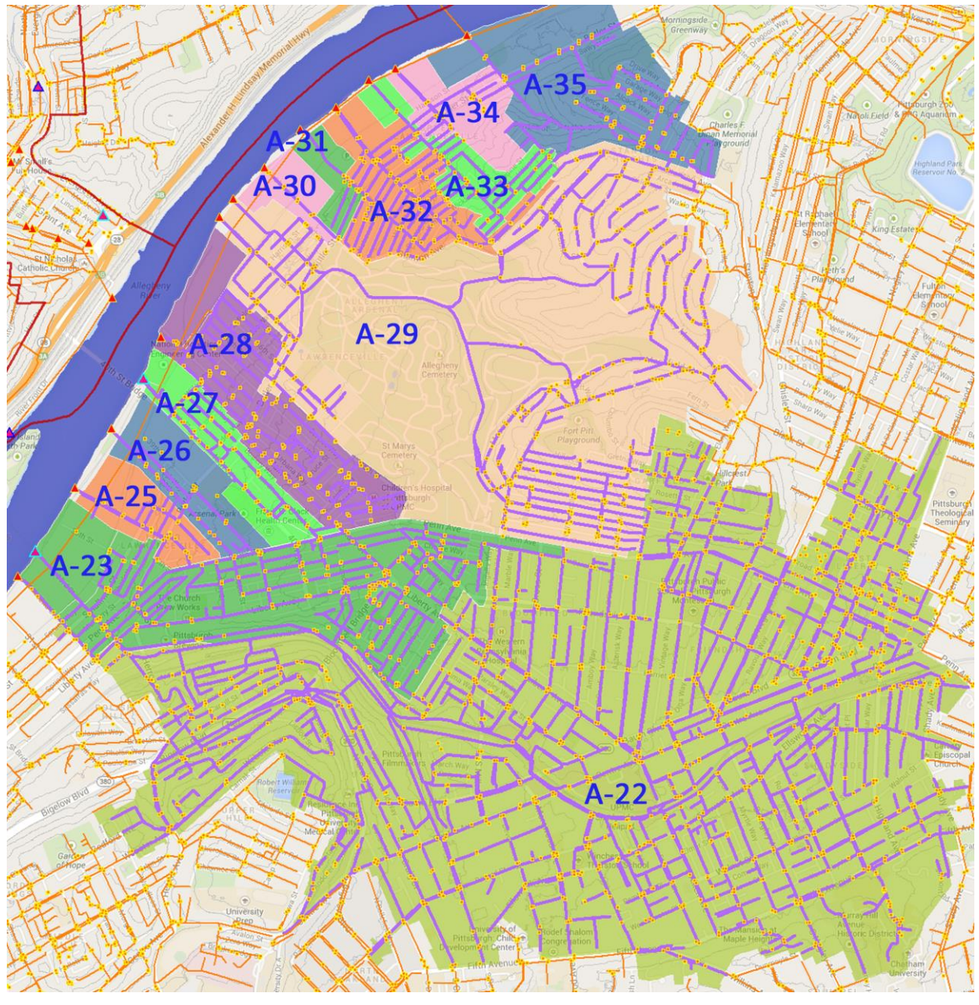
# Appendix E-6 – Lawrenceville GSI Pilot Study

# High-Yield Green Stormwater Infrastructure (GSI) Pilot Study

# Combined Wastewater Sheds A-22 through A-35

Prepared for ALCOSAN

07-25-2014 updated 7-30-2014




Landbase Systems GOALprocess + EPA SWMM

412 563-1920

ALCOSAN Lawrenceville GSI Pilot in Sheds A-29/29z and A-34

# 1 Task 1 Pilot Area Maps for Review

***SCOPE:*** *Provide a GIS shape file and accompanying PDF showing all known or assumed stormwater inlets within the pilot study area. The shape file should include the following information for each inlet:*

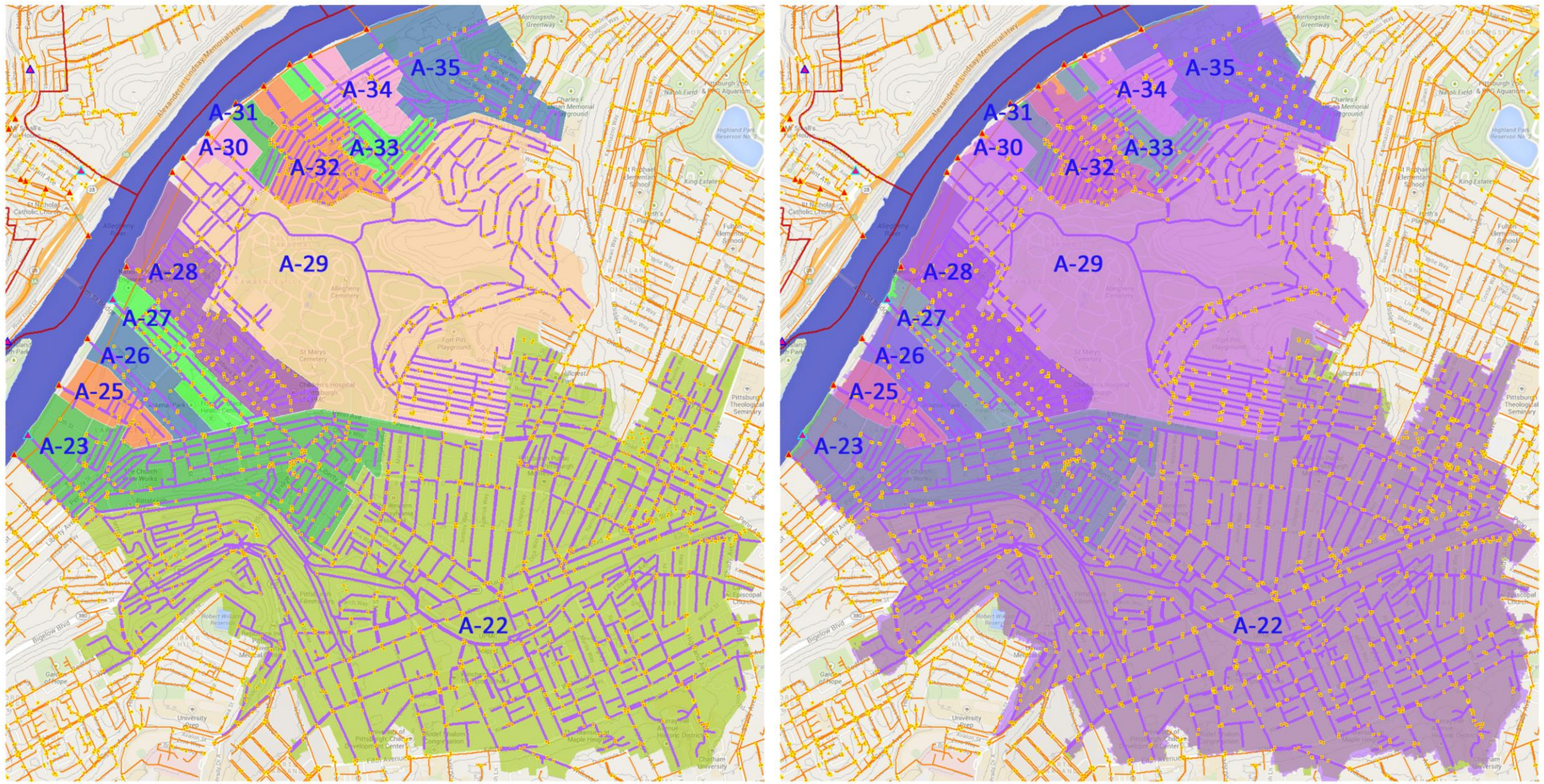
- *The sewershed the inlet is located within*
- *A unique ID number for each inlet*

Landbase Systems provided ALCOSAN with 2,194 known inlet locations to the pilot area A-22 through A-35.

## 1.1 A-22 through A-35 Pilot area with Points-of-Connection, Waste Water Pipe, known Inlets, and detailed 3D GOALprocess catchment boundaries

Landbase Systems delivered current known inlet locations to ALCOSAN. The image on the right has a transparent purple overlay of detailed 3D GOALprocess surface flow catchments. In the boundary of the Pilot area there are only minor outside edge differences between the underlying SWMM catchments/master sewersheds and the GOALprocess 3D surface catchment boundaries.

**PIlot Area, Wastewater Sheds, Point-of-Connection Names,** and **GOALprocess catchments** (purple overlay)



## 2 Task 2: Runoff, Net Impervious Acres, and Gross Impervious Acres Summary of Known Inlets in POCs A-22 through A-35

***SCOPE:*** *Using the 2003 typical year precipitation data and SWMM model Green-Ampt infiltration parameters rank all known or assumed stormwater inlets and their drainage areas by:*

- *2a) NET annual runoff volume, as estimated by the GOALprocess using the calibrated SWMM runoff model*
- *2b) Areas of NET impervious cover tributary to the inlet (impervious = roof tops plus impervious ground surfaces)*
- *2c) Areas of GROSS impervious cover tributary to the inlet*

*The summaries of impervious cover should include all building rooftop acres.*

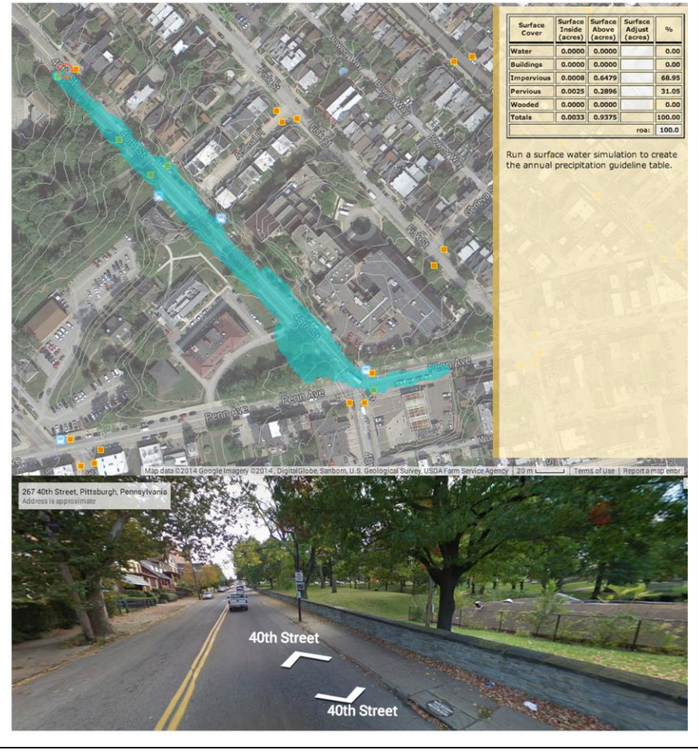
### 2.1 Example of Gross versus Net Drainage Areas in a Developed Landscape

In the developed environment, curbs, gutters, road crowns, buildings, and walls must be taken into account when defining drainage areas. These real world three-dimensional features have a dominant effect on where and how surface water runoff flows and the boundary of drainage areas. The GOALprocess accounts for these features when evaluating and defining high-yield sites.

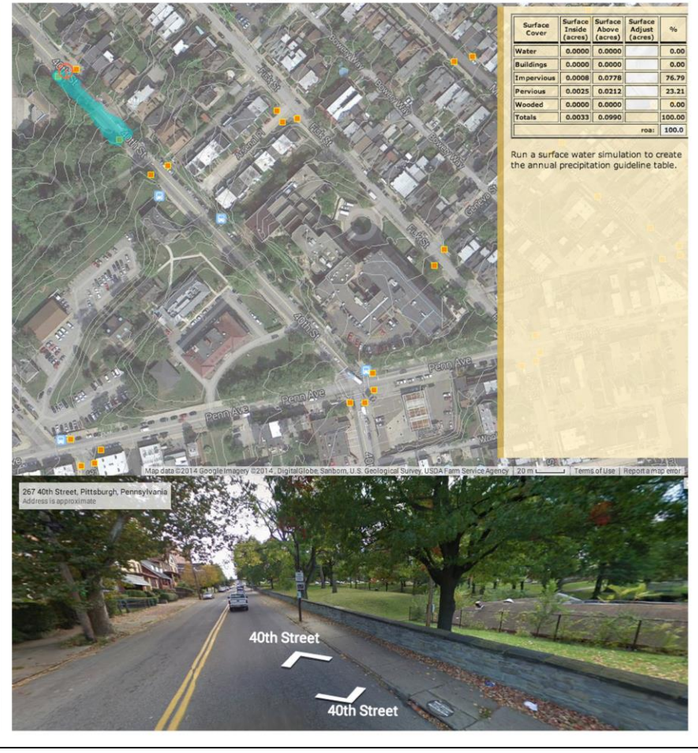
The following drainage areas represent the range of likely drainage area (and runoff area) under various conditions (low rainfall, high rainfall, functional inlets, clogged/unmaintained inlets…)

GROSS drainage area (left image below) assumes all inlets above a focus location do NOT work. The image on the left illustrates a 'Gross Drainage Area' that assumes all inlets within the highlighted area do NOT intercept any runoff. The gross drainage area is 0.9375 acres (nearly 10 times larger than the Net drainage area). NET drainage area assumes all inlets above a focus location DO work and NO runoff flows to the focus location. The image on the right illustrates a 'Net Drainage Area' that assumes all inlets above the highlighted area DO intercept all runoff. The Net drainage area is 0.099 acres (about 1/9th of the Gross drainage area).

