9. CITY-WIDE GI ASSESSMENT SUMMARY

The goal of this City-Wide Green Infrastructure (GI) Assessment, hereafter referred to as the Green First Plan, was developed based on a GI-based integrated planning approach to reduce CSO and SSO overflows, remove or detain stream inflows, reduce specific flood hazards, and reduce the occurrence of basement sewage backups. This effort has also allowed us to develop a stormwater overlay lens for use as a comprehensive planning tool for future new and redevelopment. The findings of our assessment include both common metrics such as untreated overflow volumes reduced, but also ancillary benefits derived from GI implementations such as Triple Bottom Line (TBL) benefits and reduced flows being conveyed to the wastewater treatment plant (WWTP). The 30 sewersheds included in this assessment are each located within the City of Pittsburgh (City). The volume of untreated overflow and stormwater flow from these sewersheds represent approximately one third of the total untreated overflow discharged from the entire collection system tributary to the ALCOSAN Woods Run WWTP.

Earlier sections of this report describe each of the detailed investigations undertaken during this GI Assessment. This section integrates these various results, place them in context and present a summary of key findings and recommendations. It is important to understand the following points when reading this section.

- **Different GI applications provide different types of benefits.** No one metric is sufficient to decide if a particular GI project proceeds to design and then on to construction. Some GI benefits directly overlap with the benefits provided by traditional gray infrastructure, such as reducing untreated overflows to meet regulatory goals. However, since GI also provides multiple benefits and helps address multiple water quality and public health regulatory issues, the GI evaluation process is often more complex than the often more straightforward evaluative process typically applied to a gray infrastructure.
- **The Green First Plan has a green focus, but is also dependent on key gray infrastructure improvements.** All collection systems are interactive networks whose adequacy is based on inputs (entering flows), conveyance (flow traveling throughout the network) and outputs (discharges from the WWTP, CSOs, SSOs, etc.). Changes to any of these elements have impacts on the other elements. The development of an effective plan which includes GI depends on all of the elements working effectively together. GI investments primarily address the input component of the system by slowing and reducing the flows entering the system that then need to be conveyed and discharged through an output location. Although GI elements can be very effective at addressing the system's flow inputs, the conveyance and treatment components of the entire system must also function optimally to maximize the overall results. As demonstrated in the GI Assessment's results, key gray infrastructure investments must still be made for the GI elements to be maximally effective.

- **It is important to understand not simply the cost of an alternative, but its value.** Just because an alternative is cheaper than others does not automatically mean it is the best alternative (although it may be). Because a sizable portion of the value of a GI project may derive from factors other than volume of untreated overflow reduced, GI projects need to be evaluated with the overall value that they provide. However, these ancillary benefits are often weighed differently by different stakeholders and further discussions would be needed to determine how the results provided in this report should be used to influence any future decision-making.
- **This Assessment only focused on 30 priority sewersheds within the PWSA system, not the entire collection system tributary to ALCOSAN's Woods Run Wastewater Treatment Plant (WWTP).** The results provided in this report are important for understanding the effectiveness of applying large scale GI within the City at high yield and high benefit locations. Although the results of this Assessment provide insight on the benefits of applying GI across the larger region tributary to the ALCOSAN conveyance and treatment system, those regional results would need to be investigated further with the inclusion of additional information.
- **The benefits from this Assessment extend to the municipalities beyond PWSA and the City.** Having PWSA and City adopt the Green First plan which includes GI to meet target regulatory goals may also provide multiple regional benefits to tributary municipalities. The sewer collection system is inextricably and hydraulically linked. Theoretically, taking a gallon of stormwater out at one location frees up pipeline capacity for another stormwater gallon to enter elsewhere. By capturing and slowing the entry of stormwater into the collection system within the City and surrounding areas, capacity is freed up in the existing interceptors to accept more flow and be conveyed to the WWTP, thereby reducing regional overflows. The results show that the system-wide overflow volume reduction is competitive with the 2013 ALCOSAN Recommended Wet Weather Plan (Recommended Plan) at potentially a lower overall cost per gallon, which would benefit all of the region's ratepayers.
- **The methodologies and "blueprints" from this Assessment can be applied Region-wide.** High yield stormwater capture locations within the combined sewer systems (CSS), the separate sewer systems (SSS) in which the stormwater flows are conveyed to a downstream CSS, and the sanitary sewers with excessive infiltration and inflow (I/I) in which the flows are conveyed to a downstream CSS exist across the regional ALCOSAN service area. In addition there may be stormwater capture locations in the SSS that may reduce flooding hazards that stem from excess stormwater. This study revealed that the region has a stormwater management problem with excessive stormwater entering the CSS that highly influences CSO frequency and magnitude in many locations across the service area. Addressing the root cause of this problem by intercepting and managing this stormwater locally provides multiple benefits for far reaches downstream. The results support and re-affirm a regional approach for targeted stormwater management at high-yield locations that maximize stormwater management, overflow reduction, and community benefits.

9.1 High Yield GI Locations

A principal focus of this GI Assessment has been investigating the expected performance of distributed GI applied across the 30 priority sewersheds. The magnitude of GI Best Management Practices (BMPs) evaluated was based on the calculated impervious area stormwater runoff to be managed by GI within each sewershed, and defined as “GI investment”. Impervious areas are defined as areas that allow all or a significant portion of the precipitation that falls on them to run off the ground (topographic) surface. Impervious areas include rooftops, sidewalks, driveways, parking lots, impervious solids and rock, and streets, unless specifically designed, constructed, and maintained to prevent or control runoff.

The EPA’s CSO Control Policy (1994) requires at least 85% combined sewage capture be achieved within combined sewer systems as part of a CSO long-term control plan. For this Assessment 85% combined sewage capture was the target selected as it is consistent with the CSO Control Policy and other approved long term control plans across the United States. The current Recommended Plan was developed assuming a standard of no more than four overflows per year at each combined sewer outfall. The 85% combined sewage capture target is not meant to presume a final level of control for the region’s CSOs, but simply to define a target that has been required as a presumptive compliance goal for other cities like Pittsburgh. This approach also allows flexibility to scale the eventually required amount of GI investment, in conjunction with necessary gray infrastructure, to meet whatever CSO target is ultimately agreed upon with regulators.

Analyses completed for this Assessment, described in Section 2, revealed that the level of GI investment needed to achieve the goal of 85% combined sewage capture would be highly influenced by the capacity and operation of ALCOSAN’s Woods Run WWTP and the conveyance capacity of ALCOSAN’s existing interceptors. These critical infrastructure components are planned to be expanded or supplemented as part of the Recommended Plan. However, the ultimate build out capacity of these conveyance and treatment components and the timing of their expansions is subject to regulatory and other items. With this understanding the high yield GI analysis was evaluated with four different potential scenarios of this existing gray infrastructure as listed in Table 9-1. As the capacity of the existing gray infrastructure increases, the level of GI investment needed to reach the 85% combined sewage capture target decreases. Under existing conditions, 13 of the sewersheds already meet the 85% combined sewage capture goal and therefore would not need any GI implementation. As the capacities of the WWTP and tunnels are expanded, an increasing number of sewersheds would meet the 85% combined sewage capture goal. Under the Lowered Hydraulic Grade Line (HGL) Operation During Wet Weather Conditions (Lowered HGL Operation) option, which represents an attempt to maximize the performance of the existing conveyance and treatment infrastructure, 17 of the 30 high priority sewersheds would achieve 85% combined sewage control and would not require any GI implementation.

