Water Dynamics

Goals

Using designs inspired by natural processes, we aim to address predictable, small scale threats (i.e.. runoff) through the creation of mo, long-term vegetative buffers and bioretention. The plants chosen will be specific to the contaminates located on-site to promote phytoremediation. In order to address immediate, less predictable, and potentially large scale threats we will focus on implementing riparian zones on a regional scale, and developing floodwater diversion methods.

(1) Identify threatened landscapes
(2) Mitigate within determined watershed
(3) Regenerate upstream of chosen location by implementing mitigation strategies that incorporate riparian buffers, bioretention areas, and phytoremediative designs.
(4) Protect Water Resources

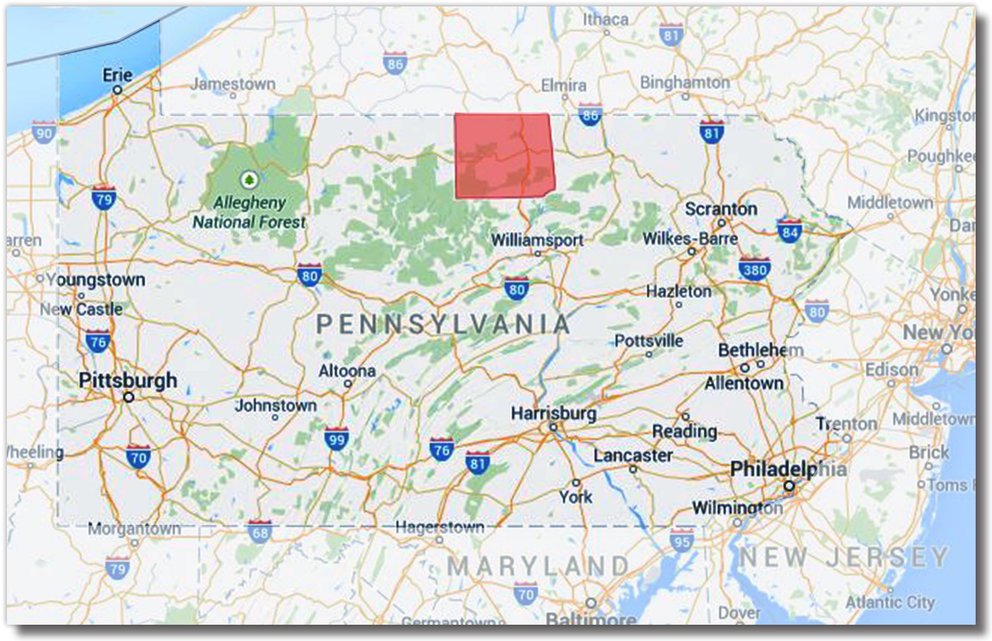
"Identify, Protect, Mitigate & Regenerate for the Present, Past & Future"

Explore

Project Goals
Analysis
Designs & Plans
Resources
About the Students

Issues from Marcellus Drilling & Water

Pollution issues range from surface water contamination (due to runoff, spills, and illegal or improper disposal of wastewater) to groundwater contamination (due to substandard well casings that leak or are insufficient, non-point source pollution, and improperly treated flowback water disposal). This contaminated water affects both ecosystems and communities.



Location of Project

The *Water Dynamic Project* is located within Tioga County, Pennsylvania, an area greatly impacted by Marcellus Shale gas drilling.

Community Outreach

To best understand water as a threat and asset to local ecosystems and society, the citizens of Wellsboro provided valuable input during community meetings.

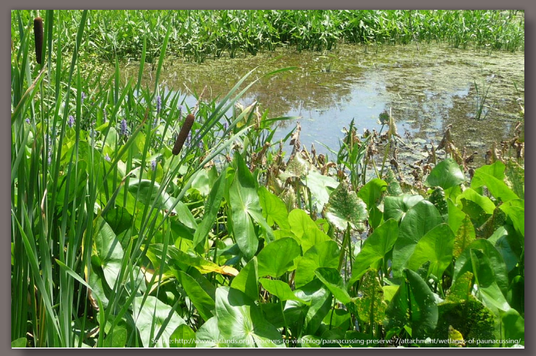
Water Dynamics - Analysis

Human & Natural Assets

Water provides numerous benefits, but under certain circumstances, it can become a threat to both ecosystems and communities. Through analysis, seven components are identified and addressed that influence the quality as well as the quantity of water entering Tioga County hydrological system.

Town Centers

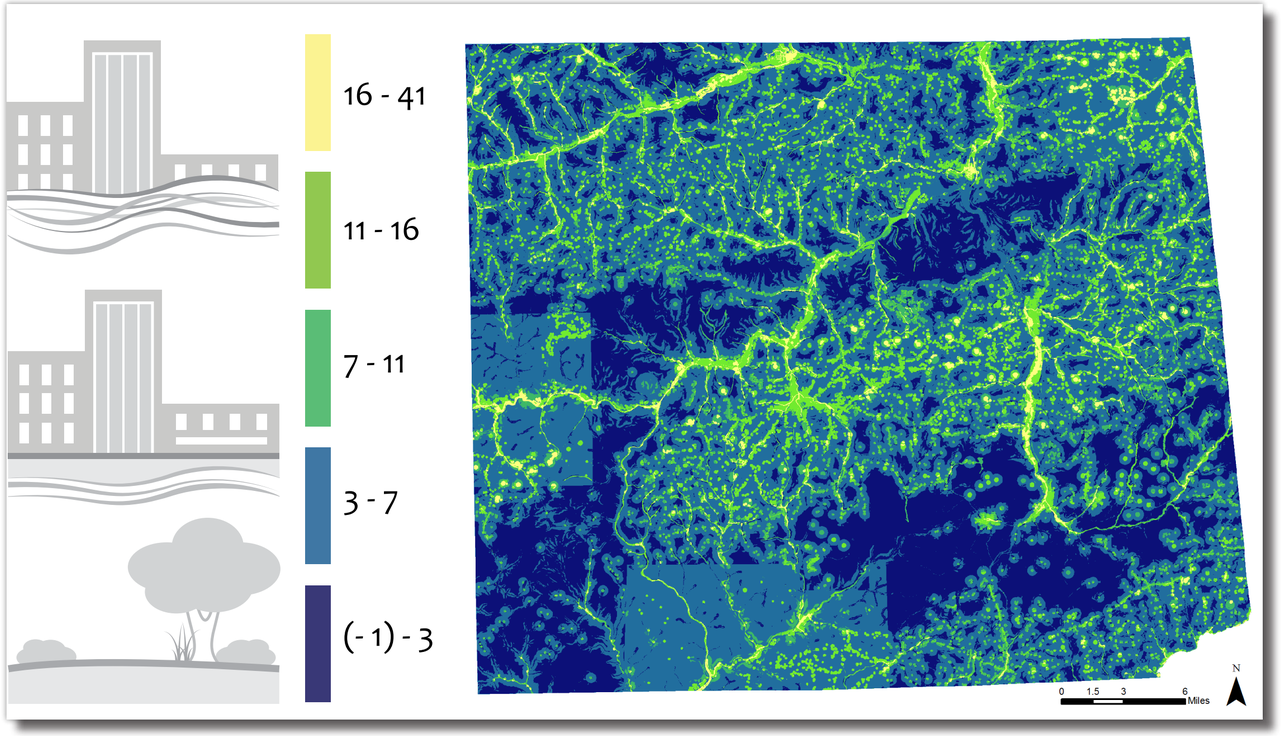
Floods pose the largest threat to infrastructure (i.e. homes, businesses, and industrial sites) which may in turn degrade water quality through pollution.



Wetlands, Lakes & Ponds

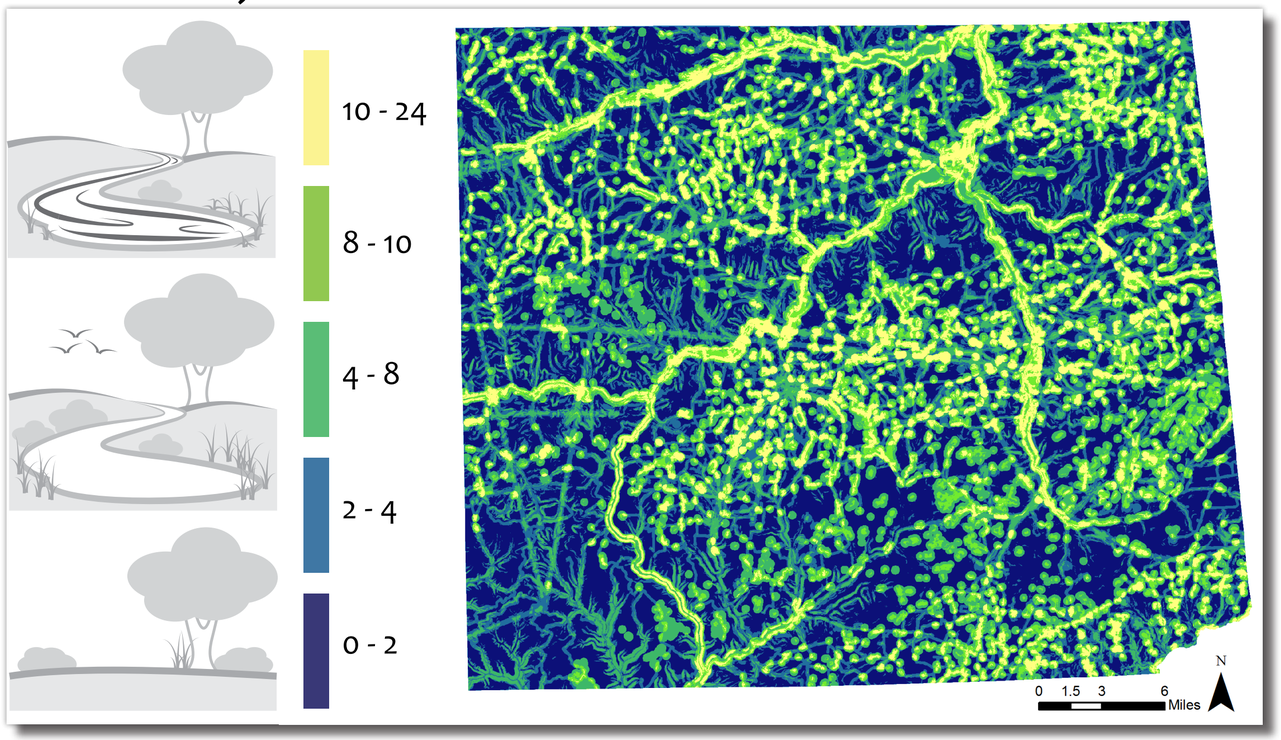
These bodies of water are critical to the function and quality of the hydrological system and water resources but are easily damaged by human influences such as agricultural runoff and industrial activity.