GOALprocess GROSS drainage area to an inlet




GOALprocess NET drainage area to an inlet



## 2.2 Ranking Data: Database ranking of current known inlets within wastewater sheds A-22 through A-35 along the east short of the Allegheny River

Below is a thumbnail image and summary of the database attributes provided on each of the 2,177 ranked combined network inlet locations (2,194 total included dedicated storm inlets). The document was provided on 4/3/2014 and named '140403_LBs-Task2-Gp_SurfaceFlowRanked_Inlet…xlsx'

**GOALprocess Summary of Inlet Drainage Areas in A-22 through A-35**
Task 2 and Foundation for Task 3 Ranking POCs
LBs20140319 updated 20140327

| status | Pilot_ID | focus_area | swmm_model | swmm_catchment | swmm_outfall | meta_RO_rank_pilot | meta_net_imperv_rank_pilot | meta_of ALL gross_imperv | meta_storm_sys | runoff_net_MG | imperv_bldg_net | imperv_bldg_gross | net_above | net_above_buildi | net_above_imperv | net_above_perv | gross_above | gross_above_buildi | gross_above_imperv | gross_above_perv | inlet_above |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | ua | ua_A-35 | ua_A-35-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 15.373 | 4.81 | 5.61 | 28.65 | 1.91 | 2.89 | 23.84 | 30.83 | 2.25 | 3.36 | 25.22 | 11 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | ua | ua_A-35 | ua_A-35-OF | highest 5% inlet runoff wit | highest 10% net impervious [43.9% o | highest 50% of ALL gross impervi | combined storm | 3.575 | 0.84 | 0.84 | 6.90 | 0.31 | 0.52 | 6.06 | 6.90 | 0.31 | 0.52 | 6.06 | 0 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-30 | mr_A-30-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 3.356 | 4.07 | 4.13 | 4.24 | 3.16 | 0.90 | 0.17 | 4.31 | 3.17 | 0.96 | 0.19 | 1 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-23 | mr_A-23-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 3.089 | 3.51 | 15.46 | 5.10 | 1.68 | 1.83 | 1.59 | 27.06 | 7.58 | 7.88 | 11.60 | 19 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | ua | ua_A-35 | ua_A-35-OF | highest 5% inlet runoff wit | highest 10% net impervious [43.9% o | highest 15% of ALL gross impervi | combined storm | 3.115 | 0.69 | 1.69 | 6.09 | 0.37 | 0.31 | 5.40 | 13.38 | 0.68 | 1.01 | 11.69 | 3 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-23 | mr_A-23-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 3.015 | 3.26 | 6.75 | 5.94 | 1.84 | 1.41 | 2.68 | 12.08 | 3.55 | 3.20 | 5.33 | 9 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-22 | mr_A-22-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.996 | 3.00 | 5.91 | 7.01 | 1.13 | 1.87 | 4.01 | 15.82 | 2.31 | 3.60 | 9.90 | 20 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-22 | mr_A-22-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.971 | 3.64 | 3.78 | 4.07 | 3.41 | 0.23 | 0.43 | 4.51 | 3.43 | 0.36 | 0.73 | 4 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-23 | mr_A-23-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.853 | 3.05 | 4.30 | 4.83 | 1.12 | 1.93 | 1.78 | 6.80 | 1.71 | 2.59 | 2.50 | 4 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-27 | mr_A-27-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.780 | 3.00 | 3.61 | 5.27 | 1.53 | 1.47 | 2.27 | 6.32 | 1.86 | 1.75 | 2.71 | 5 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-23 | mr_A-23-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.782 | 3.09 | 3.35 | 4.80 | 1.86 | 1.23 | 1.72 | 5.13 | 1.87 | 1.49 | 1.78 | 3 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | ua | ua_A-35 | ua_A-35-OF | highest 5% inlet runoff wit | highest 10% net impervious [43.9% o | highest 10% of ALL gross impervi | combined storm | 2.628 | 0.76 | 2.67 | 4.95 | 0.31 | 0.45 | 4.19 | 18.77 | 1.06 | 1.61 | 16.10 | 6 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-32 | mr_A-32-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.622 | 2.88 | 3.05 | 4.61 | 1.47 | 1.41 | 1.73 | 4.83 | 1.49 | 1.56 | 1.78 | 4 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-22 | mr_A-22-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 10% of ALL gross impervi | combined storm | 2.538 | 2.65 | 2.65 | 5.03 | 1.04 | 1.61 | 2.38 | 5.03 | 1.04 | 1.61 | 2.38 | 0 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-29 | mr_A-29-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 10% of ALL gross impervi | combined storm | 2.394 | 2.11 | 2.11 | 8.24 | 0.69 | 1.43 | 6.13 | 8.24 | 0.69 | 1.43 | 6.13 | 0 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-22 | mr_A-22-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.380 | 2.56 | 4.54 | 4.09 | 0.99 | 1.57 | 1.53 | 11.08 | 1.81 | 2.73 | 6.54 | 9 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-28 | mr_A-28-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.286 | 2.50 | 3.81 | 4.02 | 1.25 | 1.25 | 1.52 | 6.01 | 1.93 | 1.87 | 2.21 | 11 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-28 | mr_A-28-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.274 | 2.57 | 7.88 | 3.11 | 1.15 | 1.42 | 0.54 | 10.47 | 3.86 | 4.02 | 2.59 | 22 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-23 | mr_A-23-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.170 | 2.35 | 8.90 | 3.83 | 1.14 | 1.21 | 1.48 | 14.56 | 3.80 | 5.10 | 5.65 | 6 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-23 | mr_A-23-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.171 | 2.45 | 5.36 | 2.93 | 1.18 | 1.27 | 0.47 | 6.32 | 2.00 | 3.35 | 0.96 | 10 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-23 | mr_A-23-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.122 | 2.25 | 6.55 | 3.92 | 0.96 | 1.30 | 1.67 | 10.73 | 2.66 | 3.89 | 4.17 | 5 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-22 | mr_A-22-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 5% of ALL gross impervic | combined storm | 2.075 | 2.55 | 3.24 | 2.92 | 2.32 | 0.23 | 0.37 | 4.06 | 2.85 | 0.40 | 0.82 | 2 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-29 | mr_A-29Z-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 10% of ALL gross impervi | combined storm | 1.922 | 2.00 | 2.66 | 3.76 | 0.48 | 1.52 | 1.76 | 6.04 | 0.74 | 1.92 | 3.39 | 3 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-28 | mr_A-28-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 10% of ALL gross impervi | combined storm | 1.955 | 2.20 | 2.34 | 3.00 | 1.17 | 1.03 | 0.80 | 3.18 | 1.17 | 1.17 | 0.84 | 1 |
| delivered_1 | cdmPilot_00 | cdmPilot22-35 | mr | mr_A-22 | mr_A-22-OF | highest 5% inlet runoff wit | highest 5% net impervious [29.2% o | highest 15% of ALL gross impervi | combined storm | 1.813 | 1.68 | 1.68 | 6.07 | 0.76 | 0.92 | 4.39 | 6.07 | 0.76 | 0.92 | 4.39 | 0 |

### 2.2.1 Description of database attributes provided for each of the 2,294 known inlet locations within sheds A22 through A-35:

| GOALprocess Inlet Metadata Attribute | Description of contained values | Data Source |
|---|---|---|
| status | delivery date to CDM | management |
| Pilot_ID | unique feature identifiaction value | management |
| focus_area | project reference name | management |
| swmm_model | EPA SWMM model region (mr = MainRivers or ua = UpperAllegheny) | swmm model and wastewater network |
| swmm_catchment_poc | SWMM model point-of-connection name | swmm model and wastewater network |
| swmm_catchment_outfall | SWMM model outfall structure name | swmm model and wastewater network |
| meta_RO_rank_pilot | cateogy summarizing ranking of 2003 typical year SWMM model runoff to each inlet | GOALprocess 3D surface flow network |
| meta_net_imperv_rank_pilot | cateogy summarizing ranking of impervious surface and building rooftop in NET drainage area of each inlet | GOALprocess 3D surface flow network |
| meta_of ALL gross_imperv_rank_pilot | cateogy summarizing ranking of impervious surface and building rooftop in GROSS drainage area of each inlet | GOALprocess 3D surface flow network |
| meta_storm_system | type of stormwater network to which inlet appears to be connected (combined storm, dedicated storm…) | GOALprocess 3D surface flow network |
| runoff_net_MG_swmm | millions of gallons of 2003 typical year runoff that appears to flow off the NET drainage area to the inlet location | GOALprocess 3D surface flow network |
| imperv_bldg_net_AC_above | acres of impervious surface and building rooftop witin the NET drainage area of each inlet | GOALprocess 3D surface flow network |
| imperv_bldg_gross_AC_above | acres of impervious surface and building rooftop witin the GROSS drainage area of each inlet | GOALprocess 3D surface flow network |
| net_above | total acres of NET drainage area of each inlet | GOALprocess 3D surface flow network |
| net_above_buildings | acres of building rooftop in the NET drainage area of each inlet | GOALprocess 3D surface flow network |
| net_above_impervious | acres of impervious surface in the NET drainage area of each inlet | GOALprocess 3D surface flow network |
| net_above_pervious | acres of pervious surface in the NET drainage area of each inlet | GOALprocess 3D surface flow network |
| gross_above | total acres of GROSS drainage area of each inlet | GOALprocess 3D surface flow network |
| gross_above_buildings | acres of building rooftop in the GROSS drainage area of each inlet | GOALprocess 3D surface flow network |
| gross_above_impervious | acres of impervious surface in the GROSS drainage area of each inlet | GOALprocess 3D surface flow network |
| gross_above_pervious | acres of pervious surface in the GROSS drainage area of each inlet | GOALprocess 3D surface flow network |
| inlet_above_count | total nnumber of known inlets within the GROSS drainage area above of each inlet | GOALprocess 3D surface flow network |

Sections 2.2.2 through 2..2.5 on the following pages contain cross-tabulated tables and charts ranking high-yield to low-yield of runoff, net impervious acres, gross impervious listed in this database.

### 2.2.2 Ranking Data: 2a) Millions of Gallons of Net Annual Runoff by Ranked Inlet Location and POC Shed

Millions of Gallons of Net Runoff Grouped by Highest Ranked Inlets and Points of Connection

**Millions of Gallons of Runoff Grouped by Highest Ranked Inlets and Points-of-Connection**

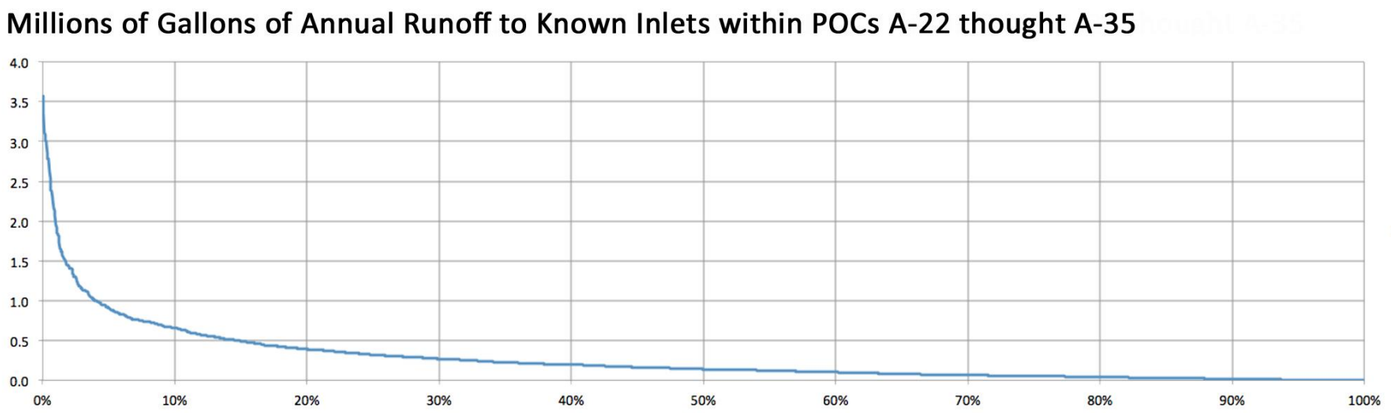
| POC | highest 0-5% inlet runoff within pilot area [30.1% of ALL inlet RO] | highest 5-10% inlet runoff within pilot area [44.1% of ALL inlet RO] | highest 10-15% inlet runoff within pilot area [54.5% of ALL inlet RO] | highest 15-20% inlet runoff within pilot area [62.5% of ALL inlet RO] | highest 20-50% inlet runoff within pilot area [89.1% of ALL inlet RO] | lowest 50% inlet runoff within pilot area [10.9% of ALL inlet RO] | TOTAL |
|---|---|---|---|---|---|---|---|
| mr_A-22 | 58.107 | 39.074 | 32.524 | 20.238 | 85.713 | 38.368 | **274.024** |
| mr_A-23 | 35.165 | 13.659 | 4.540 | 5.368 | 10.963 | 5.239 | **74.934** |
| mr_A-25 | 3.408 | | 2.355 | 0.799 | 1.791 | 0.440 | **8.793** |
| mr_A-26 | 2.321 | 2.327 | 1.723 | 1.826 | 1.718 | 0.190 | **10.105** |
| mr_A-27 | 3.714 | 1.421 | 3.304 | 1.251 | 2.882 | 1.184 | **13.756** |
| mr_A-28 | 11.902 | 5.305 | 4.716 | 5.173 | 9.490 | 3.346 | **39.931** |
| mr_A-29 | 14.487 | 8.882 | 8.118 | 8.366 | 30.193 | 10.450 | **80.496** |
| mr_A-30 | 3.336 | 1.734 | | | 0.497 | 0.150 | **5.716** |
| mr_A-31 | 1.055 | | | | 0.257 | 0.291 | **1.603** |
| mr_A-32 | 13.029 | 2.926 | 2.304 | 1.823 | 6.283 | 2.706 | **29.071** |
| mr_A-33 | 2.480 | 3.056 | 0.556 | 0.431 | 3.114 | 1.077 | **10.715** |
| mr_A-34 | 3.112 | 2.413 | 0.658 | 0.473 | 0.475 | 0.484 | **7.613** |
| ua_A-35 | 27.947 | 2.963 | 1.732 | 2.166 | 5.945 | 1.267 | **42.021** |
| **TOTAL** | **180.062** | **83.760** | **62.530** | **47.913** | **159.321** | **65.192** | **598.778** |

