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WATER & WASTEWATER ENGINEERING DIVISION

Dundalk Sewershed Evaluation Study Plan
Project No. 1047
RJN Job No. 17-2252

Alternative Analysis and Recommendations Report

Sanitary Sewer Overflow Consent Decree
Civil Action No. JFM-02-1524

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Executive Summary

As part of Baltimore City Project No. 1047: Dundalk Collection System Evaluation and Sewershed Plan, RJN Group developed and calibrated a hydraulic model established for the Dundalk Sewershed. Further, the capability of the sewer system to convey peak flows during dry weather and wet weather events under baseline and future conditions was evaluated. This report evaluates alternatives and recommends cost effective capital improvements to the sanitary collection system necessary to ensure adequate long term capacity during the 2, 5, 10, 15, and 20-year storm events.

Per the Consent Decree and the BaSES manual, the hydraulic model should be used to evaluate the performance of alternatives to mitigate sanitary sewer overflows (SSOs) in the City of Baltimore. In accordance with the BaSES manual, alternatives evaluated should include, but not be limited to replacement of malfunctioning pump station equipment, installation of pump backup equipment, reduction in inflow and infiltration, installation of larger diameter pipes or relief sewers, and installation of storage facilities.

In recommending improvements, I/I removal in areas upstream of the predicted overflow locations was evaluated prior to increasing pipe diameters, installation of storage facilities and other SSO control technologies. Based on the technical program guideline provided by the City, it is estimated that up to 80% inflow/infiltration reduction can be achieved if a comprehensive inflow and infiltration program (cured in place pipe (CIPP) lining of all public and private sewers and manhole rehabilitation/replacement) is implemented. It is proposed to only rehabilitate the public side of the sewer system; therefore a 40% reduction in rainfall dependent inflow/infiltration was applied to areas selected for inflow/infiltration reduction. Alternatives analysis assumes no inflow and infiltration reduction from the four Baltimore County basins. However, any inflow and infiltration reduction in the County has the potential to reduce the required improvements within the City's collection system.

To estimate construction costs for alternatives, standard unit costs for manhole repair/replacement, sewer lining (cured in place pipe lining), and sewer replacement were provided by the City. The fully loaded costs provided include raw unit costs plus costs for mobilization, paving restoration, bypass pumping, and miscellaneous utility work to complete a project. For costs not provided by the City, such as installation of storage facilities ($6 per gallon of storage was used in this study), recent projects within the City and surrounding areas were reviewed to assist in estimation of construction costs. These costs are further increased by an additional 42 percent to accommodate engineering design, construction management/inspection, administration, and contingencies. A 7 percent annual inflation rate is used to project costs beyond 2008. The incremental and cumulative costs for the recommended improvements to accommodate each design storm, and the incremental and cumulative costs for recommended improvements to eliminate each gallon of sewer overflow under each design storm are provided in tables at the end of the Executive Summary.

The major conclusions from the analysis of alternatives are summarized below.

(1) To convey a 2-year storm, it is recommended to perform an extensive I/I removal for sub-catchments 29-02-06-00A, 29-02-06-00B, and 29-02-06-00C in basin DU06 and sub-catchment 29-02-10-00A in basin DU07 upstream of the predicted overflow locations. The Dundalk Force Main is not in compliance with the velocity threshold of 7 fps during peak rain and it is recommended to inspect the force main every 5 years to ensure its normal functioning. The cost for these improvements is estimated to be $642,000 in 2008 dollars and the cost to eliminate each gallon of the predicted overflow is $257.

(2) Upon completion of the 2-year improvements, 5-year improvements are required to eliminate predicted overflows in basins DU03 and DU06. The recommended improvements include I/I removal projects for the entire DU06 basin, two SSAs (29-02-11-00 and 29-02-10-00) in DU07 and sub-catchment 29-01-09-00E in DU03. In addition, a segment of 12-inch pipe receiving BDU01 flow needs to be upsized to 15 inches in order to remove flow restrictions. The Dundalk Force Main is not in compliance with the velocity threshold of 7 fps during peak rain and it is recommended to inspect the force main every 5 years to ensure its normal functioning. The incremental (cost for 5-year improvements alone) and cumulative (cost for 2 and 5-year improvements) costs are estimated to be $4,410,000 and $5,050,000 respectively in 2008 dollars. The incremental and cumulative costs to eliminate each gallon of the predicted overflow are $33.1 and $37.2, respectively in 2008 dollars.

(3) To convey the 10-year storm, it is recommended to perform I/I removal projects for the entire DU07 basin and sub-catchment 29-01-09-00C in DU03. In addition to this, other major improvements include upsizing a segment of 27-inch pipe on Dundalk Avenue to 30 inches and upsizing a segment of 15-inch pipe in DU01 to 18 inches. The Dundalk Force Main is not in compliance with the velocity threshold of 7 fps during peak rain and it is recommended to inspect the force main every 5 years to ensure its normal functioning. The incremental and cumulative costs are estimated to be $6,100,000 and $11,150,000 respectively in 2008 dollars. The incremental and cumulative costs to eliminate each gallon of the predicted overflow are $30.9 and $33.5 respectively in 2008 dollars.

(4) Upon completion of I/I removal projects under 2, 5, and 10-year improvements, the primary work for the 15-year improvements is to increase flow conveyance capacity by installation of larger diameter pipes. Such work is to be carried out in basins DU01, DU03, DU05, DU06, and DU07. In particular, approximately 652 feet of 27-inch and 1,880 feet of 30-inch interceptors need to be upsized to 30 and 33 inches, respectively. The Dundalk Force Main is not in compliance with the velocity threshold of 7 fps during peak rain and it is recommended to inspect the force main every 5 years to ensure its normal functioning. The incremental and

cumulative costs are estimated to be $6,350,000 and $17,500,000 respectively in 2008 dollars. The incremental and cumulative costs to eliminate each gallon of the predicted overflow are $46.9 and $37.3 respectively in 2008 dollars.

(5) To convey the 20-year storm, the improvements include upsizing another segment of 15-inch pipe in DU01 to 18 inches, upsizing a segment of 10-inch pipe in DU03 to 12 inches, upsizing approximately 2,164 feet of 30-inch interceptor in DU05 to 33 inches, and raising six (6) manholes in DU05. After completing all recommended improvements, the three main pumps do not have enough capacity to handle the peak flow when the backup pump is offline for maintenance. It is recommended to reactivate approximately 572 feet of abandoned 36-inch force main to eliminate the predicted SSO at the wet well. It is also recommended to inspect the force main every 5 years to ensure its normal functioning. The incremental and cumulative costs are estimated to be $3,400,000 and $20,900,000 respectively in 2008 dollars. The incremental and cumulative costs to eliminate each gallon of the predicted overflow are $23.7 and $34.2 respectively in 2008 dollars.

Alternatives Analysis and Recommendations Report: Alternatives Analysis Summary

Estimated Improvement Costs for Dundalk

Project Year	2-year Storm	5-year Storm		10-year Storm		15-year Storm		20-year Storm	
		Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
2008	$642,000	$4,410,000	$5,050,000	$6,100,000	$11,150,000	$6,350,000	$17,500,000	$3,400,000	$20,900,000
2009	$687,000	$4,710,000	$5,400,000	$6,530,000	$11,930,000	$6,790,000	$18,720,000	$3,650,000	$22,370,000
2010	$735,000	$5,050,000	$5,780,000	$6,980,000	$12,760,000	$7,270,000	$20,030,000	$3,900,000	$23,930,000
2011	$786,000	$5,400,000	$6,190,000	$7,470,000	$13,660,000	$7,780,000	$21,440,000	$4,170,000	$25,610,000
2012	$841,000	$5,780,000	$6,620,000	$7,990,000	$14,610,000	$8,330,000	$22,940,000	$4,460,000	$27,400,000
2013	$900,000	$6,180,000	$7,080,000	$8,560,000	$15,640,000	$8,900,000	$24,540,000	$4,780,000	$29,320,000
2014	$963,000	$6,620,000	$7,580,000	$9,150,000	$16,730,000	$9,530,000	$26,260,000	$5,110,000	$31,370,000
2015	$1,031,000	$7,080,000	$8,110,000	$9,790,000	$17,900,000	$10,200,000	$28,100,000	$5,470,000	$33,570,000
2016	$1,103,000	$7,580,000	$8,680,000	$10,480,000	$19,160,000	$10,910,000	$30,070,000	$5,850,000	$35,920,000
2017	$1,180,000	$8,100,000	$9,280,000	$11,220,000	$20,500,000	$11,670,000	$32,170,000	$6,260,000	$38,430,000

Alternatives Analysis and Recommendations Report: Alternatives Analysis Summary

Estimated Improvement Costs per Gallon of SSO Removed

Project Year	2-year Storm	5-year Storm		10-year Storm		15-year Storm		20-year Storm	
	SSO 2,500 gal	SSO 135,600 gal		SSO 333,200 gal		SSO 468,700 gal		SSO 611,900 gal	
		Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
2008	$257	$33.1	$37.2	$30.9	$33.5	$46.9	$37.3	$23.7	$34.2
2009	$275	$35.4	$39.8	$33.0	$35.8	$50.1	$39.9	$25.5	$36.6
2010	$294	$37.9	$42.6	$35.3	$38.3	$53.7	$42.7	$27.2	$39.1
2011	$314	$40.6	$45.6	$37.8	$41.0	$57.4	$45.7	$29.1	$41.9
2012	$336	$43.4	$48.8	$40.4	$43.8	$61.5	$48.9	$31.2	$44.8
2013	$360	$46.4	$52.2	$43.3	$46.9	$65.7	$52.4	$33.4	$47.9
2014	$385	$49.7	$55.9	$46.3	$50.2	$70.3	$56.0	$35.7	$51.3
2015	$412	$53.2	$59.8	$49.5	$53.7	$75.3	$60.0	$38.2	$54.9
2016	$441	$56.9	$64.0	$53.0	$57.5	$80.5	$64.2	$40.9	$58.7
2017	$472	$60.9	$68.4	$56.8	$61.5	$86.1	$68.6	$43.7	$62.8

1.0 PROJECT DESCRIPTION

1.1 Sewershed Description

The Dundalk sewershed, shown in **Figure 1-1**, is generally bounded by Eastern Avenue to the north, the Inner Harbor to the south, the Baltimore City/Baltimore County line (Central Avenue) to the east, and Newkirk Avenue to the west. Interstate 95 runs along the northwest border of the sewershed.

The Dundalk sewershed is about 2,500 acres in size with approximately 153,000 lf of pipe ranging in diameter from 8-inch to 66-inch, 600 manholes, and one pump station. The covered area is generally a combination of residential and commercial property with a heavy industrial component.

1.2 Meter Basins

The Dundalk sewershed in the City consists of a total of seven meter basins and they are named as DU01, DU02, DU03, DU04, DU05, DU06, and DU07. In addition, there are four major points of connection where the City portion Dundalk Sewershed receives flow from Baltimore County and these four meter basins are named as BDU01, BDU02, BDU03 and BDU04.

Wastewater from all basins in the Dundalk Sewershed is collected at the Dundalk Pump Station and then discharged through a 36-inch force main to a 54-inch gravity interceptor. The wastewater is finally discharged to the Outfall Sewershed at one location before being treated at the City's Back River Wastewater Treatment Facility.

1.3 Objectives

In previous modeling efforts, a hydraulic model was developed for the Dundalk sewershed and calibrated in accordance with the BaSES manual. Further, the capability of the sewer system to convey peak flows during dry weather and wet weather events under baseline and future conditions was evaluated. Two reports, Model Development and Calibration Report, and Baseline Analysis and Capacity Assessment Report, were submitted to the City for review. This report evaluates and recommends alternatives for the Dundalk Collection System to eliminate sanitary sewer overflows (SSOs) under design storms as specified in Paragraph 9 of the Consent Decree (CD).

1.4 BaSES Manual Requirements

1.4.1 Future Conditions

Based on the Consent Decree, the model for the future conditions should be used to determine improvements necessary to convey peak flows without an SSO. As stated in

the Baseline Analysis and Capacity Assessment Report, future conditions are based on Year 2025 with projections for population changes, industrial flow changes, and collection system deterioration. Population data in Year 2025 is based on an intersection of the GIS shapefiles for the Transportation Analysis Zones (TAZs) with the GIS shapefiles for meter basins. Industrial flows in Year 2025 are based on a flow projection study performed by the Baltimore Metropolitan Council. A 10% increase in base infiltration is applied to account for sewer deterioration.

1.4.2 Design Storms

Seven design storms were used to assess system capacity, and they are:

(a) 1, 2, 5, 10, 15, and 20 year, 24 hour duration storm events

(b) 3-month storm with duration equal to the time of concentration for the Dundalk sewershed

As discussed in the Baseline Analysis and Capacity Assessment Report, there is no sewer overflow predicted by the model for the 3-month and 1-year storms. It is also understood that the minimum design improvements for the City of Baltimore is the ability to accommodate a 2-year design storm. Therefore, the analysis will evaluate improvements necessary to handle a 2-year storm and above.