Town Centers



Layers Used: Floodplain, Flood Depth, Buildings, Groundwater Complaints, Impervious Surfaces, Streams, Natural Gas Wells, Wastewater Disposal Sites, Roads, Natural Gas Company Violations, Soil Erodability, Slope, Townships, Forest Riparian Areas, Streams, and Bodies of water

Wetlands, Lakes & Ponds

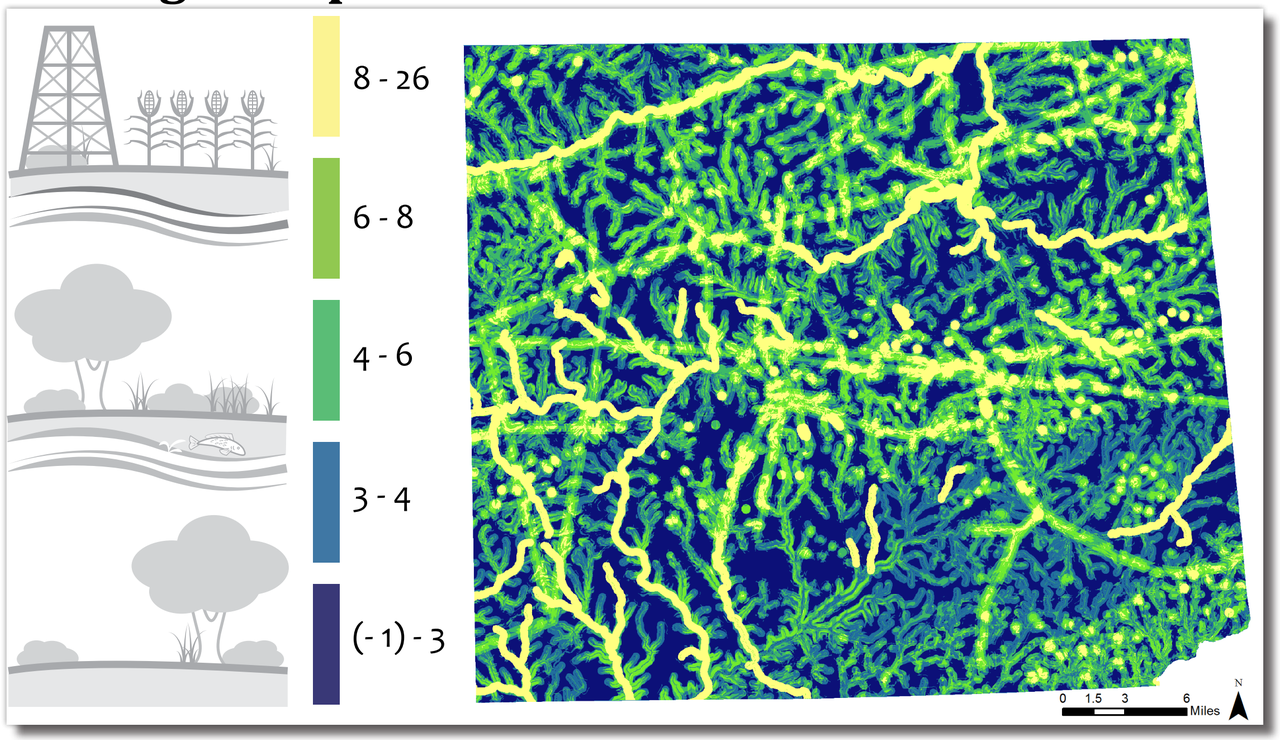


Layers Used: Wastewater disposal sites, natural gas company violations, agricultural riparian areas, roads, soil erodability, slope, pipelines, natural gas well locations, forest riparian areas, streams, and bodies of water

Fishing Hot Spots

One of the major recreational attractions of Tioga County is fishing. It is critical to maintain the quality of these aquatic habitats, especially of the sensitive Class "A" Trout streams, to enable future use of this valuable resource.

Fishing Hot Spots

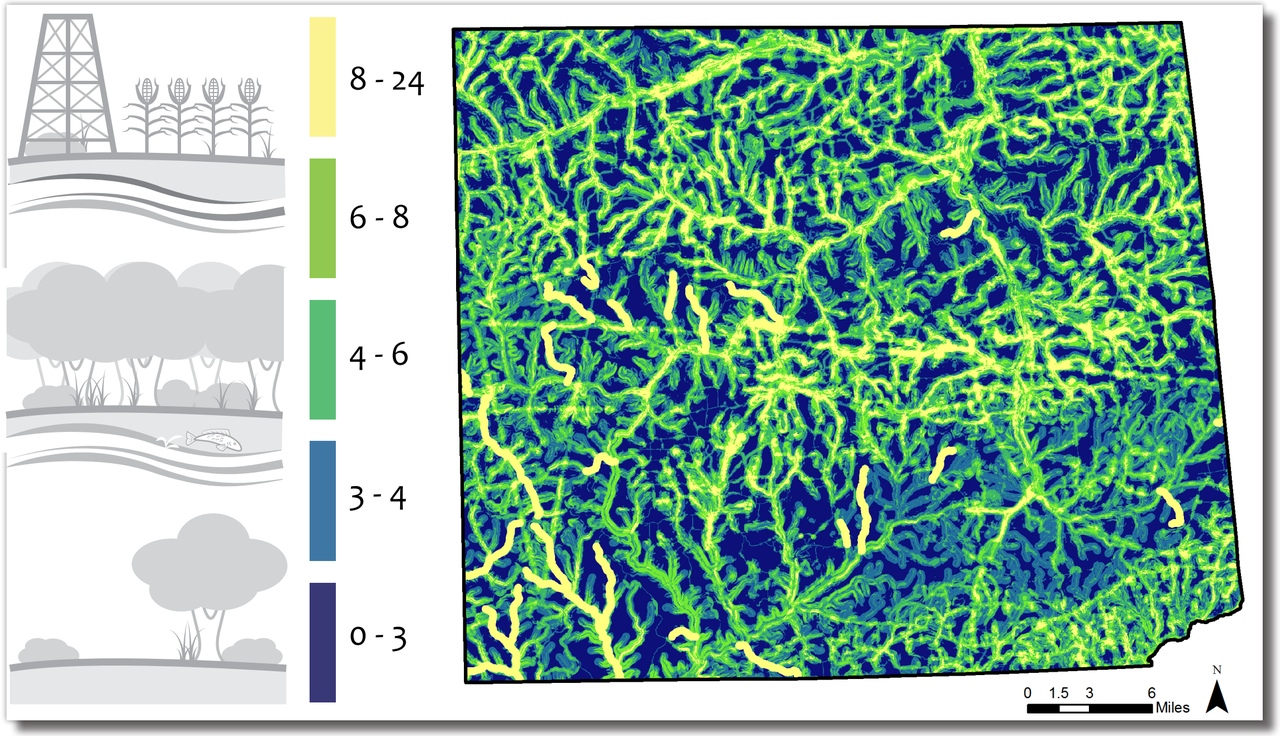


Layers Used: Roads, Streams, Natural Gas Wells, Pipelines, Slope, Soil Erodability, Agricultural Riparian Areas, Forest Riparian Areas, Wastewater Disposal Sites, and Natural Gas Company Violations

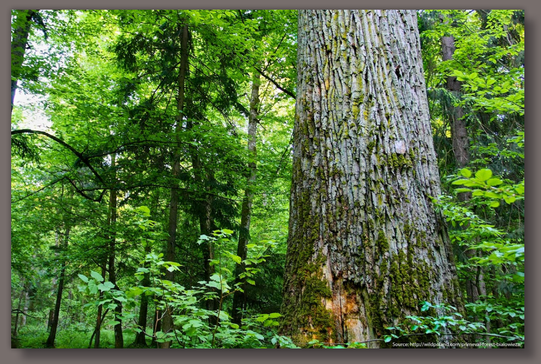
Grade 'A' Trout Streams

Tioga County has several trout streams used for recreational purposes. In order to continue fishing practices, these streams need to be maintained to ensure the persistence of trout habitats.

Grade A Trout Streams



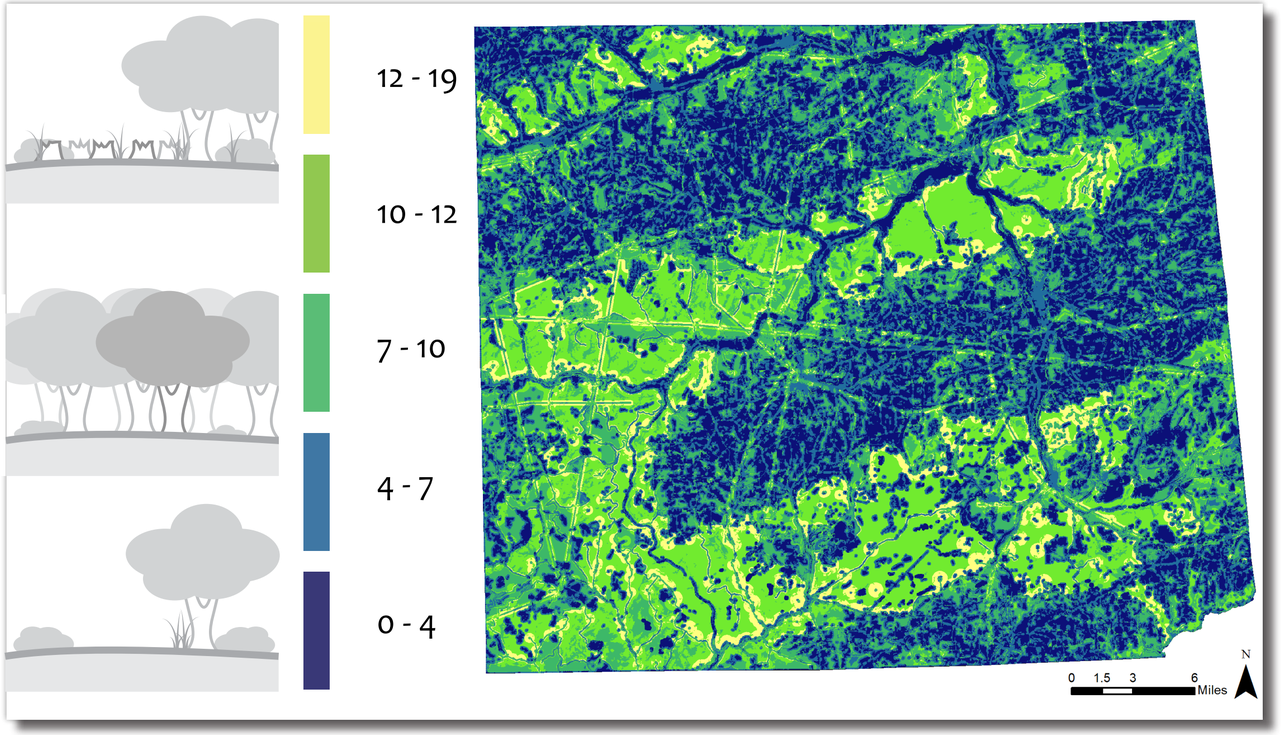
Layers Used: Agricultural riparian areas, Class "A" trout streams, Flood depth, Forest riparian areas, Natural gas well locations, Pipelines, Roads, Slope, Soil Erodability, Streams, and Wastewater disposal sites