Number of Inlets in each Grouping

**Number of Inlets in each Grouping**

| POC | highest 0-5% inlet runoff within pilot area [30.1% of ALL inlet RO] | highest 5-10% inlet runoff within pilot area [44.1% of ALL inlet RO] | highest 10-15% inlet runoff within pilot area [54.5% of ALL inlet RO] | highest 15-20% inlet runoff within pilot area [62.5% of ALL inlet RO] | highest 20-50% inlet runoff within pilot area [89.1% of ALL inlet RO] | lowest 50% inlet runoff within pilot area [10.9% of ALL inlet RO] | TOTAL |
|---|---|---|---|---|---|---|---|
| mr_A-22 | 41 | 51 | 58 | 46 | 361 | 639 | **1,196** |
| mr_A-23 | 22 | 18 | 8 | 12 | 44 | 94 | **198** |
| mr_A-25 | 3 | | 4 | 2 | 7 | 9 | **25** |
| mr_A-26 | 2 | 3 | 3 | 4 | 7 | 4 | **23** |
| mr_A-27 | 2 | 2 | 6 | 3 | 12 | 19 | **44** |
| mr_A-28 | 7 | 7 | 8 | 12 | 37 | 56 | **127** |
| mr_A-29 | 10 | 12 | 14 | 19 | 124 | 168 | **347** |
| mr_A-30 | 1 | 2 | | | 2 | 4 | **9** |
| mr_A-31 | 1 | | | | 1 | 7 | **9** |
| mr_A-32 | 10 | 4 | 4 | 4 | 24 | 49 | **95** |
| mr_A-33 | 2 | 4 | 1 | 1 | 11 | 21 | **40** |
| mr_A-34 | 2 | 3 | 1 | 1 | 2 | 7 | **16** |
| ua_A-35 | 6 | 4 | 3 | 5 | 26 | 21 | **65** |
| **TOTAL** | **109** | **110** | **110** | **109** | **658** | **1,098** | **2,194** |

Distribution of Millions of Gallons of flow to Inlets Sorted by Ranked Inlets




The top 12.6% highest net runoff ranked inlet locations appear to receive 50% of runoff tributary to known inlets in sheds A-22 through A-35.

### 2.2.3 Ranking Data: 2b) Net Acres of Impervious and Building Roof Surfaces Grouped by Ranked Inlet Location and POC Shed

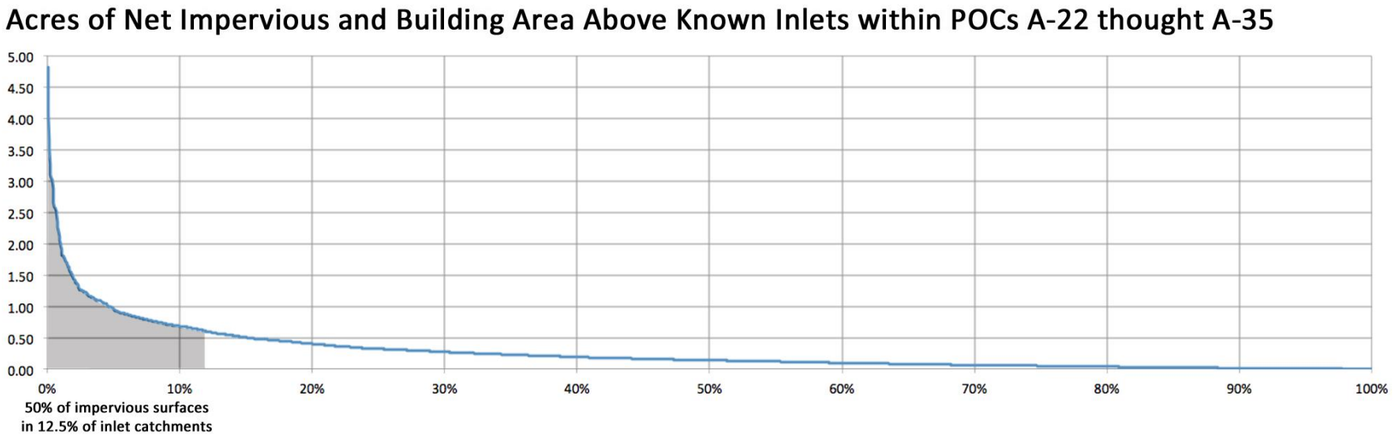
Net Acres of Impervious Surfaces Grouped by Highest Ranked Inlets and Points of Connection

| | highest 0-5% net impervious | highest 5-10% net impervious | highest 10-15% net impervious | highest 15-20% net impervious | highest 20-50% net impervious | lowest 50% net impervious | |
|---|---|---|---|---|---|---|---|
| POC | [29.2% of ALL imperv 28.8% of inlet RO] | [43.9% of ALL imperv 43.7% of inlet RO] | [54.8% of ALL imperv 54% of inlet RO] | [63.1 of ALL imperv 62.0% of inlet RO] | [ 89.7% of ALL imperv 88.8% of inlet RO] | [10.3% of of ALL imperv 11.2% of inlet RO] | TOTAL |
| mr_A-22 | 64.46 | 42.02 | 30.94 | 24.78 | 84.04 | 35.27 | **281.52** |
| mr_A-23 | 39.51 | 14.68 | 6.27 | 5.42 | 10.52 | 4.92 | **81.33** |
| mr_A-25 | 3.79 | 0.76 | 1.89 | 0.84 | 1.91 | 0.45 | **9.66** |
| mr_A-26 | 2.31 | 2.48 | 2.36 | 0.47 | 2.47 | 0.17 | **10.27** |
| mr_A-27 | 4.04 | 1.58 | 4.08 | 0.88 | 3.43 | 0.99 | **15.00** |
| mr_A-28 | 13.22 | 7.41 | 4.96 | 5.63 | 10.18 | 2.96 | **44.36** |
| mr_A-29 | 11.72 | 7.03 | 8.74 | 8.04 | 29.77 | 10.21 | **75.50** |
| mr_A-30 | 6.06 | | | | 0.37 | 0.30 | **6.73** |
| mr_A-31 | 1.14 | | | | 0.27 | 0.29 | **1.71** |
| mr_A-32 | 14.45 | 3.95 | 2.44 | 1.83 | 5.85 | 2.81 | **31.32** |
| mr_A-33 | 3.38 | 1.49 | 1.19 | 0.42 | 3.00 | 0.95 | **10.42** |
| mr_A-34 | 3.71 | 2.46 | 1.18 | | 0.50 | 0.43 | **8.28** |
| ua_A-35 | 5.99 | 3.82 | 0.59 | 0.87 | 5.95 | 1.60 | **18.81** |
| **TOTAL** | **173.79** | **87.68** | **64.64** | **49.20** | **158.26** | **61.34** | **594.91** |

Number of Inlets in each Grouping

| | highest 0-5% net impervious | highest 5-10% net impervious | highest 10-15% net impervious | highest 15-20% net impervious | highest 20-50% net impervious | lowest 50% net impervious | |
|---|---|---|---|---|---|---|---|
| POC | [29.2% of ALL imperv 28.8% of inlet RO] | [43.9% of ALL imperv 43.7% of inlet RO] | [54.8% of ALL imperv 54% of inlet RO] | [63.1 of ALL imperv 62.0% of inlet RO] | [ 89.7% of ALL imperv 88.8% of inlet RO] | [10.3% of of ALL imperv 11.2% of inlet RO] | TOTAL |
| mr_A-22 | 43 | 53 | 54 | 55 | 360 | 631 | **1,196** |
| mr_A-23 | 23 | 18 | 11 | 12 | 44 | 90 | **198** |
| mr_A-25 | 3 | 1 | 3 | 2 | 7 | 9 | **25** |
| mr_A-26 | 2 | 3 | 4 | 1 | 9 | 4 | **23** |
| mr_A-27 | 2 | 2 | 7 | 2 | 14 | 17 | **44** |
| mr_A-28 | 7 | 9 | 8 | 12 | 39 | 52 | **127** |
| mr_A-29 | 8 | 9 | 14 | 18 | 122 | 176 | **347** |
| mr_A-30 | 3 | | | | 1 | 5 | **9** |
| mr_A-31 | 1 | | | | 1 | 7 | **9** |
| mr_A-32 | 10 | 5 | 4 | 4 | 22 | 50 | **95** |
| mr_A-33 | 3 | 2 | 2 | 1 | 11 | 21 | **40** |
| mr_A-34 | 2 | 3 | 2 | | 2 | 7 | **16** |
| ua_A-35 | 2 | 5 | 1 | 2 | 26 | 29 | **65** |
| **TOTAL** | **109** | **110** | **110** | **109** | **658** | **1,098** | **2,194** |

Distribution of Net Impervious Surfaces Sorted by Ranked Inlet




The top 12.5% highest ‘net impervious’ ranked inlet catchments contain 50% of tributary impervious acres in sheds A-22 through A-35.

### 2.2.4 Ranking Data: 2c) Gross Acres of Impervious and Building Roof Surfaces Grouped by Ranked Inlet Location and POC Shed

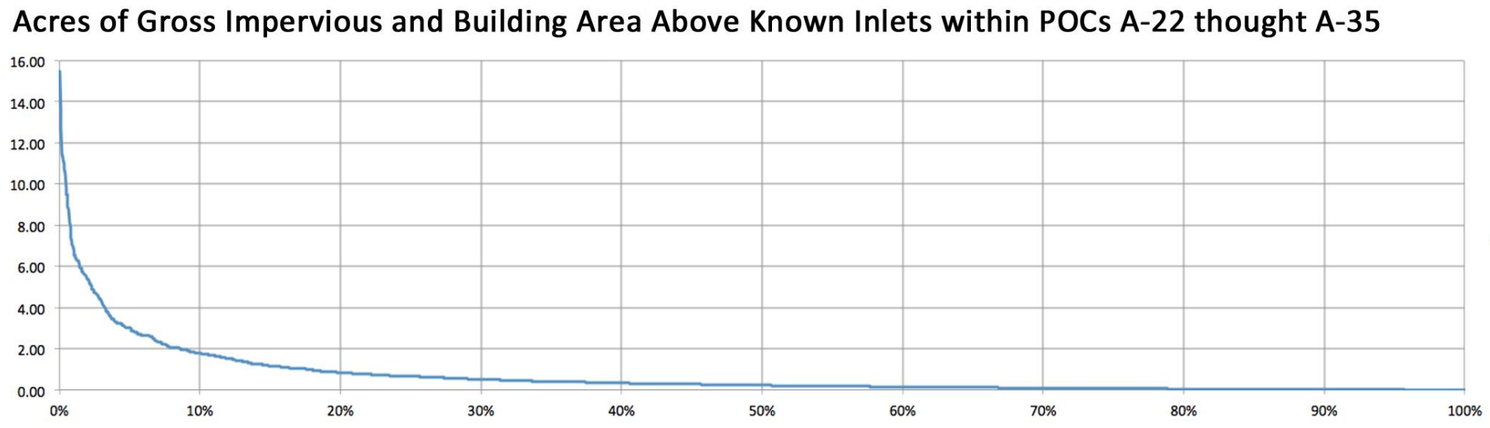
Gross Acres of Impervious Surfaces Grouped by Highest Ranked Inlets and Points of Connection

| POC | highest 0-5% gross impervious | highest 5-10% gross impervious | highest 10-15% gross impervious | highest 15-20% gross impervious | highest 20-50% gross impervious | lowest 50% gross impervious | TOTAL |
|---|---|---|---|---|---|---|---|
| mr_A-22 | 146.07 | 105.92 | 87.13 | 55.58 | 169.74 | 54.75 | **619.20** |
| mr_A-23 | 149.31 | 31.52 | 10.10 | 14.40 | 23.49 | 8.30 | **237.12** |
| mr_A-25 | 19.09 | 2.71 | 2.73 | 3.11 | 3.49 | 0.64 | **31.77** |
| mr_A-26 | 7.41 | 4.14 | 4.39 | 4.37 | 2.84 | 0.33 | **23.48** |
| mr_A-27 | 31.18 | 8.92 | 4.33 | 2.00 | 6.78 | 1.22 | **54.42** |
| mr_A-28 | 63.08 | 21.53 | 15.56 | 5.87 | 19.13 | 4.55 | **129.72** |
| mr_A-29 | 72.48 | 39.13 | 22.22 | 14.10 | 47.14 | 17.44 | **212.51** |
| mr_A-30 | 4.13 | | 1.44 | 2.07 | 0.43 | 0.28 | **8.34** |
| mr_A-31 | | | 1.42 | | 0.27 | 0.38 | **2.07** |
| mr_A-32 | 72.67 | 14.60 | 9.47 | 1.89 | 12.02 | 3.45 | **114.10** |
| mr_A-33 | 11.13 | 10.47 | | 3.19 | 3.32 | 1.40 | **29.50** |
| mr_A-34 | 8.95 | 5.00 | | 1.04 | 2.19 | 0.42 | **17.61** |
| ua_A-35 | 12.15 | 7.53 | 2.95 | 1.96 | 9.68 | 3.28 | **37.55** |
| **TOTAL** | **597.64** | **251.46** | **161.75** | **109.59** | **300.52** | **96.44** | **1517.39** |

