Economic Ecology

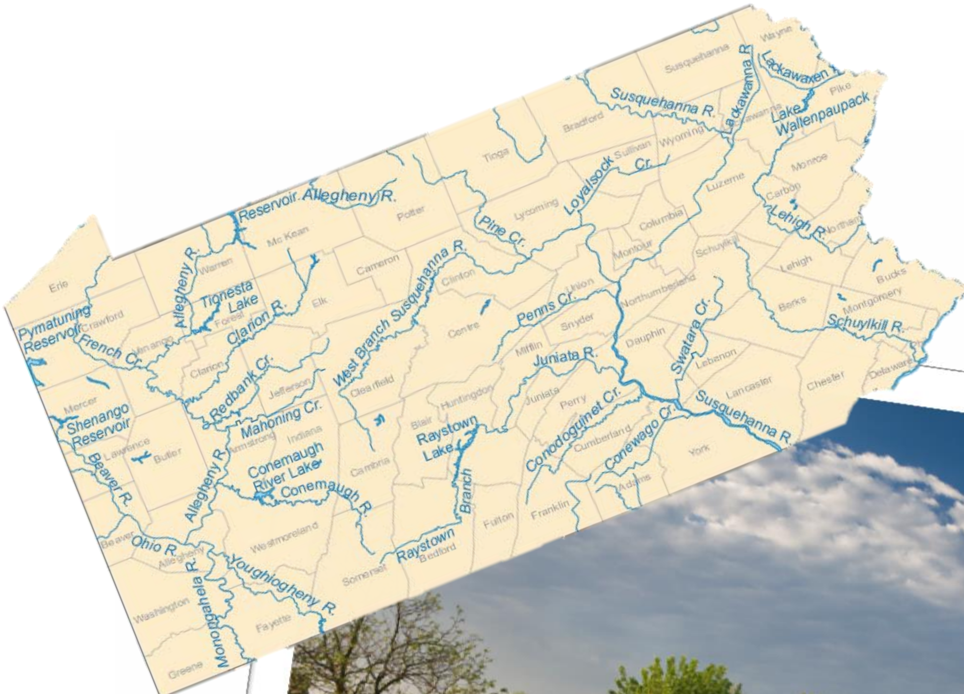
American Planning Association – PA Chapter Spring Forum
April 14, 2015
Mark Gutshall, Founder and Vice President

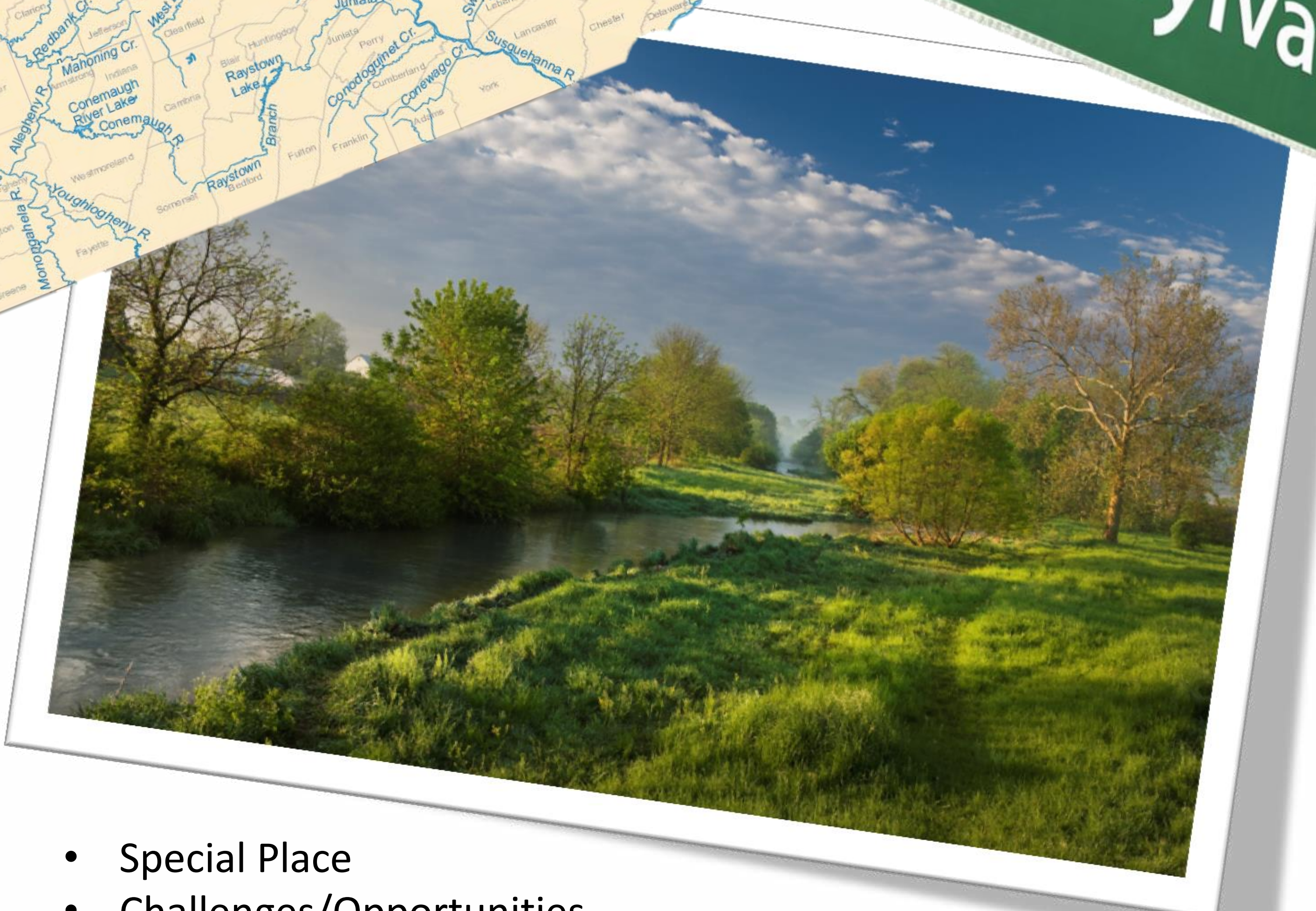
Land Studies

Applied Ecological Restoration – Experiential Learning

(Mark Gutshall)

LandStudies Background – 26 Years





Land
Studies

- Special Place
- Challenges/Opportunities

Principles of Economic Ecology:
Emphasis on the Floodplain

Banta Floodplain Restoration

Talking Points

What is Economic Ecology

Regulatory Drivers

Planning Obstacles in PA

A Regional Approach

Economic Ecology

- Maximizes both economic and environmental returns to solve water issues, such as flood reduction and pollutant removal, at a regional scale.
- Defined by ecological principles that are validated by engineering measurement and performance standards.
- Proactive rather than reactive, addressing the causes of problems not merely symptoms.
- Applied to stormwater, MS4, TMDL, and flooding.
- The outcome involves forming partnerships with government, public, nonprofit, and private organizations to share costs and increase benefits throughout a region or watershed.

“Either or” Mentality

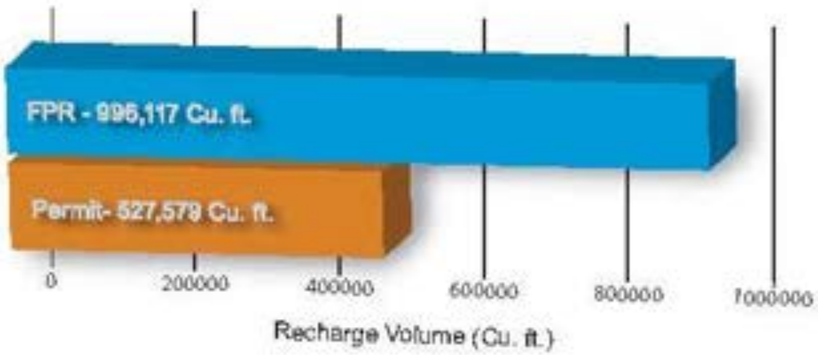
$ ***verses*** 

“Mutual Gain” Proposition

$ ***and***

"Game Changer": Ecological Stability followed by Validation

- **996,117 cubic feet** of recharge volume
- Total **reduction in pollutants:**
  - 1,010 lbs. of Nitrogen
  - 173 lbs. of Phosphorus
  - 124 tons of sediment
    - 248,000 lbs.
- SWM **Peak Flow Reduction:**
  - 588% reduction (site) for 2-year event
  - 83% reduction (watershed) for 2-year event



Understanding and Communication

TMDL

BMP

CBPRP

MCM

MS4

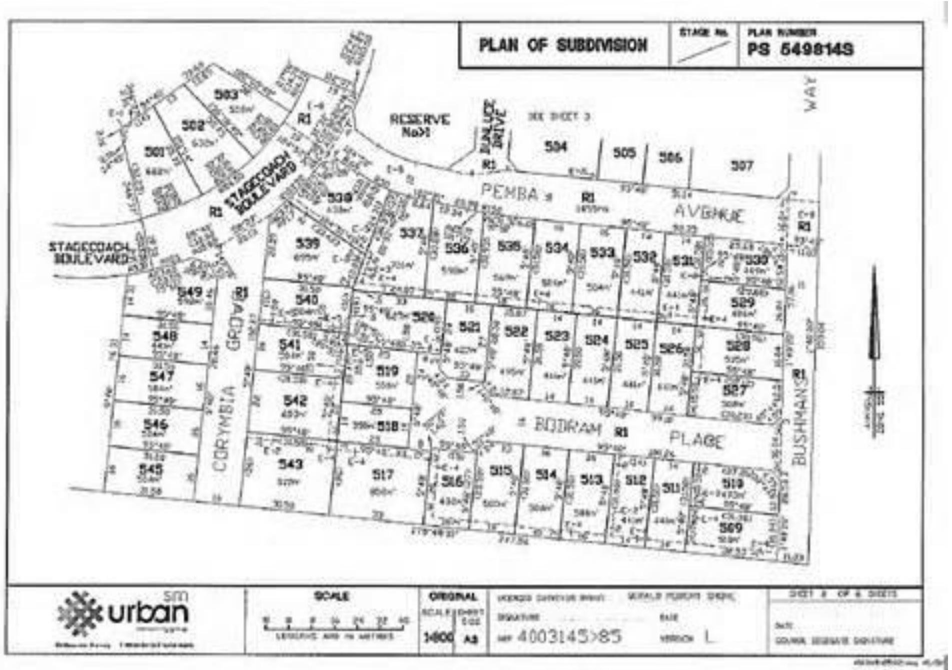
HEC RAS

or

Flood Reduction

Pollutant Removal

Pennsylvania Planning Challenges & Opportunities



- Ordinances are recipe books that drive conventional development
- Comprehensive Plans are guidebooks
- Engineers/surveyors – conventional, pragmatic thinking

Planners can synthesize a variety of information including economics and ecology – bigger picture

Systems Based Approach

- Creating a sustainable, natural system and plant community provides long term benefits

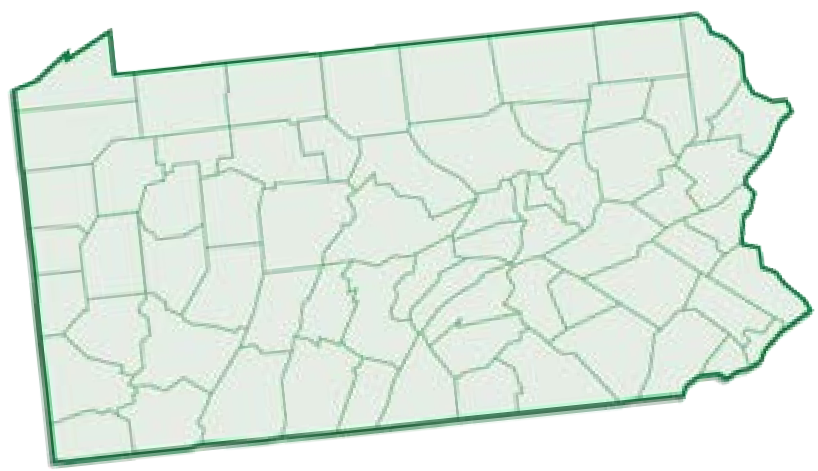
Think Regionally “Beyond Your Footprint”

Economic Ecology

Pennsylvania Project Scale

Millions of
Development Sites

2562
Municipalities



67
Counties

Wastewater Evolution (Site to Regional) – Infrastructure Investment

Outhouse

Large Multi Septic Field

Small Package Field

Individual Septic Field

Conventional Sewer Plant

Economic Ecology on a Regional Scale

Conventional Regional SWM Basin

Floodplain Restoration with Regional SWM Benefits

Economic Ecology

Single Function

$ Value

Multiple Function

$$$$ Value

Economic Ecology on a Regional Scale

Cost Effective – Value Proposition

or

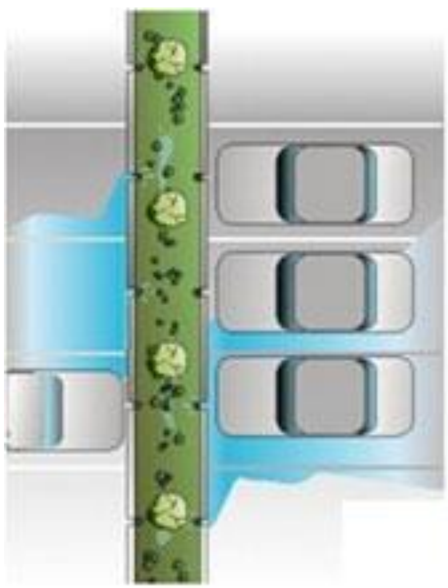
bandaide

cure

Grey Infrastructure

Grey Infrastructure

Current Green Infrastructure Approach – Individual BMP's



LandStudies

What is missing

- Scale
- Context
- Planning Process – **The process dictates results!**

Wissahickon TMDL alternative

[Comments]

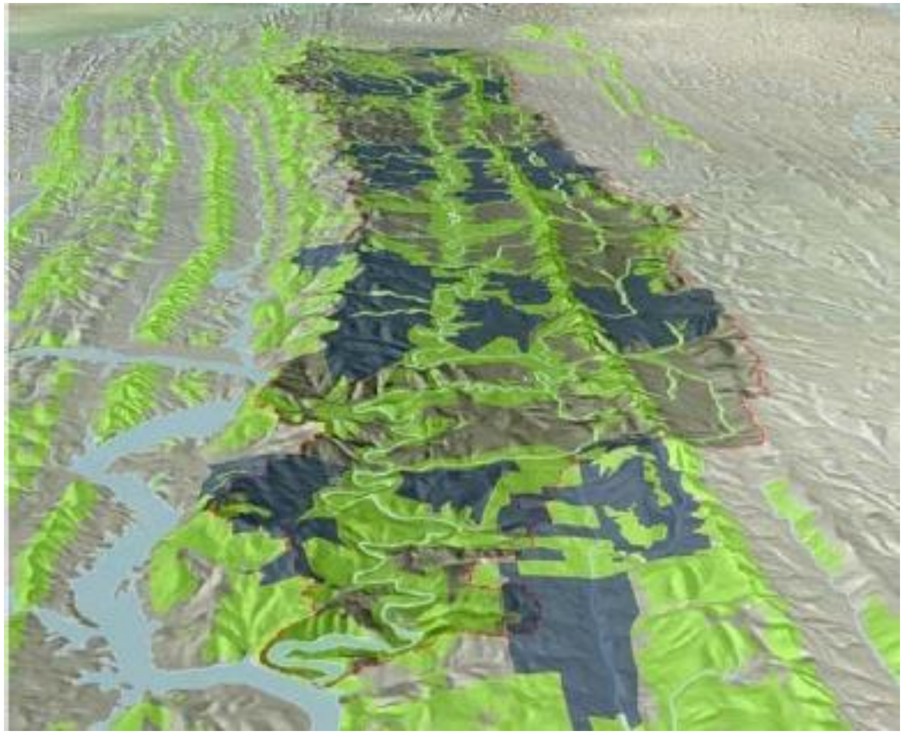
Framing the issue:

- *We all share in the responsibility to find a way to address the Wissahickon's WQ problems.*
- *Our water quality problems are difficult because: 1) They push our science, our engineering, and our public policy to the limits of what can be done; and 2) ecology, engineering, and public policy are three disciplines that don't integrate neatly or easily with one another.*
- *Around the country, there is no single conventional way in which ecology, engineering, and public policy are woven together to make solutions to water quality problems in rivers and streams. It's done differently in different places.*
- *Federal and State law provide room for stakeholder-led processes.*

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Integrated Water Resource Planning

Green Infrastructure



Green Infrastructure Corridors in green
Urbanized

Proposed Park and Soft Transit System

Green Infrastructure

Green Infrastructure

Green Infrastructure

Pollutant Reduction

over 7,800 tons of sediment
over 8,930 pounds of phosphorus
over 26,080 pounds of nitrogen