Core Forest

Forests provide several benefits to both social and environmental realms. They minimize surface runoff of contaminants, provide shade relief to nearby streams (stabilize water temperature), reduce erosion, offer recreational opportunities, minimize flooding, and create vital ecosystem habitats. As a result, core forest is identified as a valuable resource and mitigation tool for minimizing contaminant spills from natural gas drilling processes and agricultural runoff.

Core Forest

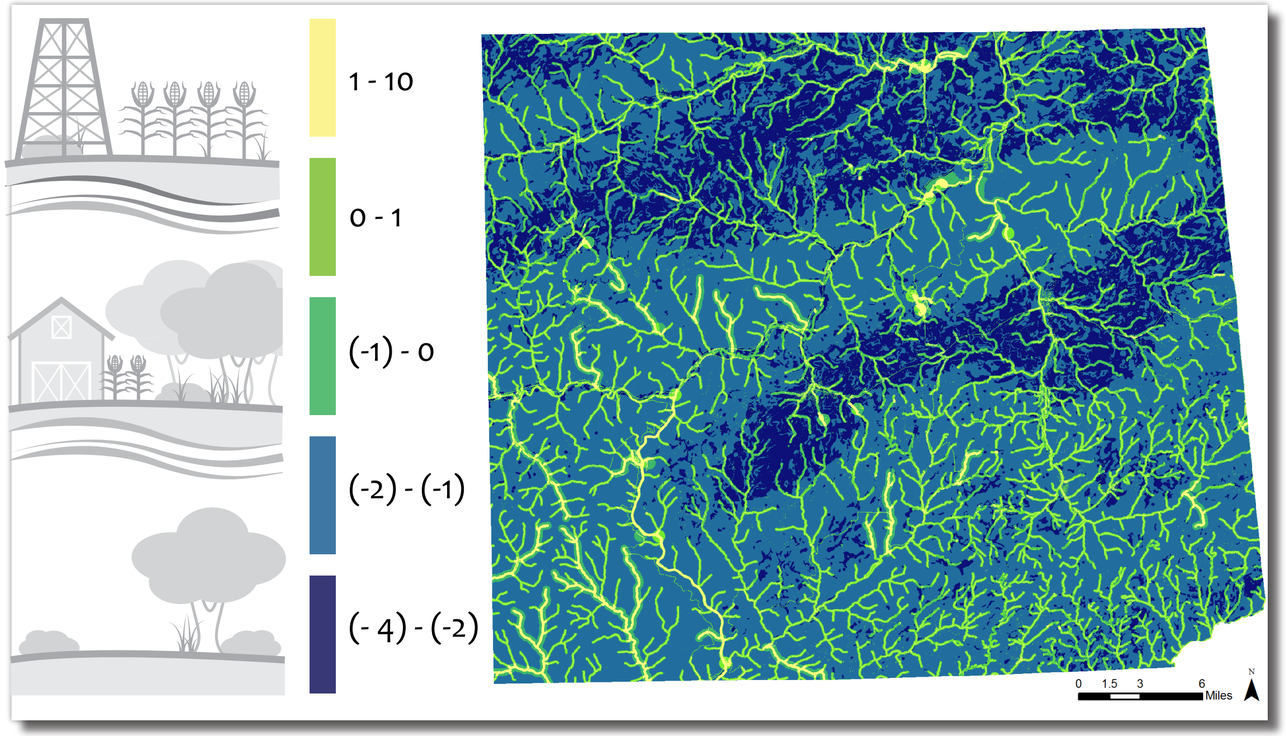


Layers Used: Building buffers, Core forest, Logging, Natural gas well locations, Pipelines, Roads, and Wastewater disposal sites

Scenic Rivers

The beauty of the Pennsylvania landscape is in part due to its scenic waterways. Tioga County has several state and local parks along rivers, which provide passive as well as active opportunities for people enjoy.

Scenic Rivers

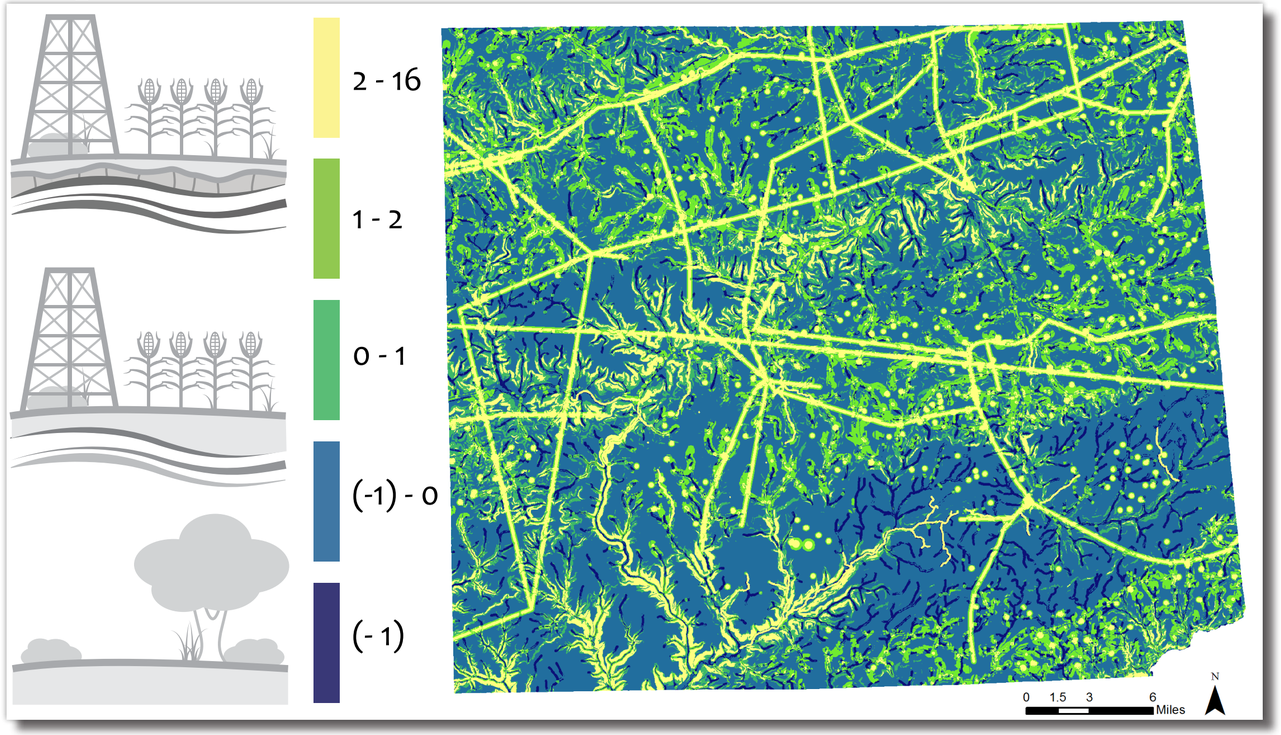


Layers Used: Access areas, Stream visibility from buildings, Class "A" trout streams, Picnic areas, Recreational trails, Soil Erodability, Streams, Water trails, and Well visibility from stream

Impaired Streams

Water quality is essential to maintain hydrological dynamics as well as to preserve viable drinking water sources. Streams serve as a valuable water resource for not only recreational use but also for important ecosystem processes and therefore must be sustained for future use.

Impaired Streams

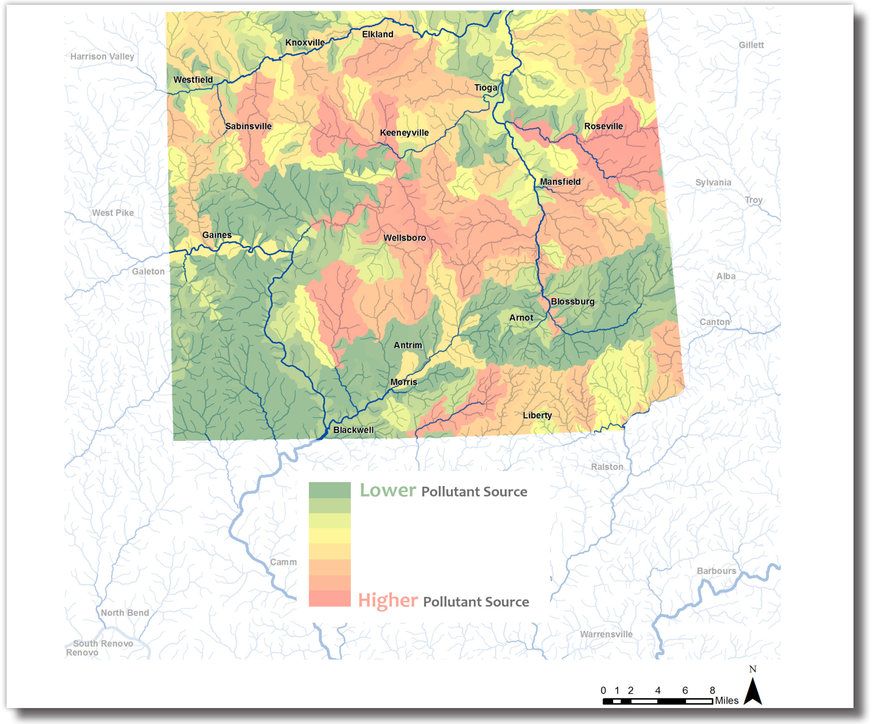


Layers Used: Floodplain, Agricultural riparian areas, Forest riparian areas, Impaired streams, Natural gas company violations, Pipelines, Road proximity to streams, Road-stream intersections, Slope, and Wastewater disposal sites

Pollutant Sources

Agricultural runoff from fertilizers and contaminants greatly impact water quality, local ecosystems, and the value of water resources.

