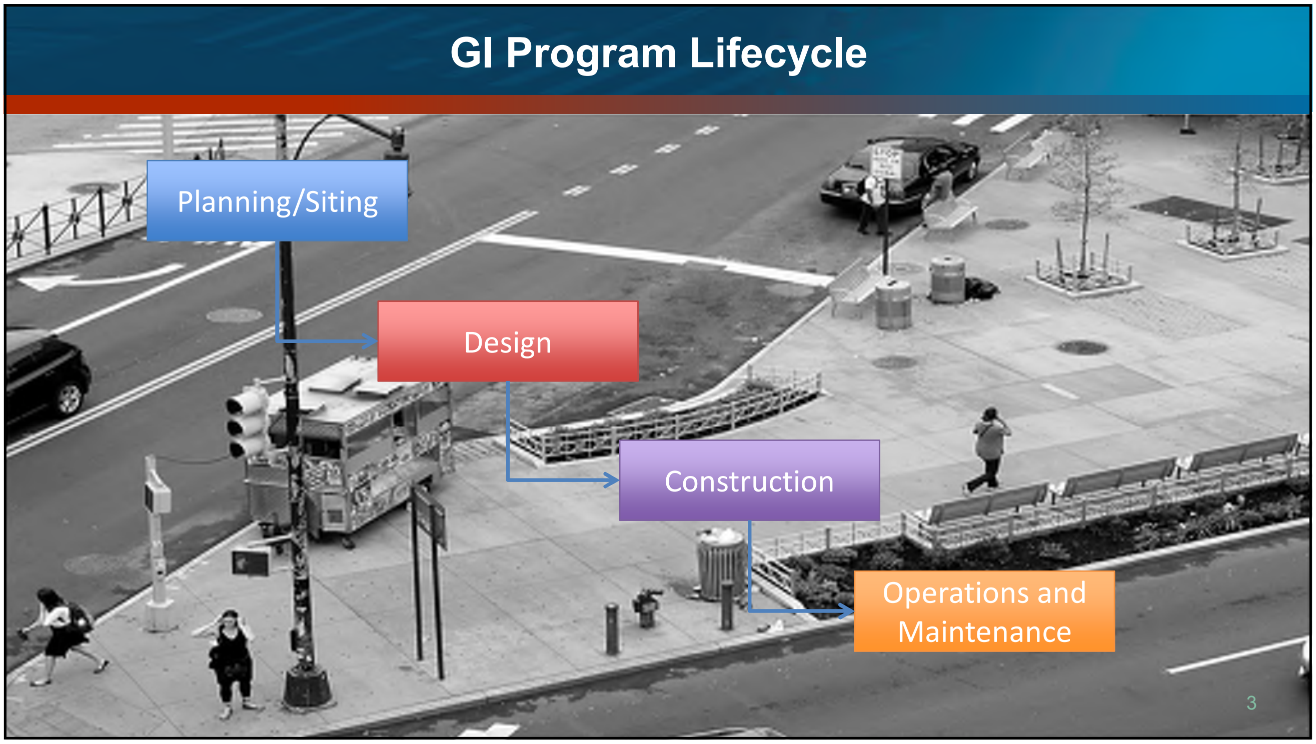
LIFE CYCLE COST & ASSET MANAGEMENT FOR GREEN INFRASTRUCTURE

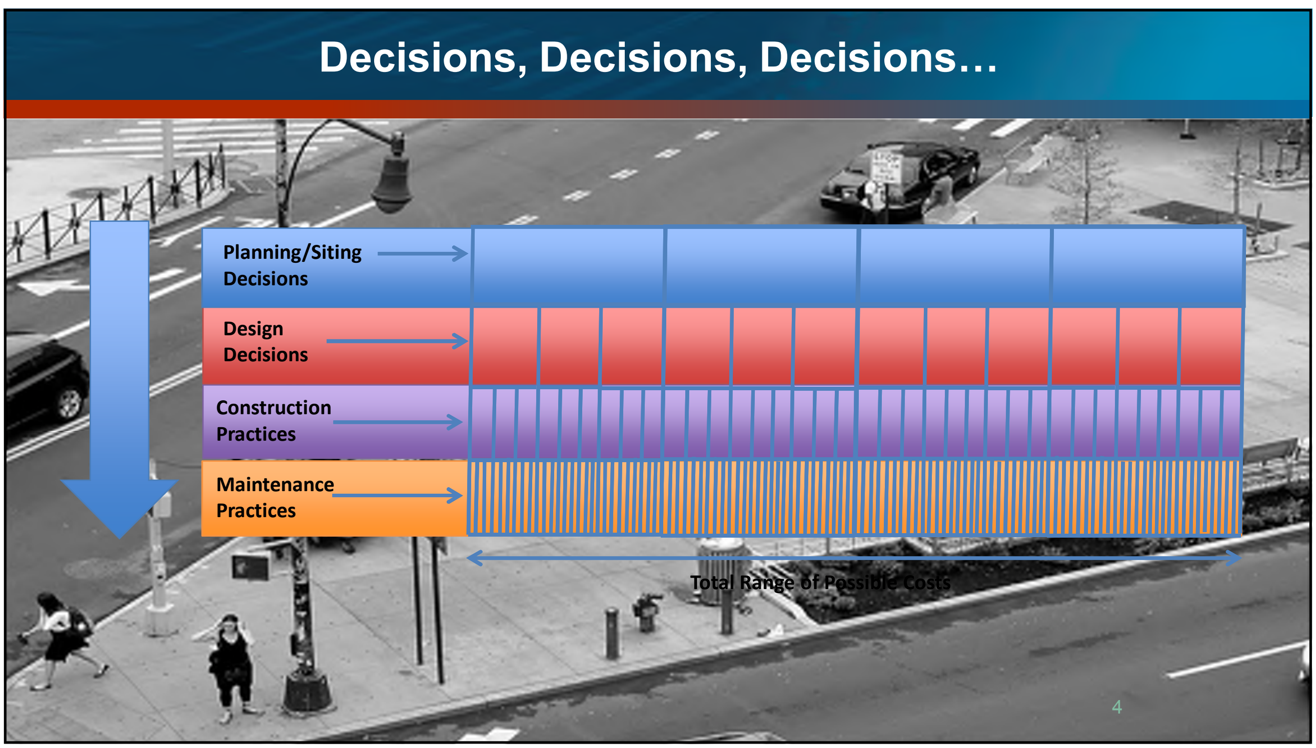
CWEA SPRING SEMINAR
JUNE 14, 2018

PRESENTERS: AKTA PATEL AND BIANCA SANTOS

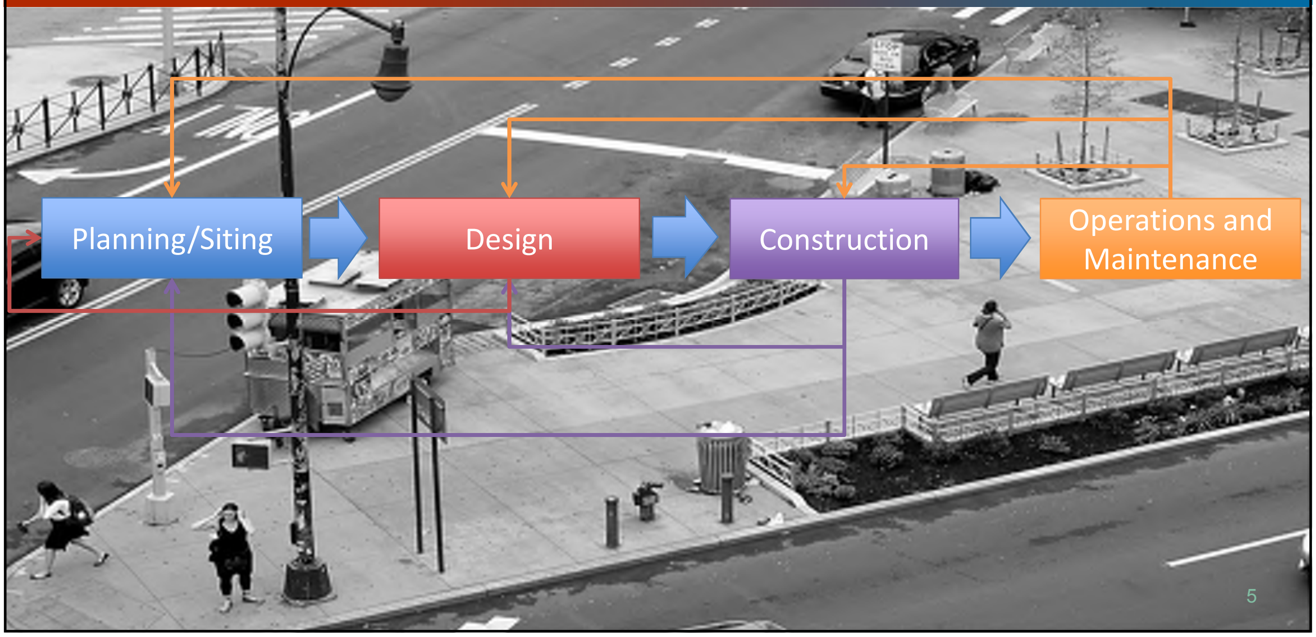
Outline

- INTRODUCTION
- FRAMEWORK TO EVALUATE LIFE CYCLE COST
- PLANNING, DESIGN, CONSTRUCTION, AND O&M INTERACTIONS AND FEEDBACK
- ASSET MANAGEMENT PROGRAM SET UP AND IMPLEMENTATION


GI Program Lifecycle
Planning/Siting
Design
Construction
Operations and Maintenance
3


Decisions, Decisions, Decisions…
Planning/Siting Decisions
Design Decisions
Construction Practices
Maintenance Practices
Total Range of Possible Costs
4

Adaptive Management and Feedback Loops



5

Institutional Commitment to Data Driven and Iterative Learning

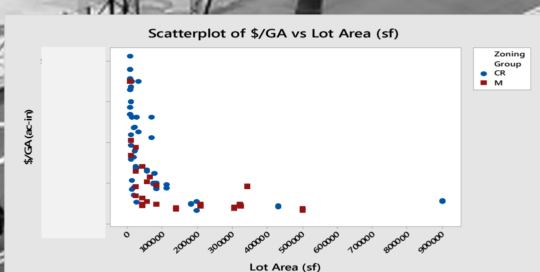
- Break down silos that insulate/prevent communication
- Benchmark program performance
- Drive the culture - data matters!
- Dedicate resources to data collection and systematic learning
- Set up asset management systems to drive and support data collection
- Set up data systems to extract costs at a granular (asset) level
- Use the power of multivariate analysis to understand relationships and drive innovation
- Collaborate with academics!

