-1 provides descriptions of the ten flood mitigation measures for which a detailed evaluation was conducted. The measures are not applicable for all structures or focus areas, and the measures have limitations on their use as described in the previous sections. Table 7-1 summarizes the limitations for each mitigation measure and lists the focus areas that benefit from each measure.

Table 7-1: Applicability of Flood Mitigation Measures

Description	Limitations	Recommended Focus Area
Floodproofing	Applicable for flood depths of less than 3 feet for structures with no basements	All
Acquire properties	Applicable for stand alone structures or where all attached units in the structure are affected by flooding	Not recommended
Elevate structures	Applicable for wood structures, single-story structures. Not recommended for historic structures	Not recommended
Floodwall	High project costs and significant aesthetic and humanistic impacts	Waterfront Commercial, King Street
Jones Point berm	High project costs	Not recommended
Elevated walkway	Maximum height of pedestrian floodwall is 6.0 feet NAVD, which does not protect against large storms	Waterfront Commercial King Street
Inlet and road elevation improvements	Adjacent curbs and building entrances limit level of protection	King Street
Relocate internal supplies	Most applicable in commercial establishments	Waterfront Commercial King Street
Floodplain and zoning ordinance recommendations	No limitations	All
Sandbag program improvements	No limitations	All

The remainder of this section presents the recommendations in the following order: focus areas, floodwall, and nonstructural options. The floodwall and nonstructural measures are discussed after the focus area discussion because they protect multiple focus areas.

7.2 KING STREET

Elevated Walkway

The elevated walkway is recommended as the primary flood mitigation measure for this focus area. This flood control project protects up to the 10-year flood event, and the reduced height and design of the walkway are more aesthetically pleasing than the floodwall. The elevated walkway does not significantly impact the Potomac River viewshed. Figures 7-1, 7-2, and 7-3 show visualizations of the proposed walkway. These visualizations are examples of a potential configuration for the walkway. The low profile floodwall at elevation 6 feet (NAVD 88) is the critical flood control element for the elevated walkway. This option allows for a new pedestrian pathway that can be implemented in conjunction with the Waterfront Plan improvements. It would significantly reduce the frequency of sandbagging efforts and road closures in the downtown area.

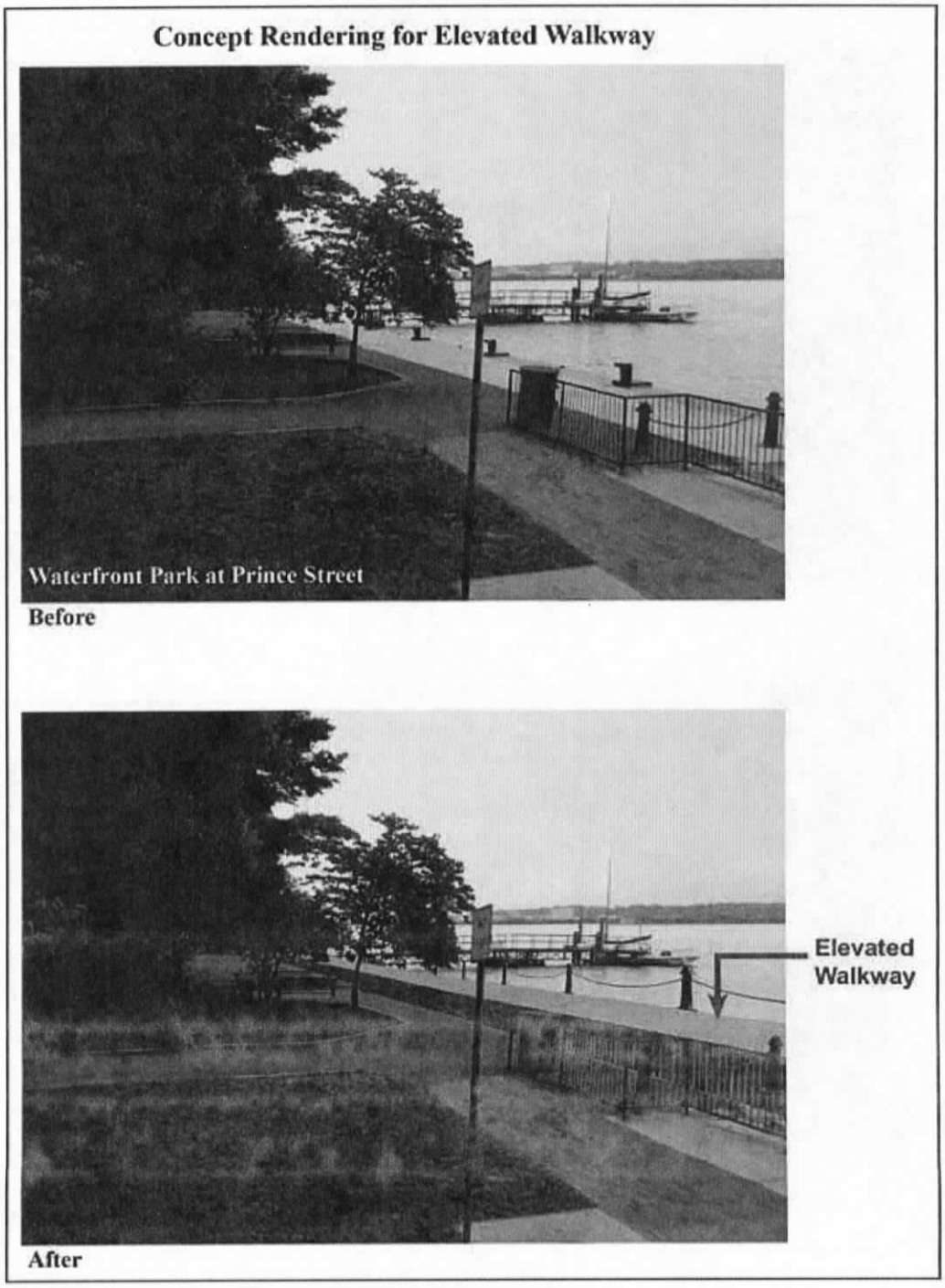


Figure 7-1: Elevated Walkway at Waterfront Park (View 1)

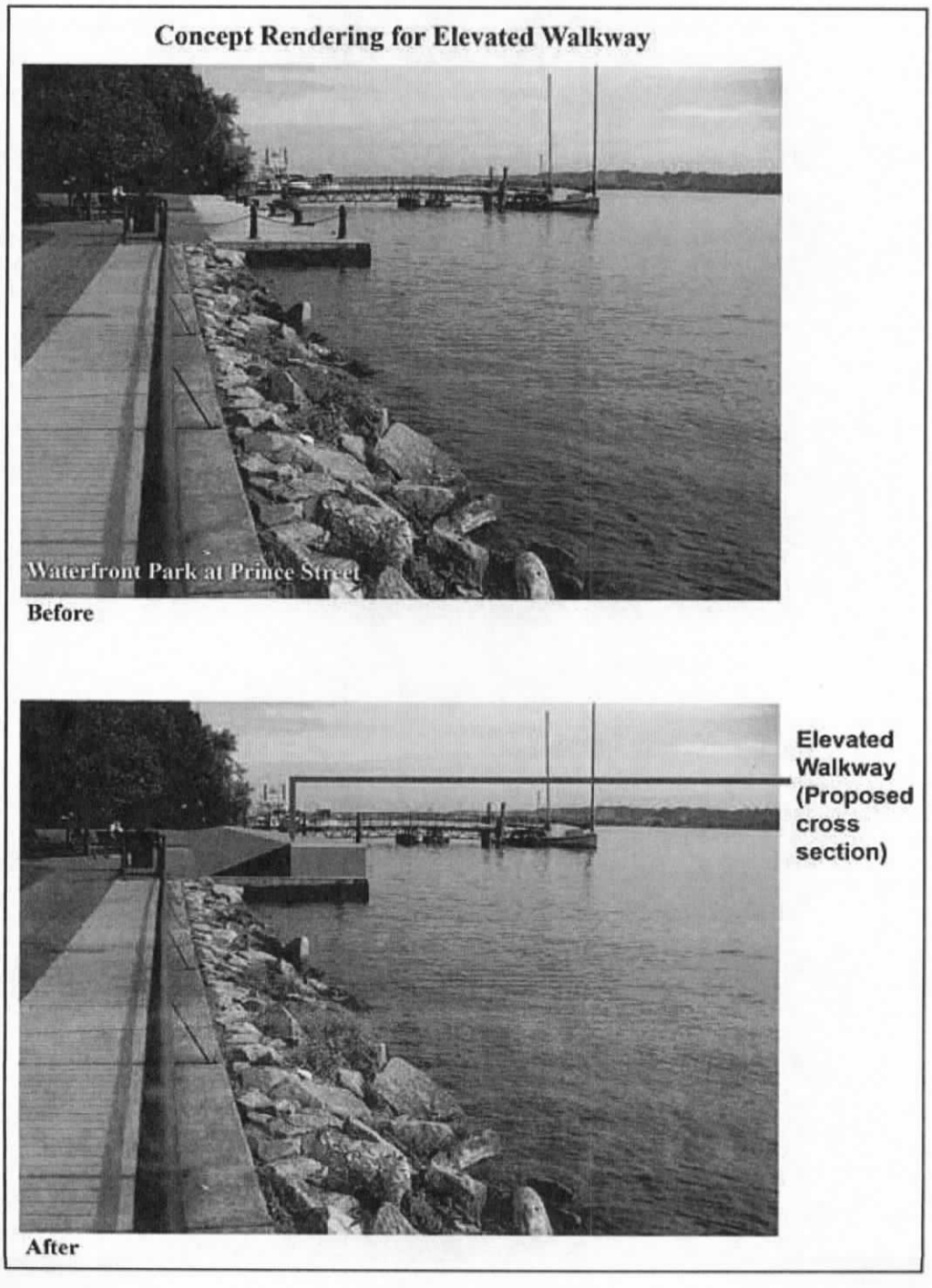


Figure 7-2: Elevated Walkway at Waterfront Park (View 2)

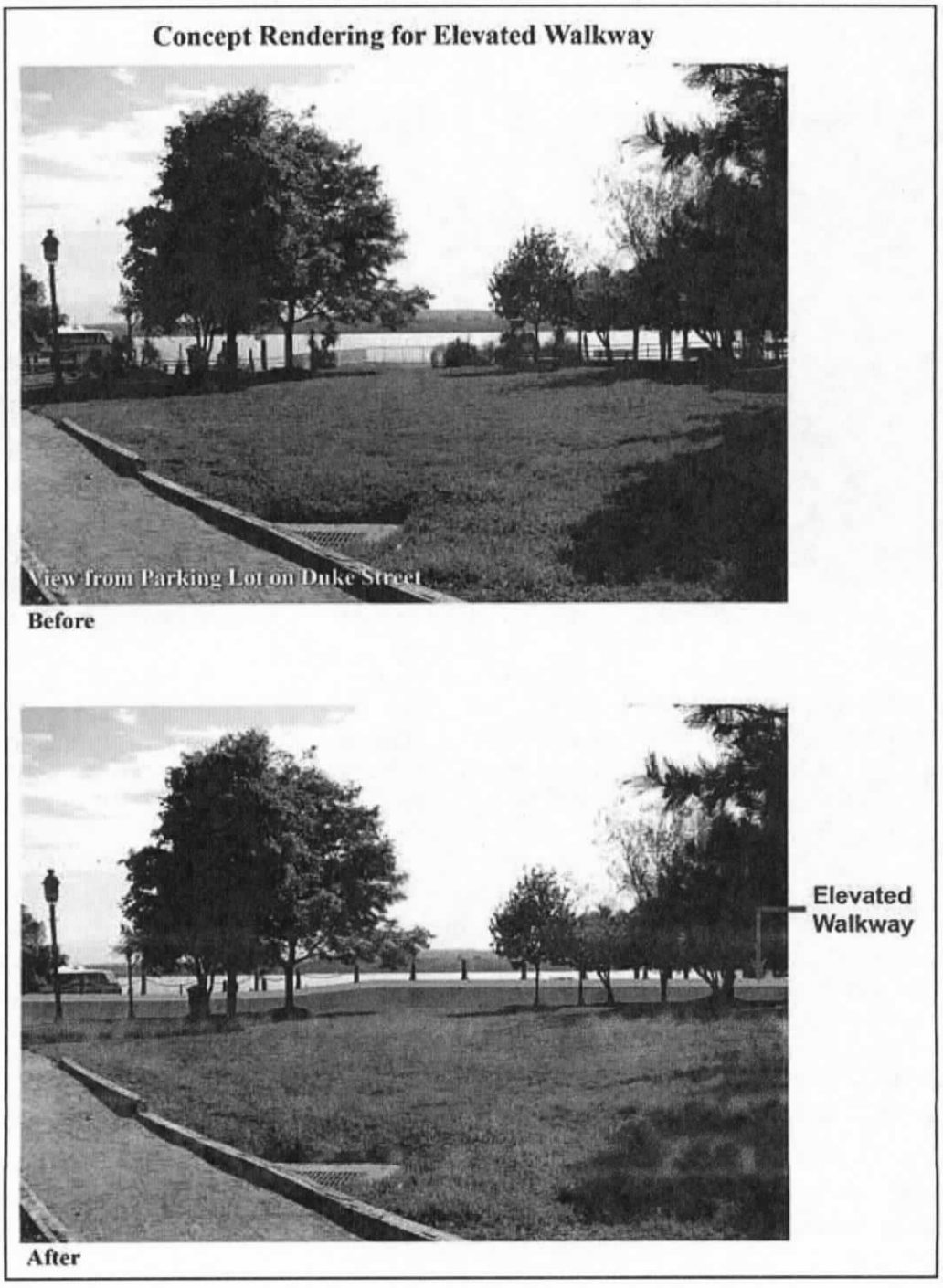


Figure 7-3: Elevated Walkway at Park South of Parking Lot on Strand Street

The elevated walkway is limited in that it only provides protection for up to the 10-year flood event (elevation 6.0 feet NAVD). Figure 7-4 shows a rendering of the before and after inundation at The Strand during the 10-year flood event.

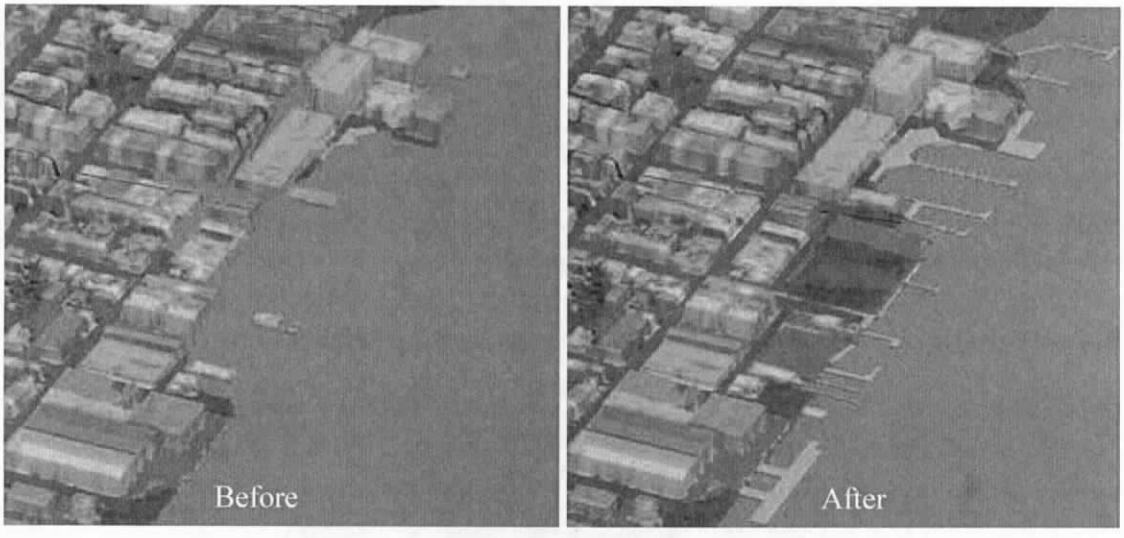


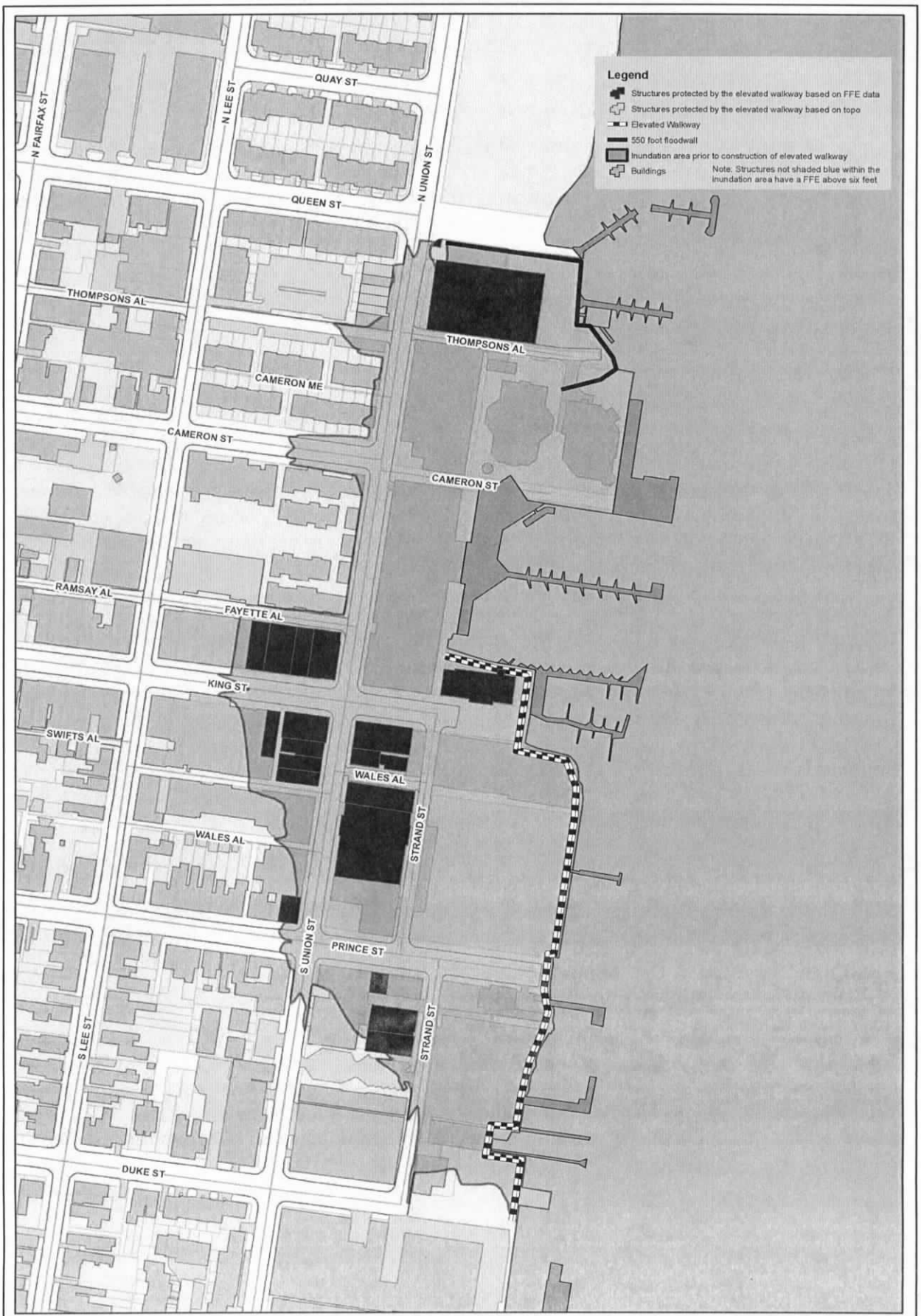
Figure 7-4: 10-Year Flood Inundation Before and After Elevated Pedestrian Walkway

Figure 7-5 shows the structures that are predicted to be protected by the elevated walkway. The proposed elevated walkway protects approximately one-third of the structures in the King Street focus area. In addition, this measure significantly reduces the frequency of road flooding in the vicinity of Strand Street.

Floodproofing

Floodproofing is recommended to provide protection for all the commercial structures. As discussed throughout the report, the historic nature of the area poses challenges to floodproofing. However, it is an effective option for property owners to protect building contents. The recommendation consists of a combination of internal elevation of commercial buildings and floodproofing openings, with gates and custom floodproof doors and windows. There are approximately eight commercial structures within this focus area where internal elevation would be feasible, including 100 King Street, Windsor Studio, Ben & Jerry's, Firehook Bakery, Art Craft, Old Town Trading Post, The Small Mall, and Christmas Attic.

For historic brick structures, waterproof membranes to cover the outside of the structures are not recommended. Residential structures in the focus area that have basements will need to be considered separately to determine the applicability of floodproofing measures for those structures.



CLIENT	City of Alexandria				
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	CJL	09/11/09	
SCALE	1 inch = 150 feet	DR BY	CJL	09/24/09	
W:\City of Alexandria\15298670 - Lower King St\Task 3\Report\Final Figures\MXDs\F3-5 Buildings Protect by Elevated Walkway.mxd		CHK BY	MER	10/04/09	

TITLE: Structures Predicted to be Protected by the Proposed Elevated Walkway

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO: 15298592

FIGURE: 7-5

King/Strand Street Intersection Roadway Improvements

It may be many years before construction of the elevated walkway is complete. Through that timeframe, the King/Strand Street area roadways will continue to be closed for storm events that are less than the nuisance event. The roadway improvement project is relatively simple and has a low cost compared to the other alternatives. As a result, it is recommended that the City consider implementing this alternative as described in the conceptual design presented in Section 6.7 as an interim flood mitigation measure.

7.3 WATERFRONT COMMERCIAL

Elevated Walkway

As mentioned above, the elevated walkway is recommended as the primary flood mitigation measure for this study area. The elevated walkway provides protection for up to the 10-year (elevation 6.0 feet NAVD88) flood event for seven buildings in this study area with FFEs below 6.0 feet. Because most of the flood damages occur at the more frequent events, the elevated walkway provides substantial benefits as compared to the cost of the project, as seen by the BCR. Additionally, some of the aesthetic and viewshed issues with the larger floodwall (discussed below) are not present.

Floodproofing

While the proposed elevated walkway does not protect all structures in the Commercial Waterfront focus area, the floodproofing option could protect commercial structures up to the intermediate storm event, with the exception of the Mai Thai Restaurant, Starbucks, and Old Dominion Boat Club. As discussed throughout the report, the historic nature of the area poses challenges to floodproofing. However, it is an effective option for property owners to protect building contents. The recommendation for the entire area is floodproofing openings with gates and custom floodproof doors and windows. During field visits, the low floor to ceiling heights within the buildings eliminated internal elevation from consideration.

For historic brick structures, waterproof membranes to cover the outside of the structures are not recommended. Floodproofing through internal elevation and covering openings is also an option, although the flooding depths are greater in this area, so the method is not applicable for as many structures as in the King Street focus area. Residential structures that have basements will need to be considered separately to determine the applicability of floodproofing measures for those structures.

Acquisition

Acquisition is not generally recommended in this study because it is not a cost-effective alternative. However, the City recently purchased waterfront properties as part of the waterfront redevelopment initiative. The City may decide to acquire additional waterfront properties as part of the waterfront initiative. The purpose of the acquisition in this case is economic development rather than flood mitigation.

7.4 NORTH UNION

Floodproofing is recommended for this study area, primarily through covering openings. This is a cost-effective and low-impact solution of flood protection for this study area. As discussed throughout the report, the historic nature of the area poses challenges to floodproofing. However, it appears to be an effective option for property owners to protect building contents. Residential structures that have basements will need to be considered separately to determine the applicability of floodproofing measures for those structures.

7.5 JONES POINT

Floodproofing is recommended for this study area, primarily through covering openings. The floodproofing option could protect all the residential structures that are impacted by flooding of up to the extreme flood event. As discussed throughout the report, the historic nature of the area poses challenges to floodproofing. However, it is an effective option for property owners to protect building contents. The recommendation consists of a combination of localized flood barriers (e.g. raised patios) and floodproofing openings, with gates and custom floodproof doors and windows.

For historic brick structures, waterproof membranes to cover the outside of the structures are not recommended. Residential structures in the focus area that have basements will need to be considered separately to determine the applicability of floodproofing measures for those structures.

7.6 FLOODWALL

Our preliminary investigations show that the floodwall is a technically feasible solution that provides protection for all of the structures in the King Street focus area, all but one structure in the Waterfront Commercial focus area, and the Cameron Mews portion of the North Union focus area from the nuisance, intermediate, and extreme flood events. The floodwall would remove the repetitive loss properties from the floodplain. While the floodwall is not as cost effective as the other alternatives analyzed, it is technically feasible. Additionally, it is the only option for the King Street focus area that effectively provides protection against the 100-year flood event.

However, the floodwall may not be a palatable option for area businesses, residents, and tourists. Its substantial viewshed and aesthetic impacts may prevent this measure from gaining public support. Because residential and commercial access to the river is an essential part of the Alexandria economy, those are also important considerations. An additional factor is the potential for increased City liability, specifically if redundant systems fail and residential structures flood. Figures 7-5 and 7-6 illustrate the visual impact of the proposed floodwall concept.

Another important aspect for consideration of the floodwall is that the BCR is low due to the high cost of the project. In comparison, the elevated walkway cost-effectively provides protection against the frequent storm events and has a high BCR. It is recommended that the floodwall be implemented *only* if the City's sole priority is to reduce all flooding to the maximum extent technically feasible. Otherwise, the floodwall is not recommended over other flood mitigation measures described in this section.

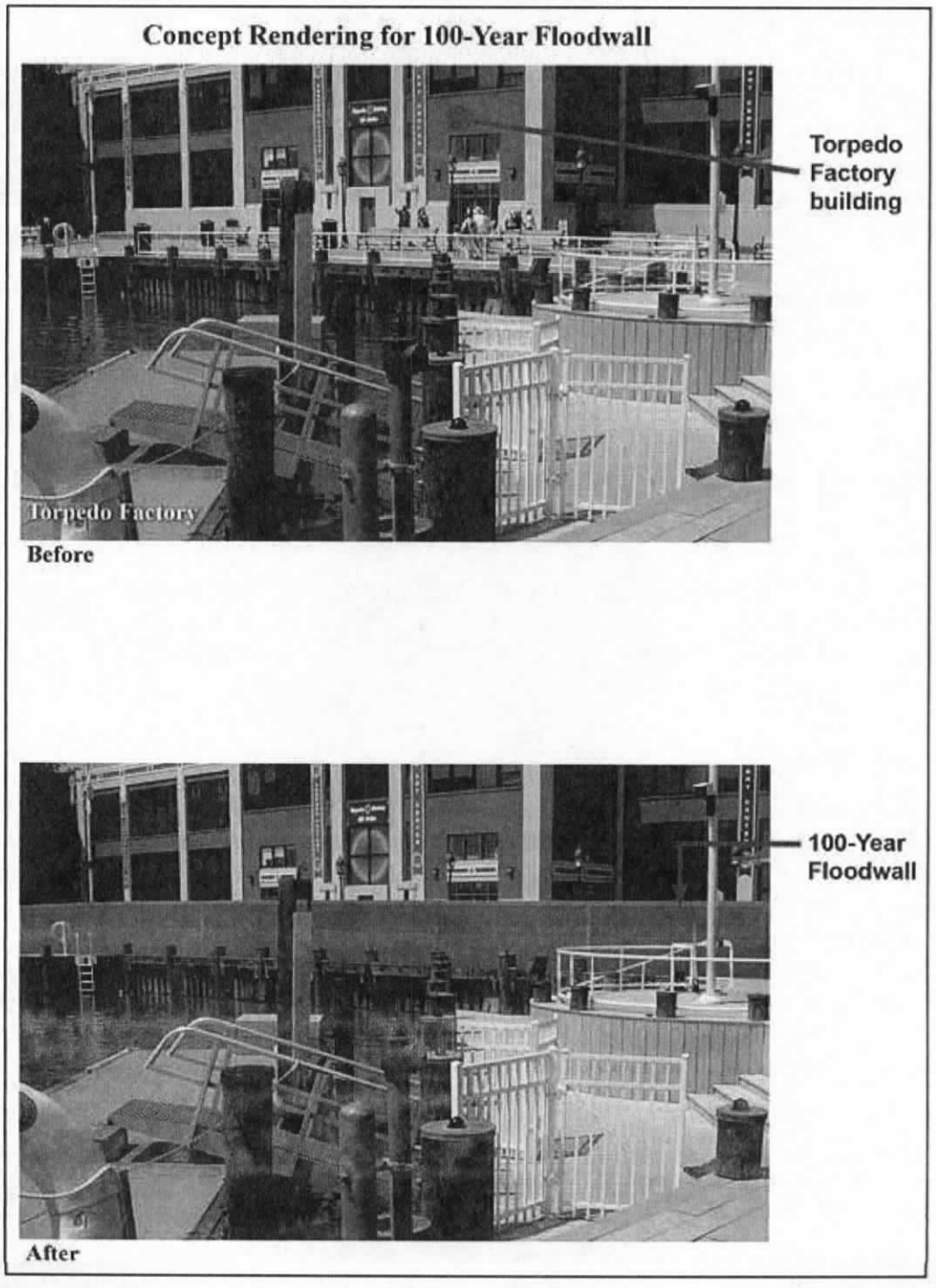


Figure 7-6: Floodwall behind Torpedo Factory

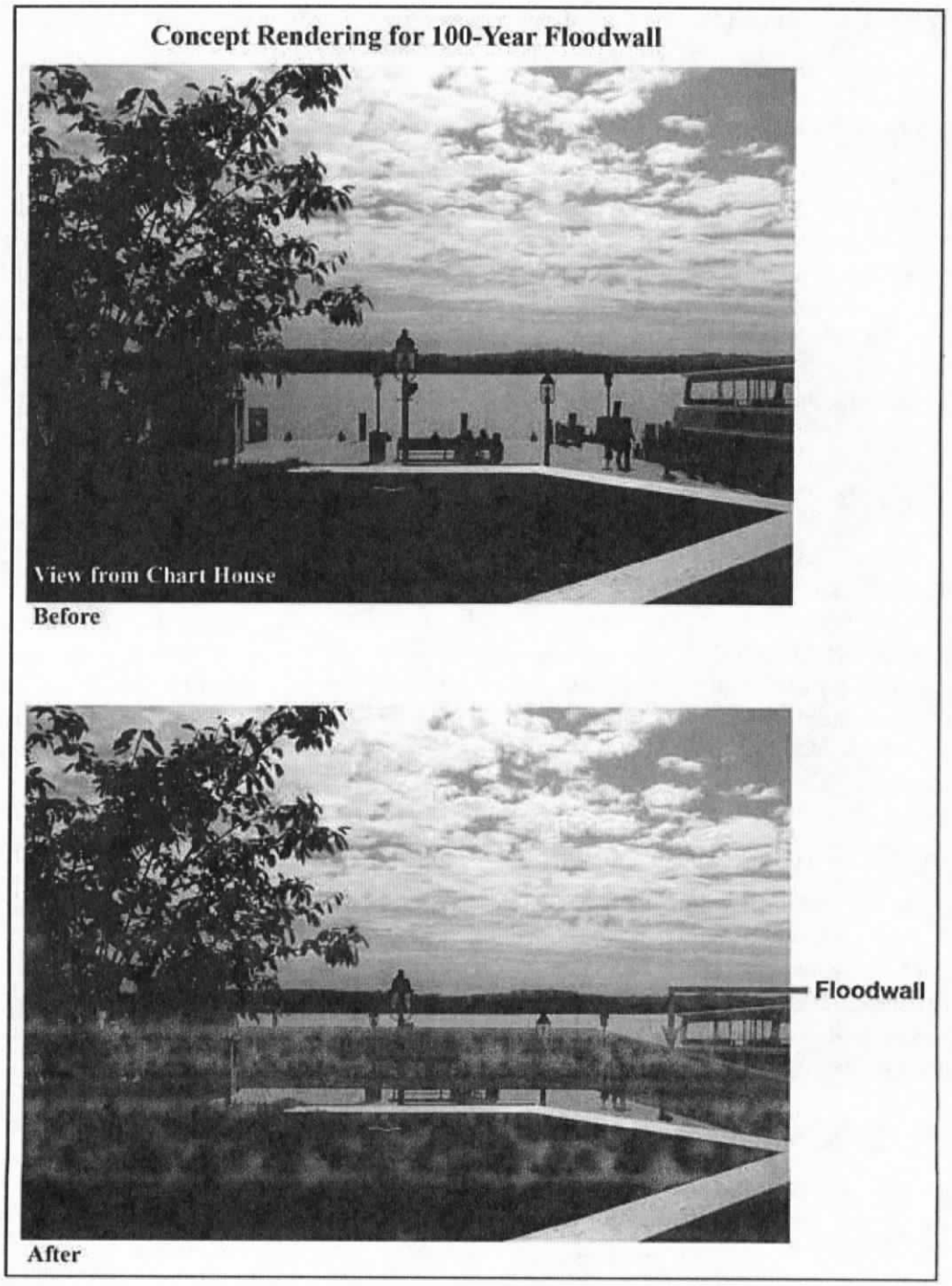


Figure 7-7: Floodwall in Front of Chart House

7.7 REPETITIVE LOSS PROPERTIES

For emphasis, recommendations that affect the repetitive loss properties are summarized in this section.

1 King Street (Boat Club)

This structure has a first-floor base elevation of 3.76 feet (NAVD 88). Because it is not recommended to floodproof a structure above a height of 3 feet, this building can be floodproofed to an elevation of approximately 6.75 feet. This will protect it from nuisance flooding, but not intermediate or extreme floods. There are at least three exterior doorways at ground level that could be floodproofed with a gate. This is a relatively inexpensive solution. However, because it is an active system, someone would have to be available to install them after the flood warning. There are no windows that are low enough to benefit from floodproofing. Additionally, the elevated walkway would provide protection for this structure against nuisance flooding.

6 King Street (Mai Thai / Starbucks)

This structure has a first-floor base elevation of 3.51 feet (NAVD 88). Because it is not recommended to floodproof a structure above a height of 3 feet, this building can be floodproofed to an elevation of approximately 6.5 feet. This will protect it from nuisance flooding but not intermediate or extreme floods. There are four doorways to this structure that could be floodproofed with a gate. This is a relatively inexpensive solution. However, because it is an active system, someone would have to be available to install them after the flood warning. This building has approximately 10 windows that appear low enough to benefit from floodproofing.

101 King Street (Conrad's Furniture)

This building has a first floor elevation of 5.01 feet (NAVD 88). This means that it is not impacted by nuisance flooding. It can be floodproofed up to the intermediate flood elevation, but it will not be protected from the extreme flood event. Three doorways on the southern side, one doorway on the eastern side of this building, and one window on the eastern side would all need to be floodproofed. Additionally, the elevated walkway would provide protection for this structure against nuisance flooding.

104 South Union

The first floor of this building is at 4.5 feet (NAVD 88). Therefore, it is not affected by nuisance flooding. It can be floodproofed up to approximately 7.5 feet and, therefore, cannot be fully protected from the intermediate and extreme flood events. Nevertheless, floodproofing can significantly reduce the probability of flood-related damages to this property. Floodproofing of the structure openings including a doorway on the northern side and a doorway on the western side of this building is recommended. Three low windows on the western side of the structure would also need to be floodproofed. Additionally, the elevated walkway would provide protection for this structure against nuisance flooding.

120 Cameron Street

As mentioned previously, the first floor of this structure is above the extreme flood elevation. Based on our review of available data, the first floor is elevated more than 3 feet above the ground with storage space underneath. However, since this property is identified by FEMA as a repetitive loss structure, floodproofing of the openings is recommended.