Pollutant Sources



The intensity of agricultural pollutant sources per small watershed was identified and used as a factor in choosing the final area of focus for the final design.

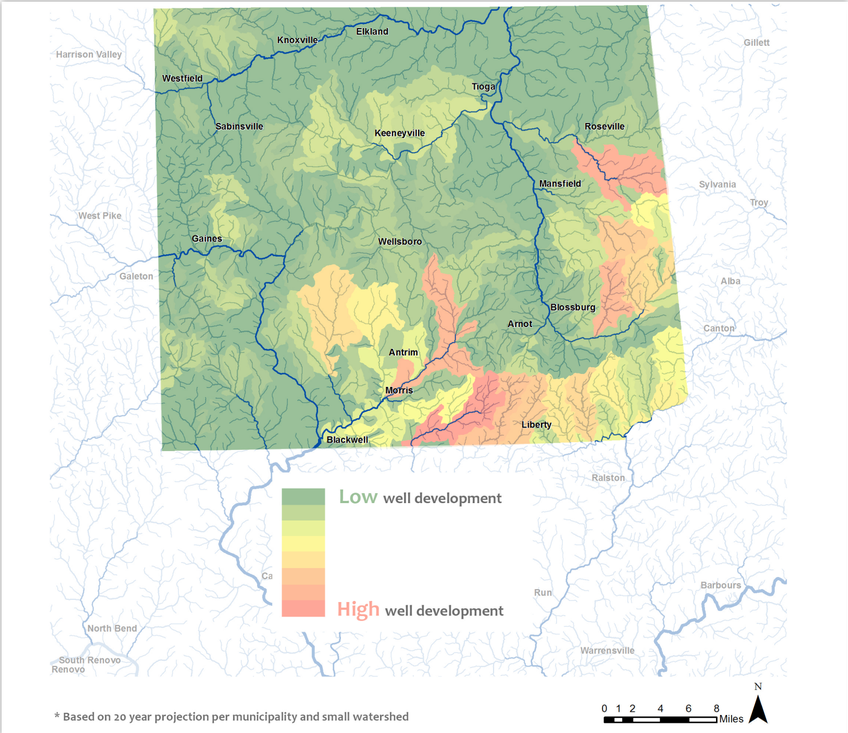
Well Projections

Based on a 20 year projection, future Marcellus Shale well locations are identified within Tioga County.

Areas of Focus

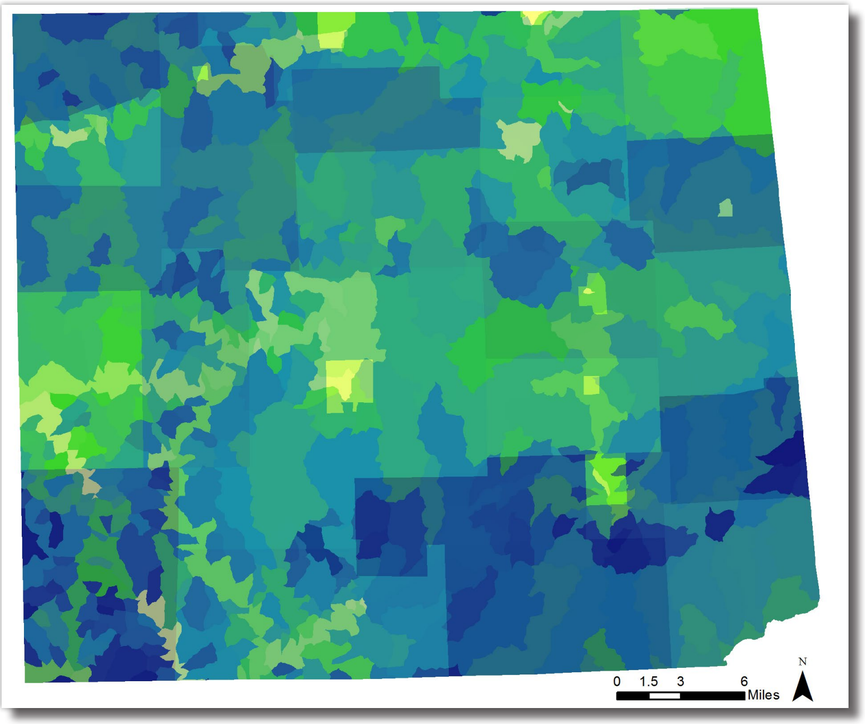
The seven components of the landscape analyzed were compiled into a single map that identifies key areas within Tioga County where mitigation measures would be most beneficial.

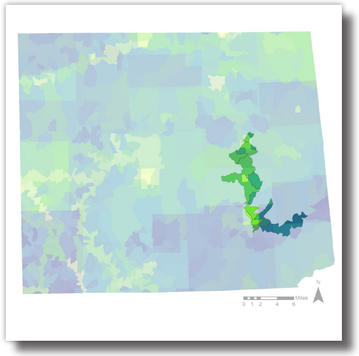
Well Projections

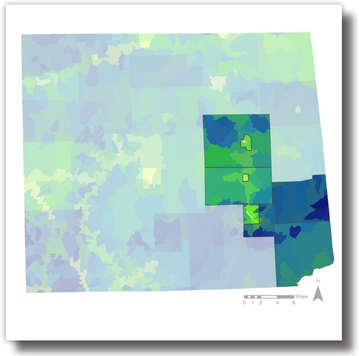


Using data from Tim Murtha, a professor at the Pennsylvania State University, a 20 year Marcellus Shale well projection was calculated. The map to the left shows likely well development per small watershed within Tioga County in order to identify streams that may be impacted most.

Areas of Focus





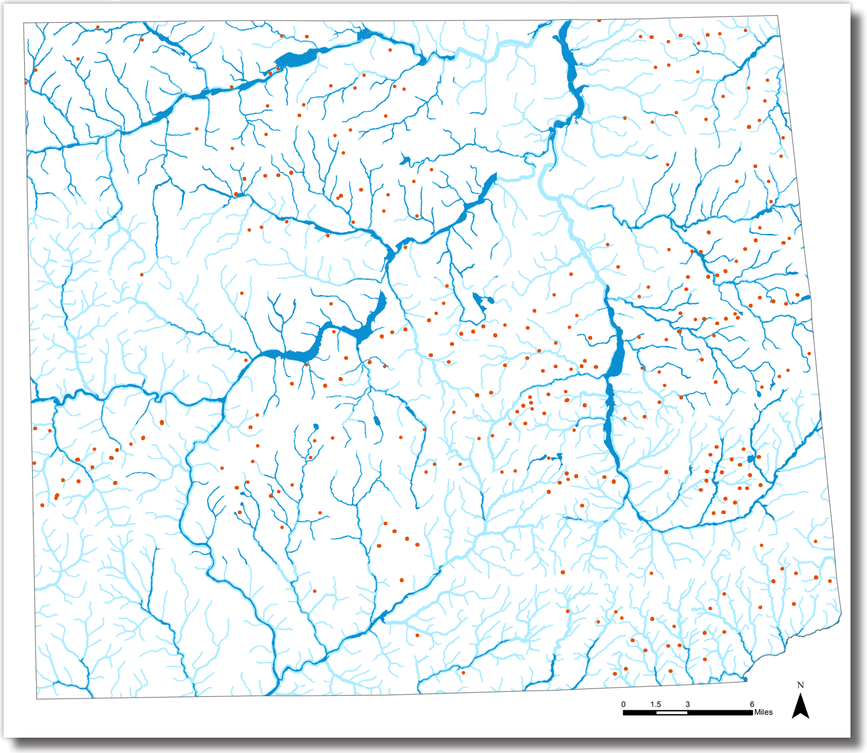


Based on seven analysis maps (core forest, fishing hot spots, impaired streams, class 'A' trout streams, scenic rivers, town centers, and wetlanks, lakes and ponds), a composite map was created using zonal statistics within ArcGIS to calculate values for individual areas. Several small watersheds within a few municipalities were chosen as a focus area for further analysis and design.

Mitigation: Floodplains

Floodplains are areas of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls and experiences flooding during periods of high discharge. Buildings and infrastructure can experience damage if built within floodplains, and water can become polluted if exposed to contaminates during a flood.