Number of Inlets in each Grouping

| POC | highest 0-5% gross impervious | highest 5-10% gross impervious | highest 10-15% gross impervious | highest 15-20% gross impervious | highest 20-50% gross impervious | lowest 50% gross impervious | TOTAL |
|---|---|---|---|---|---|---|---|
| mr_A-22 | 32 | 46 | 60 | 56 | 376 | 626 | **1,196** |
| mr_A-23 | 18 | 14 | 7 | 14 | 46 | 99 | **198** |
| mr_A-25 | 3 | 1 | 2 | 3 | 8 | 8 | **25** |
| mr_A-26 | 2 | 2 | 3 | 4 | 7 | 5 | **23** |
| mr_A-27 | 5 | 4 | 3 | 2 | 15 | 15 | **44** |
| mr_A-28 | 10 | 9 | 10 | 6 | 42 | 50 | **127** |
| mr_A-29 | 18 | 18 | 15 | 14 | 101 | 181 | **347** |
| mr_A-30 | 1 | | 1 | 2 | 1 | 4 | **9** |
| mr_A-31 | | | 1 | | 1 | 7 | **9** |
| mr_A-32 | 13 | 6 | 6 | 2 | 26 | 42 | **95** |
| mr_A-33 | 3 | 5 | | 3 | 8 | 21 | **40** |
| mr_A-34 | 2 | 2 | | 1 | 5 | 6 | **16** |
| ua_A-35 | 2 | 3 | 2 | 2 | 22 | 34 | **65** |
| **TOTAL** | **109** | **110** | **110** | **109** | **658** | **1,098** | **2,194** |

Distribution of Gross Impervious Surfaces Sorted by Ranked Inlets



### 2.2.5 Ranking Data: Millions of Gallons of Net Runoff Grouped by Ranked Inlet Location and Net Impervious Surfaces Above

Millions of Gallons of Net Runoff Grouped by Highest Ranked Inlets and Net Impervious Surfaces Above

**GOALprocess Summary of Inlet Drainage Areas in A-22 through A-35**

Summary of Runoff AND Net Acres of Impervious Areas Above Highest Ranked Inlet

LBs20140319 updated 20140327

**Millions of Gallons of Net Runoff Grouped by Highest Ranked Inlets AND Highest Grouping of Net Acres of Impervious Surfaces and Buildings Above**

| Net Acres Above Ranking | highest 0-5% inlet runoff within pilot area [30.1% of ALL inlet RO] | highest 5-10% inlet runoff within pilot area [44.1% of ALL inlet RO] | highest 10-15% inlet runoff within pilot area [54.5% of ALL inlet RO] | highest 15-20% inlet runoff within pilot area [62.5% of ALL inlet RO] | highest 20-50% inlet runoff within pilot area [89.1% of ALL inlet RO] | lowest 50% inlet runoff within pilot area [10.9% of ALL inlet RO] | TOTAL |
|---|---|---|---|---|---|---|---|
| highest 5% net imperv inlets [29.2% of ALL imperv 28.8% of inlet RO] | 166.372 | 6.155 | | | | | **172.527** |
| highest 10% net imperv inlets [43.9% of ALL imperv 43.7% of inlet RO] | 12.629 | 63.644 | 12.670 | | | | **88.943** |
| highest 15% net imperv inlets [54.8% of ALL imperv 54% of inlet RO] | | 10.143 | 41.560 | 9.932 | | | **61.635** |
| highest 20% net imperv inlets [63.1 of ALL imperv 62.0% of inlet RO] | | 3.078 | 4.912 | 31.128 | 9.007 | | **48.125** |
| highest 50% net imperv inlets [ 89.7% of ALL imperv 88.8% of inlet RO] | | 0.740 | 3.388 | 6.853 | 143.912 | 5.332 | **160.225** |
| lowest 50% net imperv inlets [10.3% of ALL imperv 11.2% of inlet RO] | 1.062 | | | | 6.401 | 59.860 | **67.323** |
| **TOTAL** | **180.062** | **83.760** | **62.530** | **47.913** | **159.321** | **65.192** | **598.778** |

**Number of Inlets in each Grouping**

| Net Acres Above Ranking | highest 0-5% inlet runoff within pilot area [30.1% of ALL inlet RO] | highest 5-10% inlet runoff within pilot area [44.1% of ALL inlet RO] | highest 10-15% inlet runoff within pilot area [54.5% of ALL inlet RO] | highest 15-20% inlet runoff within pilot area [62.5% of ALL inlet RO] | highest 20-50% inlet runoff within pilot area [89.1% of ALL inlet RO] | lowest 50% inlet runoff within pilot area [10.9% of ALL inlet RO] | TOTAL |
|---|---|---|---|---|---|---|---|
| highest 5% net imperv inlets [29.2% of ALL imperv 28.8% of inlet RO] | 102 | 7 | | | | | **109** |
| highest 10% net imperv inlets [43.9% of ALL imperv 43.7% of inlet RO] | 6 | 84 | 20 | | | | **110** |
| highest 15% net imperv inlets [54.8% of ALL imperv 54% of inlet RO] | | 14 | 75 | 21 | | | **110** |
| highest 20% net imperv inlets [63.1 of ALL imperv 62.0% of inlet RO] | | 4 | 9 | 72 | 24 | | **109** |
| highest 50% net imperv inlets [ 89.7% of ALL imperv 88.8% of inlet RO] | | 1 | 6 | 16 | 596 | 39 | **658** |
| lowest 50% net imperv inlets [10.3% of ALL imperv 11.2% of inlet RO] | 1 | | | | 38 | 1,059 | **1,098** |
| **TOTAL** | **109** | **110** | **110** | **109** | **658** | **1,098** | **2,194** |

Locations categorized in the upper left 3 x 3 highest ranked quarter of the above tables have the greatest potential to intercept the most runoff per GSI or source reduction installation dollar. The sheds that contain those higher ranked locations are summarized in the table below:

**Locations in the Top 15% Net Runoff and Top 15% Net Impervious Acreas**

| POC Shed | Number of Locations | Total Annual Runoff Million Gallons | Total Runoff Rank | Average Annual Runoff Million Gallons | Avg Runoff Rank | Total Impervious Net Acres | Total Impervious Rank | Average Impervious Net Acres | Avg Impervious Rank |
|---|---|---|---|---|---|---|---|---|---|
| mr_A-22-OF | 142 | 124.910 | 1 | 0.880 | 10 | 133.25 | 1 | 0.94 | 8 |
| mr_A-23-OF | 47 | 52.522 | 2 | 1.117 | 3 | 57.81 | 2 | 1.23 | 3 |
| mr_A-25-OF | 7 | 5.763 | 12 | 0.823 | 14 | 6.45 | 10 | 0.92 | 9 |
| mr_A-26-OF | 7 | 5.848 | 11 | 0.835 | 13 | 6.08 | 11 | 0.87 | 13 |
| mr_A-27-OF | 10 | 8.439 | 8 | 0.844 | 12 | 9.20 | 8 | 0.92 | 10 |
| mr_A-28-OF | 22 | 21.922 | 4 | 0.996 | 7 | 24.54 | 3 | 1.12 | 7 |
| mr_A-29-OF | 11 | 10.111 | 7 | 0.919 | 9 | 10.01 | 7 | 0.91 | 11 |
| mr_A-29Z-OF | 19 | 17.613 | 6 | 0.927 | 8 | 16.94 | 5 | 0.89 | 12 |
| mr_A-30-OF | 3 | 5.069 | 13 | 1.690 | 2 | 6.06 | 12 | 2.02 | 1 |
| mr_A-31-OF | 1 | 1.055 | 14 | 1.055 | 4 | 1.14 | 14 | 1.14 | 4 |
| mr_A-32-OF | 18 | 18.259 | 5 | 1.014 | 6 | 20.28 | 4 | 1.13 | 6 |
| mr_A-33-OF | 7 | 6.093 | 10 | 0.870 | 11 | 6.05 | 13 | 0.86 | 14 |
| mr_A-34-OF | 6 | 6.182 | 9 | 1.030 | 5 | 6.84 | 9 | 1.14 | 5 |
| ua_A-35-OF | 8 | 29.388 | 3 | 3.674 | 1 | 10.39 | 6 | 1.30 | 2 |
| | **308** | **313.173** | | **1.017** | | **315.04** | | **1.02** | |

## 3 Task 3 – Ranking of Sewer Sheds based upon Top Runoff and Impervious Surfaces

***SCOPE:*** *Rank each sewershed based on each of the following metrics:*

- *3a) Potential runoff volume intercepted by top 5%, 10%, and 20% ranked ROW installations based on the GOALprocess annual runoff volume ranking (2a)*
- *3b) Potential net impervious area controlled by top 5%, 10%, and 20% of ranked ROW installations based on the GOALprocess net impervious cover ranking (2b)*

The tables below summarize and rank the potential for high-yield GSI runoff capture within each shed. The following runoff and net impervious summaries rank each sewer shed based on runoff in million gallons and net acres of impervious surface at top high-yield sites (no summary of wastewater network overflow response):

**POC Sheds Ranked by Millions of Gallons of Annual High-Yield Site Runoff**

| POC | highest 5% inlet runoff within pilot area [30.1% of ALL inlet RO] | Rank | Avg MG | Avg Rank | POC | highest 10% inlet runoff within pilot area [44.1% of ALL inlet RO] | Total Rank | Avg MG | Avg Rank | POC | highest 20% inlet runoff within pilot area [62.5% of ALL inlet RO] | Rank | Avg MG | Avg Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mr_A-22 | 58.107 | 1 | 1.42 | 8 | mr_A-22 | 97.181 | 1 | 1.06 | 10 | mr_A-22 | 149.943 | 1 | 0.77 | 10 |
| mr_A-23 | 35.165 | 2 | 1.60 | 5 | mr_A-23 | 48.824 | 2 | 1.22 | 5 | mr_A-23 | 58.732 | 2 | 0.98 | 6 |
| mr_A-25 | 3.408 | 8 | 1.14 | 12 | mr_A-25 | 3.408 | 12 | 1.14 | 7 | mr_A-25 | 5.938 | 10 | 0.66 | 12 |
| mr_A-26 | 2.321 | 12 | 1.16 | 11 | mr_A-26 | 4.648 | 11 | 0.93 | 12 | mr_A-26 | 14.593 | 8 | 1.22 | 4 |
| mr_A-27 | 3.714 | 7 | 1.86 | 3 | mr_A-27 | 5.135 | 9 | 1.28 | 3 | mr_A-27 | 11.102 | 7 | 0.85 | 8 |
| mr_A-28 | 11.902 | 6 | 1.70 | 4 | mr_A-28 | 17.206 | 5 | 1.23 | 4 | mr_A-28 | 24.683 | 5 | 0.73 | 11 |
| mr_A-29 | 14.487 | 4 | 1.45 | 7 | mr_A-29 | 23.369 | 4 | 1.06 | 9 | mr_A-29 | 35.039 | 3 | 0.64 | 13 |
| mr_A-30 | 3.336 | 9 | 3.34 | 2 | mr_A-30 | 5.069 | 10 | 1.69 | 2 | mr_A-30 | 6.792 | 12 | 2.26 | 1 |
| mr_A-31 | 1.055 | 13 | 1.05 | 13 | mr_A-31 | 1.055 | 13 | 1.05 | 11 | mr_A-31 | 1.712 | 13 | 1.71 | 3 |
| mr_A-32 | 13.029 | 5 | 1.30 | 9 | mr_A-32 | 15.955 | 6 | 1.14 | 6 | mr_A-32 | 18.334 | 6 | 0.83 | 9 |
| mr_A-33 | 2.480 | 11 | 1.24 | 10 | mr_A-33 | 5.537 | 7 | 0.92 | 13 | mr_A-33 | 8.322 | 11 | 1.04 | 5 |
| mr_A-34 | 3.112 | 10 | 1.56 | 6 | mr_A-34 | 5.525 | 8 | 1.10 | 8 | mr_A-34 | 5.997 | 9 | 0.86 | 7 |
| ua_A-35 | 27.947 | 3 | 4.66 | 1 | ua_A-35 | 30.911 | 3 | 3.09 | 1 | ua_A-35 | 33.077 | 4 | 1.84 | 2 |
| **TOTAL** | **180.062** | | **1.65** | | **TOTAL** | **263.822** | | **1.20** | | **TOTAL** | **374.265** | | **0.85** | |