1.4.3 SSO Control Technology

According to Section 7.7 of the BaSES manual, alternatives evaluated should include, but are not limited to:

(c) Replacement of malfunctioning pump station equipment

(d) Installation of pump backup equipment

(e) Increase in pumping capacity

(f) Inflow and infiltration reduction

(g) Installation of larger pipes or relief sewers

(h) Installation of storage facilities

1.5 Assumptions and Guidelines

1.5.1 Assumptions

The following assumptions were made to evaluate improvements to convey required design storms:

(a) Baltimore County is in the beginning phases of their Consent Decree with Environmental Protection Agency (EPA), which will not be completed until after the Dundalk Sewershed Study is scheduled to be completed. Therefore, no inflow/infiltration reduction from the 4 Baltimore County meter basins will be taken into consideration as part of this analysis.

(b) Based on the technical program guideline provided by the City, it is estimated that up to 80% rainfall dependent inflow/infiltration (RDII) reduction can be achieved if a comprehensive inflow and infiltration program (cured in place pipe (CIPP) lining of all public and private sewers and manhole rehabilitation/replacement) is implemented. It is proposed to only rehabilitate the public side of the sewer system; therefore a 40% reduction in RDII was applied to areas selected for inflow/infiltration reduction.

(c) A median R-value determined through model calibration for each meter basin was adopted for the analysis of alternatives. As discussed in the Model Development and Calibration Report, a median R-value provides a safety factor for capacity assessment while not over-designing system improvements.

(d) The City divided the 7 meter basins as mentioned in Section 1.2 into 33 sewershed service areas (SSA) and RJN further delineated the 33 SSAs into 91 sub-catchment areas. When an inflow and infiltration removal program is deemed better than other SSO control methods, an I/I removal project is recommended on a sub-catchment basis.

1.5.2 Cost Estimation Guidelines

To estimate costs for elimination of sanitary sewer overflows, the City reviewed documented unit costs on City projects for various types of repair, rehabilitation, and replacement of the sanitary collection system, and provided all sewershed consultants standard unit costs for manhole repair/replacement, sewer lining (cured in place pipe lining), and sewer replacement (Table 8-34 in BaSES) in 2008 dollars. The fully loaded costs include raw unit costs plus costs for mobilization, paving restoration, bypass pumping, and miscellaneous utility work to complete a project. For costs not provided by the City, such as installation of storage facilities ($6 per gallon of storage was used in this study), recent projects within the City and surrounding areas were reviewed to assist in estimation of construction costs. These costs are further increased by an additional 42 percent to accommodate engineering design, construction management/inspection, administration, and contingencies. Lastly, a 7 percent annual inflation rate is used to project costs beyond 2008.

2.0 2-YEAR IMPROVEMENTS

This section of the report evaluates improvements necessary to accommodate the 2-year design storm without SSOs in the Dundalk sewershed. For the 2-year storm, the model predicts SSOs in basins DU06 and DU07 only. **Map 1** depicts the locations of the improvements described below on a meter basin basis.

2.1 DU06 Improvements

The model predicts two (2) overflows under the 2-year, 24 hour design storm and the overflows occur on a section of 8-inch pipe along Portal Street; the hydraulic profile for this section is shown in **Figure 2-1**. The inflow and infiltration analysis indicates that DU06 has one of the highest RDII and dry weather base infiltration rates. This was confirmed by closed circuit television (CCTV) inspection, smoke testing, and dye flood testing, showing defective cleanouts, building laterals, and defective pipes and manholes. Several manholes and pipes, including 3 manholes and 2 pipes on Dundalk Avenue, are in highly deteriorated condition with a condition rating of 4 or 5 as defined in Section 4.2 of the BaSES manual.

Therefore, it is recommended to perform an extensive inflow/infiltration removal project in the area of the overflowing manholes including sub-catchments 29-02-06-00A, 29-02-06-00B, and 29-02-06-00C. The I/I removal project will involve performing cured in place pipe (CIPP) lining on pipe sections upstream and rehabilitating all manholes upstream of manhole S71W__001MH, between Chandlery Street and Tributary Street. The estimated cost for this project is $237,000 in 2008 dollars. The estimated costs for this proposed project are presented in **Table 1**.

This I/I removal project will eliminate predicted overflows with no other improvements required. Following the completion of this project, the 2-year RDII for the rehabilitated area is reduced to 0.17 MG from 0.29 MG.

An alternative to the I/I removal project is to upsize approximately 319 feet of 10-inch diameter pipe between S69W__011MH and S71W__005MH east of Portal Street to 12 inches to ensure no overflow during the 2-year storm (Figure 2-1). The estimated construction cost for this alternative is $225,000 in 2008 dollars, approximately $12,000 less than that of the I/I removal project. However, to accommodate the 5-year design storm, additional pipe upsizing is required in addition to completing the pipe upsizing project described above. In comparison, the model predicts that no additional improvements will be required in this area to accommodate the 5-year storm upon completion of the I/I removal project. It is also understood that an extensive I/I removal in this area will produce less peak flow and alleviate flow restrictions in the downstream basin. Hence, it is recommended to remove inflow and infiltration versus increasing pipe size.

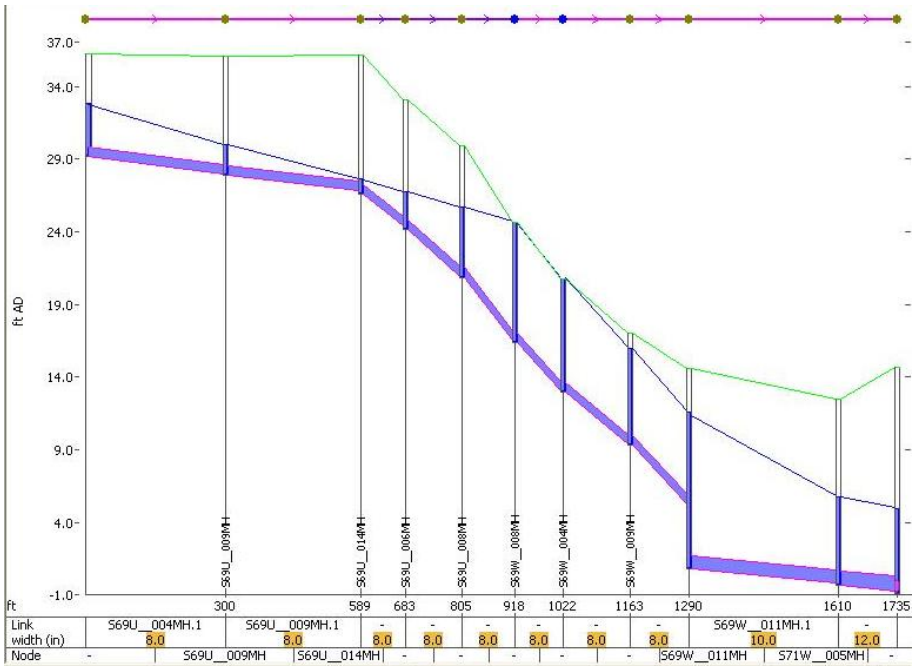


Figure 2-1: Hydraulic Profile for Sections from S69U__004MH to S71W__001MH under 2-year Storm

Table 1
Alternatives Analysis and Recommendations Report: 2-Year Improvements

2-Year DU06 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	1,844	$82,980
10” Pipe	CIPP	$64	319	$20,416
12” Pipe	CIPP	$64	125	$8,000
Manhole (each)	Rehab/Replacement	$3,719	15	$55,785
Subtotal				$167,181
Engineering Design, Construction Management and Other Costs (42%)				$70,216
2008 Total Estimated Cost				$237,000
2009 Total Estimated Cost				$254,000
2010 Total Estimated Cost				$272,000
2011 Total Estimated Cost				$291,000
2012 Total Estimated Cost				$311,000
2013 Total Estimated Cost				$333,000
2014 Total Estimated Cost				$356,000
2015 Total Estimated Cost				$381,000
2016 Total Estimated Cost				$408,000
2017 Total Estimated Cost				$436,000

2.2 DU07 Improvements

The model predicts an overflow at manhole S69M__006MH on a reach of 8-inch pipe along Dundalk Avenue which connects to a downstream 12-inch pipe on Boston Avenue. The hydraulic profile for this section is shown in **Figure 2-2**. Basin DU07 also has elevated RDII and dry weather base infiltration rates corroborated by CCTV inspection and smoke testing. It is recommended to perform an inflow/infiltration removal project for sub-catchment 29-02-10-00A by CIPP lining all the pipes and rehabilitating all the manholes upstream of manhole S69M__006MH at the intersection of Dundalk Avenue and German Hill Road. The estimated costs for this proposed project are presented in **Table 2**.

The I/I removal project will eliminate the predicted overflow with no other improvements required. Following the completion of this project, the 2-year RDII for the rehabilitated area is reduced to 0.07 MG from 0.12 MG.

An alternative to this I/I removal project is to upsize approximately 509 feet of 8-inch diameter pipe between manhole S69O__006MH and manhole S69M__030MH on Dundalk Avenue to 10 inches. The construction cost for this project is estimated to be $358,000 in 2008 dollars. This alternative can save the City approximately $46,000; however, additional pipe upsizing is required to accommodate the 5-year design storm. In comparison, the model predicts that no additional improvements will be required in this area to accommodate the 5-year storm upon completion of the I/I removal project. Therefore, it is recommended to remove inflow and infiltration versus increasing pipe size.

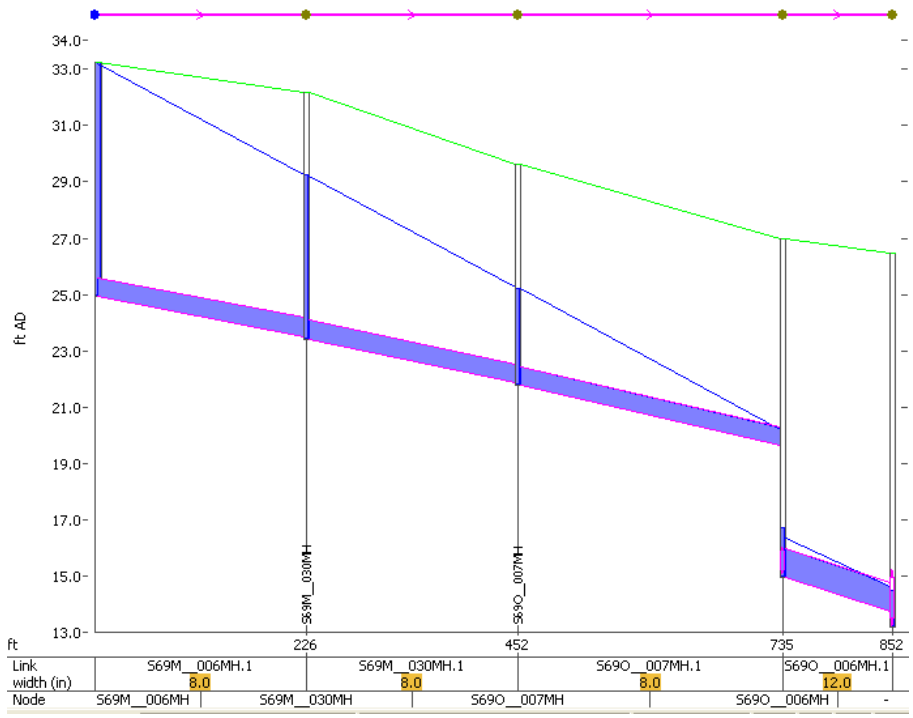


Figure 2-2: Hydraulic Profile for Sections from S69M__006MH to S69O__011MH under 2-year Storm

Table 2
Alternatives Analysis and Recommendations Report: 2-Year Improvements
2-Year DU07 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	4,841	$217,845
Manhole (each)	Rehab/Replacement	$3,719	18	$66,942
Subtotal				$284,787
Engineering Design, Construction Management and Other Costs (42%)				$119,611
2008 Total Estimated Cost				$404,000
2009 Total Estimated Cost				$433,000
2010 Total Estimated Cost				$463,000
2011 Total Estimated Cost				$495,000
2012 Total Estimated Cost				$530,000
2013 Total Estimated Cost				$567,000
2014 Total Estimated Cost				$607,000
2015 Total Estimated Cost				$649,000
2016 Total Estimated Cost				$695,000
2017 Total Estimated Cost				$743,000

2.3 Dundalk Pump Station Improvements

The Dundalk Pump Station has four (4) variable frequency drive (VFD) pumps, of which only three pumps are constantly online and the 4th pump is for backup use only. As discussed in the Baseline Analysis and Capacity Assessment Report, the Dundalk Pump Station has enough capacity to handle the peak flow from the 2-year, 24 hour storm. However, the velocities in the 36-inch force main were found slightly over 7 fps during peak rain (peak velocity 7.1 fps), and according to the BaSES manual, 7 fps is deemed excessive and may cause a scouring effect.