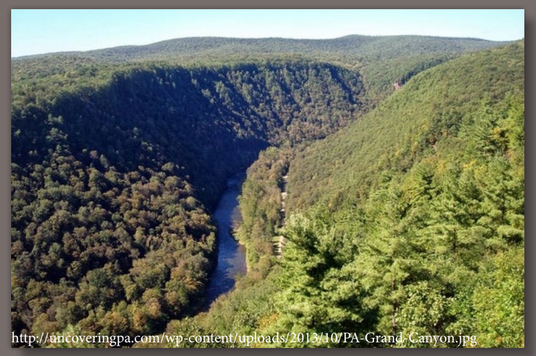
Mitigation Sites - Floodplains



Total area of floodplains within Tioga County, PA:
29,522 hectares

Current number of active well pads in Tioga County within 100 meters of a floodplain: 29

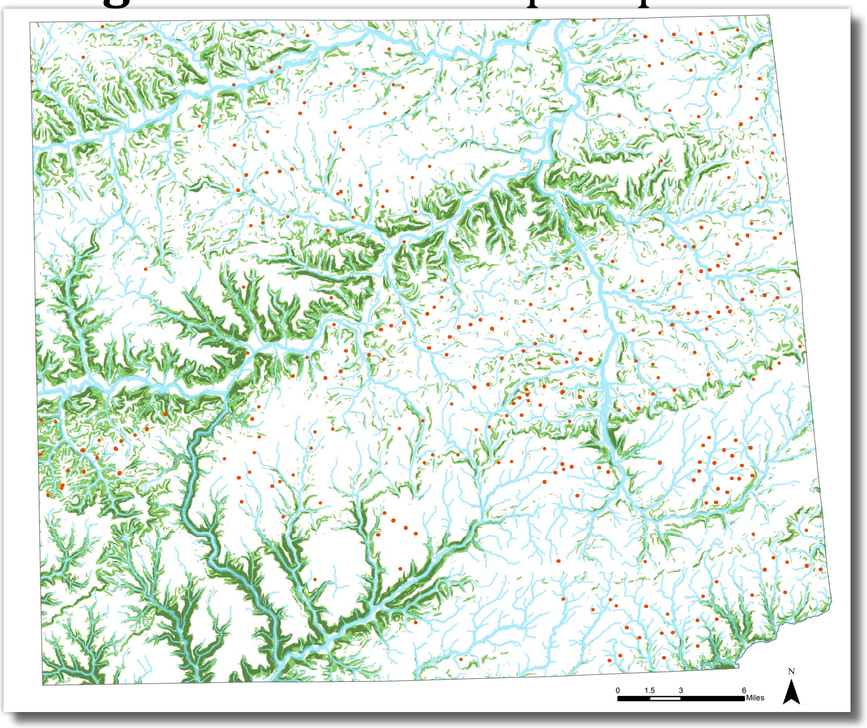
According to PennFuture: "A well or well pad may not be built in a floodplain if the well site will contain a pit or impoundment for drilling wastes. Wells and well pads may be built in a floodplain if wastes will be stored in tanks that are not located within the floodway section of the floodplain."



Mitigation: Steep Slope

Steep slopes can be created by streams over vast periods of time as the movement of water gradually erodes away the surrounding landscape. Steep slopes increase the velocity of runoff, which in turn increases the likelihood that contaminants will reach the water before they can be filtered out by riparian buffers and soil. Well pads built at the top of steep slopes increases the risk of any runoff or spills entering nearby streams.

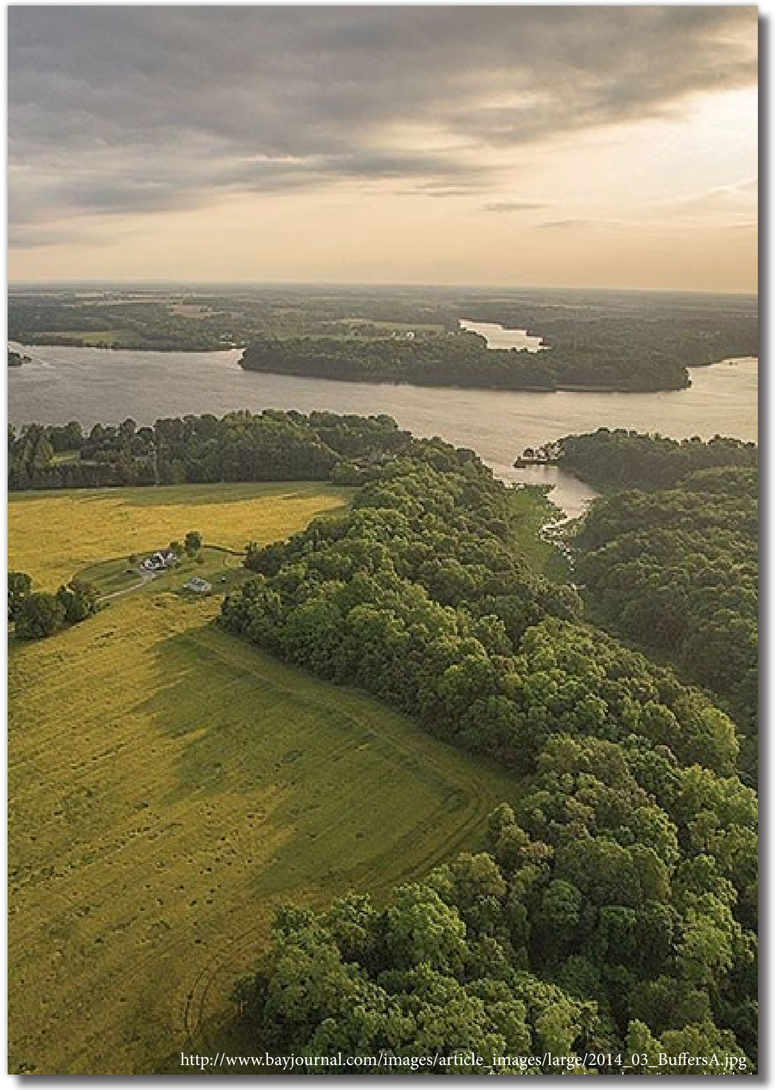
Mitigation Sites - Steep Slope



Total area of steep slopes within Tioga County, PA:
57,396 hectares

Current number of active well pads in Tioga County within 100 meters of steep slope: 140

According to a study by *Soil Science Society of America Journal:* "50 to 70 percent of shale-gas drill sites across Pennsylvania's Appalachian Plateau are situated on slopes that could be prone to erosion and sedimentation problems."


http://www.bayjournal.com/images/article_images/large/2014_03_BuffersA.jpg


http://www.painetworks.com/photos/gh/gh1736.JPG

Riparian Restoration

Riparian buffers are critical vegetative areas directly adjacent to streams and rivers. These areas reduce/prevent bank erosion/ stream turbidity, contaminants from entering the stream, spread of invasive plant species, and stream water overheating. They also provide habitats for a range of species and offer a place for flood waters to dissipate before reaching urban infrastructure. Outreach and education of local community members is crucial for the restoration and implementation of riparian buffers, as many people view them as messy or as obstructions to views of the water and as a result mow their land to the very edge of the stream. This is especially concerning on agricultural land, as this increases the risk of excess fertilizer/pesticides entering streams from runoff in addition to the degradation of the overall stream structure (Kenwick et al., 2009).

Bioretention

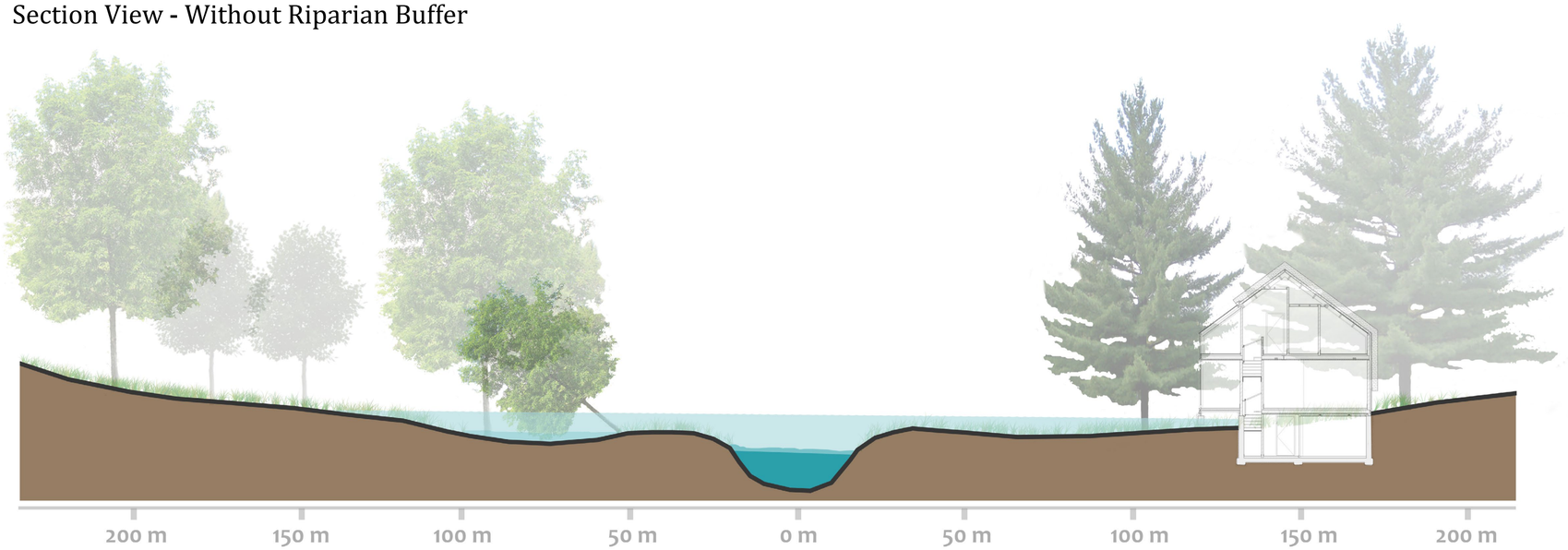
Bioretention is the use of natural basins to collect stormwater runoff and any sediments/contaminants which may be included in the water, reduces the stress placed on stormwater infrastructure, and decreases the risk of flash floods. These may be as simple as grassy berms and swales, but more advanced and visually appealing bioretention areas have a range of plant species that can also create viable habitats, including constructed wetlands (Davis & Hsieh, 2003).

Phytoremediation

Phytoremediation is the implementation of plants to stabilize or reduce contamination of soils and water. It is a natural process that is favorable in conditions with shallow streams and low concentrations of contaminants. Specific plant species will be chosen based on the possible chemicals from fracking fluid and other pollutants related to agriculture and Marcellus Shale gas drilling. Factors that will impact the functionality of phytoremediation areas are regional climate, soil compatibility, ease of planting and maintenance, and ability to filter water (Comino et al., 2012). It will also be important to use native plants when possible. These systems will typically be found within bioretention areas and are a cost effective/less invasive method compared to conventional contaminant removal strategies.