Flood Reduction

950 LF of Stream Channel Restored

Wetland Creation

1.0 Acres

Maintenance Reduction

Replaced 3.0 acres of managed turf

Habitat Creation

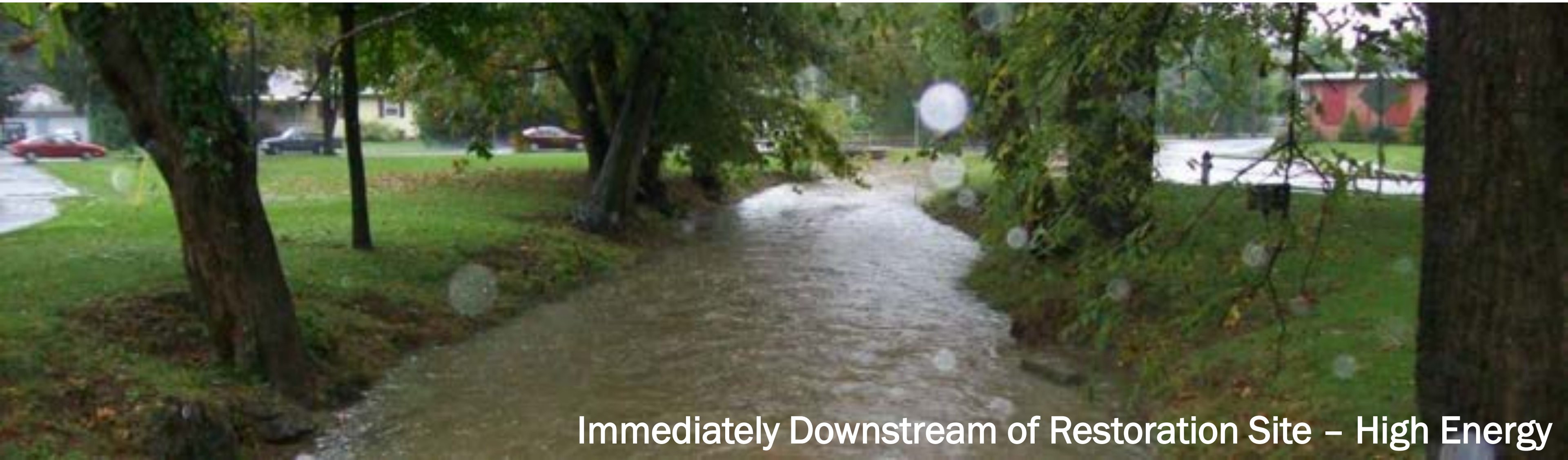
Over 2,000 Native herbaceous plugs
200 Native trees/shrubs

New Street Ecological Park – Lancaster, PA

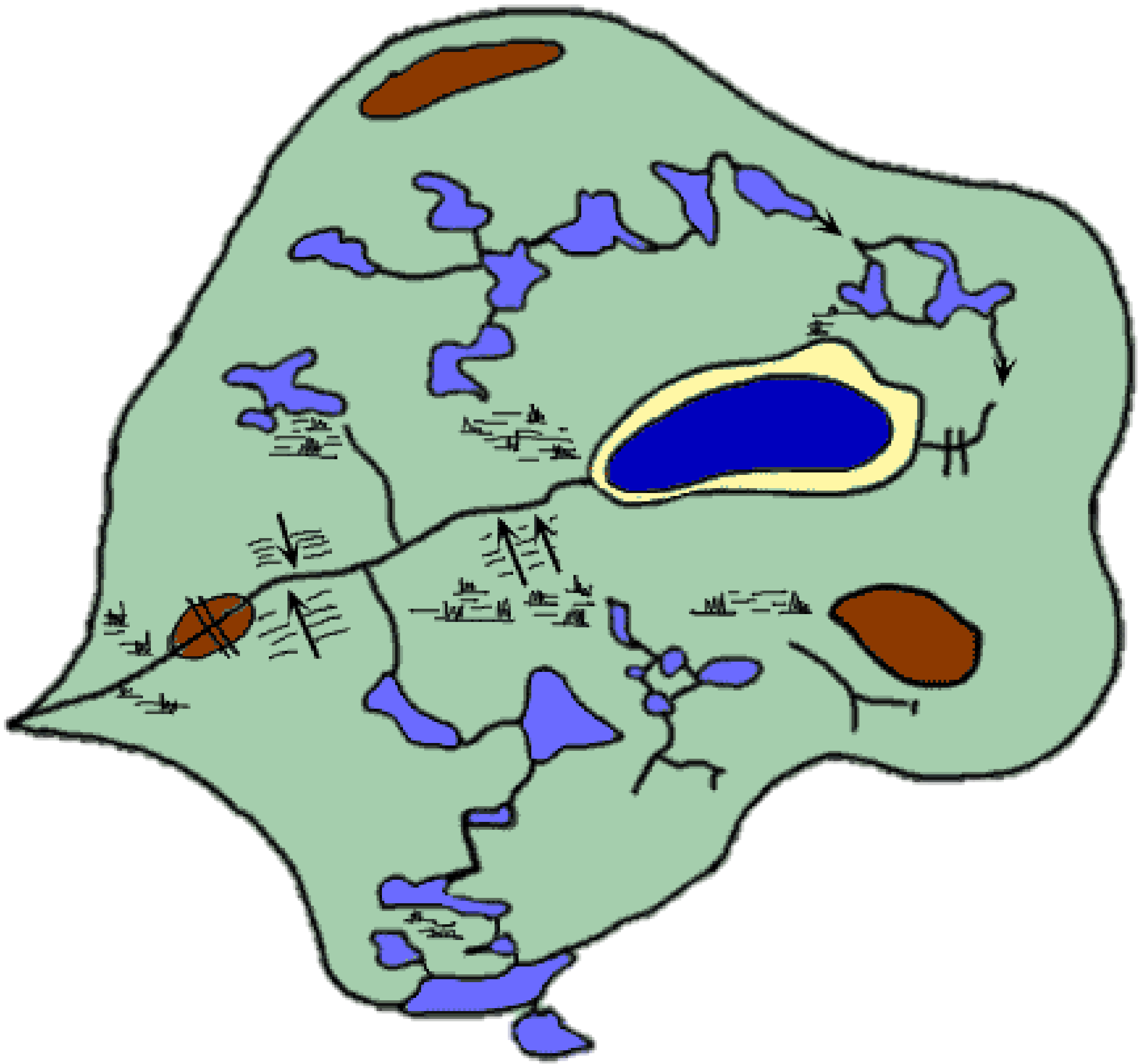
Summer 2011

New Street Ecological Park – Lancaster, PA

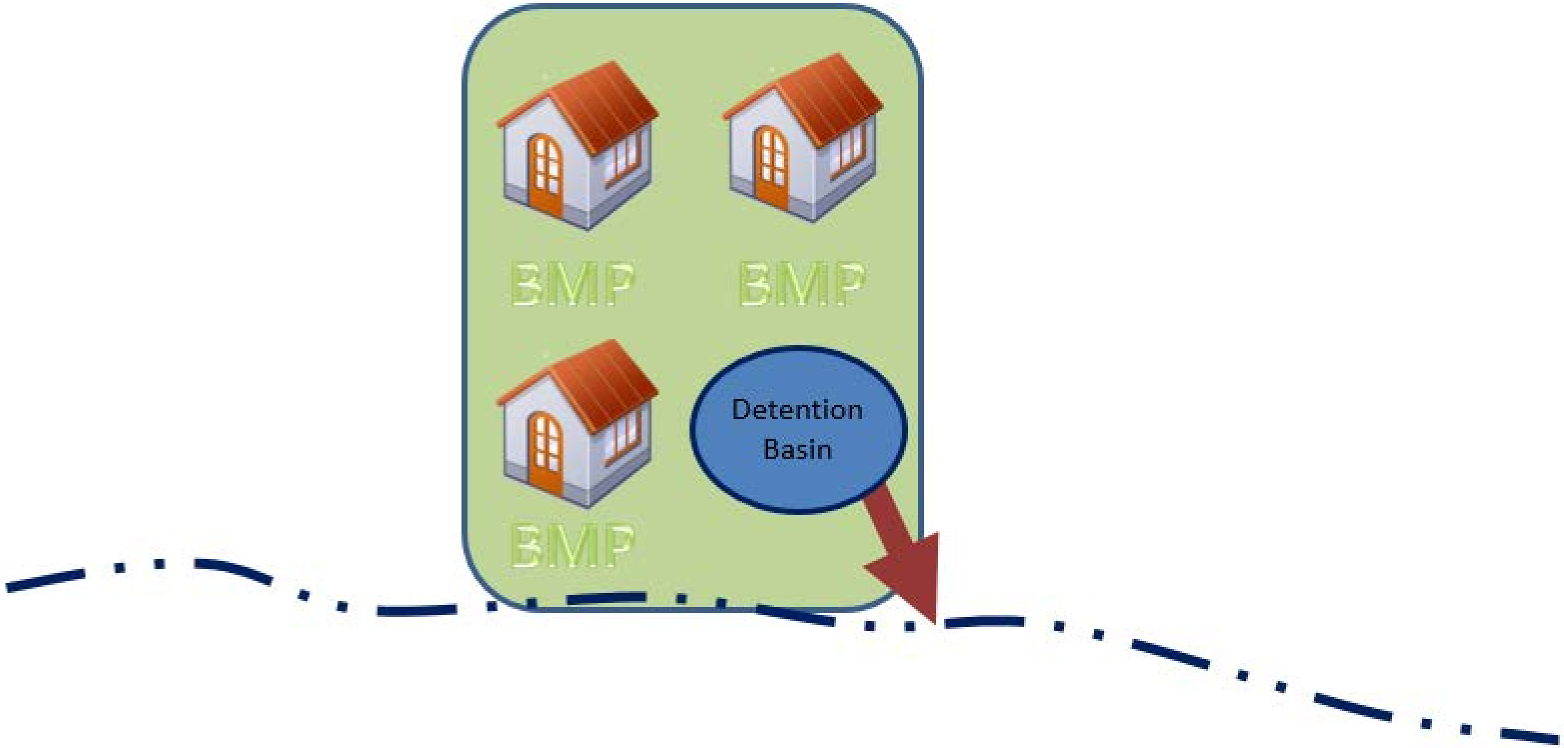
5” Rain Event



Offsetting

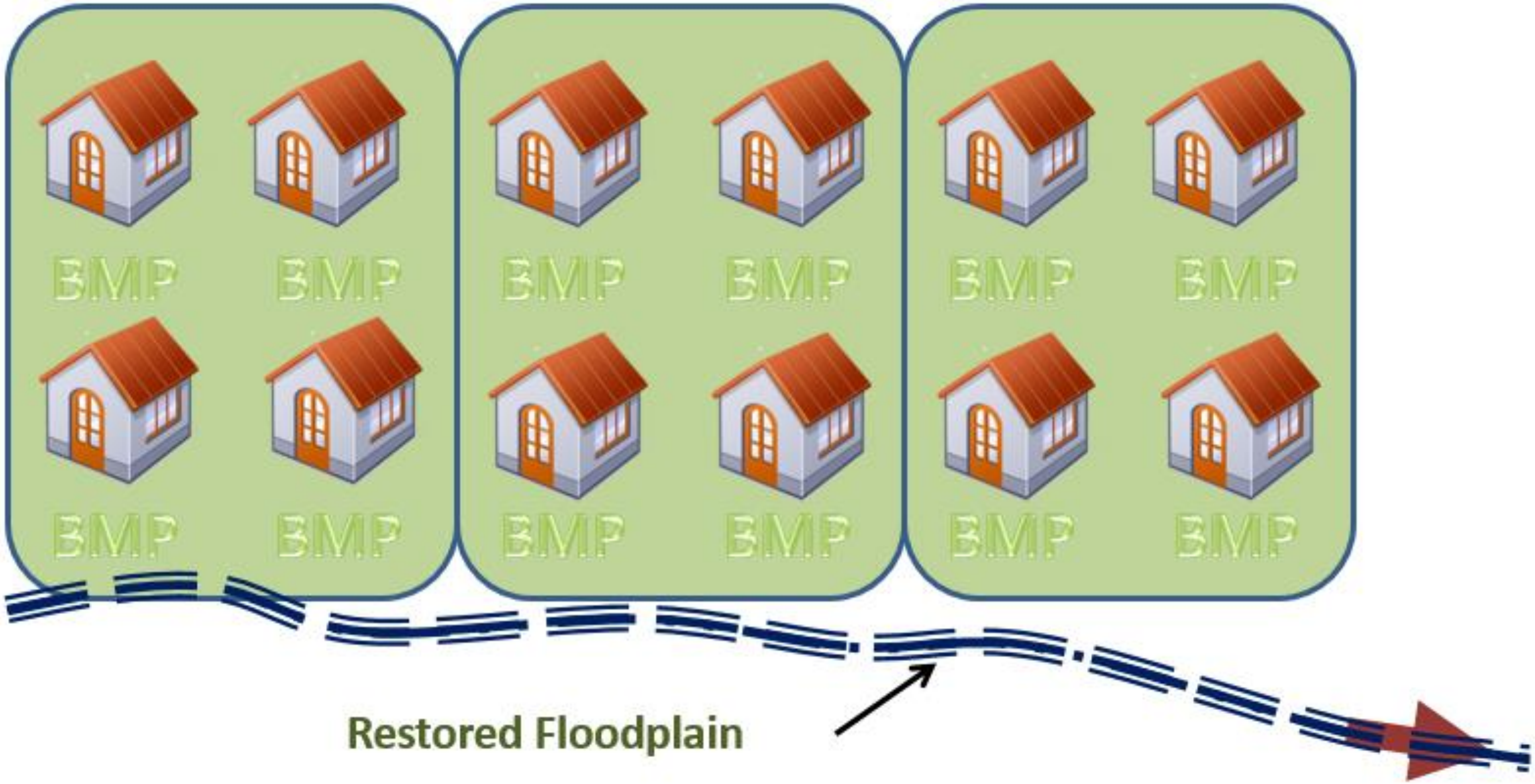


Conventional Stormwater Management Process



- **Peak Rate Requirement:** Post Development Peak Flows must be ≤ Pre-Development Peak Flows
- **Volume Requirement**: Manage 2-yr/ 24-hr volume difference
- **Water Quality Requirement**: Provide Water Quality BMPs

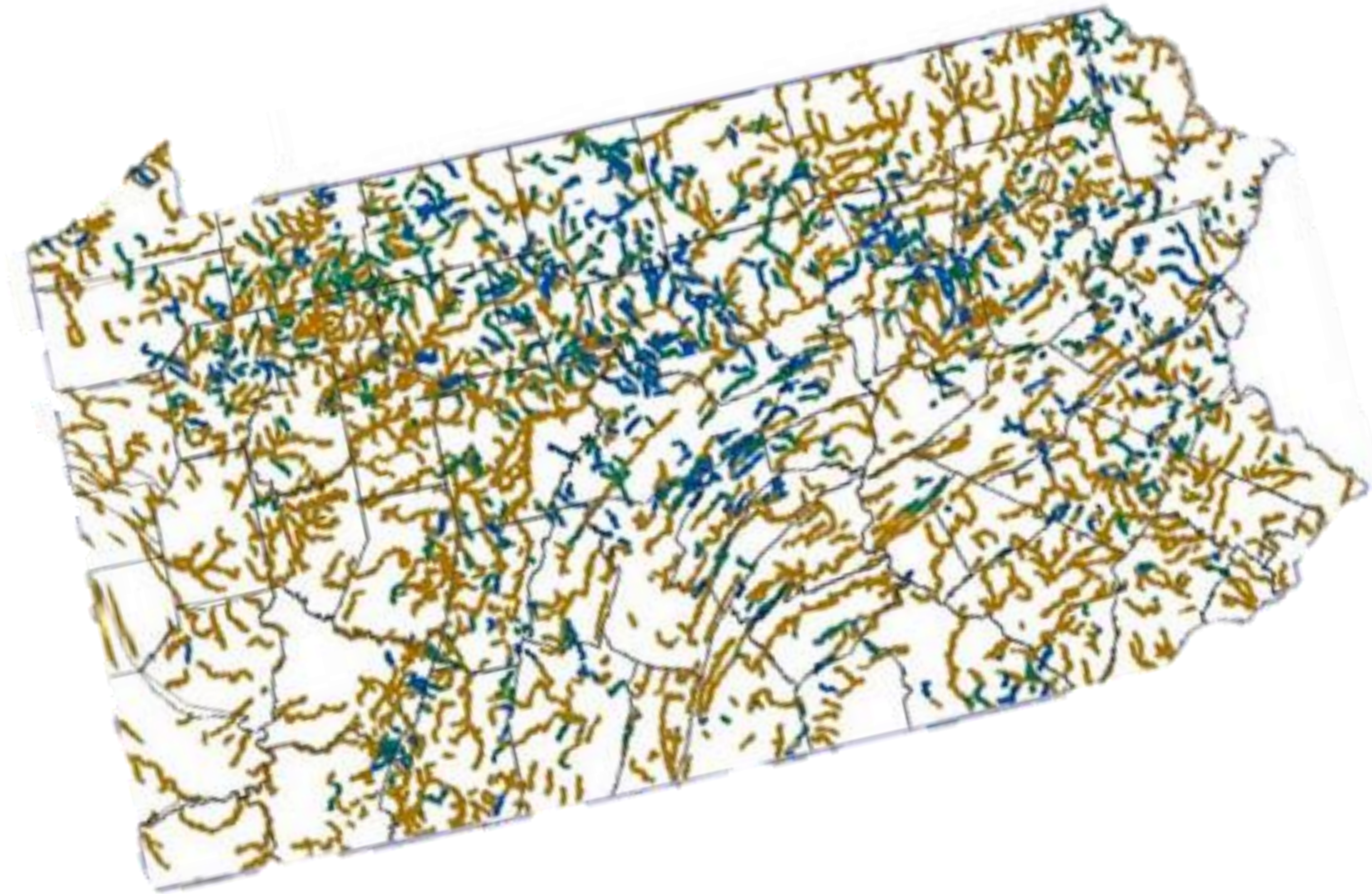
Stormwater Management with Floodplain Restoration