**POC Sheds Ranked by Acres of NET Tributary Impervious and Buildings**

| POC | highest 5% net impervious [29.2% of ALL imperv 28.8% of inlet RO] | Total Rank | Avg Net AC | Avg Rank | POC | highest 10% net impervious [43.9% of ALL imperv 43.7% of inlet RO] | Total Rank | Avg Net AC | Avg Rank | POC | highest 20% net impervious [63.1 of ALL imperv 62.0% of inlet RO] | Total Rank | Avg Net AC | Avg Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mr_A-22 | 64.46 | 1 | 1.50 | 7 | mr_A-22 | 106.49 | 1 | 1.11 | 10 | mr_A-22 | 162.22 | 1 | 0.79 | 11 |
| mr_A-23 | 39.51 | 2 | 1.72 | 6 | mr_A-23 | 54.19 | 2 | 1.32 | 4 | mr_A-23 | 65.88 | 2 | 1.03 | 5 |
| mr_A-25 | 3.79 | 9 | 1.26 | 10 | mr_A-25 | 3.79 | 13 | 1.14 | 9 | mr_A-25 | 3.79 | 13 | 0.81 | 9 |
| mr_A-26 | 2.31 | 12 | 1.16 | 11 | mr_A-26 | 4.77 | 11 | 0.96 | 13 | mr_A-26 | 5.95 | 11 | 0.76 | 12 |
| mr_A-27 | 4.04 | 8 | 2.02 | 2 | mr_A-27 | 4.04 | 12 | 1.41 | 2 | mr_A-27 | 4.04 | 12 | 0.81 | 8 |
| mr_A-28 | 13.22 | 4 | 1.89 | 4 | mr_A-28 | 15.71 | 3 | 1.29 | 5 | mr_A-28 | 18.54 | 5 | 0.87 | 7 |
| mr_A-29 | 11.72 | 5 | 1.46 | 8 | mr_A-29 | 13.30 | 6 | 1.10 | 11 | mr_A-29 | 18.26 | 6 | 0.73 | 13 |
| mr_A-30 | 6.06 | 6 | 2.02 | 3 | mr_A-30 | 13.47 | 5 | 2.02 | 1 | mr_A-30 | 24.05 | 4 | 2.02 | 1 |
| mr_A-31 | 1.14 | 13 | 1.14 | 12 | mr_A-31 | 4.96 | 9 | 1.14 | 8 | mr_A-31 | 6.42 | 10 | 1.14 | 2 |
| mr_A-32 | 14.45 | 3 | 1.45 | 9 | mr_A-32 | 15.22 | 4 | 1.23 | 7 | mr_A-32 | 17.95 | 7 | 0.99 | 6 |
| mr_A-33 | 3.38 | 11 | 1.13 | 13 | mr_A-33 | 4.86 | 10 | 0.97 | 12 | mr_A-33 | 6.47 | 9 | 0.81 | 10 |
| mr_A-34 | 3.71 | 10 | 1.86 | 5 | mr_A-34 | 7.66 | 8 | 1.23 | 6 | mr_A-34 | 11.93 | 8 | 1.05 | 4 |
| ua_A-35 | 5.99 | 7 | 2.99 | 1 | ua_A-35 | 13.01 | 7 | 1.40 | 3 | ua_A-35 | 29.80 | 3 | 1.13 | 3 |
| **TOTAL** | **173.79** | | **1.59** | | **TOTAL** | **261.47** | | **1.19** | | **TOTAL** | **375.31** | | **0.86** | |

All sheds contain high-yield sites with great potential to reduce runoff and localized flooding at cost effective rates per gallon. However, without evaluating the SWMM overflow response at each outfall, the above information provides important yet only part of the information necessary to make effective and affordable decisions. Landbase Systems recommends GSI evaluations based on precision use of the best available resources to account for both runoff reduction and network system response.

## 3.1 Summary of SWMM model response to GSI/source reduction runoff volumes at high-yield sites in each Pilot shed

Landbase Systems built the GOALprocess with the knowledge that no linear process or simplistic assumptions can be used to determine how many GSI managed gallons are required to eliminate 1 gallon of combined sewer overflow. The GOALprocess is designed to provide a precise, realistic, and transparent method to reliably represent runoff source reduction and/or GSI installation and scientifically evaluate this reduction in overflow events and volume using SWMM source code. The GOALprocess integrates SWMM model parameters, SWMM runoff methods, and EPA SWMM source code in order to match SWMM runoff calculations in every time unit. Precisely matching every SWMM runoff calculation in every catchment down to every time unit allows that GOALprocess to directly and non-invasively interface with SWMM models. This method supports faster optimization of the most effective and affordable solutions within the GOALprocess. Once the most effective conceptual and/or site-specific options are determined, verification of the changes to overflow events and volumes are estimated by running the full SWMM model(s).

Each Pilot shed, A-22 through A-35, contain high ranked runoff and net impervious surface locations that can maximize performance of source reduction strategies. However, locating high-yield and right-sizing GSI installations in any shed is only part of a complete evaluation. A complete evaluation requires the full SWMM model runs for reliable and realistic representation of changes to overflow events and volume caused by GSI or source reduction layouts and strategies. To assist the selection of two combined wastewater sheds for Tasks 5 and 6, we ran the Main Rivers SWMM model ten times. Each SWMM model run simulated removal of runoff from one shed at a time (10 of 13 sheds were run). The table below shows:

- Shed name [Outfall Shed]
- Number of high-yield GOALprocess sites used [Number of High-Yield Installation Sites]
- Million gallons of GOALprocess estimated runoff removed at installed GSI sites [Annual GSI Runoff (RO) Removed (MG)]
- SWMM Main Rivers model first downstream outfall annual million gallons of overflow reduced [Annual Overflow Reduction at Shed Outfall (MG)]
- Percent of GSI gallons as reduced overflow at the first downstream outfall [% of GSI Gallons as Reduced Overflow at Shed Outfall]
- SWMM Main Rivers model Eastern Allegheny outfalls annual million gallons of overflow reduced [Annual Overflow Reduction in Overall Model]
- Percent of GSI gallons as reduced overflow at all the Allegheny Main Rivers model outfalls [% of GSI Gallons as Reduced Overflow in Overall Model]
- Ranking of highest to lowest percent response of the Eastern Allegheny Main Rivers model outfalls [Overall Response Rank]

**Initial GOALprocess+SWMM System Overflow Response to High-Yield GSI Runoff Removal within Individual POC Outfall Sheds**

**GOALprocess CDM Pilot A-22 to A-35 Results from Running 10 Models with Annual GSI removed from one shed at a time**

Landbase Systems 20140327

| Outfall Shed | Number of High-Yield Installation Sites | Annual GSI Runoff (RO) Removed (MG) | Annual Overflow Reduction at Shed Outfall (MG) | % of GSI Gallons as Reduced Overflow at Shed Outfall | Annual Overflow Reduction in Overall Model (MG) | % of GSI Gallons as Reduced Overflow in Overall Model | Overall Response Rank |
|---|---|---|---|---|---|---|---|
| mr_A-22-OF | 9 | 10.000 | -8.967 | -89.7% | -9.677 | -96.8% | 7 |
| mr_A-23-OF | 9 | 10.000 | -8.717 | -87.2% | -9.787 | -97.9% | 4 |
| mr_A-25-OF | 3 | 2.500 | -1.529 | -61.2% | -2.073 | -82.9% | 10 |
| mr_A-26-OF | 4 | 3.000 | -2.090 | -69.7% | -2.720 | -90.7% | 8 |
| mr_A-27-OF | 4 | 4.000 | -2.313 | -57.8% | -3.891 | -97.3% | 6 |
| mr_A-28-OF | 10 | 10.000 | -9.813 | -98.1% | -10.106 | **-101.1%** | **3** |
| **mr_A-29-OF** | **13** | **10.000** | **-9.775** | **-97.8%** | **-10.403** | **-104.0%** | **2** |
| mr_A-30-OF | 2 | 3.000 | -1.518 | -50.6% | -2.698 | -89.9% | 9 |
| *mr_A-31-OF* | *model not run* | *0.000* | | | | | |
| mr_A-32-OF | 11 | 10.000 | -7.272 | -72.7% | -9.768 | -97.7% | 5 |
| *mr_A-33-OF* | *model not run* | *0.000* | | | | | |
| **mr_A-34-OF** | **3** | **3.000** | **-2.425** | **-80.8%** | **-3.551** | **-118.4%** | **1** |
| *ua_A-35-OF* | *model not run* | *0.000* | | | | | |

Based on the current GOALprocess and SWMM Main Rivers model, this table shows that sheds A-34, A-29 and A-28 appear to have the three highest percent and most effective overflow reduction response rates relative to GSI gallons removed (-118% to 104%). While sheds A-25, A-30, and A-26 appear to have the lowest percent overall reductions (-83% to -91%).

## 4 Task 4 – Process to Select Two Sheds for More Detailed GSI Installation Analysis, Layout, and Evaluation

***SCOPE:*** *ALCOSAN, and Landbase Systems work collaboratively to review available information on each of the 14 POCs from A-22 through A-35.*

ALCOSAN and Landbase Systems selected sheds A-29/29z and A-34 by using ALCOSAN data about the potential capacity of existing regulators and a mix of high-yield statistics from Pilot Tasks 1-3, including the Landbase Systems table described in Section 3 and copied below (Initial GOALprocess+SWMM System Overflow Response to High-Yield GSI Runoff Removal within Individual POC Outfall Sheds):

**Initial GOALprocess+SWMM System Overflow Response to High-Yield GSI Runoff Removal within Individual POC Outfall Sheds**

**GOALprocess CDM Pilot A-22 to A-35 Results from Running 10 Models with Annual GSI removed from one shed at a time**

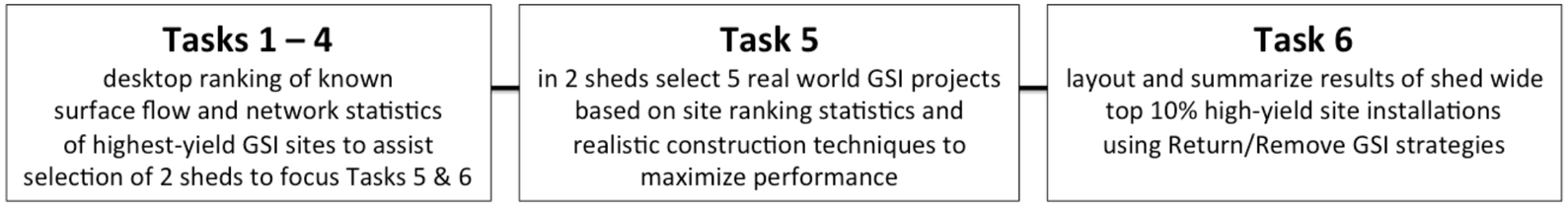
Landbase Systems 20140327

| Outfall Shed | Number of High-Yield Installation Sites | Annual GSI Runoff (RO) Removed (MG) | Annual Overflow Reduction at Shed Outfall (MG) | % of GSI Gallons as Reduced Overflow at Shed Outfall | Annual Overflow Reduction in Overall Model (MG) | % of GSI Gallons as Reduced Overflow in Overall Model | Overall Response Rank |
|---|---|---|---|---|---|---|---|
| mr_A-22-OF | 9 | 10.000 | -8.967 | -89.7% | -9.677 | -96.8% | 7 |
| mr_A-23-OF | 9 | 10.000 | -8.717 | -87.2% | -9.787 | -97.9% | 4 |
| mr_A-25-OF | 3 | 2.500 | -1.529 | -61.2% | -2.073 | -82.9% | 10 |
| mr_A-26-OF | 4 | 3.000 | -2.090 | -69.7% | -2.720 | -90.7% | 8 |
| mr_A-27-OF | 4 | 4.000 | -2.313 | -57.8% | -3.891 | -97.3% | 6 |
| mr_A-28-OF | 10 | 10.000 | -9.813 | -98.1% | -10.106 | **-101.1%** | **3** |
| **mr_A-29-OF** | **13** | **10.000** | **-9.775** | **-97.8%** | **-10.403** | **-104.0%** | **2** |
| mr_A-30-OF | 2 | 3.000 | -1.518 | -50.6% | -2.698 | -89.9% | 9 |
| *mr_A-31-OF* | *model not run* | *0.000* | | | | | |
| mr_A-32-OF | 11 | 10.000 | -7.272 | -72.7% | -9.768 | -97.7% | 5 |
| *mr_A-33-OF* | *model not run* | *0.000* | | | | | |
| **mr_A-34-OF** | **3** | **3.000** | **-2.425** | **-80.8%** | **-3.551** | **-118.4%** | **1** |
| *ua_A-35-OF* | *model not run* | *0.000* | | | | | |

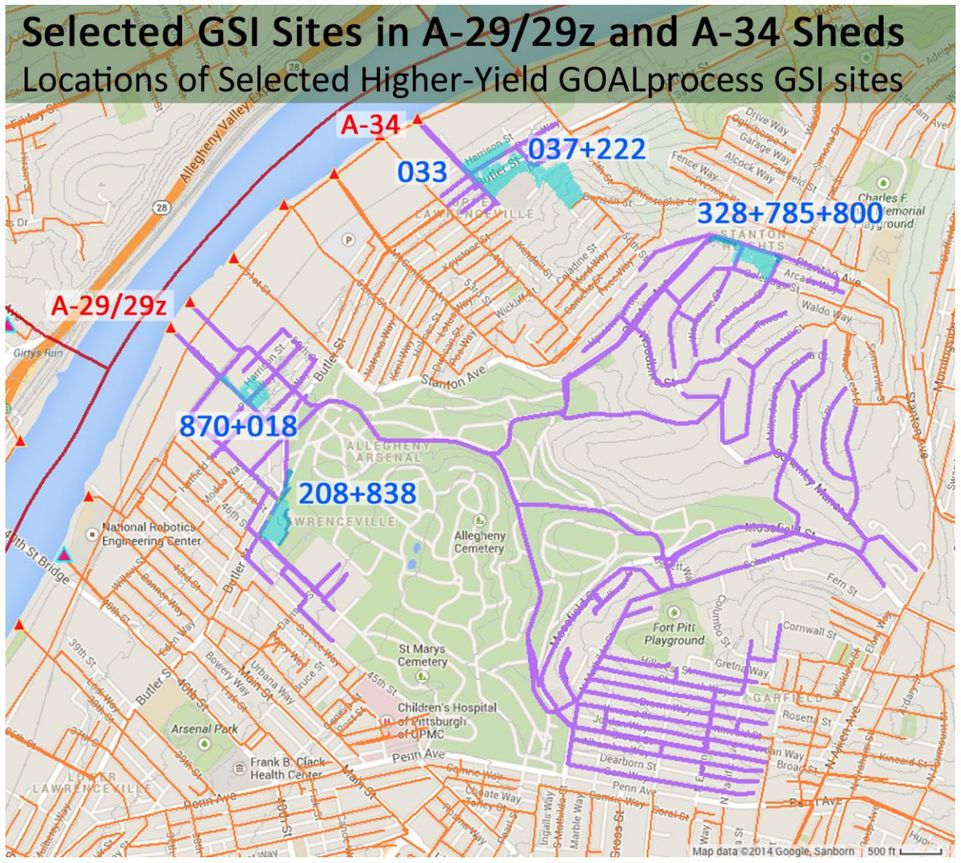
# 5 Task 5: GSI Strategies on 5 Selected Sites

***SCOPE:*** *Provide standard set of GOALprocess high-yield results for five selected high-yield projects/locations. The results at each site will include GSI that removed outflow and GSI that returns outflow to the sewer system via a slow release outlet. PDF map graphics and tables to illustrate and summarize drainage areas, estimated annual runoff volume reaching the project, and net impervious area controlled by the project.*

Tasks 1-4 provided information to guide the selection of 2 sewer sheds. Task 5 selected and evaluated five high-yield sites/project locations.