7.8 NONSTRUCTURAL FLOOD MITIGATION MEASURES

In addition to the structural flood mitigation measures recommended for implementation, nonstructural flood mitigation measures are also recommended for implementation. The recommendations consist of action items under three nonstructural mitigation measures selected for further evaluation, as described in Section 2. The following list provides a summary of the recommendations. Additional detail on the recommendations is provided in Section 3.

Improve Floodplain Zoning Ordinances

- **Cumulative Substantial Improvements** – It is recommended that the City interpret the 50 percent improvement threshold as cumulative. Implementing this measure will result in increased CRS points.
- **Lower Substantial Improvements** – It is recommended that the City consider lowering the improvement threshold for substantial improvements to less than 50 percent.
- **Protection of Critical Facilities** – If the GIS data reviewed is accurate and there are no plans to build new critical facilities within the 500-year floodplain, implementing this measure will result in increased CRS points.
- **Staff Training** – It is recommended that staff involved in reviewing plans and issuing permits for floodplain development and conducting field inspections become CFMs. Implementing this measure will result in increased CRS points.
- **Permitting and Inspection** – It is recommended that the City increase the frequency of inspecting new construction to ensure that the work is being done according to the provisions of the floodplain ordinance. The ordinance can also be amended to give the floodplain administrator the right to issue a stop work order or revoke building permits if the inspections show that a violation has taken place.
- **Accessory Structures** – It is recommended that additional regulations regarding accessory structures such as sheds and garages be added to strengthen the existing ordinances to prevent accessory structures from being constructed in the floodplain,
- **Variances** – Although the City does not grant variances related to floodplain protection often, it is recommended that the City consider strengthening language to ensure that future floodplain variances are discouraged.
- **Requiring 1 Foot of Freeboard** – It is recommended that the City require 1 foot of freeboard above the flood elevation for new construction. This consistent with the City of Alexandria building code which references the Virginia Uniform Statewide Building Code

(USBC) and International Building Code (IBC). The IBC requires 1 foot of freeboard above the FFE.

Elevation of Supplies and Goods

- Elevation of supplies and goods is recommended for eight commercial structures that experience nuisance flooding. These structures are listed in Table 3-1. Another important component of this solution is outreach and education to residents and business owners who could benefit from elevation of supplies and goods.

Sandbagging and Other Temporary Measures

- The City currently maintains a sandbag distribution guidelines for affected businesses and residential areas within the Potomac River waterfront area. It is recommended that the City maintain the sandbag program and consider the following changes to the current sandbag policy:
  - Expand the sandbag service areas to include a self-serve sand drop off point at 400 North Union Street.
  - Document a set of guidelines for City managers to use as a framework for determining when to initiate sandbag distribution.
  - Provide guidance on the City Web page for residents outside of the distribution areas that they may need to make their own provisions for sandbag procurement.
  - Modify the City's Web page search tool so that the Flooding Information page can be accessed using the search feature on the City's Web page.

7.9 ADDITIONAL RECOMMENDATIONS

The preceding sections summarize flood mitigation measure recommendations for the ten flood mitigation measures that were selected for detailed evaluation. Within the original comprehensive list of 27 potential mitigation measures, several potential measures provide flood benefits, but didn't score high enough to warrant further assessment. However, some of these measures merit consideration for implementation. For the most part, these measures are not large structural projects. Further information and specific recommendations for the following measures are provided in Appendix C.

- Improve flapgate operation at outflow points
- Add backflow preventers in homes to prevent stormwater and sewer backups
- Isolate gas and electrical service lines
- Relocate external electrical boxes
- Inform businesses and residents about NFIP contents coverage
- Improve/enhance existing business identification system
- Provide updated information to residents

- Provide education to area media outlets

7.10 POTENTIAL FEDERAL FUNDING OPTIONS

A number of the flood mitigation activities recommended in this study carry significant capital improvement costs and operation and maintenance expenditures. Opportunities exist for the City to pursue Federal Government grants to supplement City funding for implementation of mitigation measures. An overview of FEMA grant programs is provided below. A more detailed discussion regarding funding options and federal grants is provided in Appendix L.

FEMA's Hazard Mitigation Assistance (HMA) program includes five individual grant programs that can be used for flood mitigation projects including:

- Hazard Mitigation Grant Program (HMGP)
- Pre-Disaster Mitigation (PDM)
- Flood Mitigation Assistance (FMA)
- Repetitive Flood Claims (RFC)
- Severe Repetitive Loss (SRL)

While the HMA grant programs are administered by FEMA, an individual community must apply for these grants through its State government. The Virginia Department of Emergency Management is responsible for this process for the Commonwealth of Virginia. The (VDEM) Web site provides guidance on the application process for HMA grant opportunities. (Web site: http://www.vaemergency.com/grants/index.cfm)

The PDM, FMA, REC, and SRL grant programs are not disaster specific and are subject to the availability of appropriation funding. HMGP grants are only available after a major disaster declaration in the State or Commonwealth; however, the focus of the grant application can be unrelated to the disaster that caused the declaration. FEMA posts disaster declarations on its Web site: http://www.fema.gov/news/disasters.fema. Typically a major disaster declaration is active for 12 months. The City of Alexandria may submit grant applications to FEMA through VDEM. VDEM has internal deadlines for the acceptance of grant applications. As of July 2010, it appears that VDEM is not currently accepting HMGP applications.

7.11 CONCLUSIONS

This report provides detailed information on potential flood mitigation measures for the Potomac River waterfront area. Rather than a single flood mitigation solution, a series of measures are recommended to provide protection against flood events on the Potomac River. These measures require significant capital expense and cooperation from private property owners. In addition, it will take significant effort to comply with applicable regulations. However, proceeding with implementation of the recommended flood mitigation measures is essential to reduce the extensive flood damages in the City.

SECTION EIGHT: REFERENCES

Access Floor Systems, 2009. Access Floor Systems. Accessed August 2009. http://www.accessfloorsystems.com/access/costs/?access=/qq/quickQuote.php.

Appraiser Universe, 2009. Appraiser Universe. Accessed June 2009. http://www.appraiseruniverse.com/listing.php?id=11.

Babbit, Christopher et al., 2008. Kingston, MA: RSMeans Company, Inc.

Bankrate.com, 2009. "Closing cost averages: Virginia.", Accessed June 2009. http://www.bankrate.com/brm/news/mortgages/2008/closing_costs_VA.asp.

Bankrate.com, 2009. "Mortgage closing costs: State rankings." Accessed June 2009. http://www.bankrate.com/finance/exclusives/mortgage-closing-costs-state-rankings8-29952.aspx.

Black & Veatch, 2006. *South Florida Water Management District- EAA Reservoir A-1 Basis of Design Report*, Appendix 13-2: Mechanical Layout Alternatives Evaluation Technical Memorandum. Accessed September 2009. http://xlr8.sfwmd.gov/portal/page/portal/pg_grp_acceler8/pg_acceler8_projects_eaares/bodr_draft_eaares/appendices/appendix%2013-02.pdf

Bryan Fryklund, Personal communication, removable floodwall cost estimate. Flood Control America. Sudbury, MA.

Buck Schuckman, 2009. Personal communication, commercial window replacement cost estimate. September 30, 2009. Fairfax Glass Company. Falls Church, VA.

City of Alexandria, 1992. *The Zoning Ordinance of the City of Alexandria*. Virginia Section 11-411: Archaeology Protection. Accessed September 2009. http://oha.alexandriava.gov/archaeology/ar-preservation-apc.html accessed.

City of Alexandria (VA), 2004a. Final Natural Intermittent Stream Channel 50-Foot Buffer Map. June 2004.

City of Alexandria (VA), 2004b. Resource Protection Area Buffer Map, Adopted by City Council on June 12, 2004.

City of Alexandria (VA), 2006a. *Amendments to City of Alexandria Article XIII Environmental Management Ordinance*. April 2006. http://alexandriava.gov/uploadedFiles/tes/info/Article_XIII_2006.pdf .

City of Alexandria (VA), 2006b. *Guide to the Old and Historic Alexandria and Parker-Gray Historic Districts*. Department of Planning and Zoning. http://alexandriava.gov/uploadedFiles/planning/info/pnz_historic_districts_guide.pdf.

City of Alexandria (VA), 2009a. Real Estate Assessment Search. Accessed July 2009. http://realestate.alexandriava.gov/.

City of Alexandria (VA), 2009b. *The Zoning Ordinance of the City of Alexandria*. Department of Planning and Zoning. Accessed September 2009. http://www.municode.com/Resources/gateway.asp?pid=12429&sid=46.

City of Alexandria (VA), 2009c. *The Zoning Ordinance of the City of Alexandria*. Article XI. Development Approvals and Procedures. Division B. Development Approvals. Section 11-411 Archaeology Protection (1992). Department of Planning and Zoning. Accessed September 2009. http://oha.alexandriava.gov/archaeology/ar-preservation-apc.html.

CNN Money, 2009. "Who needs a property survey?" Accessed June 2009. http://money.cnn.com/2006/05/23/real_estate/who_needs_a_survey/index.htm.

Commercial Property Appraisal, 2009. Commercial Property Appraisal. Accessed June 2009. http://www.commercialpropertyappraisal.com/index2.php.

Danny Kim, 2009. Personal communication, commercial window replacement cost estimate. American Housing Contractor (Marvin Windows). September 30, 2009. Fairfax, VA.

DoorDam, 2009. Product Profile. Accessed July 2009. http://www.doordam.com/.

Fairfax County, 2009. Levee and pumping station plans search. Department of Public Works and Environmental Services. Accessed September 2009. http://www.fairfaxcounty.gov/dpwes/publications/stormwater/huntingtonfinal_ch7.pdf.

Federal Emergency Management Agency (FEMA), 1985a. *District of Columbia Flood Insurance Study*. November 1985.

Federal Emergency Management Agency (FEMA), 1985b. *Floodproofing Non-Residential Structures,* FEMA 102. 1985.

Federal Emergency Management Agency (FEMA), 1998a. *Homeowner's Guide to Retrofitting: Six Ways to Protect Your House from Flooding*, FEMA 312. June 1998.

Federal Emergency Management Agency (FEMA), 1998b. *Property Acquisition Handbook for Local Communities,* FEMA 317. http://www.fema.gov/government/grant/resources/acqhandbook.shtm.

Federal Emergency Management Agency (FEMA), 2001. *Engineering Principles of Retrofitting Flood-Prone Residential Structures*. June 2001.

Federal Emergency Management Agency (FEMA), 2002. *CRS Coordinators Manual*.

Federal Emergency Management Agency (FEMA), 2007. *Selecting Appropriate Mitigation Measures for Floodprone Structures,* FEMA 551. March 2007.

Federal Emergency Management Agency (FEMA), 2008. *Flood Damage-Resistant Materials Requirements (Technical Bulletin 2)*, August 2008.

Federal Emergency Management Agency (FEMA), 2009. *FEMA Benefit-Cost Analysis Re-engineering (BCAR), Flood Full Data Module Methodology Report,* Version 4.5. May 2009.

Federal Emergency Management Agency (FEMA), DATE. "Benefit-Cost Analysis Resource Kit," version 4.5. http://www.bchelpline.com/BCAToolkit/resources_flood.html

FloodGuard UK Ltd, 2009. Company Web site. Accessed July 2009. http://www.floodguarduk.co.uk/en-us/front.html.

Huber Technology, 2009. "Flood-proof Door TT6." Accessed July 2009. http://www.huber.de/products/stainless-steel-equipment/technical-doors/flood-proof-door.html.

State of Maryland Department of Transportation, 2009. 6-21-02. "Type B Retaining Wall Section (For Good Soil Condition and Two Foot Surcharge)." State Highway Administration. Accessed September 2009. http://www.sha.state.md.us/businesswithsha/bizStdsSpecs/obd/BridgeStandards/Bridge_Standards/15_Retaining-Walls2678/PDF/RW135_1.pdf

Mon-Ray Inc, 2009. "About Our Area of Focus." Accessed September 2009. http://www.monray.com/focus.htm#historic.

National Oceanic and Atmospheric Administration, 2009. Tides and Currents -Tide Data for Station ID: 8594900. Accessed June 2009. http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8594900%20Washington,%20DC&type=Tide%20Data

National Oceanic and Atmospheric Administration, 2009. "Point Precipitation Frequency Estimates From NOAA Atlas 14." Accessed July 2009. http://hdsc.nws.noaa.gov/cgi-bin/hdsc/buildout.perl?type=pf&units=us&series=pd&statename=VIRGINIA&stateabv=va&study=orb&season=All&intype=3&plat=&plon=&liststation=0&slat=38.8088&slon=-77.06364&mlat=41.070&mlon=-74.988

Nick Kalivretenos, 2009. Personal communication, commercial window replacement and storm window cost estimate. The Window Man. September 30, 2009. Alexandria, VA.

Reade Advanced Materials, 2009. "Weight Per Cubic Food And Specific Gravity." Accessed September 2009. http://www.reade.com/Particle_Briefings/spec_gra2.html

Spencer, Eugene R. et al., 2003. *RSMeans 2004: Site Work & Landscape Cost Data*, eds. Barbara Balboni et al. Kingston, MA: Reed Construction Data.

Spencer, Eugene R. et al., *RSMeans 2009: Heavy Construction Cost Data.* Kingston, MA: Reed Construction Data.

U.S. Army Corps of Engineers (USACE), 2009. *Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Work Programs.* July 1, 2009.

U.S. Army Corps of Engineers (USACE), 2009. *Huntington Flood Damage Reduction Study, Fairfax County, Virginia.* April 2009. http://www.fairfaxcounty.gov/dpwes/publications/stormwater/huntingtonfinal_ch7.pdf.

U.S. Army Corps of Engineers (USACE), 2009. *Flood Proofing Measures.* Accessed July 2009. https://www.nwo.usace.army.mil/nfpc/fphow/ace8_05.htm.

U.S. Census, 2009. Sales Data for Alexandria City. http://factfinder.census.gov/servlet/FindEconDatasetsServlet?_caller=geoselect&_ts=272967959021.

U.S. Department of Transportation, 2009. Best Practices Design Guide for Designing Sidewalks and Trails for Access Search. Federal Highway Administration. Accessed September 2009. http://www.fhwa.dot.gov/environment/sidewalk2/pdf.htm.

U.S. Department of Labor, 2009. "Inflation Calculator: Bureau of Labor Statistics." Accessed July 2009, http://www.bls.gov/bls/inflation.htm.

Virginia Department of Historic Resources, 2003. *Guidelines for Conducting Cultural Resource Survey in Virginia* (2003), Accessed September 2009. http://www.dhr.virginia.gov/review/Survey_Manual_Web.pdf.

Virginia Department of Conservation and Recreation, 1999. *Virginia Stormwater Management Handbook, Volume 2, First Edition*. Accessed September 2009. http://www.dcr.virginia.gov/soil_and_water/documents/Chapter_4.pdf.

Virginia Department of Transportation, 2009. Road and Bridge Standards. Retaining wall drawings search. Accessed September 2009. http://www.extranet.vdot.state.va.us/LocDes/Electronic%20Pubs/Standards/TOC400.pdf.

Zimbio Money, 2009. "Purchaser's Closing Costs in Virginia." Accessed June 2009. http://www.zimbio.com/Real+Estate/articles/414/Purchaser+Closing+Costs+Virginia.

Appendix A

Initial Ranking of Potential Flood Mitigation Solutions

Potomac River Waterfront Flood Mitigation Study
Ranking of Potential Flood Mitigation Solutions

	Criteria -->	Aesthetics	Cost Considerations	Constructability	Cost of Flood Insurance	Cost to Property Owners	City Liability	Property Ownership	General Environmental Impacts	Level of Protection for Extreme Flooding	Level of Protection for Nuisance Flooding	Extent of Flood Protection	Long Term and Maintenance Costs	Reduces Flood Damages	Reduces Flooding Extent	Loss of Business Revenue	Loss of Recreational Use	Potomac River View Shed	Historical/Archeological Resources	Private Property Acquisition	Regulatory Requirements	State/Federal Funding	Rep Loss Property Mitigated	TOTAL SCORE	RANK
	Criteria Number -->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22		
	Weighting Factor -->	**3**	**3**	**3**	**1**	**5**	**3**	**1**	**1**	**5**	**10**	**10**	**3**	**5**	**5**	**5**	**1**	**3**	**1**	**3**	**1**	**1**	**3**		
1	**PP1**	5	5	5	5	5	5	5	10	1	5	2	5	10	1	5	5	5	5	10	10	5	1	348	11
2	**PP2**	1	5	5	10	5	5	5	10	5	5	2	10	10	1	10	5	5	5	10	5	5	1	396	7
3	**PP3**	5	10	10	5	10	5	5	10	1	5	2	5	5	1	5	5	5	10	10	10	1	1	379	9
4	**PP4**	5	5	5	5	10	5	10	10	1	1	1	10	10	1	1	5	5	10	10	10	1	1	324	14
5	**PP5**	5	1	5	10	1	10	1	10	10	10	2	10	10	1	10	5	10	5	1	1	5	10	473	3
6	**PP6**	1	5	1	10	1	5	1	10	10	10	2	10	10	1	10	5	5	5	10	5	5	1	435	6
7	**S1**	1	1	1	10	10	1	5	5	10	5	10	1	10	10	10	5	1	1	5	1	10	10	500	1
8	**S2**	5	1	1	10	10	1	5	5	10	5	10	1	10	5	10	5	5	1	5	1	10	10	499	2
9	**S3**	5	1	1	5	10	5	7	10	1	10	5	5	10	1	5	5	5	10	10	5	1	5	439	5
10	**S4**	5	5	1	5	10	5	7	10	1	1	1	1	5	1	1	5	5	10	10	5	1	1	252	24
11	**S5**	5	5	5	5	10	5	7	10	1	1	1	1	1	1	1	5	5	10	10	5	1	1	244	25
12	**S6**	5	5	5	5	10	5	7	10	1	5	5	1	1	5	5	5	5	10	10	5	1	5	376	10
13	**S7**	5	5	5	5	10	5	7	10	1	1	2	1	1	1	1	5	5	10	10	5	1	1	254	23
14	**S8**	5	1	1	5	10	5	7	10	1	1	1	5	1	1	1	5	5	5	10	5	1	1	227	27
15	**S9**	1	1	1	5	10	5	7	5	1	1	1	5	1	1	1	5	5	5	10	5	1	1	210	28
16	**S10**	5	1	5	5	10	5	10	5	1	1	1	5	1	1	1	5	5	10	10	5	1	1	242	26
17	**PR1**	5	10	5	5	5	5	5	10	1	5	1	10	5	1	5	5	5	10	10	5	1	1	339	12
18	**PR2**	5	10	10	10	10	5	10	10	5	5	1	10	5	1	1	5	5	10	10	5	1	1	389	8
19	**ES1**	5	5	10	5	10	5	10	10	1	1	1	10	1	1	10	5	5	10	10	5	1	1	334	13
20	**ES2**	5	5	10	5	10	5	10	10	1	1	1	5	1	1	5	5	5	10	10	10	5	1	303	18
21	**ES3**	5	5	10	5	10	5	10	10	1	1	1	5	1	1	5	5	5	10	10	10	5	1	303	18
22	**ES4**	5	5	10	5	10	5	10	10	1	1	1	10	1	1	5	5	5	10	10	10	10	1	323	15
23	**ES5**	5	5	10	5	10	5	10	10	1	5	5	5	5	1	10	5	5	10	10	10	1	15	466	4
24	**ES6**	5	5	10	5	10	5	10	10	1	1	1	5	1	1	5	5	5	10	10	10	1	1	299	20
25	**EA1**	5	10	10	5	10	5	10	10	1	1	1	5	1	1	1	5	5	10	10	10	1	1	294	21
26	**EA2**	5	5	5	5	10	5	10	10	1	1	1	10	1	1	1	5	5	10	10	10	1	1	279	22
27	**EA3**	5	10	10	5	10	5	10	10	1	1	1	10	1	1	1	5	5	10	10	10	1	1	309	16
28	**Do Nothing**	5	10	10	5	10	5	10	10	1	1	1	10	1	1	1	5	5	10	10	10	1	1	309	16

Appendix B
Ordinance and Sandbag Information

Exhibit 1-1. Sample ordinance from the City of Charlotte, Mecklenburg County, NC regarding permitting for new construction and improvements and construction inspection.

Section. 9-17. Administrative procedures.

a. Inspections of work in progress. As the work pursuant to a permit progresses, the local administrator shall make as many inspections of the work as may be necessary to ensure that the work is being done according to the provisions of the local ordinance and the terms of the permit. In exercising this power, the administrator has a right, upon presentation of proper credentials, to enter on any premises within the territorial jurisdiction at any reasonable hour for the purposes of inspection or other enforcement action.

b. Stop orders. Whenever a building or part thereof is being constructed, reconstructed, altered or repaired in violation of this ordinance, the administrator may order the work to be immediately stopped. The stop order shall be in writing and directed to the person doing the work. The stop order shall state the specific work to be stopped, the specific reasons for the stoppage and the conditions under which the work may be resumed. Violation of a stop work order constitutes a misdemeanor.

c. Revocation of permits. The local administrator may revoke and require the return of the floodlands development permit by notifying the permit holder in writing stating the reason for the revocation. Permits shall be revoked for any substantial departure from the approved application, plans or specifications; for refusal or failure to comply with the requirements of state or local laws; or for false statements or misrepresentation made in securing the permit. Any permit mistakenly issued in violation of an applicable state or local law may also be revoked.

d. Periodic inspections. The local administrator and each member of his inspections department shall have a right, upon presentation of proper credentials, to enter on any premises within the territorial jurisdiction of the department at any reasonable hour for the purposes of inspection or other enforcement action.

e. Violations to be corrected. When the local administrator finds violations of applicable state and local laws, it shall be his duty to notify the owner or occupant of the building of the violation. The owner or occupant shall each immediately remedy the violation of law in the property he owns or occupies.

f. Actions in event of failure to take corrective action. If the owner or occupant of a building or property shall fail to take prompt corrective action, the administrator shall give him written notice, by certified or registered mail to his last known address or by personal service:

    1. That the building or property is in violation of the Floodplain Regulations;

    2. That a hearing will be held before the local administrator at a designated place and time, not later than ten (10) days after the date of the notice; at which time the

owner or occupant shall be entitled to be heard in person or by counsel and to present arguments and evidence pertaining to the matter; and

3. That following the hearing, the local administrator may issue such order to alter, vacate or demolish the building, or to remove fill, as appears appropriate.

g. Order to take corrective action. If, upon a hearing held pursuant to the notice prescribed above, the administrator shall find that the building or development is in violation of the Floodplain Ordinance, he shall make an order in writing to the owner, requiring the owner to remedy the violation within such period, not less than sixty (60) days, the administrator may prescribe; provided that, where the administrator finds that there is imminent danger to life or other property, he may order that corrective action be taken in such lesser period as may be feasible.

h. Appeal. Any owner who has received an order to take corrective action may appeal from the order to the City Council by giving notice of appeal in writing to the administrator and the clerk within ten (10) days following issuance of the final order. In the absence of an appeal, the order of the administrator shall be final. The City Council shall hear an appeal within a reasonable time and may affirm, modify and affirm or revoke the order. All such decisions of the City Council are subject to review by the Mecklenburg County Superior Court as provided in N.C.G.S. 143-215.57 (c) as such statute may be amended from time to time.

i. Failure to comply with order. If the owner of a building or property fails to comply with an order to take corrective action from which no appeal has been taken, or fails to comply with an order of the City Council following an appeal, he shall be guilty of a misdemeanor and shall be punished in the discretion of the court.

Exhibit 1-2. Sample ordinance from Charlotte, Mecklenburg County, NC regarding accessory structures.

8. Accessory Structure. When accessory structures (sheds, detached garages, etc.), are to be placed in the floodplain the following criteria shall be met:

   a. Accessory structures shall not be used for human habitation;

   b. Accessory structures shall be designed to have a low flood damage potential;

   c. Accessory structures shall be firmly anchored in accordance with Article V, Section 20 (1); and

   d. Service facilities such as electrical and heating equipment shall be elevated in accordance with Article V, Section 20 (43).

Exhibit 1-3. Sample ordinance from Roseville, CA regarding variances.

9.80.300 Nature of variances.

The variance criteria set forth in this section are based on the general principle of zoning law that variances pertain to a piece of property and are not personal in nature. A properly issued variance is granted for a parcel of property with physical characteristics so unusual that complying with the requirements of this chapter would create an

exceptional hardship to the applicant or the surrounding property owners. The characteristics must be unique to the property and not be shared by adjacent parcels. The unique characteristic must pertain to the land itself, not to the structure, its inhabitants, or the property owners.

It is the duty of the city to help protect its citizens from flooding. This need is so compelling, and the implications of the cost of insuring a structure built below flood level are so serious that variances from the flood elevation or from other requirements in the flood chapter are quite rare. Therefore, the variance guidelines provided in this chapter are more detailed and contain multiple provisions that must be met before a variance can be properly granted. The criteria are designed to screen out those situations in which alternatives other than a variance are more appropriate. (Ord. 3066 § 1 (part), 1997: Ord. 2374 § 1 (part), 1990.)

9.80.310 Variance procedure.

A. The city council of the City of Roseville shall hear and decide appeals and requests for variances from the requirements of this chapter. Applications for a variance shall be made in the usual manner provided for Zoning Ordinance variances and shall include the standard variance application fee.

B. The city council shall hear and decide appeals when it is alleged there is an error in any requirement, decision, or determination made by the floodplain administrator in the enforcement or administration of this chapter.

C. In passing upon such applications, the city council shall consider all technical evaluations, all relevant factors, standards specified in other sections of this chapter, and:

1. The danger that materials may be swept onto other lands to the injury of others;

2. The danger of life and property due to flooding or erosion damage;

3. The susceptibility of the proposed facility and its contents to flood damage and the effect of such damage on the existing individual owner and future owners of the property;

4. The importance of the services provided by the proposed facility to the community;

5. The necessity to the facility of a waterfront location, where applicable;

6. The availability of alternative locations for the proposed use which are not subject to flooding or erosion damage;

7. The compatibility of the proposed use with existing and anticipated development;

8. The relationship of the proposed use to the comprehensive plan and floodplain management program for that area;

9. The safety of access to the property in time of flood for ordinary and emergency vehicles;

10. The expected heights, velocity, duration, rate of rise, and sediment transport of the flood waters expected at the site; and,

11. The costs of providing governmental services during and after flood conditions, including maintenance and repair of public utilities and facilities such as sewer, gas, electrical, and water systems, and streets and bridges.

D. Any applicant to whom a variance is granted shall be given written notice over the signature of a community official that (1) the issuance of a variance to construct a structure below the base flood level will result in increased premium rates for flood insurance up to amounts as high as $25.00 for $100.00 of insurance coverage and (2) such construction below the base flood level increases risks to life and property. A copy of the notice shall be recorded by the floodplain board in the office of the Placer County recorder and shall be recorded in a manner so that it appears in the chain of title of the affected parcel of land.

E. The floodplain administrator will maintain a record of all variance actions, including justification for their issuance, and report such variances issued in its biennial report submitted to the Federal Insurance Administration, Federal Emergency Management Agency. (Ord. 3066 § 1 (part), 1997: Ord. 2374 § 1 (part), 1990.)

9.80.320 Conditions for variances.

A. Generally, variances may be issued by the city council for new construction, substantial improvement and other proposed new development to be erected on a lot of one-half acre or less in size contiguous to and surrounded by lots with existing structures constructed below the base flood level, providing that the procedures of Sections

9.80.130 through 9.80.150, inclusive, have been fully considered. As the lot size increases beyond one-half acre, the technical justification required for issuing the variance increases.

B. Variances may be issued for the repair or rehabilitation of "historic structures" upon a determination that the proposed repair or rehabilitation will not preclude the structure's continued designation as a historic structure and the variance is the minimum necessary to preserve the historic character and design of the structure.

C. Variances shall not be issued within any designated floodway if any increase in flood levels during the base flood discharge would result.

D. Variances shall only be issued upon a determination that the variance is the "minimum necessary," considering the flood hazard, to afford relief.

E. Variances shall only be issued upon (1) a showing of good and sufficient cause; (2) a determination that failure to grant the variance would result in exceptional "hardship" to the applicant; and (3) a determination that the granting of a variance will not result in increased flood heights, additional threats to public safety, extraordinary public expense, create "nuisances" cause "fraud or victimization" of the public, or conflict with existing local laws or ordinances.

F. Variances may be issued for new construction, substantial improvement and other proposed new development necessary for the conduct of a functionally dependent use provided that the provisions of Sections 9.80.320(A)—(E) are satisfied and that the structure or other development is protected by methods that minimize flood damages during the base flood and create no additional threats to public safety.

G. Upon consideration of the factors of Section 9.80.310(C) and the purposes of this chapter, the city council may attach such conditions to the granting of variances as it deems necessary to further the purposes of this chapter. The decision of the city council shall be final. (Ord. 3066 § 1 (part), 1997: Ord. 2374 § 1 (part), 1990.)

Appendix C
Non-Prioritized Measures

As explained in Section 3.3 of the report, these mitigation measures were not in the top 9 rated measures for the study, but since they are inexpensive and may be easy to implement, the information is being provided for the City.

Improve flap gate operation at outflow points

There are two locations in the study area where the manholes and inlets are lower than 4 feet, which is the defined nuisance flooding elevation. With a 4-foot tide, it is possible that the tide waters could back up the drain pipes and flood the area surrounding these low manholes and inlets. Increasing the inlet and road elevations is addressed in Section 6.4.

This mitigation solution addresses a different aspect of this problem - the flap gates at the outflow points. During high tides, the existing flap gates at the outflow points in the Potomac River should close to prevent tidewater from backing up the stormwater pipes. A September 26, 2007 conversation with Roy Worell and George Guiseppe in the City of Alexandria Maintenance Department indicated that the City already has a program to clean the flap gate areas prior to storm events, but storm flows bring debris though the system which blocks the flap gates again.

To address this problem, we suggest switching from standard flap gates to duckbill check valves at the King Street and Prince Street outfall locations. A conversation with Lalit Sharma of the City of Alexandria Department of Environmental Quality said that the City once tried a duckbill type of check valve, but it didn't appear to work properly. He concluded that the problem was not with the duckbill check valve but was probably caused by an improperly sized valve.

Duckbill check valves have many advantages: they don't rust and greatly reduce clogging. Additionally, they only need as little as 1 inch of head water to allow stormwater outflow. The data from the City's GIS layers show that a 21-inch diameter duckbill check valve would be needed at the King St outfall and a 24-inch diameter duckbill valve would be needed at the Prince St outfall. These check valves cost around $5,500 plus installation. The benefits of this would be a reduction in maintenance costs and a reduction in nuisance flooding in the downtown area from water backing up the storm sewers.

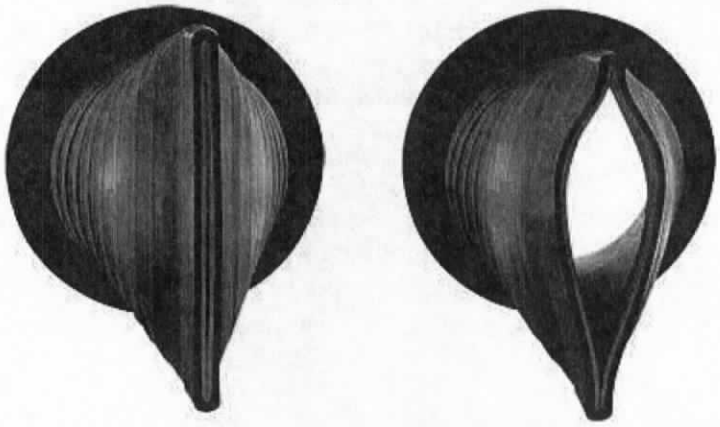


Figure 1: Duckbill Check Valve

A typical duckbill check valve is shown in Figure 1 in the open and closed positions.

Add backflow preventers to prevent stormwater and sewer backups.

There has been one reported case of internal flooding caused by sewer backup at a residence at the intersection of Royal and Pendleton Streets. This location is not in the study area, but is near the northwest border of the study area. There are combined sewers running through a portion of the study area along Pendleton, Union, South Royal, and South Pitt Streets. Along theses locations, there is the possibility for flooding caused by sewer backups.

Adding backflow preventers to homes is an easy way to prevent this type of internal flooding. The City of Alexandria sponsored a program in 2006 in the Commonwealth area of the City outside this study area to provide some financial assistance to residents who chose to install backflow preventers. The program mailed brochures about this program to residents and received many calls asking about more details. Only 20 residents applied for and received financial assistance from the City. The backflow preventers have been effective and all residents who installed them have reported no further problems.

We recommend that the City revise and reissue the brochures to focus on and around the study area and offer assistance to residents along Pendleton, Union, South Royal, and South Pitt Streets. The residents could contract any capable plumber to undertake the work, and the City may consider reimbursing the residents for a portion of the cost. In the 2006 program, the City offered residents up to $500 towards the cost of the backflow preventer and the labor to install it.

Since the brochures are essentially prepared and there is a staff member familiar with the program, the costs to implement this measure will be minimal. The costs will be to mail the brochures to an estimated 150 buildings as well as setting aside money to offer to residents. In the previous program, approximately $10,000 was given to City residents to

help defray the cost of the installation. Residents would have to contribute some of their own money as well, but would receive the benefits of avoiding future sewer backups.

Isolate gas and electrical services

Returning power and gas to homes and businesses affected by flooding is a top priority for both Washington Gas and Dominion Power.

Washington Gas has several main valves which provide gas to residents and businesses within the waterfront area of the City. Once water enters a structure the main valve line will be turned off which could affect other buildings. Washington.Gas has been working to isolate as many lines as possible by adding isolation valves. They have also been raising meters and vent lines in low lying areas.

It is in Washington Gas's best interest to isolate as many structures as possible since before the main valve can be turned back on, the meters/valves at each structure must be turned on and gas lights must be relit by the Gas Company for safety purposes. This is a labor intensive job for their employees; and for residents and businesses in the area, this means that gas service is down until a company representative can visit every structure.

Washington Gas has indicated that they have an extensive operations and management plan and can meet with the City if they want to discuss a particular line, although since Washington Gas is a private company, ultimately they decide which lines will be isolated.

Dominion Power reports that there are no significant power issues due to flooding along the waterfront and that it is very rare for the power to be turned off due to flooding. Most of the transformers in the waterfront area are on the roof and those that are submersible are protected.

The power is mainly affected during storm events that cause feeder issues due to wind and rain. If it is a small event, the Dominion Power will fix the issue as soon as possible. If a significant storm or hurricane is active or anticipated, the Emergency Operations Center of the Power Company is in constant contact with the City of Alexandria Emergency Operations Center, usually the Fire Marshalls. It doesn't happen often, but the Fire Marshalls could direct the Power Company to turn off the power. When the power is knocked out, Dominion Power would first respond to the Critical Infrastructure and then to the largest areas without power.

Dominion Power is always looking at improving the reliability of the system. They often perform maintenance on equipment and within the past few years, the underground cables at the Torpedo Factory were replaced. Although Dominion Power feels that there is not one specific area along the waterfront that has continuous power issues, they welcome future discussions with the City about their priorities.

Relocate external electrical boxes

Elevating external electrical boxes above extreme flooding elevations would help prevent electrical outages during storms. It could also help return power to the City more quickly after a storm since the electrical components of that particular building would not have to be checked.

City residents and businesses would be responsible for contracting a licensed electrician to move these components, but the City could help in several ways. They could publish a brochure or have information about floodproofing utility systems on the website under a proposed new section of the Emergency Preparedness page for Flooding. If the City wants to encourage residents to floodproof their utility systems, the City might consider offering financial help similar to the backflow preventer program described earlier in this document. Elevating internal outlets, light sockets, junction boxes, electric motors, and breakers or fuse boxes would also help with this goal.