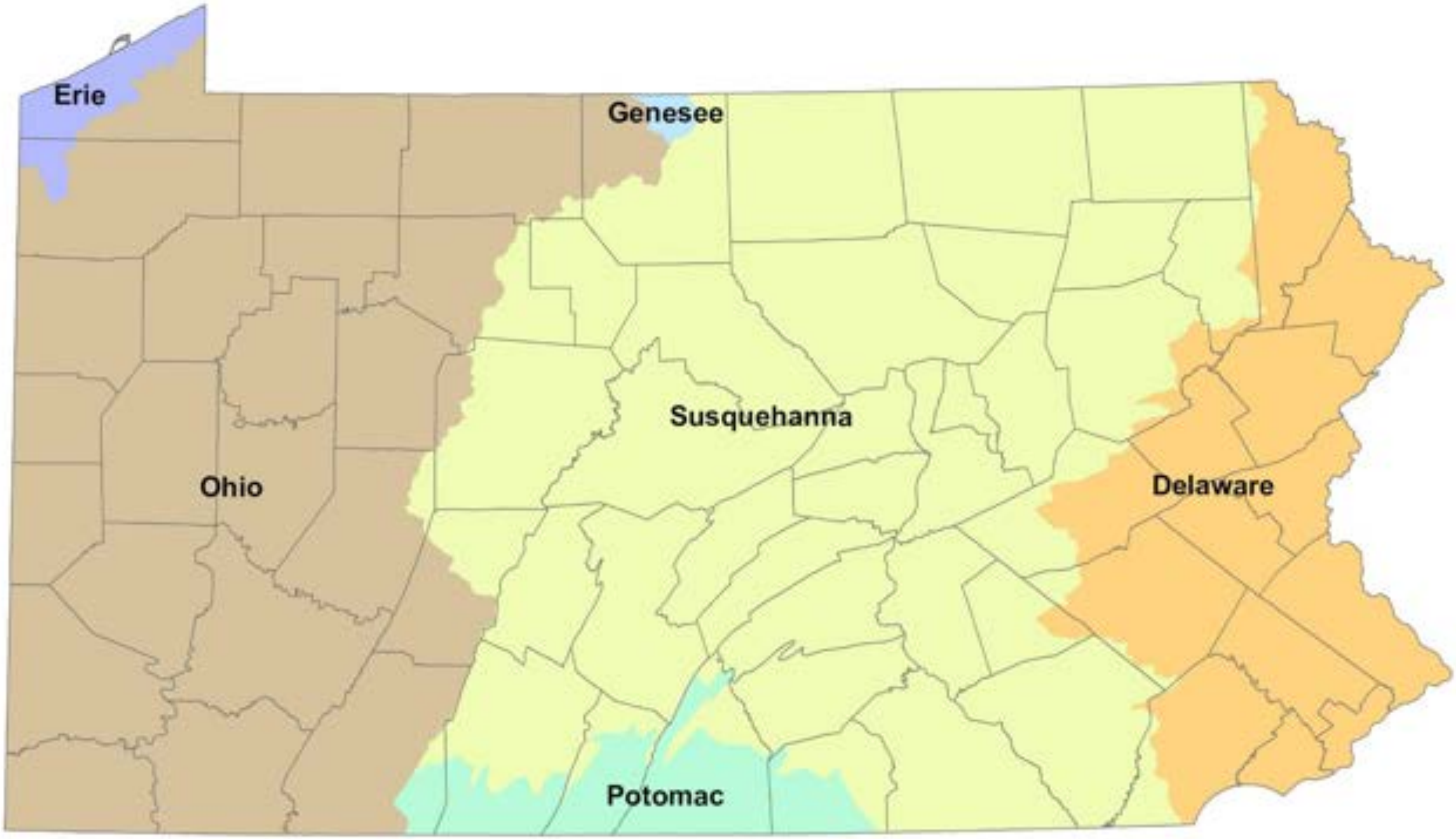
- **Peak Rate Requirement:** Post Development Peak Flows must be ≤ Pre-Development Peak Flows
- **Volume Requirement**: Manage 2-yr/ 24-hr volume difference
- **Water Quality Requirement**: Provide Water Quality BMPs

Stream Corridors/Floodplains

Pennsylvania has over 80,000 miles of streams



River Basins



LandStudies

State Water Plan Principles

(Pennsylvania Department of Environmental Protection, 2009)

"…Reestablishing natural stream corridors and floodplains through local stormwater management requirements could offer more environmentally friendly flood control options than concrete structures."

"…Innovative stormwater management should be considered and incorporated as an important component of the overall flood mitigation plan."

"Shifting from traditional stormwater management methods to designs and practices that also address channel alterations and degradation, runoff quality, dry-weather flow protection, and aquifer recharge requires an underlying change in how water resource professionals do business."

Economic Ecological Values

- Preserve
- Protect
- Manage

- Efficient Land Use
- Maximize Density in Growth Areas

The Working Landscape (Functional Natural Systems)

- “Wasteland” – Least Valuable Real Estate
- Emphasis on Restoring Floodplain Functions
- Value Proposition and Opportunity Costs
- Habitat

LandStudies

The Working Landscape (Functional Natural Systems)

Managing Resources on a Regional Level

- Intra Disciplinary Respect vs. silo approach
- Dependence for Mutual Gain – Regional level

LandStudies

Unrealized Value Proposition for Communities
(County, State, Federal)

Focus is on Economics

Infrastructure – Resiliency and Capital Projects

- Bridges
- Roads
- Sewer Lines
- Sewer Plants

Systems Based Approach

Linear Highway Infrastructure

Floodplain Restoration

Regional Open Space Management - Community Based

- Ecological Parks
- Environmental Education
- Passive Recreation
- Linear Trails

Green Infrastructure Case Studies

Case Studies

- Academic\ Research (Big Spring Run)
- Private Sector (Rock Lititz\Landis Homes\Bedford Springs)
- Municipal (Butterfly Acres\New Street Park)
- Residential – Private Residence
- Non-Profit (Cocalico Creek Watershed Association)

LandStudies

Provide new information to make informed decisions - planning

Economic ecology is a new approach that could help guide
Planning decisions

Results From the Big Spring Run Aquatic Ecosystem Restoration and Monitoring Project

Prospects for Addressing Watershed Impairments Related to Legacy Sediment

Pennsylvania
Department of Environmental Protection

Pennsylvania Legacy Sediment Workgroup

Jeffrey Hartranft

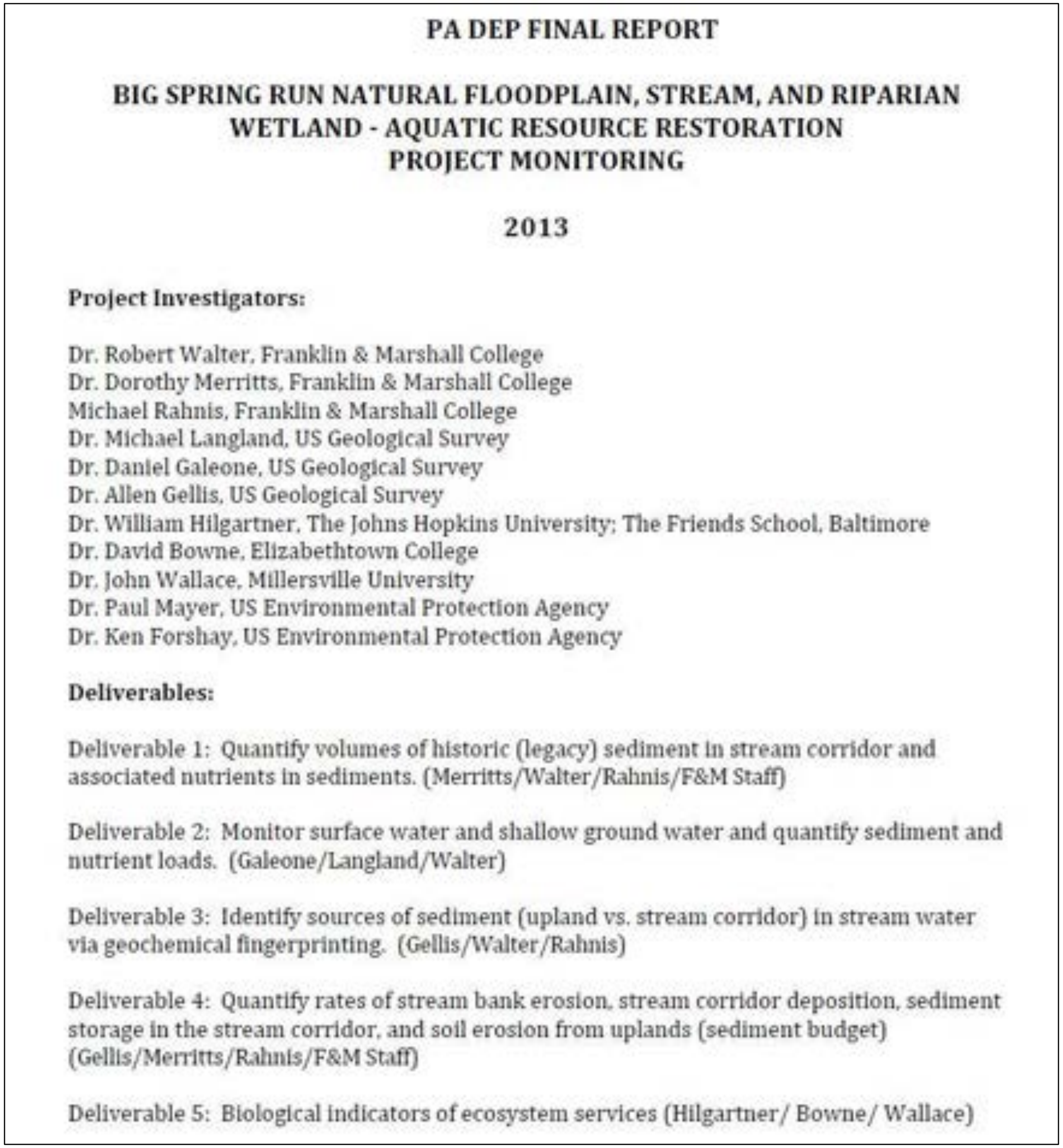
Bureau of Waterways Engineering and Wetlands

Division of Wetlands Encroachments and Training

jhartranft@pa.gov
717-772-5320

LandStudies

Academic and Government Research and Validation



PA DEP FINAL REPORT

BIG SPRING RUN NATURAL FLOODPLAIN, STREAM, AND RIPARIAN WETLAND - AQUATIC RESOURCE RESTORATION PROJECT MONITORING

2013

Project Investigators:

Dr. Robert Walter, Franklin & Marshall College
Dr. Dorothy Merritts, Franklin & Marshall College
Michael Rahnis, Franklin & Marshall College
Dr. Michael Langland, US Geological Survey
Dr. Daniel Galeone, US Geological Survey
Dr. Allen Gellis, US Geological Survey
Dr. William Hilgartner, The Johns Hopkins University; The Friends School, Baltimore
Dr. David Bowne, Elizabethtown College
Dr. John Wallace, Millersville University
Dr. Paul Mayer, US Environmental Protection Agency
Dr. Ken Forshay, US Environmental Protection Agency

Deliverables:

Deliverable 1: Quantify volumes of historic (legacy) sediment in stream corridor and associated nutrients in sediments. (Merritts/Walter/Rahnis/F&M Staff)

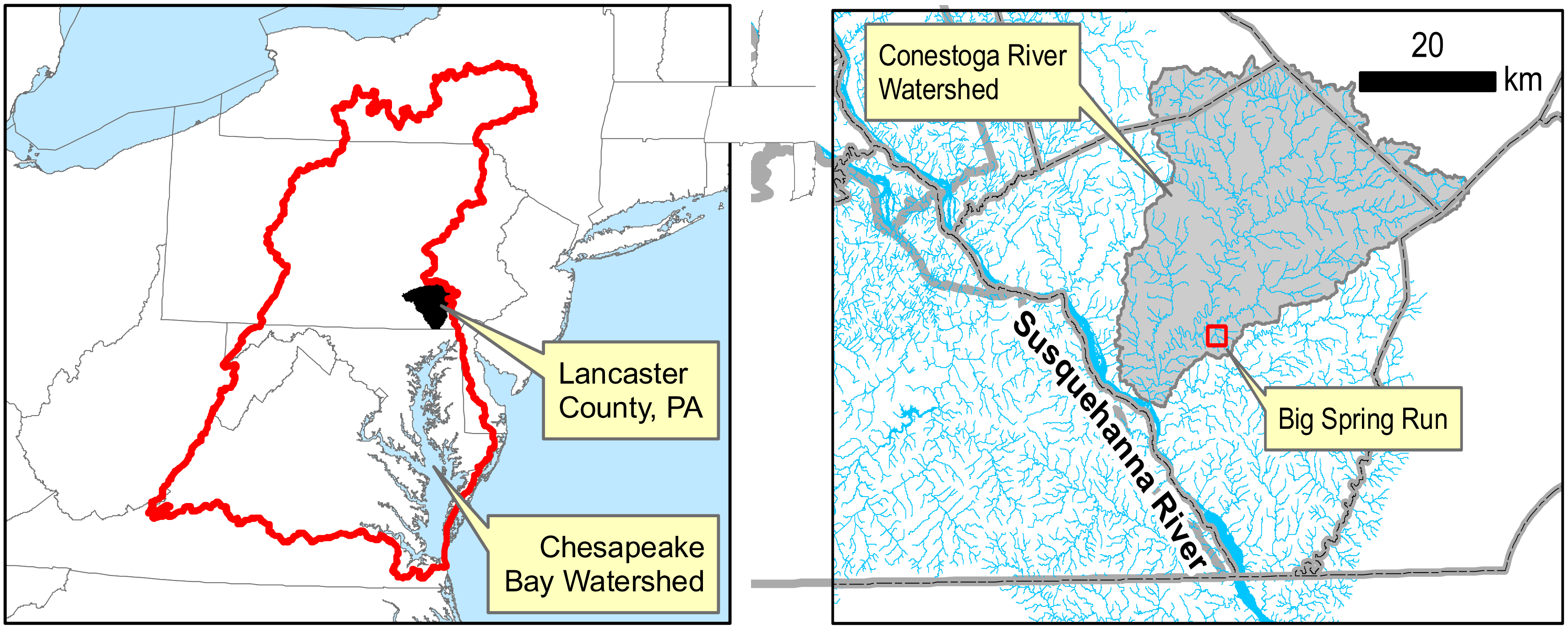
Deliverable 2: Monitor surface water and shallow ground water and quantify sediment and nutrient loads. (Galeone/Langland/Walter)

Deliverable 3: Identify sources of sediment (upland vs. stream corridor) in stream water via geochemical fingerprinting. (Gellis/Walter/Rahnis)

Deliverable 4: Quantify rates of stream bank erosion, stream corridor deposition, sediment storage in the stream corridor, and soil erosion from uplands (sediment budget) (Gellis/Merritts/Rahnis/F&M Staff)

Deliverable 5: Biological indicators of ecosystem services (Hilgartner/ Bowne/ Wallace)