On March 16 & 17, 2009, and on November 30, 2009 the Pressure Pipe Inspection Company (PPIC) inspected portions of the Dundalk Force Main using its Sahara® Leak Location System. The Sahara inspection covered a total of approximately 3,852 feet of the force main. Analysis of the data obtained during the inspections identified no leaks or gas pockets in the inspected sections. According to Section 8.1.7 of the BaSES manual, assets of the collection system should be inspected and their condition should be assessed periodically. Assuming fair condition of the force main at this time, it is recommended to inspect the force main every 5 years to assess its general condition and detect corrosion and other damages due to the scouring effect.

One alternative is to build a parallel 8-inch, 4,000-foot force main from the Dundalk Pump Station to manhole S67S__019MH. The cost for this project is estimated to be $1,530,000 in 2008 dollars. Due to the high cost and difficulties in construction, this alternative is not recommended.

2.4 2-Year Improvements Summary

The total cost estimate for the recommended improvements to accommodate the 2-year, 24 hour storm is presented in **Table 3**.

Table 3
Alternatives Analysis and Recommendations Report: 2-Year Improvements

2-Year Comprehensive Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	6,685	$300,825
10” Pipe	CIPP	$64	319	$20,416
12” Pipe	CIPP	$64	125	$8,000
Manhole (each)	Rehab/Replacement	$3,719	33	$122,727
Subtotal				$451,968
Engineering Design, Construction Management and Other Costs (42%)				$189,827
2008 Total Estimated Cost				$642,000
2009 Total Estimated Cost				$687,000
2010 Total Estimated Cost				$735,000
2011 Total Estimated Cost				$786,000
2012 Total Estimated Cost				$841,000
2013 Total Estimated Cost				$900,000
2014 Total Estimated Cost				$963,000
2015 Total Estimated Cost				$1,031,000
2016 Total Estimated Cost				$1,103,000
2017 Total Estimated Cost				$1,180,000

3.0 5-YEAR IMPROVEMENTS

This section of the report evaluates improvements necessary to accommodate the 5-year design storm without SSOs in the Dundalk sewershed. For the 5-year storm, the model predicts SSOs in basins DU03 and DU06 upon completion of the 2-year improvements. **Map 2** depicts the locations of 5-year improvements in addition to the 2-year improvements on a meter basin basis.

3.1 DU03 Improvements

Under the 5-year, 24-hour storm, the model predicts an overflow on a reach of sewer on Eastern Avenue. The hydraulic profile for this section is presented in **Figure 3-1**. The overflowing manhole (S63I__017MH) lies at the downstream end of a pipe with steep slope and is susceptible to flooding under heavy flow. DU03 has elevated RDII rates and the highest dry weather base infiltration rate. The upstream area of the overflowing manhole includes a residential area with defective cleanouts, deteriorated pipes/manholes, and storm drain connections confirmed by CCTV inspection and smoke testing. To eliminate the predicted overflow, it is recommended to perform an inflow/infiltration removal project for sub-catchment 29-01-09-00E by disconnecting storm drains, CIPP lining all the pipes and rehabilitating all the manholes upstream of manhole S65G__018MH at the intersection of Elrino Street and Eastern Avenue. The estimated costs for the proposed projects are presented in **Table 4**.

Following the completion of the I/I removal project, the 5-year RDII for the rehabilitated area is reduced to 0.04 MG from 0.06 MG.

An alternative to removing the I/I is to upsize approximately 361 feet of 10-inch diameter pipe between manhole S63I__003MH and manhole S63I__007MH east of Umbra Street to 12 inches. The cost for this improvement is $254,000 versus the I/I removal cost of $213,000 in 2008 dollars. Hence, it is recommended to remove inflow and infiltration versus increasing pipe size.

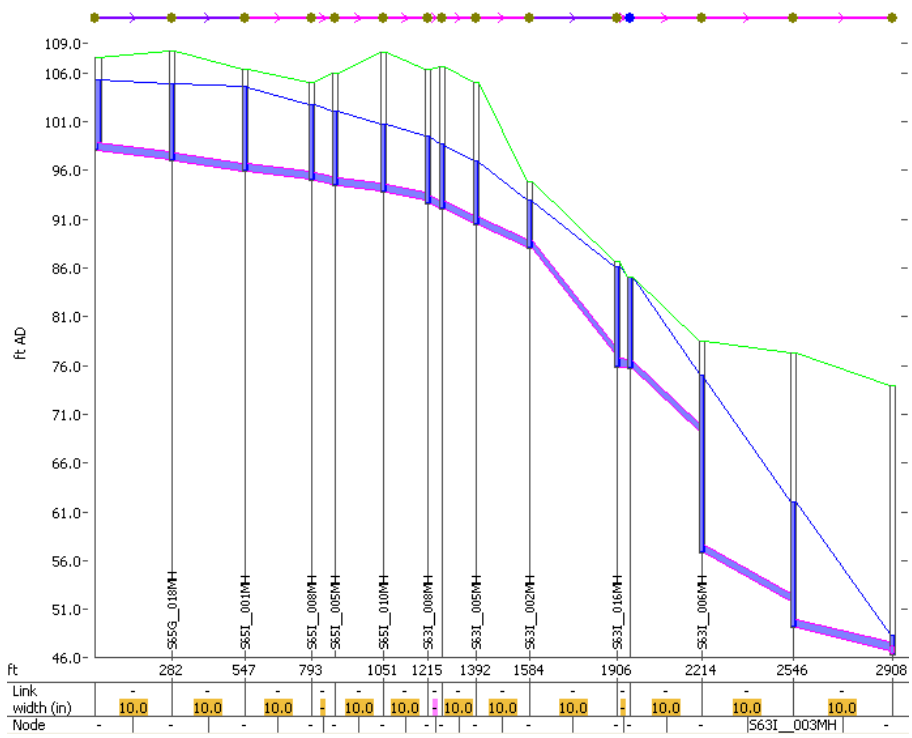


Figure 3-1: Hydraulic Profile for Sections from S65G__011MH to S63I__007MH under 5-year Storm

Table 4
Alternatives Analysis and Recommendations Report: 5-Year Improvements

5-Year DU03 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	2,192	$98,640
10” Pipe	CIPP	$64	282	$18,048
Manhole (each)	Rehab/Replacement	$3,719	9	$33,471
Subtotal				$150,159
Engineering Design, Construction Management and Other Costs (42%)				$63,067
2008 Total Estimated Cost				$213,000
2009 Total Estimated Cost				$228,000
2010 Total Estimated Cost				$244,000
2011 Total Estimated Cost				$261,000
2012 Total Estimated Cost				$279,000
2013 Total Estimated Cost				$299,000
2014 Total Estimated Cost				$320,000
2015 Total Estimated Cost				$342,000
2016 Total Estimated Cost				$366,000
2017 Total Estimated Cost				$392,000

3.2 DU06 Improvements

The model predicts three (3) new overflows on a section of pipe which begins as a 15-inch pipe, decreases to a 12-inch pipe, and then connects a 27-inch main interceptor along Dundalk Avenue. The hydraulic profile for this section is presented in **Figure 3-2**. This section of pipe receives flow from County basin BDU01, which has one of the highest RDII rates based on Dundalk Sewershed inflow and infiltration analysis. The high flow from BDU01, along with high levels of RDII in basins DU06 and DU07, causes significant surcharge in the interceptor along Dundalk Avenue all the way to the Dundalk Pump Station and leads to the predicted overflows.

The 12-inch pipe outlined in Figure 3-2 restricts flow and it must be upsized to 15 inches. It is also recommended to perform a comprehensive I/I removal for areas in basin DU06 that were not rehabilitated under the 2-year storm event including SSAs 29-02-07-00, 29-02-08-00, 29-02-09-00, and sub-catchment 29-02-06-00D. Lastly, it is recommended to perform a comprehensive I/I removal for four sub-catchments in basin DU07: 29-02-11-00A, 29-02-11-00B, 29-02-11-00C and 29-02-10-00B. The estimated costs for the proposed projects are presented in **Table 5**. Another alternative would be for the City to negotiate with the County to reduce RDII in basin BDU01 and if the inflow and infiltration from BDU01 is reduced, the required amount of improvements within the City may also be reduced. The County shares a cost in any recommended sewerage facilities that are jointly used.

Following the completion of the I/I removal projects, the 5-year RDII for the rehabilitated area is reduced to 0.7 MG from 1.2 MG.

An alternative to removing the I/I is to increase the pipe size of approximately 2,560 feet of existing 27-inch pipes between S71S__004MH on Dundalk Avenue and S71Y__004MH close to Tributary Street to 30 inches. Further, it is required to upsize approximately 2,353 feet of existing 30-inch pipes between S71A1_006MH on Oak Avenue and S69C1__013MH on Edgewater Street to 33 inches. This alternative does not eliminate the need to upsize the 12-inch pipe between manhole S71S__005MH and manhole S71S__004MH to 15 inches. The estimated cost for these improvements is $10,440,000 in 2008 dollars.

A third alternative would be the installation of an offline storage facility near the City/County boundary. The capacity of the storage tank must be 1.2 MG to accommodate flow from basin BDU01 under the 5-year storm. It is noted that the overflowing area near the City/County line is in a residential neighborhood and therefore there is difficulty in obtaining land to place the storage tank. The estimated cost for this project is approximately $10,220,000 in 2008 dollars (the fully loaded unit cost is $6 per gallon of storage including potential land acquisition if land can be obtained).

In Comparison with the proposed I/I removal project, these two options (increasing pipe sizes and installation of a storage tank) will cost the City an average additional cost of $6,140,000. Based on the estimated costs of these improvements, I/I removal is the recommended alternative.

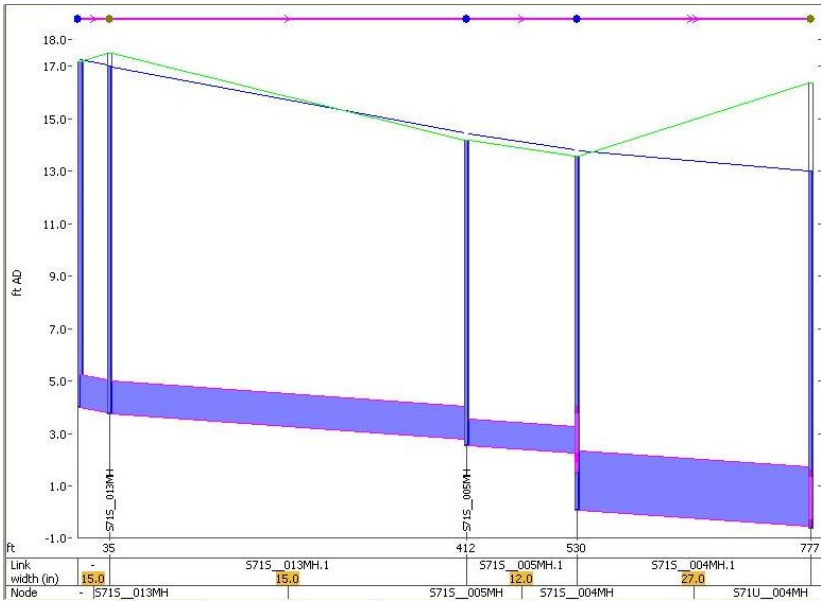


Figure 3-2: Hydraulic Profile for Sections from S71S__014MH to S71U__004MH under 5-year Storm

Table 5
Alternatives Analysis and Recommendations Report: 5-Year Improvements
5-Year DU06 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	23,856	$1,073,520
10” Pipe	CIPP	$64	1,486	$95,104
12” Pipe	CIPP	$64	1,391	$89,024
15” Pipe	CIPP	$87	577	$50,199
21” Pipe	CIPP	$124	343	$42,532
24” Pipe	CIPP	$124	1,927	$238,948
27” Pipe	CIPP	$169	4,344	$734,136
15” Pipe	Replacement	$585	117	$68,445
Manhole (each)	Rehab/Replacement	$3,719	151	$561,569
Subtotal				$2,953,477
Engineering Design, Construction Management and Other Costs (42%)				$1,240,460
2008 Total Estimated Cost				$4,190,000
2009 Total Estimated Cost				$4,490,000
2010 Total Estimated Cost				$4,800,000
2011 Total Estimated Cost				$5,140,000
2012 Total Estimated Cost				$5,500,000
2013 Total Estimated Cost				$5,880,000
2014 Total Estimated Cost				$6,290,000
2015 Total Estimated Cost				$6,740,000
2016 Total Estimated Cost				$7,210,000
2017 Total Estimated Cost				$7,710,000

3.3 Dundalk Pump Station Improvements

The three main pumps have enough capacity to handle the peak flow from the 5-year, 24 hour storm. The peak velocity in the 36-inch force main reaches 8.2 fps, rendering the force main not in compliance with the velocity threshold of 7 fps. Since the velocity threshold is exceeded only for a short period of time, it is recommended to inspect the force main every 5 years to ensure its structural integrity and normal functioning. Another alternative is to build a parallel 18-inch, 4,000-foot force main from the Dundalk Pump Station to manhole S67S__019MH. The cost for this project is estimated to be $3,320,000 in 2008 dollars. Due to the high cost and difficulties in construction, this alternative is not recommended.