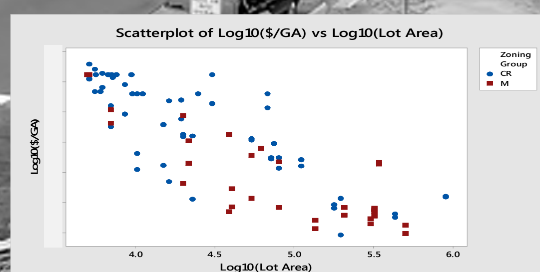
6

Analyzing Built Data

7

Regression Modeling to Support Cost Forecasting





Zoning Group	Regression Equation	Error	R^2	Adjusted R^2	Predictive R^2
Non-Manufacturing		0.180			
Manufacturing		+52% -34%	74.40%	73.87%	72.89%

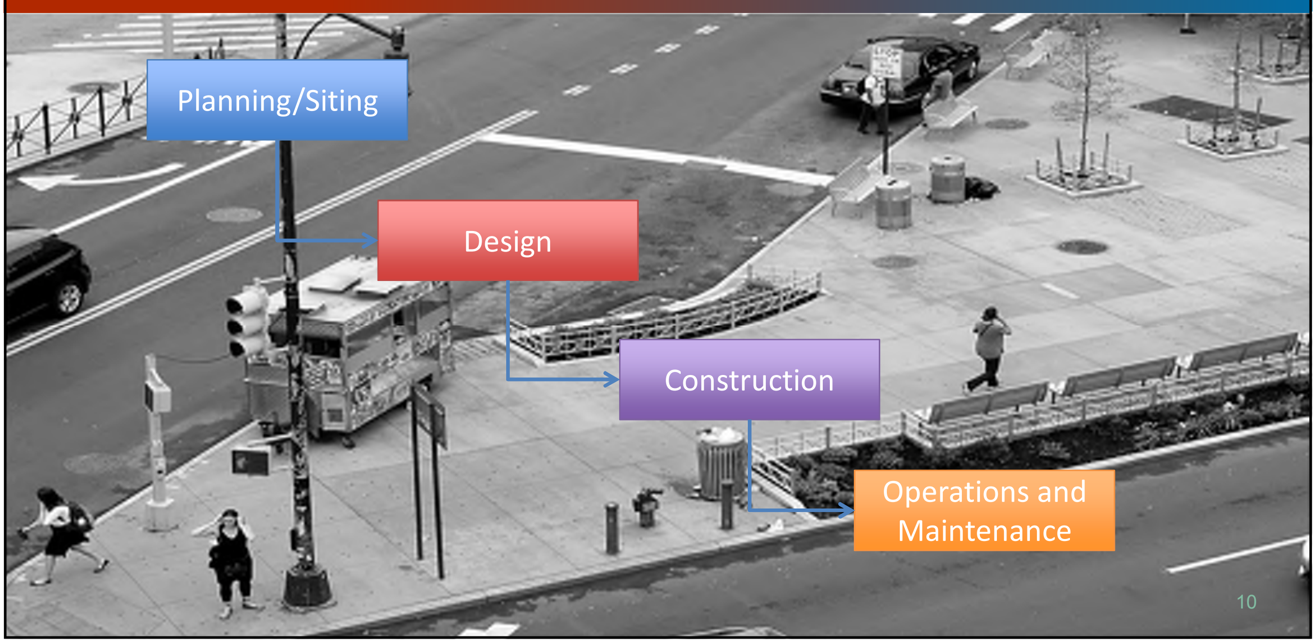
8

Institutional Commitment to Constant Innovation

- Cultivate an innovation mindset and culture
- Small innovations add up (and so do small inefficiencies)
- Dedicate funding for innovation within your organization
- Develop active vendor engagement / partnerships
- Hold design competitions and hack-a-thons
- Emphasize product development
- Partner with technology incubators
- Migrate innovations from other industries

9

GI Program Lifecycle



10

Planning/Siting

- The **Big Choices** translate **Program Goals** into…
- **Typologies** (*Technology/Scale/Setting*)
  - Distributed vs. centralized (i.e. big versus small)
  - Above ground vs. below ground
  - Vegetated vs. non-vegetated
  - ROW vs. Off-ROW
  - Public vs. private
- While focusing investments into key **City-Wide/Watershed Scale Targets** areas (*Location*)
  - Hydrologic effectiveness and modeling
  - Use equivalency ratios to target investments (if you want to)

11

GI Typologies Drive Costs and Co-benefits

	Public		Private	
Distributed	Above Ground	Below Ground	Above Ground	Below Ground
Centralized	Above Ground	Below Ground	Above Ground	Below Ground

12

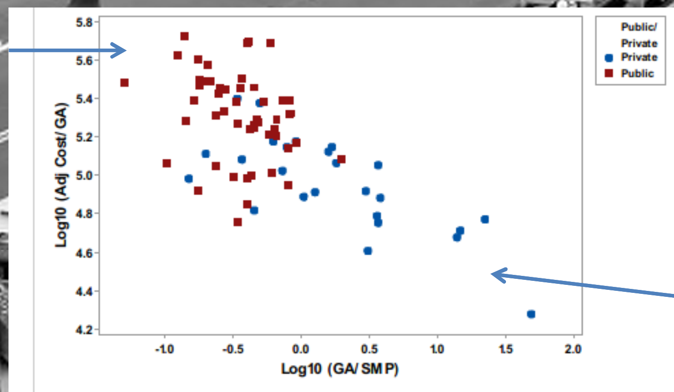
GI Typology Cost Relationships in Urban Settings

Higher Cost

Higher Co-benefits

Distributed

Vegetated
On ROW
Public
Surface



Lower Cost

Lower Co-benefits

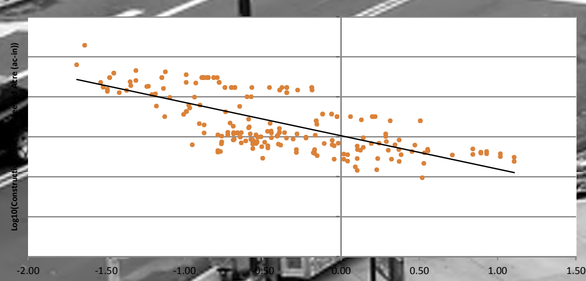
Centralized

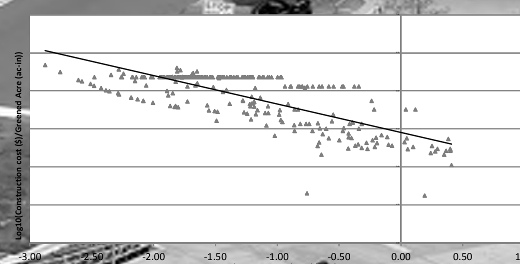
Non-vegetated
Off ROW
Private
Subsurface

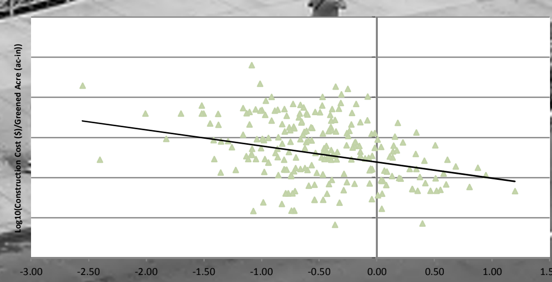
Project Type	Regression Model	R^2	$R^2_{adjusted}$	$R^2_{predictive}$
Private	$Log_{10}(Cost/GA) = 5.0109 - 0.2708*Log_{10}(GA/SMP)$	50.4%	49.1%	46.5%
Public	$Log_{10}(Cost/GA) = 5.1817 - 0.2708*Log_{10}(GA/SMP)$			