Big Spring Run (BSR) Aquatic Ecosystem Restoration and Monitoring Project



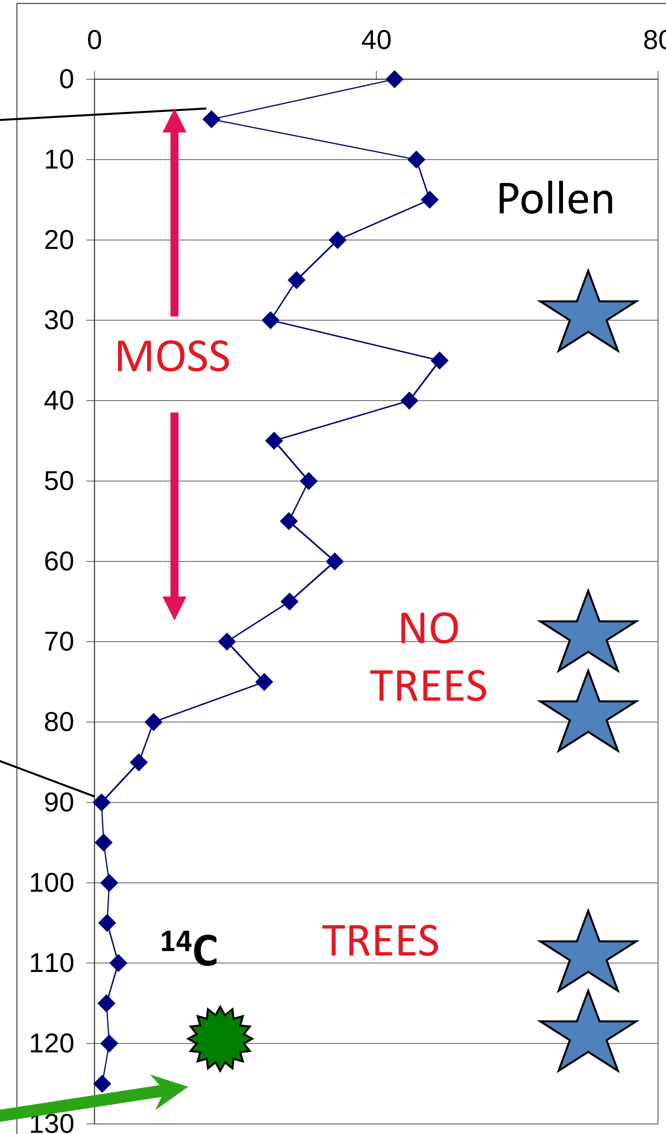
Walter, et al., 2013 PA DEP Report

Available through ftp download

http://www.bsr-project.com/

Legacy Sediment – Trench Evaluation

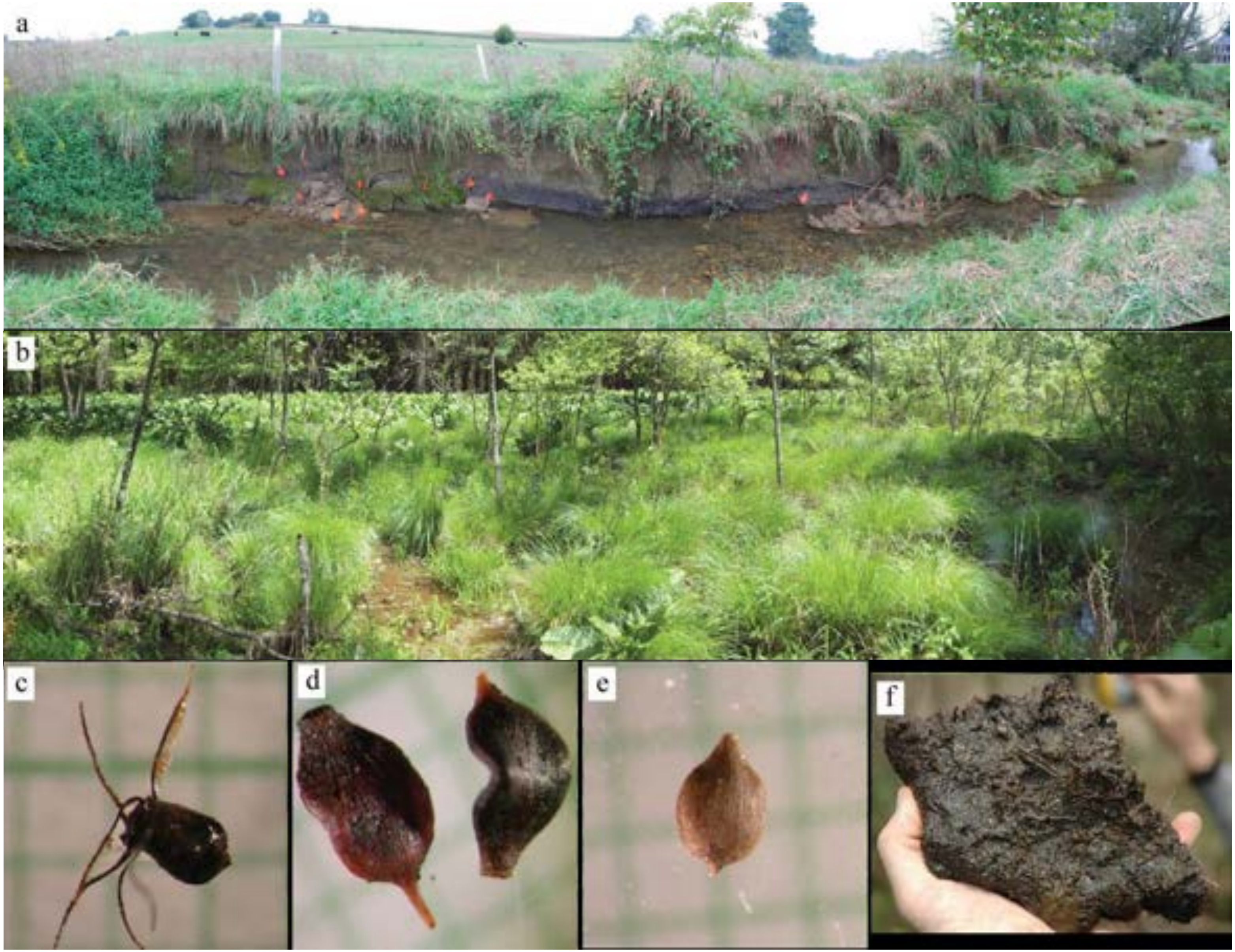
Legacy Sediment – Trench Evaluation



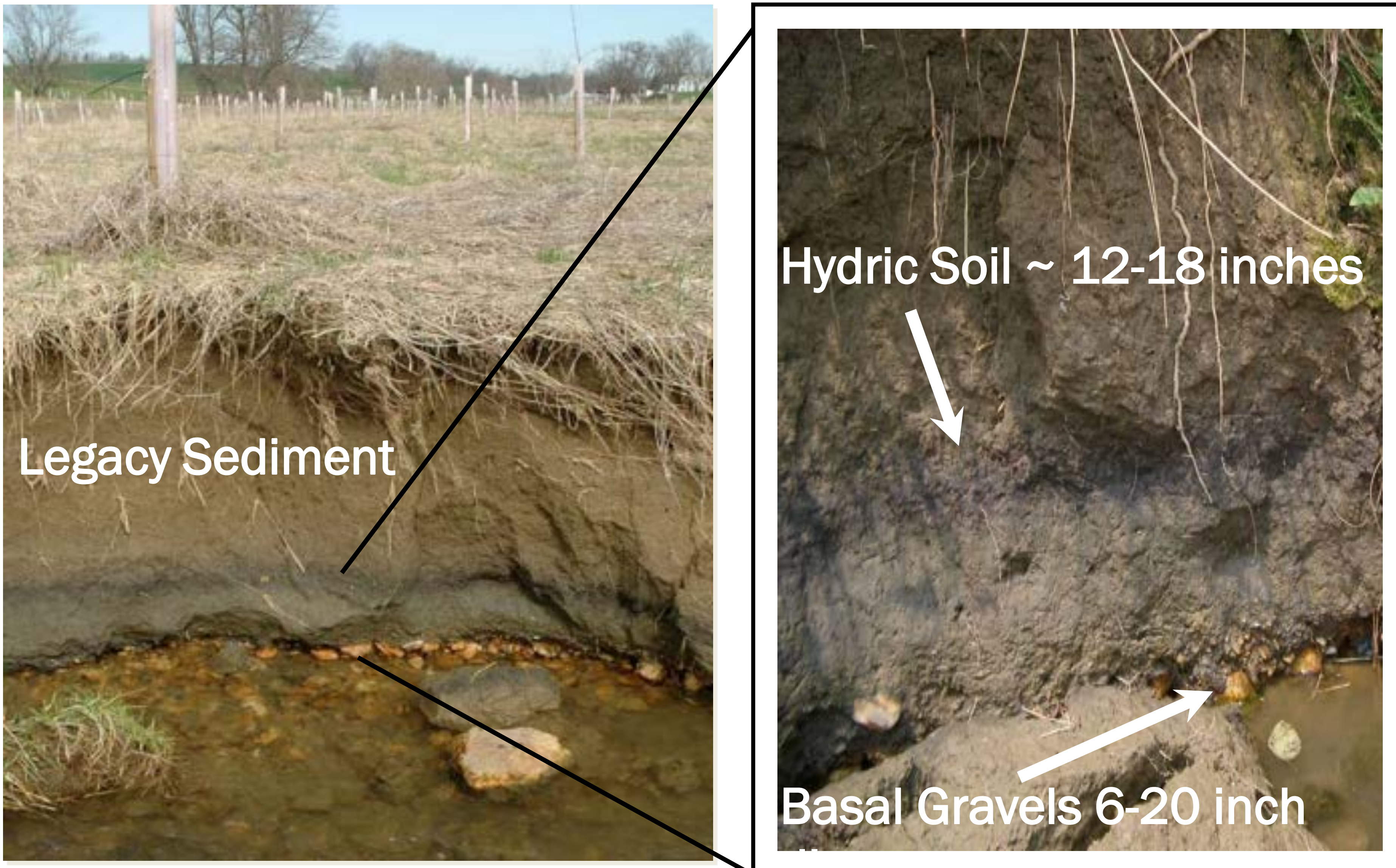
Magnetic Susceptibility

Calibrated ^{14}C Ages:

400-640 AD and 1270-1390 AD



Adapted from Merritts, et al. 2011



Photos Courtesy Franklin & Marshall College

Station 015765195 Big Spring Run near Mylin Corners, PA

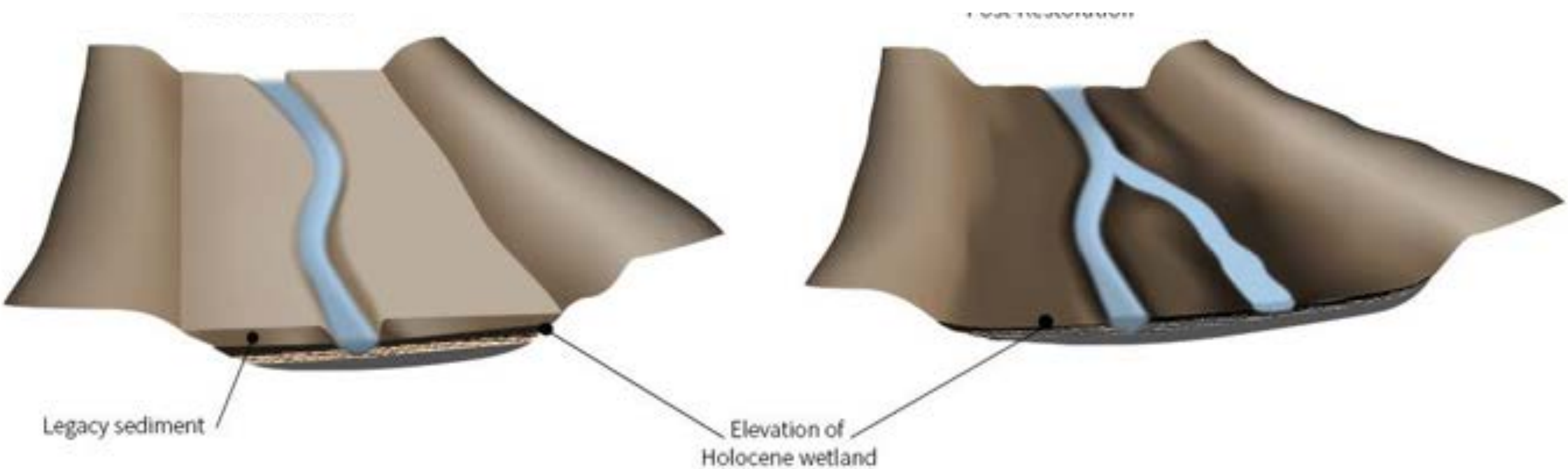
Restoration Goals

- Characteristics typical of the buried aquatic ecosystem provide reference conditions that were used to establish objectives

- Geologic, hydrologic, and ecological conditions prior to legacy sediment storage guided the engineering design and construction

Technical Criteria & Objectives

1. Removing legacy sediments re-establishes the valley bottom elevation of the pre-settlement floodplain, much of which remained in-tact.



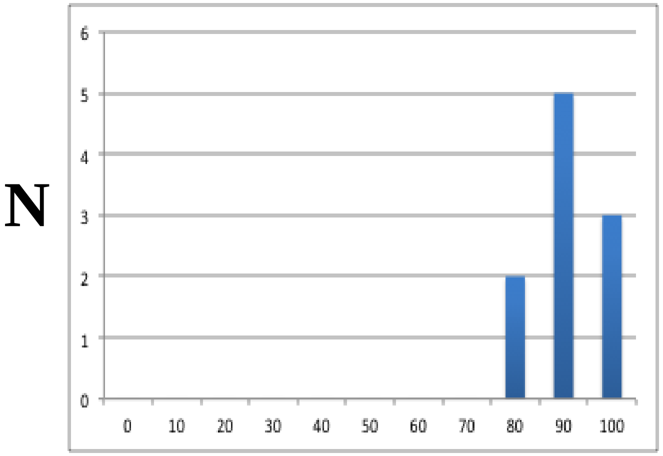
http://www.bsr-project.com/

LandStudies

Post-restoration Sediment Deposition Characteristics

March 2012

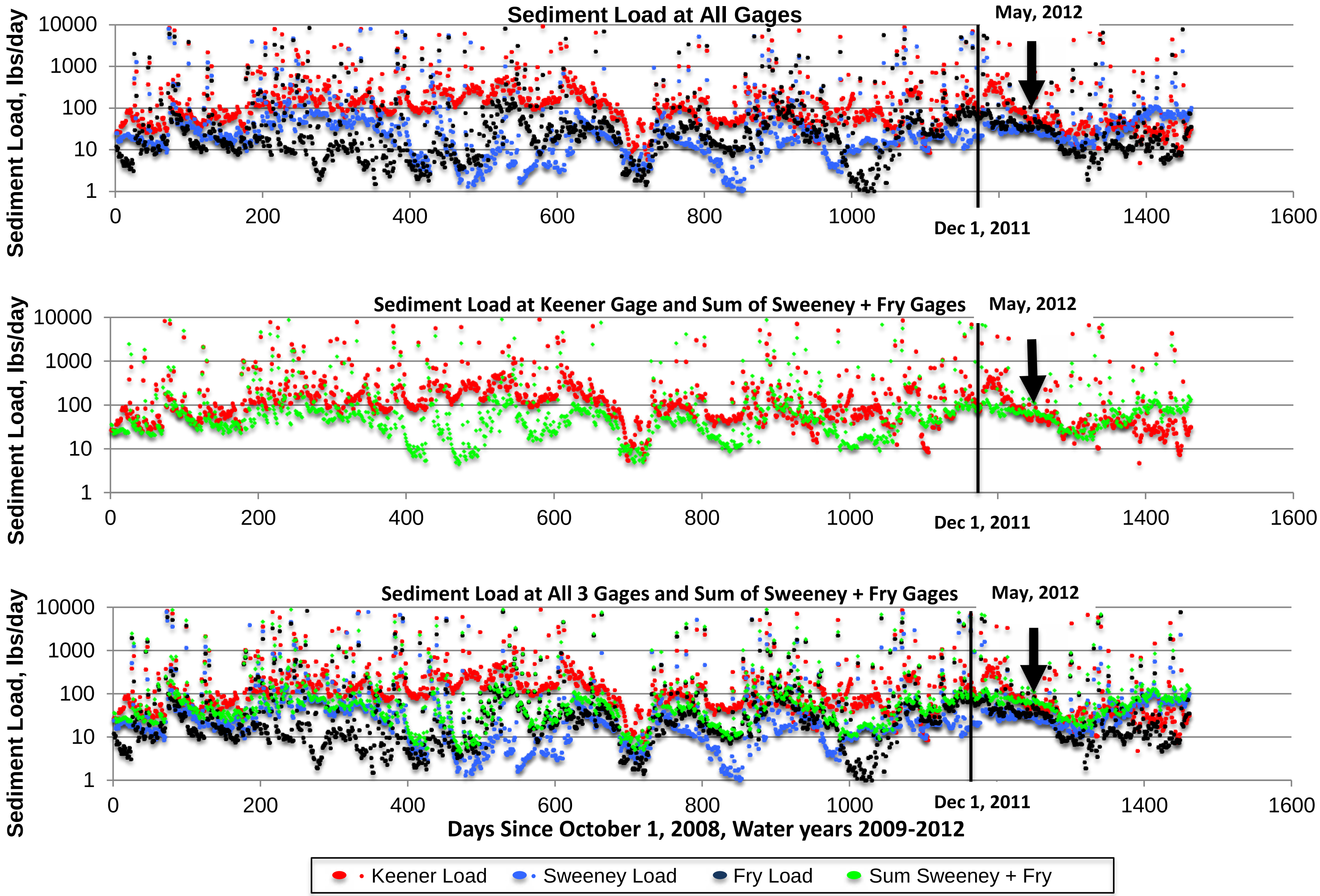
Sediment on Tile Pad



% Stream Bank
(origin is upstream bank erosion)

Walter, et al., 2013 PA DEP Report

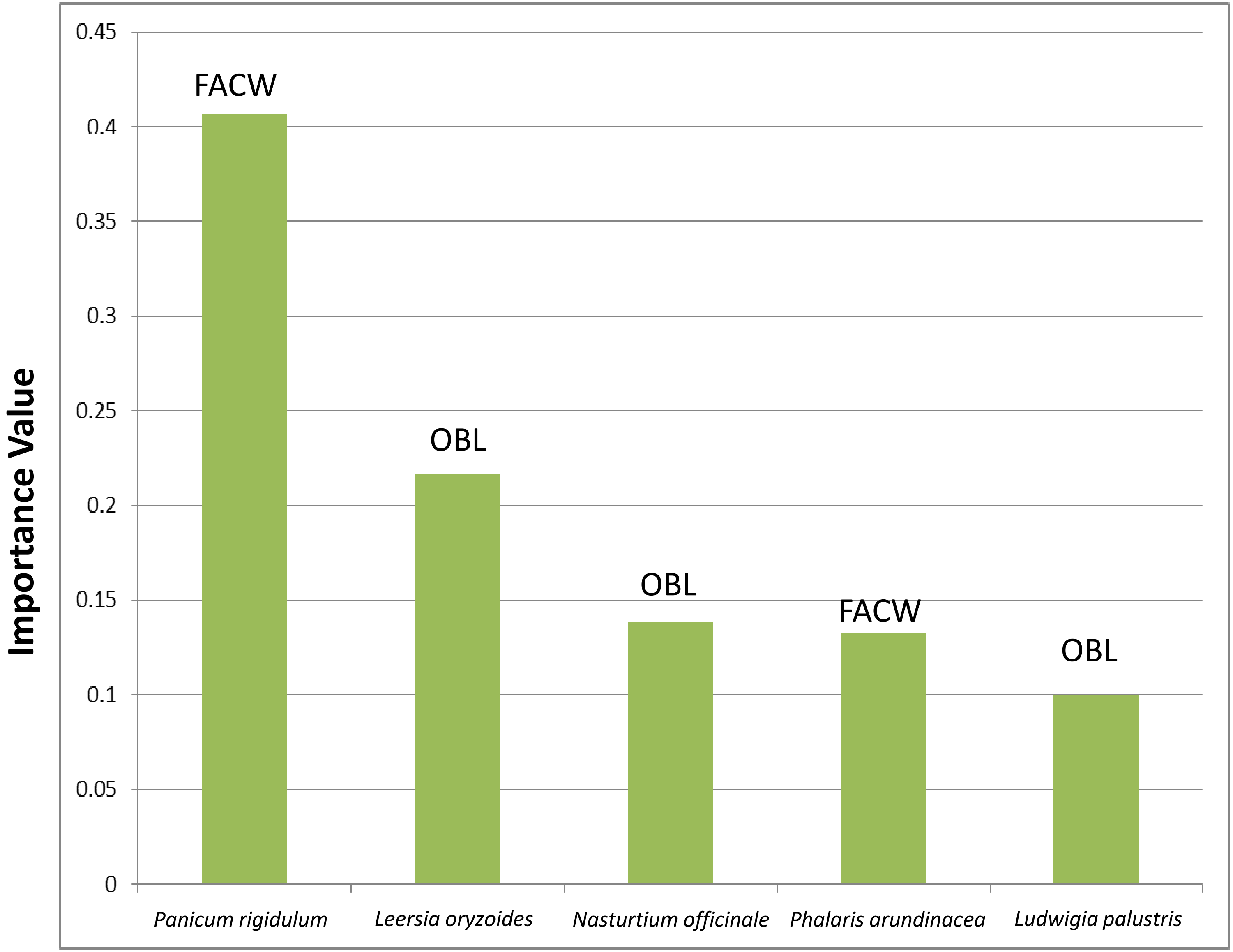
LandStudies



Daily suspended sediment loads from October 1, 2008, to September 30, 2012. Black line is end of construction, Dec 1, 2011. Black arrow is time of marked reduction in sediment load from restoration reach (May, 2012).