TABLE 9-1
SYSTEM CONFIGURATIONS EVALUATED TO DETERMINE GI SENSITIVITY

Existing Conditions	This represents the current state of the collection system and the WWTP treatment capacity. The WWTP has a 250 million gallons per day (MGD) treatment capacity and its influent pump station wet well operates at an HGL level of 670 feet. The existing interceptors have the sediment levels as defined in the current ALCOSAN model.
480 MGD (WWTP Expansion) [1]	This system state is the same as the existing conditions, except the capacity of the WWTP has been expanded to 480 MGD and its operating wet well HGL level reduced to 660 feet.
600 MGD (WWTP Expansion & System Improvements) [1]	This system state is the same as the existing conditions, except the capacity of the WWTP has been expanded to 600 MGD and its operating wet well HGL level reduced to 660 feet. Also, the existing interceptors are modeled with their sediment removed to maximize wastewater conveyance to the interceptor, and regulator structures for 19 of the 30 high priority sewersheds have modified tipping gate settings to allow more flow to enter the interceptors.
Lowered HGL Operation During Wet Weather Conditions [1]	This system state represents an attempt to maximize the performance of the existing gray infrastructure. This alternative is not currently planned to be implemented by ALCOSAN. In this scenario, the WWTP is modeled as a free outfall to represent lowering the water level at the existing pump station during wet weather conditions such that it is below the crown of the connecting deep tunnel. This provides for the existing conveyance capacity to be maximized. This scenario also assumes that the necessary high rate treatment infrastructure is constructed at the WWTP to process any flows above 600 MGD (modeling results indicate peak flows at or above 600 MGD occur 29 hours in a typical year). The necessary infrastructure to accomplish this scenario is discussed in Section 3.3. The existing interceptors are modeled with their sediment removed and regulator structures for 19 of the 30 high priority sewersheds have modified tipping gate settings to allow more flow to enter the interceptors. A more detailed explanation of this configuration is included in Section 2 of this report.

[1] The technical feasibility of all potential treatment plant wet weather capacity scenarios is currently under discussion between PWSA and ALCOSAN.

Table 9-2 details the directly connected impervious area (DCIA) generated stormwater runoff that must be managed by GI for each of the 30 priority sewersheds to achieve the 85% combined sewage capture goal under the four configuration scenarios. Under existing conditions, 63% of the DCIA stormwater runoff would need to be managed. However, only 35% of the DCIA stormwater runoff would need to be managed under the Lower HGL Operation condition. Entries with a green highlight indicate that the sewershed achieves the 85% combined sewage capture goal and no additional GI investment is needed.

Table 9-3 includes planning level capital cost estimates for each of the sewersheds based on the amount of impervious acres in high yield drainage areas that need to be managed by GI to achieve at least the 85% combined sewage capture goal. Entries with a green highlight indicate that the sewershed achieves the 85% combined sewage capture goal and no additional GI investment is needed. GI BMP costs were developed using a detailed and itemized costing spreadsheet estimating the quantities and unit costs for each primary component of the BMPs. Costs were developed and compared to the equivalent cost per acre of impervious surface managed for a reasonableness check. Construction costs without contingency were calculated to be $150,000 to $200,000 per impervious acre managed. Using the high end of this range, the base construction cost was selected to be $200,000 per impervious acre. These costs were compared to costs from other Mott MacDonald GI projects, costs from other communities implementing GI programs, as well as the ALCOSAN Starting at the Source report (August 2015) and found to be in-line with the reported costs. The contingencies added to these construction costs to develop overall capital costs are listed in Table 9-4. Applying these contingencies, the low range cost was estimated at $324,000 per acre and the high range cost was estimated at $432,000 per acre.

TABLE 9-2
CONTINGENCIES FACTORS

Planning Level Cost Contingencies	Percentage
Construction	25%
Engineering (Planning, Design and Construction Administration Services)	20%
Overall Project	20%
Class 4 Cost Estimate Range	+20% to -10%

Operation and maintenance (O&M) costs over both a 25-year and 50-year life cycle were developed for the GI under both the 1,835 and 1,286 impervious acres scenarios. Section 7 details the development of these O&M costs. Table 9-12 summarizes the O&M costs for both scenarios.

TABLE 9-3
GI IMPERVIOUS AREA STORMWATER RUNOFF MANAGED TO ACHIEVE 85% COMBINED SEWAGE CAPTURE GOAL IN 30 PRIORITY SEWERSHEDS

Sewershed	Impervious Area (Ac)	Existing Conditions (250 MGD WWTP)		480 MGD (WWTP Expansion)		Lowered HGL Operation	
		Percentage	Acres	Percentage	Acres	Percentage	Acres
A-22-OF	898.0	56.7%	509.1	43.2%	387.7	30.2%	271.0
A-41-OF	234.7	85.0%	199.5	85.0%	199.5	60.0%	140.8
A-42-OF	839.7	85.0%	713.8	73.1%	614.1	57.8%	485.1
A-47-OF	9.0	0.0%	0.0	0.0%	0.0	0.0%	0.0
A-48-OF	167.1	25.0%	41.8	25.0%	41.8	25.0%	41.8
A-51-OF	34.6	0.0%	0.0	0.0%	0.0	0.0%	0.0
A-58-OF	151.7	25.0%	37.9	25.0%	37.9	25.0%	37.9
A-60-OF	175.2	85.0%	148.9	25.0%	43.8	25.0%	43.8
A-61-OF	10.7	53.9%	5.8	37.3%	4.0	0.0%	0.0
A-62-OF	5.7	86.0%	4.9	0.0%	0.0	0.0%	0.0
A-63-OF	1.0	0.0%	0.0	0.0%	0.0	0.0%	0.0
A-64-OF	18.4	0.0%	0.0	0.0%	0.0	0.0%	0.0
A-65-OF	4.6	85.0%	3.9	15.1%	0.7	0.0%	0.0
M-15-OF	3.7	85.0%	3.1	65.3%	2.4	0.0%	0.0
M-15Z-OF	3.1	0.0%	0.0	0.0%	0.0	0.0%	0.0
M-16-OF	100.0	85.0%	85.0	85.0%	85.0	25.2%	25.2
M-17-OF	6.2	0.0%	0.0	0.0%	0.0	0.0%	0.0
M-18-OF	5.1	0.0%	0.0	0.0%	0.0	0.0%	0.0
M-19A-OF	142.6	40.0%	57.1	41.0%	58.4	35.0%	49.9

TABLE 9-3
GI IMPERVIOUS AREA STORMWATER RUNOFF MANAGED TO ACHIEVE 85% COMBINED SEWAGE CAPTURE GOAL IN 30 PRIORITY SEWERSHEDS

Sewershed	Impervious Area (Ac)	Existing Conditions (250 MGD WWTP)		480 MGD (WWTP Expansion)		Lowered HGL Operation	
		Percentage	Acres	Percentage	Acres	Percentage	Acres
M-19B-OF	32.1	27.1%	8.7	28.0%	9.0	33.0%	10.6
M-19-OF	119.1	85.0%	101.2	55.2%	65.7	25.0%	29.8
M-20-OF	6.2	0.0%	0.0	0.0%	0.0	0.0%	0.0
M-21-OF	29.2	11.6%	3.4	7.9%	2.3	0.0%	0.0
M-22-OF	16.4	0.0%	0.0	0.0%	0.0	0.0%	0.0
M-29-OF	362.3	85.0%	307.9	60.1%	217.7	25.0%	90.5
O-27-OF	195.6	25.0%	48.9	22.3%	43.7	22.3%	43.7
O-39-OF	23.8	31.6%	7.5	21.4%	5.1	0.0%	0.0
O-40-OF	2.8	0.0%	0.0	0.0%	0.0	0.0%	0.0
O-41-OF	27.9	56.3%	15.7	56.0%	15.6	56.0%	15.6
O-43-OF	9.8	0.0%	0.0	0.0%	0.0	0.0%	0.0
Totals	**3,636**	**63%**	**2,304**	**50%**	**1,835**	**35%**	**1,286**