## 5.1 Site-Specific GSI Project Selection




Landbase Systems used the products of Tasks 1 through 4 and a range of possible GSI strategies (Infiltrate ONLY, Return, and Remove) to select five initial and suitable high-yield sites for field review. ALCOSAN and Landbase Systems reviewed each site in the field during sunny weather. While in the field reviewing the initial selected sites, site visibility was added to the high-yield site selection criteria (the original high-yield site selection process was based purely upon runoff and impervious statistics within the focus sheds). Adding site visibility parameters allowed the team to retire two originally selected high-yield sites and update the selected list with two new locations. As a result, the final five selected high-yield sites also have relatively good visibility.

The two sites that were added for performance and visibility are ‘208+838’ and ‘328+785+800’. The number or numbers in each of the selected site names represent the unique inlet ID numbers associated with each GSI installation. These inlet ID numbers represent the locations (and drainage areas) from which the proposed GSI layouts intercept and manage runoff, changing the volumes and rates at which surface water entering the combined sewer network.

After initial dry weather sites visits and selection of the final sites, Landbase Systems visited the 5 selected sites during wet weather events to verify current GOALprocess surface flow paths and drainage area analysis is consistent with real world conditions.

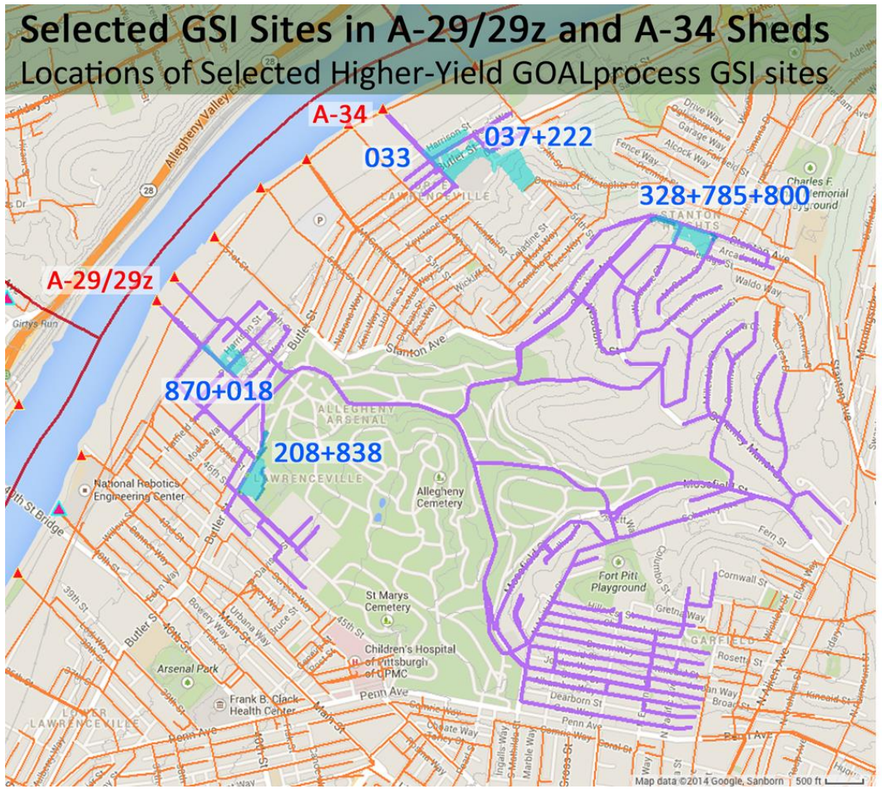
## 5.2 GSI Strategies reviewed on each of the five selected sites

In the 'Return GSI' strategy, outflow of non-infiltrated runoff intercepted by the GSI installation is slowly released back into the nearest downstream combined network connection.

In contrast, the 'Remove GSI' strategy typically requires a new low flow collection network of small diameter pipe to convey slow release outflow of non-infiltrated water to the nearest downstream under-utilized natural infrastructure low flow release location. There is added expense for the low flow collector network, however right-sized 'Remove GSI' strategy generates higher volumes of GSI filtered water (good for environment), does not release GSI filtered water back to the combined network (treatment reduced), reduces more overflow volume, and has a lower cost per eliminated overflow gallon.

Landbase Systems reviewed A29/29z and A-34 sheds for application of 'Infiltration ONLY GSI'. We found a few dozen sites that appear they could physically support sizable 'Infiltration ONLY' GSI that could reduce localized flooding and influence combined overflows. We selected 2 'Infiltration ONLY' sites to be used in the 5 selected sites because of their visibility and fairly good performance statistics.

On each of the 5 selected sites, we reviewed up to 3 potential GSI strategies: Infiltration ONLY, Return, and/or Remove GSI. We found two of the 5 selected sites ('870+018' and '033') are not suitable for 'Infiltration ONLY' GSI so we only reviewed 'Return' and 'Remove' strategies on those sites. The table below summarizes the GSI strategy currently proposed on each of the 5 selected sites.

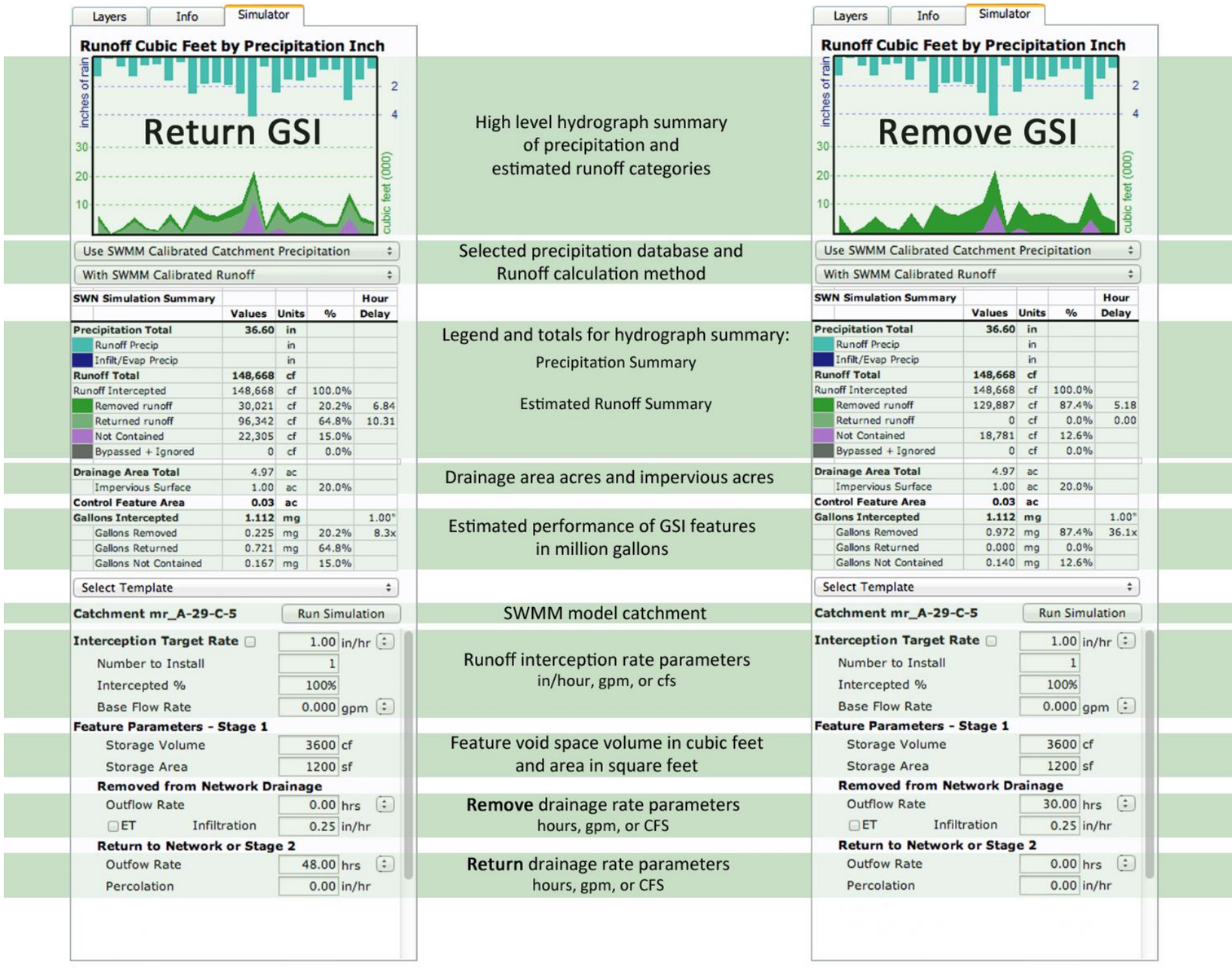



| Selected Site ID | Shed | GSI Strategy Used | Location |
|---|---|---|---|
| 870+108 | A-29/29z | Remove | 48th Street |
| 208+838 | A-29/29z | Infiltration ONLY | Butler Avenue |
| 328+785+800 | A-29/29z | Return | Stanton Avenue |
| 033 | A-34 | Return | 55th Street |
| 037+222 | A-34 | Infiltration ONLY | Butler Avenue |

The following pages contain GOALprocess screen pictures illustrating some layout details, drainage areas, street view, and statistics for each 5 selected site layouts.

## 5.3 Site-specific maps, drainage areas, and Green Stormwater Infrastructure (GSI) performance simulations

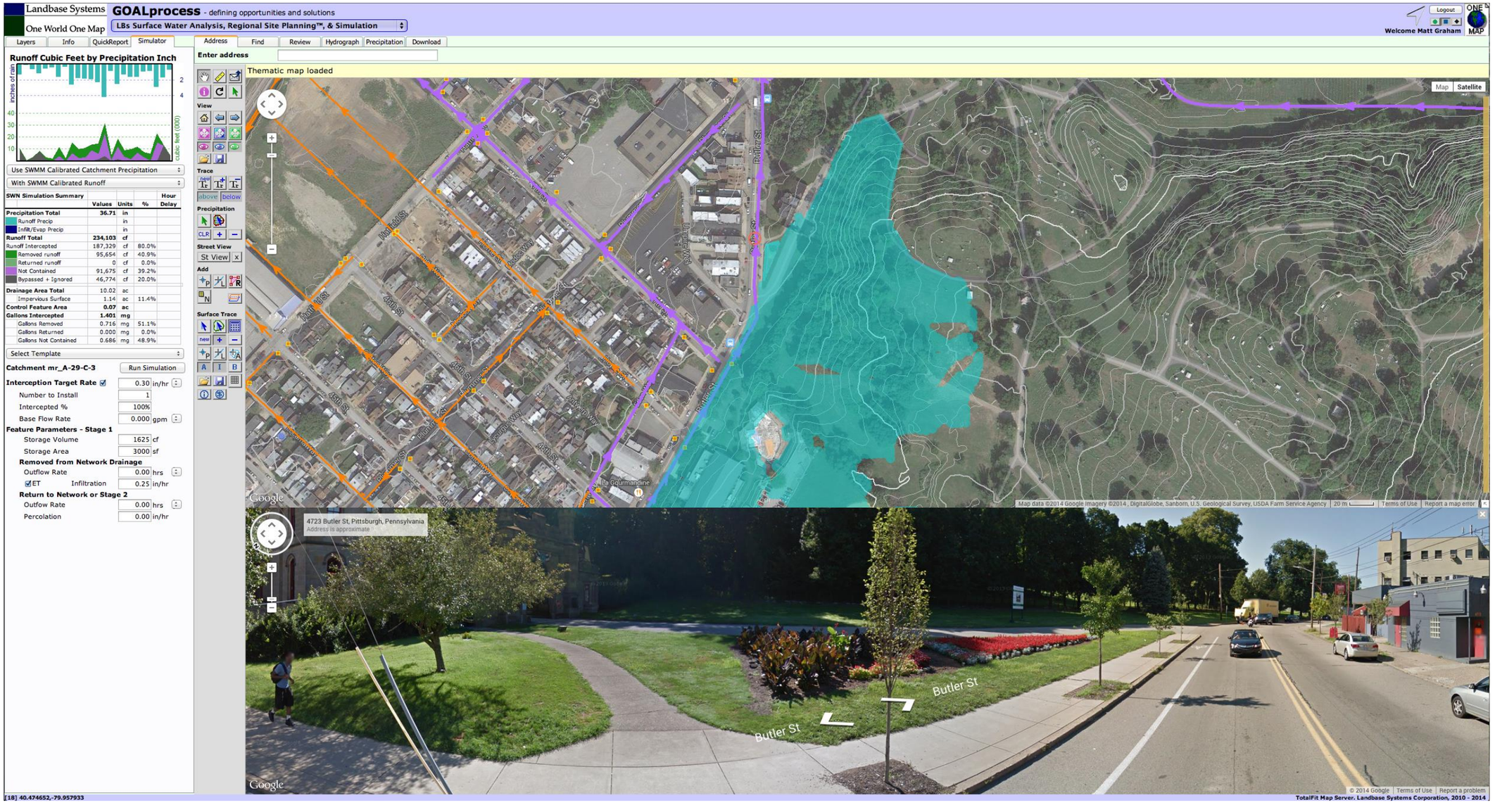
Summary of GOALprocess Simulation TAB Graphs, Tables, and Inputs illustrated in the following pages