3.4 5-Year Improvements Summary

The combined cost estimate for all recommended improvements to convey the 5-year, 24 hour storm is presented in **Table 6**. The 5-year improvements recommended above are in

addition to the 2-year improvements to accommodate the 5-year storm. Hence, quantities and costs presented in Table 6 include 2-year recommendations.

Table 6
Alternatives Analysis and Recommendations Report: 5-Year Improvements

5-Year Comprehensive Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	32,733	$1,472,985
10” Pipe	CIPP	$64	2,087	$133,568
12” Pipe	CIPP	$64	1,516	$97,024
15” Pipe	CIPP	$87	577	$50,199
21” Pipe	CIPP	$124	343	$42,532
24” Pipe	CIPP	$124	1,927	$238,948
27” Pipe	CIPP	$169	4,344	$734,136
15” Pipe	Replacement	$585	117	$68,445
Manhole (each)	Rehab/Replacement	$3,719	193	$717,767
Subtotal				$3,555,604
Engineering Design, Construction Management and Other Costs (42%)				$1,493,354
2008 Total Estimated Cost				$5,050,000
2009 Total Estimated Cost				$5,400,000
2010 Total Estimated Cost				$5,780,000
2011 Total Estimated Cost				$6,190,000
2012 Total Estimated Cost				$6,620,000
2013 Total Estimated Cost				$7,080,000
2014 Total Estimated Cost				$7,580,000
2015 Total Estimated Cost				$8,110,000
2016 Total Estimated Cost				$8,680,000
2017 Total Estimated Cost				$9,280,000

4.0 10-YEAR IMPROVEMENTS

This section of the report evaluates improvements necessary to accommodate the 10-year design storm without SSOs in the Dundalk sewershed. For the 10-year storm, the model predicts SSOs in basins DU01, DU03 and DU06 upon completion of the 2 and 5-year improvements. **Map 3** depicts the locations of 10-year improvements in addition to the 2 and 5-year improvements on a meter basin basis.

4.1 DU01 Improvements

The model predicts an overflow on a section of 15-inch pipe located just east of South Newkirk Street, between Holabird Avenue and Keith Avenue. The hydraulic profile for this section is presented in **Figure 4-1**. The overflowing manhole S61W__007MH and the manhole immediately upstream (S61W__006MH) are relatively shallow and therefore susceptible to flooding during large storm events. This section of pipe was not televised during the time of the study due to construction activities related to the Chesapeake Commerce Center project (old General Motors plant). In addition, manholes along the reach of the pipe have not been rated. Therefore, the severity of inflow and infiltration in this area can not yet be determined. It is recommended to verify field conditions (e.g., rim elevation), fully televise this section of pipe and inspect all manholes upon completion of the Chesapeake Commerce Center project to determine if sealing, raising the two shallow manholes or I/I removal is an appropriate approach. To eliminate the overflow without completing additional field work, the 15-inch pipe between manhole S61Y__009MH and manhole S59Y__001MH east of Newkirk Street needs to be upsized to 18 inches. The estimated costs for the proposed project are presented in **Table 7**.

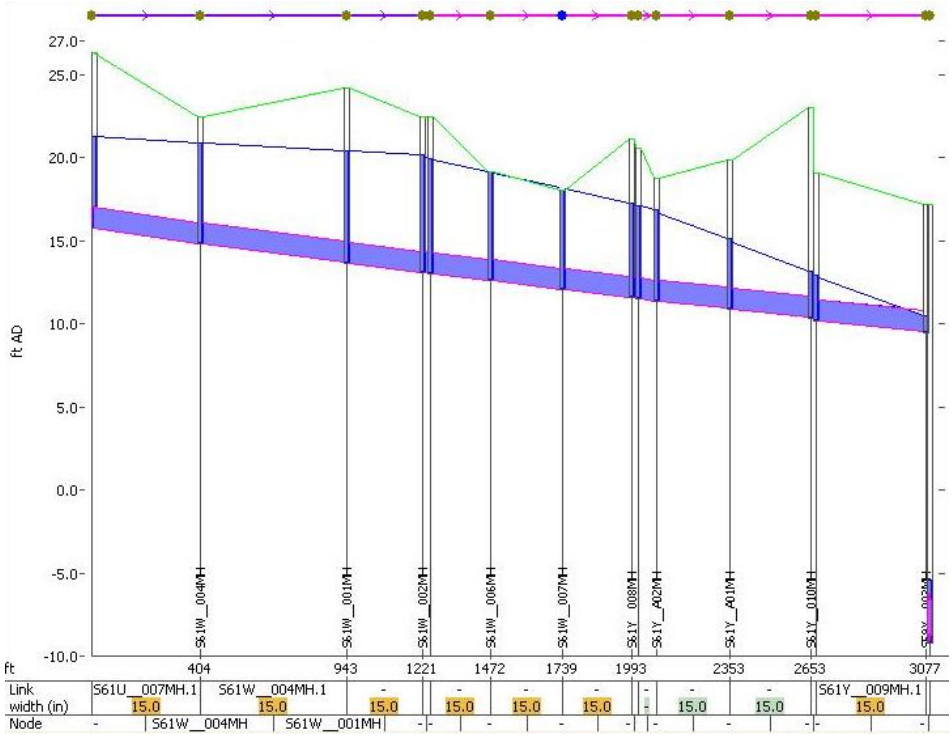


Figure 4-1: Hydraulic Profile for Sections from S61U__007MH to S59Y__001MH under 10-year Storm

Table 7
Alternatives Analysis and Recommendations Report: 10-Year Improvements

10-Year DU01 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
18” Pipe	Replacement	$585	419	$245,115
Subtotal				$245,115
Engineering Design, Construction Management and Other Costs (42%)				$102,948
2008 Total Estimated Cost				$348,000
2009 Total Estimated Cost				$372,000
2010 Total Estimated Cost				$398,000
2011 Total Estimated Cost				$426,000
2012 Total Estimated Cost				$456,000
2013 Total Estimated Cost				$488,000
2014 Total Estimated Cost				$522,000
2015 Total Estimated Cost				$559,000
2016 Total Estimated Cost				$598,000
2017 Total Estimated Cost				$640,000

4.2 DU03 Improvements

The same overflow predicted under the 5-year storm (see Figure 3-1) occurs under the 10-year storm after completing the recommended 5-year improvements. It is recommended to rehabilitate manholes and pipes within sub-catchment 29-01-09-00C upstream of the overflowing manhole. In detail, it is proposed to CIPP line all the pipes and rehabilitate all the manholes between manhole S63I__005MH and manhole S65I__008MH on Eastern Avenue, and north of manholes S63I__008MH and S65I__010MH on the two streets perpendicular to Eastern Avenue.

Upon completion of the projects, the predicted overflow at manhole S63I__017MH on Eastern Avenue still exists. It is recommended to upsize the existing 10-inch diameter pipe between manhole S63I__007MH and manhole S63I__003MH east of Umbra Street to 12-inch diameter. Or, perform an I/I removal for sub-catchment 29-01-09-00D by rehabilitating all manholes and pipes on Drew Street and Cornwall Street, and also between manhole S65I__008MH and manhole S65G__018MH on Eastern Avenue. The CCTV inspection indicates that pipes and manholes in sub-catchment 29-01-09-00D are in fair to good condition, therefore, I/I removal would not produce significant results required to eliminate the overflow. Hence, the residential area rehabilitation option is not recommended. The I/I removal project and pipe upsizing will together eliminate predicted overflows with no other improvements required. The estimated costs for the proposed projects are presented in **Table 8**.

Table 8
Alternatives Analysis and Recommendations Report: 10-Year Improvements

10-Year DU03 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	1,175	$52,875
10” Pipe	CIPP	$64	546	$34,944
12” Pipe	Replacement	$495	361	$178,695
Manhole (each)	Rehab/Replacement	$3,719	10	$37,190
Subtotal				$303,704
Engineering Design, Construction Management and Other Costs (42%)				$127,556
2008 Total Estimated Cost				$431,000
2009 Total Estimated Cost				$461,000
2010 Total Estimated Cost				$493,000
2011 Total Estimated Cost				$528,000
2012 Total Estimated Cost				$565,000
2013 Total Estimated Cost				$604,000
2014 Total Estimated Cost				$647,000
2015 Total Estimated Cost				$692,000
2016 Total Estimated Cost				$741,000
2017 Total Estimated Cost				$792,000

An alternative to I/I removal with pipe upsizing is to increase the pipe size of approximately 693 feet of existing 10-inch pipes between manhole S63I__007MH and manhole S63I__006MH east of Umbra Street to 12-inch diameter pipes. The estimated cost for this project is $487,000 as compared to I/I removal and 361 feet of 12-inch sewer replacement cost of $431,000 in 2008 dollars. Therefore, the recommended option to eliminate the predicted overflow is I/I removal combined with the upsizing of the 361 feet, 10-inch diameter pipe to 12 inches as described above.

4.3 DU06 Improvements

The same overflows predicted under the 5-year storm (see Figure 3-2) occur under the 10-year storm after completing the recommended 5-year improvements. It is recommended to complete an extensive I/I removal for SSAs 29-02-13-00 and 29-02-12-00 in basin DU07 that were not rehabilitated under conditions of the 5-year event, beginning at the most downstream manhole S69M__027MH on Dundalk Avenue and proceeding upstream.

It is further recommended to increase the pipe diameter from 15 inches to 18 inches of the section of pipe receiving flows from BDU01, beginning at manhole S71S__014MH and ending at manhole S71S__004MH south of Railway Avenue. In addition, approximately 1,900 feet of 27-inch diameter pipes between manhole S71U__010MH on Dundalk Avenue and manhole S71Y__004MH close to Tributary Street will need to be upsized to 30 inches. The estimated costs for the proposed improvements are presented in **Table 9**.

An alternative to the above recommendation is to increase the size of several sections of pipes in this area. First, the section of 15-inch diameter, 530 feet pipe receiving BDU01 flows described above must be upsized to 18 inches. Further, it is required to increase the pipe size of approximately 2,560 feet of the 27-inch diameter pipes between S71S__004MH on Dundalk Avenue and S71Y__004MH close to Tributary Street to 30 inches. Lastly, it is required to upsize approximately 1,880 feet of existing 30-inch diameter pipes in basin DU05, between S71A1_008MH on Pipe Avenue and S69C1_013MH on Edgewater Street, to 33 inches. The estimated cost for this alternative is $9,760,000 as compared to $5,420,000 in 2008 dollars for the alternative recommended in Table 9.

A third alternative would be the installation of a 1.4 MG storage tank upstream of the overflowing manholes near the City/County boundary. The cost of this alternative is estimated to be $11,930,000 in 2008 dollars. As discussed in Section 3.2 of this report, high cost and difficulty of placing such a storage tank in a residential area makes this alternative less favorable. Therefore, it is recommended to perform I/I removal in combination with increasing pipe diameters. It is also recommended for the City to

negotiate with the County to reduce I/I in BDU01 since elevated flows from BDU01 is a major cause of predicted overflows in DU06.

Table 9
Alternatives Analysis and Recommendations Report: 10-Year Improvements

10-Year DU06 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	4,261	$191,745
10” Pipe	CIPP	$64	3,623	$231,872
12” Pipe	CIPP	$64	171	$10,944
15” Pipe	CIPP	$87	344	$29,928
18” Pipe	CIPP	$87	1,445	$125,715
18” Pipe	Replacement	$585	530	$310,050
30” Pipe	Replacement	$1,440	1,908	$2,747,520
Manhole (each)	Rehab/Replacement	$3,719	45	$167,355
Subtotal				$3,815,129
Engineering Design, Construction Management and Other Costs (42%)				$1,602,354
2008 Total Estimated Cost				$5,420,000
2009 Total Estimated Cost				$5,800,000
2010 Total Estimated Cost				$6,210,000
2011 Total Estimated Cost				$6,640,000
2012 Total Estimated Cost				$7,100,000
2013 Total Estimated Cost				$7,600,000
2014 Total Estimated Cost				$8,130,000
2015 Total Estimated Cost				$8,700,000
2016 Total Estimated Cost				$9,310,000
2017 Total Estimated Cost				$9,960,000

4.4 Dundalk Pump Station Improvements

The three main pumps have enough capacity to handle the peak flow from the 10-year, 24 hour storm. The peak velocity in the 36-inch force main increases to 9.6 fps, rendering the force main not in compliance with the velocity threshold of 7 fps during peak rain. As with the 5-year recommendation, it is recommended to inspect the force main every 5 years to ensure its structural integrity and normal functioning. An alternative to this is to build a parallel 27-inch, 4000-foot force main from the Dundalk Pump Station to manhole S67S__019MH. The cost for this project is estimated to be $8,180,000 in 2008 dollars. Due to the high cost and difficulties in construction, this alternative is not recommended.