13

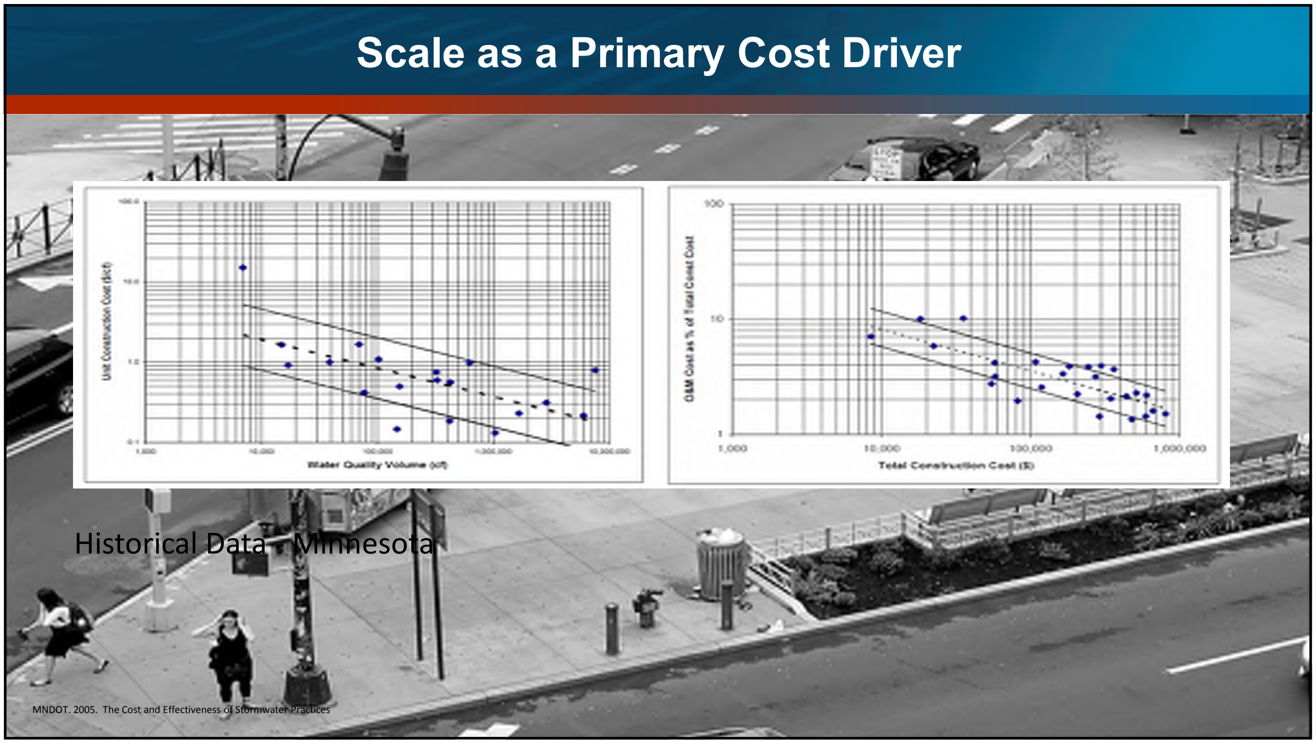
Scale as a Primary Cost Driver

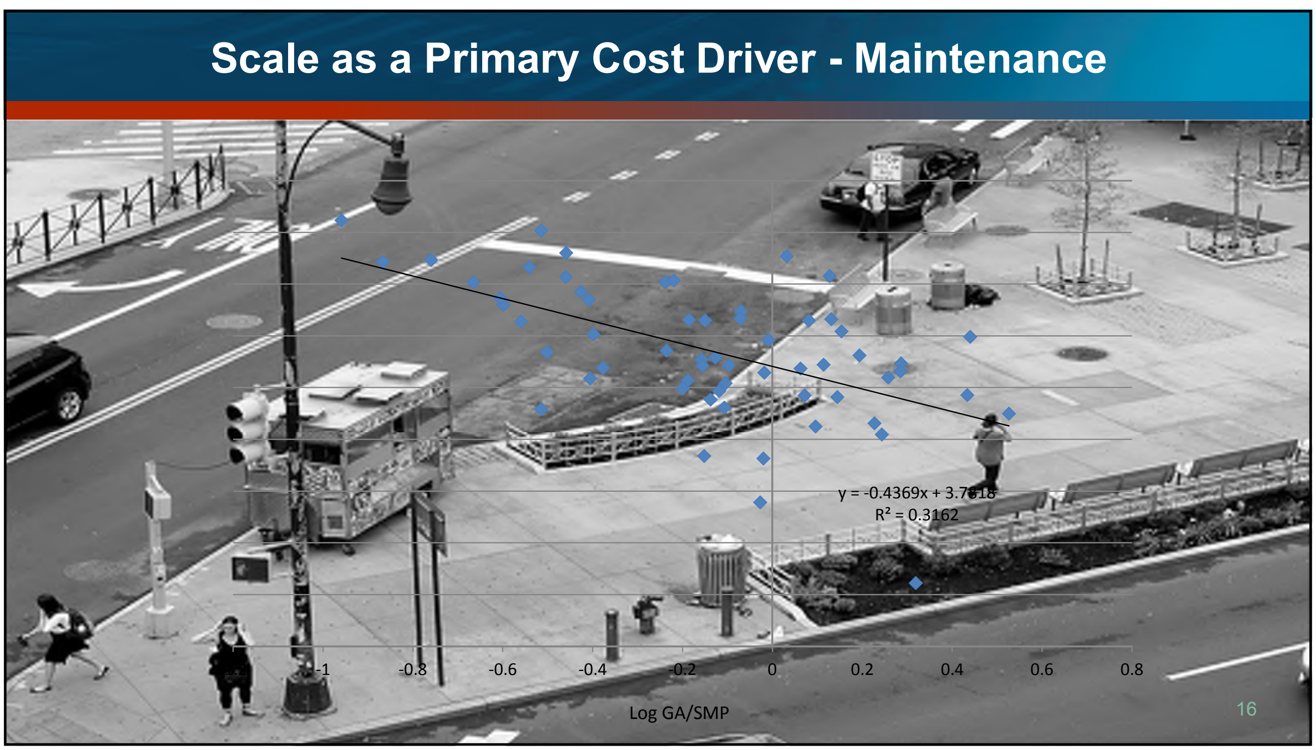






14

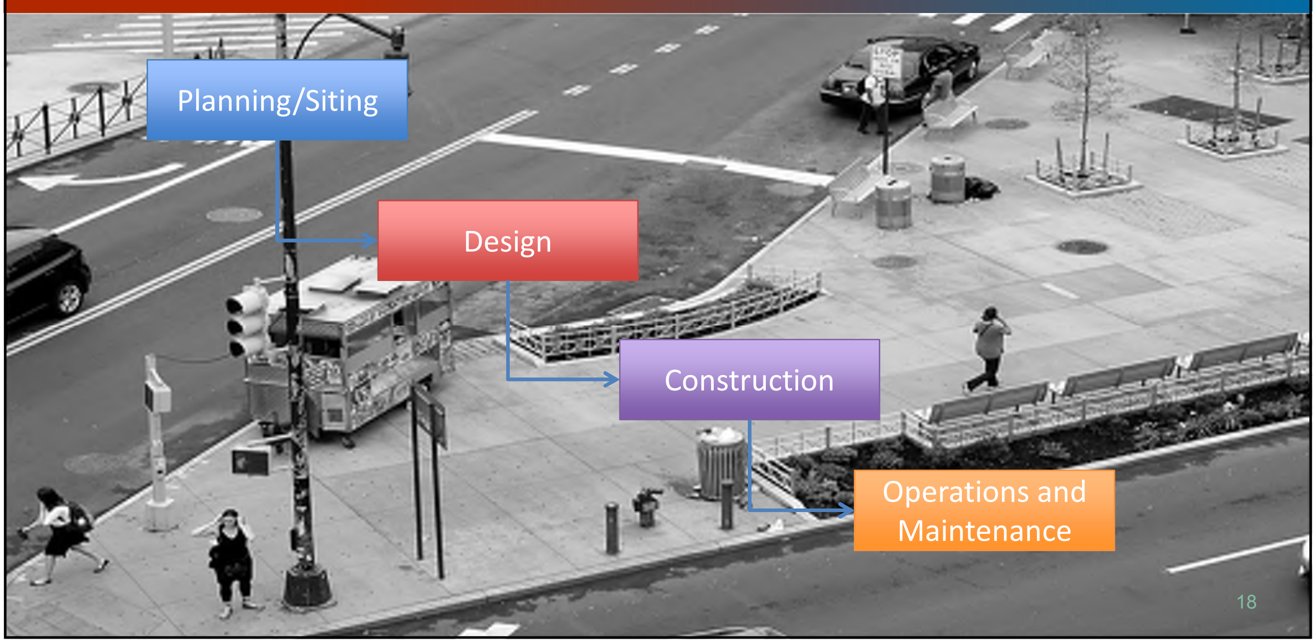

Scale as a Primary Cost Driver
Unit Construction Cost ($/cf)
Water Quality Volume (cf)
O&M Cost as % of Total Const Cost
100
10
1
1,000
10,000
100,000
1,000,000
Total Construction Cost ($)
Historical Data - Minnesota
MNDOT. 2005. The Cost and Effectiveness of Stormwater Practices


Scale as a Primary Cost Driver - Maintenance
y = -0.4369x + 3.7618
R² = 0.3162
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
Log GA/SMP
16

Life-Cycle Cost Forecasting

17

GI Program Lifecycle



18

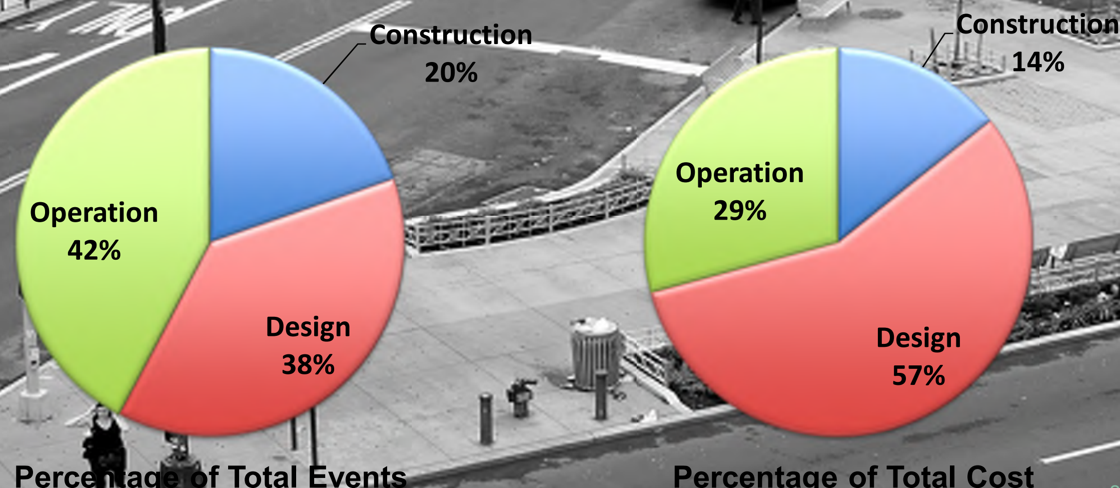
Design

- Engineers routinely evaluate **Construction Costs** associated with **Design Decisions**, but how can we effectively evaluate **Life Cycle Costs**?
  - Hydraulic loading ratio
  - Pretreatment
  - Media and plant specifications
  - Features for ease of maintenance
  - Features for monitoring

19

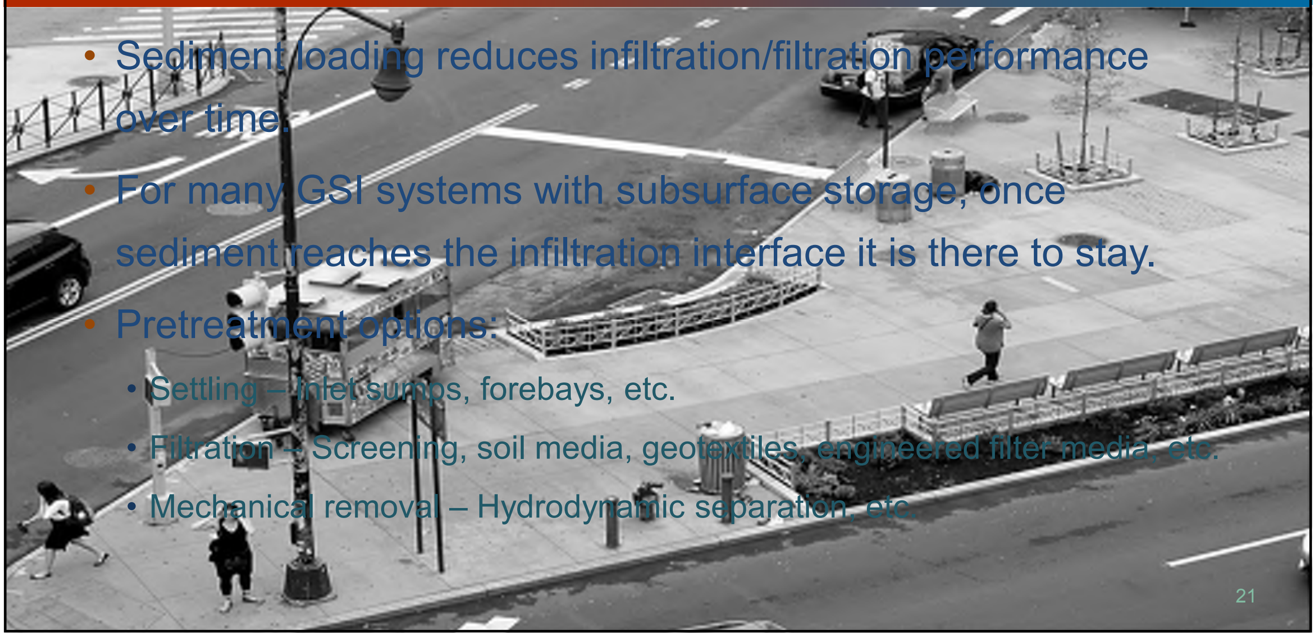
Design

Root Cause of Major Modifications / Repairs during O&M from 2011 – 2016



20

Design - Pretreatment



- Sediment loading reduces infiltration/filtration performance over time.
- For many GSI systems with subsurface storage, once sediment reaches the infiltration interface it is there to stay.
- Pretreatment options:
  - Settling – inlet sumps, forebays, etc.
  - Filtration – Screening, soil media, geotextiles, engineered filter media, etc.
  - Mechanical removal – Hydrodynamic separation, etc.