### 5.3.1 Site 870+038: Remove GSI Strategy in Shed A-29/29z on 48th and Harrison Streets

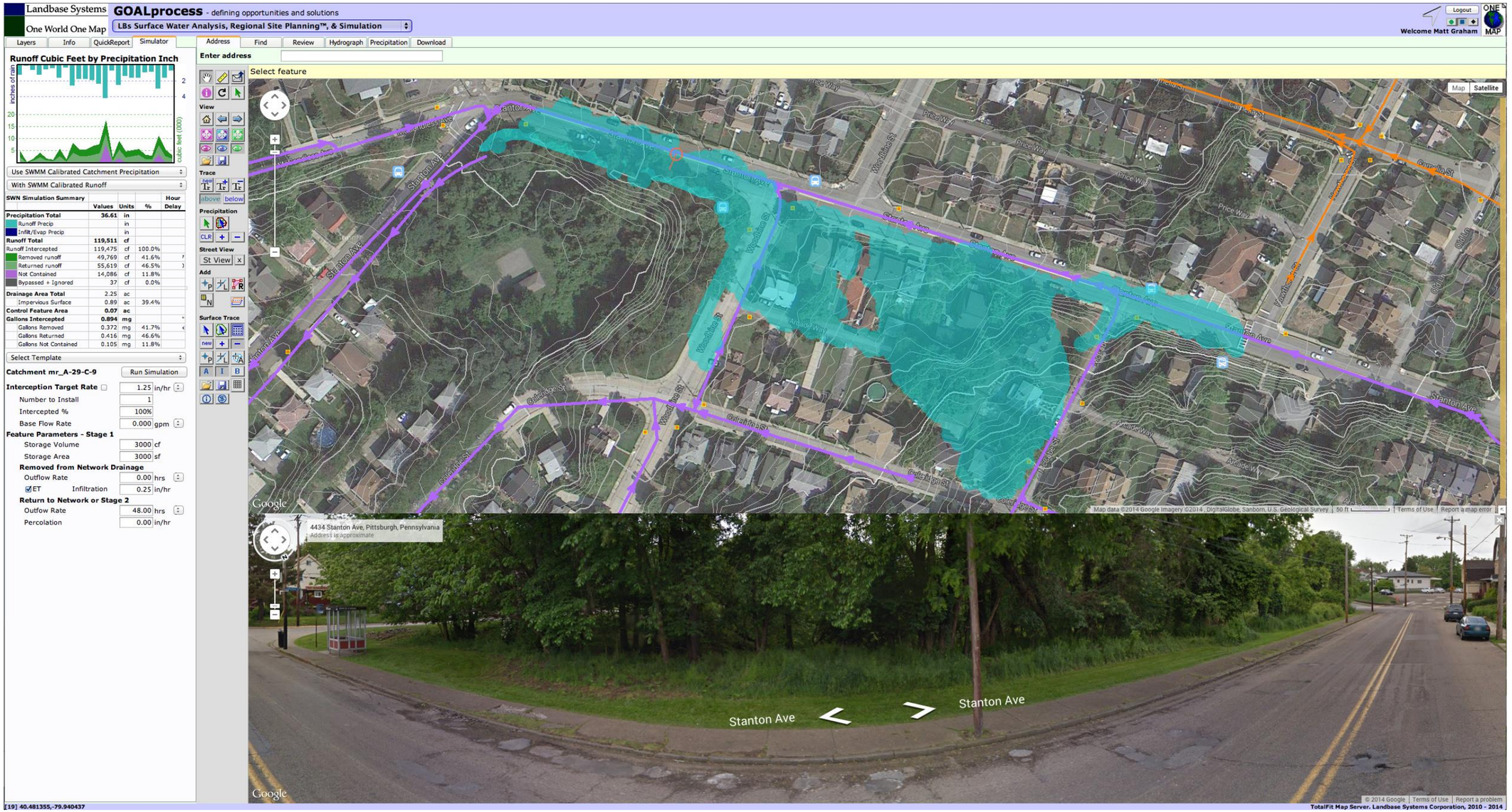

One known upstream inlet exists within the current defined drainage area.

### 5.3.2 Site 208+838: 'Infiltrate ONLY' GSI in Shed A-29/29z on Butler Street and Allegheny Cemetery



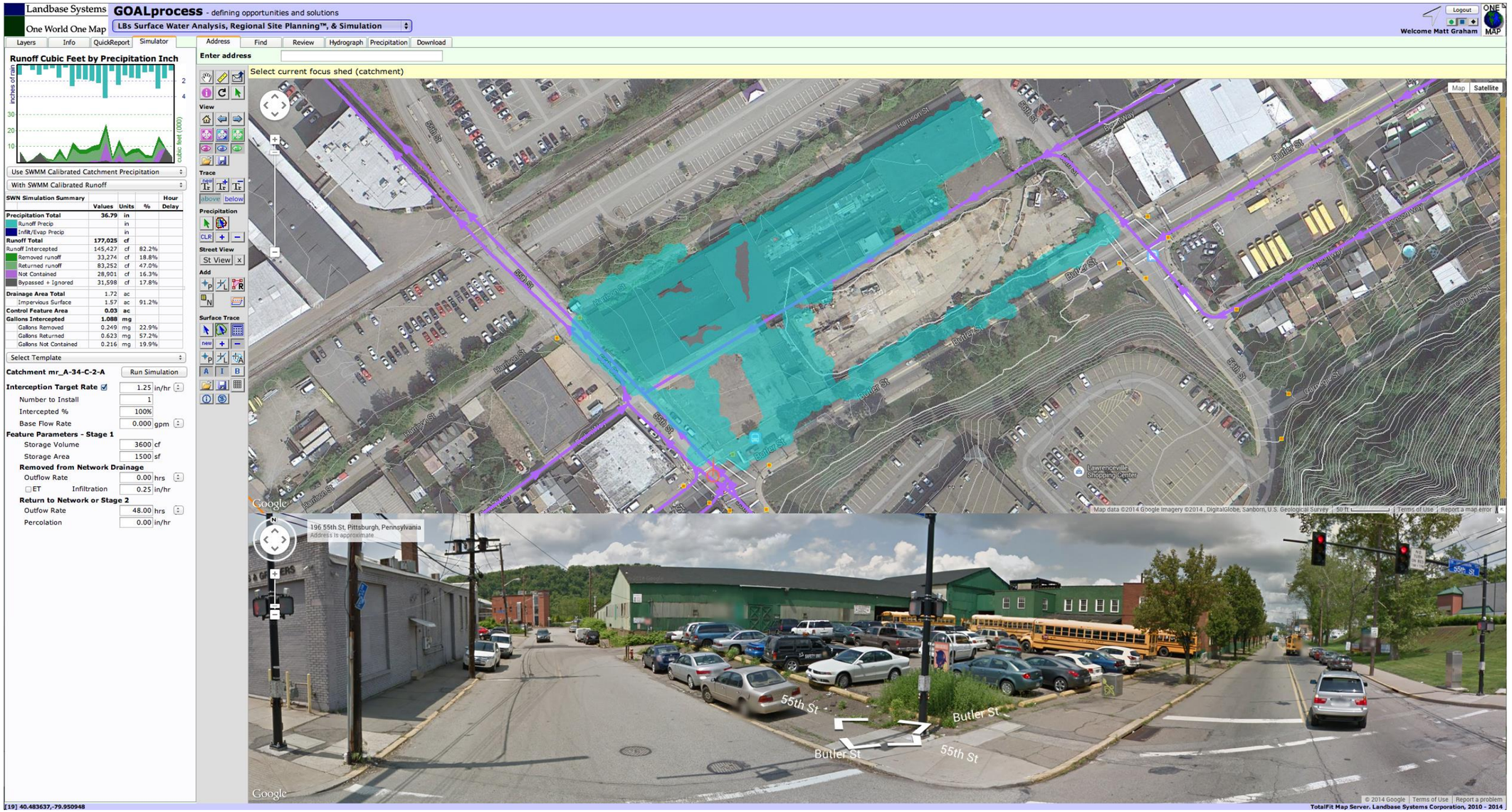

Two known inlets exist within the illustrated drainage area.

### 5.3.3 Site 328+785+800: Return GSI Strategy in Shed A-29/29z on Stanton Avenue and Woodbine Street



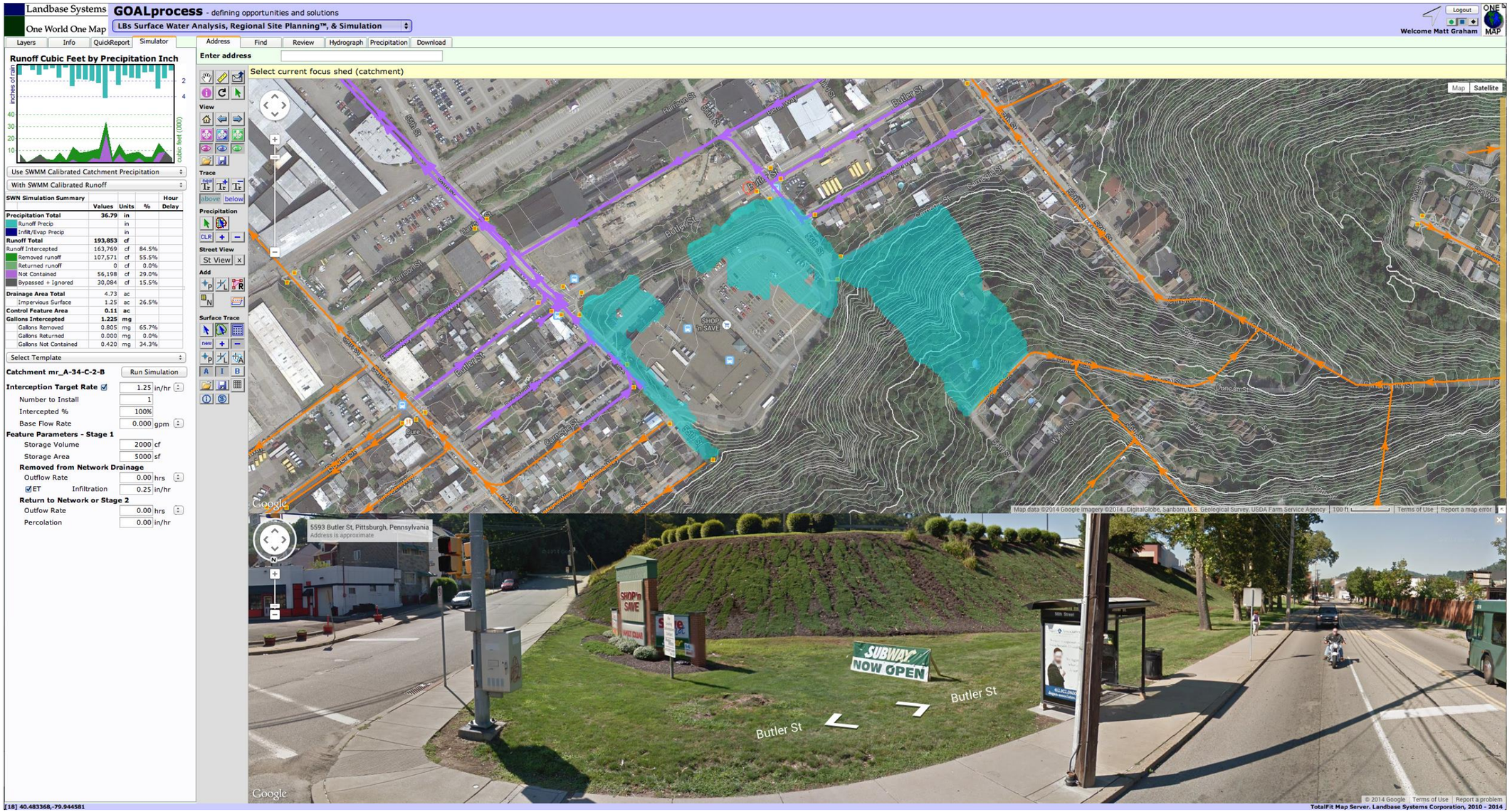

Two known inlets exist within the illustrated drainage area.

### 5.3.4 Site 033: GSI Return strategy in Shed A-34 on Bulter 55th Streets




One known upstream inlet exists within the current defined drainage area. Rooftop drainage areas need to be verified.