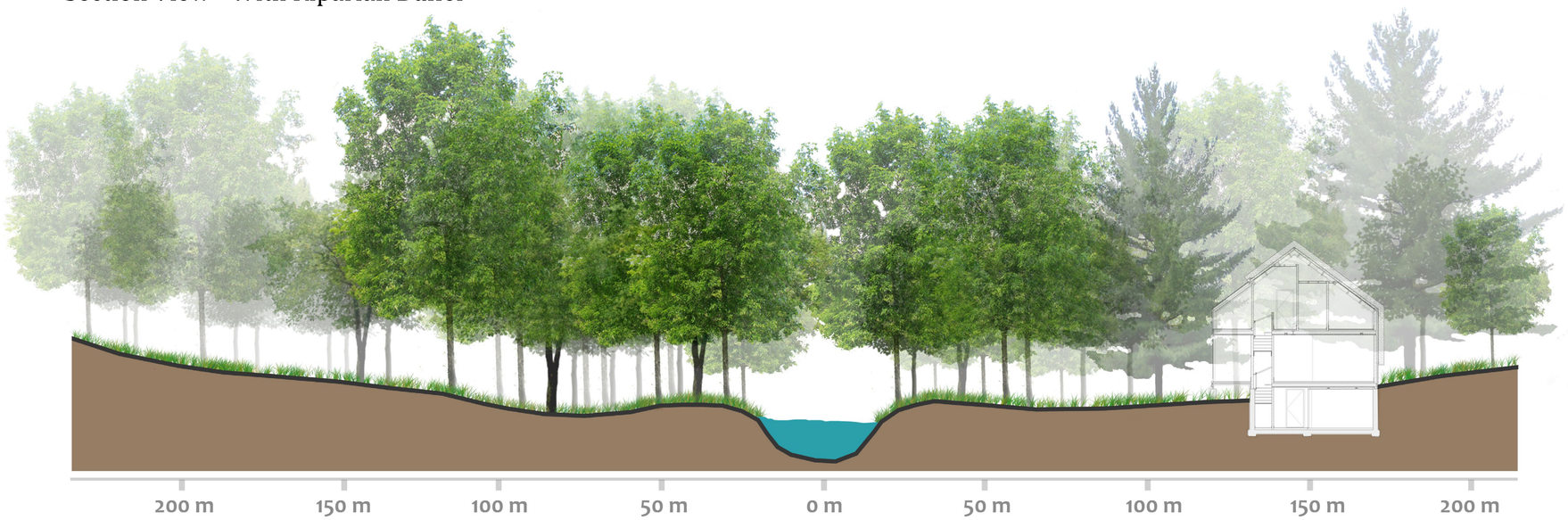
Water Dynamics - Design

Section View - Without Riparian Buffer



INCREASES **EROSION**
INCREASES **SEDIMENTATION**
INCREASES **PROPERTY DAMAGE**

Section View - With Riparian Buffer

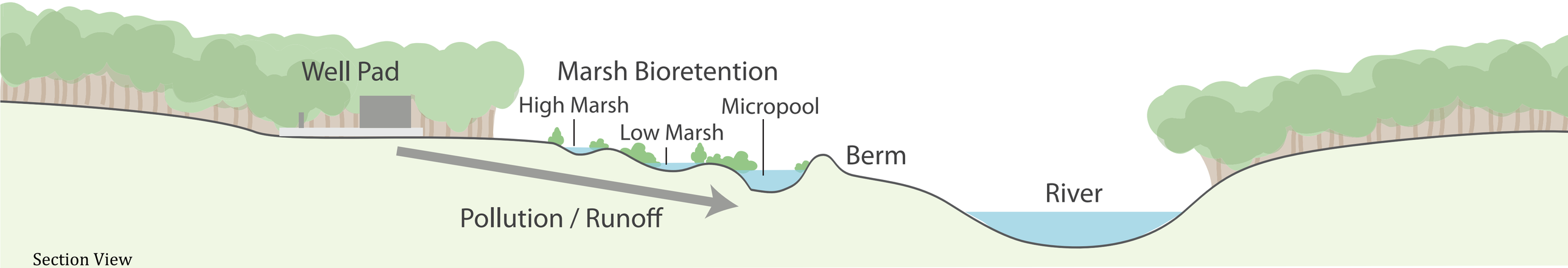


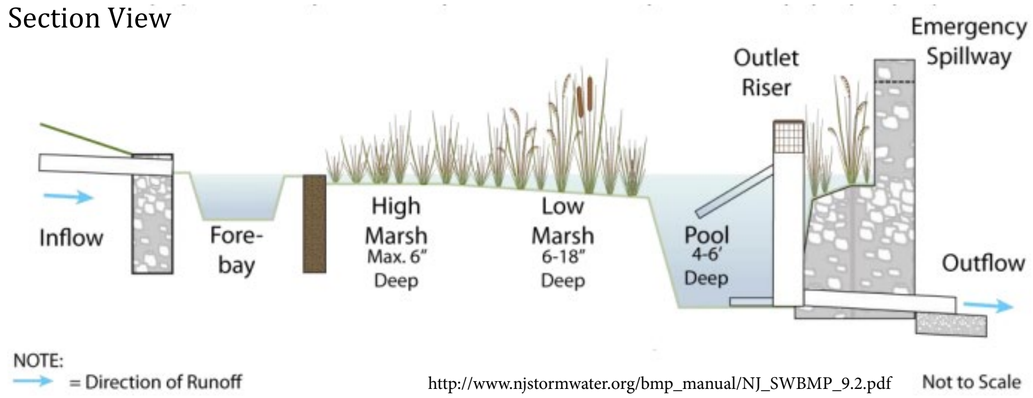
IMPROVES **WATER QUALITY**
INCREASES **WILDLIFE + FISH POPULATIONS**
PROVIDES **FLOOD PROTECTION**
MORE CONSTANT **WATER TEMPERATURES**
IMPROVES **SOILS**
INCREASES **CHANNEL STABILIZATION**
SERVE AS **WIND BUFFER**

Riparian Buffers

The main riparian buffer functions are stream bank erosion control, pollutant absorbency, temperature control (from shade), and wildlife habitat are all critical for maintaining ideal habitat conditions. 15 meters is the minimal baseline to generate a basically functional riparian buffer, although 100 meters is the idea length to fully mitigate against polluted runoff and flood scenarios. Shade provided by the canopies of large trees is critical for the survival of native trout, which require cold water habitats. Areas lacking trees along the stream bank are at risk of overheating on hot, sunny summer days. The trees' roots are also capable of stabilizing the banks to prevent erosion and slow the rate of runoff enter the stream. Urban streams increase their velocities exponentially during storm events due to the rate of runoff entering them. This creates a deeper center channel, disrupting the naturally rocky, shallow stream beds needed for native aquatic species. Riparian buffers also naturally possess limited phytoremediation abilities, as trees, shrubs and grasses are adapted to intercept 90-95% of sediments and remove the phosphorous attached to it (up to 85%). Sedge, switchgrass, and gamagrass have been proven to remove approximately 70% of petroleum hydrocarbons (TPH) after one year of growth.

Water Dynamics - Design





http://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.2.pdf

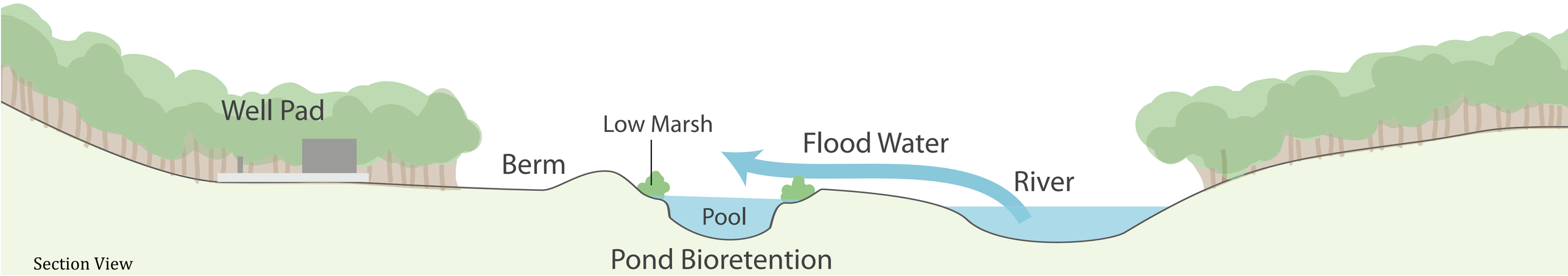
http://static.panoramio.com/photos/large/88888489.jpg

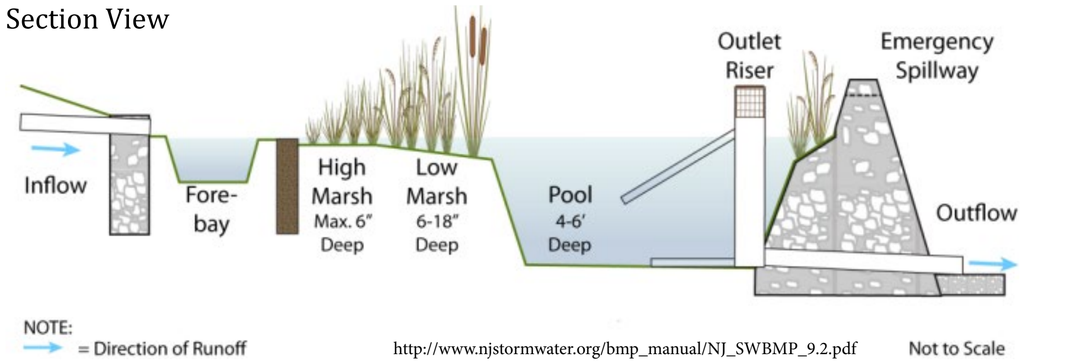
Bioretention - Sloped Marsh System

Retention basins and wet ponds are common stormwater control methods deployed across the landscape, and while effective at slowing and managing runoff rates, they tend to be lacking in terms of removing pollutants, especially ones dissolved within the water itself. To remedy this, extensive research has been placed into stormwater wetlands, which according to the EPA, "detain stormwater, remove pollutants, and provide habitat and aesthetic benefits." These systems combine the retention abilities of traditional wet ponds with the natural phytoremediation capabilities of existing wetlands. However, stormwater wetlands are fundamentally different from natural wetlands in that their specific purpose is for stormwater runoff treatment, they have less biodiversity, and are heavily designed. It is not recommended to divert stormwater to natural wetlands despite their natural phytoremediation abilities because the intricate balance natural systems can be easily disrupted by sudden changes in hydrology and water quality. Stormwater wetlands require sufficient drainage areas (at least 10 – 25 acres as a minimum), dry weather base flows, a permanent pool level, and a proper maintenance plan. There are a range of design option for stormwater wetlands based on local conditions/landscape and desired effect, but the most common two are the pond system and the marsh system.