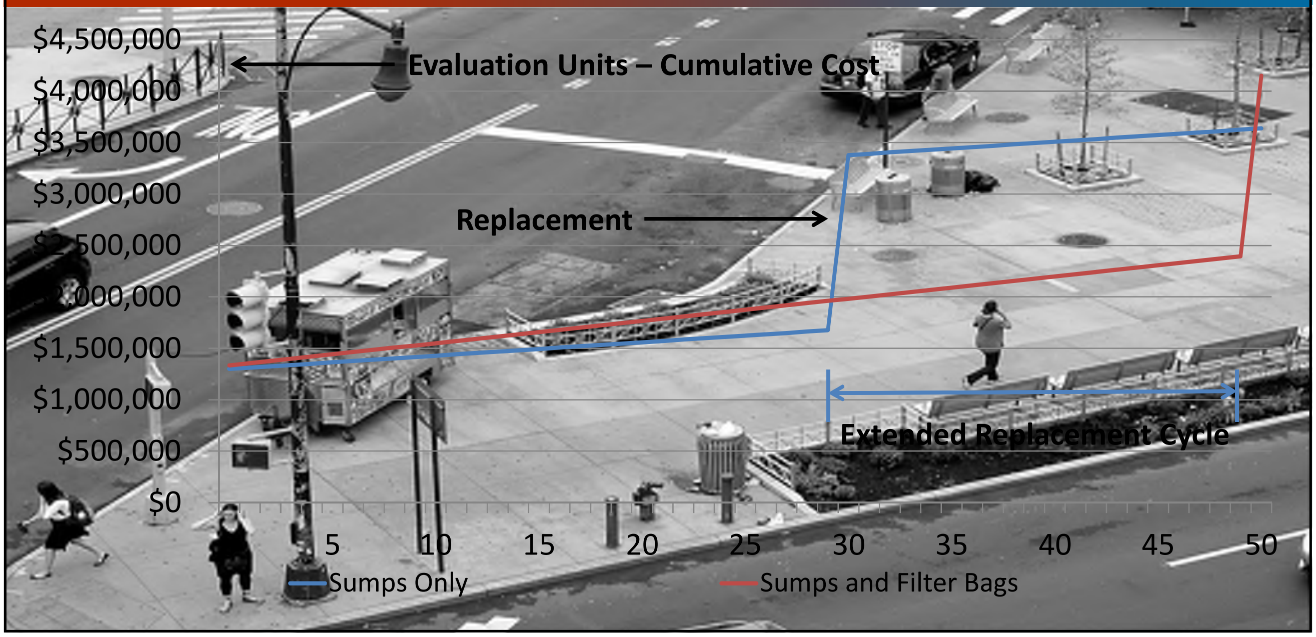
21

Design - Pretreatment

- Evaluating investments in pretreatment:
  - Costs:
    - Pretreatment construction cost
    - Pretreatment routine maintenance cost
    - Pretreatment replacement cost
  - Benefits:
    - Decrease in routine maintenance cost
    - Decrease in GSI replacement / refurbishment cycle