Additional information on floodproofing utility systems can be found in Appendix K, Exhibit 3.

Inform businesses and residents about NFIP contents coverage

Even a few inches of water can cause thousands of dollars in repair and restoration costs for homeowners and businesses. Flood insurance is "single peril" insurance, sold separately from homeowners insurance. Flood insurance protects against losses to buildings and their contents, but not the land surrounding them. The coverage applies whether the flooding results from heavy or prolonged rains, coastal storm surge, snow melt, blocked storm drainage systems, levee dam failure, or other causes. To be considered a flood, the waters must cover at least two acres or affect at least two properties.

While many residents and businesses in the City of Alexandria are aware of and may have flood insurance for their buildings, they may not be aware of the availability of contents insurance. Especially for businesses that are frequently affected by nuisance floods, obtaining contents insurance may help reduce the burden of flooding.

The City could extend an outreach program to inform residents and businesses about flood insurance options. This information would be distributed through hand-outs, mailings, and the City's website.

This outreach program could be done at a minimal cost to the City. The City could develop a small brochure and add content to their website. There would be additional costs for the distribution of these materials. City residents and business owners could decide how to respond, but will hopefully would purchase contents insurance, which would reduce their liability after a flood.

Improve/enhance existing business identification system

There is currently no identification/badge (ID) system in place for the Old Town area of Alexandria to facilitate quicker returns to residences and businesses after a flood. Right now, the business owners make a list of employees and give that to the people who are manning the check points; people on the list are then let through the check points.

Since some business owners have expressed frustration with this system, a system that includes creation of permanent IDs could help people pass more quickly through check points. If the City does not already have a machine to make badges, it could invest from $1,000 to $2,500 dollars for a simple machine. Since employee turnover is high for some businesses, we do not suggest photo IDs. Rather, we suggest the City make several IDs for each business that list the business name and address. The City could allow the businesses a small number of free badges and charge for additional copies. The business owner will be responsible for distributing these to employees who can use them to get through the check points. For residents, a government issued ID with current address should be sufficient to pass through the check point.

Provide Updated Information to Residents

The City of Alexandria has developed a flood warning system for areas that are within the floodplain. Warnings are disseminated by local radio (WMAL-630 AM, WWRC-1260 AM, WTOP-103.5 FM, WKYS-93.9 FM), TV, weather radios, and by police equipped with public address systems. The flood warning system is intended to provide up to 0.5 hour advance warning of a flood hazard. The City's website provides links to three USGS river gauges in the immediate region.

Additionally, the Emergency Operations department receives weather forecasts from the National Weather Service. If a flood is impending, that group goes door-to-door in the study region to pass out flyers or leave them on the door. The flyers warn people about the impending flooding and let them know if sandbags will be available for pick up or if they will be dropped off at the businesses.

In other parts of the City, when flooding is expected they have a phone notification system in place. They use a GIS database with phone numbers coded in by address. A polygon of the expected extent of flooding is created and their program extracts all the numbers within that area and leaves a pre-recorded message about the flood event. This system is not currently used in the study areas as the precedence set is that the residents and business owners are visited by City workers. It is recommended that the phone notification system be used within the study area. This modification will save money and allow City workers to focus on other pre-flooding preparations.

The City of Alexandria also has an eNews service that sends emails or text messages about the latest information regarding City services and emergency alerts. It is recommended that the City conduct outreach activities to encourage residents and business owners to sign up for this free service to receive flood warnings.

Last, Hurricane Preparedness information is provided on the Emergency Preparedness section of the City's website, but more flooding information could be easily added. For example, this site could include the latest news alerts and tide gage information. The cost to change the website is minimal.

Provide Education to Area Media Outlets

Businesses in the City of Alexandria, particularly in the Old Town area, report lost revenue from tourists due to the media hype over pending flooding. TV stations often find the picturesque backdrop perfect for their field reporters, who then report that flooding is imminent. While the City welcomes the media to use the town as a backdrop, they would like to see more accurate reporting.

While it may seem like a struggle to limit the misreporting, the City can improve the way flood risks are communicated to the media and to the public. The following list gives several suggestions on how to provide accurate information to the media.

- Provide alternative ways for visitors and consumers to obtain information about the flood conditions by looking beyond traditional media (City's web site or another web site with maps highlighting areas open and accessible to the public).
- Create an editorial board to help reporters and editors understand the issues.
- Create "new media" news releases that get distributed to print and broadcast media outlets that would give them the real story about the flooding. This could be set up through an RSS feed to push the stories to the outlets directly.
- Create a "media card" with information about who to contact for accurate and up-to-date information about flooding conditions.
- Give the media something different to report. Innovative campaigns will catch their attention. Flashy signs will create interesting backdrops for reporters.

Appendix D
Data Collection

Potomac River Waterfront Flood Mitigation Study

Exhibit 1: Survey Data

FID Buildings	Address	Description	Landuse	Number of Floors	Z_ELEV
76	211 N UNION ST	Garage with Offices on top	Commercial	4	3.7
764	120-130 CAMERON ST	Condos	Residential	4	9.2
767	110-120 CAMERON ST	Condos	Residential	4	4.6
802	102-160 N UNION ST	Residences At Torpedo Factory	Residential	4	4.0
819	211 STRAND ST	Mystic Jewellers	Commercial	1	6.0
828	220 S UNION ST	Art League	Commercial	1	6.0
905	115 S UNION ST	Structure On Garage	Commercial	2	4.1
1398	100 CAMERON MW	Cameron Mews	Residential	3	4.0
1404	104 S UNION ST	The Virginia Shop	Commercial	3	3.9
1419	1 WALES AL	Shops	Commercial	4	2.2
1465	115 N LEE ST	Residences Of Torpedo Factory Condominium	Residential	4	6.0
1468	104 CAMERON MW	Cameron Mews	Residential	3	7.6
1479	105 CAMERON MW	Cameron Mews	Residential	3	8.0
1481	101 CAMERON MW	Cameron Mews	Residential	3	4.0
1497	109 QUEEN ST	Row house	Residential	3	8.0
1498	113 QUEEN ST	Row house	Residential	3	8.0
1506	100 QUAY ST	Row Houses With Garage / Appeared Split Level With A Walkdowm Living Space	Residential	3	8.0
1575	430 N UNION ST	Row Houses With Garage	Residential	3	8.0
1577	426 N UNION ST	Row Houses With Garage	Residential	3	8.0
1579	422 N UNION ST	Row Houses With Garage	Residential	3	8.8
1584	412 N UNION ST	Row Houses With Garage	Residential	3	9.6
1587	406 N UNION ST	Row Houses With Garage	Residential	3	9.7
1590	400 N UNION ST	Row Houses With Garage	Residential	3	9.6
1599	101 QUAY ST	Row House With Garage	Residential	3	8.9
1600	100 PRINCESS ST	Row Houses With Garage / Appeared Split Level With A Walkdowm Living Space	Residential	3	9.5
1636	221 N LEE ST	Row Hourses On Parking Garage	Residential & Commercial	2	4.2
1674	102 PRINCE ST	Row House	Residential	1	7.3
1692	109 PRINCE ST		Residential	2	9.0
1697	215 S UNION ST	The Carraige House Coffee Shop	Commercial	2	8.1
1699	204 S UNION ST	Business	Commercial	3	4.7
1700	206 S UNION ST	Business	Commercial	3	5.7
1938	830 S LEE ST	Business	Residential	2	9.9
2017	827 S ROYAL ST	Business	Residential	1	12.4
2038	201 KING ST	Business	Commercial	3	10.2
0	409 S UNION ST	Semi-Detached House	Residential	1	10.4

Exhibit 2: Field Visit Summary – July 23, 2009

All elevations noted in the field visit summary are referenced to NAVD88.

Area No 1 – Structures along N Union Street between Oronoco St and Princess St

All structures in this area are Residential, row houses with garages. All garages are approximately at the road elevation, which is about 8.0 ft. structures have 3-4 steps up to the door way (Refer figure A1-1). The lowest point of entry (LPE) for these structures is at the garage elevation. The first floor elevation appears to be lower than the LPE. Corner units (observed at Union and Princess Intersection) have side windows which show that these houses have living space lower than the garage elevation. (5 +/- ft) However it appears that the structures have split floors (3-4 floors), so when you enter the house through the main front door, there is a staircase leading upstairs to a living area and stairs leading downstairs. Downstairs probably there is an escape window lower than the elevation at the entrance; however the water might not be able to go around these structures, to the backyard. 430 N Union St appears to be abandoned.

Figure A1-1

Structures on Princess Street are most likely to follow the same trend but with 1 step up to the doorway. There appeared to be a jump in the first floor elevations at 113/115 and also at the 117/119 princess st. (Refer Figure A1-12)

Figure A1-12

There are no existing flood control measures but the mitigation measures for this area should extend up to 121 Princess St. (structures West of this don't have any flood problem as they are high enough).

Area No 2 – Robinson Terminal

This is a warehouse located at the Oronoco and Union Street intersection. Garage located at the ground level. They have 2 buildings with loading docks approximately 3.5 ft above the ground. (Refer figures A2-1 and A2-4) Both buildings have first floors located at the dock level, which appears to be at 12 ft and flooding is not a problem to these buildings. No major flood protection measures are required for these buildings, however acquire these buildings would provide great aesthetics, recreational and environmental benefits to the city.

Figure A2-1

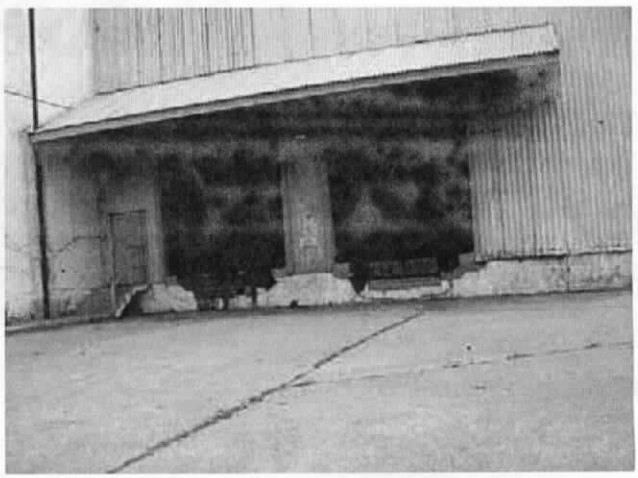


Figure A2-4

Area No 3 – Structures along N Union Street between Princess St and Quay St.
All the structures have garages at the road elevation and the Lowest Point of Entry is at the garage level for most of these structures. Main door way is at the garage elevation or 1-2 steps above the garage level. (Refer Figure A3-1)

Figure A3-1

Figure A3-3

These structures appeared to have a living area lower than garage elevation. (Appeared as split level with a walk down living space- Refer Figure A3-3, same as area 1)
Based on the information from one of the residents (112 Princess St), this street has never been flooded.

Once flood risk will be confirmed by surveyed elevations, flood proofing may be a suitable mitigation option for these properties, which may be removable household products, such as flood boards, air brick covers, which are fitted temporarily to individual properties to form a barrier to stop water coming in. Also should consider how the fabric of the walls, services, floors etc will respond to the pressure of the floodwater, including making walls more water resistant and repairing and sealing cracks.

Area No 4: Structures along N Union between Quay and Queen Streets

This area is similar to Area no 3. Some of the structures have garages and doors at ground elevation where as others have their door way 1 or 2 steps above the garage level. (Refer Figure A4-1) LPE for all the structures is at the garage level. Based on the information from one of the residents staying at 106 Quay Street, most of the structures have family room /living space below the garage level. (A window at the lower living space can be observed from figure A4-4).There was no flooding in this street during Isabel. It appears that the first floor elevations were taken at the door level for these structures. (Actual first floor starts below the garage elevation, which due to the split floor design). Flood proofing would be a suitable mitigation option for these properties, which will need to include sealing any windows lower than entrance level located in the back.

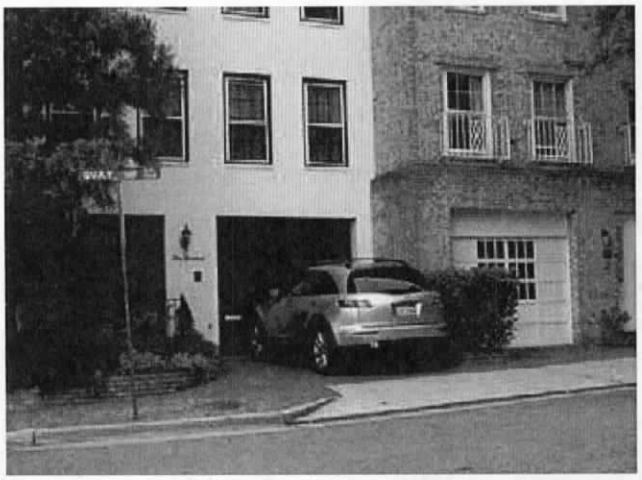


Figure A4-1

Figure A4-4

Area No 5: Queens Row (Along Queen St between N Union and N Lee St)

These are 3 level Residential row houses with located on a private parking garage. (Refer figure A5-1) Elevated structures with the LPE as well as the first floor elevation approximately 8 feet above ground. (Refer figure A5-5)Vents appearing below the main door belong to the parking garage.

No flood mitigation measures are needed for this area as the buildings are located high. The residents park their vehicles in the parking lot located behind their buildings. GIS layer seems to be incorrect; 220 N Union St is the entrance to the garage instead of a vacant land.

Figure A5-1

Figure A5-5

Area No 6 (6A -6G):
Commercial Structures long N Union St between Queen and King St)

Most of the buildings in the area would flood from the 10.2 ft flood event. Flood proofing or seawall would be a suitable option. However aesthetics would be an issue with the seawall as the flood water elevation would be high. Unless it was a wall that could be moved up in a flood event would be a suitable solution. Also a temporary free-standing barrier might be a suitable solution for some of the buildings (depending on the flood elevation).

6A: Commercial space above parking garage. First floor elevation at 11.6 ft. No flood protection is needed as the structure is above the garage.

←Figure A6a-1

6B: Alexandria Seaport Foundation located along the water. May need some flood proofing options for the boat building and their office.

← Figure A6b-1

6C: Chart house – Restaurant located on the storage space. (Refer figure A6c-2) Storage space about 3 ft above the lowest elevation. (Refer Figure A6c-4) All A/C appeared to be at the storage level. Survey was requested for this structure.

Figure A6c-2

Figure A6c-4

6D: Food Pavillion – floor elevation approximately at elevation 12. No flooding problems. No mitigation measures needed for this structure.

←Figure A6d-1

6E: First floor elevation is 8.62 which starts at the door elevation. Flood proofing (mitigation) would be required for extreme (1% annual probability) flood events.

←Figure A6e-2

6F: Torpedo factory

The building is used for art display, concerts, and studios. It has a historical significance as it used to be a torpedo factory.

The main building has a finished first floor at 7.03ft NAVD and the extension on the south is at 6.94 ft NAVD. Extension doesn't have any garages but the windows and door way are at the same elevation. (Refer figure A6f-2) Display portions of the windows are located below the flood elevation level. (refer to figure A6f-4)

Need to consider the art display portions since they are almost close to the ground elevation. Might consider raising the display portions to the floor elevation as part of the mitigation measures as the ceiling appears to be at a high elevation and also the doors and windows need to be flood proofed or temporary flood barriers to the windows and doors can protect the building from flooding.

Figure A6f-2

Figure A6f-4

6G Old Dominion Boat Club

First floor elevation is 3.75ft at ground level. (Refer figure A6g-2, may be between 4-5). Sandbags located in front of the entrance, which confirms frequent flooding of the building. Damaged during Isabel. It is not clear what is at the first floor. It appears that the bar and the party room are located upstairs. Perhaps the first floor is not in use. No basements to this structure. Flood protection, might be required. However it is a boathouse, so the structure might be designed to flood.

←Figure A6g-2

Area No 7 – Cameron Mews

Structures with no garages. First floor of the **structure is at ground level on the back side.** Structures have a pedestrian court yard on the front side. Front side door located 4 steps above courtyard. All the structures have a brick compound wall on the Cameron Street (back side of the structures) with gates to individual units. (refer to figure A7-3). On the tax assessors website up to 105 and 106 Cameron MW has no finished basements, however rest of the houses do have finished basements.

Flood protection is necessary for these structures as they are located on the ground level and the back of the houses are located in the 8ft flood elevation. Might consider making the privacy wall as a localized flood barrier but also need to consider the drainage pipes located in the backyard. (can be observed from figure A7-5) Dry flood proofing might be an option here.

Figure A7-3

Figure A7-5

Area No 8 – Torpedo Factory Condominiums

Condos built over a parking garage. Four apartments closest to the water have had repetitive loss. The finished flood appears to be high here; however survey was requested for these apartments. (refer to figure A8-2)

←Figure A8-2

Area No 9 – Businesses along King Street (West of Union Street)

New construction was taking place at King and Union intersection. The owner is the builder of the property. (refer to figure A9-1) The first floor for all the businesses along the street appeared to be the grade or 1 to 2 steps above the grade (refer figure A9-2). No structures have basements. All structures along King Street between Union and Lee Street would require flood protection; one of these options would be removable household products, such as flood boards, air brick covers, which are fitted temporarily to individual properties to form a barrier to stop water coming in. Also should consider how the fabric of the walls, services, floors etc will respond to the pressure of the floodwater, including making walls more water resistant and repairing and sealing cracks. Ceilings appear to be high, so internal elevation in combination with other solutions could be a good mitigation option. Structures have A/C systems backside of the street, those will need to be elevated on the concrete slab. Other mitigation options might be flood wall, or temporary flood barrier.

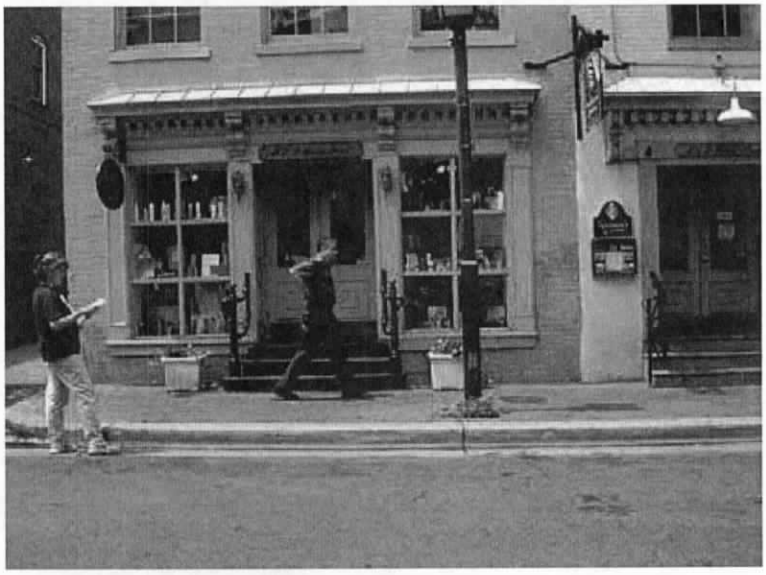
Figure A9-1

Figure A9-2

Area No 10 – (10A – 10C)
(Businesses Southwest of King and Union intersection, along King Street)

10A: These are all commercial structures located along union and King Street. The ones on the union street appear to have 2 – 3 steps up to the door way and are about 2 ft high from the ground. (figure A10a-8). Spoke to one of the representatives from 107 S Union Street business. This structure received 4 ft of water during Isabel. Same mitigation options should be considered as for Area 9.

Figure A10a-8 →



Structures along King Street are about a foot higher than the ground. They don't have basements and the door ways are at grade level (figure A10a-3).

Figure A10a-3

10B: business store along S Union Street

Structure located on the garage, the front of the building has few shops, with stairs leading up to the shops. The water is not likely to reach the floor above the garage, therefore no mitigation needed for this structure.

10C: (Intersection of Prince and S Union Street – structures along Union Street)

Door ways/first floors located at the grade level or 1 step above for businesses. Christmas Attic's first floor appeared to be a foot above the grade. These shops appears to have high ceilings, might be suitable for the same mitigation options as Area 9.
Residential structures along Prince Street also have 1-2 steps above the grade. First floor appeared to be around 2ft above the road. (Can be observed in Figure A10c-3)

Figure A10c-3 →

Area No 11- Southwest of Union and Prince Intersection

All these residential structures along Prince Street don't have any basements and also just about 10 inches above the road. 110 Prince St is outside the 10.2ft flood boundary, but flooded 22 inches from the toilet. Dry flood proofing may be an option here if there are no basements.

The GIS database shows a misleading floor elevation for this structure. First floor for this structure appeared around 7.0 (refer figure A11-1 below)

Fig A11-1→

There are other commercial structures / shops located along S Union Street. Many of them will require flood protection, as the FFE is between 6-7 ft. There are no current flood protection measures for all these structures. The Carriage House Shop is about a foot above the grade (3 steps). (Refer figure A11-3) survey was requested. Dry flood proofing or internal elevation may be an option.

Figure A11-3→

Structure to the south of The Carriage House coffee shop is an elevated structure built above a garage, no mitigation would be required.

Area 12 – Structures along S Union Street between Duke St and Wolfe Street

Structures don't have any basements. Most of the Residential structures along Duke Street have their door ways a step above the grade (figure A12-3). First floor elevations look fine in the database. Some of the structures along the Union street have their garages below the first floor elevation. (Refer figure 12-1) The adjacent grade is located at 12. According to the information from the resident of 303 S Union Street, the structure was never flooded and the first floor appeared to be approximately at 15. (Refer figure A12-5). No flood mitigation is required.

Figure A12-3

Figure A12-5

Area 13 – Residential structures just South side of Wolfe Street

Structures have no basements and garages and the first floor appeared to be about 1.5 feet above the grade. GIS elevation data looks correct. (Refer figure A13-3) No flood mitigation is required.

←Figure A13

Area No 14 – Harborside Development

All the structures in this development are located on the parking garage. (Refer figure A14-1) and the first floor appeared to be a minimum of 3 feet above the grade everywhere. Some also have a privacy wall on the water side and are located high. (Figure A14-6). No flood mitigations are required for this development.

Figure A14-1

Figure A14-6

Area No 15 – Robinson South Terminal

The loading dock is 3 feet above the grade and first floor is at 14 for this building (Figure A15-2). **No flood mitigation measures are required for this structure. Loading dock appears to be at grade?**

← Figure A15-2

Area No 16 – Commercial stores East of South Union Street between Duke and Prince Street

Area consists of the Art league, Chadwick's place restaurant, Potomac River Boat Company etc. Mystic Jewelers is an elevated structure and its fist floor is at 10.6. The first floors are at the grade for these structure or 1 or 2 steps above the grade. The first floor values for big wheel bikes, gem shop and the empty office at the corner is bellow 8ft. (Figure A16-3)
The first floor elevations for the Potomac River boat company appear to be around 6 and for Art league about 10, we requested surveys for these structures. (Figure A16-1) There is a low point of entry to the Art League in the east side of the building. Dry flood proofing or internal elevation would be an option here. It's possible that the first floor is already elevated. Survey will tell.

Figure A16-1


Figure A16-3

Area No 17 – (ex) Olson's book store FFE is at 5.87. The property flooded several times in the past and at the site visit in July 2009 the building was vacant. It might be a suitable property for the city to acquire, however there might be structural limitation to it. Alternatively a combination of mitigations could be provided. These could be, raising the ground internally, sealing the walls, window, blocking the doors with removable boards.

Area No 18 - structure at the corner of Wales and Strand Street is about 3 ft.
All the first floors appeared to be at the grade or a step above that. (Figure A18-1) survey is being requested for these units. For Starbucks and Mai Thai, flood mitigation will be required, both had repetitive loss claims and the FFE is between 6-7ft. The Mai Thai is already elevated internally. The first floor is concrete for both places. For this block of buildings buying out would be a suitable option as the street and the buildings floods regularly as well as dry flood proofing would be an option here.

Figure A18-1 →

Area No 19 and 20 – Backyard Boats
First floor elevation and the lowest point of entry are 2 to 3 steps above the grade. (Figure A19-5). Structures on the Alexandria Street have their lowest point of entry as well as first floors at the grade. (Figure A19-9)

Figure A19-5

figure A19-9

Structures west of South Union Street are on the garages and there appeared to be a flood gate at the entrance of the garage. (Refer figure A20-3). Also one of the structures in this building has its first floor lower than the ground. Stairs appeared at the entrance. (Figure A20-1) Peter Chaput mentioned that a private contractor was hired to flood proof these buildings, so no mitigation is needed.

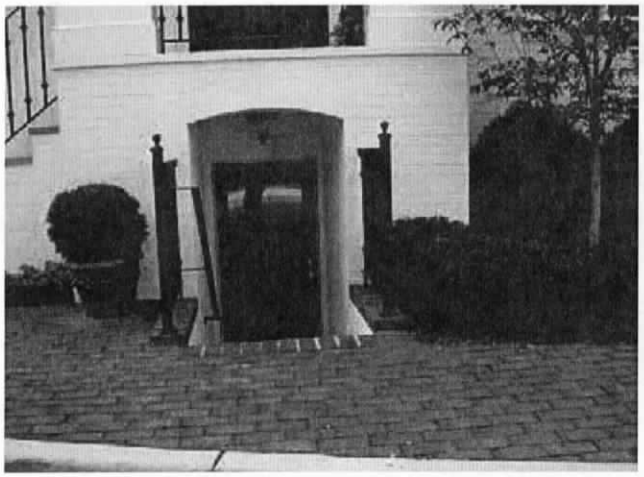


Figure A20-1

figure A20-3

Area 21

This is the most southern part of the study area, located just to the north of I495. There is a forest between I-495 and properties. Most of the buildings have finished basements and somewhat elevated. However some of them have low point of entry to the lowest floor. See Figure 21-1, 21-2. Also found some sandbags in front of 211 Lee Ct, see figure 21-3 bellow.

Figure 21-1

Figure 21-2

Figure 21-3

210 Lee Ct seems to be abandoned, only built in 1961. It is located in the 8 ft Flood Plain and the first floor seems to be 1 step above ground. The FFE is 8.74. See picture 21-3. There is a wall next to the building, but not behind where the water would be coming from, see picture 21-4. Also a swimming pool located next to the building.

Figure 21-3

Figure 21-4

Perhaps buy out would be a feasible solution for 210 Lee Ct. It would not only provide final solution to the flooding problem, but also it would provide environmental benefits, as it is located next to the forest(park), which could be extended. However also elevation, flood proofing would probably be suitable. Alternatively Area 21 a small flood wall could provide protection as well.

Exhibit 3: Rainfall Data

TR-20 was used and the online version of the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 were averaged to get the rainfall precipitation frequency estimates used for our study as shown in Table 1.

Average rainfall data was determined from the Windows version of TR-20. Screen shots from TR-20 and Atlas 14 are shown in Figures 1 and 2 below.

Table 1: Rainfall precipitation frequency data used for study

Precipitation (inches)			
Frequency	**Win TR-55**	**NOAA**	**Average**
10-year	5.5	4.76	5.13
25-year	6.0	5.96	5.98
50-year	7.0	7.01	7.01
100-year	7.7	8.21	7.96

Figure 1: Screen shot from Win TR-20

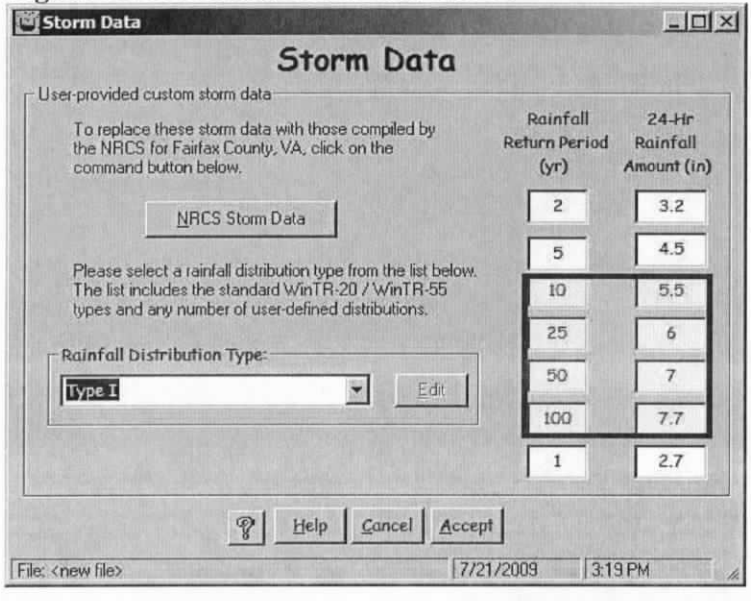


Figure 2: Screen shot from NOAA Atlas 14

Pop-up blocked. To see this pop-up or additional options click here...

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Virginia 38.8088 N 77.06364 W 95 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3
G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2004

Extracted: Tue Jul 21 2009

Confidence Limits | Seasonality | Location Maps | Other Info. | GIS data | Maps | Docs

Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
1	0.36	0.57	0.71	0.98	1.22	1.41	1.51	1.84	2.21	2.56	2.98	3.32	3.84	4.39	5.93	7.30	9.17	10.90
2	0.43	0.69	0.86	1.19	1.50	1.72	1.83	2.22	2.67	3.10	3.60	4.01	4.62	5.28	7.06	8.64	10.81	12.82
5	0.51	0.82	1.03	1.47	1.88	2.18	2.32	2.81	3.39	3.98	4.62	5.13	5.84	6.59	8.53	10.27	12.64	14.81
10	0.57	0.91	1.15	1.67	2.17	2.53	2.71	3.29	4.01	4.76	5.49	6.09	6.89	7.68	9.72	11.59	14.04	16.32
25	0.65	1.03	1.30	1.93	2.57	3.04	3.27	4.00	4.96	5.96	6.81	7.53	8.45	9.28	11.39	13.40	15.89	18.26
50	0.70	1.12	1.42	2.13	2.89	3.44	3.73	4.61	5.78	7.01	7.96	8.78	9.79	10.62	12.73	14.84	17.30	19.70
100	0.76	1.20	1.52	2.33	3.21	3.88	4.21	5.26	6.70	8.21	9.23	10.17	11.27	12.06	14.13	16.31	18.68	21.08
200	0.81	1.29	1.62	2.53	3.55	4.32	4.73	5.97	7.72	9.57	10.65	11.72	12.91	13.61	15.58	17.82	20.03	22.39
500	0.88	1.39	1.75	2.79	4.01	4.96	5.47	7.01	9.27	11.65	12.80	14.04	15.35	15.90	17.59	19.87	21.78	24.05
1000	0.94	1.47	1.85	3.00	4.37	5.48	6.08	7.88	10.62	13.47	14.64	16.03	17.42	17.80	19.17	21.47	23.07	25.25

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to NOAA Atlas 14 Document for more information. NOTE: Formatting forces estimates near zero to appear as zero.