Walter, et al., 2013 PADEP Report

2012



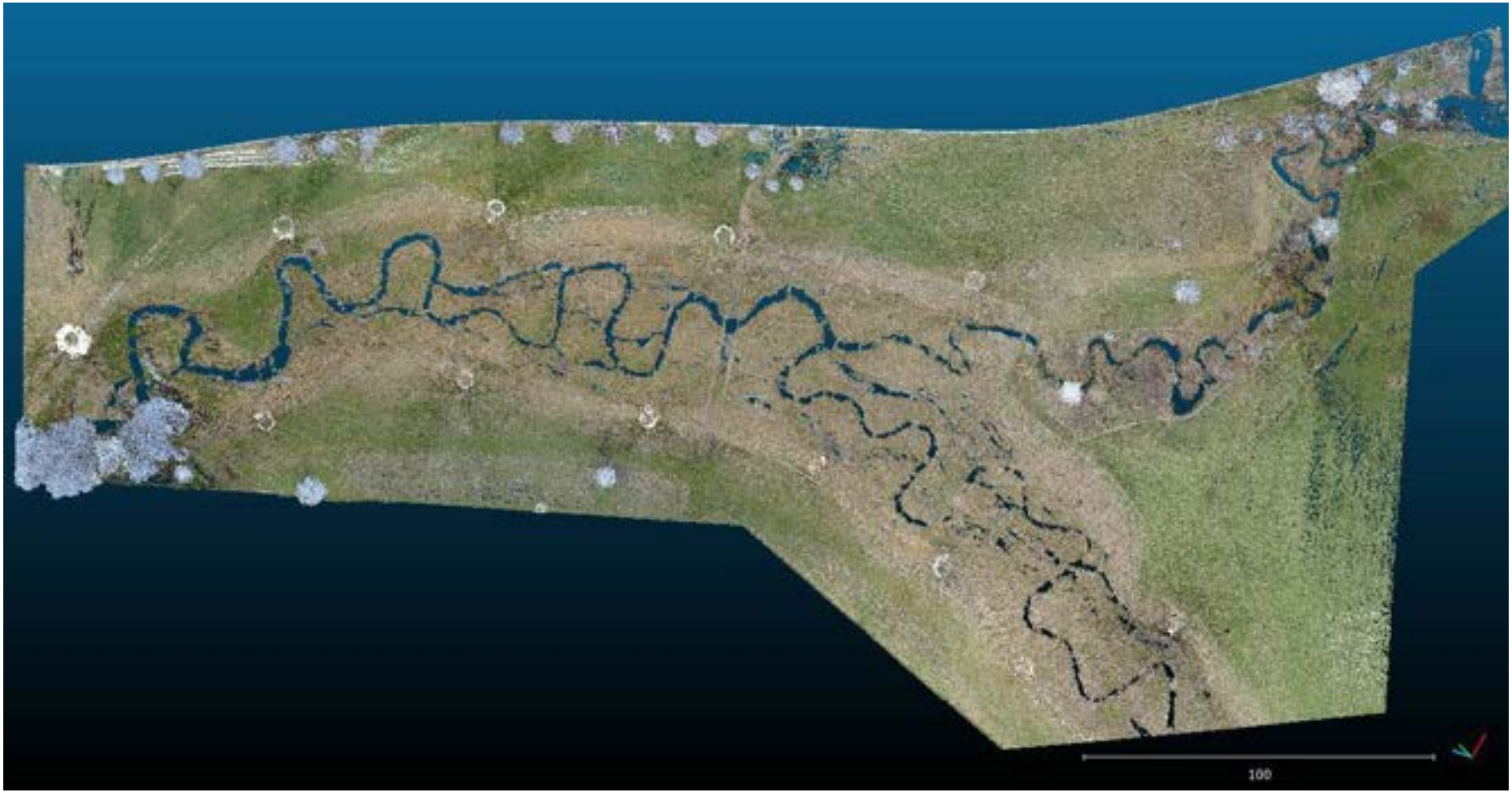
Importance Value is the sum of relative percent cover and relative frequency for each species.

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

LandStudies

Big Spring Run Floodplain Restoration

April 2014 – ~ 2.5 years after construction



Courtesy Franklin & Marshall College

Big Spring Run, Lancaster County PA

Courtesy Telemonitor, Inc.

September 18, 2012 @ 3:30 PM

Post-Restoration

LandStudies

Big Spring Run, Lancaster County PA

Courtesy Telemonitor, Inc.

September 18, 2012 @ 4:00 PM

Post-Restoration

LandStudies

Big Spring Run, Lancaster County PA

Courtesy Telemonitor, Inc.

September 18, 2012 @ 4:30 PM
Post-Restoration

LandStudies

Big Spring Run, Lancaster County PA

Courtesy Telemonitor, Inc.

September 18, 2012 @ 4:35 PM

Post-Restoration

LandStudies

Big Spring Run, Lancaster County PA

Courtesy Telemonitor, Inc.

September 18, 2012 @ 4:45 PM

Post-Restoration

LandStudies

Big Spring Run, Lancaster County PA

Courtesy Telemonitor, Inc.

September 18, 2012 @ 5:00 PM

Post-Restoration

LandStudies

Big Spring Run, Lancaster County PA

Courtesy Telemonitor, Inc.

September 18, 2012 @ 7:15 PM

Post-Restoration

Big Spring Run, Lancaster County PA

Courtesy Telemonitor, Inc.

September 18, 2012 @ 8:30 PM

Post-Restoration

LandStudies

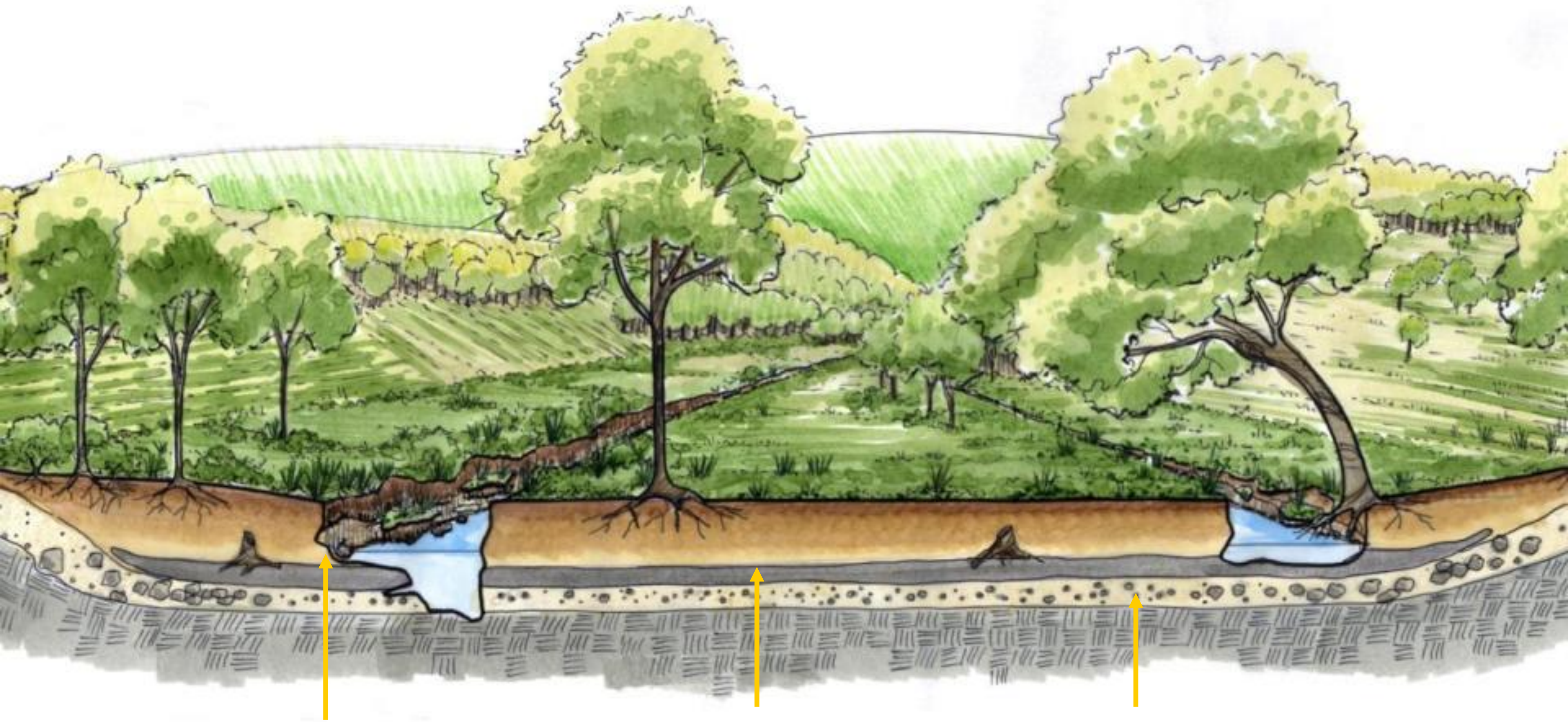
Big Spring Run, Lancaster County PA

Courtesy Telemonitor, Inc.

September 20, 2012 @ 10:00 AM

Post-Restoration

Existing Conditions



LandStudies

Historical Floodplain

Roots extend to groundwater

Floodplain Soils – Shallow, Peaty, Organic, & Porous

Cobble/Gravel Bed (Groundwater)

Bedrock

Legacy sediment removed = 21,704 cy (~21,955 tons)
Total phosphorus removed = ~50,498 lbs (2.3 lbs-P/ton)
Total nitrogen removed = ~63,669 lbs (2.9 lbs-N/ton)
Reduction in sediment flux out of site = 109 tons/year

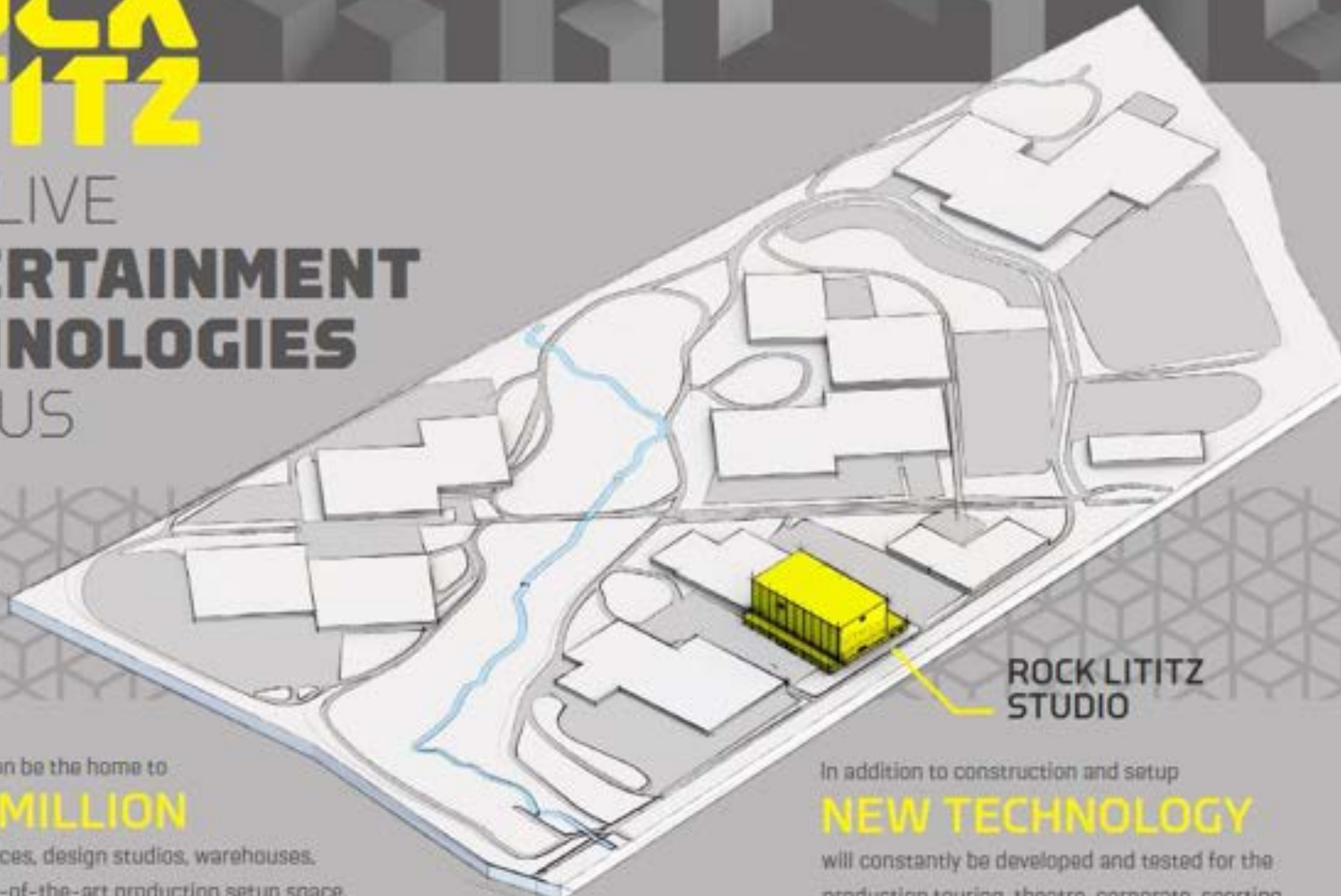
PA DEP FINAL REPORT 2013

BIG SPRING RUN NATURAL FLOODPLAIN, STREAM, AND RIPARIAN WETLAND - AQUATIC RESOURCE RESTORATION PROJECT MONITORING

- Sediment loading decreased 218 tons per year to 109 tons per year (94 tons/year was contributed to bank erosion prior to restoration)
- The source of the load of sediment from bank erosion within the restored reach no longer exists
- Post-restoration: increase in number of days the observed amount of sediment entering reach is greater than that measured downstream – deposition

ROCK LITITZ

...IS A LIVE
ENTERTAINMENT TECHNOLOGIES
CAMPUS



Rock Lititz will soon be the home to

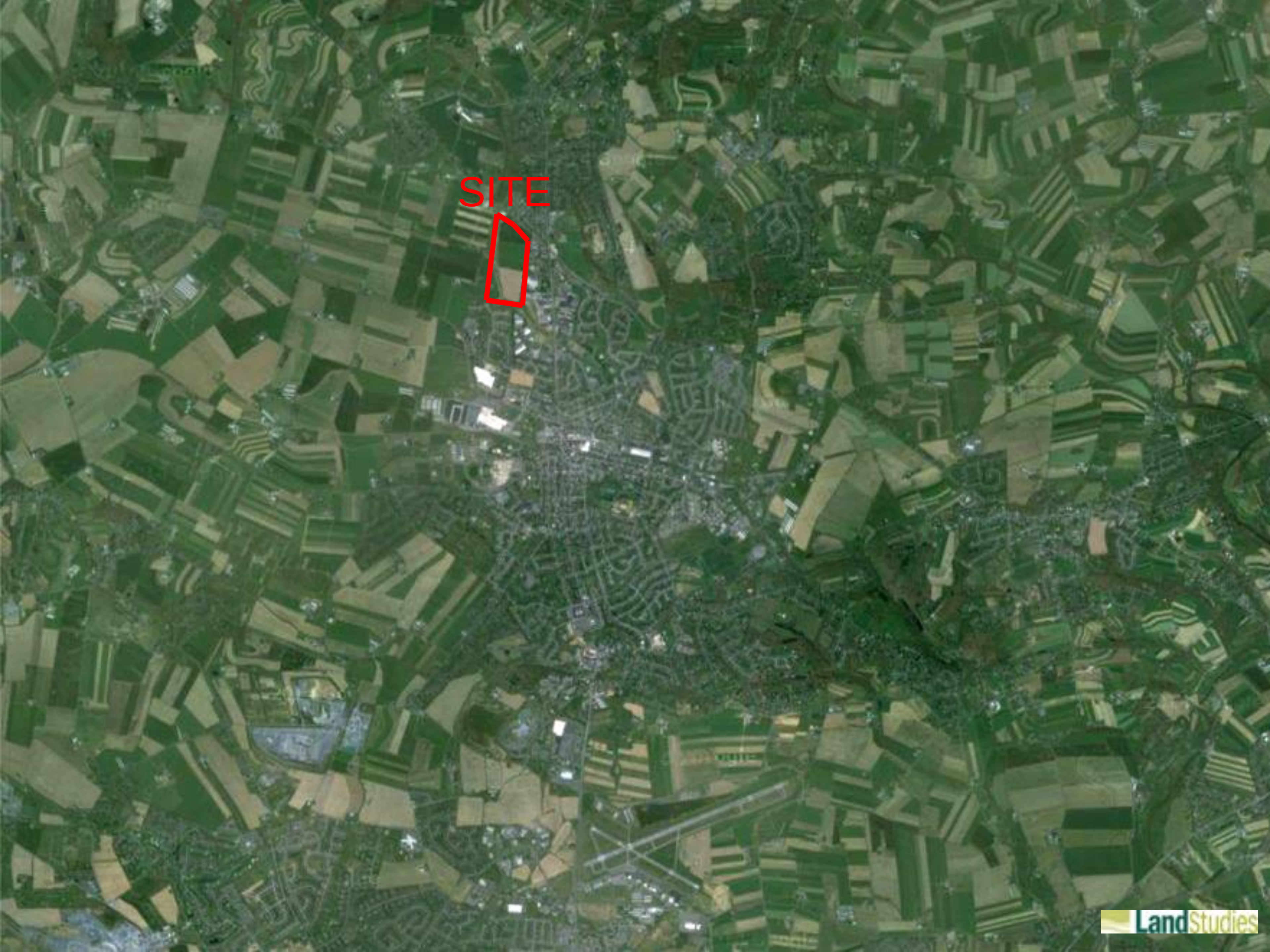
OVER 1 MILLION

square feet of offices, design studios, warehouses, storage and state-of-the-art production setup space.