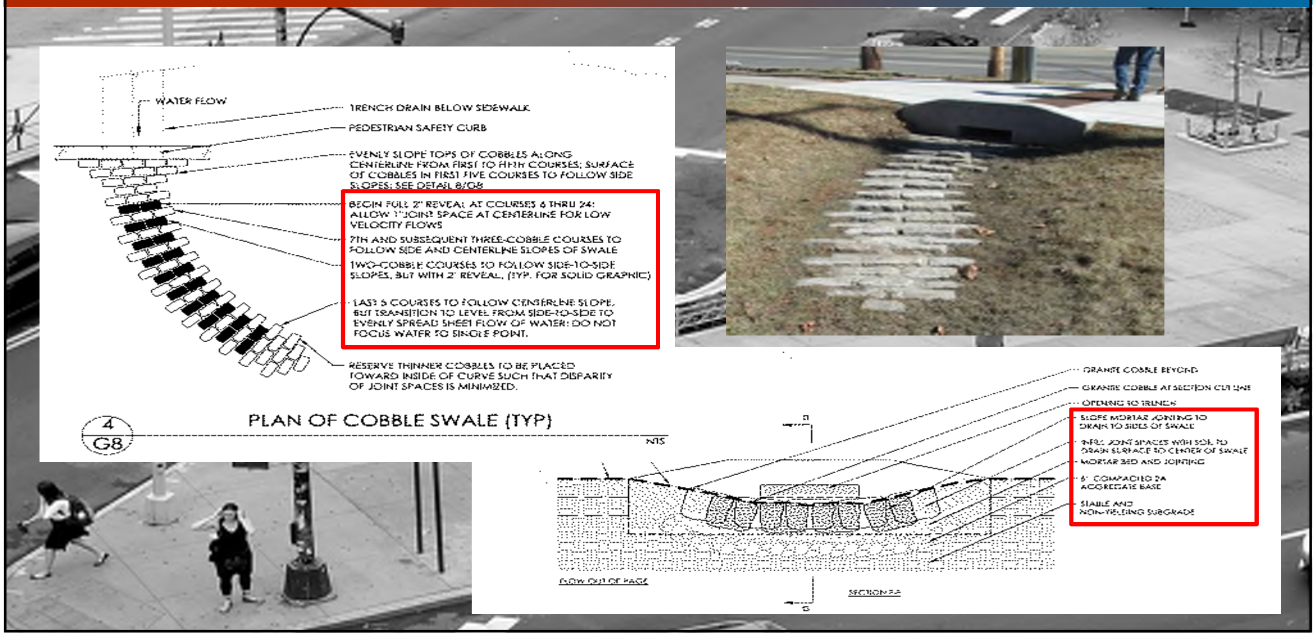
22

Pretreatment: Infiltration Basin Example

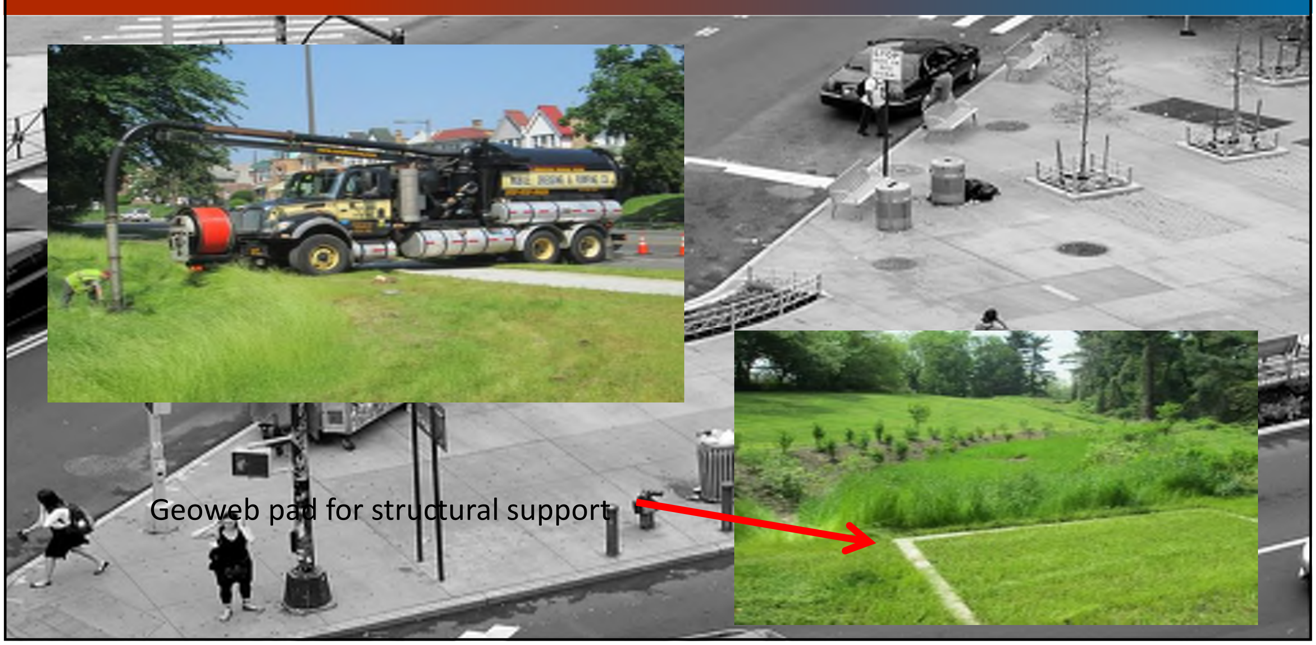


Design

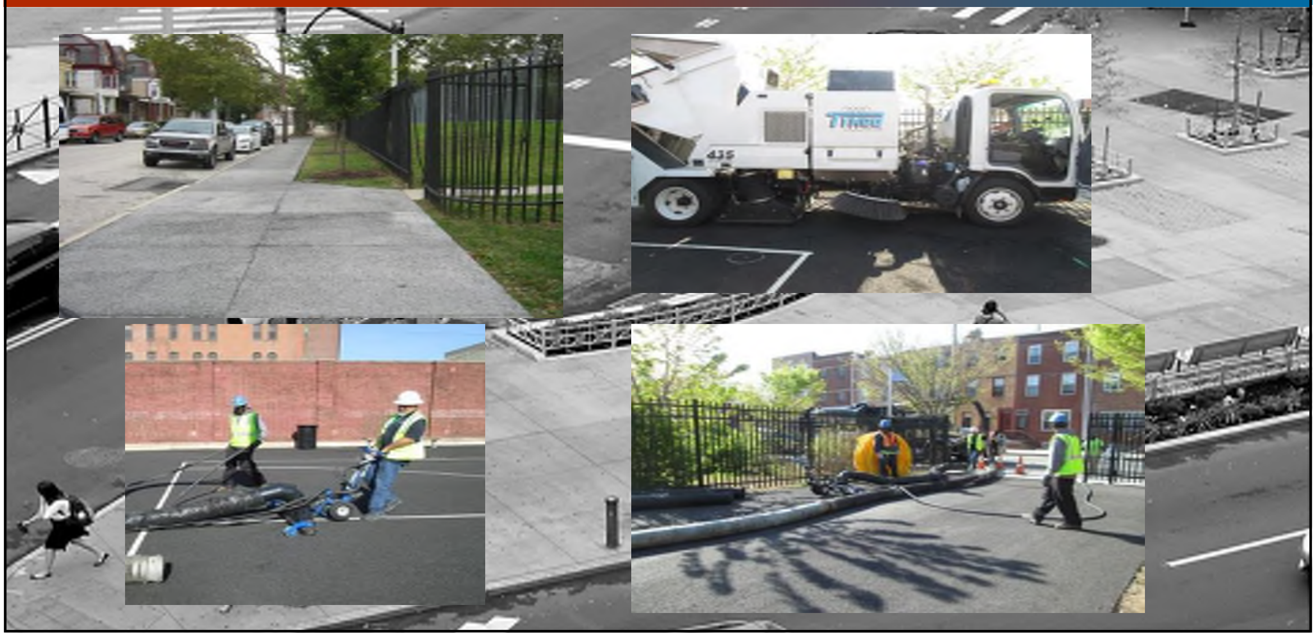
DESIGN FEEDBACK: EROSION AND SEDIMENTATION CONTROL AT INFLOW POINTS



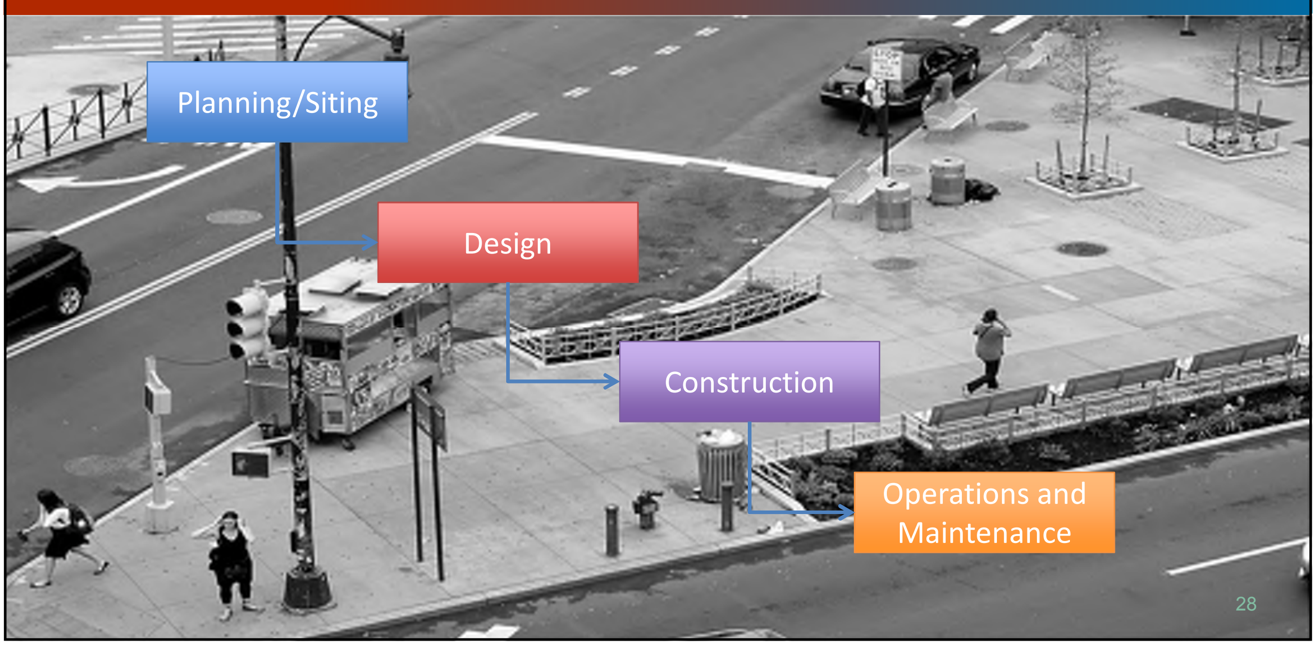
DESIGN FEEDBACK - ACCESS



DESIGN FEEDBACK – ACCESSIBILITY FOR ROUTINE & RESTORATIVE CLEANING

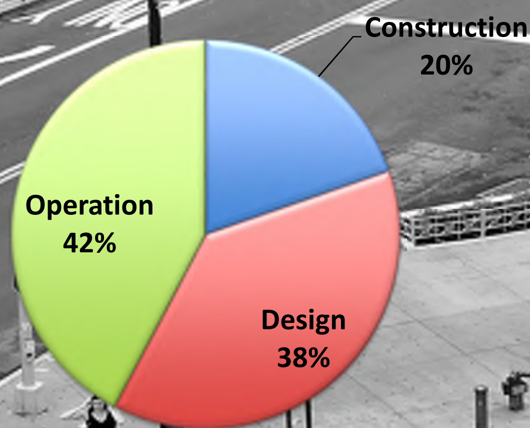


GI Program Lifecycle

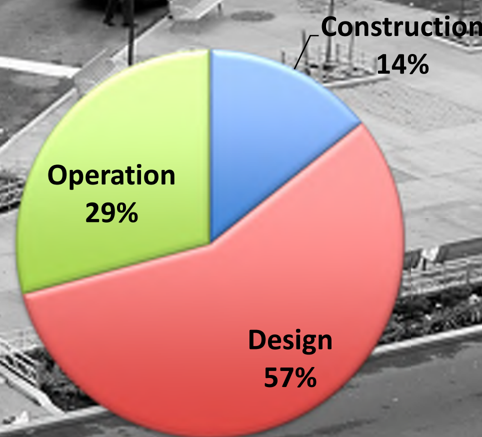


Construction

Root Cause of Major Modifications / Repairs during O&M from 2011 – 2016



Percentage of Total Events



Percentage of Total Cost

29

Construction

Overflow structure elevation at or below the infiltration/filtration surface

Construction

System bypass during low intensity events

Construction

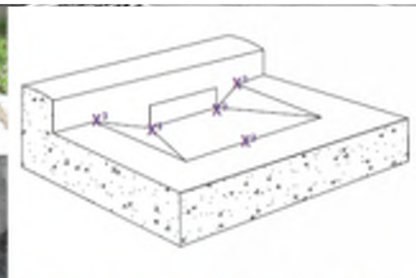
- Resolve construction issues <u>during construction</u>, not during operation and maintenance.
  - Construction quality control
  - Accurate as-builts
  - Contractor guarantee period enforcement

32

Construction – As-Built Survey

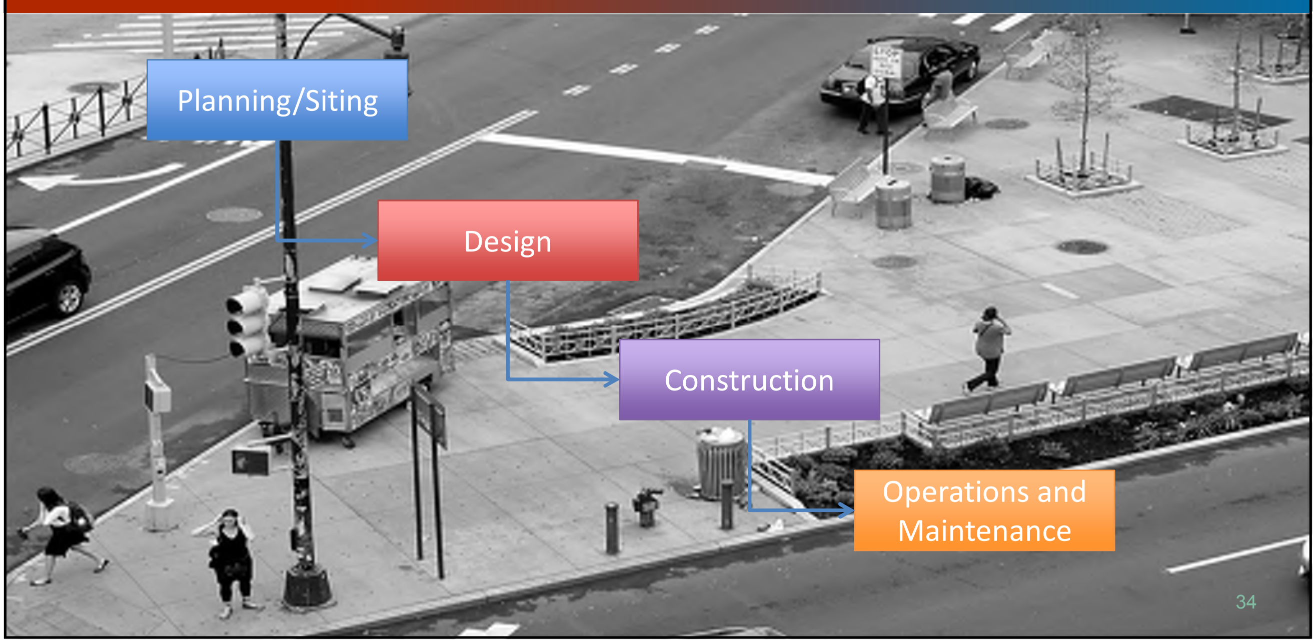
Feature	Required Survey Point	Description of Survey Point
Trench Drain	X¹ Lowest point of trench drain	Lowest points at both upslope and downslope locations along the length of the channel.
	X² Top of grate	Top/center elevation on front and back of grate (width of trench drain to be included).
	X³ Concrete Apron Dimensions	Grade changes of concrete apron along the gutter line, plus apron extent opposite trench drain opening

Trench drain: lowest point of trench drain, top of grate, and width of the grate.



Concrete apron dimensions: Grade changes of concrete apron along the gutter line, plus apron extent opposite trench drain opening

GI Program Lifecycle



34

Operation & Maintenance

- Preventative vs. Reactive
- Data analysis
- Inspections to inform maintenance
- Importance of O&M Considerations during planning, design, and construction