TABLE 9-4
GI CAPITAL COSTS TO ACHIEVE 85% COMBINED SEWAGE CAPTURE GOAL IN 30 PRIORITY SEWERSHEDS

Sewershed	Existing Conditions		480 MGD (WWTP Expansion)		Lowered HGL Operation	
	$324,000/ac	$432,000/ac	$324,000/ac	$432,000/ac	$324,000/ac	$432,000/ac
A-22-OF	$164,953,931	$219,938,575	$125,626,939	$167,502,585	$87,816,098	$117,088,131
A-41-OF	$64,641,888	$86,189,184	$64,641,888	$86,189,184	$45,629,568	$60,839,424
A-42-OF	$231,256,960	$308,342,614	$198,980,500	$265,307,333	$157,172,400	$209,563,200
A-47-OF	$0	$0	$0	$0	$0	$0
A-48-OF	$13,537,357	$18,049,810	$13,536,720	$18,048,960	$13,536,720	$18,048,960
A-51-OF	$0	$0	$0	$0	$0	$0
A-58-OF	$12,285,476	$16,380,635	$12,286,080	$16,381,440	$12,286,080	$16,381,440
A-60-OF	$48,246,743	$64,328,991	$14,190,004	$18,920,006	$14,190,004	$18,920,006
A-61-OF	$1,872,535	$2,496,713	$1,296,000	$1,728,000	$0	$0
A-62-OF	$1,595,381	$2,127,175	$0	$0	$0	$0
A-63-OF	$0	$0	$0	$0	$0	$0
A-64-OF	$0	$0	$0	$0	$0	$0
A-65-OF	$1,265,959	$1,687,945	$224,532	$299,376	$0	$0
M-15-OF	$1,013,472	$1,351,296	$778,352	$1,037,802	$0	$0
M-15Z-OF	$0	$0	$0	$0	$0	$0
M-16-OF	$27,553,324	$36,737,765	$27,548,317	$36,731,089	$8,160,336	$10,880,447
M-17-OF	$0	$0	$0	$0	$0	$0
M-18-OF	$0	$0	$0	$0	$0	$0
M-19A-OF	$18,489,622	$24,652,830	$18,924,565	$25,232,753	$16,170,565	$21,560,753

TABLE 9-4
GI CAPITAL COSTS TO ACHIEVE 85% COMBINED SEWAGE CAPTURE GOAL IN 30 PRIORITY SEWERSHEDS

Sewershed	Existing Conditions		480 MGD (WWTP Expansion)		Lowered HGL Operation	
	$324,000/ac	$432,000/ac	$324,000/ac	$432,000/ac	$324,000/ac	$432,000/ac
M-19B-OF	$2,822,056	$3,762,741	$2,916,000	$3,888,000	$3,434,400	$4,579,200
M-19-OF	$32,800,140	$43,733,520	$21,286,323	$28,381,765	$9,645,208	$12,860,277
M-20-OF	$0	$0	$0	$0	$0	$0
M-21-OF	$1,098,600	$1,464,800	$748,203	$997,604	$0	$0
M-22-OF	$0	$0	$0	$0	$0	$0
M-29-OF	$99,764,571	$133,019,427	$70,531,447	$94,041,930	$29,322,000	$39,096,000
O-27-OF	$15,840,701	$21,120,935	$14,148,979	$18,865,305	$14,148,979	$18,865,305
O-39-OF	$2,428,887	$3,238,515	$1,643,494	$2,191,325	$0	$0
O-40-OF	$0	$0	$0	$0	$0	$0
O-41-OF	$5,082,994	$6,777,325	$5,054,400	$6,739,200	$5,054,400	$6,739,200
O-43-OF	$0	$0	$0	$0	$0	$0
Totals	**$746,550,598**	**$995,400,797**	**$594,362,743**	**$792,483,657**	**$416,566,757**	**$555,422,343**

9.1.1 Downspout Disconnection Program

The GI analysis included identifying high yield drainage areas tributary to mapped catch basin inlets. These high yield drainage areas include both public and private sources of stormwater. To provide the maximum benefits of managing stormwater to reduce CSO, localized surface flooding, and basement sewage backups, strategic cost-effective disconnection of private property downspouts is recommended to be performed. The GI cost-basis described above includes the necessary sizing of BMPs to include stormwater runoff from private impervious surfaces. While the overall capital cost range for GI of $324,000 - $432,000 per impervious acre managed was conservatively estimated to also include strategic cost-effective disconnection of downspouts in the locations of BMPs, it was decided to explicitly include a separate line item cost for downspout disconnections in the CSS to add additional conservatism to the GI costs.

To estimate the downspout disconnections cost, several sources were evaluated, including:

- a literature review was performed of the various utilities currently performing downspout disconnection programs, including the Water Environment Federation (WEF) Private Property Library;
- MM's experience with private source projects in other communities; and
- the 3RWW / ALCOSAN ACT tool extension for private property I/I disconnections

Based on this information, an average cost estimate of $3,000 per property was utilized for downspout disconnections where either the downspouts are directed to a right-of-way BMP or disconnected on the property where an adequate discharge location exists. This cost also realizes that only cost-effective downspout disconnections falling within this average cost range would be performed. If more expensive downspout disconnections on average were encountered then those locations would be re-examined and other more cost-effective areas for impervious surface runoff capture would be identified. To determine an overall cost for the 1,835 impervious acres managed and 1,286 impervious acres managed scenarios, the number of buildings in each of the sewersheds within the targeted high yield drainage areas was determined. A total of 24,000 buildings and 16,900 buildings, for the scenarios, respectively, were calculated. A total cost of $72 million for the 1,835 acre scenario and $50.7 million for the 1,286 acre scenario was calculated for the targeted downspout disconnections. A Class 4 cost range of +20% to -10% was also applied to (and already included within) these costs.

9.2 Stream Inflow Removal

An integral part of PWSA's GI program includes the removal of direct stream inflow (DSI) into the combined sewer system. DSI is defined as a surface stream that connects into the combined sewer system. There are several known (and potentially other unknown) DSIs within the PWSA service area. Depending upon the nature of the stream, DSI can take up valuable conveyance capacity in the collection system and also uses a portion of the available treatment plant capacity. A perennial stream can contribute flow throughout the year, adding to the base wastewater flow in the collection system. An understanding of the significant amounts of stormwater runoff, including the perennial stream baseflow and other seasonal streams' influences, is extremely important for a capacity deficient collection system. Removing stream inflows into the sewer system provides several benefits, including:

- Removing a major source of sediment being transported into the existing interceptors thereby reducing the conveyance capacity of the existing interceptors and requiring potentially costly cleaning
- Removing a continuous source of (stream and stormwater) flow that needs to be treated at the WWTP. This has the benefit of reducing flows being transported to the WWTP unless greater infiltration occurs to make up for this reduction.
- Restoring significant amounts of wastewater conveyance and treatment capacity in dry and wet weather conditions within the system resulting in reduced CSOs.
- Potentially provide opportunities for catalyzing new development and redevelopment of surrounding land areas.

As discussed in Section 1 of this report, the 10 largest DSI locations were reviewed and identified as listed below. Section 5 of the report discusses the evaluations performed for each location, options for detaining and/or removing the DSI (stream base flow and stormwater runoff during wet weather conditions) from the sewer system, and opinions of estimated capital cost for the following stream inflow solutions:

- Woods Run (8 locations)
- Spring Garden
- Panther Hollow Stream and Lake

Section 5 of this report describes the following solutions that were recommended for each location:

1. **Woods Run** – Detention with slow release of flows into the CSS utilizing GI best management practices (BMPs) to address the 8 inflow locations. A summary of the types of BMPs and capital cost per location is provided in Table 9-5.
2. **Spring Garden** – Detention with slow release into a shallow storm sewer that ultimately discharges to the Allegheny River.
3. **Panther Hollow** – Detention with daylighted surface channel and discharge into the Monongahela River. Modeling estimates of base flow are varied: the current SWMM model provided from ALCOSAN shows 14.0 MG/year of stream base (dry weather) flow, although estimates based on 2015 ALCOSAN flow monitoring data indicate a base stream flow of 68.0 MG/year. Additional flow monitoring and model calibration should be performed to confirm the CSO reduction indicated in Table 9-6.