4.5 10-Year Improvements Summary

The combined cost estimate for all recommended improvements to convey the 10-year, 24 hour storm is presented in **Table 10**. The 10-year improvements recommended above are in addition to the 2-year and 5-year improvements to accommodate the 10-year storm. Hence, quantities and costs presented in the Table 10 include 2-year and 5-year recommendations.

Table 10
Alternatives Analysis and Recommendations Report: 10-Year Improvements

10-Year Comprehensive Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	38,169	$1,717,605
10” Pipe	CIPP	$64	6,256	$400,384
12” Pipe	CIPP	$64	1,687	$107,968
15” Pipe	CIPP	$87	921	$80,127
18” Pipe	CIPP	$87	1,445	$125,715
21” Pipe	CIPP	$124	343	$42,532
24” Pipe	CIPP	$124	1,927	$238,948
27” Pipe	CIPP	$169	4,344	$734,136
12” Pipe	Replacement	$495	361	$178,695
18” Pipe	Replacement	$585	949	$555,165
30” Pipe	Replacement	$1,440	1,908	$2,747,520
Manhole (each)	Rehab/Replacement	$3,719	248	$922,312
Subtotal				$7,851,107
Engineering Design, Construction Management and Other Costs (42%)				$3,297,465
2008 Total Estimated Cost				$11,150,000
2009 Total Estimated Cost				$11,930,000
2010 Total Estimated Cost				$12,760,000
2011 Total Estimated Cost				$13,660,000
2012 Total Estimated Cost				$14,610,000
2013 Total Estimated Cost				$15,640,000
2014 Total Estimated Cost				$16,730,000
2015 Total Estimated Cost				$17,900,000
2016 Total Estimated Cost				$19,160,000
2017 Total Estimated Cost				$20,500,000

5.0 15-YEAR IMPROVEMENTS

This section of the report evaluates improvements necessary to accommodate the 15-year design storm without SSOs in the Dundalk sewershed. For the 15-year storm, the model predicts SSOs in basins DU01, DU03, DU06, and DU07 upon completion of the 2, 5, and 10-year improvements. **Map 4** depicts the locations of 15-year improvements in addition to the 2, 5, and 10-year improvements on a meter basin basis.

5.1 DU01 Improvements

Under the 15-year, 24-hour storm, the model predicts two overflowing manholes: S61W__006MH and S61W__007MH east of Newkirk Street (see Figure 4-1). It is recommended to upsize approximately 321 feet of 15-inch pipes between S61Y__009MH and S61Y__A01MH east of Newkirk Street to 18 inches. The costs for this upgrade are presented in **Table 11**. As mentioned in Section 4.1, an I/I removal program, raising the two shallow manholes or simply sealing the two manholes could be more cost effective to eliminate the predicted overflows. Hence, it is worthwhile to verify field conditions (e.g., rim elevation), fully televise this section of pipe and inspect all manholes upon completion of the Chesapeake Commerce Center project.

Table 11
Alternatives Analysis and Recommendations Report: 15-year Improvements
15-Year DU01 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
18” Pipe	Replacement	$585	321	$187,785
Subtotal				$187,785
Engineering Design, Construction Management and Other Costs (42%)				$78,870
2008 Total Estimated Cost				$267,000
2009 Total Estimated Cost				$286,000
2010 Total Estimated Cost				$306,000
2011 Total Estimated Cost				$327,000
2012 Total Estimated Cost				$350,000
2013 Total Estimated Cost				$374,000
2014 Total Estimated Cost				$401,000
2015 Total Estimated Cost				$429,000
2016 Total Estimated Cost				$459,000
2017 Total Estimated Cost				$491,000

5.2 DU03 Improvements

The same overflow predicted under the 5-year and 10-year storms (see Figure 3-1) occurs again under the 15-year storm after completing the recommended 10-year improvements.

It is required to upsize a 10-inch pipe between manhole S63I__003MH and S63I__006MH east of Umbra Street to 12 inches. The costs for this upgrade are presented in **Table 12**.

Table 12
Alternatives Analysis and Recommendations Report: 15-Year Improvements
15-Year DU03 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
12" Pipe	Replacement	$495	332	$164,340
Subtotal				$164,340
Engineering Design, Construction Management and Other Costs (42%)				$69,023
2008 Total Estimated Cost				$233,000
2009 Total Estimated Cost				$249,000
2010 Total Estimated Cost				$267,000
2011 Total Estimated Cost				$285,000
2012 Total Estimated Cost				$305,000
2013 Total Estimated Cost				$327,000
2014 Total Estimated Cost				$350,000
2015 Total Estimated Cost				$374,000
2016 Total Estimated Cost				$400,000
2017 Total Estimated Cost				$428,000

5.3 DU05 and DU06 Improvements

Overflows on the section of 8-inch diameter pipe along Portal Street (Figure 2-1) and on the section of pipe receiving BDU01 flows (Figure 3-2) occur again under the 15-year storm after completing the recommended 10-year improvements. In addition to these, the model predicts three new overflows on a section of 8-inch pipe through Ft. Holabird Park and the hydraulic profile for this section is presented in **Figure 5-1**. This section of pipe is shown under severe backwater conditions due to elevated surcharge in the 30-inch diameter interceptor to which the 8-inch pipe discharges.

To eliminate these overflows, it is required to upsize the 10-inch pipe between S69W__011MH and S71W__005MH east of Portal Street to 12 inches. In addition, approximately 652 feet of existing 27-inch pipes between S71S__004MH and S71U__010MH on Dundalk Avenue need to be increased to 30 inches in diameter. Lastly, approximately 1,880 feet of existing 30-inch pipes in basin DU05 between S69C1__013MH on Edgewater Street and S71A1__008MH on Pine Avenue need to be increased to 33-inch diameter. The costs for the improvements are presented in **Table 13**.

Construction of the proposed pipe between S71S__004MH and S71U__010MH on Dundalk Avenue may be difficult due to traffic and other existing utilities. Such work

may not be required if the inflow and infiltration from County basin BDU01 can be reduced.

An alternative to increasing pipe diameters is to install a 1.5 MG storage tank to accommodate the peak flow from basin BDU01 during the 15-year storm event. The estimated cost of this alternative is $12,780,000 in 2008 dollars. This alternative is not recommended due to the difference in cost of $7,130,000, compared to cost of pipe upsizing described above.

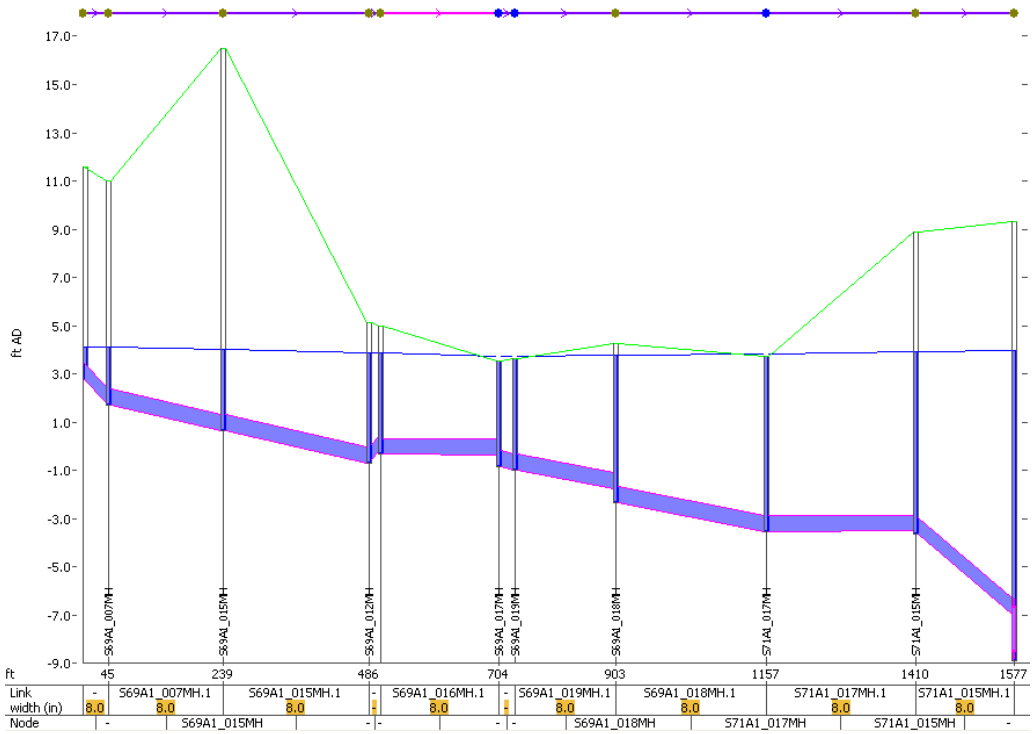


Figure 5-1: Hydraulic Profile for Sections from S69A1_006MH to S71A1_001MH under 15-year Storm

Table 13
Alternatives Analysis and Recommendations Report: 15-Year Improvements
15-Year DU05 and DU06 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
12” Pipe	Replacement	$495	332	$164,340
30” Pipe	Replacement	$1,440	652	$938,880
33” Pipe	Replacement	$1,530	1,880	$2,876,400
Subtotal				$3,979,620
Engineering Design, Construction Management and Other Costs (42%)				$1,671,440
2008 Total Estimated Cost				$5,650,000
2009 Total Estimated Cost				$6,050,000
2010 Total Estimated Cost				$6,470,000
2011 Total Estimated Cost				$6,920,000
2012 Total Estimated Cost				$7,410,000
2013 Total Estimated Cost				$7,920,000
2014 Total Estimated Cost				$8,480,000
2015 Total Estimated Cost				$9,070,000
2016 Total Estimated Cost				$9,710,000
2017 Total Estimated Cost				$10,390,000

5.4 DU07 Improvements

The overflow previously depicted in Figure 2-2, at manhole S69M__006MH on German Hill Road, occurs again under the 15-year, 24 hour storm after completing the recommended 2-year improvements. For the 15-year storm event, approximately 283 feet of an existing 8-inch diameter pipe between S69O__006MH and S69O__007MH on Dundalk Avenue is recommended to be upsized to 10 inches. The costs for this upgrade are presented in **Table 14**.

Table 14
Alternatives Analysis and Recommendations Report: 15-Year Improvements

15-Year DU07 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
10” Pipe	Replacement	$495	283	$140,085
Subtotal				$140,085
Engineering Design, Construction Management and Other Costs (42%)				$58,836
2008 Total Estimated Cost				$199,000
2009 Total Estimated Cost				$213,000
2010 Total Estimated Cost				$228,000
2011 Total Estimated Cost				$244,000
2012 Total Estimated Cost				$261,000
2013 Total Estimated Cost				$279,000
2014 Total Estimated Cost				$299,000
2015 Total Estimated Cost				$320,000
2016 Total Estimated Cost				$342,000
2017 Total Estimated Cost				$366,000

5.5 Dundalk Pump Station Improvements

The three main pumps have enough capacity to handle the peak flow from the 15-year, 24 hour storm. The peak velocity in the 36-inch force main increases to 10.1 fps, rendering the force main not in compliance with the velocity threshold of 7 fps during peak rain. As with the 10-year recommendation, it is recommended to inspect the force main every 5 years to ensure its structural integrity and normal functioning. An alternative to this is to build a parallel 27-inch, 4000-foot force main from the Dundalk Pump Station to manhole S67S__019MH. The cost for this project is estimated to be $8,180,000 in 2008 dollars. Due to the high cost and difficulties in construction, this alternative is not recommended.

5.6 15-Year Improvement Summary

The combined cost estimate for all recommended improvements to convey the 15-year, 24 hour storm is presented in **Table 15**. The 15-year improvements recommended above are in addition to the 2, 5, and 10-year improvements to accommodate the 15-year storm. Hence, quantities and costs presented in Table 15 include the 2, 5, and 10-year improvements.