Appendix E
Economic Valuation Results

Potomac River Waterfront Flood Mitigation Study
Benefit Cost Summary for All Structural Projects

BENEFITS	Flood Wall[1]	Flood Proofing[2]	Acquisition[3]	Walkway[4]	Berm[5]
King Street	$ 1,017,062	$ 7,470,452	$ 4,227,045		N/A
Waterfront Commercial	$ 11,022,291	$ 6,727,889	$ 7,336,054	$ 14,745,415	N/A
N Union St	$ 156,934	$ 733,539	$ 608,916		N/A
Jones Point	N/A	$ 230,843	$ 197,424	N/A	$ 236,410
Total:	$ 12,196,287	$ 14,931,880	$ 12,172,015	$ 14,745,415	$ 236,410
COST	**Flood Wall**	**Flood Proofing**	**Acquisition**	**Walkway**	**Berm**
King Street		$ 1,180,560	$ 90,826,273		N/A
Waterfront Commercial	$ 18,863,273	$ 2,790,754	$ 104,375,470	$ 6,072,490	N/A
N Union St		$ 1,084,100	$ 19,865,796		N/A
Jones Point	N/A	$ 238,050	$ 11,279,417	N/A	$ 5,491,975
Total:	$ 18,863,273	$ 5,055,414	$ 215,067,539	$ 6,072,490	$ 5,491,975
BCR	**Flood Wall**	**Flood Proofing**	**Acquisition**	**Walkway**	**Berm**
King Street		6.33	0.05	2.43	N/A
Waterfront Commercial	0.65	2.41	0.07		N/A
N Union St		0.68	0.03	no protection	N/A
Jones Point	N/A	0.97	0.02	no protection	0.04

[1] Structure lifetime is 50 years, and provides protection to the 100 year flood event

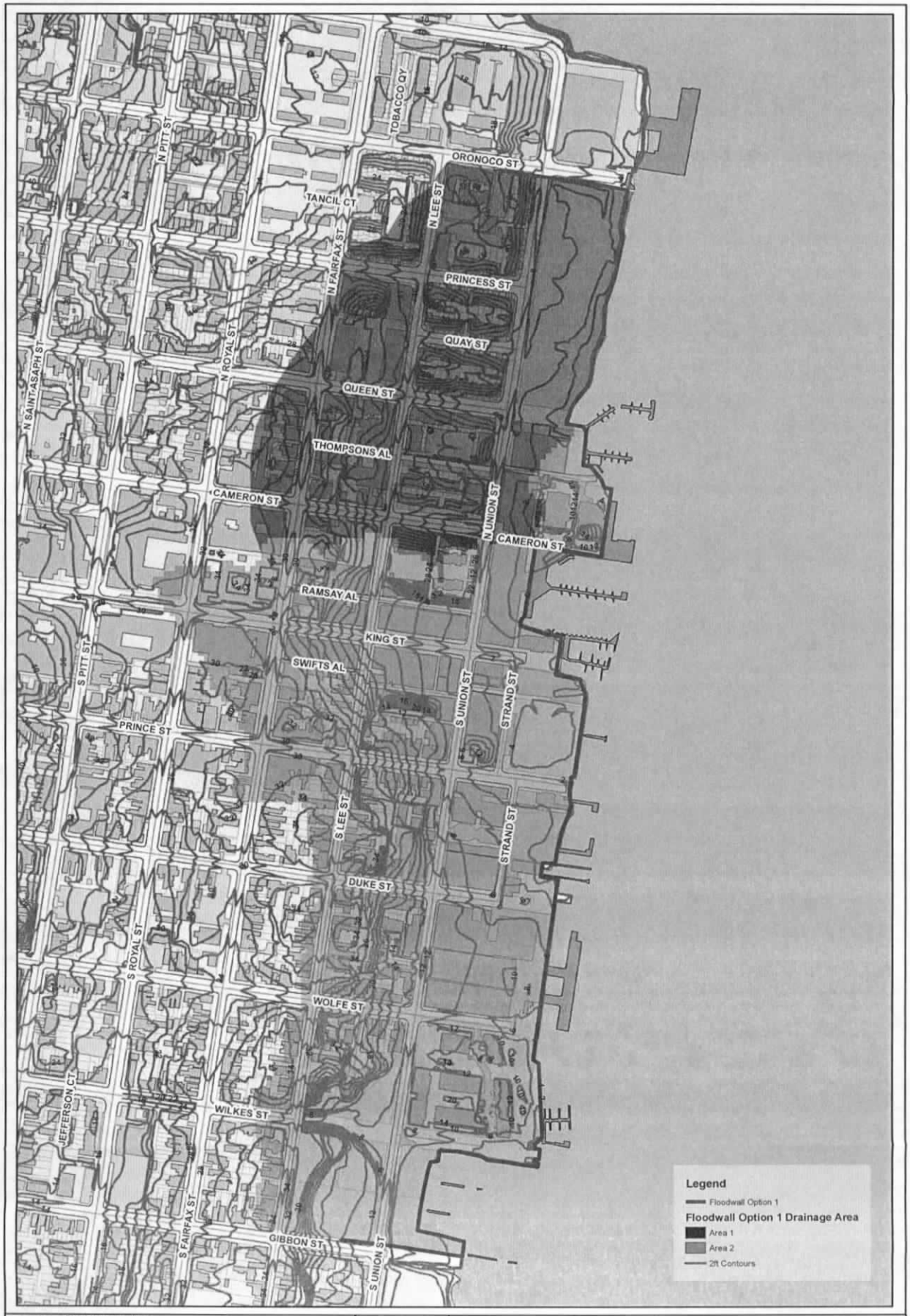
[2] Floodproofing lifetime is 30 years

[3] Acquisition lifetime is 100 years

[4] Walkway lifetime is 50 years

[5] Berm lifetime is 50 years

Appendix F
Floodwall



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/11/09
SCALE	1 inch = 300 feet	DR BY	CJL	09/24/09
W:\City of Alexandria\15298592 - Lower King St\GIS\Projects\Floodwall_Option1_115317.mxd		CHK BY	xxx	00/00/00

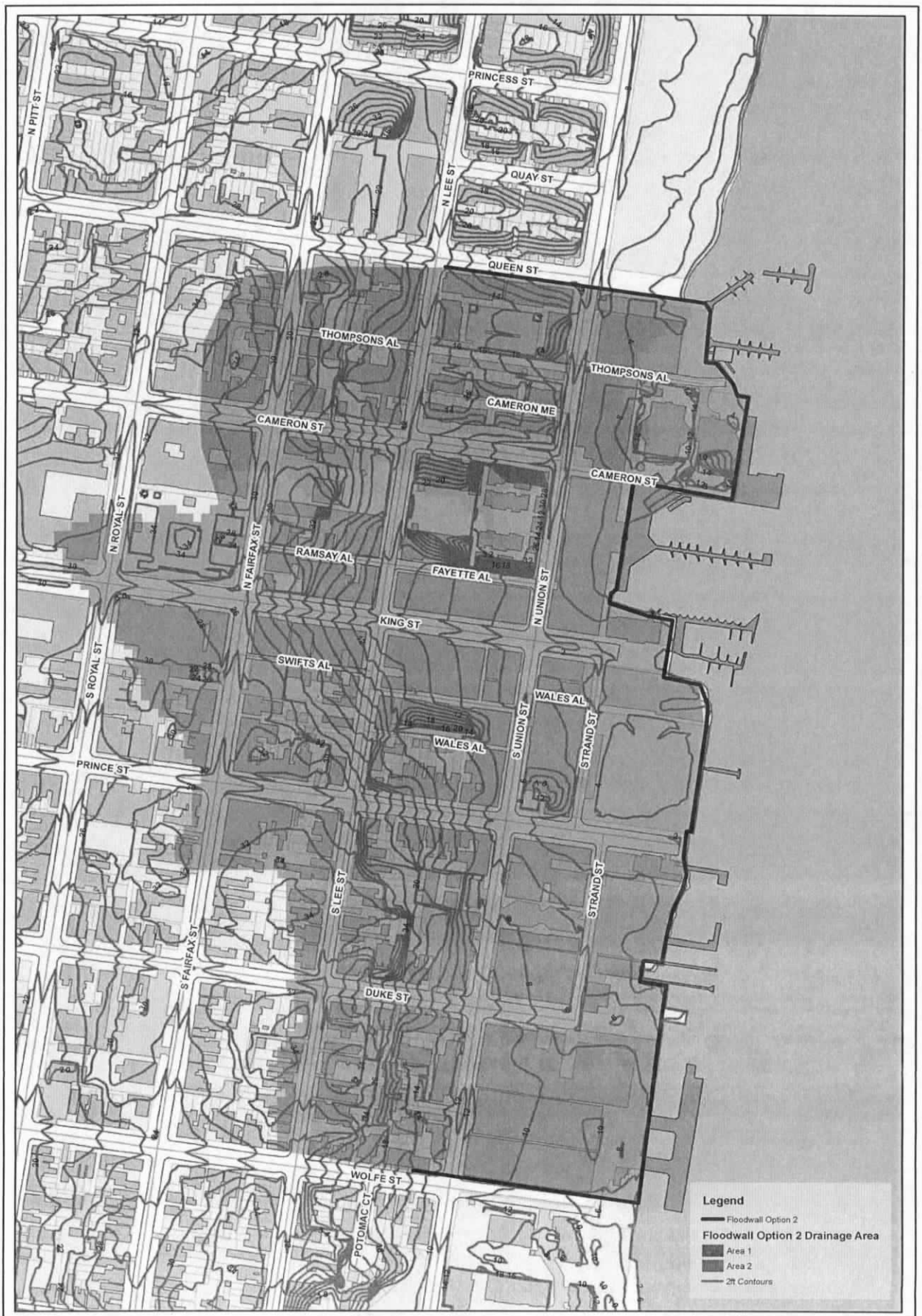
TITLE: Floodwall Layout Option 1

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

EXHIBIT 1-1



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/11/09
SCALE	1 inch = 200 feet	DR BY	CJL	09/24/09
W:\City of Alexandria\15296470 - Lower King St\Report\Draft Report\New Figures\Floodwall_Option2_113237.mxd		CHK BY	xxx	00/00/00

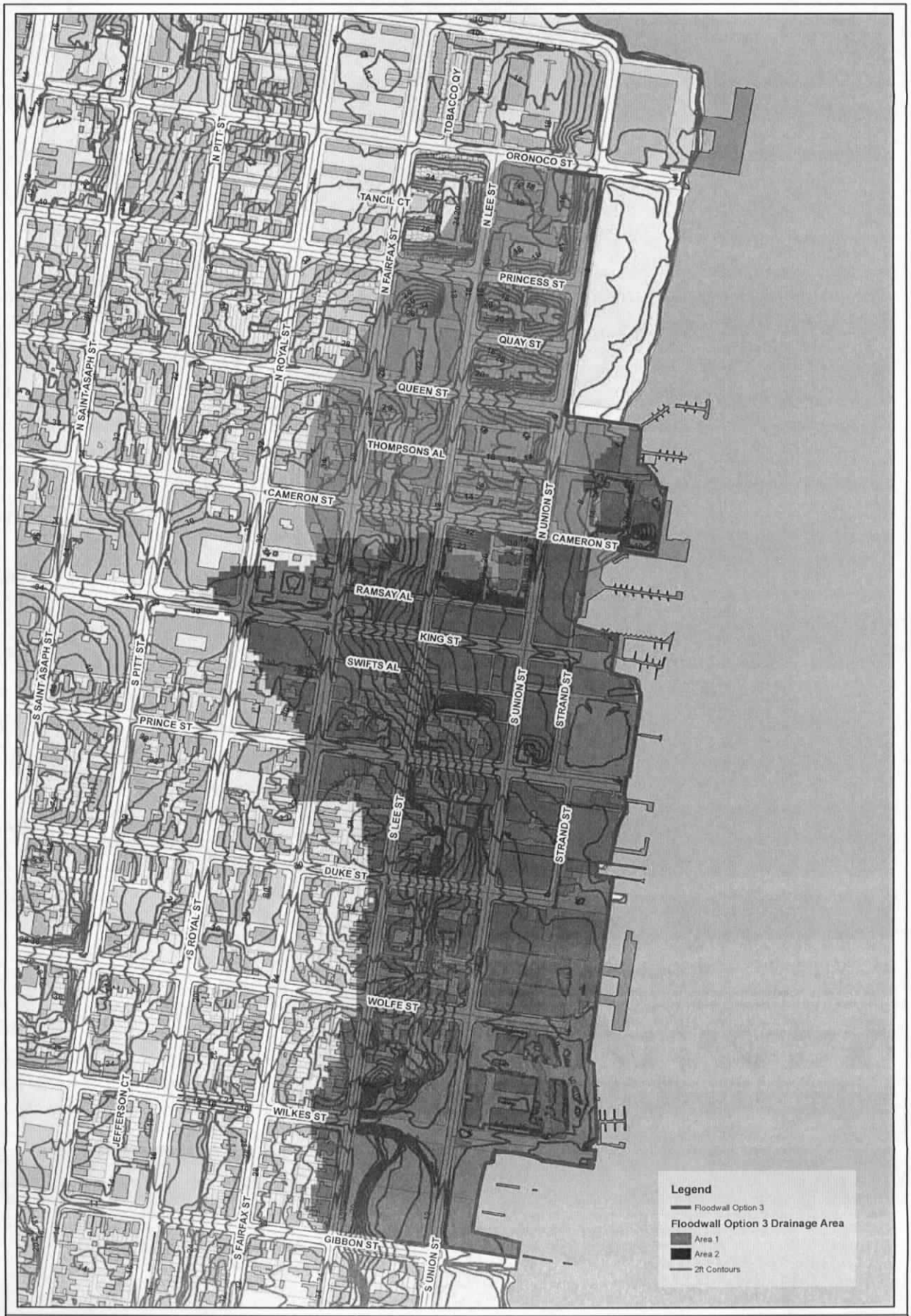
TITLE: Floodwall Layout Option 2

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15296592

EXHIBIT 1-2



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/11/09
SCALE	1 inch = 300 feet	DR BY	CJL	09/24/09
W:\City of Alexandria\15298470 - Lower King St\GIS\Projects\Floodwall_Option3_115017.mxd		CHK BY	xxx	00/00/00

N

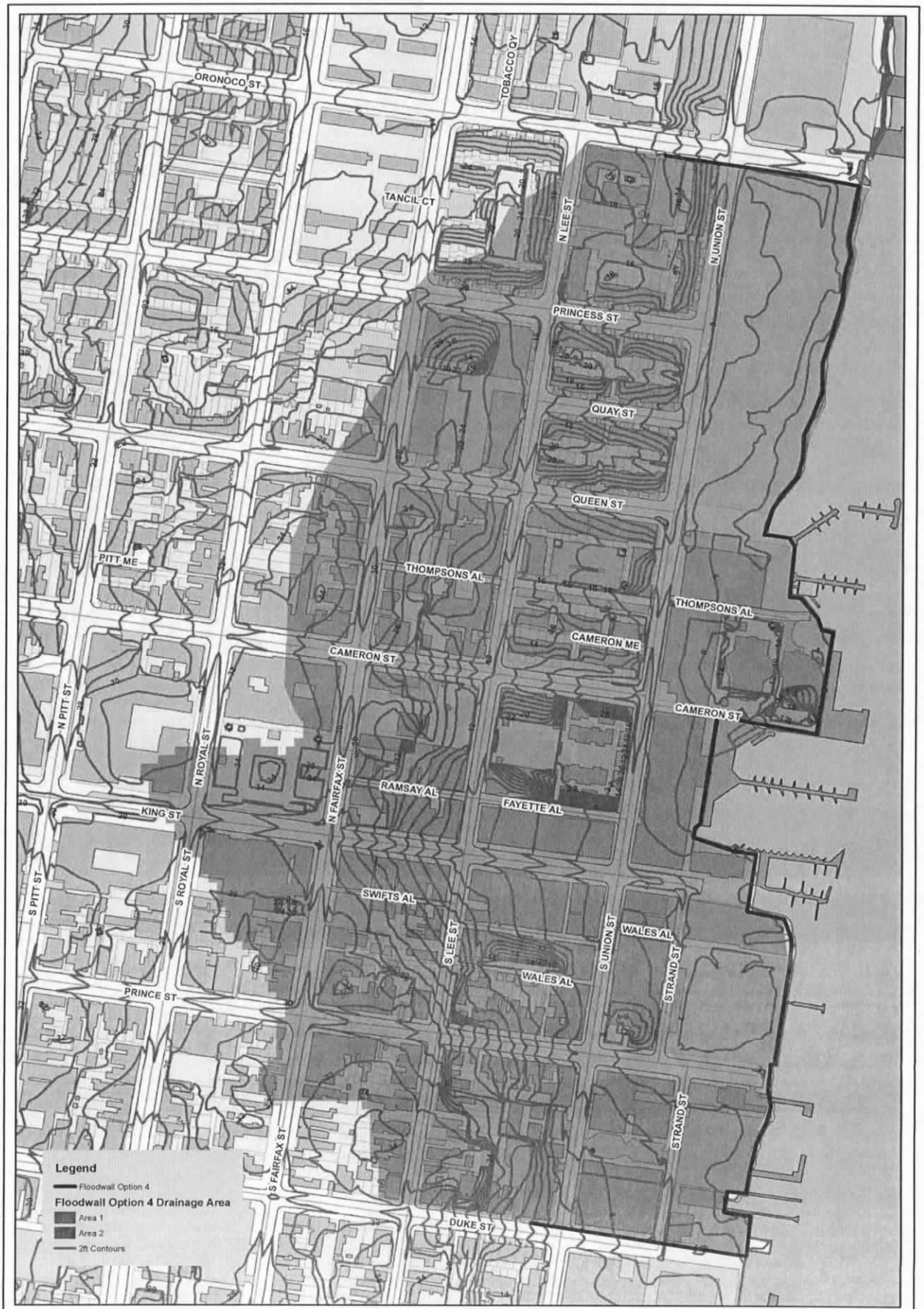
0 75 150 300 Feet

TITLE
Floodwall Layout Option 3

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO 15298592

EXHIBIT 1-3



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/11/09
SCALE	1 inch = 200 feet	DR BY	CJL	09/24/09
W:\City of Alexandria\15298476 - Lower Eng 30\Report\Draft Report\New Figures\Floodwall Option4 11X17.mxd		CHK BY	xxx	00/00/00

0 50 100 200 Feet

TITLE: Floodwall Layout Option 4

URS

200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO: 15298592

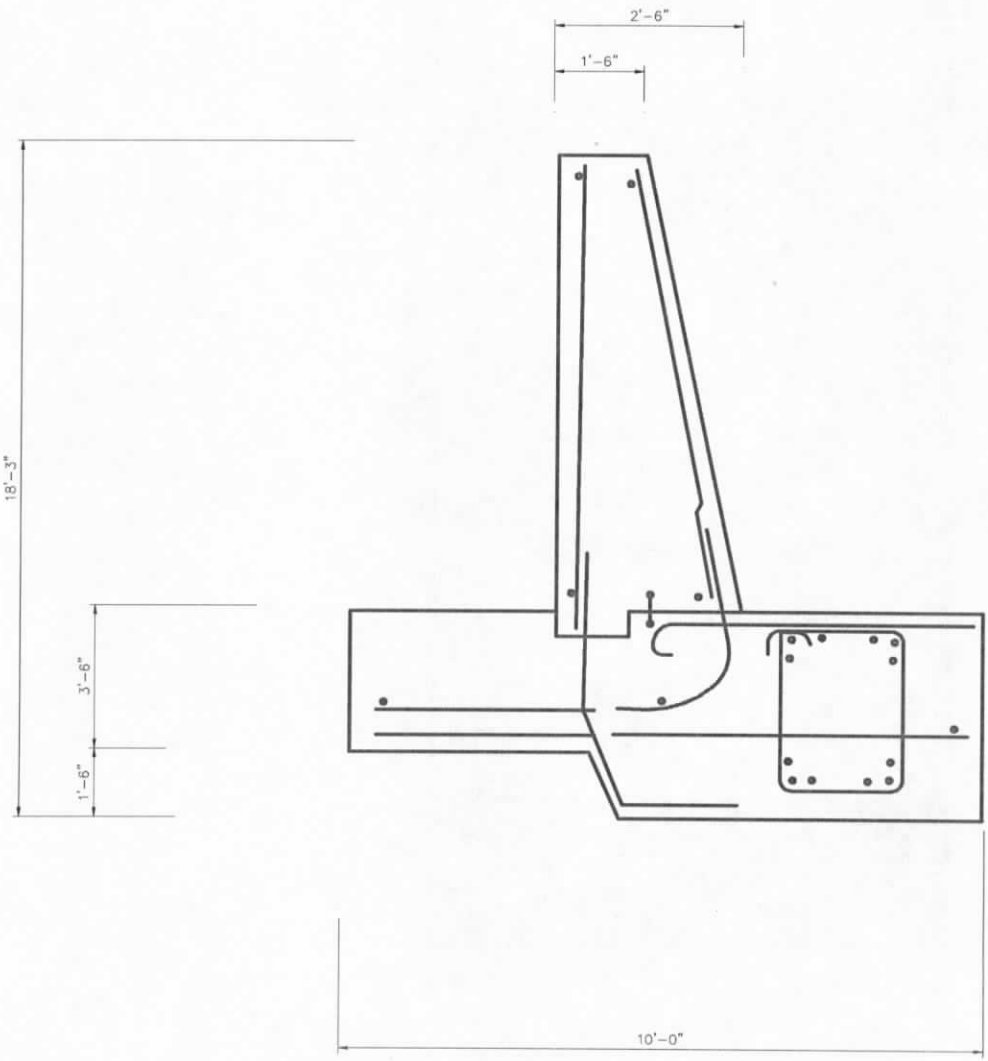
EXHIBIT: 1-4

CLIENT	City of Alexandria			TITLE	Floodwall Layout Option 5
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	CJL	09/11/09	
SCALE	1 inch = 300 feet	DR BY	CJL	09/24/09	
G:\arc\.mxd		CHK BY	xxx	00/00/00	

URS 200 Orchard Ridge Drive Gaithersburg, MD 20878

PROJ NO 15296592

EXHIBIT 1-5

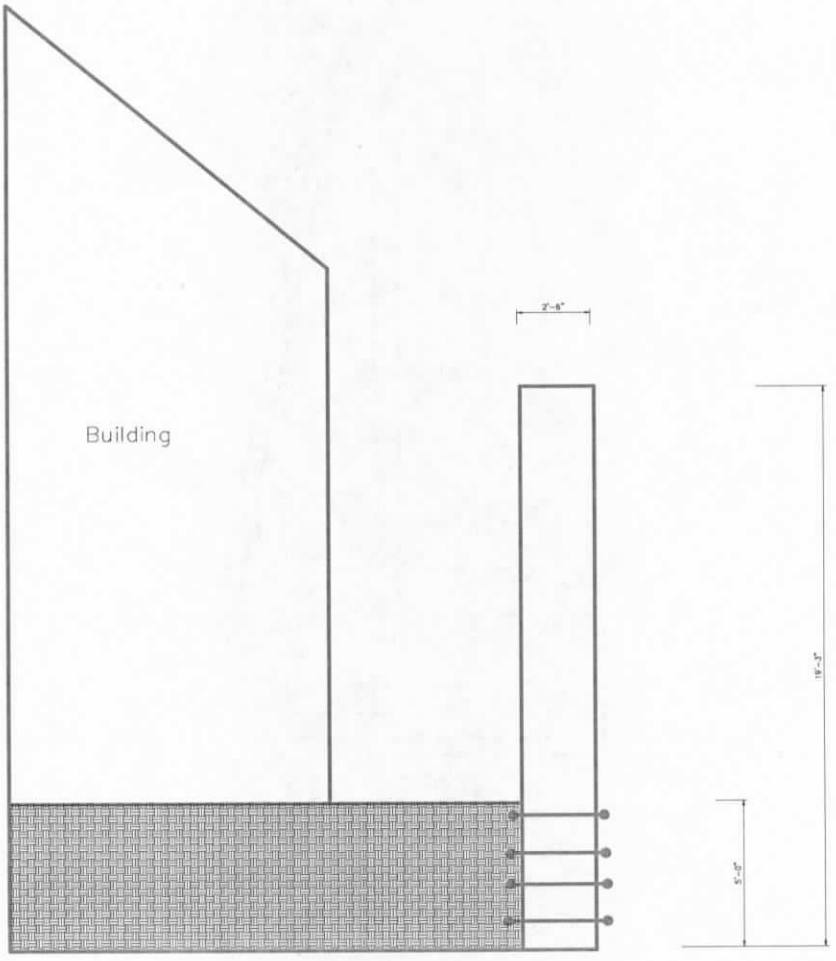


CLIENT	City of Alexandria			TITLE	Floodwall - Cross Section
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	CJL	09/30/09	
SCALE		DR BY	CJL	09/30/09	
W:\City of Alexandria\15298470 - Lower King St\Report\Draft Report\New Figures\Floodwall Figures\Floodwall_Spec.mxd		CHK BY	MER	09/10/09	

URS 200 Orchard Ridge Drive Gaithersburg, MD 20878

PROJ NO 15298592

EXHIBIT 2-1



CLIENT	City of Alexandria			
PROJ	Potomac River Waterfront Flood Mitigation Study			
REVISION NO	0	DES BY	CJL	09/30/09
SCALE		DR BY	CJL	09/30/09
W:\City of Alexandria\15298470 - Lower King St\Report\Draft Report\New Figures\Floodwall Figures\Floodwall_Spec.mxd		CHK BY	MER	09/10/09

TITLE: Floodwall - Slab Portion Cross Section

URS
200 Orchard Ridge Drive
Gaithersburg, MD 20878

PROJ NO: 15298592

EXHIBIT: 2-2

Exhibit 3: Various Floodwall Tables

Tables providing additional data for the floodwall design. Drainage area 1 is 11 acres with a time of concentration of 12 minutes. Drainage area 2 is 39 acres with a time of concentration of 16 minutes. Computations for time of concentrations are provided as Exhibit 4 in this appendix.

Table 1: Peak discharges and pipe sizes for floodwall drainage area 1

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10 year	5.52	0.95	56.4	25,303	2.82
25 year	6.45	0.95	65.8	29,566	2.99
50 year	7.23	0.95	73.8	33,141	3.12
100 year	7.95	0.95	81.2	36,441	3.23

Table 2: Peak discharges and pipe sizes for floodwall drainage area 2

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10 year	4.87	0.95	180.8	81,191	4.36
25 year	5.82	0.95	216.1	97,029	4.66
50 year	6.43	0.95	238.8	107,199	4.84
100 year	7.09	0.95	263.3	118,202	5.02

Table 3: Flood runoff and volume table for floodwall

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	14.53
25-year	5.98	4.3	17.85
50-year	7.01	5.3	21.93
100-year	7.96	6.2	25.73

Table 4: Detailed cost estimate for floodwall

Item	Description	Quantity	Unit	Unit Price	Total
Design					
	Design	1	LS	$1,970,817.72	$ 1,970,818
	Permitting	1	LS	$1,175,000.00	$ 1,175,000
				Subtotal	$ 3,145,818
Construction					
1	Concrete for base of wall	5,426	CY	$390.00	$ 2,116,111
2	Concrete for wall (13.2 ft)	2,447	CY	$390.00	$ 954,287
3	Concrete for wall (7.2 ft)	814	CY	$390.00	$ 317,460
4	Concrete for slabs (Boat Club to Chart House)	1,724	CY	$450.00	$ 776,000
6	Anchor Bolts, 1.5 ft, 36 in long	388	each	$100.00	$ 38,800
7	Aluminum Planks for Removable Floodwall at road crossings	80	LF	$750.00	$ 60,000
8	Removable floodwall base	2	each	$50,000.00	$ 100,000
7	Pump Stations and Features	3	each	$1,500,000.00	$ 4,500,000
9	Excavation	8,652	CY	$11.05	$ 95,605
10	Easements (10% of construction cost)	1	LS	$895,826.24	$ 895,826
				Subtotal	$ 9,854,089
				Construction Contingency (20%)	$ 1,970,818
				Mobilization/Demobilization/Stakeout ($50,000 min or 5%)	$ 492,704
				TOTAL	$15,463,428
				Annual Maintenance	$3,399,844
				Cost used in BCA	$18,863,273

Pump Stations and Features include costs for: Dewatering, structural, mechanical, HVAC, Electrical, Communication/Control, and site work

Mobilization cost also includes erosion and sediment control measures

Permitting costs include natural resources and cultural resources; assumes NEPA review is not required

Design cost is assumed to be 20 percent of construction costs (without contingency or mobilization)

Exhibit 4-1: Floodwall Drainage Area 1

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
06/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac River Waterfront Flood Mitigation St | Designed By: _____ Date: _____

Location: Floodwall Option 2 - Area 1 | Checked By: _____ Date: _____

Check one: Present Developed

Check one: ✓ T_c T_t through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to T_c only)	Segment ID	1			
1. Surface description (Table 3-1)		short grass, pr			
2. Manning's roughness coeff., n (Table 3-1)		0.15			
3. Flow length, L (total L ≤ 100 ft)	ft	100			
4. Two-year 24-hour rainfall, P_2	in	3.1			
5. Land slope, s	ft/ft	0.040			
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr	0.13	+		= 0.13
Shallow Concetrated Flow	Segment ID	2			
7. Surface description (paved or unpaved)		paved			
8. Flow length, L	ft	1,000			
9. Watercourse slope, s	ft/ft	0.040			
10. Average velocity, V (Figure 3-1)	ft/s	4.0			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.07	+		= 0.07
Channel Flow	Segment ID				
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, P_w	ft				
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft				
15. Channel Slope, s	ft/ft				
16. Manning's Roughness Coeff., n					
17. $V = \frac{1.49\ r^{2/3} s^{1/2}}{n}$ Compute V	ft/s				
18. Flow length, L	ft				
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+		=
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19	hr	0.20			

Exhibit 4-2: Floodwall Drainage Area 2

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
06/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac River Waterfront Flood Mitigation St | Designed By: _____ | Date: _____

Location: Floodwall Option 2 - Area 2 | Checked By: _____ | Date: _____

Check one: Present Developed

Check one: ✓ T_c T_t through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

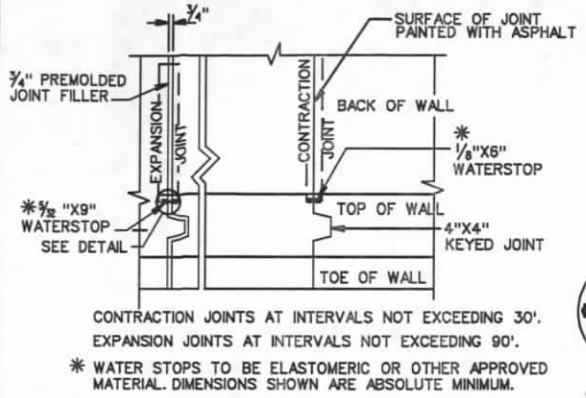
Sheet Flow (Applicable to T_c only)	Segment ID	1			
1. Surface description (Table 3-1)		short grass, pr			
2. Manning's roughness coeff., n (Table 3-1)		0.15			
3. Flow length, L (total L ≤ 100 ft)	ft	100			
4. Two-year 24-hour rainfall, P_2	in	3.1			
5. Land slope, s	ft/ft	0.020			
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr	0.17	+		= 0.17
Shallow Concetrated Flow	Segment ID	2			
7. Surface description (paved or unpaved)		paved			
8. Flow length, L	ft	1,400			
9. Watercourse slope, s	ft/ft	0.060			
10. Average velocity, V (Figure 3-1)	ft/s	4.0			
11. $T_t = \frac{L}{3600 V}$ Compute T_t	hr	0.10	+		= 0.10
Channel Flow	Segment ID				
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, P_w	ft				
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft				
15. Channel Slope, s	ft/ft				
16. Manning's Roughness Coeff., n					
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V	ft/s				
18. Flow length, L	ft				
19. $T_t = \frac{L}{3600 V}$ Compute T_t	hr		+		=
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19	hr				0.26

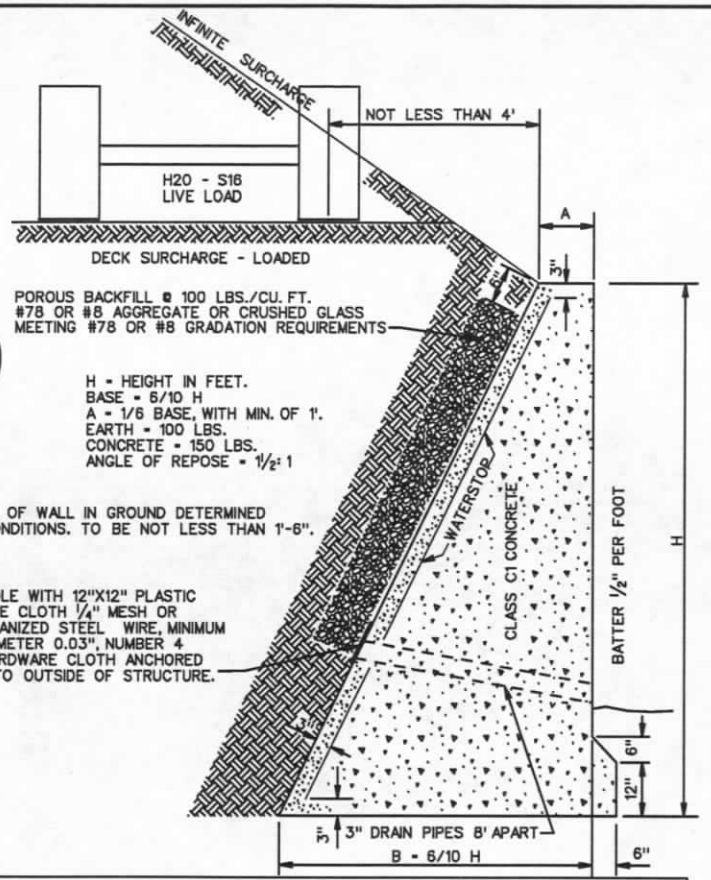
2 (q min)

Appendix G
Elevated Walkway

Exhibit 1: Retaining Wall Specification

RW-3





HEIGHT OF WALL "H" IN FEET	THICKNESS AT TOP "A" IN FEET	THICKNESS AT BASE B=.6H	COMPRESSION AT TOE LBS. PER SQ. FT.	AREA OF SECTION SQ. FT.
3	1'-0"	1'-9⅝"	856	4.83
4	1'-0"	2'-4¾"	1141	7.43
5	1'-0"	3'-0"	1427	10.63
6	1'-0"	3'-7¼"	1712	14.43
7	1'-0"	4'-2⅜"	1997	18.83
8	1'-0"	4'-9⅝"	2283	23.83
9	1'-0"	5'-4¾"	2568	29.43
10	1'-0"	6'-0"	2853	35.63
11	1'-1 1/4 "	6'-7¼"	3139	42.98
12	1'-2 3/8 "	7'-2⅜"	3424	51.03
13	1'-3 5/8 "	7'-9⅝"	3709	59.78
14	1'-4 3/4 "	8'-4¾"	3995	69.23
15	1'-6"	9'-0"	4280	79.38

SAFE BEARING CAPACITY OF SOIL	
ROCK MINIMUM	10,000 - 20,000 LBS. PER SQ. FT.
GRAVEL AND COARSE SAND, WELL CEMENTED	16,000 - 20,000 LBS. PER SQ. FT.
CLAY IN THICK BEDS, ALWAYS DRY	12,000 - 16,000 LBS. PER SQ. FT.
CLAY IN THICK BEDS, MODERATELY DRY	8,000 - 12,000 LBS. PER SQ. FT.
CLAY, SOFT	2,000 - 4,000 LBS. PER SQ. FT.
SAND, DRY, COMPACT, AND WELL CEMENTED	8,000 - 12,000 LBS. PER SQ. FT.
SAND, CLEAN, DRY	4,000 - 8,000 LBS. PER SQ. FT.
ALLUVIAL SOILS, ETC	1,000 - 2,000 LBS. PER SQ. FT.

NOTE: IF COMPRESSION AT TOE EXCEEDS SAFE BEARING CAPACITY OF SOIL, A SPECIAL FOOTING IS TO BE USED.

CONCRETE GRAVITY RETAINING WALLS
INFINITE SURCHARGE AND DECK SURCHARGE - LOADED

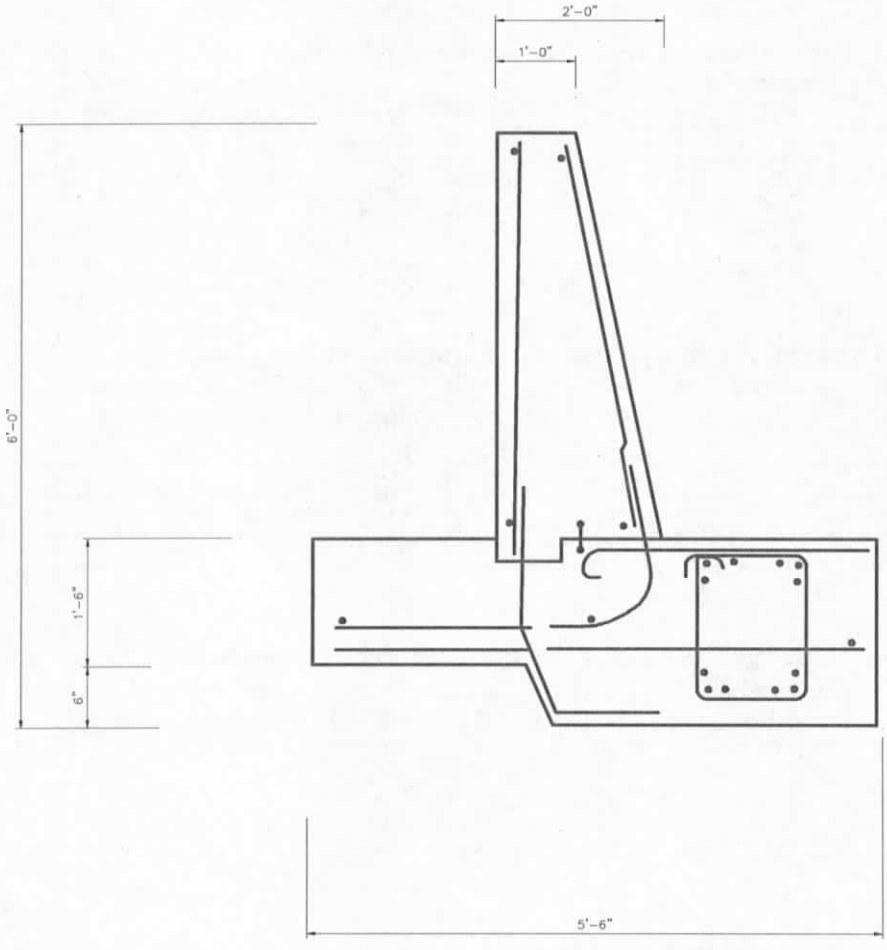
VIRGINIA DEPARTMENT OF TRANSPORTATION

REV 8/07

401.02

SPECIFICATION REFERENCE

506



CLIENT	City of Alexandria			TITLE	Elevated Walkway - Cross Section
PROJ	Potomac River Waterfront Flood Mitigation Study				
REVISION NO	0	DES BY	CJL	09/30/09	
SCALE		DR BY	CJL	09/30/09	
W:\City of Alexandria\15298792 - Lower King St Report\Word Figures\Elevated Walkway		CHK BY	MER	09/10/09	

URS 200 Orchard Ridge Drive Gaithersburg, MD 20878

PROJ NO 15298592

EXHIBIT 2

Exhibit 3: Various Elevated Walkway Tables

Tables providing additional data for the 550 foot floodwall and elevated walkway design. The drainage area for the 500 foot floodwall is 3.5 acres with a time of concentration of 10 minutes. The drainage area for the walkway at King Street is 19.1 acres with a time of concentration of 11 minutes. The drainage area for the walkway at Duke Street is 4 acres with a time of concentration of 10 minutes. The drainage area for the remainder of the walkway is 4.8 acres with a time of concentration of 10 minutes. The total drainage area of the elevated walkway is 28 acres. Computations for time of concentrations are provided as Exhibit 4 in this appendix.