In addition to construction and setup

NEW TECHNOLOGY

will constantly be developed and tested for the production touring, theatre, corporate, sporting, film, and television markets.


SITE


SITE
501
501
LandStudies

Rock Lititz– Masterplan

Plan By: Derck & Edson Associates, LLP

LandStudies

Stormwater Management Facility (site & regional) - 17 acres

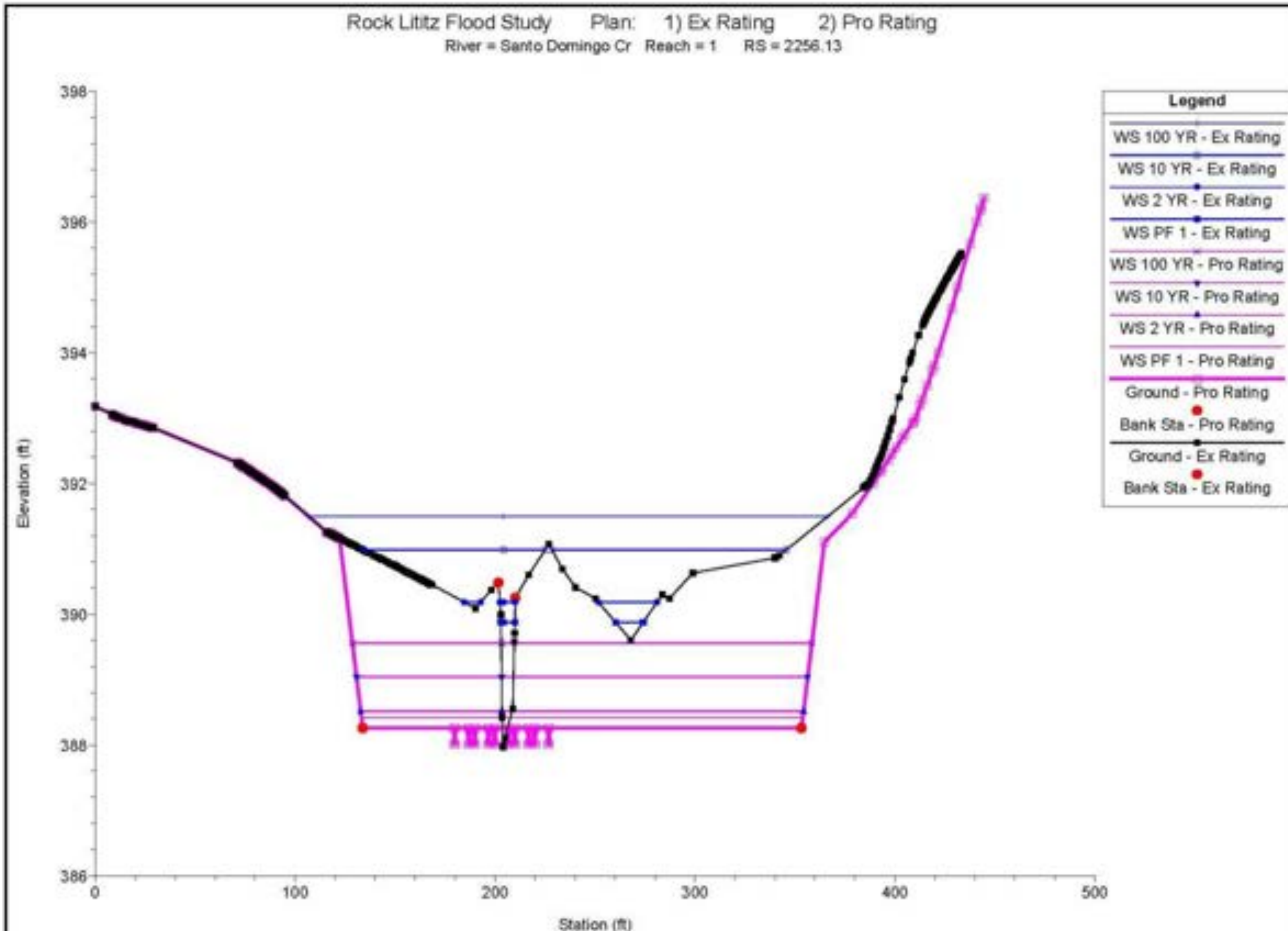
Rock Lititz Floodplain Restoration


LandStudies

LandStudies


Gravel
From Stream Bed
LandStudies

Rock Lititz Floodplain Restoration



LandStudies

Rock Lititz Comparison of Pre & Post Restoration Flow Areas

Flow Rate (cfs)	Existing Flow Area (sf)	Proposed Flow Area (sf)
28.41	12.56	73.31
42.61	18.94	93.63
56.81	25.98	121.99
179.81	85.40	215.90
340.92	147.63	306.39
447.12	183.38	363.37
611.26	234.89	459.89
816.58	293.00	656.78

LandStudies

Peak Rate Control

Rock Lititz - Santo Domingo Floodplain Restoration

Peak Rate Summary Considering Full Masterplan Build-Out

Return Period	Existing @ Property Line (cfs)	Existing On-site (cfs)	Post Devel. @ Property Line (cfs)	% Reduction (Site)	Sub Watershed % Reduction (Total)
2-yr	49.78	7.01	8.57	588%	83%
5-yr	170.51	34.43	129.07	120%	24%
10-yr	342.48	72.35	309.29	46%	10%
25-yr	463.29	97.74	435.57	28%	6%
50-yr	657.70	136.60	638.65	14%	3%
100-yr	910.72	184.57	903.42	4%	1%

Volume Control

Rock Lititz
Enhanced Infiltration Potential Summary

	Wetted Area at 2-yr flow rate (ac)	Average Infiltration Rate (in/hr)	Estimated 2-yr Floodplain Infiltration Rate (cfs)
Existing Condition	4.94	0.125	0.62
Restored Floodplain	16.61	1.875	31.41
Increase	**11.67**	**1.75**	**30.79**

Rock Lititz – Volume BMP Summary

	Volume Retained (cf)
Total Recharge Volume Outside of Floodplain	**12,800**
Floodplain Restoration	
Increased 2-year wetted area(sf)	513,139
Floodplain Restoration 2-yr Infiltration (from Hydrograph Diversion)	**970,725**
Grand Total Recharge Volume	***983,525***
CG-1 Required Volume Reduction	***529,362***

Note: This Volume is only for Phase 1A; Additional upland BMPS will be included with future phases

LandStudies

Rock Lititz – Worksheet 13

Worksheet 13 – Pollutant Reduction Through BMP Applications*

*Fill this worksheet out for each BMP type with different pollutant removal efficiencies. Sum pollutant reduction achieved for all BMP types on final sheet.

BMP Type: Floodplain Restoration

Disturbed Area Controlled by this BMPs (AC) 96.29

Disturbed Area Controlled by this BMPs:

	Land Cover Classification	TSS EMC (mg/l)	TP EMC (mg/l)	Nitrate-Nitrite EMC (mg/l as N)	Cover (Acres)	Runoff Volume (AF)	TSS** (LBS)	TP** (LBS)	NO_3 (LBS)
Pervious Surfaces	Forest	39	0.15	0.17					
	Meadow	47	0.19	0.3	17.21	0.44	55.84	0.23	0.36
	Fertilized Planting Area	55	1.34	0.73					
	Native Planting Area	55	0.4	0.33					
	Lawn, Low-Input	180	0.4	0.44	21.58	0.73	354.78	0.79	0.87
	Lawn, High-Input	180	2.22	1.46					
	Golf Course Fairway/Green	305	1.07	1.84					
	Grassed Athletic Field	200	1.07	1.01					
Impervious Surfaces	Rooftop	21	0.13	0.32	28.75	6.87	389.53	2.41	5.94
	High Traffic Street/Highway	261	0.4	0.83					
	Medium Traffic Street	113	0.33	0.58					
	Low Traffic/Residential Street	86	0.36	0.47					
	Res. Driveway, Play Courts, etc.	60	0.46	0.47					
	High Traffic Parking Lot	120	0.39	0.6					
	Low Traffic Parking Lot	58	0.15	0.39	28.75	6.87	1075.84	2.78	7.23
	TOTAL LOAD TO THIS BMP TYPE						1,876	6.2	14.4
	POLLUTANT REMOVAL EFFICIENCIES FROM APPENDIX A, STORMWATER MANUAL (%)								
	POLLUTANT REDUCITON ACHIEVED BY THIS BMP TYPE (LBS)						248,622	173.0	1009.8

POLLUTANT REDUCTION ACHIEVED BY ALL BMP TYPES (LBS)			
REQUIRED REDUCTION from WS12 (LBS)			

*Pollutant Load = [EMC, mg/l] X [Volume, AF] X [2.7, Unit Conversion]

**TSS and TP calculations only required for projects not meeting CG1/CG2 or not controlling less than 90% of the disturbed area

Landis Homes Floodplain Restoration

Landis Homes Floodplain Restoration – Lititz, PA

Landis Homes Floodplain Restoration


LandStudies


LandStudies

Landis Homes Floodplain Restoration

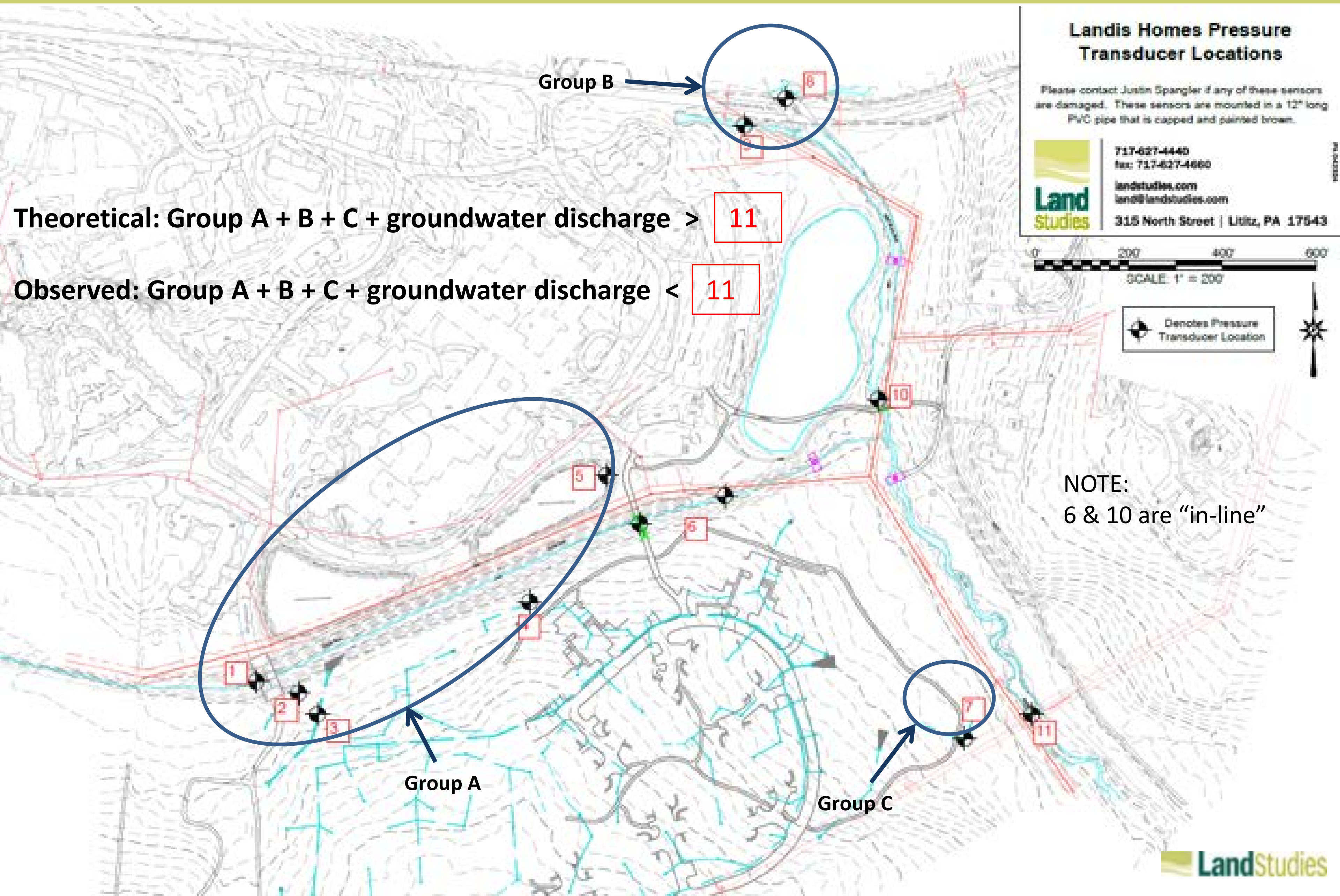
Landis Homes Floodplain Restoration

No retrofits of basins or new basins – "eliminating the basins"

Data Monitoring

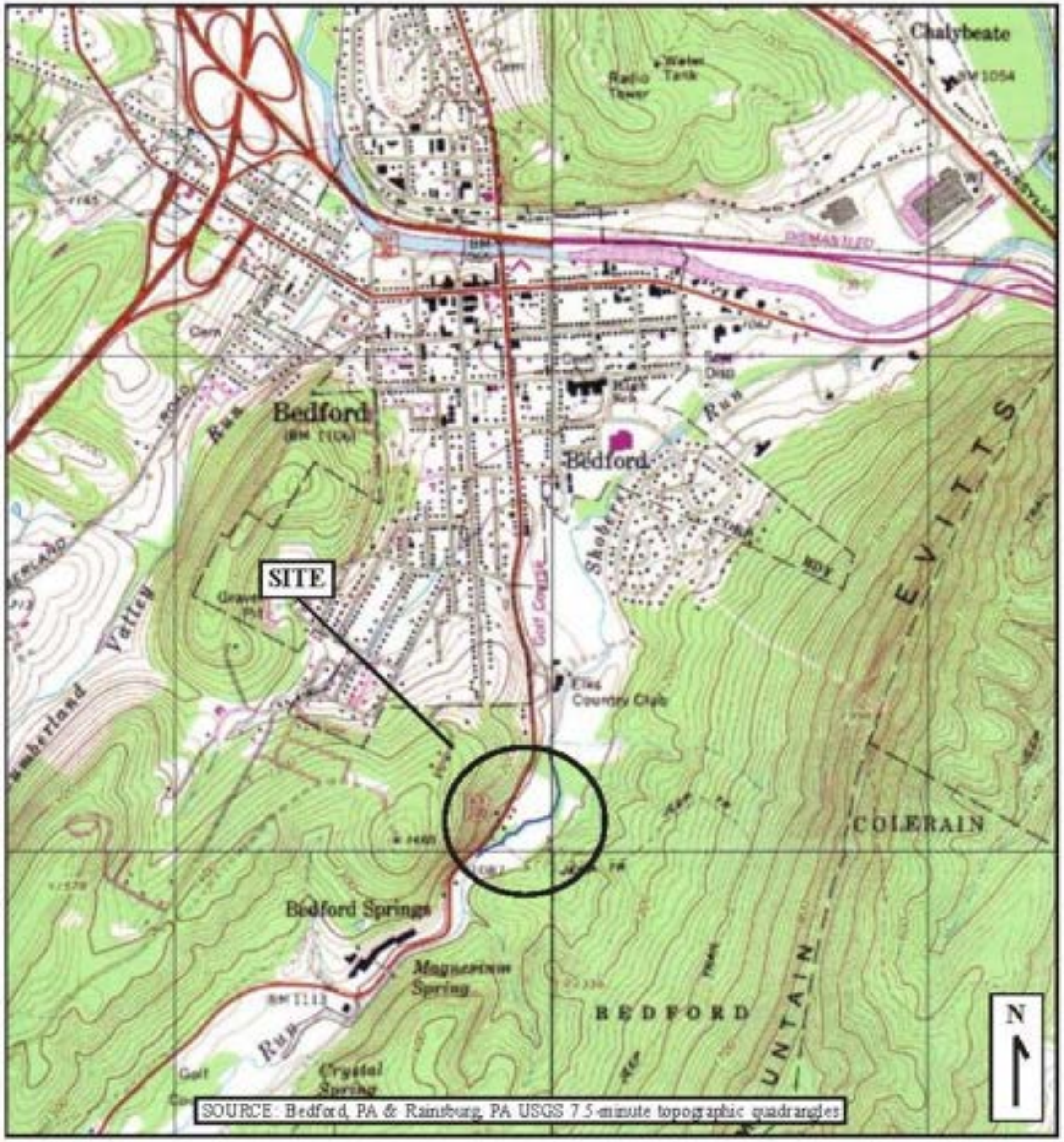
A Pressure Transducer called a Levelogger is used as a cost-effective solution for continuously measuring water level and temperature.