Table 15
Alternatives Analysis and Recommendations Report: 15-Year Improvements

15-Year Comprehensive Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	38,169	$1,717,605
10” Pipe	CIPP	$64	6,256	$400,384
12” Pipe	CIPP	$64	1,687	$107,968
15” Pipe	CIPP	$87	921	$80,127
18” Pipe	CIPP	$87	1,445	$125,715
21” Pipe	CIPP	$124	343	$42,532
24” Pipe	CIPP	$124	1,927	$238,948
27” Pipe	CIPP	$169	4,344	$734,136
10” Pipe	Replacement	$495	283	$140,085
12” Pipe	Replacement	$495	1,025	$507,375
18” Pipe	Replacement	$585	1,270	$742,950
30” Pipe	Replacement	$1,440	2,560	$3,686,400
33” Pipe	Replacement	$1,530	1,880	$2,876,400
Manhole (each)	Rehab/Replacement	$3,719	248	$922,312
Subtotal				$12,322,937
Engineering Design, Construction Management and Other Costs (42%)				$5,175,634
2008 Total Estimated Cost				$17,500,000
2009 Total Estimated Cost				$18,720,000
2010 Total Estimated Cost				$20,030,000
2011 Total Estimated Cost				$21,440,000
2012 Total Estimated Cost				$22,940,000
2013 Total Estimated Cost				$24,540,000
2014 Total Estimated Cost				$26,260,000
2015 Total Estimated Cost				$28,100,000
2016 Total Estimated Cost				$30,070,000
2017 Total Estimated Cost				$32,170,000

6.0 20-YEAR IMPROVEMENTS

This section of the report evaluates improvements necessary to accommodate the 20-year design storm without SSOs in the Dundalk sewershed. For the 20-year storm, the model predicts SSOs in basins DU01 DU03, and DU06 upon completion of the 2, 5, 10, and 15-year improvements. **Map 5** depicts the locations of 20-year improvements in addition to the 2, 5, 10, and 15-year improvements on a meter basin basis.

6.1 DU01 Improvements

The model predicts a small amount of overflow at shallow manhole S61W__006MH, east of Newkirk Street (see Figure 4-1). As discussed in Section 4.1, the overflow could be eliminated by simply sealing this manhole or elevating the manhole rim elevation by 2.1 feet if field conditions allow. As an alternative, the pipe diameter of the 15-inch pipe between S61Y__A01MH and S61Y__A02MH east of Newkirk Street may be increased to 18 inches. The estimated costs for this upgrade are presented in **Table 16**.

Table 16
Alternatives Analysis and Recommendations Report: 20-Year Improvements
20-Year DU01 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
18” Pipe	Replacement	$585	268	$156,780
Subtotal				$156,780
Engineering Design, Construction Management and Other Costs (42%)				$65,848
2008 Total Estimated Cost				$223,000
2009 Total Estimated Cost				$239,000
2010 Total Estimated Cost				$255,000
2011 Total Estimated Cost				$273,000
2012 Total Estimated Cost				$292,000
2013 Total Estimated Cost				$313,000
2014 Total Estimated Cost				$335,000
2015 Total Estimated Cost				$358,000
2016 Total Estimated Cost				$383,000
2017 Total Estimated Cost				$410,000

6.2 DU03 Improvements

Manhole S65I__001MH on Eastern Avenue previously presented in Figure 3-1 floods during the 20-year storm event after completing the recommended 15-year improvements. To eliminate the overflow, it is recommended to upsize 260 feet of the existing pipe between manhole S63I__006MH and manhole S63I__017MH on Eastern Avenue from 10-inch diameter to 12-inch diameter. The costs for this upgrade are presented in **Table 17**.

Table 17
Alternatives Analysis and Recommendations Report: 20-Year Improvements
20-Year DU03 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
12" Pipe	Replacement	$495	260	$128,700
Subtotal				$128,700
Engineering Design, Construction Management and Other Costs (42%)				$54,054
2008 Total Estimated Cost				$183,000
2009 Total Estimated Cost				$196,000
2010 Total Estimated Cost				$210,000
2011 Total Estimated Cost				$224,000
2012 Total Estimated Cost				$240,000
2013 Total Estimated Cost				$257,000
2014 Total Estimated Cost				$275,000
2015 Total Estimated Cost				$294,000
2016 Total Estimated Cost				$314,000
2017 Total Estimated Cost				$336,000

6.3 DU05 and DU06 Improvements

Overflows occur at two (2) locations during the 20-year storm after completing the recommended 15-year improvements. In basin DU06, overflows occur on the section of pipe receiving flows from basin BDU01 (Figure 3-2) and in basin DU05, overflows occur on the section of pipe through Ft. Holabird Park (Figure 5-1).

To eliminate the overflows in basin DU06, it is recommended to upsize approximately 2,164 feet of the 30-inch diameter pipes between manholes S71W__007MH east of Portal Street and S71A1__008MH on Pine Avenue to 33 inches. A large portion of this falls within basin DU05. To eliminate the overflows in basin DU05, RJN visited the site, evaluated field conditions and deemed that raising manholes is cost effective and easy to implement. In detail, it is recommended to raise manholes S69A1_017MH, S69A1_019MH and S71A1_017 by 2 feet and raise manholes S69A1_012MH, S69A1_016MH and S69A1_018MH by 1 foot. The costs for the proposed projects are presented in **Table 18**.

Table 18
Alternatives Analysis and Recommendations Report: 20-Year Improvements
20-Year DU05 and DU06 Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
33" Pipe	Replacement	$1,530	2,164	$3,310,920
Manhole (each)	Rehab	$3,719	6	$22,314
Subtotal				$3,333,234
Engineering Design, Construction Management and Other Costs (42%)				$1,399,958
2008 Total Estimated Cost				$4,730,000
2009 Total Estimated Cost				$5,060,000
2010 Total Estimated Cost				$5,420,000
2011 Total Estimated Cost				$5,790,000
2012 Total Estimated Cost				$6,200,000
2013 Total Estimated Cost				$6,630,000
2014 Total Estimated Cost				$7,100,000
2015 Total Estimated Cost				$7,600,000
2016 Total Estimated Cost				$8,130,000
2017 Total Estimated Cost				$8,700,000

6.4 Dundalk Pump Station Improvements

During the 20-year, 24 hour storm event, the three main pumps do not have enough capacity to handle the peak flow after completing recommended improvements to this point, rendering the flooding of the wet well. It is required to turn on the 4th pump (i.e., the backup pump) to eliminate this projected overflow. In the case that the backup pump is offline for maintenance, one alternative is to install a 0.02 MG storage tank near the Dundalk Pump Station to attenuate the peak flow entering the wet well. The estimated cost for this alternative is $170,000 in 2008 dollars based on a unit cost of $6 per gallon of storage.

An alternative to installation of a storage tank is to upgrade the force main. Notably, a project was completed in 1999 on a section of Dundalk Force Main near 6200 to 6300 Beckley Street. A new 36-inch ductile iron bypass was installed and the new line lies approximately 12 feet to the west of the old line and runs parallel with it. The old line was capped in 1999 and the bypass was then used. There are four (4) 90 degree bends and two 24-inch connection pipes between the new and the old 36-inch lines. These bends and connections restrict flow in the system and leads to the SSO at the wet well. The model predicts that if the abandoned 36-inch line is reactivated, the projected SSO at the wet well does not activate. Since this line was abandoned, it was not internally inspected as part of the Paragraph 9 requirements of the CD. Internal inspection of the section of sewer and further upgrade (if necessary) should be performed prior to reactivation. The costs for this alternative are presented in **Table 19**. This alternative

can save the City approximately $15,000 as compared to installation of a 0.02 MG storage tank. Hence, it is recommended to reactivate the abandoned line.

The peak velocity in the force main is slightly above 10 fps regardless of the aforementioned improvements, rendering the force main not in compliance with the velocity threshold of 7 fps. It is recommended to inspect the force main every 5 years to ensure its structural integrity and normal functioning. An alternative to this is to build a parallel 27-inch, 4000-foot force main from the Dundalk Pump Station to manhole S67S__019MH. The cost for this project is estimated to be $8,180,000 in 2008 dollars. Due to the high cost and difficulties in construction, this alternative is not recommended.

Table 19
Alternatives Analysis and Recommendations Report: 20-Year Improvements
Dundalk Pump Station Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
36-inch Pipe	CCTV	$5	572	$2,860
Following CCTV, assuming the 36-inch pipe requires rehabilitation				
36-inch Pipe	CIPP	$186	572	$106,392
Subtotal				$109,252
Engineering Design, Construction Management and Other Costs (42%)				$45,886
2008 Total Estimated Cost				$155,000
2009 Total Estimated Cost				$166,000
2010 Total Estimated Cost				$178,000
2011 Total Estimated Cost				$190,000
2012 Total Estimated Cost				$203,000
2013 Total Estimated Cost				$218,000
2014 Total Estimated Cost				$233,000
2015 Total Estimated Cost				$249,000
2016 Total Estimated Cost				$267,000
2017 Total Estimated Cost				$285,000

6.5 20-Year Improvement Summary

The combined cost estimate for all recommended improvements to convey the 20-year, 24 hour storm is presented in **Table 20**. The 20-year improvements recommended above are in addition to the 2, 5, 10, and 15-year improvements to accommodate the 20-year storm. Hence, quantities and costs presented in Table 20 include the 2, 5, 10, and 15-year recommendations.

Table 20
Alternatives Analysis and Recommendations Report: 20-Year Improvements

20-Year Comprehensive Improvements

Item	Rehab Method	Unit Cost	Quantity (LF)	Cost
8” Pipe	CIPP	$45	38,169	$1,717,605
10” Pipe	CIPP	$64	6,256	$400,384
12” Pipe	CIPP	$64	1,687	$107,968
15” Pipe	CIPP	$87	921	$80,127
18” Pipe	CIPP	$87	1,445	$125,715
21” Pipe	CIPP	$124	343	$42,532
24” Pipe	CIPP	$124	1,927	$238,948
27” Pipe	CIPP	$169	4,344	$734,136
10” Pipe	Replacement	$495	283	$140,085
12” Pipe	Replacement	$495	1,285	$636,075
18” Pipe	Replacement	$585	1,538	$899,730
30” Pipe	Replacement	$1,440	1,636	$2,355,840
33” Pipe	Replacement	$1,530	4,044	$6,187,320
Manhole (each)	Rehab/Replacement	$3,719	254	$944,626
36” Force Main	CCTV	$5	572	$2,860
36” Force Main	CIPP	$186	572	$106,392
Subtotal				$14,720,343
Engineering Design, Construction Management and Other Costs (42%)				$6,182,544
2008 Total Estimated Cost				$20,900,000
2009 Total Estimated Cost				$22,370,000
2010 Total Estimated Cost				$23,930,000
2011 Total Estimated Cost				$25,610,000
2012 Total Estimated Cost				$27,400,000
2013 Total Estimated Cost				$29,320,000
2014 Total Estimated Cost				$31,370,000
2015 Total Estimated Cost				$33,570,000
2016 Total Estimated Cost				$35,920,000
2017 Total Estimated Cost				$38,430,000

7.0 ALTERNATIVE ANALYSIS SUMMARY

As required by the Consent Decree and the BaSES manual, the City of Baltimore should identify all modeled components of the collection system that have the potential to cause or contribute to sanitary sewer overflows. This report evaluates alternatives and recommends cost effective capital improvements to the sanitary collection system necessary to ensure adequate long term capacity during 2, 5, 10, 15, and 20-year storm events. **Table 21** provides incremental and cumulative costs for recommended improvements to accommodate each of the design storms. **Table 22** provides incremental and cumulative costs for recommended improvements to eliminate each gallon of sewer overflow under each design storm. The major conclusions from the analysis of alternatives are summarized below.

(1) To convey a 2-year storm, it is recommended to perform an extensive I/I removal for sub-catchments 29-02-06-00A, 29-02-06-00B, and 29-02-06-00C in basin DU06 and sub-catchment 29-02-10-00A in basin DU07 upstream of the predicted overflow locations. The Dundalk Force Main is not in compliance with the velocity threshold of 7 fps during peak rain and it is recommended to inspect the force main every 5 years to ensure its normal functioning. The cost for these improvements is estimated to be $642,000 in 2008 dollars and the cost to eliminate each gallon of the predicted overflow is $257.

(2) Upon completion of the 2-year improvements, 5-year improvements are required to eliminate predicted overflows in basins DU03 and DU06. The recommended improvements include I/I removal projects for the entire DU06 basin, two SSAs (29-02-11-00 and 29-02-10-00) in DU07 and sub-catchment 29-01-09-00E in DU03. In addition, a segment of 12-inch pipe receiving BDU01 flow needs to be upsized to 15 inches in order to remove flow restrictions. The Dundalk Force Main is not in compliance with the velocity threshold of 7 fps during peak rain and it is recommended to inspect the force main every 5 years to ensure its normal functioning. The incremental (cost for 5-year improvements alone) and cumulative (cost for 2 and 5-year improvements) costs are estimated to be $4,410,000 and $5,050,000 respectively in 2008 dollars. The incremental and cumulative costs to eliminate each gallon of the predicted overflow are $33.1 and $37.2, respectively in 2008 dollars.

(3) To convey the 10-year storm, it is recommended to perform I/I removal projects for the entire DU07 basin and sub-catchment 29-01-09-00C in DU03. In addition to this, other major improvements include upsizing a segment of 27-inch pipe on Dundalk Avenue to 30 inches and upsizing a segment of 15-inch pipe in DU01 to 18 inches. The Dundalk Force Main is not in compliance with the velocity threshold of 7 fps during peak rain and it is recommended to inspect the force main every 5 years to ensure its normal functioning. The incremental and cumulative costs are estimated to be $6,100,000 and $11,150,000 respectively in

2008 dollars. The incremental and cumulative costs to eliminate each gallon of the predicted overflow are $30.9 and $33.5 respectively in 2008 dollars.