Table 1: Peak discharges and pipe sizes for 550 foot walkway

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10-year	5.91	0.95	19.2	8,634	1.88
25-year	6.88	0.95	22.4	10,051	1.99
50-year	7.68	0.95	25.0	11,219	2.08
100-year	8.4	0.95	27.3	12,271	2.15

Table 2: Peak discharges and pipe sizes for walkway at King Street

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10-year	5.7	0.95	103.5	46,489	3.54
25-year	6.65	0.95	120.8	54,237	3.75
50-year	7.45	0.95	135.3	60,762	3.91
100-year	8.18	0.95	148.6	66,716	4.05

Table 3: Peak discharges and pipe sizes for walkway at Duke Street

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10-year	5.91	0.95	22.7	10,207	2.00
25-year	6.88	0.95	26.5	11,883	2.12
50-year	7.68	0.95	29.5	13,264	2.21
100-year	8.4	0.95	32.3	14,508	2.29

Table 4: Peak discharges and pipe sizes for remainder of walkway drainage area

Recurrence interval	Intensity (in/hr)	C	Q (cfs)	Q (gpm)	Diameter of the pipe required (ft)
10-year	5.91	0.95	26.8	12,048	2.13
25-year	6.88	0.95	31.2	14,025	2.26
50-year	7.68	0.95	34.9	15,656	2.35
100-year	8.4	0.95	38.1	17,124	2.43

Table 5: Flood runoff and volume table for elevated walkway

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	8.43
25-year	5.98	4.3	10.35
50-year	7.01	5.3	12.72
100-year	7.96	6.2	14.92

Table 6: Flood runoff and volume table for 550 foot floodwall

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	0.99
25-year	5.98	4.3	1.22
50-year	7.01	7.01	1.50
100-year	7.96	7.96	1.76

Table 7: Detailed cost estimate for elevated walkway and 550 foot floodwall

Item	Description	Quantity	Unit	Unit Price	Total
Design					
	Design	1	LS	$604,170.85	$ 604,171
	Permitting	1	LS	$650,000.00	$ 650,000
				Subtotal	$ 1,254,171
Construction					
1	Concrete for base of elevated walkway	521	CY	$390.00	$ 203,378
2	Concrete for wall of elevated walkway	379	CY	$390.00	$ 147,911
3	Concrete for base of 550 foot floodwall	130	CY	$390.00	$ 50,844
4	Concrete for wall of 550 foot floodwall	122	CY	$390.00	$ 47,667
5	Bituminous Sidewalk, 1" thick paving, 4" gravel base, 5' width	1,276	LF	$8.02	$ 10,234
6	Common earth backfill	2,269	CY	$13.46	$ 30,541
7	Pump Stations and Features	2	each	$1,150,000.00	$ 2,300,000
8	42" concrete pipe	1,470	lf	$144.00	$ 211,680
9	Curb inlet frame, grate, curb box: Large 24" x 36" heavy duty	2	each	$1,250.00	$ 2,500
10	Flap Gates	2	each	$8,050.00	$ 16,100
11	Excavation	4,067	CY	$11.02	$ 44,818
12	Easements (10% of construction cost)	1	LS	$306,567.26	$ 306,567
				Subtotal	$ 3,020,854
				Construction Contingency (20%)	$ 604,171
				Mobilization/Demobilization/Stakeout ($50,000 min or 5%)	$ 151,043
				TOTAL	$ 5,030,239
				Annual Maintenance	$1,042,251
				Cost used in BCA	$ 6,072,490

Exhibit 4-1: 550 foot Floodwall

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
06/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac River Waterfront Flood Mitigation Sto | Designed By: _____ | Date: _____

Location: 550 foot Floodwall | Checked By: _____ | Date: _____

Check one: Present Developed

Check one: ✓ T_c T_t through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to T_c only)	Segment ID	1			
1. Surface description (Table 3-1)		short grass, pre			
2. Manning's roughness coeff., n (Table 3-1)		0.15			
3. Flow length, L (total L ≤ 100 ft)	ft	100			
4. Two-year 24-hour rainfall, P_2	in	3.1			
5. Land slope, s	ft/ft	0.060			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	0.11	+		= 0.11
Shallow Concetrated Flow	Segment ID	2			
7. Surface description (paved or unpaved)		paved			
8. Flow length, L	ft	900			
9. Watercourse slope, s	ft/ft	0.080			
10. Average velocity, V (Figure 3-1)	ft/s	4.0			
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr	0.06	+		= 0.06
Channel Flow	Segment ID				
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, P_w	ft				
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft				
15. Channel Slope, s	ft/ft				
16. Manning's Roughness Coeff., n					
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s				
18. Flow length, L	ft				
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+		=
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19	hr				0.17

Exhibit 4-2: Elevated Walkway - King Street

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
06/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac Waterfront Flood Mitigation Study Designed By: _____ Date: _____

Location: Elevated Walkway - King Street - Post Diver Checked By: _____ Date: _____

Check one: Present Developed

Check one: ✓ T_c T_t through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to T_c only)	Segment ID	1			
1. Surface description (Table 3-1)		short grass, pra			
2. Manning's roughness coeff., n (Table 3-1)		0.15			
3. Flow length, L (total L ≤ 100 ft)	ft	100			
4. Two-year 24-hour rainfall, P_2	in	3.1			
5. Land slope, s	ft/ft	0.070			
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr	0.10	+		= 0.10
Shallow Concetrated Flow	Segment ID	2			
7. Surface description (paved or unpaved)		paved			
8. Flow length, L	ft	1,100			
9. Watercourse slope, s	ft/ft	0.070			
10. Average velocity, V (Figure 3-1)	ft/s	4.0			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.08	+		= 0.08
Channel Flow	Segment ID				
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, P_w	ft				
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft				
15. Channel Slope, s	ft/ft				
16. Manning's Roughness Coeff., n					
17. $V = \frac{1.49\ r^{2/3} s^{1/2}}{n}$ Compute V	ft/s				
18. Flow length, L	ft				
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+		=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19 ..... hr 0.18

Exhibit 4-3: Elevated Walkway - Prince Street

U.S. Department of Agriculture
Natural Resources Conservation Service

FL-ENG-21B
06/04

TR 55 Worksheet 3: Time of Concentration (T_c) or Travel Time (T_t)

Project: Potomac River Flood Mitigation Study Designed By: _____ Date: _____

Location: Elevated Walkway - Prince St - Post Diversi Checked By: _____ Date: _____

Check one: Present Developed

Check one: ✓ T_c T_t through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet. Include a map, schematic, or description of flow segments.

Sheet Flow (Applicable to T_c only)	Segment ID	1				
1. Surface description (Table 3-1)		short grass, pr				
2. Manning's roughness coeff., n (Table 3-1)		0.15				
3. Flow length, L (total L ≤ 100 ft)	ft	100				
4. Two-year 24-hour rainfall, P_2	in	3.1				
5. Land slope, s	ft/ft	0.070				
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr	0.10	+		=	0.10
Shallow Concetrated Flow	Segment ID	2				
7. Surface description (paved or unpaved)		paved				
8. Flow length, L	ft	1,000				
9. Watercourse slope, s	ft/ft	0.070				
10. Average velocity, V (Figure 3-1)	ft/s	4.0				
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.07	+		=	0.07
Channel Flow	Segment ID					
12. Cross sectional flow area, a	ft^2					
13. Wetted perimeter, P_w	ft					
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	ft					
15. Channel Slope, s	ft/ft					
16. Manning's Roughness Coeff., n						
17. $V = \frac{1.49\ r^{2/3} s^{1/2}}{n}$ Compute V	ft/s					
18. Flow length, L	ft					
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+		=	
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19	hr					0.17

Appendix H
Berm

Various Jones Point Berm Tables

Tables providing additional data for the Jones Point Berm design. Drainage Area 1 is 3.5 acres and Drainage Area 2 is 3.2 acres. A time of concentration of 5 minutes was assumed for both areas.

Table 1: Stage-Storage information for Drainage Area 2

Elevation (ft)	Area (sq ft)	Area (ac)	Average Area (ac)	Depth (ft)	Interval Storage (ac-ft)	Cumulative Storage (ac-ft)
6	4,780	0.110				0.000
			0.218	2.00	0.437	
8	14,249	0.327				0.437
			0.457	2.00	0.915	
10	25,604	0.588				1.352

Table 2: Peak discharges and pipe sizes for berm drainage area 1

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	1.02
25-year	5.98	4.3	1.25
50-year	7.01	5.3	1.53
100-year	7.96	6.2	1.80

Table 3: Peak discharges and pipe sizes for berm drainage area 2

Recurrence interval	24-hour Rainfall (in)	Runoff, Q (in)	Volume (ac-ft)
10-year	5.13	3.5	0.93
25-year	5.98	4.3	1.14
50-year	7.01	5.3	1.40
100-year	7.96	6.2	1.65

Table 4: Detailed cost estimate for berm

Item	Description	Quantity	Unit	Unit Price	Total
Permitting					
	Design	1	LS	$534,233.94	$ 534,234
	Permitting	1	LS	$210,000.00	$ 210,000
				Subtotal	$ 744,234
Construction					
1	Common Earth	12,786	CY	$13.45	$ 171,972
2	Clay Fill	2,538	CY	$21.00	$ 53,298
	Curb Inlet frame, grate, curb box:				
3	Large 24" x 36" heavy duty	4	each	$1,250.00	$ 5,000
4	36" concrete pipe	400	LF	$112.00	$ 44,800
5	48" concrete pipe	450	LF	$189.00	$ 85,050
6	36" aluminum flap gates	2	each	$5,525.00	$ 11,050
7	Pump Station and Features	2	each	$1,150,000.00	$2,300,000
				Subtotal	$2,671,170
	Construction Contingency (20%)				$ 534,234
	Mobilization/Demobilization/Stakeout ($50,000 min or 5%)				$ 133,558
				TOTAL	$4,083,196
	Annual Maintenance				$1,408,779
	Cost used in BCA				$5,491,975

Pump Stations and Features include costs for: Dewatering, structural, mechanical, HVAC, Electrical, Communication/Control, and site work

Mobilization cost also includes erosion and sediment control measures

Permitting costs include natural resources and cultural resources

Design cost is assumed to be 20 percent of construction costs (without contingency or mobilization)

Appendix I
Roadway Drainage

Roadway Drainage Additional Data

Table 1: Detailed cost estimate for roadway and inlet improvements

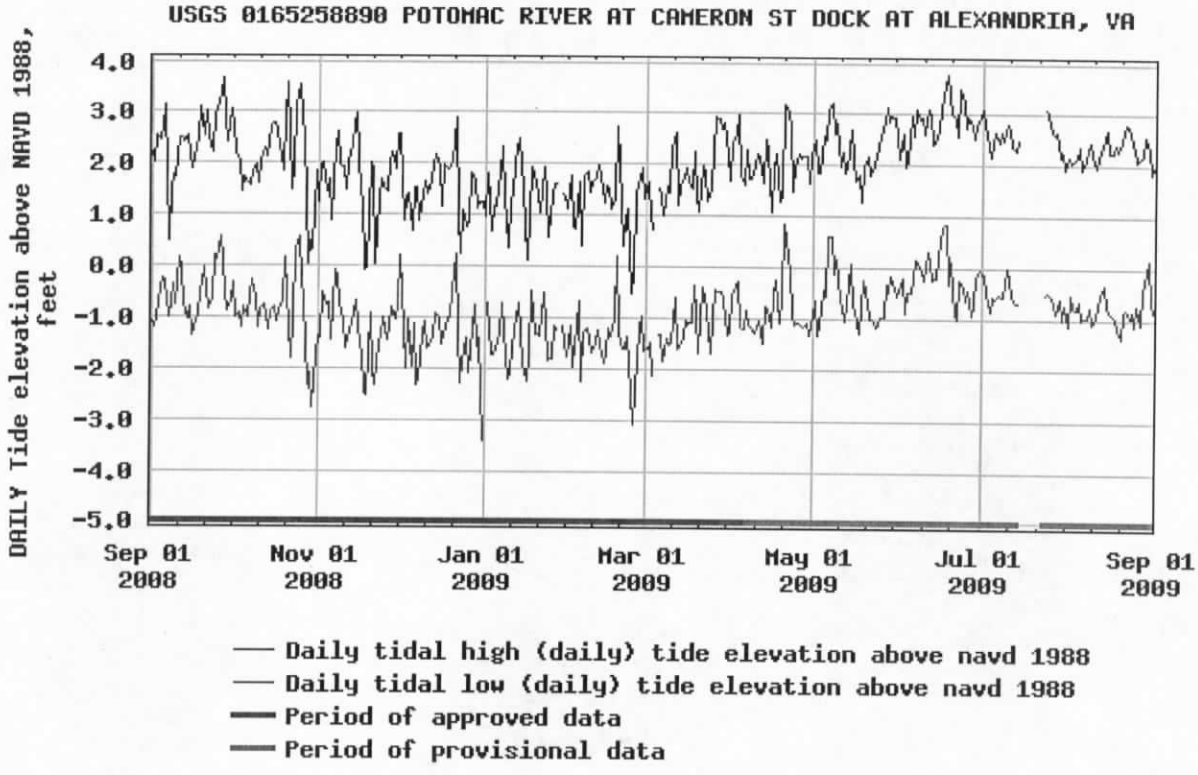
Item	Description	Quantity	Unit	Unit Price	Total
Design					
	Design	1	LS	$56,523.78	$ 56,524
	Permitting	1	LS	$120,000	$120,000
				Subtotal	$176,524
Construction					
1	Pavement Removal, bituminous roads, 4" to 6" thick	2,633	SY	$7.90	$ 20,801
2	Grading Subgrade for base course	2,633	SY	$0.42	$ 1,106
3	Asphaltic Concrete Pavement, Binder, coarse, 4" thick	2,633	SY	$15.54	$ 40,917
4	Common Earth fill (for road elevation)	3,950	CY	$13.45	$ 53,128
4	Cement Concrete Curb and Gutter, steel forms, 6"x18", straight	1,220	LF	$9.90	$ 12,078
5	Manhole/inlet frames and covers, including row of brick, concrete collar	8	each	$265	$ 2,120
6	Storm Drainage Manholes, Frames and Covers, Brick 4' deep	8	each	$1,325	$ 10,600
6	Brick Paving for sidewalk replacement	6,100	SF	$12.10	$ 73,810
7	Trench Drain	83	LF	$820	$ 68,060
				Subtotal	$282,619
				Construction Contingency (20%)	$ 56,524
				Mobilization/Demobilization/Stakeout ($50,000 min or 5%)	$ 50,000
				TOTAL	$565,666
				Annual Maintenance Cost used in BCA	$565,666

Permitting costs include natural resources and cultural resources.

Mobilization cost also includes erosion and sediment control measures.

Design cost is assumed to be 20 percent of construction costs (without contingency or mobilization).

Figure 1: USGS Gage Data



Appendix J
Property Acquisition

Exhibit 1. Additional Costs for Acquisition

Administrative Costs for each Focus Area

The Administrative costs were based on a sliding scale provided by the FEMA Property Acquisition Handbook, as shown in Figures 1 and 2 below. They include the extraordinary costs the community may incur to administer funding, such as the cost of preparing reports, overtime, and incidental expenses.

Figure 1:

Sliding Scale

Project Costs	Percent
first $100,000	3%
next $900,000	2%
next $4,000,000	1%
costs over $5,000,000	½%

Figure 2:

Project Costs	Scale	Administrative Costs
$6,000,000	$100,000 x 3%	$3,000
($6,000,000-$1000,000) $5,900,000	$900,000 x 2%	$18,000
($5,900,00-$900,000) $5,000,000	$4,000,000 x 1%	$40,000
($5,000,00-$4,000,000) $1,000,000	$1,000,000 x ½%	$5,000
Total Administrative Costs		**$66,000**

Appraisals
Based on data from AppraiserUniverse.com, residential appraisals in Virginia are $350 on average.

An average of $3500 was used for the commercial calculations based on a phone call to Northern Virginia Appraisal Services.

Property Survey
Based on information from a CNNMoney.com article, property surveys will typically cost between $500 and $1500. Property surveys may be more costly for larger properties. We used $250 for residential properties and $3500 for commercial properties in our cost estimates.

Closing
Based on information from various real estate websites, closing costs in Virginia are between 2-3% of the property sale price, so 2.5% was used in our computations.
http://www.zimbio.com/Real+Estate/articles/414/Purchaser+Closing+Costs+Virginia

Demolition
Demolition fees for structures in Virginia average between $6 and $15 per square foot. If asbestos is present, demolition will be an additional $2-$3 per square foot.
Source: phone calls to Aceco LLC and Demolition Services Inc.

Relocation
Residential: $3,500 per building
Source: phone calls to Jk Moving and Storage, Twins moving and storage

Commercial: $ 121,751

Table 1: Estimate of Average Commercial Relocation Expenses

SBA Referenced Example Costs[1]	Estimated Costs
Legal/Licenses/Permits	$1,000
Printed materials	$7,500
Consultants	$15,000
Insurance	$250
Research and Development	$1,000
Expensed Equipment	$3,500
Other	$5,000
Loss of Revenue[2]	$32,501
Utility fees	$1,000
Additional marketing	$5,000
Retrofit costs	$20,000
Moving Company[3]	$30,000
TOTAL	$121,751

[1] The Small Business Administration directs users looking for commercial startup costs to the PaloAlto Startup Cost Estimator. PaloAlto provided an example of startup costs for businesses at the following link: http://articles.bplans.com/starting-a-business/estimating-realistic-start-up-costs.
[2] Loss of Revenue assumed average loss of business for one week of interrupted time.
[3] Based on estimate for average commercial area for the project of 15215 square feet. Made calls to two local moving companies using assumption of move of less than 50 miles on 2nd floor of a building without elevator access. One quote was for $15,000 and another was for $45,000. The average of $30,000 was used.

Please note that the values are only approximate. Most of the cost in property acquisition is the FMV of the property.

Exhibit 2. Total Other Costs for Property Acquisition

The following tables list the other projects costs (outlined in Exhibit 1) for each study area. These costs were used to calculate the total cost of property acquisition.

Table 1: Jones Point Residential Acquisition Costs

Project Costs		
Appraisal		4,550
Relocation Assistance		45,500
Closing		21,059
Demolition		192,083
Property Survey		3,250
Total Project Costs		**$266,442**
Administrative Costs		
Project Cost (10,950,643 + 266,422 = $11,217,085)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
6,217,085	0.005	31,085
Total Administrative Costs		**$92,085**
TOTAL OTHER COSTS		**$358,527**

Table 2: King Street Commercial Acquisition Costs

Project Costs		
Appraisal		80,500
Relocation Assistance		2,800,273
Closing		2,025,961
Demolition		1,160,880
Property Survey		57,500
Total Project Costs		**$6,125,114**
Administrative Costs		
Project Cost (85,319,319 + 6,125,144 = 91,444,433)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
86,444,433	0.005	432,222
Total Administrative Costs		**$493,222**
TOTAL OTHER COSTS		**$6,618,336**

Table 3: King Street Residential Acquisition Costs

Project Costs		
Appraisal		1,750
Relocation Assistance		17,500
Closing		107,022
Demolition		76,410
Property Survey		1,500
Total Project Costs		**$204,182**
Administrative Costs		
Project Cost (85,319,319 + 204,182 = 85,523,501)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
80,523,501	0.005	402,618
Total Administrative Costs		**$463,618**
TOTAL OTHER COSTS		**$667,800**

Table 4: North Union Acquisition Costs

Project Costs		
Appraisal		11,900
Relocation Assistance		119,000
Closing		462,654
Demolition		690,105
Property Survey		8,500
Total Project Costs		**$1,292,159**
Administrative Costs		
Project Cost (18,506,176 + 1,292,159 = 19,798,335)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
14,798,335	0.005	73,992
Total Administrative Costs		**$134,992**
TOTAL OTHER COSTS		**$1,427,151**

Table 5: Waterfront Commercial Acquisition Costs

Project Costs		
Appraisal		77,000
Relocation Assistance		2,678,522
Closing		2,475,027
Demolition		3,974,049
Property Survey		55,000
Total Project Costs		**$9,259,598**
Administrative Costs		
Project Cost (99,001,085 + 9,259,598 = 108,260,683)	*Percent*	
100,000	0.03	3,000
900,000	0.02	18,000
4,000,000	0.01	40,000
103,260,683	0.005	516,303
Total Administrative Costs		**$577,303**
TOTAL OTHER COSTS		**$9,836,901**

Exhibit 3. Method for Calculating the Fair Market Value

Market Data Method or sales comparison method was used for calculating the Fair Market Value (FMV). The market data estimate of FMV is obtained by comparing the subject property with "comparable" properties that have been sold. The properties need to have similar location, physical features, condition, etc. in order to be suitable to use to obtain an accurate FMV.

The following data was collected from http://realestate.alexandriava.gov

1. Assessed Land Value [Land_Value]
2. Assessed Building Value [Building_Value]
3. Sale Date [Sale_Date]
4. Sale Price [Sale_Price]
5. Assessed Value at time of the sale - up to year 2000 [Ass_at_sal]
6. Year Build [Year_Built]
7. Construction Quality [Constr_Quality]
8. Story [Story]
9. Ext. Wall Construction[Ext_Wall]
10. Above Grade Living Area (Does not include basement area) [BLDGSF]
11. Total Basement Area [Bsm_A_sqf]

Data was collected for 55 commercial and 395 Residential units. Most of these properties were within the 100-year floodplain; however, data collection also included additional buildings just outside the floodplain that were connected to a row house or part of the same complex that were within the floodplain. This was important to increase the accuracy. Some of the row townhouses were studied as one unit.

Method for calculating the RATIO.

RATIO = Average(Sale Price/Assessed Value at time of sale)

The ratio that was used for the FMV was based on available sales data since 2000. Usually the last 12 months sales data is used when using the Market Data Method. However because of the limitation on the available sales prices and an extreme market situation, an average ratio was used which is a more conservative estimate than the past twelve month ratio.

Method for Calculating the FMV

FMV = (Property OR Building Value)*RATIO

NOTE: For acquisition the price for the land and building (property) was used, while for DDV only the building price was used.

Appendix K
Floodproofing

Exhibit 1. Floodproofing Cost Estimates

Flood Gate

Price quotes from DoorDam's website, http://www.doordam.com/, show floodgates priced from $500-$700 dollars. Therefore, the average price for a floodgate was estimated to be $600.

Floodproof Doors

Price quotes from FloodGuard UK's website, http://www.floodguarduk.co.uk/en-us/front.html, showed floodproof doors to cost approximately 4,500 pounds or about $7,000.

Raising the Lowest Adjacent Grade (LAG)

RSMeans 2009 was used to estimate the cost for raising the LAG. This price included cost and labor for fill placement and rebuilding a surface if necessary (i.e. patio or driveway). The fill costs were based on the estimate of 300 cubic yards of clay soil, which would be about $1,100. The rebuild price was estimated to be about $4,200. Therefore the total cost for raising the LAG was estimated to be about $5,300.

Internal Elevation

Price quotes from Access Floor System's website, http://www.accessfloorsystems.com/, were used to estimate the cost for internal elevation. The website has a tool that provides a price estimate based on the square footage, height of elevation, and materials used. Two focus areas, King Street and Waterfront, have structures that were considered for internal elevation. Separate price estimates were generated for each of the focus areas, using the average square footage from the GIS data provided by the City. The structures where internal elevation is considered in the King Street focus area have an average area of about 3,600 square feet. This resulted in a price estimate of approximately $69,700 per structure for internal elevation in the King Street focus area. The structures where internal elevation is considered in the Waterfront focus area have an average area of about 24,500 square feet. This resulted in a price estimate of approximately $430,500 per structure for internal elevation in the Waterfront focus area.

Cost Benefit Ratio

In an effort to make sure the costs for floodproofing are not underestimated in the BCR calculations, the price estimates were all increased by 50 percent to account for shipping, installation, and any other unforeseen costs. The price estimates used are shown in Table 1 below.

Table 1: Price Estimates for Floodproofing Measures

Method	Cost per Unit
Flood Gate	$900.00
Flodproof Door	$10,000.00
Raise Patio / Fill	$8,000.00
Internal Elevation (King Street)	$104,580.00
Internal Elevation (Waterfront)	$645,688.50

Exhibit 2. Window Replacement Costs

Cost estimates were derived for window replacements in historic Alexandria from the Fairfax Glass Company of Falls Church, Virginia and the American Housing Contractor of Fairfax, Virginia. Both estimates were based on the type of material used (wood or aluminum) and whether or not a true replication of the existing window is required. Considering that windows should meet historic district criteria, the conservative cost estimate of window replacement received was approximately $100 per square foot. To calculate the estimated price of window replacements, average window size, sales tax and any contingencies during installation were considered.

For residential properties, colonial windows with dimensions of 6 feet x 4 feet at $100 per square foot for a 24 square foot window, the cost of one colonial window is $2,400. With a five percent sales tax and accounting for 20 percent for contingencies, the total cost is approximately $3,000 per residential window.

Because commercial windows are larger and may be more difficult to replace, commercial windows were assumed to be twice as expensive as residential. Therefore, window replacement for commercial properties in the historic district is approximately $6,000 per window.

Another option besides replacing historic windows would be to modify existing windows using secondary glazing and caulking. This method is designed to stop water penetration. It meets the historical requirements in Alexandria and does not affect the window appearance. The cost of secondary glazing for windows is between $300 and $400, depending on window size.

Window replacement is suggested instead of window shields to preserve the aesthetics of the historic district. Window replacement prices will vary based on size and specifications. Windows should be appropriate to the historic period and architectural style of the building. Specific information on acceptable window types can be found in the City of Alexandria's *Design Guidelines for the Old and Historic Alexandria District and the Parker-Gray District.*

References:

Buck Schuckman from Fairfax Glass Company. Falls Church, VA. 703-560-1140
Danny Kim from American Housing Contractor (Marvin Windows). Fairfax, VA. 703-293-6393
Nick Kalivretenos. The Window Man. 703-932-7220. 3000 Jefferson Davis Hwy. Alexandria, Virginia 22305

Design Guidelines for the Old and Historic Alexandria District and the Parker-Gray District, City of Alexandria, Virginia, Department of Planning and Community Development.

Mon-Ray Inc, Storm Window Search, Accessed September 2009
http://www.monray.com/mr500.htm

Exhibit 3. FEMA guidance on floodproofing utility systems.

You Can Floodproof Your Utility Systems Before Disaster Strikes

Release Date: October 23, 2006
Release Number: 1661-010

GLEN ALLEN, VA -- If you aren't located in a flood zone, you may think you don't have to worry about protecting your home or business against flood damage. But, Mother Nature would tell you otherwise. Nearly a quarter of National Flood Insurance (NFIP) claims come from areas that aren't considered at high risk for flooding.

The Federal Emergency Management Agency (FEMA) has information for both home and business property owners on how to floodproof electrical, plumbing and heating systems.

"Before they begin, property owners must call their local planning commission to get the base flood-elevation levels for their location," said Gracia Szczech, FEMA's federal coordinating officer for recovery operations. "Specific rules apply based on your community's risk for floods."

Advice for property owners is available on FEMA's web site, www.floodsmart.gov, that will save you money and, in the long run, help keep your home or business safe.

"The first and most important thing a property owner should do is elevate electrical and heating systems 12 inches above the height water would reach during a 100-year flood event or the highest known flood levels for the area," said Michael Cline, the state coordinating officer. "That information is available from your local planning commission office, and making use of it could save you a lot of money and inconvenience in the future."

Below are other important safety measures to take before the next flood:

Electrical and Heating Systems

- Elevate all outlets, switches, light sockets and junction boxes, as well as the main breaker or fuse box and electric motors. Junctions should be located in approved junction boxes with the 100-year rule in mind.
- Run wires overhead. If they have to be in areas where they could get wet, use a wire rated for underground use.
- Elevate electric baseboard heater systems. For the wall area below the baseboard units, use waterproof wall construction materials and techniques.

- Elevate or relocate the electric panel with the 100-year rule in mind. The maximum panel height is regulated by the code. Check with your local county commission office for the maximum height that applies to your community.
- Elevate or relocate the heating unit. Consider installing utilities on the second floor or in the attic. If you are replacing your furnace, ask the supplier for information about a downdraft system.
- You can also consider suspending the heating system, making sure it is 12 inches above the highest flood levels.
- Elevate your air conditioner or heat pump on masonry, concrete or pressure-treated lumber base at least 12 inches above the highest flood levels.
- Anchor your fuel tank. Unanchored fuel tanks can tip over or float, and escaping fuel may result in spills or fires. Use non-corrosive metal structural supports and fasteners. Check with the fuel tank manufacturer for recommendations since the type of anchorage, including slab dimensions, varies depending on tank size. Keep the tank topped off to reduce its tendency to float.

Appliances

- Elevate a basement-level washer and dryer on a masonry or pressure treated lumber base to at least 12 inches above the highest flood levels.
- Relocate the washer and dryer to a higher floor in the home.
- Elevate or relocate the water heater to at least 12 inches above the highest flood levels.

When making repairs or putting up a building, you should always check with the local planning commission, local building official or floodplain administrator to make sure you are following local zoning regulations and state and local building codes. Damaged properties should be checked before any work, since repairs to very badly damaged buildings are not permitted.

Be sure you have all the necessary permits before any work begins. Electrical wiring has to be done by a licensed electrician and approved by the building department.

For more information on how to protect your home, call FEMA publications at 1-800-480-2520 and ask for booklet F-0206, Coping With a Flood; Before, During and After.

FEMA manages federal response and recovery efforts following any national incident, initiates mitigation activities and manages the National Flood Insurance Program. FEMA works closely with state and local emergency managers, law enforcement personnel, firefighters and other first responders. FEMA became part of the U.S. Department of Homeland Security on March 1, 2003.

Source: http://www.fema.gov/news/newsrelease.fema?id=30984

Appendix L
Potential Federal Funding Options

Potential Federal Funding Options

Overview

A number of the flood mitigation activities recommended in the Potomac River Waterfront Flood Mitigation Study carry significant capital improvement costs and operation and maintenance expenditures. Available funding sources include:

- Government Grants
- Revenue Bonds
- Enterprise Funds
- Special Purpose Local Option Sales Taxes
- State Revolving Fund Loans
- Impact Fees
- Special Assessments

There are several Federal grants that may be appropriate with the mitigation measures recommended in this Potomac River Waterfront Flood Mitigation Study. Information regarding these grants can be accessed in a variety of ways.

As part of the Federal government's E-Grants Initiative the Grants.gov Web site: http://www.grants.gov/ is a central repository and clearinghouse for over 1,000 grants with over $500 billion in awards per year. Through Grants.gov over 300,000 applications were submitted in fiscal year 2009. Grants.gov provides a grants search engine with several search categories including agency name or funding activities. The most appropriate grants for flood mitigation are those administered by FEMA's Hazard Mitigation Assistance (HMA) grant programs.

FEMA has detailed descriptions of each of its HMA grant programs on its Web site http://www.fema.gov/government/grant/hma/index.shtm. However, since applications for these programs are submitted through individual State governments, it is required that the City of Alexandria coordinate with the Virginia Department of Emergency Management (VDEM) when preparing HMA grant applications. It is important to note that, in addition to FEMA deadlines, VDEM has its own internal deadlines for the acceptance of grant applications. VDEM provides information on grant opportunities on its Web site, including an E-mail alert service to receive Grant Alerts http://www.vaemergency.com/grants/index.cfm.

While there are numerous grant options, eligibility requirements can restrict the types of funding mechanisms available to the City. Some common eligibility restrictions include:

- Grants by invitation only (e.g., Economic Development Initiative—Special Project)
- Open only to rural communities or disadvantaged populations
- Participation in the National Flood Insurance Program (NFIP)
- Inclusion in a recent Presidential major disaster declaration that is still open

Hazard Mitigation Assistance (HMA) Grant Programs

Under the Department of Homeland Security (DHS), FEMA oversees HMA grant programs. The five different HMA programs are listed below with the associated Catalog of Federal Domestic Assistance (CFDA) numbers.

- Hazard Mitigation Grant Program (HMGP) – CFDA 97.039
- Pre-disaster Mitigation (PDM) – CFDA 97.047
- Flood Mitigation Assistance (FMA) – CFDA 97.029
- Repetitive Flood Claims (RFC) – CFDA 97.092
- Severe Repetitive Loss (SRL) – CFDA 97.110

The FEMA brochure included in this appendix provides an overview of each program including cost share requirements, subapplicant eligibility, available funding, eligible activities, management costs, and general requirements.

The PDM, FMA, RFC, and SRL programs are subject to the availability of appropriation funding. The HMA Unified Guidance for Fiscal Year 2011 (FY11) was released on June 1, 2010. The application period for PDM, FMA, RFC and SRL is June 1, 2010, to December 3, 2010. FEMA intends to report projects identified for further review in March 2011. During that time the City of Alexandria must work with VDEM to submit grant applications to FEMA through eGrants. It is important to note that VDEM has its own internal deadlines for the acceptance of grant applications.

HMGP grants can only be sought after a major disaster declaration within the Commonwealth of Virginia. FEMA posts disaster declarations at http://www.fema.gov/news/disasters.fema. The amount of funding available to the applicant depends on the funding allocated by FEMA for disaster recovery under the major disaster declaration. Typically a major disaster declaration is active for 12 months. As with the other HMA grant programs, the City of Alexandria is required to coordinate with VDEM to submit an HMGP grant application to FEMA. VDEM has its own internal deadlines for the acceptance of grant applications. As of July 2010, the VDEM deadlines have passed for the three active major disaster declarations. However, major disaster declarations happen relatively frequently, and the type of mitigation measure for which HMGP funding is sought does not necessarily have to mitigate the effects of the hazard that led to the disaster declaration.

Applicability for the Potomac River Waterfront Flood Mitigation Study

The mitigation measures recommended for the City of Alexandria that may be available for funding through the HMA programs include the following:

- Elevated pedestrian walkway
- Dry floodproofing
- Inlet and road elevation improvement

Table 1 summarizes the mitigation measure activities allowed for funding through the above-mentioned programs.

Table 1. HMA Funding Options by Project Type

Flood Mitigation Project Type	HMGP	PDM	FMA	RFC	SRL
Dry Floodproofing					
Historic residential	x	x	x	x	x
Non-residential	x	x	x	x	
Elevated Pedestrian Walkway	x	x	x		
Inlet and Road Elevation Improvements	x	x			

In general, HMA funds may be used to pay up to 75 percent of the eligible activity costs. The remaining 25 percent of eligible activity costs are derived from non-Federal sources. More information about each program can be found on the FEMA HMA Web site: www.fema.gov/government/grant/hma/index.shtm.

Dry Floodproofing
Funding for dry floodproofing is available under most HMA grant programs. Floodproofing is typically only allowed for non-residential structures. Historic residential structures may be considered for dry floodproofing when other techniques that would mitigate to the BFE would cause the structure to lose its status. Structures that remain in the Special Flood Hazard Area (SFHA) after the implementation of the mitigation project, must maintain flood insurance for the life of the structure.

Elevated Walkway
Localized minor flood reduction projects are fundable under the HMGP, PDM and FMA grant programs. These projects may include the installation or modification of culverts and floodgates, minor floodwall systems that generally protect an individual structure or facility, stormwater management activities such as creating retention and detention basins, and the upgrade of culverts to bridges. Whereas, major flood control projects related to the construction of a floodwall or seawall are not eligible projects.

The elevated walkway is considered a floodwall. As of July 2010, FEMA does not have a definitive description of a large flood control system. However, the elevated walkway proposed in this study is not a typical mitigation measure. It is a site specific flood barrier and does not greatly alter the grounds of the floodplain or impound water; therefore, there is a chance that it will be considered a localized minor flood reduction project.

Inlet and Road Elevation Improvements
Raising the road elevations and inlet openings for catch basins would be considered an infrastructure retrofit project, which is eligible for both HMGP and PDM grants. PDM grants can be pursued through the VDEM application schedule. For an HMGP grant, the City could prepare to apply, but would need to wait for a disaster declaration before it could submit an application to VDEM and FEMA.