Table 9-6 also includes the results for the three stream removal/detention solutions. A range of capital costs for the Panther Hollow stream removal solution is provided. Further study and coordination with other projects in the areas adjacent to these DSI opportunities are needed to confirm estimated costs.

TABLE 9-5 ESTIMATED COSTS OF THE WOODS RUN STREAM IMPROVEMENTS ALTERNATIVES			
Distributed Detention			
System #	**Location**	**Description**	**Capital Cost**
1	Northern end of Oakdale Street	Subsurface Storage	$752,000
2	Near Oakdale Street and Mairdale Avenue	Distributed BMPs	$3,869,000
3	Mairdale Avenue and River View Drive	Surface and Subsurface Storage	$1,057,000
4	Benton Field	Surface and Subsurface Storage	$319,000
5	Behind 915 Woods Run Avenue Houses	Distributed BMPs and Subsurface storage	$1,245,000
6	Kilbuck Road	Distributed BMPs and Subsurface storage	$2,343,000
7	Smithton Avenue and Henley Street	Subsurface Storage	$890,000
		Total:	**$10,475,000**

TABLE 9-6 STREAM INFLOW REMOVAL/DETENTION RESULTS				
Category	**Spring Garden**	**Woods Run**	**PANTHER HOLLOW**	**Total**
Capital Cost	$10.7M	$10.5M	$25M - $40M	$46.2M - $62.0M
Overflow Volume Reduced (MG)	52.9	15.0	31.9[1]	99.8
Capital Cost per Overflow Gallon Reduced ($/gallon)	$0.20	$0.70	$0.78 - $1.25	$0.46 - $0.61
Typical Year Stream Volume Removed (MG)	168.8	19.7	98.7[2]	267.5
Capital Cost per Stream Volume Removed ($/gallon)	$0.06	$0.53	$0.25 - $0.41	$0.16 - $0.21

[1]Current SWMM model shows 14.0 MG/year stream base flow, while a base stream flow of 68 MG/year was estimated based on 2015 ALCOSAN flow monitoring. Additional flow monitoring and model calibration should be performed to confirm the CSO reduction.

[2] Based on field measured flow from 2015 ALCOSAN flow monitoring. A base dry weather stream flow of 68 MG/year was estimated. It appears from field investigation that the majority of the wet weather flow is diverted around the existing lake.

The results indicate that stream removal can be cost-effective and competitive with other gray and GI improvements while also providing additional benefits.

9.3 High Yield GI and Stream Inflow Removal Overflow Reduction Results

Table 9-7 provides the overflow reduction results as a result of the implementation of high yield GI and direct stream inflow removal as described in this report and as summarized in Sections 9.1 and 9.2. The results of the evaluation completed as part of this report indicate that 970 MG of overflow (CSO and SSO) would be reduced by the implementation of GI to manage 1,835 impervious acres and direct stream inflow removal/detention for the 480 MGD and 600 MGD WWTP expansion scenarios. Under the Lowered HGL Operation scenario, 690 MG of overflow would be reduced by implementing GI to manage 1,286 impervious acres and direct stream inflow removal/detention. The incorporation of GI and strategic stream removal/detention alternatives, coupled with the three scenarios involving potential WWTP expansion and existing conveyance system configurations (Section 9.1), provide a system-wide overflow (CSO and SSO) volume reduction range of 4.09 BG to 5.20 BG for typical year conditions.

TABLE 9-7
OVERFLOW REDUCTION RESULTS FOR THREE SYSTEM CONFIGURATIONS WITH GREEN INFRASTRUCTURE AND STREAM INFLOW, TYPICAL YEAR, SYSTEMWIDE [1]

Stormwater Management Scenario	480 MGD WWTP WWTP Expansion	600 MGD WWTP Expansion, Sediment Removed, and 19 Regulator Modifications	Lowered HGL Operation During Wet Weather, Sediment Removed, and 19 Regulator Modifications
Number of Priority Sheds Retrofitted with GI	18	18	13
Impervious Acres Managed	1,835	1,835	1,286
Overflow Volume Reduction Attributable to GI (BG)	0.97	0.97	0.69
Aggregate Combined Sewage Capture (30 Sewersheds)	85%	91%	91%
Total ALCOSAN Systemwide Overflow Volume Reduction (BG)[2]	4.09	5.00	5.20

[1] Including overflow reduction that may occur in neighboring sewersheds.

[2] SWMM Model Version 5.1.009 Results (as described in Section 2 of this report).

9.4 Flood Hazard Mitigation

The flood hazard mitigation investigation focused on known highly prone flood hazard areas within the City. PWSA coordinated with the City's Office of Emergency Management and Homeland Security (OEMHS) to obtain background information on the flood hazard sites. Four locations were evaluated as part of this study as listed in Table 9-8.

TABLE 9-8
FLOOD HAZARD MITIGATION EVALUATION SITES

Priority	Location	Description (Provided by PWSA and City)	Focus	Suspected Root Cause
1	13th Ward - Frankstown Ave.	Recurrent flooding along roadway	Level of Service (sewer system)	Sewer surcharges during storm events cause street flooding slopes
2	Chartiers Creek / Morange Rd.	Recurrent flooding at roadway	Level of Service (sewer system)	Sewer surcharges during storm events cause street flooding
3	Streets Run Stream at Calera St.	Recurrent flooding from stream overtopping roadway	Stream	Stream floods due to large rain events; stream flooding interacting with sewer system
4	Nine Mile Run Stream at Commercial Rd.	Recurrent flooding from stream overtopping roadway and culvert	Stream / Culvert Size	Insufficient culvert capacity under Commercial Road

The evaluation revealed that the root causes of the flooding, overflows from the sewer system, and identified poor water quality in the streams were common and were either due to excessive amounts of stormwater entering the sewer system during rain events, poor condition of the existing storm or sanitary sewer assets, or a combination of both. An approach for reducing the flood hazard locations was then determined to be a combination of stormwater management through source control GI BMPs and renewing or improving the existing storm or sanitary assets. This approach allows reduction of the multiple root causes of flooding, overflows, and poor in-stream water quality. Multiple storm events of varying sizes and intensities were analyzed for each location to determine the extents of flooding and levels of protection. Estimates were developed, assuming GI and other improvements would be designed for a flooding level of protection up to the August 31, 2014 storm event condition, with a peak rainfall intensity of 1.05 inches in 15 minutes, and a rainfall volume of 2.25 inches in 10 hours..

1. **13th Ward - Frankstown Avenue Flooding:** This area is located in the combined sewer system and the collection system model indicates that the combined sewer system surcharges in this area from excessive amounts of stormwater runoff leading to flooding at least once in a typical year. To increase the level of protection against flooding from the sewer system in this area to the August 31, 2014 event (1.05 inches of rain in 15 minutes), the stormwater runoff from 23 acres of tributary area would need to be managed with GI. The evaluation also found a flat slope section of 15-inch sewer that needs to be upsized in conjunction with the stormwater runoff management. The pipe upsizing will be performed as part of PWSA's ongoing asset management capital improvement program. The cost for the 23 acres of stormwater management is included as part of the A-42 sewershed high yield GI locations identified for reduction of CSOs.
2. **Chartiers Creek / Morange Road Flooding:** This area is located in the combined sewer system and the collection system model indicates that the sewer system surcharges in this area from excessive amounts of stormwater runoff leading to flooding at least once in a typical year. To increase the level of protection of flooding from the sewer system in this area to the August 31, 2014 event (1.05 inches of rain in 15 minutes), the stormwater runoff from 262 acres of tributary area would need to be managed with GI. By addressing the stormwater runoff from the 262 acres, not only would flooding be reduced, but a CSO reduction of 50 million gallons, representing a 59% reduction, would also be achieved. The capital cost for this work was determined to be $33 million.
3. **Nine Mile Run and Streets Run Stream Flooding:** Both areas experience stream flooding that leads to extensive road and surface flooding from excessive amounts of stormwater runoff. The stormwater runoff appears to primarily originate from the upstream separate sewer systems. The in-stream hydraulic models indicate that flooding occurs in rain events of 0.8 inches or more in 15 minutes. To increase the level of protection against flooding from the sewer system in these areas to the August 31, 2014 event (1.05 inches of rain in 15 minutes), extensive stormwater management is necessary.