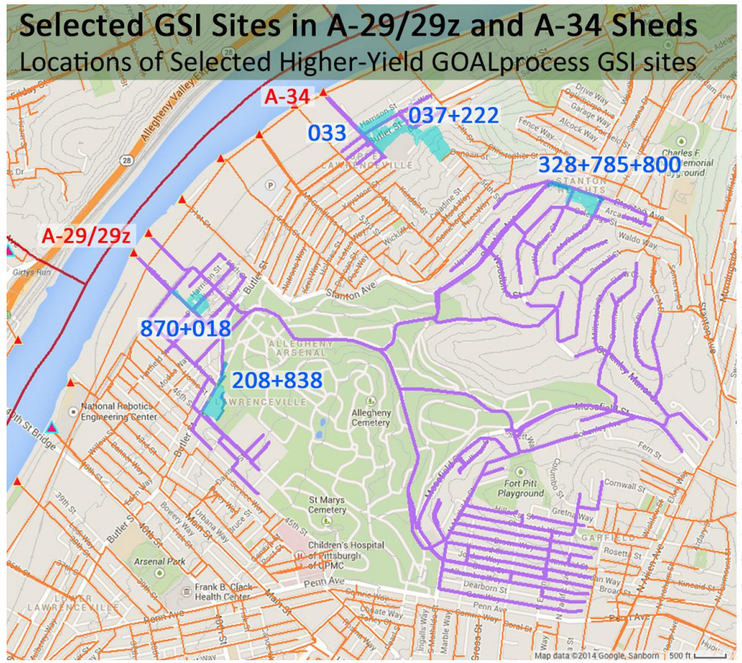
### 5.3.5 Site 037+222: GSI Infiltration ONLY strategy in A-34 between Butler Street between 55th and 56th




Multiple known upstream inlets exist within/adjacent to the current defined gross drainage area. Also, three to five private inlets could be added to the gross drainage of this GSI feature.

## 5.4 Summary of GOALprocess+SWMM Modeling Results for 5 Selected Site Installations

Results of GOALprocess+SWMM modeling a combination of 3 different GSI strategies (Remove GSI, Return GSI, and Infiltration ONLY GIS) on the 5 selected and field reviewed sites.




| Summary of High-Yield GSI Site Specific Layouts | Results of | Remove GSI | Return GSI | Return GSI | Infiltrate ONLY | Infiltrate ONLY |
|---|---|---|---|---|---|---|
| GOALprocess+SWMM Results | All 5 Selected | Site 870+018 | Site 328+785+800 | Site 033 | Site 208+838 | Site 037+222 |
| **Comparison Items** | **GSI Sites** | **in Shed A-29/29z** | **in Shed A-29/29z** | **in Shed A-34** | **in Shed A-29/29z** | **in Shed A-34** |
| Number of GSI installations (count) | 5 | 1 | 1 | 1 | 1 | 1 |
| GSI Area (SF) | 14,100 | 1,600 | 3,000 | 1,500 | 3,000 | 5,000 |
| GSI Storage (CF) [$45/cf] | 13,725 | 3,500 | 3,000 | 3,600 | 1,625 | 2,000 |
| Slow release outflow pipe within improved areas (FT) [$250/ft] | 680 | 480 | 90 | 110 | | |
| Slow release outflow pipe within unimproved areas (FT) [$150/ft] | 270 | | | | 90 | 180 |
| | | | | | | |
| Annual GSI runoff removed (MG) | 3.392 | 1.250 | 0.372 | 0.249 | 0.716 | 0.805 |
| Annual GSI runoff delayed and returned to combined sewer (MG) | 1.039 | 0.000 | 0.416 | 0.623 | 0.000 | 0.000 |
| **Annual Overflow gallons reduced at A-29/A-29z/A-34 (MG)** | **3.580** | **1.209** | **0.519** | **0.554** | **0.713** | **0.571** |
| | | | | | | |
| **Overall estimated installation cost ($)** | **$828,125** | **$277,500** | **$157,500** | **$189,500** | **$86,625** | **$117,000** |
| Average cost per installation ($) | $165,625 | $277,500 | $157,500 | $189,500 | $86,625 | $117,000 |
| | | | | | | |
| Cost per gallon of GSI runoff removed ($) | $0.244 | $0.222 | $0.423 | $0.761 | $0.121 | $0.145 |
| **Cost per reduced overflow gallon at A-29/A-29z/A-34 ($)** | **$0.231** | **$0.230** | **$0.303** | **$0.342** | **$0.121** | **$0.205** |
| | | | | | | |
| Drainage Area (AC) | 20.57 | 2.05 | 2.16 | 1.72 | 10.02 | 4.61 |
| Impervious Area (AC) | 6.59 | 1.73 | 0.89 | 1.57 | 1.14 | 1.25 |
| Percent Impervious (%) | 32.0% | 84.5% | 41.0% | 91.2% | 11.4% | 27.2% |

Main points from the table above (all runoff and overflow values are based on and generated by SWMM v513 Main Rivers model with the GOALprocess used for site layout):

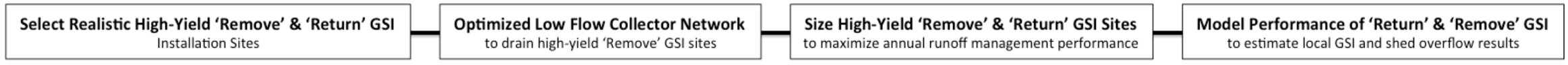
- Based on GOALprocess and SWMM v513 results, all five sites together appear to reduce localized flooding by 3.39mg/year and decrease combined overflows by a total of 3.58mg at outfall A-29-OF, A-29z-OF and A-34-OF at an estimated cost of $0.23 per reduced overflow gallon.
- The one 'Remove GSI' site option reduces overflows by an estimated 1.21mg/year at an estimated cost of $0.23 per eliminated overflow gallon.
- The two 'Return GSI' sites reduce overflows by about 1.073mg/year at an estimated cost of $0.323 per eliminated overflow gallon
- The two 'Infiltration ONLY GSI' sites reduce overflows by about 1.294mg/year at an estimated cost of $0.143 per eliminated overflow gallon. These two "Infiltrate ONLY" sites are not within public rights-of-way. Due to the dense development of the two study sheds (outside the cemetery), there are not many locations were the larger area requirements of high-yield 'Infiltration ONLY GSI' can be used.

Unit costs are estimated using recent bid and construction price information summarized into $45/cubic foot for GSI, $250/foot or $150/foot for small diameter pipe in improved or unimproved areas.

# 6 Task 6: Layout and Modeling of Top 10+% High-Yield Sites in Sheds A-29/29z and A-34

***SCOPE:*** *For the two selected sewersheds (A-29/29z and A-34), provide planning level cost estimates for each of the top 10% ROW installation sites in units of dollars, and dollars per gallon of overflow eliminated in the typical year. Provide a description of the method used to develop these cost estimates, including the assumptions used.*

## 6.1 General Steps to establish an effective 'Remove' and 'Return' GSI design process




Right-sized high-yield sites provide the most effective and affordable locations to use GSI strategies. High-yield sites typically manage higher flows. To manage sediment it is important that high-yield GSI installations pretreat intercepted water to reduce maintenance and increase longevity by settling suspended solids before runoff enters the GSI treatment and/or storage volumes.

In this shed wide planning process, we reviewed all high-yield sites and selected sites that could be most easily connected along a shortest path for a low flow collector pipe network. We then used the gross drainage area of those selected site to aid in selection of additional high-yield sites. This process identified and used 78 high-yield sites in sheds A-29/29z and A-34 that based upon current knowledge, integrated databases, and modeling processes appear to support both 'Phase 1 Return GSI' and a 'Phase 2 Remove GSI'.

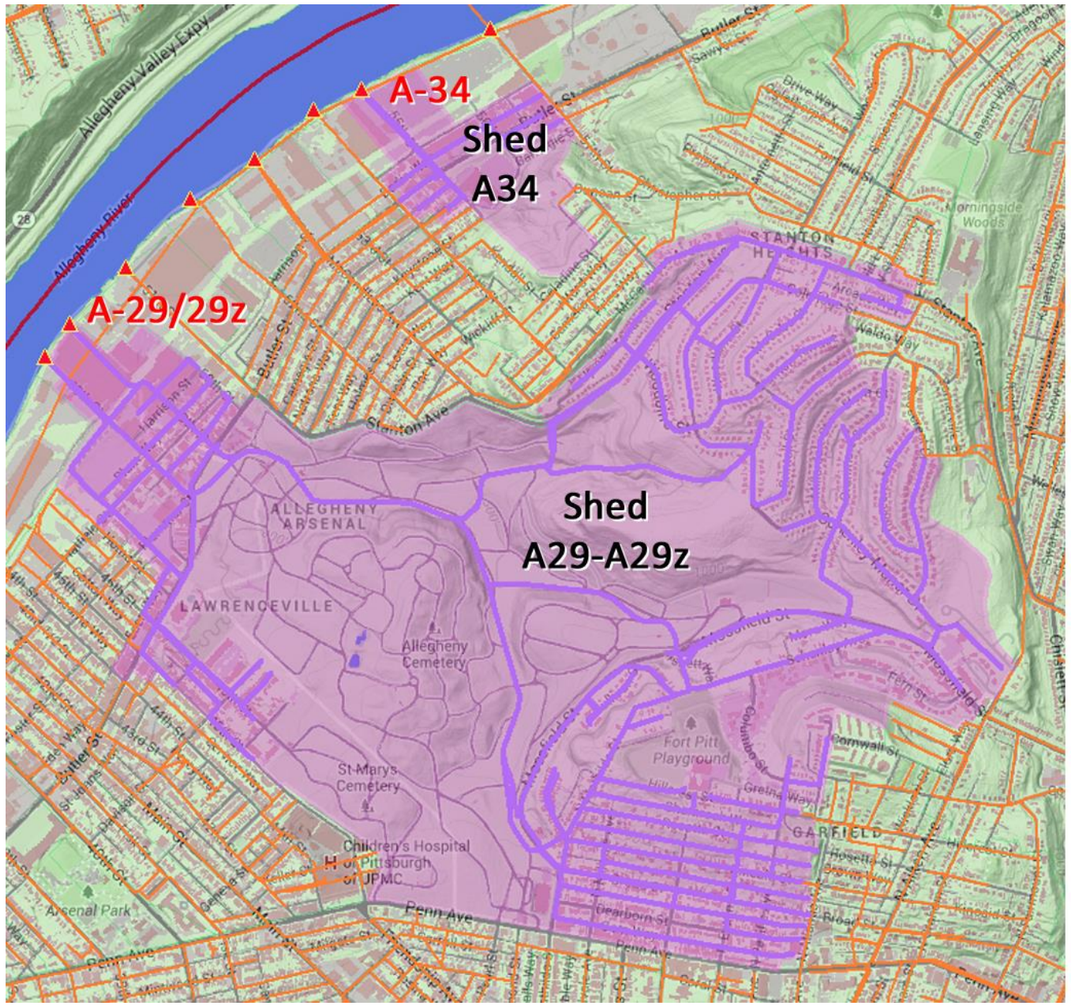
This process resulted in SWMM calibrated hydrographs used by the SWMM Main Rivers model to determine the effects of GSI layouts on outfalls, nodes, and conduits.

## 6.2 Shed wide 'Infiltration ONLY' GSI Option

Landbase Systems reviewed layouts for shed wide 'Infiltration ONLY' GSI. We found several dozen possible 'large' sites that appear they could physically support 'Infiltration ONLY' GSI to help reduce localized flooding and decrease some combined overflows. The total overall volume managed by these larger 'Infiltration ONLY' sites appears relatively small (about 6-7 million gallons) when compared to the opportunities using a phased Return/Remove GSI approach. For the volume of water it can handle, 'Infiltration ONLY' GSI can provide a cost effective solution. It is beyond the scope of this pilot study to provide a shed wide master plan showing how 'Infiltrate ONLY' GSI can be best used. Based upon our work on projects in this region, 'Infiltration ONLY' GSI has a cost effective and affordable role in key locations.

## 6.3 Summary of Top High-Yield Installations of Return GSI (Phase 1 Local Flooding Reduction) and Remove GSI (Phase 2 Local Flooding and Overflow Reduction)

Layouts for two different Top 10+% GSI strategies (Remove GSI and Return GSI) were created for A-29/29z and A-34.




| Summary of High-Yield GSI Shed Layouts<br>GOALprocess+SWMM Results<br>Comparison Items | Return GSI<br>Phase 1 Local<br>Flood Reduction | Remove GSI<br>Phase 2 Local Flood &<br>Overflow Reduction |
|---|---|---|
| Number of GSI installations (count) | 78 | 78 |
| GSI Area (SF) | 109,050 | 109,050 |
| GSI Storage (CF) [$45/cf] | 218,100 | 218,100 |
| Slow release outflow pipe within improved areas (FT) [$250/ft] | 5,060 | 17,170 |
| Slow release outflow pipe within unimproved areas (FT) [$150/ft] | 0 | 6,325 |
| | | |
| Annual GSI runoff removed (MG) | 14.942 | 58.817 |
| Annual GSI runoff delayed and returned to combined sewer (MG) | 31.886 | 0.000 |
| **Annual Overflow gallons reduced at A-29/A-29z/A-34 (MG)** | **30.644** | **56.985** |
| | | |
| **Overall estimated installation cost ($)** | **$11,079,500** | **$15,055,750** |
| Average cost per installation ($) | $142,045 | $193,022 |
| | | |
| Cost per gallon of GSI runoff removed ($) | $0.742 | $0.256 |
| **Cost per reduced overflow gallon at A-29/A-29z/A-34 ($)** | **$0.362** | **$0.264** |
| | | |
| Drainage Area (AC) | 179.74 | 179.74 |
| Impervious Area (AC) | 65.74 | 65.74 |
| Percent Impervious (%) | 36.6% | 36.6% |

Shed-wide implementation of a 'Phase 1 Return GSI' at the 78 selected sites appear to eliminate 30.64 million gallons of 2003 typical year overflow from A29/29z and A-34 for about $0.36 per gallon. Implementing a low flow collector network to the 78 selected sites in a 'Phase 2 Remove GSI' requires about $3.9 million more investment and appears to improve GSI performance by eliminating 56.96 million gallons of 2003 typical year overflow from A29/29z and A-34 for about $0.26 per gallon. In addition, a 'Phase 2 Remove GSI' strategy eliminates an additional 31.88 million gallons of from water the combined sewer network (reduce overflow volume and treatment costs) and increases the amount of GSI filtered water released into the environment to about 58.82 million gallons during a 2003 typical year.