Grant Application Elements

The PDM, FMA, RFC, and SRL applications must be submitted through the eGrants system by the applicant, generally VDEM, by December 3, 2010, at 3 PM Eastern Time. Prior to the

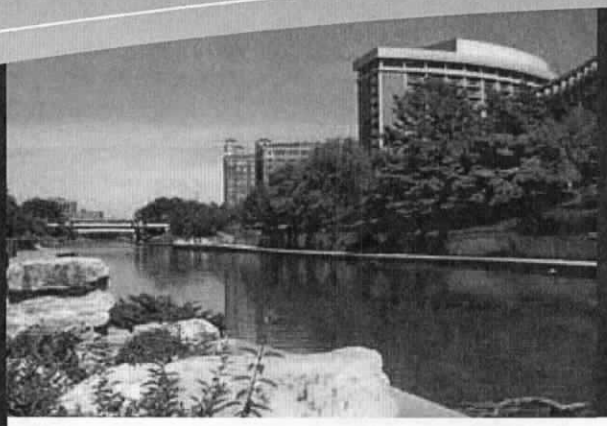
submission, applicants and subapplicants such as the City of Alexandria are encouraged to work with their regional FEMA office to ensure that the application is complete, clear, and appropriate for the grant program. The application must be cost-effective, technically feasible, effective at mitigating risk, and able to meet HMA Unified Guidance program requirements including Environmental Planning and Historic Preservation requirements.

The application should describe the process that the City undertook and make a case for the City's chosen flood mitigation project. A detailed scope of work (SOW) provides a clear and concise means of describing the proposed conceptual design and means of implementation of the project; it also clearly identifies the risks to be mitigated and the intended project accomplishments. Future residual risks to the project should also be described. Necessary documents supporting a SOW include credible sources for the following: assessment of past damages, preliminary design drawings/sketches, FIRMs, and photos. In addition, a work schedule that identifies all of the tasks outlined in the SOW must be included.

Caution must be taken with the application's cost estimate. It must accurately reflect the SOW and must include costs associated with mitigating environmental impacts or impacts to historic properties, appraisal costs, construction demolition, survey, and material disposal costs. The cost estimate cannot have a line item for contingencies.

A Benefit Cost Analysis (BCA) must be submitted with the application. As the name implies, the BCA compares the project benefits to the project costs. Project costs include those that are explained above as well as an estimate for annual maintenance costs. Annual maintenance costs are not funded by HMA, so they should only be included in the BCA submittal and not in the application's cost estimate. Benefits are calculated as avoided damages and losses. The benefit cost ratio (BCR) is simply the benefit divided by cost and must be equal to or greater than 1.0 to be eligible for HMA program funds. The BCA must be performed using the FEMA approved software as noted in the most recent HMA Unified Guidance document.

FEMA Program Information Mitigation



HAZARD MITIGATION ASSISTANCE

HMA GRANT PROGRAMS

Hazard Mitigation Assistance

The Department of Homeland Security (DHS) Federal Emergency Management Agency (FEMA) Hazard Mitigation Assistance (HMA) programs present a critical opportunity to reduce the risk to individuals and property from natural hazards while simultaneously reducing reliance on Federal disaster funds.

A COMMON GOAL

While the statutory origins of the programs differ, all share the common goal of reducing the risk of loss of life and property due to natural hazards.

FUNDING DISASTER RECOVERY EFFORTS

The Hazard Mitigation Grant Program (HMGP) may provide funds to States, Territories, Indian Tribal governments, local governments, and eligible private non-profits following a Presidential major disaster declaration .

The Unified Hazard Mitigation Assistance Grant Programs

Authorities and Purpose

The Hazard Mitigation Grant Program (**HMGP**) is authorized by Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended (the Stafford Act), Title 42, United States Code (U.S.C.) 5170c. The key purpose of HMGP is to ensure that the opportunity to take critical mitigation measures to reduce the risk of loss of life and property from future disasters is not lost during the reconstruction process following a disaster. HMGP is available, when authorized under the Presidential major disaster declaration, in the areas of the State requested by the Governor. The amount of HMGP funding available to the Applicant is based upon the total Federal assistance to be provided by FEMA for disaster recovery under the major disaster declaration.

The Pre-Disaster Mitigation (**PDM**) program is authorized by Section 203 of the Stafford Act, 42 U.S.C. 5133. The PDM program is designed to assist States, Territories, Indian Tribal governments, and local communities to implement a sustained pre-disaster natural hazard mitigation program to reduce overall risk to the population and structures from future hazard events, while also reducing reliance on Federal funding from future major disaster declarations.

The Flood Mitigation Assistance (**FMA**) program is authorized by Section 1366 of the National Flood Insurance Act of 1968, as amended (NFIA), 42 U.S.C. 4104c, with the goal of reducing or eliminating claims under the National Flood Insurance Program (NFIP).

The Repetitive Flood Claims (**RFC**) program is authorized by Section 1323 of the NFIA, 42 U.S.C. 4030, with the goal of reducing flood damages to individual properties for which one or more claim payments for losses have been made under flood insurance coverage and that will result in the greatest savings to the National Flood Insurance Fund (NFIF) in the shortest period of time.

The Severe Repetitive Loss (**SRL**) program is authorized by Section 1361A of the NFIA, 42 U.S.C. 4102A, with the goal of reducing flood damages to residential properties that have experienced severe repetitive losses under flood insurance coverage and that will result in the greatest amount of savings to the NFIF in the shortest period of time.

Additional HMA resources, including the HMA Unified Guidance may be accessed at www.fema.gov/government/grant/hma/index.shtm

program comparisons

Cost Share Requirements

COST SHARE

In general, HMA funds may be used to pay up to 75 percent of the eligible activity costs. The remaining 25 percent of eligible costs are derived from non-Federal sources.

The table to the right outlines exceptions to the 75 percent Federal and 25 percent non-Federal share.

Programs	Mitigation Activity Grant (Percent of Federal/Non-Federal Share)
HMGP	75/25
PDM	75/25
PDM—subgrantee is small impoverished community	90/10
PDM—Tribal grantee is small impoverished community	90/10
FMA	75/25
FMA—severe repetitive loss property with Repetitive Loss Strategy	90/10
RFC	100/0
SRL	75/25
SRL—with Repetitive Loss Strategy	90/10

Eligible Subapplicants

✓ Subapplicant is eligible for program funding

ELIGIBLE APPLICANTS AND SUBAPPLICANTS

States, Territories, and Indian Tribal governments are eligible HMA Applicants. Each State, Territory, and Indian Tribal government shall designate one agency to serve as the Applicant for each HMA program.

All interested subapplicants must apply to the Applicant. The table to the left identifies, in general, eligible subapplicants. For specific details regarding eligible subapplicants, refer to 44 CFR Part 206.434(a) for HMGP and 44 CFR Part 79.6(a) for FMA and SRL. For HMGP and PDM see 44 CFR Part 206.2(16) for a definition of local governments.

	HMGP	PDM	FMA	RFC	SRL
State agencies	✓	✓	✓	✓	✓
Tribal governments	✓	✓	✓	✓	✓
Local governments/communities	✓	✓	✓	✓	✓
Private non-profit organizations (PNPs)	✓				

Individuals and businesses are not eligible to apply for HMA funds, however, an eligible subapplicant may apply for funding to mitigate private structures. RFC funds are only available to subapplicants who cannot meet the cost share requirements of the FMA program.

Available Funding

HMA programs are subject to the availability of appropriation funding or funding based on disaster recovery expenditures, as well as any directive or restriction made with respect to such funds.

HMGP funding depends on federal assistance provided for disaster recovery, while PDM, FMA, RFC, and SRL funding is appropriated annually by Congress.

program comparisons (continued)

Eligible Activities

ELIGIBLE ACTIVITIES

The table to the right summarizes eligible activities that may be funded by HMA programs. Detailed descriptions of these activities are found in the HMA Unified Guidance.

Eligible Activities	HMGP	PDM	FMA	RFC	SRL
1. Mitigation Projects	✓	✓	✓	✓	✓
Property Acquisition and Structure Demolition or Relocation	✓	✓	✓	✓	✓
Structure Elevation	✓	✓	✓	✓	✓
Mitigation Reconstruction					✓
Dry Floodproofing of Historic Residential Structures	✓	✓	✓	✓	✓
Dry Floodproofing of Non-residential Structures	✓	✓	✓	✓	
Minor Localized Flood Reduction Projects	✓	✓	✓	✓	✓
Structural Retrofitting of Existing Buildings	✓	✓			
Non-structural Retrofitting of Existing Buildings and Facilities	✓	✓			
Safe Room Construction	✓	✓			
Infrastructure Retrofit	✓	✓			
Soil Stabilization	✓	✓			
Wildfire Mitigation	✓	✓			
Post-disaster Code Enforcement	✓				
5% Initiative Projects	✓				
2. Hazard Mitigation Planning	✓	✓	✓		
3. Management Costs	✓	✓	✓	✓	✓

✓ Mitigation activity is eligible for program funding

Management Costs

For HMGP only: The Grantee may request 4.89 percent of HMGP allocation for management costs. The Grantee is responsible for determining the amount, if any, of funds that will be passed through to the subgrantee(s) for their management costs.

Applicants for PDM, FMA, RFC, or SRL may apply for a maximum of 10 percent of the total funds requested in their grant application budget (Federal and non-Federal shares) for management costs to support the project and planning subapplications included as part of their grant application.

Subapplicants for PDM, FMA, RFC, or SRL may apply for a maximum of 5 percent of the total funds requested in a subapplication for management costs.

General Requirements

All mitigation projects must be cost-effective, be both engineering and technically feasible, and meet Environmental Planning and Historic Preservation requirements in accordance with HMA Unified Guidance. In addition, all mitigation activities must adhere to all relevant statutes, regulations, and requirements including other applicable Federal, State, Indian Tribal, and local laws, implementing regulations, and Executive Orders.

program information

National Flood Insurance Program (NFIP) Participation

NFIP INFORMATION

In 1968, Congress created the National Flood Insurance Program (NFIP) to help provide a means for property owners to financially protect themselves. The NFIP offers flood insurance to homeowners, renters, and business owners if their community participates in the NFIP. Participating communities agree to adopt and enforce ordinances that meet or exceed FEMA requirements to reduce the risk of flooding.

Find out more about the NFIP and how it can help you protect yourself.

http://www.floodsmart.gov

NATIONAL FLOOD INSURANCE PROGRAM

NFIP Participation Requirement

There are a number of ways that HMA eligibility is related to the NFIP.

- **Subapplicant eligibility**: All subapplicants for FMA, RFC, or SRL must currently be participating in the NFIP, and not withdrawn or suspended, to be eligible to apply for grant funds. Certain non-participating political subdivisions (i.e., regional flood control districts or county governments) may apply and act as subgrantee on behalf of the NFIP-participating community in areas where the political subdivision provides zoning and building code enforcement or planning and community development professional services for that community.
- **Project eligibility**: HMGP and PDM mitigation project subapplications for projects sited within a Special Flood Hazard Area (SFHA) are eligible only if the jurisdiction in which the project is located is participating in the NFIP. There is no NFIP participation requirement for HMGP and PDM planning subapplications or project subapplications located outside of the SFHA.
- **Property eligibility:** Properties included in a project subapplication for FMA, RFC, and SRL funding must be NFIP-insured at the time of the application submittal. Flood insurance must be maintained at least through completion of the mitigation activity.

Mitigation Plan Requirement

All Applicants and subapplicants must have hazard mitigation plans meeting the requirements of 44 CFR Part 201.

Application Process

MITIGATION ELECTRONIC GRANTS SYSTEM

For PDM, FMA, RFC, and SRL, FEMA has developed a web-based, Electronic Grants (eGrants) management system to allow States, Federally-recognized Indian Tribal governments, territories, and local governments to apply for and manage their mitigation grant application processes electronically.

Applications for HMGP are processed through the National Emergency Management Information System (NEMIS). Applicants use the Application Development Module of NEMIS, which enables each Applicant to create project applications and submit them to the appropriate FEMA Region in digital format for the relevant disaster.

Applications for PDM, FMA, RFC, and SRL are processed through the Electronic Grants (*e*Grants) system. The *e*Grants system encompasses the entire grant application process and provides the means to electronically create, review, and submit a grant application to FEMA via the Internet. Applicants and subapplicants can access *e*Grants at https://portal.fema.gov.

eGrants
Electronic Grants System

program information

GovDelivery Notifications

Stay up to date on the HMA Grant Programs by subscribing to GovDelivery notifications.

Have email updates delivered to an email address or mobile device.

To learn more visit www.fema.gov or just click the icon below.

Email Updates

Application Deadline

The PDM, FMA, RFC, and SRL application period is anticipated to be from June 1, 2010, through December 3, 2010. Applicants must submit an FY11 grant application to FEMA through the *e*Grants system by December 3, 2010, at 3:00:00 p.m. Eastern Time.

The HMGP application deadline is 12 months after the date of the disaster declaration date and is not part of the annual application period.

Details can be found in the HMA Unified Guidance.

FEMA Review and Selection

All subapplications will be reviewed for eligibility and completeness, cost-effectiveness, engineering feasibility and effectiveness, and for Environmental Planning and Historical Preservation compliance. Subapplications that do not pass these reviews will not be considered for funding.

FEMA will notify Applicants of the status of their subapplications and will work with Applicants on subapplications identified for further review.

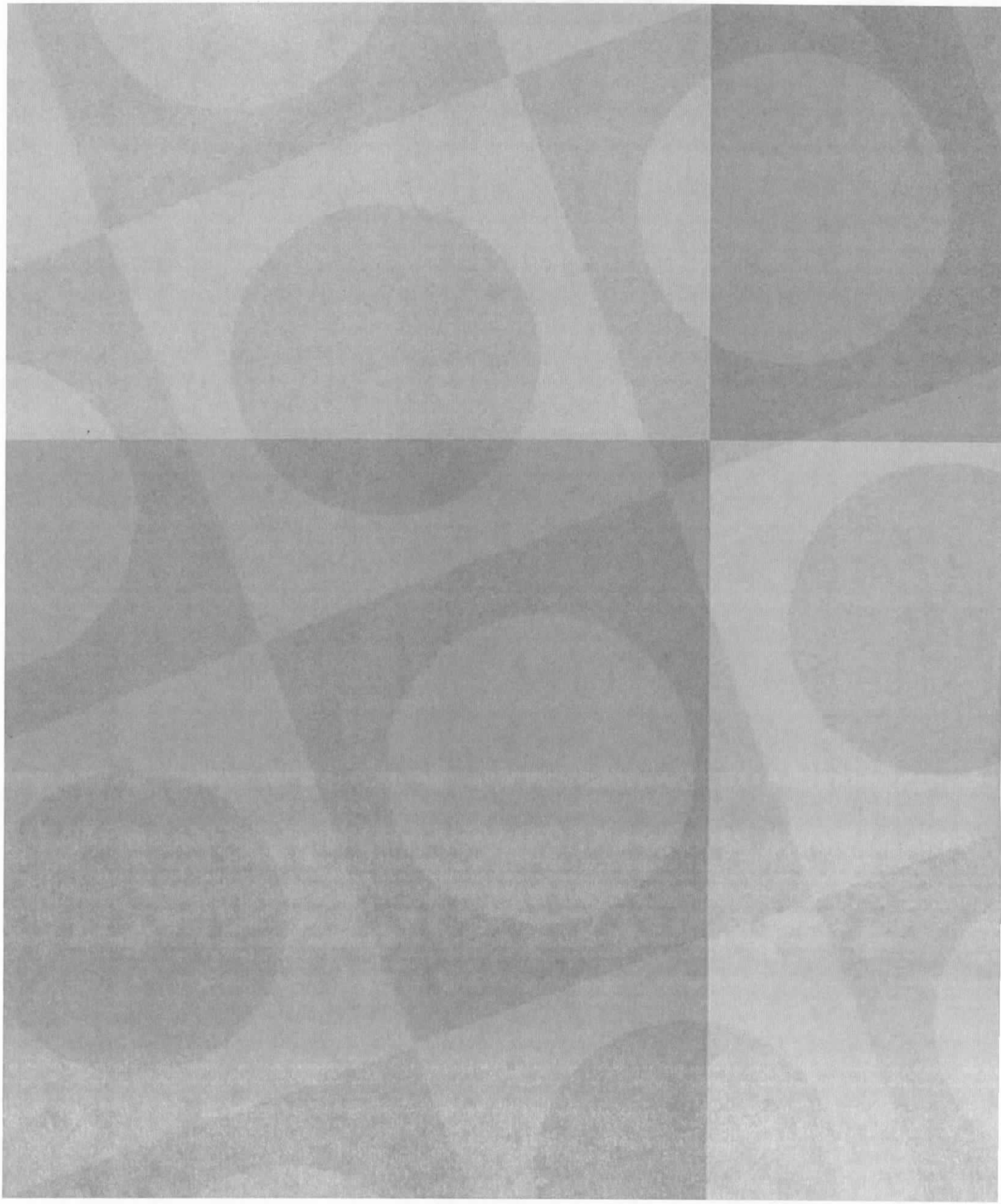
Contact Information

HMA Helpline: (866) 222-3580
hmagrantshelpline@dhs.gov

Contact information for FEMA Regional Offices is provided at:
http://www.fema.gov/about/contact/regions.shtm

Contact information for each State Hazard Mitigation Officer (SHMO) is provided at:
http://www.fema.gov/about/contact/shmo.shtm

Mitigation Works

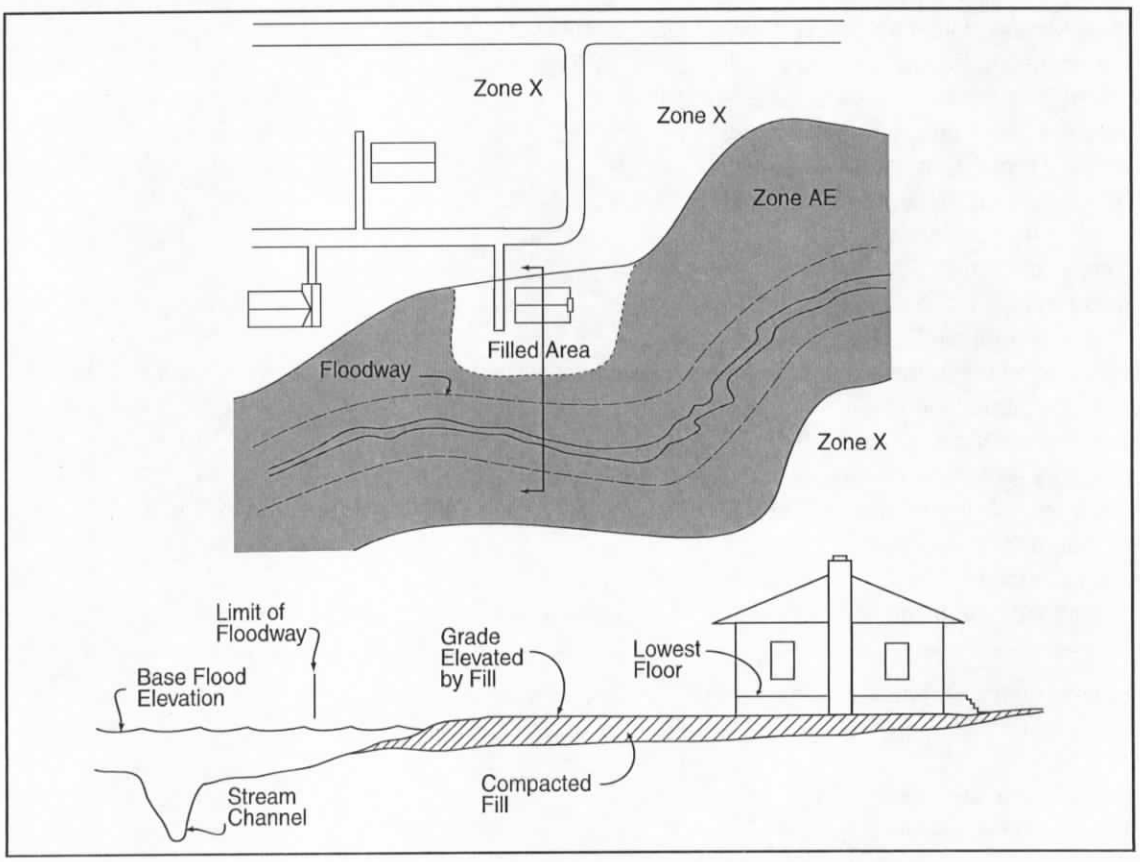


Technical Bulletin 10-01

Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe From Flooding

in accordance with the

National Flood Insurance Program



FEDERAL EMERGENCY MANAGEMENT AGENCY
MITIGATION DIRECTORATE

FIA-TB-10
(5/01)

Key Word/Subject Index

This index allows the user to locate key words and subjects in this Technical Bulletin. The Technical Bulletin User's Guide (printed separately) provides references to key words and subjects throughout the Technical Bulletins. For definitions of selected terms, refer to the Glossary at the end of this bulletin.

Any comments on the Technical Bulletins should be directed to:

Federal Emergency Management Agency
Mitigation Directorate
Program Policy and Assessment Branch
500 C Street, SW.
Washington, DC 20472

Wave design on cover based on the Japanese print *The Great Wave Off Kanagawa*, by Katsuchika Hokussai (1760–1849), Asiatic Museum of Fine Arts, Boston.

TECHNICAL BULLETIN 10-01

Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe From Flooding in accordance with the National Flood Insurance Program

Introduction

For the purpose of administering the National Flood Insurance Program (NFIP), FEMA identifies and maps flood hazard areas nationwide by conducting flood hazard studies and publishing Flood Insurance Rate Maps (FIRMs). These flood hazard areas, referred to as Special Flood Hazard Areas (SFHAs), are based on a flood having a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood or Base Flood).

Structures within the SFHA in a community participating in the NFIP are subject to floodplain management regulations that impact building standards and are designed to minimize flood risk. For example, Title 44, Part 60, Section 3(c)(2) of the Code of Federal Regulations—abbreviated as 44 CFR 60.3(c)(2)—requires that the lowest floor of a residential structure, including basement, built within the SFHA be at or above the Base Flood Elevation (BFE). In addition, flood insurance must be purchased for these structures if they are used as collateral to secure a loan provided by a federally regulated lender. Flood insurance coverage may be purchased for all eligible structures within a participating community. Insurance rates for structures located within the SFHA differ from the rates for structures located outside the SFHA.

When permitted under applicable Federal, state, and local laws, ordinances, and regulations, earthen fill is sometimes placed in an SFHA to reduce flood risk to the filled area. Under certain conditions, when engineered earthen fill is placed within an SFHA to raise the surface of the ground to or above the BFE, a request may be submitted to FEMA to revise the FIRM to indicate that the filled land is outside of the SFHA. When such revisions are warranted, FEMA usually revises the FIRM by issuing a Letter of Map Revision based on fill (LOMR-F). After FEMA has revised the FIRM to show that the filled land is outside the SFHA, the community is no longer required to apply the minimum NFIP floodplain management standards to any structures built on the land and the mandatory flood insurance purchase requirements no longer apply. It is worth noting that states and local communities may have floodplain regulations that are more restrictive than the minimum requirements of the NFIP and may continue to enforce some or all of their floodplain management requirements in areas outside the SFHA.

Although a structure built on a site that has been elevated by the placement of fill may be removed by FEMA from the SFHA, the structure may still be subject to damage during the Base Flood and higher-magnitude floods. Constructing the entire structure at or above the level of the BFE will minimize the flood risk from the Base Flood and is therefore the most prudent approach to constructing on fill. Conversely, a structure with a basement (subgrade area) adjacent to or near the floodplain may well be impacted by subsurface flooding brought on by surface flooding.

This bulletin provides guidance on the construction of buildings on land elevated above the BFE through the placement of fill. Several methods of construction are discussed, and the most prudent—those that result in the entire building being above the BFE—are recommended.

In some areas of the country, basements are a standard construction feature. Individuals may wish to construct basements on land after it has been removed from the floodplain by a FEMA revision. Buildings with basements built in filled areas are at an added risk of flooding when compared to buildings on other types of foundations. However, there are two major ways to minimize this additional risk from subsurface flooding. First, the building should be located farther back from the edge of the fill closest to the flooding source. Second, the higher the basement floor is elevated, the less the risk. This technical bulletin provides guidance on how to determine that these buildings will be reasonably safe from flooding during the occurrence of the Base Flood and larger floods. To be reasonably safe from flooding during the Base Flood condition, the basement must (1) be dry, not have any water in it, and (2) be structurally sound, not have loads that either exceed the structural capacity of walls or floors or cause unacceptable deflections. In practice, this means that soils around the basement must have low permeability to minimize or stop water infiltration to the basement wall and floors. Any water that does permeate to the basement must be removed by a drainage layer on the outside (soil side) of the basement. In addition, the foundation walls and floor slab must be designed and constructed for any increased loads that may occur during the Base Flood condition.

NFIP Regulations

Part of a community's application to participate in the NFIP must include "a commitment to recognize and duly evaluate flood hazards in all official actions in the areas having special flood hazards and to take other such official actions reasonably necessary to carry out the objectives of the program" [44 CFR 59.22 (a)(8)].

NFIP regulations at 44 CFR 60 include Subpart A: Requirements for Flood Plain Management Regulations. Each community participating in the NFIP adopts a floodplain management ordinance that meets or exceeds the minimum requirements listed in 44 CFR 60. Subpart A establishes specific criteria for determining the adequacy of a community's floodplain management regulations. The overriding purpose of the floodplain management regulations is to ensure that participating communities take into account flood hazards, to the extent that they are known, in all official actions relating to land management and use.

One of the minimum requirements established by the regulations is set forth at 44 CFR 60.3 (a)(3), which states that, for all proposed construction or other development within a participating community, the community must "Review all permit applications to determine whether the proposed building sites will be reasonably safe from flooding." 44 CFR 59.1 defines "development" as

> *"...any manmade change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operation or storage of equipment or materials,"*

Warning

Construction of a residential building in an identified SFHA with a lowest floor below the BFE is a violation of the floodplain management requirements set forth at 44 CFR 60.3(c)(2), unless the community has obtained an exception to NFIP requirements from FEMA and has approved procedures in place.

By issuance of this Technical Bulletin, FEMA is noting that residual flood hazards may exist in areas elevated above the BFE by the placement of engineered earthen fill. Residual risks in these areas include subsurface flood conditions and flooding from events that exceed the base flood. This bulletin is intended to guide local floodplain management officials in determining whether structures placed in filled areas are reasonably safe from flooding. FEMA will require that the jurisdiction having authority for floodplain management determine that an area is reasonably safe from flooding before removing it from the SFHA.

Floodways, V Zones, and Alluvial Fan Flood Hazard Areas

This bulletin does **not** apply to the following:

- Construction in the floodway. The NFIP prohibits encroachments into the floodway that would cause increases in flood stage.
- Construction in SFHAs designated Zone V, VE, or V1-V30 on FIRMs. The NFIP prohibits the use of structural fill for support of buildings in V zones. Buildings constructed in a V zone must be constructed on an open foundation consisting of piles, piers, or posts and must be elevated so that the bottom of the lowest horizontal structural member is at or above the BFE. In addition, this bulletin strongly recommends that structural fill **not** be used to elevate buildings constructed in A zones in coastal areas. Detailed guidance concerning proper construction methods for buildings in coastal areas is presented in FEMA's *Coastal Construction Manual* (FEMA 55) and in NFIP Technical Bulletin 5, *Free-of-Obstruction Requirements*.
- Construction in SFHAs subject to alluvial fan flooding (designated Zone A0 with depths and velocities shown on FIRMs). The NFIP will not remove land from the floodplain based on the placement of fill in alluvial fan flood hazard areas.

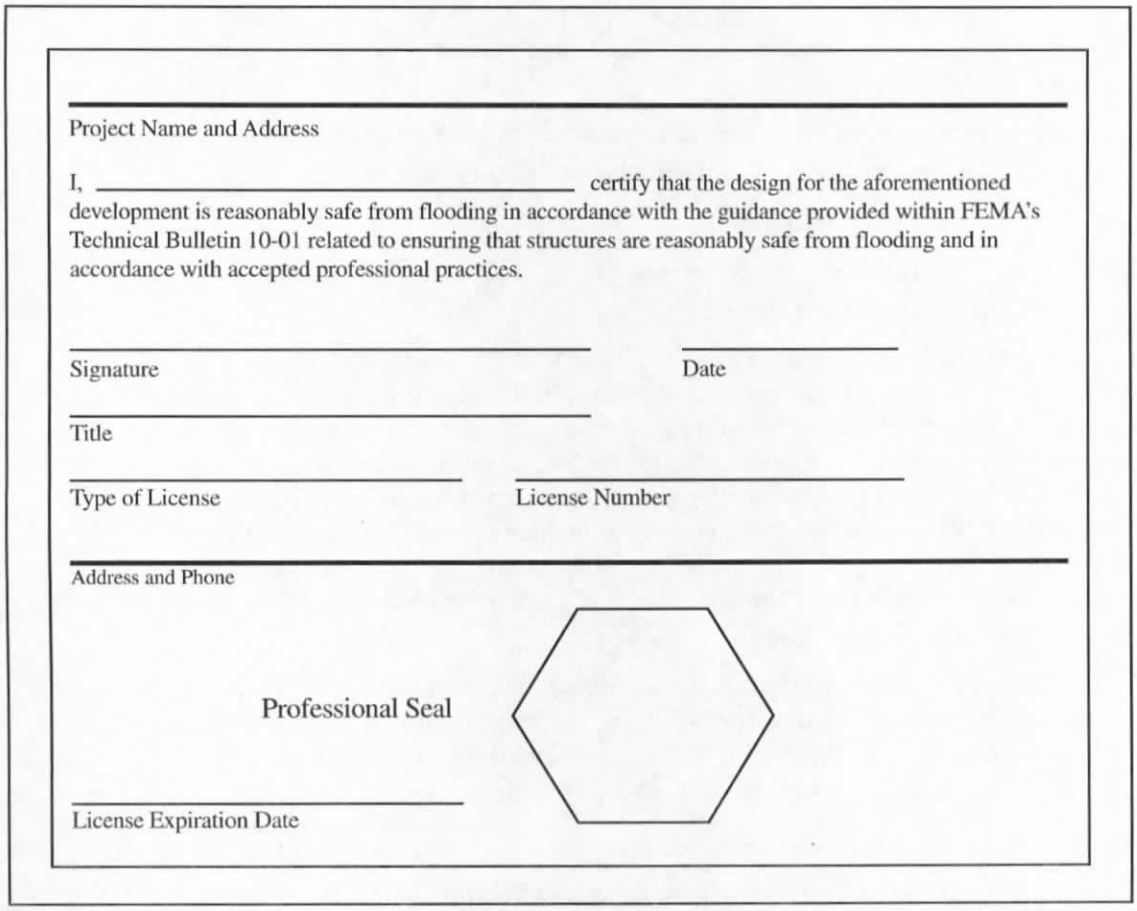
More Restrictive State and Local Requirements

NFIP Technical Bulletins provide guidance on the **minimum** requirements of the NFIP regulations. State or local requirements that exceed those of the NFIP take precedence. Design professionals should contact community officials to determine whether more restrictive state or local regulations apply to the building or site in question. All applicable standards of the state or local building code must be met for any building in a flood hazard area.

Notes for Local Officials

Professional Certification

As required by state and local floodplain management ordinances, a proposed development must be determined to be reasonably safe from flooding. The official having the authority to make this determination should require all appropriate information for making the determination. This may include a certification by a qualified design professional that indicates the land or structures to be removed from the SFHA are reasonably safe from flooding, according to the criteria described in this technical bulletin. Such a professional certification may come from a professional engineer, professional geologist, professional soil scientist, or other design professional qualified to make such evaluations. A sample of such a certification is shown in Figure 1.



Project Name and Address

I, _____ certify that the design for the aforementioned development is reasonably safe from flooding in accordance with the guidance provided within FEMA's Technical Bulletin 10-01 related to ensuring that structures are reasonably safe from flooding and in accordance with accepted professional practices.

_____ _____
Signature Date

_____
Title

_____ _____
Type of License License Number

_____
Address and Phone

Professional Seal

_____
License Expiration Date

Figure 1 Sample of professional certification form.

Administrative Options for Community Permitting

Communities may choose a variety of administrative procedures to assist them in gathering information that can be used to determine whether a proposed development is reasonably safe from flooding. Communities are encouraged to establish procedures that alert them to potential future development of a filled area. These procedures should allow for the evaluation of future development and a means to determine whether it will be reasonably safe from flooding. The following are examples of such procedures:

- Require building sites to be identified on final subdivision plats and evaluate those building sites against the standards described in this Technical Bulletin.
- Require grading plans as a condition of issuing fill permits and require that those grading plans include building sites, and evaluate those building sites based on this Technical Bulletin.
- Require buffer zones or setback zones around the perimeter of fill pads or at the edge of the floodplain and establish construction requirements within these buffer zones to ensure that buildings are safe from residual risk.
- Require as a condition of final subdivision plat approval that the developer agree that no basements will be built in any flood areas.
- Adopt or have regulations that control development of areas immediately adjacent to floodplains that would ensure that any construction is reasonably safe from flooding. For example, under the Minnesota State Building Code, communities designate areas outside of the floodplain as "Secondary Flood Hazard Areas" where building officials evaluate plans for basements and can require modifications to the basement if an official believes there is a residual risk.
- When issuing a permit for the placement of fill only in the SFHA, stipulate that no buildings will be built on the site without a subsequent building permit.

Placement of Fill

Properly placing fill requires an understanding of soil mechanics, local site conditions, the specific characteristics of the soils being placed, the methods used to place and compact the fill, and soil testing procedures. Standard engineering and soil mechanics texts cover these subjects in detail. The performance of these filled areas should consider, but is not limited to, the following:

- the consolidation of the fill layers and any underlying layers
- the effect of this consolidation on either excessive settlement or differential settlement
- how the permeability of the soils affects water infiltration on any structures built on the site

Loss of Storage and Conveyance

The placement of fill in the SFHA can result in an increase in the BFE by reducing the ability to convey and store flood waters. This can result in increased flood damage to both upstream and downstream properties. To prevent these possible results, some communities prohibit fill, require compensatory storage for filled areas, and/or identify a more restrictive floodway.

Risk of Flood Damage in Areas Adjacent to the SFHA

Areas adjacent to the SFHA may have residual risks of flood damage similar to those in areas removed from the SFHA through the placement of fill. Both areas are subject to residual risk from subsurface water related to flooding and from floods greater than the Base Flood. Methods of construction discussed in this bulletin should also be used in these areas.

Building on Land Removed From the SFHA by the Placement of Fill

The safest methods of constructing a building on filled land removed from the SFHA are those that result in the entire structure being above the BFE. Methods that place the lowest floor of the building at, rather than above, the BFE are at greater flood risk, and methods that result in the lowest floor (including a basement floor) below the BFE have the highest flood risk of all. Placement of the lowest floor of these structures below the BFE, even through they are outside the SFHA, will result in an increased threat from subsurface flooding and magnified damages from flooding that exceeds the BFE.

Freeboard

Freeboard is an additional height used as a factor of safety in determining the elevation of a structure, or floodproofing, to compensate for factors that may increase the flood height (ASCE 24-98, *Flood Resistant Design and Construction*). When fill is used to protect buildings from the Base Flood, the community should consider whether freeboard should be required. This consideration should include whether better information exists or conditions have changed (from when the BFE was originally established) that indicate that the BFE may be higher than originally expected. One example of when the BFE may be higher is when a culvert or bridge is blocked by debris. Flood modeling assumes an open channel or culvert. Even when the BFE is not expected to be higher, freeboard may be appropriate to provide increased protection from flood events less frequent than the Base Flood or to account for future changes that may increase the BFE.

The foundation types for buildings outside the SFHA described in the following sections are listed in order of their increasing risk of flood damage.

Non-Basement Foundations

Non-basement foundations consist primarily of stem wall, crawlspace, and slab-on-grade foundations.