   The separate sewer areas tributary to the flooding locations were observed to have excessive amounts of stormwater entering the sanitary sewer system (called rainfall derived inflow and infiltration – RDII) in most locations. In order to manage the stormwater to reduce flooding it is also necessary to manage the stormwater entering the sanitary sewer system as this water leads to SSOs and CSOs into the same streams during both small and large rain events. To optimize both the stormwater management locations for flooding and reductions in the RDII, the stormwater high yield drainage areas were selected in the areas with the highest amounts of RDII. Stormwater can enter sanitary sewers through multiple locations in the public sewers as well as the private property lateral (sewer from a building to the main public sewer). Stormwater can enter through structural defects and leaks in the public sanitary sewers, cross-connections between the sanitary sewers and storm sewers, defects or leaks in the public storm sewers, as well as downspouts or other storm drain connections from private property improperly connected to the sanitary sewer lateral. Separate sanitary sewers were not designed to carry stormwater; only sewage. In both Streets Run and Nine Mile Run sewersheds, the separate sewer systems ultimately enter the downstream combined sewer systems. Therefore, stormwater is not only causing flooding in the streams, but also likely contributing to both downstream sanitary sewer and combined sewer overflows due to RDII influences within the separate sanitary sewers.

Acknowledging these issues, approaches to holistically address the stormwater problems at their sources and manage the stormwater entering both the storm sewers (leading to the flooding) and the sanitary sewers (leading to SSOs and CSOs) were developed. Holistic approaches addressing both issues may be more cost-effective and provide more local community benefits by reducing the root causes of the flooding and overflows. These approaches also allow investment back into the existing sanitary and storm systems (asset management) to address the defects in the systems already constructed rather than building new conveyance and treatment based systems and then having to come back in the future to spend more on asset management of the still failing existing systems.

The evaluation determined for Nine Mile Run that stormwater would holistically need to be managed as described above within 466 acres (29%) of the combined sewer area, and 1,408 acres (59%) of the separate sewer area. For Streets Run, 1,291 acres of the separate sewer area requires holistic stormwater management. The associated capital costs to reduce the flooding, reduce RDII, and manage the sanitary and storm sewer assets within both areas are provided in Table 9-9.

Table 9-9 presents the costs to reduce flooding under two CSO and SSO reduction scenarios. The first includes an RDII removal based solution and the second a conveyance and treatment based solution. Both scenarios were examined to illustrate that regardless of the type of CSO and SSO reduction solution selected, the costs to reduce flooding and asset management must be added to both overflow reduction approaches.

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TABLE 9-9
FLOOD HAZARD REDUCTION (COMPARED TO EXISTING CONDITIONS)

	RDII Removal Based Overflow Reduction	Conveyance and Treatment Based Overflow Reduction
Commercial St - Nine Mile Run (M47)		
Capital Cost to Reduce Flooding[1]	$243M	$243M
Sewer Asset Management Cost	$85.7M	$55.7M[2]
RDII Private Source Reduction Cost	$39.6M	Convey and Treat. No RDII removal
Calera St - Streets Run (M42)		
Capital Cost to Reduce Flooding[1]	$29.8M	$29.8M
Sewer Asset Management Cost	$43.5M	$32.6M
RDII Private Source Reduction Cost	$20.8M	Convey and Treat. No RDII removal
Total Cost	$462.4M	$361.1M[2]
Overflow Volume Reduction (MG)	123	62[3]
TY Volume Removed from RDII reduction (MG)	110	0

[1] Average of regional detention and distributed GI BMP costs. If regional detention can be performed, costs could be lower. Additional evaluation, including storm sewer system surveying, beyond the scope of this Assessment is required to develop final capital costs.

[2] 65% applied to asset management cost for convey and treat to account for lower cost due to only addressing structural and maintenance defects over time and not I/I related defects.

[3] Only about a 50% reduction in overflow volume may be achieved because RDII removal is not performed.

The following observations are noted regarding Table 9-9:

- The costs to reduce flooding are substantial, $243 million for Nine Mile Run and $29.8 million for Streets Run. The capital costs are considered order of magnitude estimate and include the average of regional detention and distributed GI BMP costs. If regional detention can be performed, costs could be lower. Additional evaluation, including storm sewer system surveying, beyond the scope of this Assessment, is required to develop final capital costs. See Section 4 of this report for further details.
- Regardless of the type of overflow reduction solution selected, additional costs to reduce flooding and manage the existing sanitary and storm sewer assets are required. On a relative cost per gallon of overflow reduced, the RDII removal based solution provides a better value. Demonstration projects to holistically address the stormwater in both the storm and sanitary systems should be performed to better quantify the costs and associated benefits. For this reason, the capital costs for this work in Nine Mile Run and Streets Run are not included in the alternatives presented later in this section.
- The results indicate that the stormwater runoff leading to the flooding primarily originates from municipalities outside of the City's borders. It is recommended that PWSA work with the upstream municipalities, primarily Wilkinsburg and Edgewood in Nine Mile Run, and Brentwood, Baldwin and Whitehall in Streets Run, to perform the recommended demonstration projects. This type of collaboration and the types of demonstration projects encouraged are consistent with the flow targets and source reduction approach being required by the regulators and would provide good example demonstrations to show the multiple benefits of flooding reduction, RDII reduction, and asset renewal that can be achieved.

9.5 Urban Planning

PWSA undertook a strategic urban planning process focused on developing a holistic "Green First" approach. This approach emphasizes the identification of opportunities that support both resilient infrastructure strategies and are catalytic redevelopment opportunities within individual Pittsburgh sewersheds. The City and many engaged collaborative partners continue active planning pursuits that focus on the same streets, neighborhoods, and parks; these are common areas with the high-yield drainage areas where GI was being targeted as part of this Assessment. Through a highly collaborative planning process, PWSA worked with various stakeholders to understand each community's assets, current planning processes, and community goals, and secured community and stakeholder input. Section 6 of this report more fully describes this process and approach.

From the synthesis of three primary factors (planned redevelopment, existing conditions, and high yield stormwater runoff areas targeted for GI), six priority sewersheds were selected where proposed GI would best complement strategic urban development plans, existing characteristics, and high yield areas to most effectively illustrate what a Green First approach could look like for the six selected priority sewersheds in the City. The six selected areas are shown in Table 9-10.

TABLE 9-10 GI AND URBAN PLANNING ANALYSIS LOCATIONS		
City Area/Neighborhood	**Sewershed Point of Connection (POC)**	**River Basin**
Four Mile Run	M-29	Monongahela River
Washington Blvd and Negley Run	A-42	Allegheny River
South Side	M-16	Monongahela River
Woods Run	O-27	Ohio River
Heth's Run	A-41	Allegheny River
Hill District/Uptown	M-19	Monongahela River

PWSA worked with the stakeholders to establish a set of Guiding Principles to further assist in the selection of the GI locations with the sewersheds that combined the data driven, technical metrics used to measure the effectiveness of CSO reduction within the priority sewersheds. These Guiding Principles emerged from discussions with the Mayor and his staff, multiple City departments, and key community stakeholders.

Many of these Guiding Principles support the quantitative outcomes for CSO reduction; others, however serve to broaden the lens and establish qualitative outcomes to improve the communities where these investments are being made, further complementing the redevelopment efforts proposed in these areas. The Guiding Principles offer an additional benefit: they better leverage the limited resources of City departments into a shared effort.