Water Dynamics - Design

MARCELLUS BY DESIGN The Pennsylvania State University



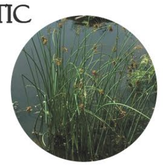


Bioretention - Floodplain Pond System

Each design possesses three main components: a permanent pool, a high marsh, and a low marsh. The pool zone consists of standing water 2-6 feet deep with submerged or floating vegetation. A forebay may be included by the inlet and a micropool by the outlet to help prevent clogging. The marsh zone is further divided into the high marsh (standing water of no more than 6 inches) and low marsh (standing water 6-18 inches). These areas offer emergent wetland vegetation and habitat for invertebrates, insects, and birds. Pond systems are focused on storing a large volume of water, with most of the area dedicated to the pool which is rimmed by low and high marsh. These systems are ideal for flood mitigation and require less area due to their deeper volume. Marsh systems are the inverse of pool systems, with most of the area devoted to low and high marsh which is supported by only a small micropool. Complex micro-topography allows for a higher diversity of plants capable of remediating any pollutants present in the water and also decreases the velocity of the runoff in these systems. A detailed plan is needed for both systems, highlighting the plant species to be used and their location in the stormwater wetland.

Water Dynamics - Design

AQUATIC



Soft Stem Bull Rush
Schoenoplectus tabernaemontani

Arrow Arum
Peltandra virginica

Prairie Cordgrass
Spartina pectinata

Soft Rush
Juncus effusus

Big Blue Stem
Andropogon gerardii

Marsh Hibiscus
Hibiscus moscheutos

UPLAND

Alpine Pennycress
Thlaspi caerulescens

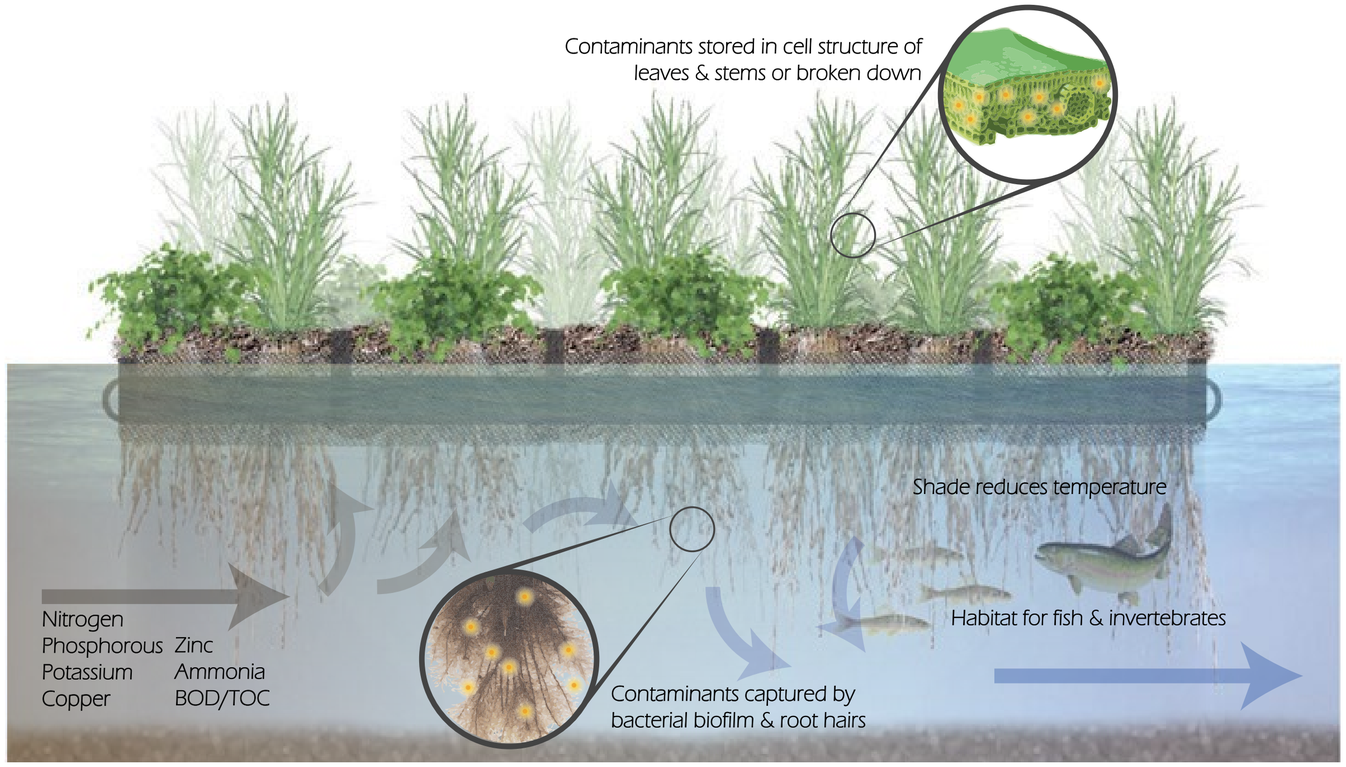
White Clover
Trifolium repens

Black Willow
Salix nigra

Black Spruce
Picea mariana

Alfalfa
Medicago sativa

Red Mulberry Tree
Morus rubra

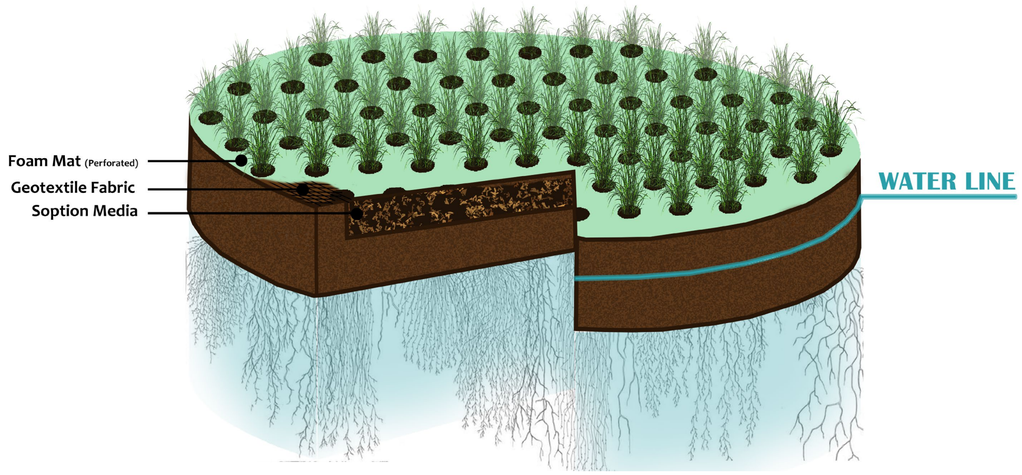


Phytoremediation - Aquatic & Terrain

The U.S. Environmental Protection Agency defines phytoremediation as "the direct use of green plants and their associated microorganisms to stabilize or reduce contamination in soils, sludges, sediments, surface water, or ground water." There are a range of types of phytoremediation, determined by where contaminants are intercepted, where they are transported to, and the final composition of former contaminants. The primary focus for all forms of phytoremediation is to reduce, remove, degrade, or immobilize contaminants. Phytostabilization includes the sequestration or immobilization of contaminants when they are either absorbed by the plant or simply interact with biochemicals exuded by the roots. Phytohydraulics utilizes deep rooted plants such as trees to contain, degrade, or sequester contaminants that are present in groundwater via contact with roots. Phytovolatilization does not store or degrade volatile contaminants. Instead they are released (volatilized) into the air through the plants' stomata. Rhizosphere degradation functions similarly to phytodegradation, except that the degradation occurs due to the enzymatic microbial activity found around the plant roots rather than any processes occurring in the plant itself.