Stem Wall Foundation

A stem wall foundation can be used to raise the lowest floor above the surrounding grade. After the stem walls have been constructed and extended to the desired elevation, the area enclosed by the stem walls is filled with engineered compacted fill and a slab is poured on top (see Figure 2). Through the placement of additional fill, the site may be elevated above the BFE. This approach provides freeboard—an additional amount of elevation that helps protect against subsurface flooding and floods that exceed the Base Flood. Constructing a stem wall foundation and placing this additional fill on the site provide the highest level of flood protection.

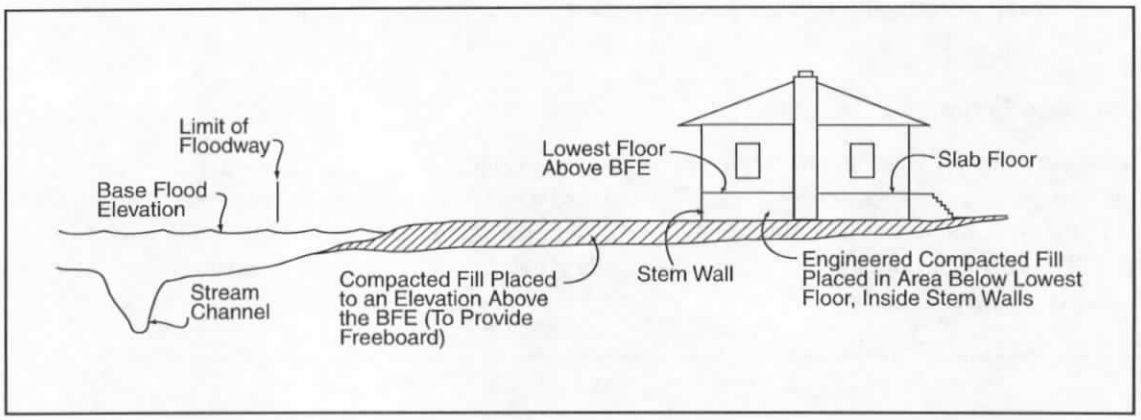


Figure 2 Structure on a stem wall foundation. The lowest floor is raised above the BFE. The space enclosed by the stem walls is filled with engineered compacted fill.

Crawlspace Foundation

Constructing a crawlspace beneath the first floor will raise the lowest floor of the structure above the surrounding grade (see Figure 3). Openings in the foundation walls are recommended. If flooding reaches the building, the openings allow flood waters to enter the area below the lowest floor and equalize the hydrostatic pressure on the foundation walls (see NFIP Technical Bulletin 1, *Openings In Foundation Walls*).

The crawlspace alternative is less preferable than stem wall construction, which does not result in an enclosed area under the first floor and therefore requires no flood openings. Placing additional fill to a level above the BFE provides freeboard that helps protect against subsurface flooding and floods that exceed the Base Flood. Constructing a crawlspace foundation and placing additional fill on the site provide increased flood protection.

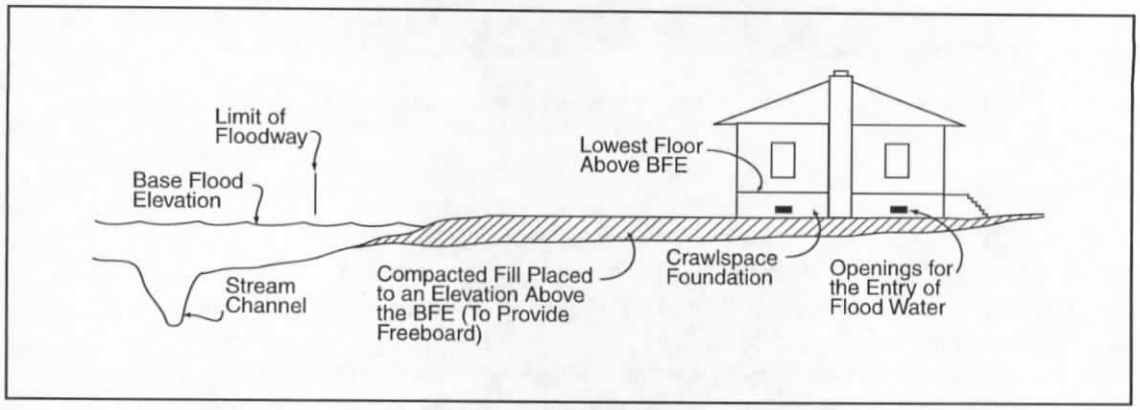


Figure 3 Structure on a crawlspace foundation. The lowest floor is raised above the BFE. Openings in the foundation walls allow water from floods higher than the fill elevation to enter the crawlspace and equalize the pressure on foundation walls.

Slab-On-Grade Foundation

This method normally provides less flood protection than crawlspace construction because it does not elevate the house above the adjacent grade (see Figure 4). As a result, the lowest floor of the house can be as low as the BFE and would be inundated by any flood greater than the BFE. Placing additional engineered fill beneath the building to a level above the BFE would provide freeboard and therefore increased flood protection.

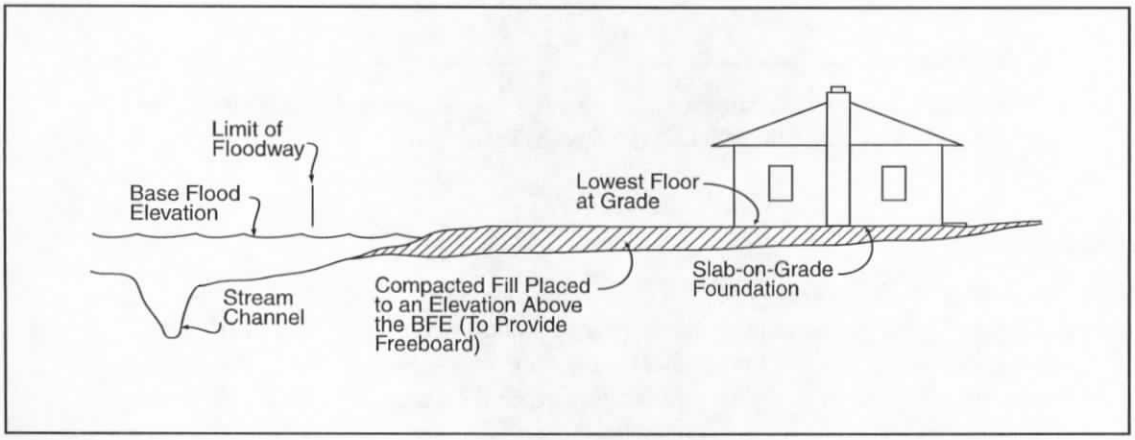


Figure 4 Structure on a slab-on-grade foundation. The lowest floor is typically slightly higher than the surrounding grade.

Basement Foundations

Although basements are a desired feature in some areas of the United States, NFIP minimum requirements generally do not allow their construction in the SFHA, because of the increased risk of flood damages. The only instances where this is not the case are buildings for which FEMA has granted a special exemption to allow floodproofed basements. However, once land is removed from the SFHA through a map revision, these NFIP minimum requirements no longer apply. As a result, builders and property owners who build on land removed from the SFHA sometimes elect to install basements, which are at a higher risk of flood damage than the foundation types described previously.

Constructing a basement on such land is **not** recommended, because the basement (i.e., lowest) floor and portions of the basement walls may well be subjected to subsurface flooding. The basement may therefore be subject to seepage and lateral hydrostatic and uplift pressure caused by high groundwater levels associated with flooding in surrounding areas. Additionally, when flooding exceeds the BFE, the basement area may be totally inundated with floodwater. When builders and homeowners decide to accept the additional risk associated with basement construction on filled land, they need to ensure that the basement and the rest of the house are reasonably safe from flooding.

Warning

In filled areas adjacent to floodplains, floods can still greatly influence the groundwater at the filled site. High groundwater at a site with a basement can result in water infiltrating the basement or greatly increased hydrostatic pressures on the walls and basement slab that can cause failure or permanent deformation. Even when floods have not reached houses with basements, FEMA has seen numerous examples of flooded basements, bowed basement floors, and collapsed basement walls that have resulted from the effects of high groundwater caused by flooding. In addition, the collapse of flooded basements has also occurred when water is rapidly pumped from basements surrounded by saturated soils whose pressure exceeds the capacity of the basement walls.

Flood Insurance Coverage for Basements

It is extremely important to note that the NFIP offers only limited coverage for basement flooding. First, in order for a claim to be paid, there must be a general condition of overland flooding where floodwaters come in contact with the structure. Secondly, the NFIP does not provide coverage for finished nonstructural elements such as paneling and linoleum in basement areas. Contents coverage is restricted to a limited number of items listed in the flood insurance policy. Contact a local insurance agent for more information.

Four basement construction methods are described below in increasing order of flood risk.

Basement Foundation With Lowest Floor At or Above BFE

Placing the lowest floor of the basement at or above the BFE has the effect of eliminating flood-induced damage up to the BFE (see Figure 5). In general, the higher the basement floor is above the BFE the lower the risk of damage from seepage and hydrostatic pressure caused by flood-related groundwater. Where possible, the basement should be built with its floor at or above the BFE. An added benefit is that floods that exceed the BFE will cause significantly less damage to a structure with this type of basement than to structures with basements whose floors are at greater depths.

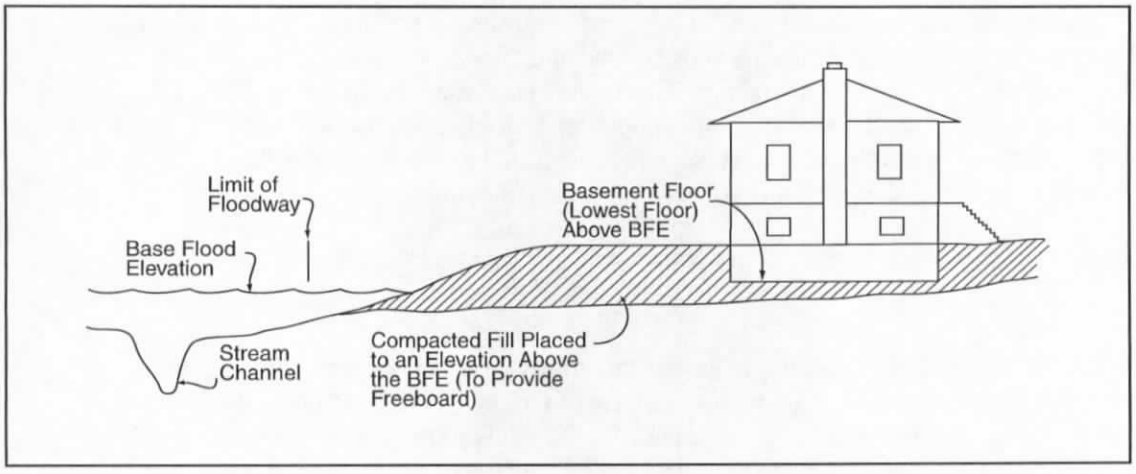


Figure 5 Basement foundation with lowest floor above the BFE. Damage from floods below the BFE is eliminated.

Basement Foundation in Fill Placed Above BFE

Placing fill to a level higher than the BFE has the effect of reducing the depth of the basement floor below the BFE (see Figure 6). It is recommended that fill be placed to a level at least 1 foot above the BFE. In general, the higher the basement floor the lower the risk of damage from seepage and hydrostatic pressure caused by flood-related groundwater. Where possible, enough fill should be properly placed so that the lowest grade adjacent to the structure is raised to an elevation greater than the BFE. An added benefit of fill placed above the BFE is that it helps protect the building from floods greater than the Base Flood. These floods are less likely to reach the structure.

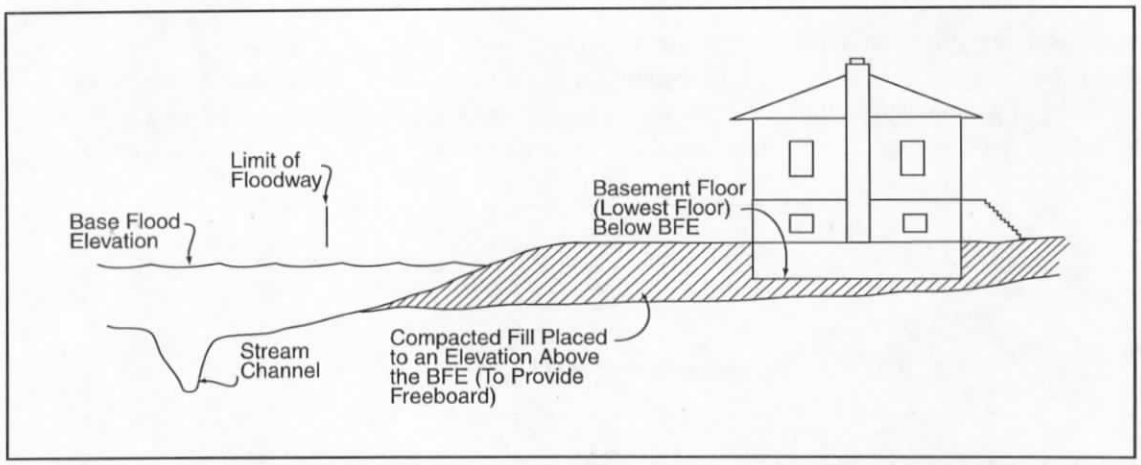


Figure 6 Basement foundation in fill placed above the BFE. The depth of the basement floor below the BFE is less than when no fill is placed.

Basement Foundation With Lowest Opening Above BFE

In the event that the lowest floor is not elevated to or above the BFE and fill is not placed to a level above the BFE, the next best method of reducing flood risk is to place the lowest opening into the basement (e.g., window well) at a level higher than the BFE (see Figure 7). This will reduce the chances that surface flooding will enter and inundate the basement. However, the basement walls and floor slab will still be subjected to hydrostatic pressure with the potential for damage and seepage into the basement. In addition, the above-grade basement walls will be exposed to water from floods greater than the Base Flood. For this reason, the lowest opening in the basement walls should be above the BFE, as shown in Figure 7.

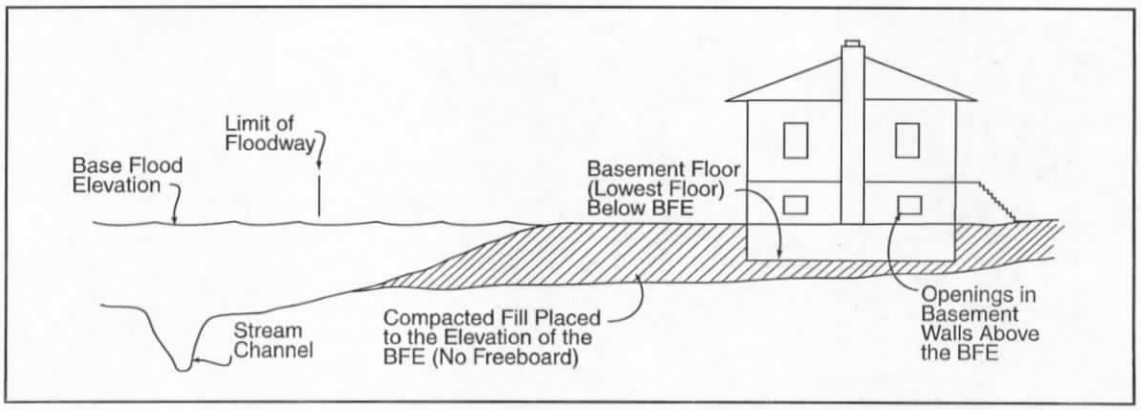


Figure 7 Basement foundation with lowest opening above the BFE. Surface flooding is less likely to enter and inundate the basement.

Basement Foundation With Lowest Opening at BFE

This is the least preferable condition of all because it results in the highest flood risk and is not recommended (see Figure 8). The lack of fill above the BFE, coupled with the lowest floor being below BFE and lowest opening at the BFE, exposes the basement to flooding from both subsurface flooding and any flood greater than the Base Flood.

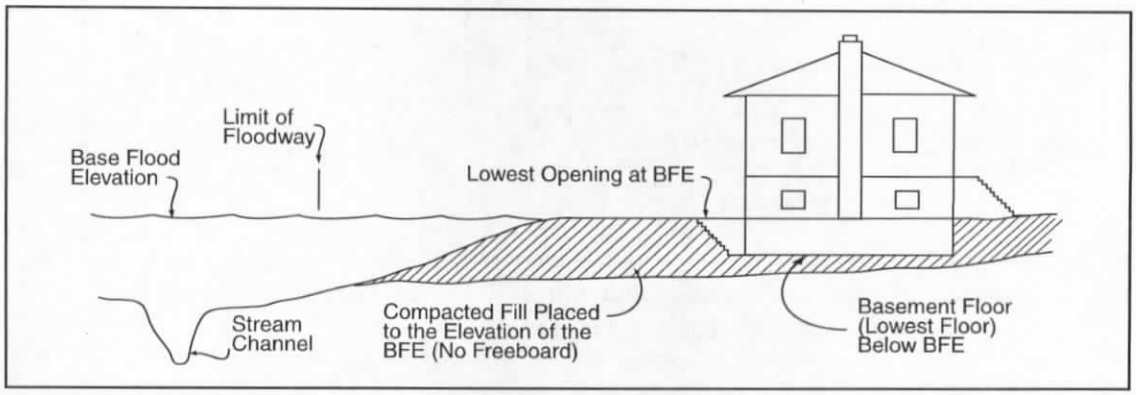
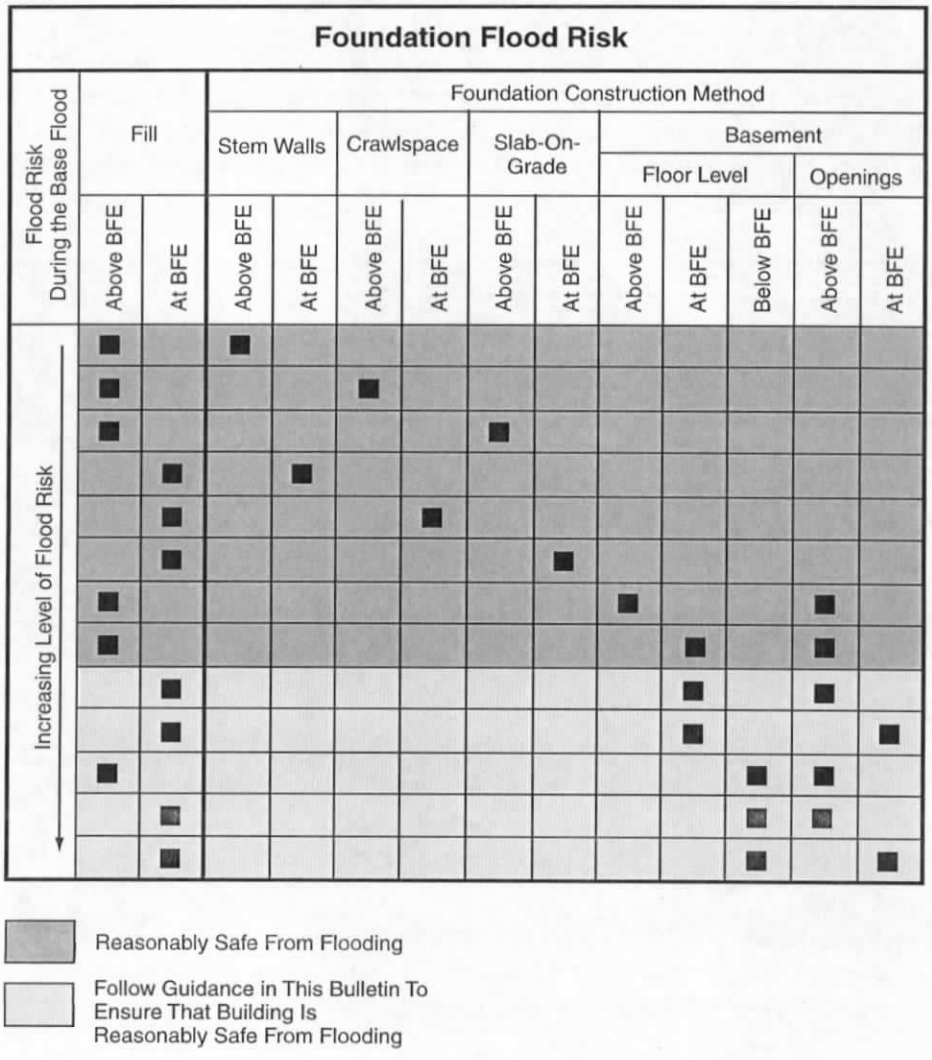


Figure 8 Basement foundation with lowest opening at the BFE. The basement is exposed to flooding from any flood greater than the Base Flood.

Flood Risk by Foundation Type

Table 1 summarizes the foundation construction methods described in this bulletin and ranks them in order of increasing flood risk—the safest foundation types appear near the top; the less safe foundation types appear near the bottom. The foundation construction methods that result in a building that is reasonably safe from flooding are shown in the dark gray area of the table. If the basement construction methods shown in the light gray area are used, the requirements described in the following sections of this bulletin must be met in order for the building to be considered reasonably safe from flooding.

Table 1 Flood Risk by Foundation Construction Method



Basement Construction Guidance

For those who have chosen to accept the additional risk associated with basement construction below the Base Flood on filled land that has been removed from the SFHA, this bulletin provides technical guidance about measures that can be taken to protect basements and meet the requirement that buildings be made reasonably safe from flooding. A simplified approach, including the requirements that must be met for its use, is presented first. For buildings that do not meet the criteria for the simplified approach, this bulletin provides technical guidance for the development of an engineering design tailored to the site conditions.

Structural Design

Design of foundation elements is addressed in model building codes. This technical bulletin does not address the structural design of basement walls or foundations. Floors and slabs should be designed for the hydrostatic pressures that can occur from the Base Flood. For the structural design, it is recommended that the full hydrostatic pressures be assumed unrelieved by the drainage system. Foundation walls that have not been designed for hydrostatic pressures, such as unreinforced masonry or pressure-treated wood wall systems, should not be used (see Figure 9).

Figure 9 Failure of this unreinforced masonry basement during flooding in East Grand Forks, MN, in 1997 caused approximately $32,000 in damage.

Simplified Approach

Design Requirements

If, for a building and building site, **all** the requirements listed below are met (see Figure 10), the building is reasonably safe from flooding. If all of these requirements are not met, the more detailed analysis described under Engineered Basement Option, on page 19 of this bulletin, should be performed to determine whether the building is reasonably safe from flooding.

- ☐ The ground surface around the building and within a defined setback distance from the edge of the SFHA (see next item) must be at or above the BFE.
- ☐ The setback is the distance from the edge of the SFHA to the nearest wall of the basement. The minimum allowable setback distance is 20 feet.
- ☐ The ground around the building must be compacted fill; the fill material—or soil of similar classification and degree of permeability—must extend to at least 5 feet below the bottom of the basement floor slab.
- ☐ The fill material must be compacted to at least 95 percent of Standard Laboratory Maximum Dry Density (Standard Proctor), according to ASTM Standard D-698. Fill soils must be fine-grained soils of low permeability, such as those classified as CH, CL, SC, or ML according to ASTM Standard D-2487, *Classification of Soils for Engineering Purposes*. See Table 1804.2 in the 2000 *International Building Code* (IBC) for descriptions of these soil types.
- ☐ The fill material must be homogeneous and isotropic; that is, the soil must be all of one material, and the engineering properties must be the same in all directions.
- ☐ The elevation of the basement floor should be no more than 5 feet below the BFE.
- ☐ There must be a granular drainage layer beneath the floor slab, and a ¼-horsepower sump pump with a backup power supply must be provided to remove the seepage flow. The pump must be rated at four times the estimated seepage rate and must discharge above the BFE and away from the building. This arrangement is essential to prevent flooding of the basement or uplift of the floor under the effect of the seepage pressure.
- ☐ The drainage system must be equipped with a positive means of preventing backflow.
- ☐ Model building codes (such as the 2000 International Residential Code) also address foundation drainage (IRC Section R405) and foundation walls (IRC Section R404). Model building codes generally allow foundation drains to discharge through either mechanical means or gravity drains. In addition, there is often an exception to the requirement for drainage systems in well-drained soils. However, in or near floodplains, well-drained soils can, in fact, help convey groundwater towards the building foundation. Therefore, this exception should not apply in or near floodplains.

In some cases in or near floodplains, even with standard drainage systems, hydrostatic pressures from groundwater against the basement can result. When a standard drainage system is unable to eliminate hydrostatic pressure on the foundation, model building codes, including the 2000 International Residential Code (IRC Section R404.1.3), require that the foundation be designed in accordance with accepted engineering practice. **The simplified approach contained in this Technical Bulletin assumes no hydrostatic pressure on the foundation and should be used only when a standard drainage system, discharged by a sump pump that is equipped with backup power and that discharges above BFE, is employed.** For other drainage systems, the designer should use the engineered basement option presented on page 19 of this bulletin and other appropriate building code requirements.

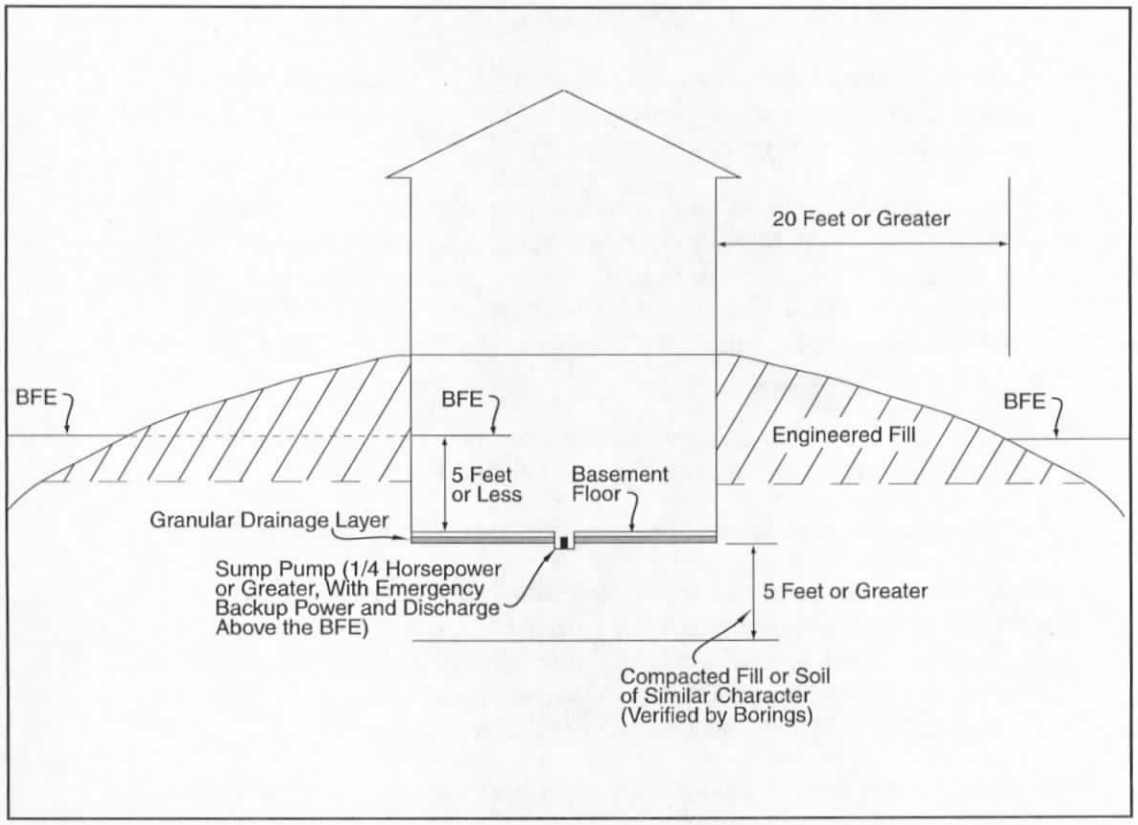


Figure 10 Requirements for use of the simplified approach to basement construction.

Technical Background for the Simplified Approach

The simplified approach is based on the following conditions:

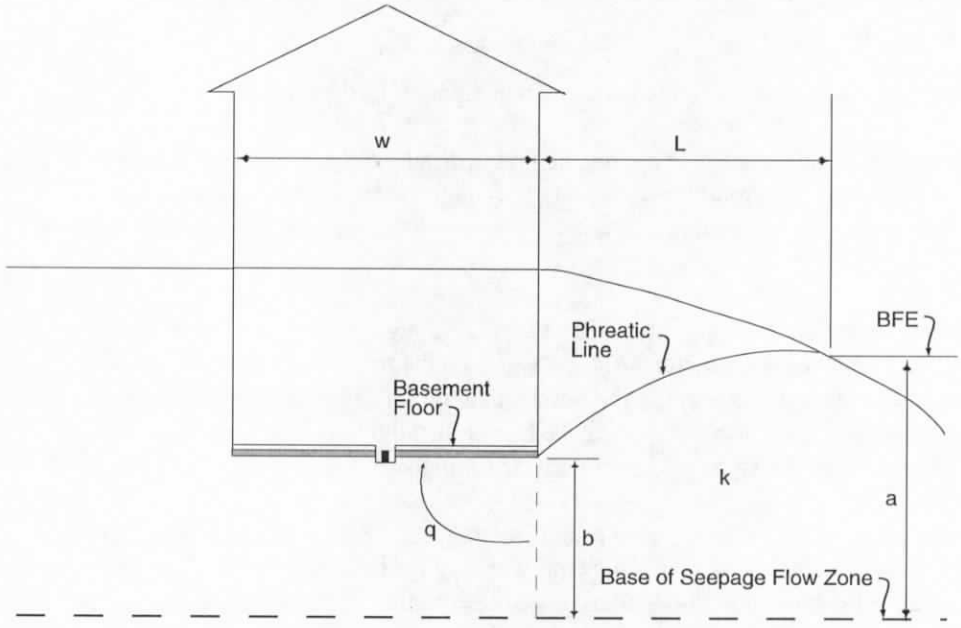
1. The area of the footprint of the basement is less than or equal to 1,200 square feet.

2. The soil is saturated; therefore, there is no time lag in the development of the seepage pattern with a change in flood water level. The groundwater table in floodplains is typically very shallow, and fine-grained soils have a substantial potential for maintaining saturation above the water table by capillary rise.

3. The tailwater level is at the elevation of the BFE. For this bulletin, "tailwater" is defined as the groundwater level beyond the structure, on the side away from the flood water surface. This is a reasonably conservative assumption because the flood would raise the groundwater level in the general area. In some cases, the tailwater level can be higher than the flood level because there is higher ground, as a valley wall, that feeds the groundwater into the floodplain soils.

4. The effective elevation of the base of the seepage flow zone can be defined (see Figure 11). This elevation is needed to permit calculation of the quantity of seepage flow. If the base elevation is not known, its depth below the base of the floor slab can be conservatively approximated as one-half of the building width most nearly perpendicular to the shoreline of the flood water. This would approximate the boundary effects of the three-dimensional seepage flow, in that it would represent the flow coming in from all sides and meeting in the center beneath the floor slab. This approach assumes a constant soil type and density over the flow zone. If the site has stratified soil layers, the engineered basement option should be used (see page 19 of this bulletin).

5. The quantity of seepage flow can be calculated by a simplified method based on Dupuit's assumption that equipotential lines are vertical. (The Dupuit method uses Darcy's law with specific physical characteristics. A more detailed description can be found in the first two references listed under "Further Information," on page 23 of this bulletin.) The elements of the method are presented in Figure 11. The entry surface, with hydraulic head "a," is a vertical line extending downward from the edge of the flood surface. The exit surface, with hydraulic head "b," is a vertical line extending downward from the side of the structure closest to the flood water's edge. The length of the flow path, "L," is the setback distance. Flow is assumed to be horizontal, and the horizontal coefficient of permeability is the effective permeability. For simplicity, the small inclined entry zone at the river bank and the exit zone below the basement floor are ignored. This is a reasonably conservative measure. The phreatic line, or the line below which the seepage flow occurs under positive pressure, extends from the edge of the flood water to the elevation of the bottom of the basement floor slab. If the exit zone below the basement floor were included, the hydraulic head at "b" would be higher. As shown in Figure 11, the phreatic line is not a straight line, but within the limits of the assumed boundary values, it is close to a straight line.



(1) $q = k(a^2 - b^2)/2L$

where: q = flow in cfs for a 1-foot width of seepage zone
k = soil permeability in feet per second
a = head at entry surface in feet
b = head at drain surface in feet
L = length of seepage zone (setback distance) in feet

(2) $Q = Pq$

where: Q = total seepage flow into drain in cfs
P = 2(basement length + width)
(for a square basement, P = 4w)

(3) Required sump pump capacity = 4Q for a safety factor of 4

Figure 11 Method for calculation of seepage flow.

The Dupuit equation for the quantity of seepage flow is:

$$q = k(a^2 - b^2)/2L$$

where: q is the flow in cubic feet per second for a 1-foot width of seepage zone

k is the soil permeability in feet per second (fps) (maximum value of k is 1×10^{-3} fps)

a and b are hydraulic heads in feet ($a < b + 5$)

L is the length of the flow zone in feet ($L > 20$ feet)

To obtain Q, the total seepage flow, in cubic feet per second, q must be multiplied by the length around the periphery of the four sides of the structure. This is a simplifying approach that obviates the need for a three-dimensional flow net calculation and is reasonably conservative.

It should be noted that the soil permeability does not affect the geometry of the seepage zone or the geometry of the phreatic line. The permeability does have a significant effect on the quantity of seepage that must be collected and discharged by the drainage layer and the sump pump. The calculation of the quantity Q provides a basis for the selection of a sump pump of adequate capacity. To allow for possible errors in the estimation of the soil permeability, the pump should have a capacity of at least four times the calculated value of Q. As noted in the requirements section, a standard sump pump of ¼ horsepower or greater will generally satisfy the requirements of seepage removal for the conditions described above.

Engineered Basement Option

If the requirements specified for the simplified approach are not met, a licensed soils engineer or geologist should perform a detailed engineering analysis to determine whether the structure will be reasonably safe from flooding. The analysis should consider, but is not limited to, the issues described in the following sections.

Depth, Soil Type, and Stratification of Subsurface Soils

The depth, soil type, and stratification of the subsurface soils may be complex. Four potential generalized scenarios are shown in Figures 12 and 13. Figure 12 shows two cases of homogeneous soil. The depth of penetration of the basement and the depth of the flow zone are not limited to the assumptions on which the simplified approach is based. Case I represents a foundation consisting of clayey soils, either fill or natural deposits or a combination, which are more or less homogeneous because they have similar engineering properties. If an adequate setback distance is provided, the seepage quantity would be relatively low, and uplift pressure beneath the slab could be controlled by an appropriately sized sump pump because of low permeability.

Case II represents a foundation consisting of sandy soils, either fill or natural soil deposits or a combination, which are more or less homogeneous because they have similar engineering properties. The seepage quantity would be fairly large, and more attention would have to be given to the setback distance and to the provision of an adequately sized sump pump to prevent excessive uplift pressure beneath the floor slab because of high permeability.

Figure 13 shows two simple cases of stratified soils, with impervious clays overlying pervious sands. This is a common occurrence in natural floodplain deposits. In Case III, the contact between the two soil strata is at some distance **below** the basement floor. This case would involve a moderate quantity of seepage, depending on the thickness, d, of the impervious stratum below the basement floor. There is also a potential for excessive uplift pressure beneath the floor, at the level of the bottom of the clay stratum. If d is equal to h, the net hydraulic head between the flood level and the floor level, the safety factor against uplift would be approximately 1.0. If d is less than h, there would be excessive uplift, with a safety factor equal to less than 1.0.