The seven Guiding Principles that framed the urban planning processes included in this effort are outlined below along with a brief description of each:

1. **Cost-Effective Public Realm Investment:** By investing in City-owned property within the public realm the cost of acquired private property for GI is avoided. Furthermore, improvements can be more efficiently shared across City departments when other planned improvements are coordinated

2. **Create Workforce Development Opportunities:** Investment in GI should be viewed as an opportunity to provide jobs, especially within communities that would best benefit from access to new or better employment opportunities. Ideally, workforce development will encompass all segments of the populations to develop lifelong careers, from the PhD's researching and monitoring the effectiveness of GI, to the "Ph-Do" working to implement the construction of proposed GI in addition to maintaining it.

3. **Re-Establish Riverfront Connections:** As Pittsburgh further redevelops and enhances its numerous riverfront areas, opportunities to improve and create new

riverfront connections should be explored in conjunction with proposed GI, providing pathways linking people and runoff to the City's three rivers.

4. **Complete Streets Approach:** Pittsburgh is looking to develop a network of key City corridors into complete streets, which are streets that focus multiple modes of transportation, placing emphasis on public transit, bicyclists, and pedestrians. GI should be incorporated within these complete streets as many of the corridors also have the highest potential to reduce CSO.
5. **Focus on Healthy, Walkable Communities:** Emphasis should be placed on enhancing corridors to improve access to recreation and healthy food, and encourage walking beyond the Complete Street corridors. GI can leveraged to further enhance the effectiveness of improving the overall health and safety of a community.
6. **Resilient Infrastructure:** GI can be used to support the efforts of the City in becoming more resilient by reducing flooding, decentralizing runoff capture, and upgrading the aging infrastructure through asset management. Creating a smart system utilizing and optimizing the existing infrastructure that more effectively and efficiently handles stormwater today and in the future.
7. **Align with People, Planet, Place and Performance (P4) Metrics:** Pittsburgh's P4 looks to forge a new model for urban growth and development that is innovative, inclusive and sustainable. GI certainly addresses all four of the components of this framework.

From these Guiding Principles, GI concept plans were developed within each of the 6 urban planning sewersheds focused around the high yield stormwater runoff areas while also weaving these opportunities into a larger vision that creates neighborhood nodes, corridors, and links community assets with interconnected GI strategies. The sewershed-based systems approach used urban planning and community revitalization to shape the GI concept plans, serving as a catalyst for a broader vision that can be implemented and embraced by the local communities.

9.5.1 Urban Plan Capital Costs

The capital costs for the GI proposed as part of the six sewersheds urban plans assume that the identified high yield stormwater runoff areas are captured within each sewershed and stormwater runoff is detained and slowly returned back to the CSS. The same assumptions for GI sizing and cost estimating as described in Sections 7 and 9.1 of this report were applied to the GI included in the urban plans. The following items are not included in the urban plan GI capital costs:

- Daylighting of captured stormwater flows to the rivers in each of the 6 sewersheds, except for Panther Hollow Lake in M-29 (which was included in the costs as a stream removal location). Further study and stakeholder coordination is required to evaluate the costs and added benefits of additional stream daylighting of captured stormwater flows to the rivers.
- Property acquisition costs outside of the right-of-way were not included. Some urban plan concepts have been developed that could be located on currently abandoned private properties or properties not currently owned by the City, for

example, the re-creation of Silver Lake in A-42. Because of the unknowns of property acquisition, the costs and associated benefits of siting GI at these private property locations requires further study. However, the associated stormwater in the high yield stormwater runoff areas surrounding these locations is still included in the developed capital costs with the designation of GI being located in the right of way to capture high yield stormwater runoff should the private property acquisition costs prove to not be feasible or cost-effective.

The GI costs for the urban plans, not including the above described exceptions, are included in the Green First Plan costs presented in Section 9.6 below.

9.6 Green First Plan Results

The purpose of the City-Wide GI Assessment was to determine the opportunities for implementing large scale GI across the City to address a variety of issues, including combined sewer and sanitary sewer overflows, stream inflow removal/detention, localized flood hazard reduction, basement sewage backup reduction during rain events, and developing a stormwater overlay lens for use as a comprehensive planning tool for future new and redevelopment. The results of the developed Green First alternatives are summarized in Tables 9-11 and 9-12. The results indicate that maximizing the treatment plant capacity and optimizing the existing tunnel assets have great value. The GI that is needed for additional overflow reduction to meet the 85% combined sewage capture goal can also reduce basement sewage backups and localized surface flooding.

TABLE 9-11 CAPITAL COSTS AND OVERFLOW REDUCTION FOR THE 30 PRIORITY SEWERSHED GREEN FIRST APPROACH				
System	Plant Capacity (MGD)	480 MGD WWTP Expansion	600 MGD WWTP Expansion & System Improvements	Lowered HGL Operation During Wet Weather Conditions
	Sediment Removed From Existing Tunnel?	No	Yes	Yes
	19 of 30 CSO Underflows Modified to Allow More Flow to Tunnel?	No	Yes	Yes
City-Wide	GI Impervious Area Managed (acres)	1,835	1,835	1,286
	Flood Hazard Reduction and Overflow Reduction Costs included?	Only Frankstown Road and Morange Road Included		
	Stream Removal/Detention Costs included?	Panther Hollow, Woods Run, and Spring Garden Included		
	Surface Flooding and Basement Sewage Backup Reduction Costs Included?	In sewersheds where GI is located, it was assumed that GI would be designed for a flooding level of protection up to a rainfall intensity of 1.05 inches in 15 minutes.		
System Improvements	WWTP Upgrade Capital Cost ($M) [1]	$334	$378	$378
	Existing Tunnel Cleaning and Modernization Allowance ($M) [2]	$0	$200	$200
	New Wet Weather Pump Station Cost to Allow Lower HGL Operation ($M) [3]	$0	$0	$150
	High Rate Treatment at WWTP to treat flows above 600 MGD ($M) [2]	$0	$0	$70-$100

TABLE 9-11
CAPITAL COSTS AND OVERFLOW REDUCTION FOR THE 30 PRIORITY SEWERSHED GREEN FIRST APPROACH

GI + Stream Removal	Green Infrastructure ($M) [4]	$690 – 920	$690 – 920	$490 – 660
	Stream Removal/Detention ($M)	$46 – 62	$46 – 62	$46 – 62
	Total Capital Cost ($M)	**$1,070 – 1,310**	**$1,310 – 1,560**	**$1,340 – 1,550**
	Total System Wide Overflow Reduction (BG)	**4.09**	**5.00**	**5.20**

[1] From ALCOSAN Wet Weather Plan Report (2013).

[2] Allowance.

[3] From ALCOSAN Wet Weather Plan report (2013). Used cost for new tunnel dewatering pump station.

[4] Includes costs for GI, downspout disconnections, Frankstown Road (part of the A-42 estimated cost), and Morange Road flooding reduction ($33 M).

TABLE 9-12
TOTAL COSTS (INCLUDING O&M) FOR THE 30 PRIORITY SEWERSHED GREEN FIRST APPROACH

	480 MGD WWTP Expansion	600 MGD WWTP Expansion & System Improvements	Lowered HGL Operation During Wet Weather Conditions
GI Impervious Area Managed (acres)	1,835	1,835	1,286
Total Capital Cost ($ Million)	**$1,070 – 1,310**	**$1,310 – 1,560**	**$1,340 – 1,550**
Total System Wide Overflow Reduction (billion gallons)[1]	**4.09**	**5.00**	**5.20**
Total Capital Cost Per Overflow Gallon Reduced	**$0.26 – 0.32**	**$0.26 – 0.31**	**$0.26 – 0.30**
Annual O&M Cost for GI (at buildout) ($ Million)	$8.1	$8.1	$5.7
50-Year Net Present Value (Annual O&M + GI Replacement at Year 25) ($ Million)	$288	$288	$202
Total Net Present Value Cost ($ Million)	**$1,358 – 1,598**	**$1,598 – 1,848**	**$1,542 – 1,752**

[1] SWMM 5.1.009 Results.