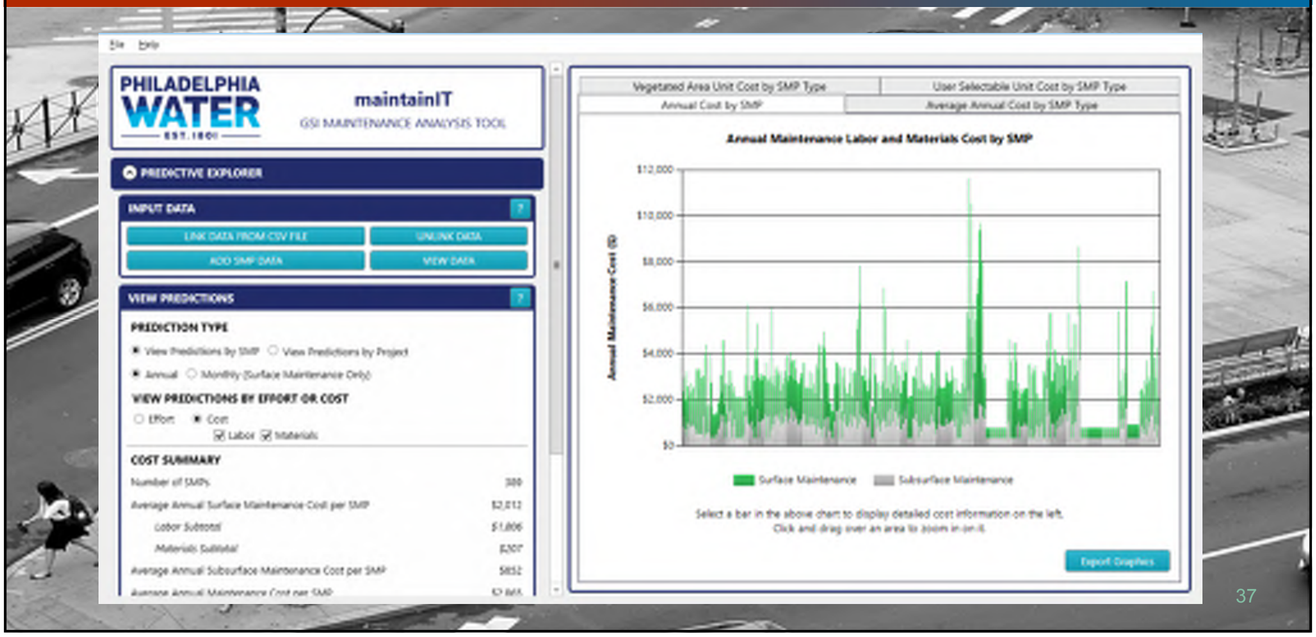
35

Design Decision Impacts on Routine O&M Effort & Cost – Multivariate Analysis

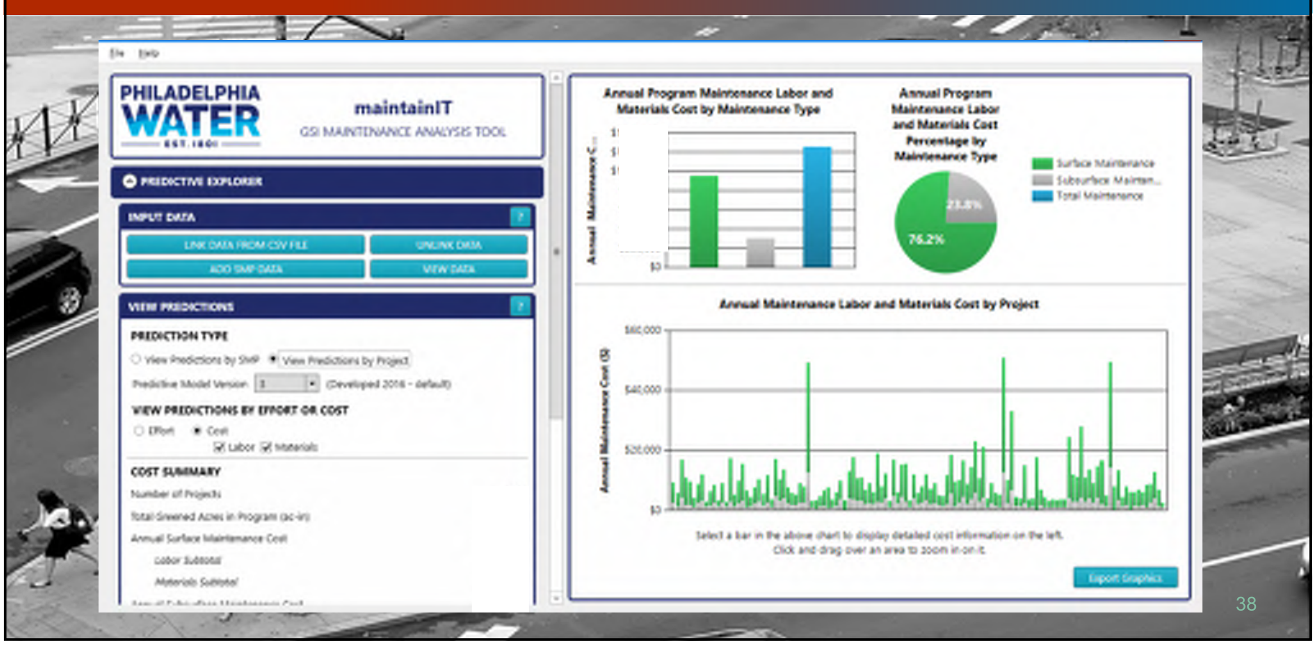
- SMP type
- Number of SMPs
- Vegetated / non-vegetated
- Formal / natural landscape
- SMP footprint
- SMP vegetated area
- Infiltration footprint area
- Number of SMP trees
- Number of filter bags
- Number of trash guards
- Number of green inlets
- Number of grey inlets
- Number of inlets
- Number of domed risers
- Number of control structures
- Number of flow control structures
- Trench drain length
- Distribution pipe length
- Underdrain length
- Total pipe length
- Conveyance length
- Number of pipes
- Number of pipe fittings
- Storage depth
- Storage volume
- Drainage area
- Impervious drainage area

36

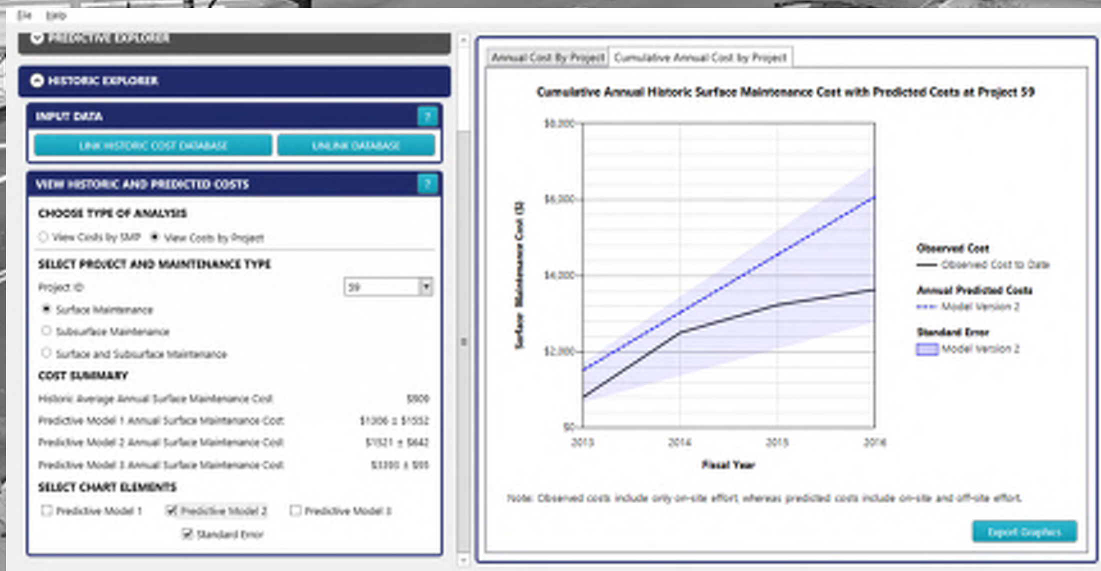
Routine Maintenance Cost Prediction



Routine Maintenance Cost Prediction



Routine Maintenance Cost Prediction



39

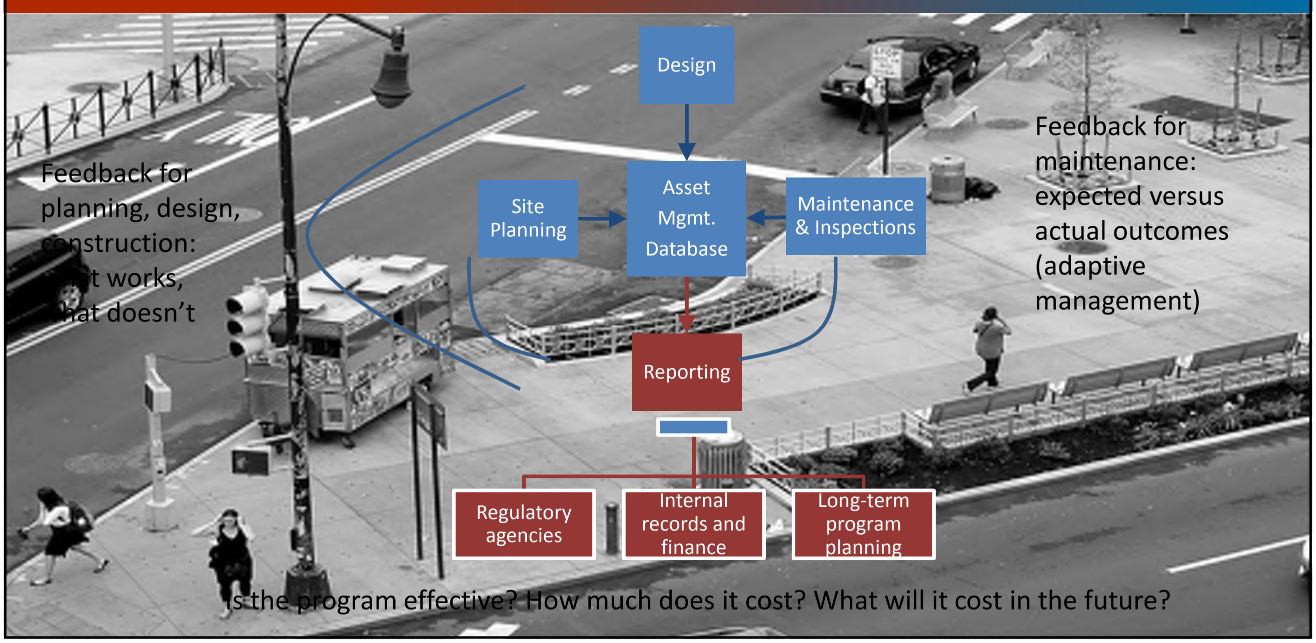
Asset Management - Infrastructure Asset Registry

- An inventory of all uniquely identifiable assets, in hierarchical format, with all of their associated attributes;
- Highly recommended to share the GI Asset Registry among county or city departments;
  - Ensuring the GI footprint is on record to prevent GI structural damage from surrounding development or external forces.
- An Asset Management System (AMS) measures the performance of grouped green infrastructure on a routine basis by an Operations & Maintenance (O&M) group.

AMS Set Up: What are your program goals?

"Deliver the desired **Level of Service**, at the **lowest life cycle** cost, at an **acceptable level of risk**"

Infrastructure Asset Registry



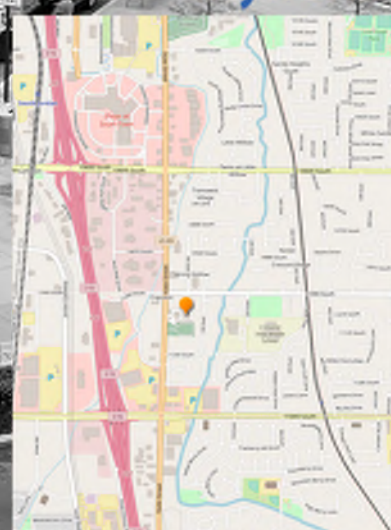
Fundamental AMS Questions

- What is the current state of my assets?
- What is my required level of service?
- Which assets are critical to sustain performance?
- What are my best O&M and CIP investment strageties?
- What is my best long-term funding strategy?

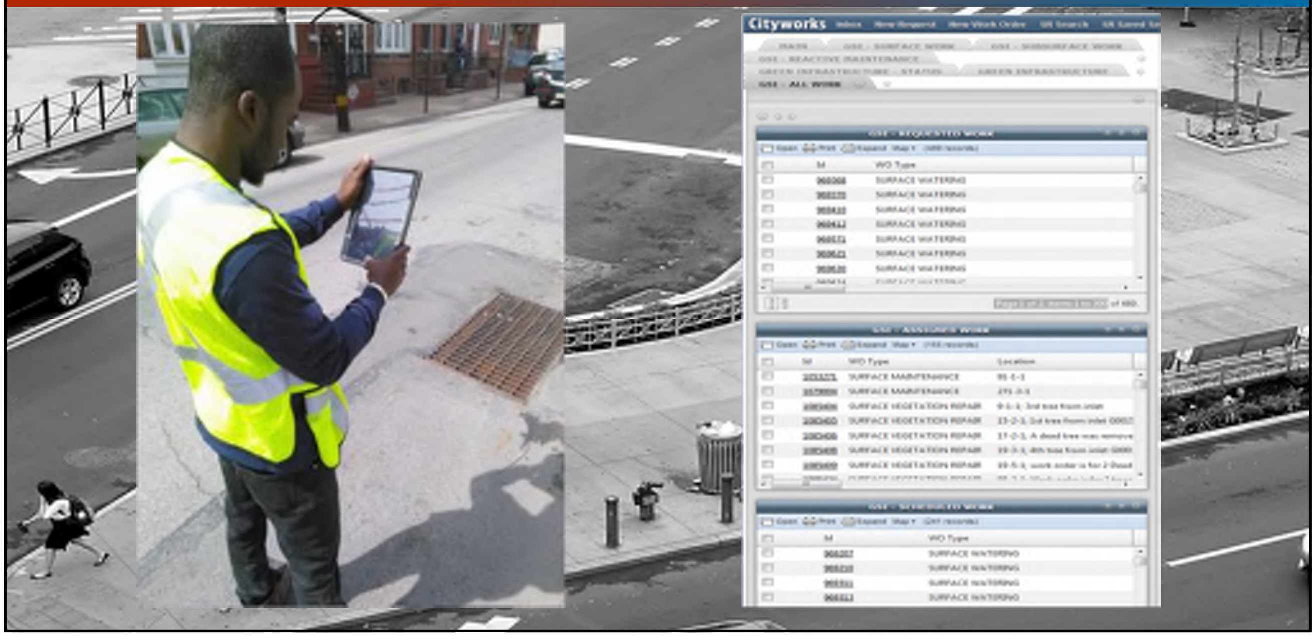
Philadelphia Water Department (PWD) GI AMS Platform: Cityworks