Infiltration Monitoring



Landis Homes Floodplain Restoration

Bedford Springs Resort, Bedford, PA



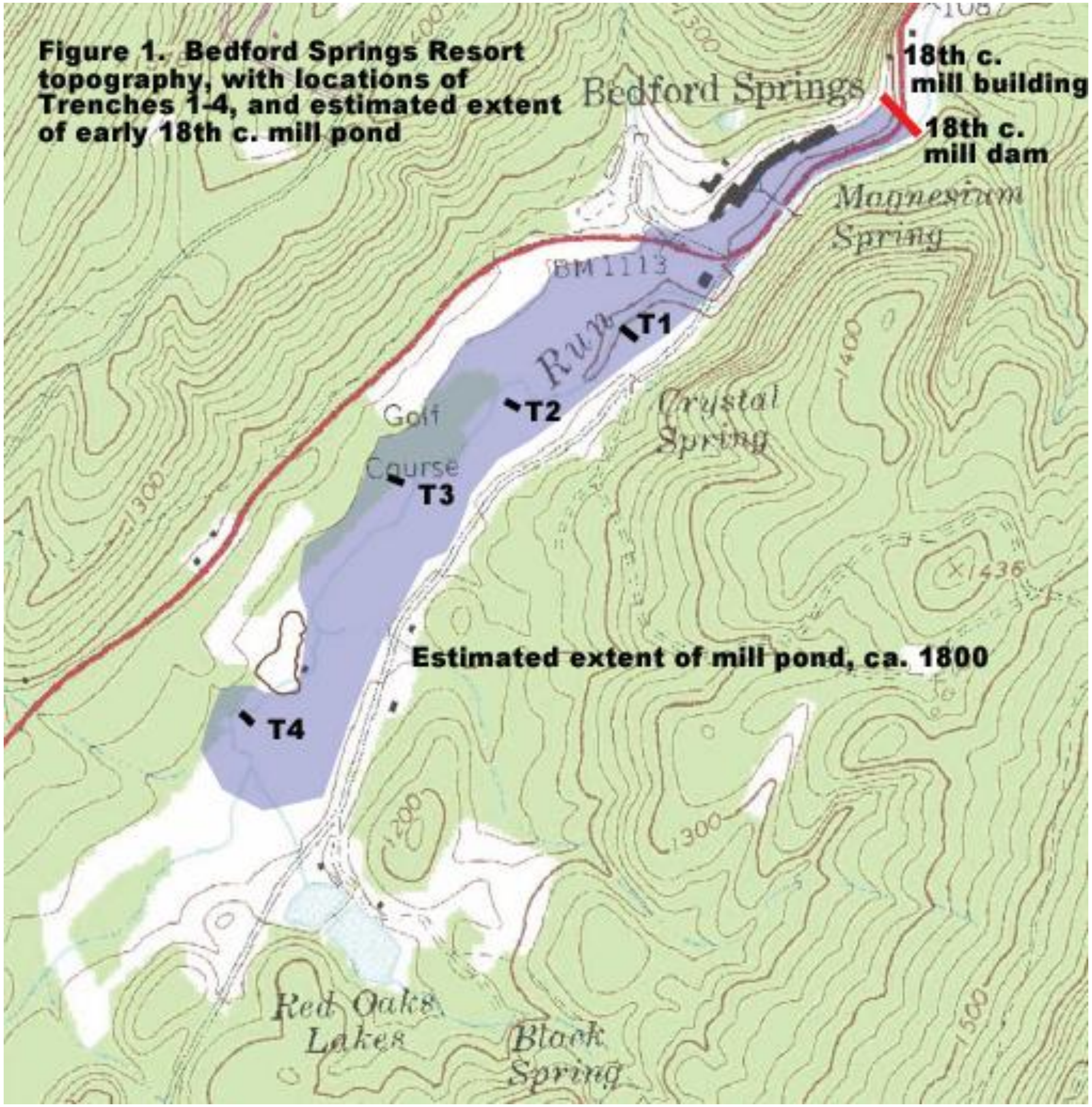
Bedford Springs Resort, Bedford, PA

Shober's Run Restoration

Bedford Springs Resort, Bedford, PA

Bedford Springs Resort, Bedford, PA

Bedford Springs Resort, Bedford, PA



Bedford Springs Resort, Bedford, PA

Bedford Springs Resort, Bedford, PA

Bedford Springs Resort, Bedford, PA

Bedford Springs Resort, Bedford, PA

Golf Inc. Magazine
"2007 Restoration of the Year"

Bedford Springs Resort, Bedford, PA

Golf Inc. Magazine
"2007 Restoration of the Year"

Bedford Springs Resort, Bedford, PA

Golf Inc. Magazine
"2007 Restoration of the Year"

Bedford Springs Resort, Bedford, PA

Golf Inc. Magazine
“2007 Restoration of the Year”

Bedford Springs Resort, Bedford, PA

Golf Inc. Magazine
"2007 Restoration of the Year"

Bedford Springs Resort, Bedford, PA

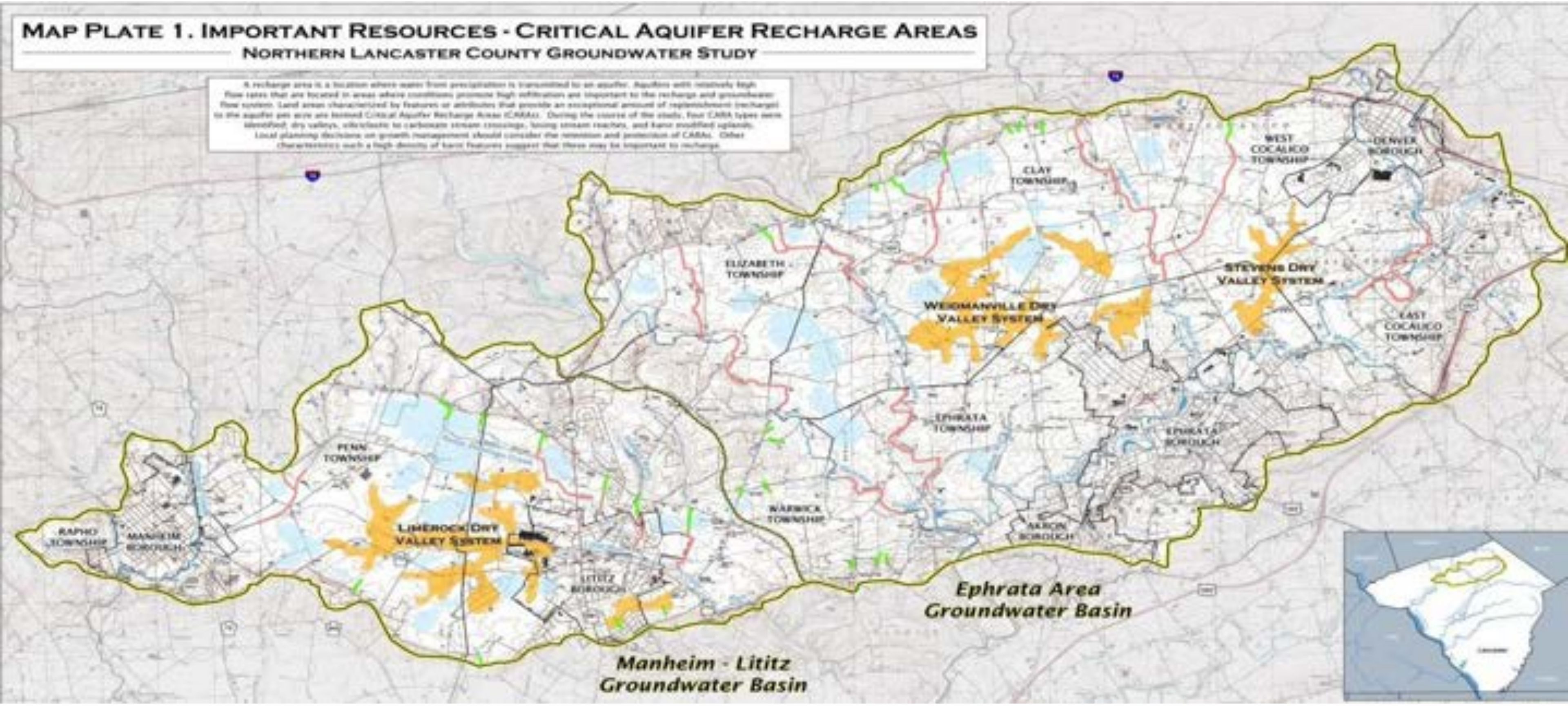
Golf Inc. Magazine
"2007 Restoration of the Year"

Bedford Springs Resort – Bedford, PA

Bedford Springs Resort– Results Summary

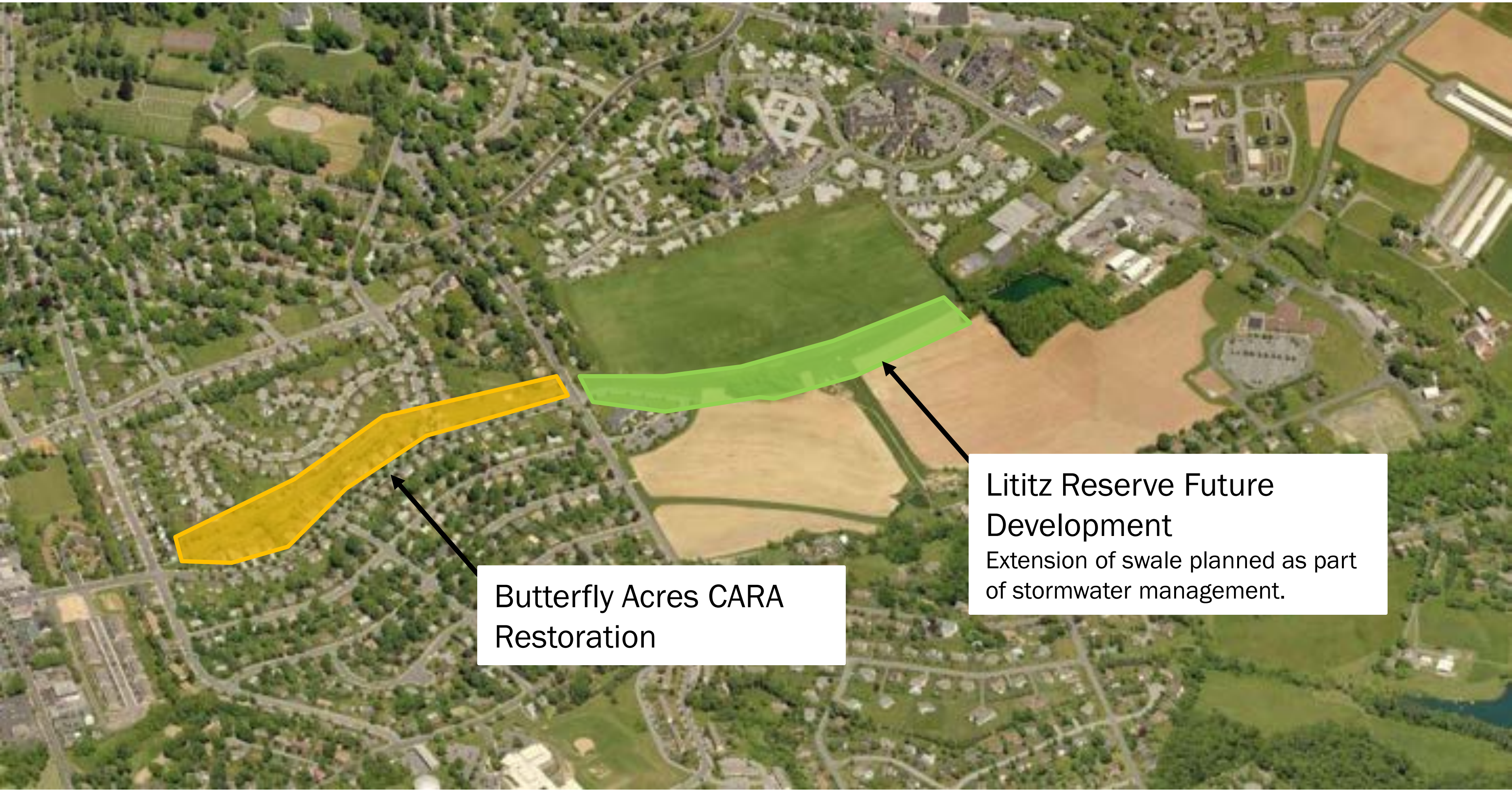
- 6,800 linear feet of Shober's Run restored
- 80 foot minimum floodplain corridor created
- 10 acres of wetland created
- 70,000 cubic yards of legacy sediment removed

Butterfly Acres: Critical Aquifer Recharge Area (CARA) Restoration



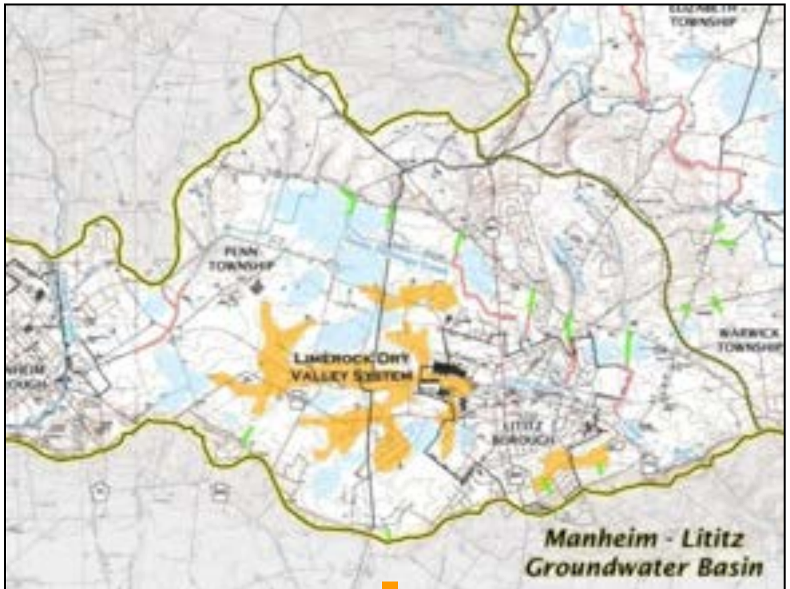
Lititz Run Watershed –

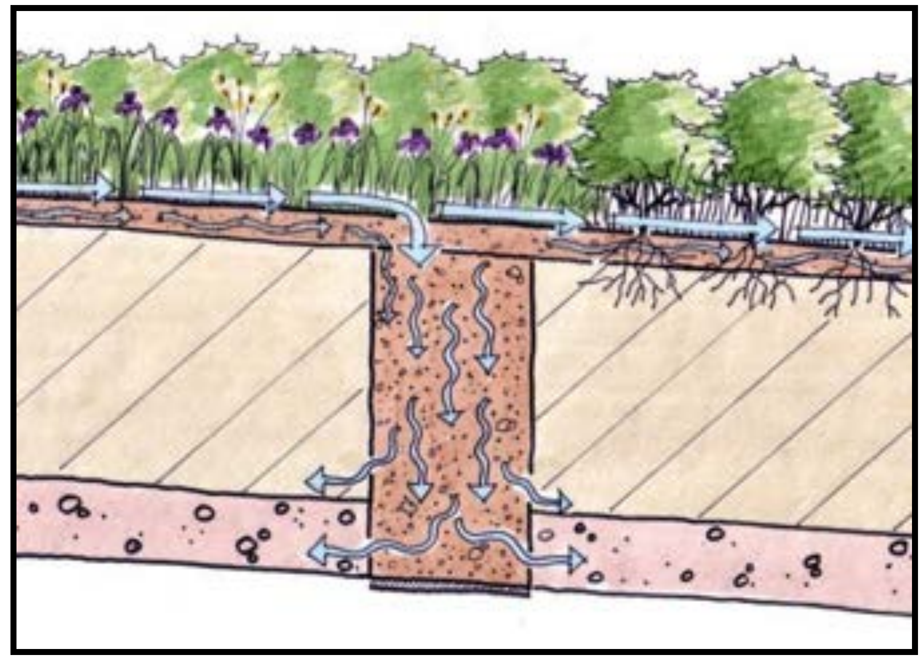
Butterfly Acres Critical Aquifer Recharge Area (CARA) Restoration



LandStudies

Lititz Run Watershed – Butterfly Acres CARA Restoration





LandStudies

Lititz Run Watershed – Butterfly Acres CARA Restoration

LandStudies

Lititz Run Watershed – Butterfly Acres CARA Restoration

Coreopsis tinctoria – Plains Coreopsis

Lititz Run Watershed – Butterfly Acres CARA Restoration

Quantifiable Results:
- 2,250 linear feet of drainage channel restored
- 2.85 acres of native plant bio-swale seeding

Construction dates:
Phase 1 – 2006
Phase 2 – 2007
Phase 3 – 2008
Phase 4 – 2010


LandStudies


LandStudies

Lititz Run Watershed – Butterfly Acres CARA Restoration

LandStudies

New Street Ecological Park- Nutrient Credit Trading Pilot Project

Lititz Run Watershed

New Street Ecological Park

LandStudies

New Street Ecological Park – *Before Construction*

New Street Ecological Park – *Before Construction*

The churning flood flow makes it easy to see why the stream banks are so eroded. The inability of the stream to release high flows onto the floodplain creates excessive energy in the channel itself.

LandStudies

The man is standing on the new, more historically accurate and natural floodplain elevation. Behind him is the old floodplain, created by sedimentation that occurred within the past century or two.