(4) Upon completion of I/I removal projects under 2, 5, and 10-year improvements, the primary work for the 15-year improvements is to increase flow conveyance capacity by installation of larger diameter pipes. Such work is to be carried out in basins DU01, DU03, DU05, DU06, and DU07. In particular, approximately 652 feet of 27-inch and 1,880 feet of 30-inch interceptors need to be upsized to 30 and 33 inches, respectively. The Dundalk Force Main is not in compliance with the velocity threshold of 7 fps during peak rain and it is recommended to inspect the force main every 5 years to ensure its normal functioning. The incremental and cumulative costs are estimated to be $6,350,000 and $17,500,000 respectively in 2008 dollars. The incremental and cumulative costs to eliminate each gallon of the predicted overflow are $46.9 and $37.3 respectively in 2008 dollars.

(5) To convey the 20-year storm, the improvements include upsizing another segment of 15-inch pipe in DU01 to 18 inches, upsizing a segment of 10-inch pipe in DU03 to 12 inches, upsizing approximately 2,164 feet of 30-inch interceptor in DU05 to 33 inches, and raising six (6) manholes in DU05. After completing all recommended improvements, the three main pumps do not have enough capacity to handle the peak flow when the backup pump is offline for maintenance. It is recommended to reactivate approximately 572 feet of abandoned 36-inch force main to eliminate the predicted SSO at the wet well. It is also recommended to inspect the force main every 5 years to ensure its normal functioning. The incremental and cumulative costs are estimated to be $3,400,000 and $20,900,000 respectively in 2008 dollars. The incremental and cumulative costs to eliminate each gallon of the predicted overflow are $23.7 and $34.2 respectively in 2008 dollars.

Table 21
Alternatives Analysis and Recommendations Report: Alternatives Analysis Summary
Estimated Improvement Costs for Dundalk

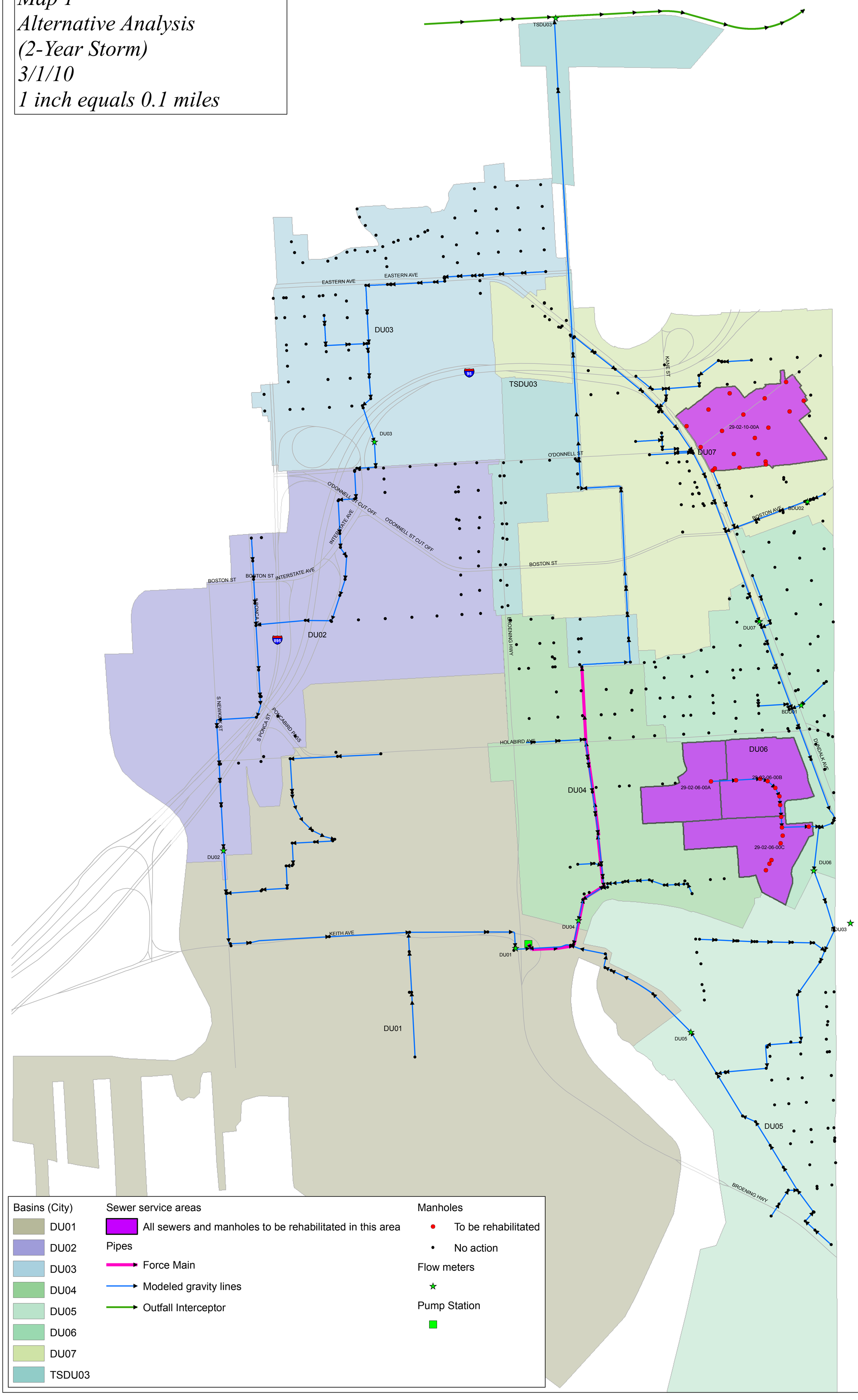
Project Year	2-year Storm	5-year Storm		10-year Storm		15-year Storm		20-year Storm	
		Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
2008	$642,000	$4,410,000	$5,050,000	$6,100,000	$11,150,000	$6,350,000	$17,500,000	$3,400,000	$20,900,000
2009	$687,000	$4,710,000	$5,400,000	$6,530,000	$11,930,000	$6,790,000	$18,720,000	$3,650,000	$22,370,000
2010	$735,000	$5,050,000	$5,780,000	$6,980,000	$12,760,000	$7,270,000	$20,030,000	$3,900,000	$23,930,000
2011	$786,000	$5,400,000	$6,190,000	$7,470,000	$13,660,000	$7,780,000	$21,440,000	$4,170,000	$25,610,000
2012	$841,000	$5,780,000	$6,620,000	$7,990,000	$14,610,000	$8,330,000	$22,940,000	$4,460,000	$27,400,000
2013	$900,000	$6,180,000	$7,080,000	$8,560,000	$15,640,000	$8,900,000	$24,540,000	$4,780,000	$29,320,000
2014	$963,000	$6,620,000	$7,580,000	$9,150,000	$16,730,000	$9,530,000	$26,260,000	$5,110,000	$31,370,000
2015	$1,031,000	$7,080,000	$8,110,000	$9,790,000	$17,900,000	$10,200,000	$28,100,000	$5,470,000	$33,570,000
2016	$1,103,000	$7,580,000	$8,680,000	$10,480,000	$19,160,000	$10,910,000	$30,070,000	$5,850,000	$35,920,000
2017	$1,180,000	$8,100,000	$9,280,000	$11,220,000	$20,500,000	$11,670,000	$32,170,000	$6,260,000	$38,430,000

Table 22
Alternatives Analysis and Recommendations Report: Alternatives Analysis Summary
Estimated Improvement Costs per Gallon of SSO Removed

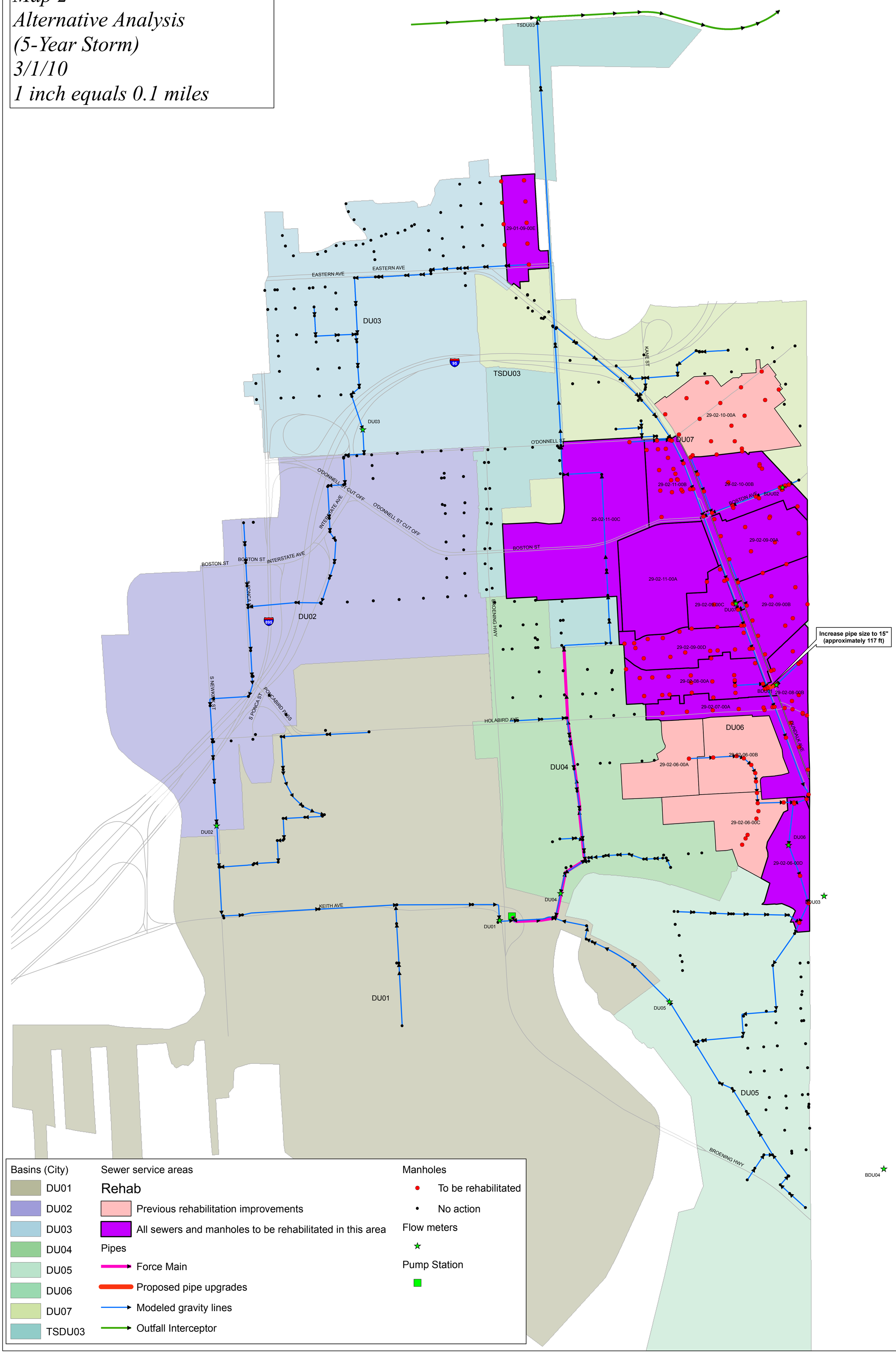
Project Year	2-year Storm	5-year Storm		10-year Storm		15-year Storm		20-year Storm	
	SSO 2,500 gal	SSO 135,600 gal		SSO 333,200 gal		SSO 468,700 gal		SSO 611,900 gal	
		Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative	Incremental	Cumulative
2008	$257	$33.1	$37.2	$30.9	$33.5	$46.9	$37.3	$23.7	$34.2
2009	$275	$35.4	$39.8	$33.0	$35.8	$50.1	$39.9	$25.5	$36.6
2010	$294	$37.9	$42.6	$35.3	$38.3	$53.7	$42.7	$27.2	$39.1
2011	$314	$40.6	$45.6	$37.8	$41.0	$57.4	$45.7	$29.1	$41.9
2012	$336	$43.4	$48.8	$40.4	$43.8	$61.5	$48.9	$31.2	$44.8
2013	$360	$46.4	$52.2	$43.3	$46.9	$65.7	$52.4	$33.4	$47.9
2014	$385	$49.7	$55.9	$46.3	$50.2	$70.3	$56.0	$35.7	$51.3
2015	$412	$53.2	$59.8	$49.5	$53.7	$75.3	$60.0	$38.2	$54.9
2016	$441	$56.9	$64.0	$53.0	$57.5	$80.5	$64.2	$40.9	$58.7
2017	$472	$60.9	$68.4	$56.8	$61.5	$86.1	$68.6	$43.7	$62.8