- ESRI GIS-Based Utility Platform
- Enterprise asset management package designed for utilities and public works
  - Templates for water/sewer and stormwater
- Geodatabase integration
  - Map-based scheduling
  - GIS-modeling of utility networks
- Desktop and mobile capabilities
- Setup is a significant investment

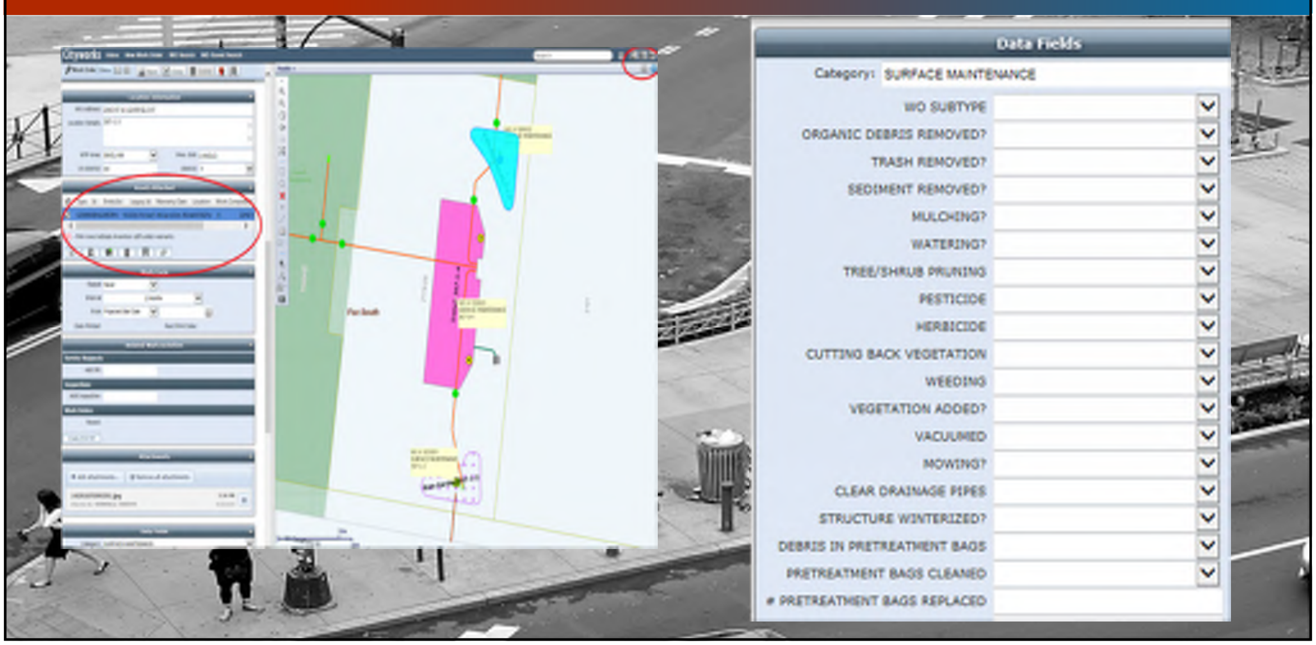
Cityworks



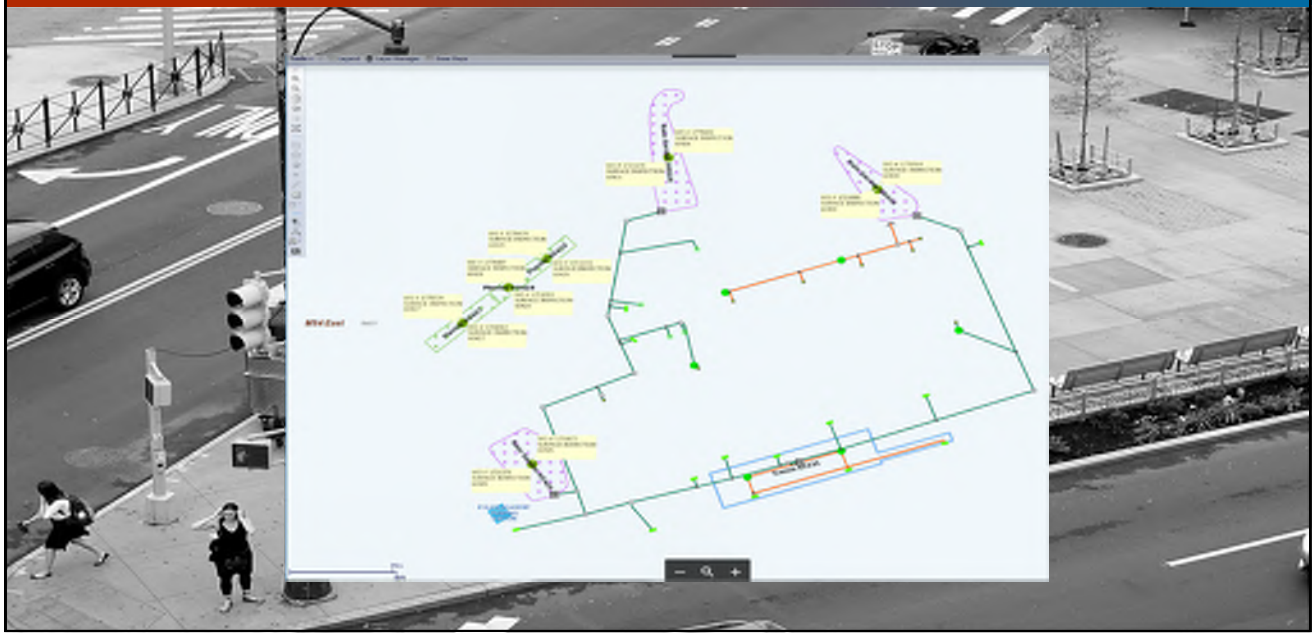
PWD GI AMS Platform: Cityworks



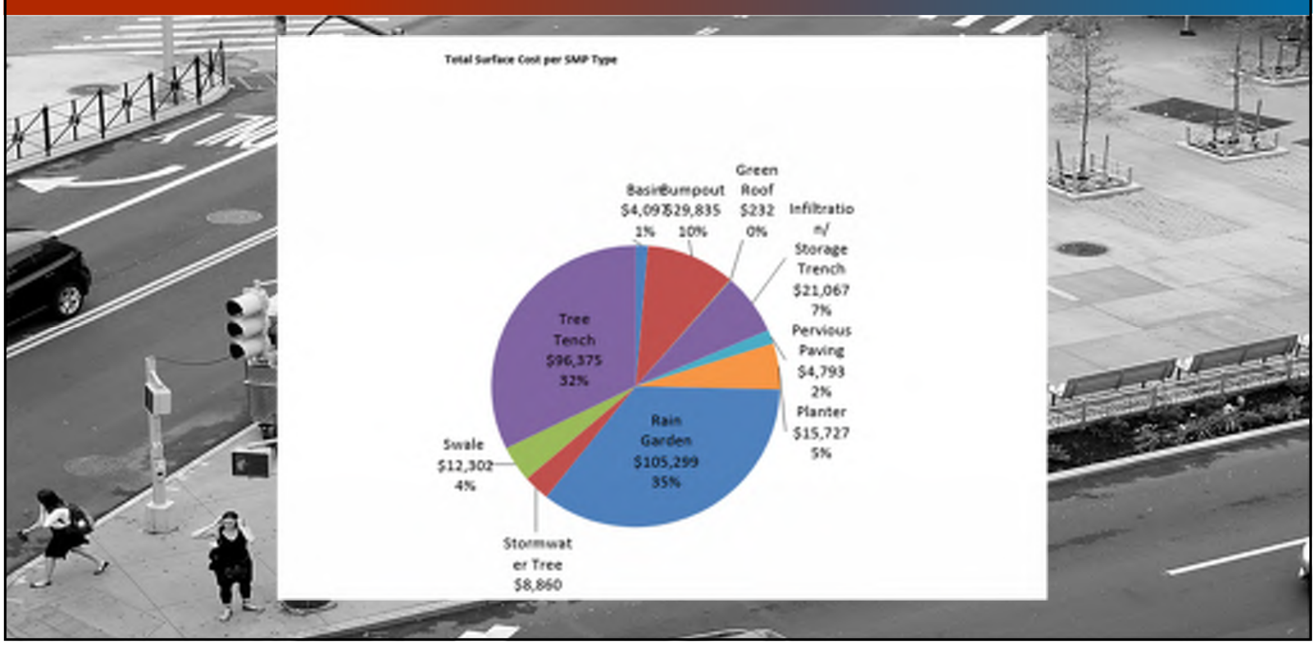
PWD GI AMS Platform: Cityworks



PWD GI AMS Platform: Cityworks



PWD Inspection and Maintenance

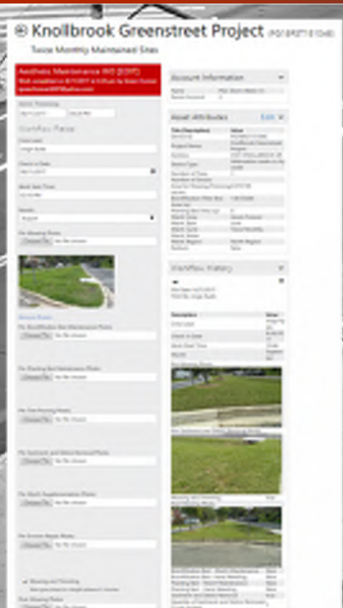


Clean Water Partnership (CWP) Prince George's County, MD AMS Platform for GI: utilitycloud