LandStudies

New Street Ecological Park – *After Restoration*

Removed from the watershed:

- over 7,800 tons of sediment
- over 8,930 pounds of phosphorus
- over 26,080 pounds of nitrogen

Santo Domingo Creek- New Street Ecological Park

-Small Storm Event

New Street Ecological Park-Flood Flow

4.74” inches of rainfall Sept. 30, 2011

New Street Ecological Park

Site Characteristics

NEW STREET ECOLOGICAL PARK

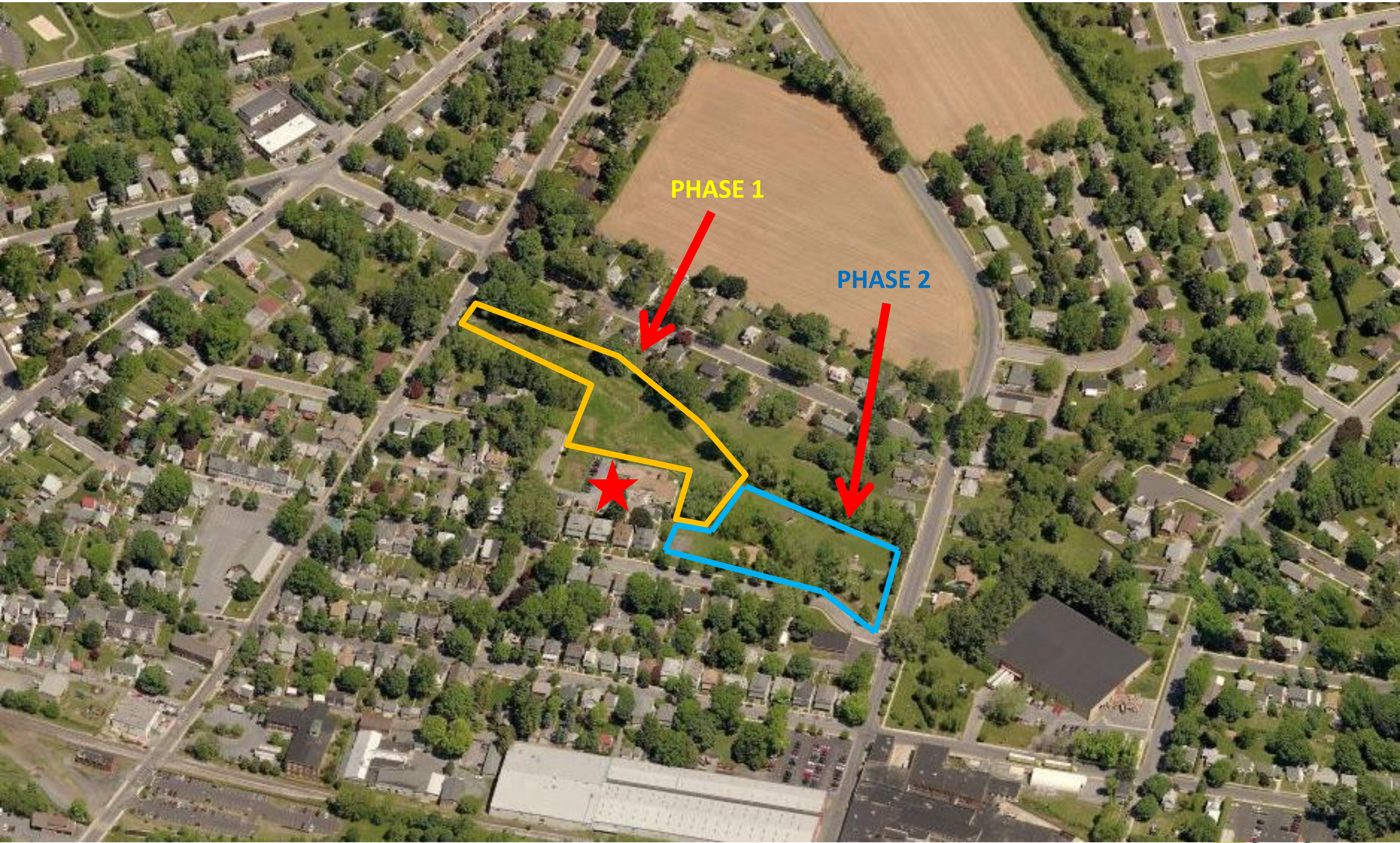
- Existing municipal-owned park in Lititz, PA
- Dated facilities, eroding streambanks, continuous threats to infrastructure in "dense" residential area
- Ecological development opportunities:
    - Innovative stormwater management (via Floodplain Restoration-FPR)
    - Improved water quality through restoration
    - Regulatory compliance (MS4 Permit)
    - Stream restoration and stabilization
    - Through FPR: Increased flood storage…reduced flood peak rates
- Economic and community development opportunities (as a result of initial ecological focus):
    - Improved park facilities
    - Transportation corridor protection
    - Residential and commercial corridor protection (flooding)
    - Desired aesthetic enhancements
    - Return on investment

LandStudies

New Street Ecological Park – Phase 2 (2015)

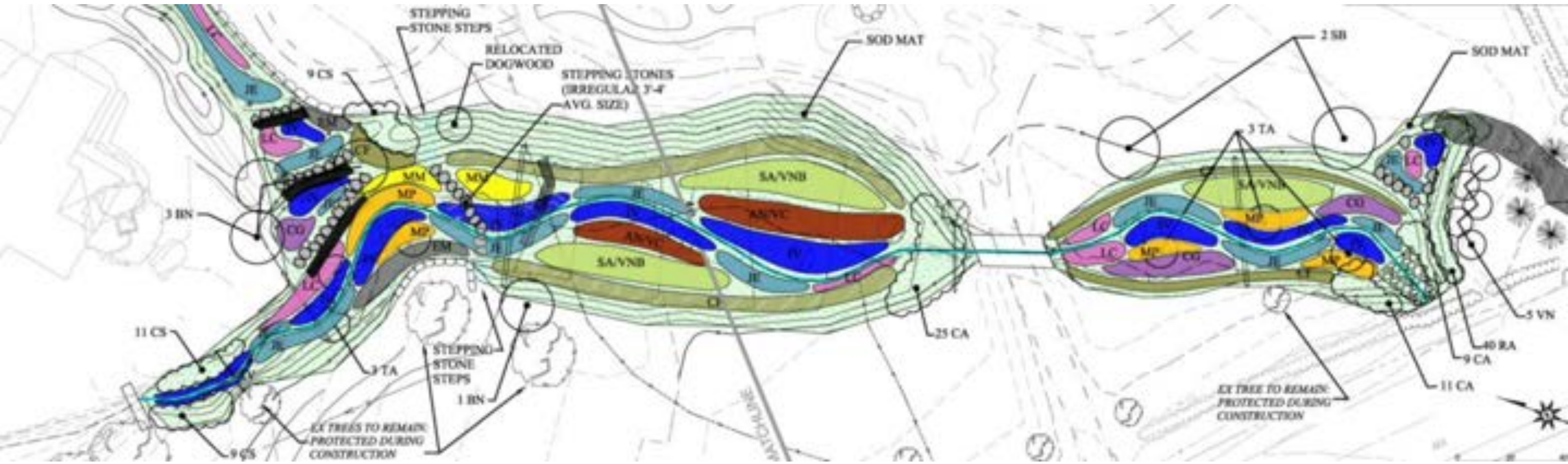
LandStudies

New Street Ecological Park, Lititz, PA



LandStudies

Private Residence



Post Construction – September 2011

September 2011 Storms – 18”+ in 2 week period

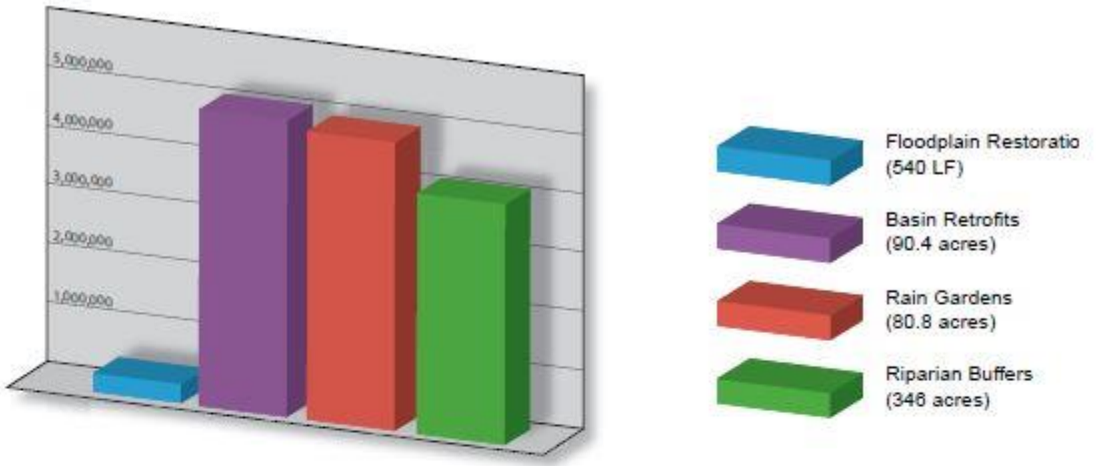
Early October 2011

Cocalico Watershed Association – BMP Effectiveness

The cost-effectiveness data shows that not all BMPs are created equal:

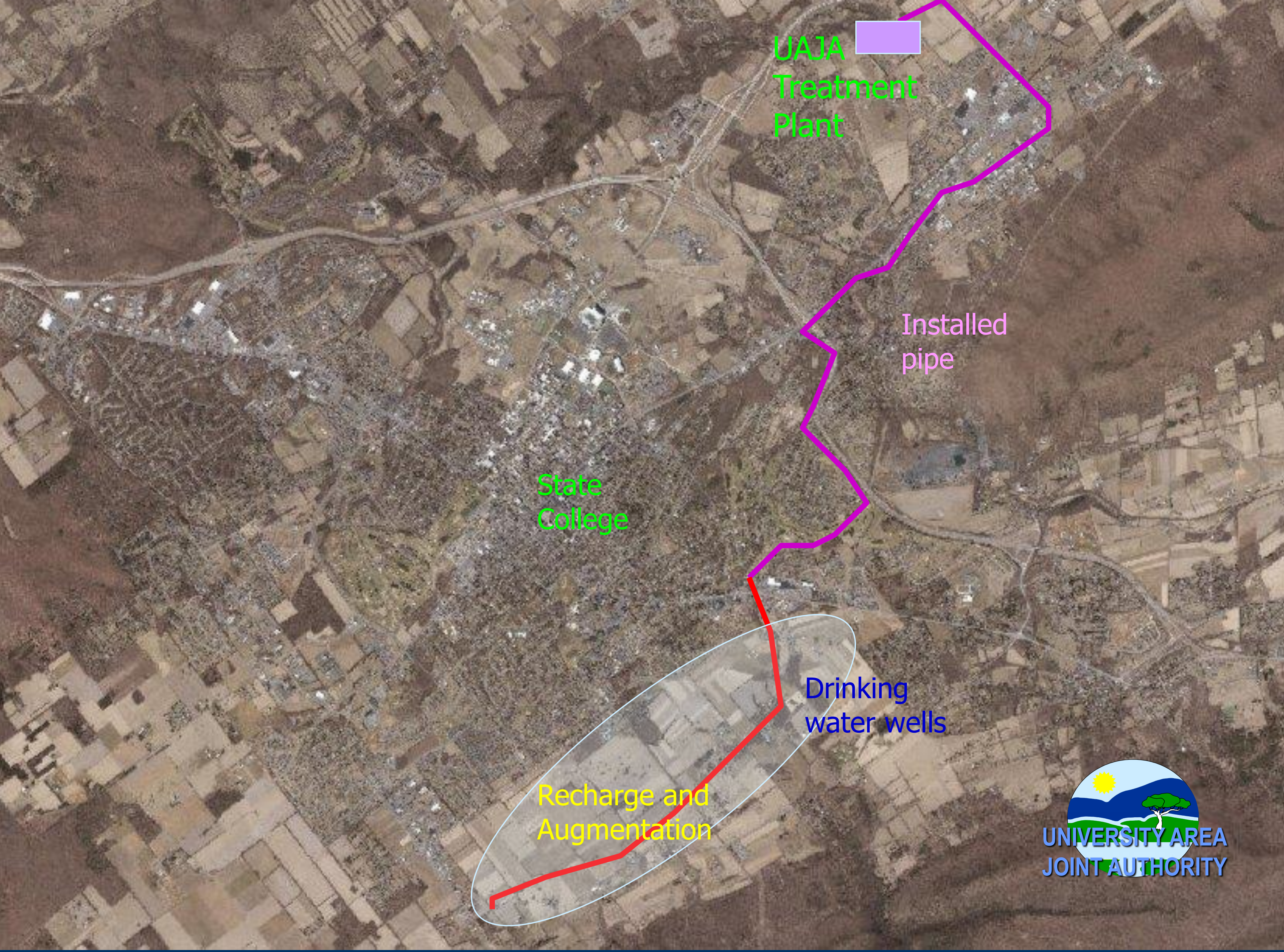
To reduce sediment loads by 100,000 pounds in the Cocalico Creek watershed using floodplain restoration it would cost about $329,000.

To achieve the same result using basin retrofits, rain gardens, or riparian buffers, the cost rises sharply: $5.25 million, $5.09 million, and $4.24 million respectively.



New Street Park floodplain restoration (during construction, 2005)

LandStudies


UAJA
Treatment
Plant
Installed
pipe
State
College
Drinking
water wells
Recharge and
Augmentation
UNIVERSITY AREA
JOINT AUTHORITY

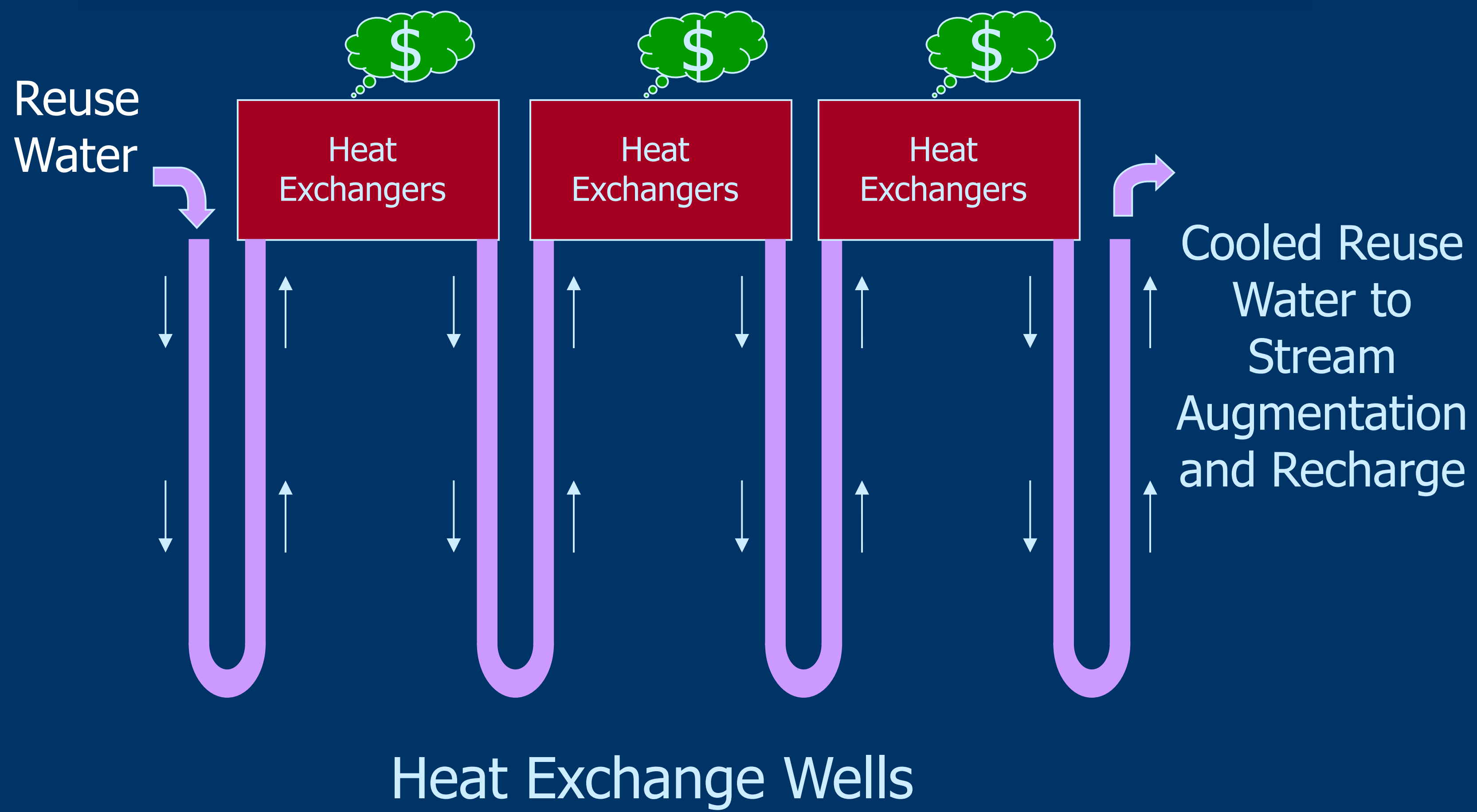
UAJA Beneficial Reuse Project

Wastewater purified through Micro-filtration and Reverse Osmosis used to augment Slab Cabin Run and recharge the drinking water aquifer

- Up to 3 million gallons per day
- Moves water seven miles upstream
- Provide energy benefit to region
- Restore Slab Cabin Run to historical conditions

UNIVERSITY AREA
JOINT AUTHORITY

Geothermal On A Grand Scale



Heat exchangers proposed for industrial and commercial use along the reuse water transmission main

UNIVERSITY AREA JOINT AUTHORITY


Land
Studies