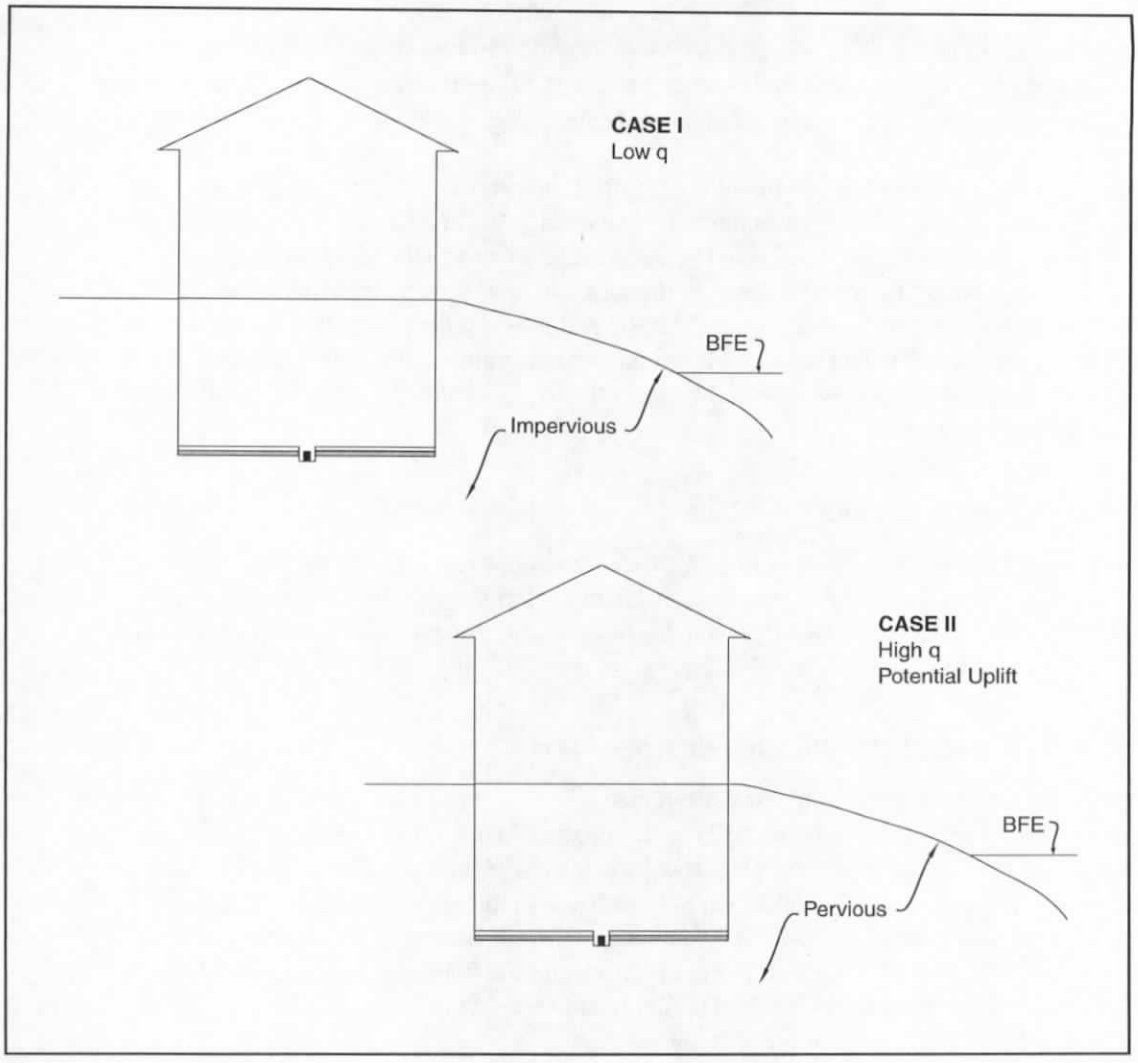


Figure 12 Case I and Case II – homogeneous soil.

Case IV shows impervious soils overlying pervious soils, with the contact between the soil strata at some distance **above** the basement floor. This case would involve a large quantity of seepage and potential for excessive uplift beneath the basement floor.

Geotechnical Investigations

Geotechnical investigations must be made for cases that do not conform with the assumptions on which the simplified approach is based. Information that is needed to permit an adequate engineering analysis includes the following:

- The BFE, which is to be used as the design flood water surface for calculating expected seepage.

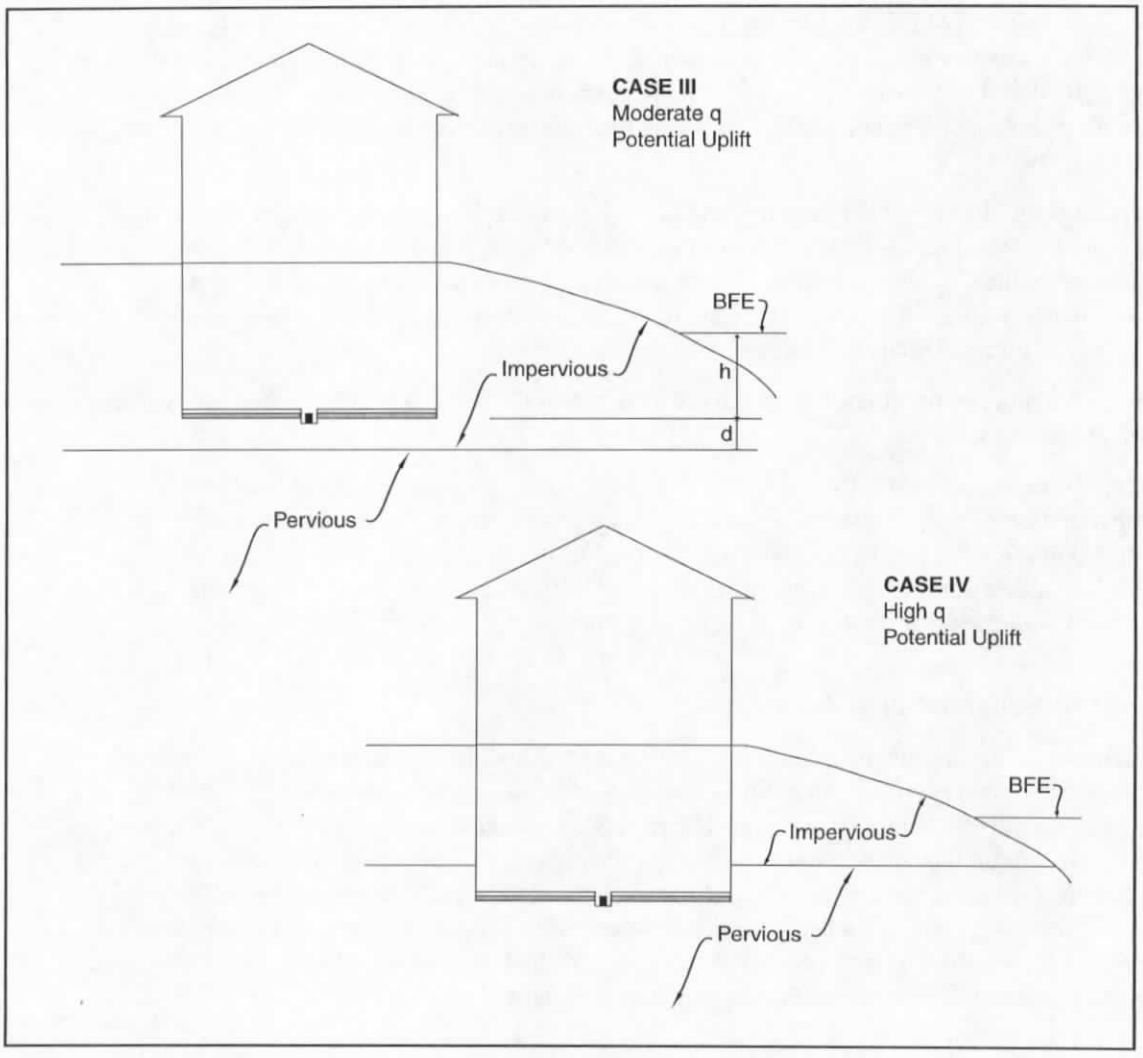


Figure 13 Case III and Case IV – stratified soils.

- The elevation of the **bottom** of the basement floor. This can be adjusted as needed to achieve more suitable conditions.
- The setback distance of the basement wall from the edge of the flood water. This can be adjusted to achieve more suitable seepage control or to accommodate available space restraints.
- The elevation of the groundwater table and its seasonal variations. A high water table would cause problems with groundwater control during construction of a basement, even without a flood event.
- The stratification of the subsurface materials, for both natural and fill soils. In general, borings should be drilled to a depth below the bottom of the floor slab that is at least two times as great as the depth of the bottom of the floor slab below the BFE.

- The engineering classification of the soils, for both natural and fill soils. This must be done in accordance with ASTM D2487, *Classification of Soils for Engineering Purposes*. This is the Unified Soil Classification System that is universally used throughout the United States. Local or county agricultural soil survey maps should not be used, because they do not give specific information about location and depth of soils, and their designations are not pertinent to civil engineering use.
- Subsurface conditions landward from the structure. This includes information about the location of the water table, whether it is higher or lower than the flood level, and information about any penetrations of the soil, such as ponds. Attention should be given to the possibility that higher ground, such as valley walls, could contribute to the groundwater level in the floodplain, either perennially or during periods of heavy rain.
- Information about any penetrations through the basement walls below the BFE, such as utility lines and other openings.
- Analysis of seepage quantity. The analysis can be made by the conservative simplified method described in Item 5 in the section titled Technical Background for the Simplified Approach (illustrated in Figure 11), or by the construction of a flow net that takes into account all of the boundary conditions more rigorously. A flow net may be required to permit analysis of uplift pressures. Uplift pressures may be more significant in laminated or stratified soil deposits.

Buildings in Existing Filled Areas

In evaluating buildings in existing filled areas, the two approaches already described—the simplified approach or the engineered basement option—can be used. If the simplified approach is used, all the requirements for the use of this approach must be met. Some possible means for evaluating whether these requirements are met include soil tests and investigations, including soil borings and hand augers; field records from the time the fill was placed; and soil surveys. If the requirements for the simplified approach are not met, a licensed soils engineer or geologist should perform a more detailed engineering analysis as described under Engineered Basement Option on page 19. More extensive soil investigations and testing may be required to complete the analysis.

The NFIP

The NFIP was created by Congress in 1968 to provide federally backed flood insurance coverage, because flood coverage was generally unavailable from private insurance companies. The NFIP is also intended to reduce future flood losses by identifying floodprone areas and ensuring that new development in these areas is adequately protected from flood damage. The NFIP is based on an agreement between the Federal government and participating communities that have been identified as floodprone. FEMA, through the Federal Insurance Administration (FIA), makes flood insurance available to the residents of a participating community, provided the community adopts and enforces adequate floodplain management regulations that meet the minimum NFIP requirements. The NFIP encourages communities to adopt floodplain management ordinances that exceed the minimum NFIP criteria set forth in Part 60 of the NFIP Floodplain Management Regulations (44 CFR 60). Included in the NFIP requirements, found under Title 44 of the U.S. Code of Federal Regulations, are minimum building design and construction standards for buildings located in SFHAs. Through their floodplain management

ordinances or laws, communities adopt the NFIP performance standards for new, substantially improved, and substantially damaged buildings in floodprone areas identified on FEMA's FIRMs.

Technical Bulletins

This publication is one of a series of Technical Bulletins that FEMA has produced to provide guidance concerning the building performance standards of the NFIP. These standards are contained in 44 CFR 60.3. The bulletins are intended for use primarily by state and local officials responsible for interpreting and enforcing NFIP regulations and by members of the development community, such as design professionals and builders. New bulletins, as well as updates of existing bulletins, are issued periodically, as necessary. The bulletins do not create regulations; rather they provide specific guidance for conforming with the minimum requirements of existing NFIP regulations. Users of the Technical Bulletins who need additional guidance concerning NFIP regulatory requirements should contact the Mitigation Division of the appropriate FEMA regional office or the local floodplain administrator. NFIP Technical Bulletin 0, the *User's Guide to Technical Bulletins,* lists the bulletins issued to date, provides a key word/subject index for the entire series, and lists addresses and telephone numbers for FEMA's 10 Regional Offices.

Ordering Information

Copies of FEMA Technical Bulletins can be obtained from the FEMA Regional Office that serves your area. In addition, Technical Bulletins and other FEMA publications can be ordered from the FEMA Publications Distribution Facility at 1-800-480-2520. The Technical Bulletins are also available at the FEMA web site at www.fema.gov.

Further Information

The following publications contain information related to the guidance presented in this bulletin:

American Society of Civil Engineers. 1998. SEI/ASCE 24-98, *Flood Resistant Design and Construction.*

Cedergren, H. R. 1977. *Seepage, Drainage and Flow Nets.* Wiley. New York.

Harr, M. E. 1977. *Mechanics of Particulate Media.* McGraw Hill. New York.

International Code Council. 2000. *International Building Code.* Birmingham, AL.

International Code Council. 2000. *International Residential Code.* Birmingham, AL.

U.S. Department of the Army, Corps of Engineers. 1986. EM 1110-2-1901, *Seepage Analysis and Control for Dams.* Washington, DC.

U.S. Department of the Army, Corps of Engineers. 1978. EM 1110-2-1913, *Design and Construction of Levees.* Washington, DC.

Glossary

Base Flood – The flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).

Basement – Any area of a building having its floor subgrade (below ground level) on all sides.

Community – Any state or area or political subdivision thereof, or any Indian tribe or authorized tribal organization, or Alaska Native village or authorized native organization, which has the authority to adopt and enforce floodplain management regulations for the areas within its jurisdiction.

Federal Emergency Management Agency (FEMA) – The independent Federal agency that, in addition to carrying out other activities, administers the NFIP.

Federal Insurance Administration (FIA) – The component of FEMA directly responsible for administering the flood insurance aspects of the NFIP.

Flood Insurance Rate Map (FIRM) – The insurance and floodplain management map issued by FEMA that identifies, on the basis of detailed or approximate analysis, areas of 100-year flood hazard in a community.

Floodprone area – Any land area susceptible to being inundated by flood water from any source.

Mitigation Directorate – The component of FEMA directly responsible for administering the flood hazard identification and floodplain management aspects of the NFIP.

New construction/structure – For floodplain management purposes, new construction means structures for which the start of construction commences on or after the effective date of a floodplain management regulation adopted by a community and includes subsequent improvements to the structure. For flood insurance purposes, these structures are often referred to as "post-FIRM" structures.

Special Flood Hazard Area (SFHA) – Area subject to inundation by the base flood, designated Zone A, A1-30, AE, AH, AO, V, V1-V30, or VE.

or knowledge of conditions that require, particularly for human safety, higher standards than the minimum criteria set forth in subpart A of this part. Therefore, any flood plain management regulations adopted by a State or a community which are more restrictive than the criteria set forth in this part are encouraged and shall take precedence.

[41 FR 46975, Oct. 26, 1976. Redesignated at 44 FR 31177, May 31, 1979, as amended at 48 FR 44552, Sept. 29, 1983; 49 FR 4751, Feb. 8, 1984]

§ 60.2 Minimum compliance with flood plain management criteria.

(a) A flood-prone community applying for flood insurance eligibility shall meet the standards of § 60.3(a) in order to become eligible if a FHBM has not been issued for the community at the time of application. Thereafter, the community will be given a period of six months from the date the Federal Insurance Administrator provides the data set forth in § 60.3 (b), (c), (d), (e) or (f), in which to meet the requirements of the applicable paragraph. If a community has received a FHBM, but has not yet applied for Program eligibility, the community shall apply for eligibility directly under the standards set forth in § 60.3(b). Thereafter, the community will be given a period of six months from the date the Federal Insurance Administrator provides the data set forth in § 60.3 (c), (d), (e) or (f) in which to meet the requirements of the applicable paragraph.

(b) A mudslide (i.e., mudflow)-prone community applying for flood insurance eligibility shall meet the standards of § 60.4(a) to become eligible. Thereafter, the community will be given a period of six months from the date the mudslide (i.e., mudflow) areas having special mudslide hazards are delineated in which to meet the requirements of § 60.4(b).

(c) A flood-related erosion-prone community applying for flood insurance eligibility shall meet the standards of § 60.5(a) to become eligible. Thereafter, the community will be given a period of six months from the date the flood-related erosion areas having special erosion hazards are delineated in which to meet the requirements of § 60.5(b).

(d) Communities identified in part 65 of this subchapter as containing more than one type of hazard (e.g., any combination of special flood, mudslide (i.e., mudflow), and flood-related erosion hazard areas) shall adopt flood plain management regulations for each type of hazard consistent with the requirements of §§ 60.3, 60.4 and 60.5.

(e) Local flood plain management regulations may be submitted to the State Coordinating Agency designated pursuant to § 60.25 for its advice and concurrence. The submission to the State shall clearly describe proposed enforcement procedures.

(f) The community official responsible for submitting annual or biennial reports to the Federal Insurance Administrator pursuant to § 59.22(b)(2) of this subchapter shall also submit copies of each annual or biennial report to any State Coordinating Agency.

(g) A community shall assure that its comprehensive plan is consistent with the flood plain management objectives of this part.

(h) The community shall adopt and enforce flood plain management regulations based on data provided by the Federal Insurance Administrator. Without prior approval of the Federal Insurance Administrator, the community shall not adopt and enforce flood plain management regulations based upon modified data reflecting natural or man-made physical changes.

[41 FR 46975, Oct. 26, 1976. Redesignated at 44 FR 31177, May 31, 1979, as amended at 48 FR 29318, June 24, 1983; 48 FR 44552, Sept. 29, 1983; 49 FR 4751, Feb. 8, 1984; 50 FR 36024, Sept. 4, 1985; 59 FR 53598, Oct. 25, 1994; 62 FR 55716, Oct. 27, 1997]

§ 60.3 Flood plain management criteria for flood-prone areas.

The Federal Insurance Administrator will provide the data upon which flood plain management regulations shall be based. If the Federal Insurance Administrator has not provided sufficient data to furnish a basis for these regulations in a particular community, the community shall obtain, review and reasonably utilize data available from other Federal, State or other sources pending receipt of data from the Federal Insurance Administrator. However, when special flood hazard area

designations and water surface elevations have been furnished by the Federal Insurance Administrator, they shall apply. The symbols defining such special flood hazard designations are set forth in §64.3 of this subchapter. In all cases the minimum requirements governing the adequacy of the flood plain management regulations for flood-prone areas adopted by a particular community depend on the amount of technical data formally provided to the community by the Federal Insurance Administrator. Minimum standards for communities are as follows:

(a) When the Federal Insurance Administrator has not defined the special flood hazard areas within a community, has not provided water surface elevation data, and has not provided sufficient data to identify the floodway or coastal high hazard area, but the community has indicated the presence of such hazards by submitting an application to participate in the Program, the community shall:

(1) Require permits for all proposed construction or other development in the community, including the placement of manufactured homes, so that it may determine whether such construction or other development is proposed within flood-prone areas;

(2) Review proposed development to assure that all necessary permits have been received from those governmental agencies from which approval is required by Federal or State law, including section 404 of the Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C. 1334;

(3) Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall (i) be designed (or modified) and adequately anchored to prevent flotation, collapse, or lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, (ii) be constructed with materials resistant to flood damage, (iii) be constructed by methods and practices that minimize flood damages, and (iv) be constructed with electrical, heating, ventilation, plumbing, and air conditioning equipment and other service facilities that are designed and/or located so as to prevent water from entering or accumulating within the components during conditions of flooding.

(4) Review subdivision proposals and other proposed new development, including manufactured home parks or subdivisions, to determine whether such proposals will be reasonably safe from flooding. If a subdivision proposal or other proposed new development is in a flood-prone area, any such proposals shall be reviewed to assure that (i) all such proposals are consistent with the need to minimize flood damage within the flood-prone area, (ii) all public utilities and facilities, such as sewer, gas, electrical, and water systems are located and constructed to minimize or eliminate flood damage, and (iii) adequate drainage is provided to reduce exposure to flood hazards;

(5) Require within flood-prone areas new and replacement water supply systems to be designed to minimize or eliminate infiltration of flood waters into the systems; and

(6) Require within flood-prone areas (i) new and replacement sanitary sewage systems to be designed to minimize or eliminate infiltration of flood waters into the systems and discharges from the systems into flood waters and (ii) onsite waste disposal systems to be located to avoid impairment to them or contamination from them during flooding.

(b) When the Federal Insurance Administrator has designated areas of special flood hazards (A zones) by the publication of a community's FHBM or FIRM, but has neither produced water surface elevation data nor identified a floodway or coastal high hazard area, the community shall:

(1) Require permits for all proposed construction and other developments including the placement of manufactured homes, within Zone A on the community's FHBM or FIRM;

(2) Require the application of the standards in paragraphs (a) (2), (3), (4), (5) and (6) of this section to development within Zone A on the community's FHBM or FIRM;

(3) Require that all new subdivision proposals and other proposed developments (including proposals for manufactured home parks and subdivisions) greater than 50 lots or 5 acres, whichever is the lesser, include within such proposals base flood elevation data;

(4) Obtain, review and reasonably utilize any base flood elevation and floodway data available from a Federal, State, or other source, including data developed pursuant to paragraph (b)(3) of this section, as criteria for requiring that new construction, substantial improvements, or other development in Zone A on the community's FHBM or FIRM meet the standards in paragraphs (c)(2), (c)(3), (c)(5), (c)(6), (c)(12), (c)(14), (d)(2) and (d)(3) of this section;

(5) Where base flood elevation data are utilized, within Zone A on the community's FHBM or FIRM:

(i) Obtain the elevation (in relation to mean sea level) of the lowest floor (including basement) of all new and substantially improved structures, and

(ii) Obtain, if the structure has been floodproofed in accordance with paragraph (c)(3)(ii) of this section, the elevation (in relation to mean sea level) to which the structure was floodproofed, and

(iii) Maintain a record of all such information with the official designated by the community under § 59.22 (a)(9)(iii);

(6) Notify, in riverine situations, adjacent communities and the State Coordinating Office prior to any alteration or relocation of a watercourse, and submit copies of such notifications to the Federal Insurance Administrator;

(7) Assure that the flood carrying capacity within the altered or relocated portion of any watercourse is maintained;

(8) Require that all manufactured homes to be placed within Zone A on a community's FHBM or FIRM shall be installed using methods and practices which minimize flood damage. For the purposes of this requirement, manufactured homes must be elevated and anchored to resist flotation, collapse, or lateral movement. Methods of anchoring may include, but are not to be limited to, use of over-the-top or frame ties to ground anchors. This requirement is in addition to applicable State and local anchoring requirements for resisting wind forces.

(c) When the Federal Insurance Administrator has provided a notice of final flood elevations for one or more special flood hazard areas on the community's FIRM and, if appropriate, has designated other special flood hazard areas without base flood elevations on the community's FIRM, but has not identified a regulatory floodway or coastal high hazard area, the community shall:

(1) Require the standards of paragraph (b) of this section within all A1–30 zones, AE zones, A zones, AH zones, and AO zones, on the community's FIRM;

(2) Require that all new construction and substantial improvements of residential structures within Zones A1–30, AE and AH zones on the community's FIRM have the lowest floor (including basement) elevated to or above the base flood level, unless the community is granted an exception by the Federal Insurance Administrator for the allowance of basements in accordance with § 60.6 (b) or (c);

(3) Require that all new construction and substantial improvements of nonresidential structures within Zones A1–30, AE and AH zones on the community's firm (i) have the lowest floor (including basement) elevated to or above the base flood level or, (ii) together with attendant utility and sanitary facilities, be designed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy;

(4) Provide that where a non-residential structure is intended to be made watertight below the base flood level, (i) a registered professional engineer or architect shall develop and/or review structural design, specifications, and plans for the construction, and shall certify that the design and methods of

construction are in accordance with accepted standards of practice for meeting the applicable provisions of paragraph (c)(3)(ii) or (c)(8)(ii) of this section, and (ii) a record of such certificates which includes the specific elevation (in relation to mean sea level) to which such structures are floodproofed shall be maintained with the official designated by the community under §59.22(a)(9)(iii);

(5) Require, for all new construction and substantial improvements, that fully enclosed areas below the lowest floor that are usable solely for parking of vehicles, building access or storage in an area other than a basement and which are subject to flooding shall be designed to automatically equalize hydrostatic flood forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement must either be certified by a registered professional engineer or architect or meet or exceed the following minimum criteria: A minimum of two openings having a total net area of not less than one square inch for every square foot of enclosed area subject to flooding shall be provided. The bottom of all openings shall be no higher than one foot above grade. Openings may be equipped with screens, louvers, valves, or other coverings or devices provided that they permit the automatic entry and exit of floodwaters.

(6) Require that manufactured homes that are placed or substantially improved within Zones A1–30, AH, and AE on the community's FIRM on sites

(i) Outside of a manufactured home park or subdivision,

(ii) In a new manufactured home park or subdivision,

(iii) In an expansion to an existing manufactured home park or subdivision, or

(iv) In an existing manufactured home park or subdivision on which a manufactured home has incurred "substantial damage" as the result of a flood, be elevated on a permanent foundation such that the lowest floor of the manufactured home is elevated to or above the base flood elevation and be securely anchored to an adequately anchored foundation system to resist floatation collapse and lateral movement.

(7) Require within any AO zone on the community's FIRM that all new construction and substantial improvements of residential structures have the lowest floor (including basement) elevated above the highest adjacent grade at least as high as the depth number specified in feet on the community's FIRM (at least two feet if no depth number is specified);

(8) Require within any AO zone on the community's FIRM that all new construction and substantial improvements of nonresidential structures (i) have the lowest floor (including basement) elevated above the highest adjacent grade at least as high as the depth number specified in feet on the community's FIRM (at least two feet if no depth number is specified), or (ii) together with attendant utility and sanitary facilities be completely floodproofed to that level to meet the floodproofing standard specified in §60.3(c)(3)(ii);

(9) Require within any A99 zones on a community's FIRM the standards of paragraphs (a)(1) through (a)(4)(i) and (b)(5) through (b)(9) of this section;

(10) Require until a regulatory floodway is designated, that no new construction, substantial improvements, or other development (including fill) shall be permitted within Zones A1–30 and AE on the community's FIRM, unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the community.

(11) Require within Zones AH and AO, adequate drainage paths around structures on slopes, to guide floodwaters around and away from proposed structures.

(12) Require that manufactured homes to be placed or substantially improved on sites in an existing manufactured home park or subdivision within Zones A–1–30, AH, and AE on the community's FIRM that are not subject to the provisions of paragraph (c)(6) of this section be elevated so that either

(i) The lowest floor of the manufactured home is at or above the base flood elevation, or

(ii) The manufactured home chassis is supported by reinforced piers or other foundation elements of at least equivalent strength that are no less than 36 inches in height above grade and be securely anchored to an adequately anchored foundation system to resist floatation, collapse, and lateral movement.

(13) Notwithstanding any other provisions of §60.3, a community may approve certain development in Zones A1–30, AE, and AH, on the community's FIRM which increase the water surface elevation of the base flood by more than one foot, provided that the community first applies for a conditional FIRM revision, fulfills the requirements for such a revision as established under the provisions of §65.12, and receives the approval of the Federal Insurance Administrator.

(14) Require that recreational vehicles placed on sites within Zones A1–30, AH, and AE on the community's FIRM either

(i) Be on the site for fewer than 180 consecutive days,

(ii) Be fully licensed and ready for highway use, or

(iii) Meet the permit requirements of paragraph (b)(1) of this section and the elevation and anchoring requirements for "manufactured homes" in paragraph (c)(6) of this section.

A recreational vehicle is ready for highway use if it is on its wheels or jacking system, is attached to the site only by quick disconnect type utilities and security devices, and has no permanently attached additions.

(d) When the Federal Insurance Administrator has provided a notice of final base flood elevations within Zones A1–30 and/or AE on the community's FIRM and, if appropriate, has designated AO zones, AH zones, A99 zones, and A zones on the community's FIRM, and has provided data from which the community shall designate its regulatory floodway, the community shall:

(1) Meet the requirements of paragraphs (c) (1) through (14) of this section;

(2) Select and adopt a regulatory floodway based on the principle that the area chosen for the regulatory floodway must be designed to carry the waters of the base flood, without increasing the water surface elevation of that flood more than one foot at any point;

(3) Prohibit encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge;

(4) Notwithstanding any other provisions of §60.3, a community may permit encroachments within the adopted regulatory floodway that would result in an increase in base flood elevations, provided that the community first applies for a conditional FIRM and floodway revision, fulfills the requirements for such revisions as established under the provisions of §65.12, and receives the approval of the Federal Insurance Administrator.

(e) When the Federal Insurance Administrator has provided a notice of final base flood elevations within Zones A1–30 and/or AE on the community's FIRM and, if appropriate, has designated AH zones, AO zones, A99 zones, and A zones on the community's FIRM, and has identified on the community's FIRM coastal high hazard areas by designating Zones V1–30, VE, and/or V, the community shall:

(1) Meet the requirements of paragraphs (c)(1) through (14) of this section;

(2) Within Zones V1–30, VE, and V on a community's FIRM, (i) obtain the elevation (in relation to mean sea level) of the bottom of the lowest structural member of the lowest floor (excluding pilings and columns) of all new and substantially improved structures, and whether or not such structures contain a basement, and (ii) maintain a record of all such information with the official designated by the community under §59.22(a)(9)(iii);

(3) Provide that all new construction within Zones V1–30, VE, and V on the community's FIRM is located landward of the reach of mean high tide;

(4) Provide that all new construction and substantial improvements in Zones V1–30 and VE, and also Zone V if base flood elevation data is available, on the community's FIRM, are elevated on pilings and columns so that (i) the bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) is elevated to or above the base flood level; and (ii) the pile or column foundation and structure attached thereto is anchored to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting simultaneously on all building components. Water loading values used shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards. A registered professional engineer or architect shall develop or review the structural design, specifications and plans for the construction, and shall certify that the design and methods of construction to be used are in accordance with accepted standards of practice for meeting the provisions of paragraphs (e)(4) (i) and (ii) of this section.

(5) Provide that all new construction and substantial improvements within Zones V1–30, VE, and V on the community's FIRM have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls, open wood latticework, or insect screening intended to collapse under wind and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or supporting foundation system. For the purposes of this section, a breakway wall shall have a design safe loading resistance of not less than 10 and no more than 20 pounds per square foot. Use of breakway walls which exceed a design safe loading resistance of 20 pounds per square foot (either by design or when so required by local or State codes) may be permitted only if a registered professional engineer or architect certifies that the designs proposed meet the following conditions:

(i) Breakaway wall collapse shall result from a water load less than that which would occur during the base flood; and,

(ii) The elevated portion of the building and supporting foundation system shall not be subject to collapse, displacement, or other structural damage due to the effects of wind and water loads acting simultaneously on all building components (structural and non-structural). Water loading values used shall be those associated with the base flood. Wind loading values used shall be those required by applicable State or local building standards.

Such enclosed space shall be useable solely for parking of vehicles, building access, or storage.

(6) Prohibit the use of fill for structural support of buildings within Zones V1–30, VE, and V on the community's FIRM;

(7) Prohibit man-made alteration of sand dunes and mangrove stands within Zones V1–30, VE, and V on the community's FIRM which would increase potential flood damage.

(8) Require that manufactured homes placed or substantially improved within Zones V1–30, V, and VE on the community's FIRM on sites

(i) Outside of a manufactured home park or subdivision,

(ii) In a new manufactured home park or subdivision,

(iii) In an expansion to an existing manufactured home park or subdivision, or

(iv) In an existing manufactured home park or subdivision on which a manufactured home has incurred "substantial damage" as the result of a flood, meet the standards of paragraphs (e)(2) through (7) of this section and that manufactured homes placed or substantially improved on other sites in an existing manufactured home park or subdivision within Zones VI–30, V, and VE on the community's FIRM meet the requirements of paragraph (c)(12) of this section.

(9) Require that recreational vehicles placed on sites within Zones V1–30, V, and VE on the community's FIRM either

(i) Be on the site for fewer than 180 consecutive days,

(ii) Be fully licensed and ready for highway use, or

(iii) Meet the requirements in paragraphs (b)(1) and (e) (2) through (7) of this section.

A recreational vehicle is ready for highway use if it is on its wheels or jacking system, is attached to the site only by quick disconnect type utilities and security devices, and has no permanently attached additions.

(f) When the Federal Insurance Administrator has provided a notice of final base flood elevations within Zones A1–30 or AE on the community's FIRM, and, if appropriate, has designated AH zones, AO zones, A99 zones, and A zones on the community's FIRM, and has identified flood protection restoration areas by designating Zones AR, AR/A1–30, AR/AE, AR/AH, AR/AO, or AR/A, the community shall:

(1) Meet the requirements of paragraphs (c)(1) through (14) and (d)(1) through (4) of this section.

(2) Adopt the official map or legal description of those areas within Zones AR, AR/A1–30, AR/AE, AR/AH, AR/A, or AR/AO that are designated developed areas as defined in §59.1 in accordance with the eligibility procedures under §65.14.

(3) For all new construction of structures in areas within Zone AR that are designated as developed areas and in other areas within Zone AR where the AR flood depth is 5 feet or less:

(i) Determine the lower of either the AR base flood elevation or the elevation that is 3 feet above highest adjacent grade; and

(ii) Using this elevation, require the standards of paragraphs (c)(1) through (14) of this section.

(4) For all new construction of structures in those areas within Zone AR that are not designated as developed areas where the AR flood depth is greater than 5 feet:

(i) Determine the AR base flood elevation; and

(ii) Using that elevation require the standards of paragraphs (c)(1) through (14) of this section.

(5) For all new construction of structures in areas within Zone AR/A1–30, AR/AE, AR/AH, AR/AO, and AR/A:

(i) Determine the applicable elevation for Zone AR from paragraphs (a)(3) and (4) of this section;

(ii) Determine the base flood elevation or flood depth for the underlying A1–30, AE, AH, AO and A Zone; and

(iii) Using the higher elevation from paragraphs (a)(5)(i) and (ii) of this section require the standards of paragraphs (c)(1) through (14) of this section.

(6) For all substantial improvements to existing construction within Zones AR/A1–30, AR/AE, AR/AH, AR/AO, and AR/A:

(i) Determine the A1–30 or AE, AH, AO, or A Zone base flood elevation; and

(ii) Using this elevation apply the requirements of paragraphs (c)(1) through (14) of this section.

(7) Notify the permit applicant that the area has been designated as an AR, AR/A1–30, AR/AE, AR/AH, AR/AO, or AR/A Zone and whether the structure will be elevated or protected to or above the AR base flood elevation.

[41 FR 46975, Oct. 26, 1976]

EDITORIAL NOTE: For FEDERAL REGISTER citations affecting §60.3, see the List of CFR Sections Affected, which appears in the Finding Aids section of the printed volume and on GPO Access.

§60.4 Flood plain management criteria for mudslide (i.e., mudflow)-prone areas.

The Federal Insurance Administrator will provide the data upon which flood plain management regulations shall be based. If the Federal Insurance Administrator has not provided sufficient data to furnish a basis for these regulations in a particular community, the community shall obtain, review, and reasonably utilize data available from other Federal, State or other sources pending receipt of data from the Federal Insurance Administrator. However, when special mudslide (i.e., mudflow) hazard area designations have been furnished by the Federal Insurance Administrator, they shall apply. The symbols defining such special mudslide (i.e., mudflow) hazard designations are set forth in §64.3 of this subchapter. In all cases, the minimum requirements for mudslide (i.e., mudflow)-prone areas adopted by a particular community depend on the amount of technical data provided to the community by the Federal Insurance Administrator. Minimum standards for communities are as follows:

(a) When the Federal Insurance Administrator has not yet identified any