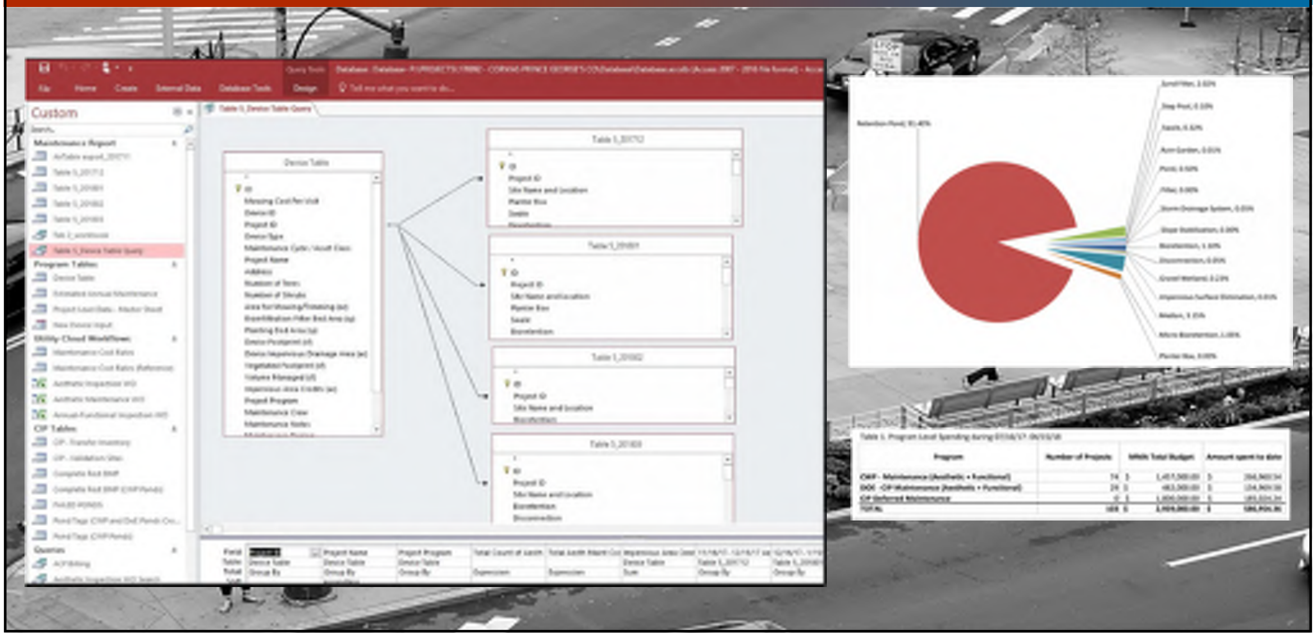
- Customizable work order interface with mapping features
- Cloud based service in which transfers work order data directly to Google Sheets or into an Excel Workbook via specialized Excel add-on
- Relies on a third party platform for database management and relationships
- Simple, inexpensive set-up

Images: utilitycloud.us

CWP Prince George's County, MD AMS Platform for GI: utilitycloud



CWP Prince George's County, MD
AMS Platform for GI: utilitycloud



DC Water
AMS Platform for GI: MAXIMO

- Enterprise asset management geared to large institutions
  - Procurement and contracts management
  - Work order/service management
  - Procurement and materials
- Flexible deployment – on-premise, or via web service contract
- Analytics – integrates with other IBM business analysis tools

SUMMARY

- A data-driven approach is key to having a cost-effective GSI program.
  - O&M data can be used to inform the planning, design, and construction processes.
- Adaptive management approach to O&M can help reduce overall program costs.
- A simple, well-organized asset management system can allow crews to collect data in the field with minimal oversight

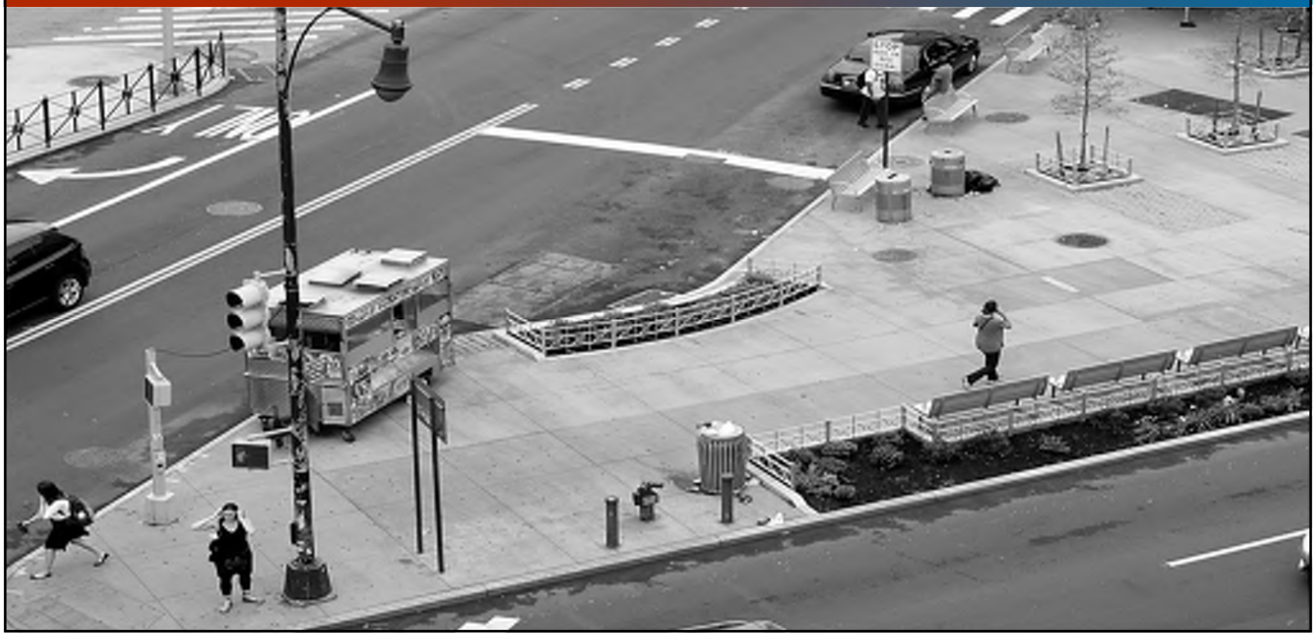
Questions?

Akta Patel, P.E.
Senior Water Resources Engineer
AKRF, Inc.
267.585.4857
apatel@akrf.com

Bianca Santos
Water Resources Specialist
AKRF, Inc.
267.585.4859
bsantos@akrf.com

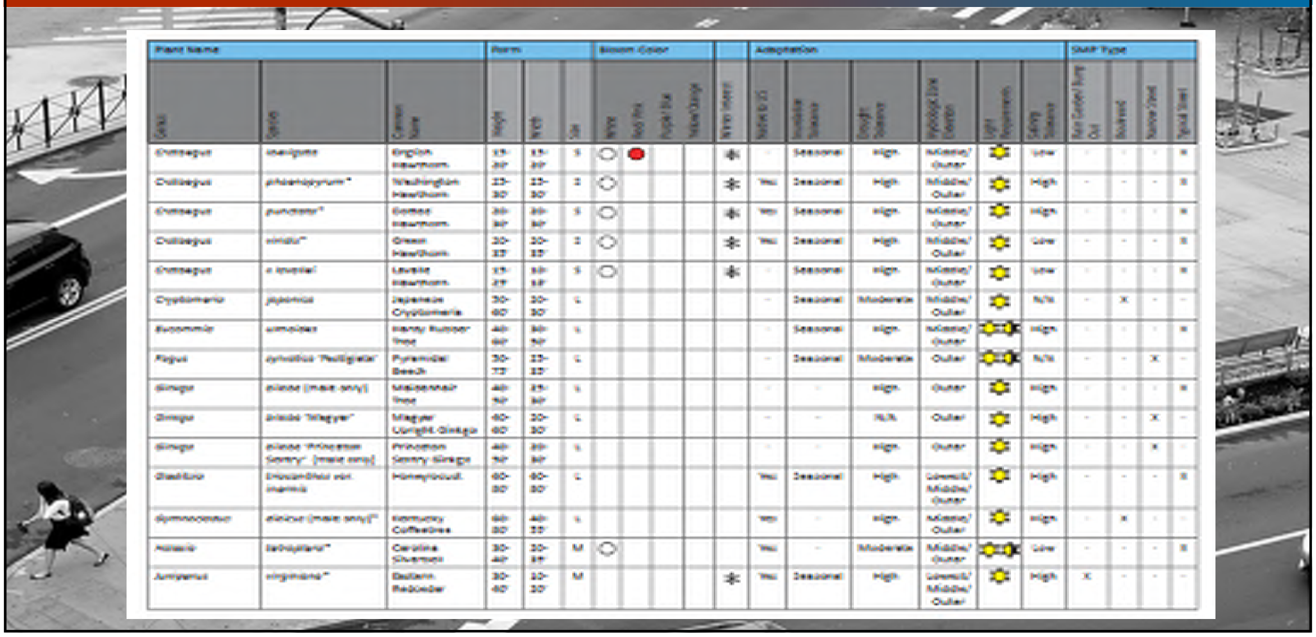
AKRF, Inc.
www.akrf.com

Additional Examples



CHALLENGE: ROOT ENCROACHMENT INTO PIPES

DESIGN FEEDBACK: STANDARD TREE SPECIES SPECIFIED



Plant Name			Form			Bloom Color					Adaptation						SMP Type			
Genus	Species	Common Name	Height	Width	Size	White	Red/Pink	Purple/Blue	Yellow/Orange	Winter Interest	Native to US	Inundation Tolerance	Drought Tolerance	Hydrologic Zone Location	Light Requirements	Salinity Tolerance	Rain Garden/Bump Out	[illegible]	Narrow Street	Typical Street
Crataegus	laevigata	English Hawthorn	15-20'	15-20'	S	○	●			❄	-	Seasonal	High	Middle/Outer	☼	Low	-	-	-	X
Crataegus	phaenopyrum*	Washington Hawthorn	25-30'	25-30'	S	○				❄	Yes	Seasonal	High	Middle/Outer	☼	High	-	-	-	X
Crataegus	punctata*	Dotted Hawthorn	20-30'	20-30'	S	○				❄	Yes	Seasonal	High	Middle/Outer	☼	High	-	-	-	X
Crataegus	viridis*	Green Hawthorn	20-35'	20-35'	S	○				❄	Yes	Seasonal	High	Middle/Outer	☼	Low	-	-	-	X
Crataegus	x lavallei	Lavalle Hawthorn	15-25'	10-15'	S	○				❄	-	Seasonal	High	Middle/Outer	☼	Low	-	-	-	X
Cryptomeria	japonica	Japanese Cryptomeria	50-60'	20-30'	L						-	Seasonal	Moderate	Middle/Outer	☼	N/A	-	X	-	-
Eucommia	ulmoides	Hardy Rubber Tree	40-60'	30-50'	L						-	Seasonal	High	Middle/Outer	☼ ◐	High	-	-	-	X
Fagus	sylvatica 'Fastigiata'	Pyramidal Beech	50-75'	15-25'	L						-	Seasonal	Moderate	Outer	☼ ◐	N/A	-	-	X	-
Ginkgo	biloba (male only)	Maidenhair Tree	40-50'	25-30'	L						-	-	High	Outer	☼	High	-	-	-	X
Ginkgo	biloba 'Magyar'	Magyar Upright Ginkgo	40-60'	20-30'	L						-	-	N/A	Outer	☼	High	-	-	X	-
Ginkgo	biloba 'Princeton Sentry' (male only)	Princeton Sentry Ginkgo	40-50'	20-30'	L						-	-	High	Outer	☼	High	-	-	X	-
Gleditsia	triacanthos var. inermis	Honeylocust	60-80'	60-80'	L						Yes	Seasonal	High	Lowest/Middle/Outer	☼	High	-	-	-	X
Gymnocladus	dioicus (male only)*	Kentucky Coffeetree	60-80'	40-55'	L						Yes	-	High	Middle/Outer	☼	High	-	X	-	-
Halesia	tetraptera*	Carolina Silverbell	30-40'	20-35'	M	○					Yes	-	Moderate	Middle/Outer	☼ ◐	Low	-	-	-	X
Juniperus	virginiana*	Eastern Redcedar	30-40'	10-20'	M					❄	Yes	Seasonal	High	Lowest/Middle/Outer	☼	High	X	-	-	-