9.6.1 Key Points for Interpreting Comparisons with ALCOSAN's Recommended Plan

Some of the components from the City-Wide GI Assessment described in this report have many similarities to, but also many important differences from, ALCOSAN's Recommended Plan. Both plans are composed of a combination of projects to help mitigate ALCOSAN's and the region's CSOs and SSOs. When the analyses were being conducted for this Assessment, the Recommended Plan report (2013) and Starting at the Source report (2015) were the most recent ALCOSAN public documents available. It is important to note that ALCOSAN is still in negotiations with the US EPA regarding the details of the plan to be implemented. If the plan agreed to between ALCOSAN and the regulators differs from the Recommended Plan, some of these points may change or no longer apply. Listed below are some of the most important differences between the Green First Plan and the Recommended Plan.

- **The Recommended Plan was developed with sufficient detail to be directly implementable while the Green First Plan was intended to determine what could be possible if a large scale GI approach were implemented.** ALCOSAN's Recommended Plan was developed over several years and by numerous consultant teams specifically to provide a detailed and implementable plan to address specific collection system issues and comply with the terms of their Consent Decree. The Green First Plan, as it has been developed to date, provides valuable insight into how effective a GI focused plan could be, but it has not been developed to the same level of detail as the Recommended Plan.
- **The Recommended Plan focuses on the entire tributary collection system to the WWTP while the Green First Plan focusses on the 30 priority sewersheds.** The Recommended Plan was specifically developed to provide particular outcomes for SSO reduction, CSO reduction, and prioritization of sensitive receiving water areas. The various components of the Recommended Plan were developed to meet specific regulatory requirements. The Green First Plan focused on the 30 priority sewersheds and what benefits could be realized in those areas from a large scale GI approach. Although both approaches provide some similar benefits (i.e., untreated overflow reduction) they do not provide benefits necessarily in the same locations or to the same benefit level.
- **The Recommended Plan was specifically developed to achieve outcomes related to ALCOSAN's responsibilities in the functioning of the overall collection system.** ALCOSAN is responsible for both larger sized conveyance features (shallow-cut and deep interceptors) that convey wastewater from tributary systems and for treating the conveyed wastewater before discharging it to receiving waters. As would be expected, the Recommended Plan focuses on mitigating negative aspects that are relevant to its responsibilities (principally reducing untreated CSO and SSO discharges). However, upstream tributary systems (such as PWSA) have other outcomes they are trying to achieve beyond just mitigating untreated overflows. Much of the Green First Plan is focused on these other outcomes such as reducing localized surface flooding, reducing basement sewage backups, disconnecting streams from entering the collection system, and evaluating the potential benefits of urban planning opportunities, in

addition to the reduction of untreated overflows. Because the focus of these two plans are very different, the results that each provides needs to be understood in the context of what they were each trying to achieve.

- **Although the goals and outcomes of ALCOSAN's Recommended Plan and the Green First Plan are different, some types of comparisons can be performed.** Reducing overflow volumes is one of the most common regulatory requirements for any long term control plan. Although the Recommended Plan and the Green First Plan have different goals and types of benefits, they both provide overflow reduction as a key benefit. As a result, comparing the overflow reduction benefits can provide meaningful insight on the benefits of the two plans. However, it is important to reemphasize that the relative portion of the CSO vs. SSO reductions of the two plans will be different and the locations of where the overflow reductions occur will not be the same.
- **The Green First Plan scenarios incorporate some common gray components and some different gray components compared to the Recommended Plan.** The Recommended Plan includes the construction of new tunnels and increasing the capacity of the Woods Run WWTP as core components of the plan. The scenarios investigated for this Assessment also include increasing the capacity of the WWTP, but also include improvements not currently in the Recommended Plan. One such element is the removal of the sediment in the existing interceptor tunnels that is assumed as part of the 600 MGD (WWTP Expansion) and the Lowered HGL Operation scenarios. Removing the sediment allows greater flows to be conveyed to the WWTP. ALCOSAN does not assume the removal of the sediment in the interceptor tunnel as part of the Recommended Plan. Also, the Lowered HGL Operation scenario assumes that an HGL level in the Main Pump Station wet well at a level that is also not incorporated into the Recommended Plan. These operational conditions would need to be studied in coordination with ALCOSAN to determine their viability.

9.7 Triple Bottom Line Benefits

TBL benefits represent a unique value addition of GI implementation. Section 8 detailed the various TBL benefits calculated for this Assessment and a summary of those results is included in Table 9-13 for both the 1,286 and 1,835 impervious acres managed scenarios. These benefits are calculated assuming a 10-year construction period and a 50-year in service period for the GI. The total TBL benefits range between $390 million and $850 million net present value (NPV). It is important to note that this flood reduction benefit is the flood reduction provided by the distributed GI and not from the specific flood hazard investigations detailed in Section 4 of this report. These TBL benefits from implementing the recommended City-Wide GI Assessment offer significant benefits to the City and associated ratepayers; benefits not currently available with a solely gray infrastructure approach to overflow and localized flooding reduction.

TABLE 9-13
50-YEAR TBL NET PRESENT VALUE (NPV) BENEFITS

Category	GI TBL Benefits (90% Confidence Interval NPV)			
	1,286 GI Managed Acres		1,835 GI Managed Acres	
	Low	High	Low	High
Air Pollution Reduced by Vegetation	$5,070,000	$9,180,000	$7,260,000	$13,090,000
Carbon Reduced by Vegetation	$710,000	$2,960,000	$1,010,000	$4,220,000
Flood Risk Reduction	$333,130,000	$666,260,000	$335,750,000	$671,500,000
Heat Island Effect Reduction	$3,020,000	$6,750,000	$4,280,000	$9,610,000
Property Value Increase	$33,120,000	$68,270,000	$54,770,000	$112,900,000
Recreational Value Addition	$9,880,000	$15,550,000	$14,120,000	$22,210,000
Economic Water Quality Benefit	$7,280,000	$9,780,000	$10,390,000	$13,950,000
Total TBL Benefit	**$392,212,000**	**$778,750,000**	**$427,580,000**	**$847,480,000**
Total Benefit / GI managed impervious acre	**$305,000**	**$606,000**	**$233,000**	**$462,000**

It is also likely that the true TBL benefits are higher than those listed in Table 9-13. The numbers are likely conservative for the following reasons:

- **Not all TBL benefit types were included in the calculations.** An example is the Shadow Wage benefit which results from jobs created by the GI projects for operations and maintenance, material supply and construction. Insufficient local data was available to perform these calculations. However, the GI O&M costs development determined that 17 to 25 new jobs, 1,286 managed acres and 1,835 managed acres scenarios respectively, for GI O&M would be created. It is recommended that further analysis is performed to confirm the Shadow Wage benefits associated with the City-Wide GI program.
- **Conservative assumptions have been made for the Flood Risk Reduction benefit.** Although the Flood Risk reduction benefit is by far the largest TBL value it is still likely conservative – meaning that the actual calculated value is less than the likely real benefit. For example, the property devaluation from having a flood prone house or property has not been included in the calculation. Having a history of basement or property flooding will almost certainly reduce a home's value when trying to sell it or it could potentially make the home unsellable. Based on the number of properties projected to be affected by localized surface flooding and basement sewage backups, the cumulative property devaluation and the associated increase in resultant property values from the localized flood reduction by GI is likely significant and if included would further increase the Flood Risk Reduction benefit.