City of Baltimore
Dundalk Collection System Evaluation
and Sewershed Plan
Project No. 1047
Figure 1-1
Dundalk Sewershed Map
Alternative Analysis and
Recommendations Report
5/15/09
1 inch equals 0.25 miles
N
Location Map
Legend
Dundalk Sewershed
Sanitary Sewer Pipes

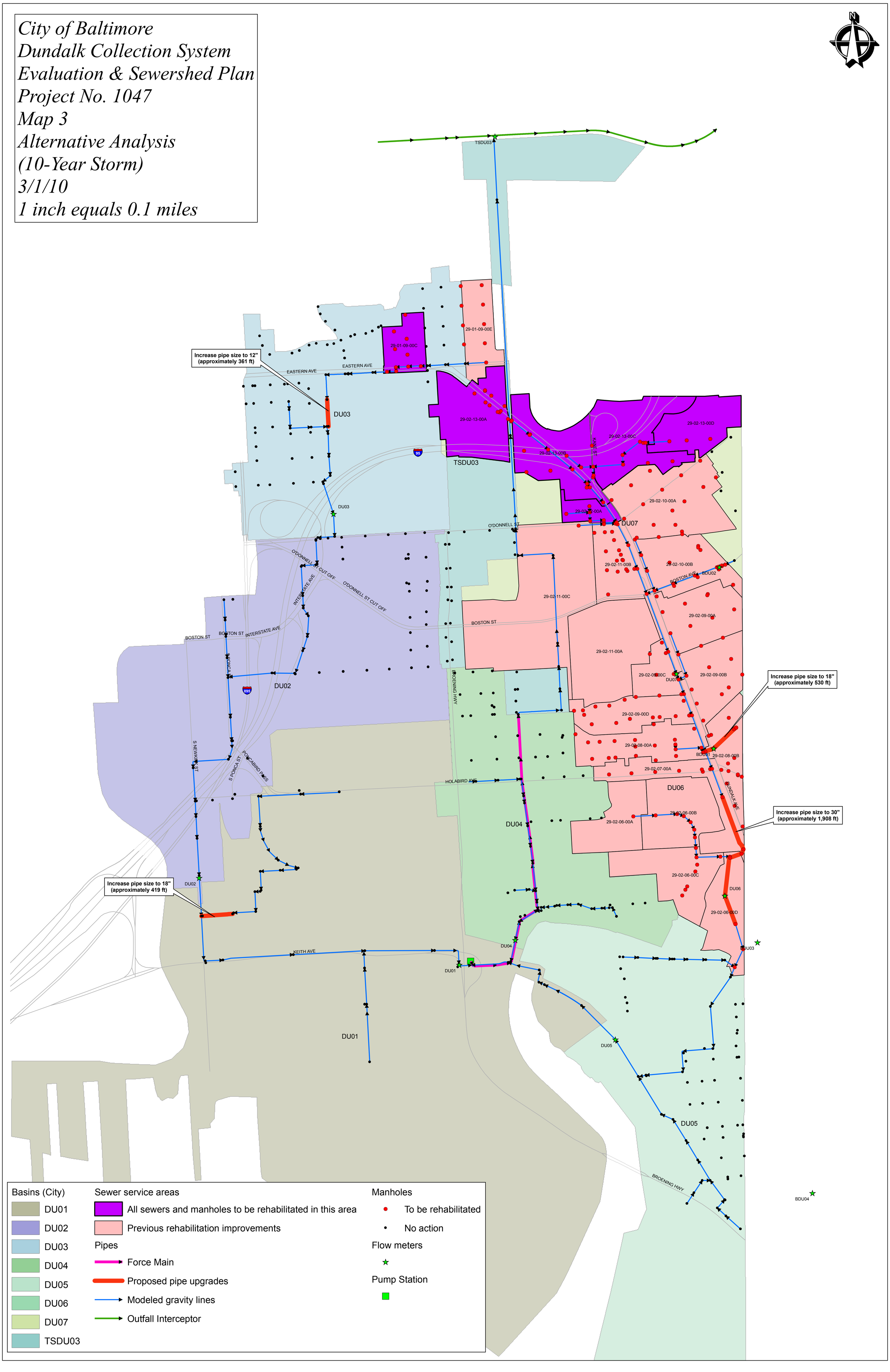
City of Baltimore
Dundalk Collection System
Evaluation & Sewershed Plan
Project No. 1047
Map 1
Alternative Analysis
(2-Year Storm)
3/1/10
1 inch equals 0.1 miles



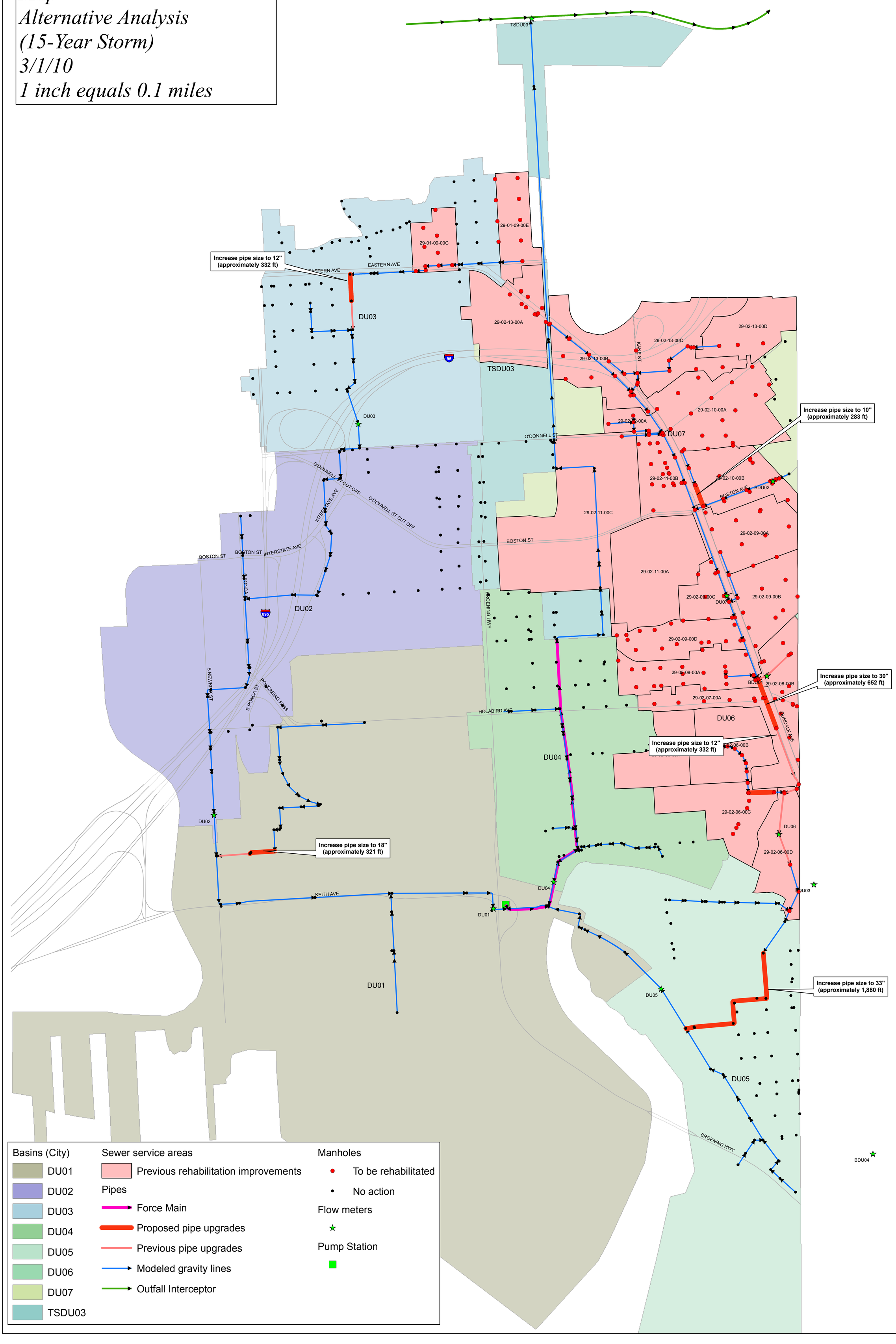
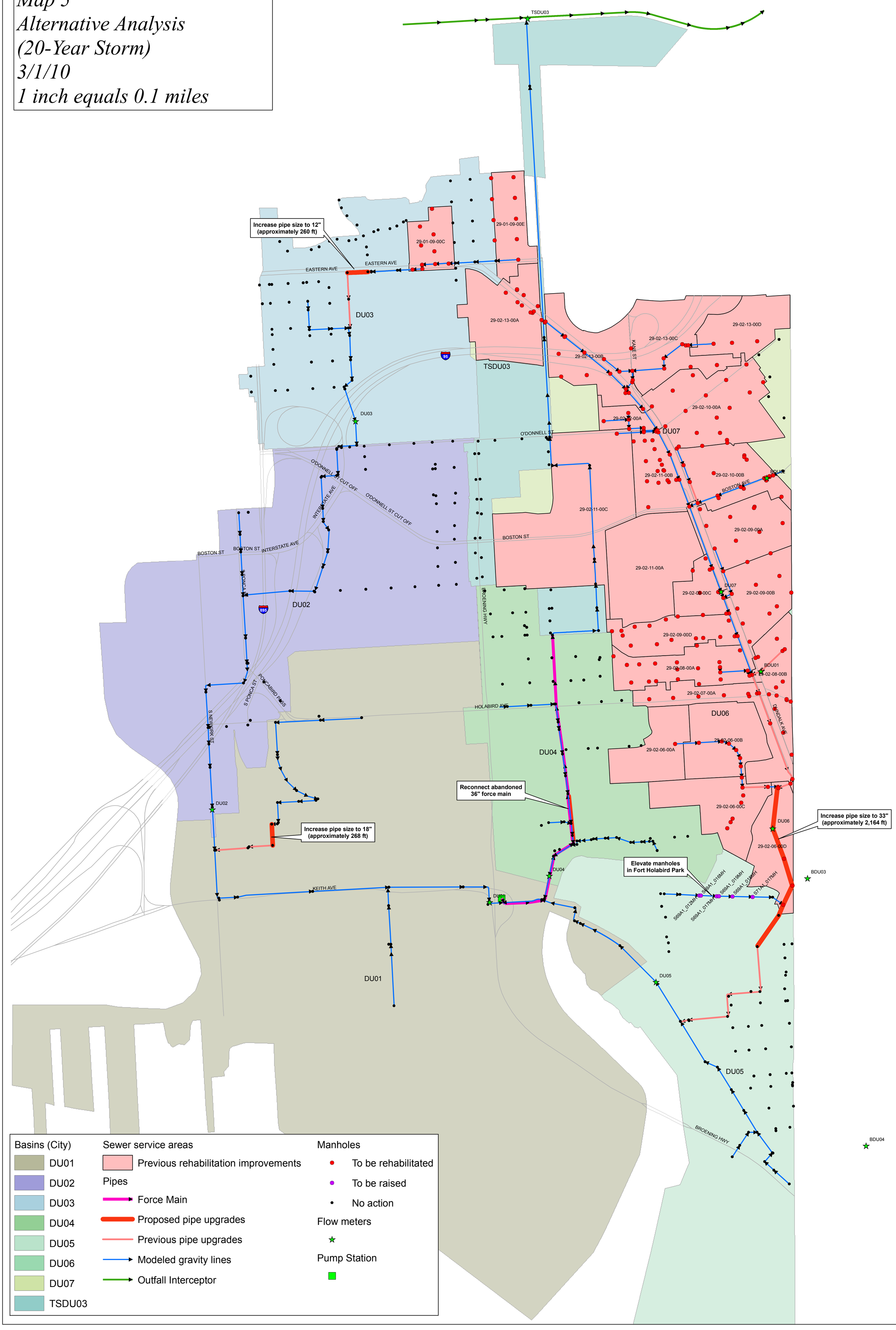
City of Baltimore
Dundalk Collection System
Evaluation & Sewershed Plan
Project No. 1047
Map 2
Alternative Analysis
(5-Year Storm)
3/1/10
1 inch equals 0.1 miles



City of Baltimore
Dundalk Collection System
Evaluation & Sewershed Plan
Project No. 1047
Map 3
Alternative Analysis
(10-Year Storm)
3/1/10
1 inch equals 0.1 miles



City of Baltimore
Dundalk Collection System
Evaluation & Sewershed Plan
Project No. 1047
Map 4
Alternative Analysis
(15-Year Storm)
3/1/10
1 inch equals 0.1 miles



City of Baltimore
Dundalk Collection System
Evaluation & Sewershed Plan
Project No. 1047
Map 5
Alternative Analysis
(20-Year Storm)
3/1/10
1 inch equals 0.1 miles