9.8 Key Findings and Recommendations

The data and results generated from this Assessment lead to the following key findings and recommendations:

9.8.1 Key Findings:

1. **Acknowledge additional clean water regulatory requirements for the City.** Large-scale GI investment is attractive because it provides multiple benefits and can address multiple regulatory requirements, including overflow reduction and water quality, localized surface flooding reduction, and basement sewage backup reduction during rain events, and can provide asset management..
2. **May achieve nearly equal overflow volume reduction and potentially reduce costs compared to the Recommended Plan.** Large scale GI investment across a subset of the selected 30 priority sewersheds combined with key gray infrastructure investments can result in a feasible and cost-effective solution. The results from Tables 9-11 to 9-13 indicate that a reduction of between 4.1 BG and 5.2 BG of untreated CSO and SSO volume in the ALCOSAN conveyance and treatment system could possibly be achieved by investing in the existing WWTP, the existing interceptors and GI in a subset of the 30 priority sewersheds evaluated in this Assessment. These scenarios also provide other TBL and flow reduction benefits that makes these compelling alternatives that appear deserving of further detailed study and demonstration.

3. **Provides significant TBL benefits.** The calculated TBL benefits range from $390M to $850M from the distributed GI implementation. The calculated TBL benefits included in this report do not include all potential TBL benefits that could be realized. It is expected that other TBL benefits, such as the creation of green jobs to construct, operate and maintain the GI could also be significant.

4. **Addresses reduction in overflows, localized surface flooding, and basement sewage backups, and increases the resiliency of the existing sewer infrastructure.** By designing GI to provide distributed storage and source control, the root causes of overflows, flooding, and poor water quality – excessive amounts of stormwater runoff – can be reduced.

5. **Removes or detains streamflows from the ALCOSAN system.** The GI program recommends that the 10 largest sources of direct stream inflow be removed and/or detained to reduce overflows and reduce sediment from entering the ALCOSAN interceptors. This approach may also allow for targeted investment to modernize the existing deep tunnel interceptors by adding additional access shafts to enable more effective cleaning and future maintenance.

6. **Supports the development of local community urban plans.** PWSA undertook a strategic urban planning process focused on developing a holistic “Green First” approach. This approach emphasized the identification of GI opportunities that can support resilient infrastructure strategies and can be catalytic redevelopment opportunities. PWSA, through a highly collaborative planning process, worked with the various stakeholders to understand each community’s assets, current planning processes, community goals, and input.

7. **Demonstrates the value of source control to the entire region. The benefits from this Assessment extend to the municipalities beyond the City.** The Green First alternatives provide multiple regional benefits to the tributary municipalities. The sewer collection system is inextricably and hydraulically linked. Taking a stormwater gallon out at one location frees up capacity for another stormwater gallon to enter elsewhere. By capturing and slowing the stormwater down within the City and surrounding areas, this effectively frees up capacity in the existing interceptors to allow portions of the municipalities’ flows to make it to the WWTP, thereby also reducing regional overflows. The results show that overflow volume systemwide is reduced and may provide similar overflow volume reduction to ALCOSAN’s Recommended Plan.

8. **The methodologies and “blueprints” from this Assessment can be applied Region-wide.** High yield stormwater runoff capture locations both within the combined sewer systems (CSS) and separate sewer systems (SSS) exist across the ALCOSAN service area. This study revealed that the region has a stormwater management problem that leads to having a CSO and SSO problem and excessive stormwater entering the CSS and SSS in many locations across the service area. Intercepting and managing this stormwater locally provides multiple benefits for far reaches downstream. The results support and re-affirm a regional approach to stormwater management at the locations that maximize stormwater management, overflow reduction, and local community benefits.

9. **Implementing GI does not limit any future gray or green infrastructure investment.** The nature of GI projects allows them to be implemented incrementally while evaluating their effectiveness on the system conveyance. Most gray infrastructure does not lend itself to an incremental investment. For example, a storage tank must be built to a defined volume that is expected to meet a performance requirement. If it is later determined that additional storage is needed, it is typically not possible to "scale up" the existing tank and a completely new tank would need to be built. Because its performance can be continuously evaluated, the risk of overbuilding or underbuilding GI is greatly reduced versus traditional gray infrastructure. GI can be complementary to any future infrastructure investment.

10. **Employs GI technologies that shave off peak flows during and after wet weather events.** The high yield GI elements in this Assessment were structured to apply a "delay and slow return" approach rather than being intended to physically remove the flows from the collection system. Even when applying a conservative 0.1 in/hr infiltration rate for the periods when the flow was resident in the GI elements, significant volumes are predicted to be offloaded from the collection system. Over the typical year roughly 40 percent of the flow that enters the modeled GI BMPs is removed due to evaporation and infiltration. These findings will be confirmed with the planned demonstration projects.

9.8.2 Key Recommendations:

1. **Work with ALCOSAN and support efforts to maximize the ultimate capacity of the Woods Run WWTP.** The system improvement modeling simulations during this Assessment determined that the most foundational improvement for reducing untreated overflows in the ALCOSAN tributary collection system is upgrading the Woods Run WWTP wet weather treatment capacity.

2. **Work with ALCOSAN and support efforts to maximize the conveyance capacity and develop effective asset management options for ALCOSAN's existing deep interceptors.** After the Woods Run WWTP, improving the conveyance and asset management condition of the existing deep interceptors is the next best investment to reduce untreated overflows and increase the viability of GI alternatives. The construction of new access shafts to the existing deep interceptors would improve accessibility, address issues with entrained air, enable proper cleaning and maintenance, and with improved access for inspection and maintenance, reduce the risk of a failure. PWSA can proactively assist by supporting removal of influent streams and building grit traps to keep sediment from being carried by streamflows into the interceptors. This can significantly reduce the sediment load being conveyed to the interceptors and reduce future cleaning needs.

3. **Advocate, support and investigate the application of real time controls to PWSA diversion chambers as a potential additional cost effective effort to increase performance of the existing collection system infrastructure.** The flow control devices in most existing diversion structures consist of tipping gates that are configured to allow reduced flows to enter the interceptors during wet weather conditions to prevent overloading. Adding real time control to these

existing flow control devices at the interceptors could allow optimized control of flows and could provide even greater overflow reduction.

4. **Implement several demonstration projects and evaluate their performance.** The GI demonstration projects will provide local data on how well the various GI BMPs perform and confirm the modeling assumptions used. Evaluation of these initial results will serve as a checkpoint to determine if the GI BMPs are performing as expected or if course correction is needed.

5. **Based on the intelligence from the GI demonstration projects, implement large-scale targeted GI installations.** Assuming the demonstration projects provide positive results, it is recommended that the highest yield stormwater locations identified in the 30 priority sewersheds be targeted first in a broader GI implementation. This implementation would provide the first large-scale results and another important check of GI performance, to evaluate if it continues to represent the most cost effective investment to meet PWSA's and the region's regulatory requirements.

6. **Use the collected data to improve the ALCOSAN SWMM model to enable it to be effectively used for PWSA, the City, and the region.** The SWMM model provided by ALCOSAN for this Assessment was originally built to evaluate larger scale gray infrastructure for the specific purpose of evaluating existing CSO and SSO volumes and the corresponding CSO and SSO reduction benefits of various gray alternatives. PWSA's goals include addressing issues such as designing specific GI implementations, evaluating upstream impacts such as basement sewage backups and direct stream inflows, as well as reducing localized surface flooding hazards. Each of these priorities require more model detail than the current SWMM model provides to allow for more accurate quantification of these geographically disparate problems and solutions. As the model detail is improved, potential GI investments can be more accurately evaluated, sized, and targeted to address specific problems.

7. **Work with neighboring municipalities to implement demonstration projects in both the CSS and SSS to confirm the value of source control.** High yield stormwater capture locations, both within the CSS and SSS, exist across the entire regional ALCOSAN service area. The region's stormwater management problem knows no political boundaries. Siting and implementing projects that can demonstrate the different types and effectiveness of source control that benefit the local municipality, and also PWSA and ALCOSAN, is an important next step.