Water Dynamics - Design

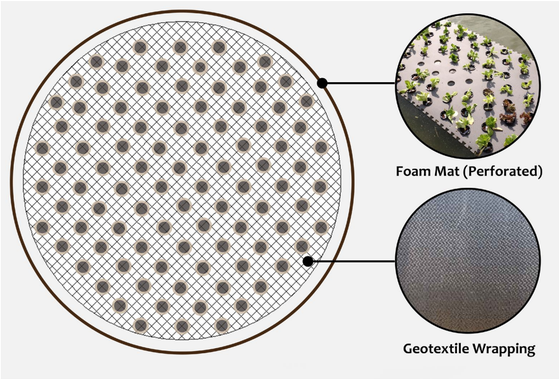
Floating Treatment Wetland Structure



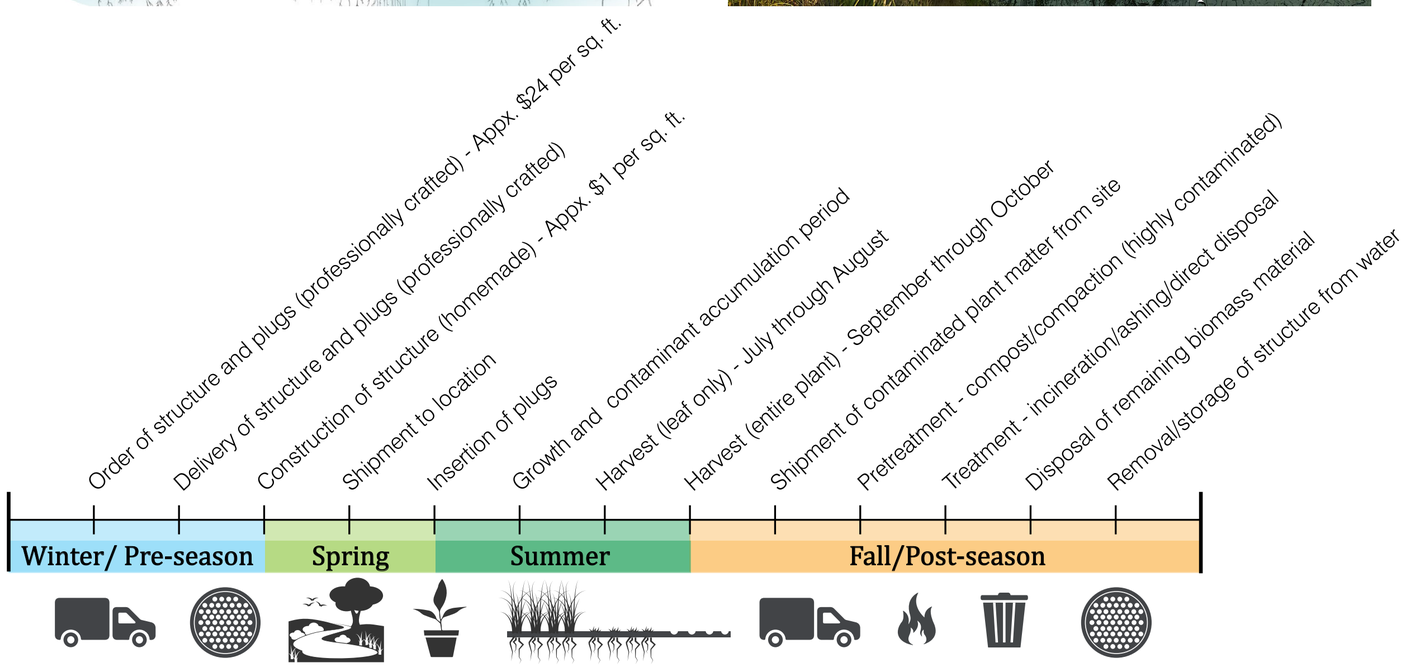
2-3 Month Plant Growth

Implementation of Structure

Compositional Components



Sorption Media



Phytoremediation - Floating Treatment Wetland

Phytoextraction primarily involves contaminants becoming absorbed by either the roots or root surface where they are taken up into the plant and accumulated within other plant tissues and cells. Proper disposal of plants used in phytoremediation is critical. While there are many regulations that must be adhered to, there are also a range of benefits able to be gained from this process. Biomass collected from phytoremediation can be placed into a lead or zinc smelter and fired, releasing stored metals in the form of oxides, reducing the dry weight of the biomass by 90%, and allowing for the re-collection of stored, valuable metals in the form of high grade ore. The burning process also generates electricity, which can be captured and used (1.2 kWh in one study). Floating treatment wetlands (FTWs) are floating rafts that grow plants that treat runoff pollutants. These are low to moderately low cost systems that can either be homemade (approximately $1 per sq. ft.) or purchased from a commercial retailer (approximately $24 per sq. ft.) Because contaminates are accumulated within the plants' biomass, they must be harvested annually. September to October is the preferred time for full plant harvest, and July to August is preferred for aerial biomass harvesting only. Nutrients such as Nitrogen and Phosphorous from agricultural runoff are the most readily absorbed by plants used in FTWs, although there has been success in studies involving copper, zinc and other metals.

Water Dynamics - Design

Phytoremediation - Large Scale Floating Treatment Wetlands in Tioga Lake

FTWs are also capable of offering habitat for fish, roosting places for birds, and shade to reduce overall water temperature. They can be placed in existing bioretention systems as a retrofit or on a larger scale such as walkable floating wetlands that can be added to lakes and offer a place to fish or launch small boats. Plant species that have been found to remediate water quality exceptionally well are pickerelweed (Pontederia cordata), soft-stem bulrush (Schoenoplectus tabernaemontani), tussock sage (Carex stricta), big blue stem (Andropogon gerardi), and marsh hibiscus (Hibiscus moscheutos). It is important to recognize that non-native species are occasionally superior in their ability to survive and accumulate toxic contaminate in comparison to native plants. If used, these non-natives must be monitored to ensure they do not spread unwantedly, however since these are not invasive species the risk of these species becoming more aggressive than the native cattail are low.

Water Dynamics - Design

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Phytoremediation - Small Scale Floating Treatment Wetlands in Bioretention System (Mansfield, PA)

This floating treatment wetland design (along the Mansfield Reservoir in Tioga County, Pennsylvania) represents a small scale proposal for an easily mobile and dynamic phytoremediative mitigation strategy for reducing surface water contamination from agricultural runoff and fracking spills. The design of the wetland structure provides natural habitat for fauna such as birds, butterflies, and fish (plant roots provide protection) and enhances the aesthetic beauty of the Pennsylvania landscape. In addition to using floating wetlands, riparian buffers are incorporated along the edges of the water body to minimize surface runoff, and bioretention measures (located on the right) to reduce risk of flash flooding. Overall, the design uses natural processes and cost-effective means to mitigate, regenerate, and protect these valuable ecosystems and water resources for future use.

Water Dynamics - Design

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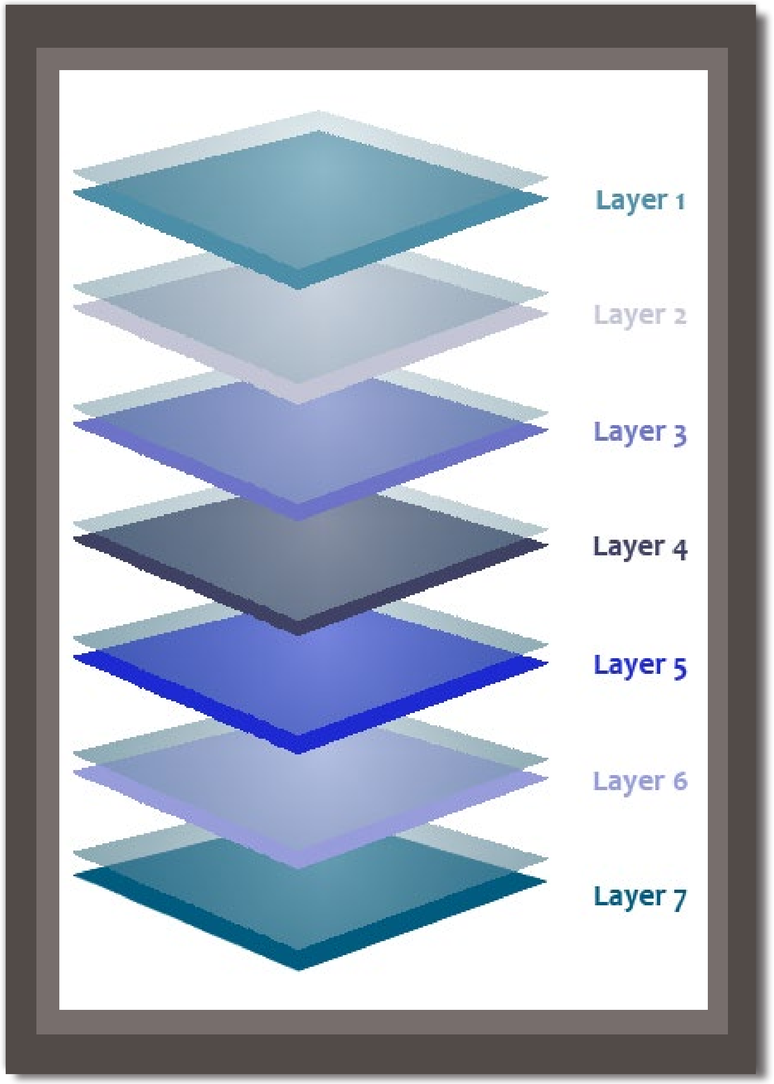
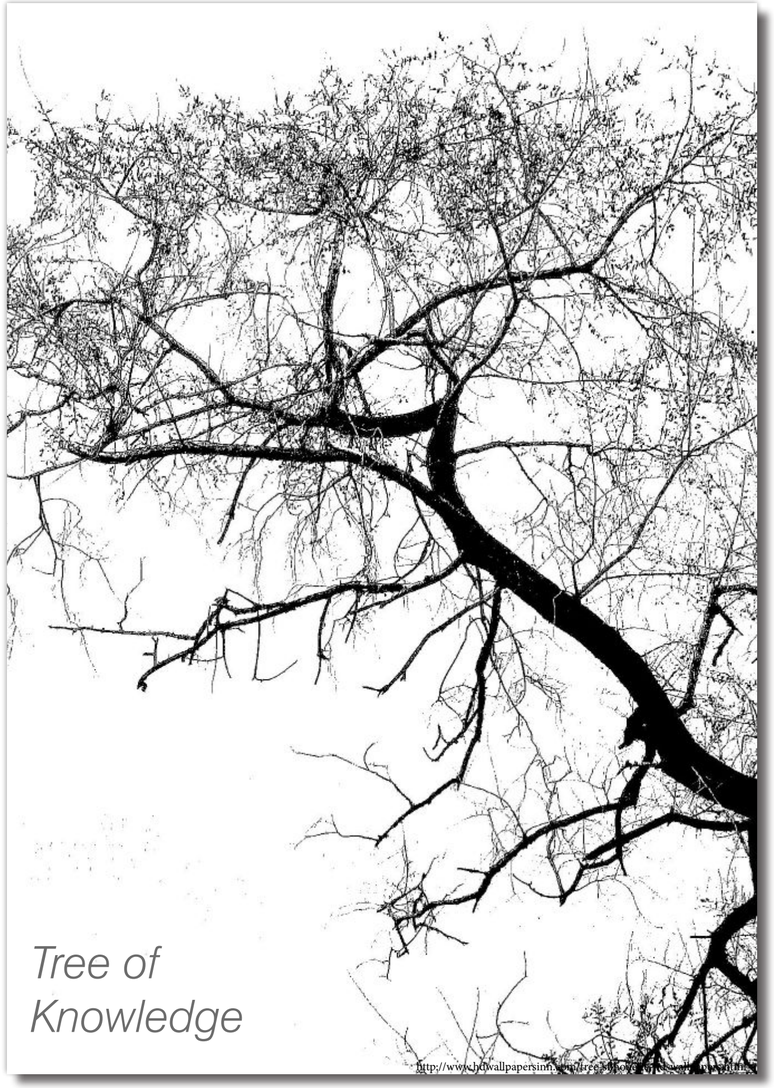




Technical Resources

Here are links to GIS coverages, 3D models, source images of renderings, and other material created for the Water Dynamics Project. Also included are PDFs of several reports used in the analysis and design phase.

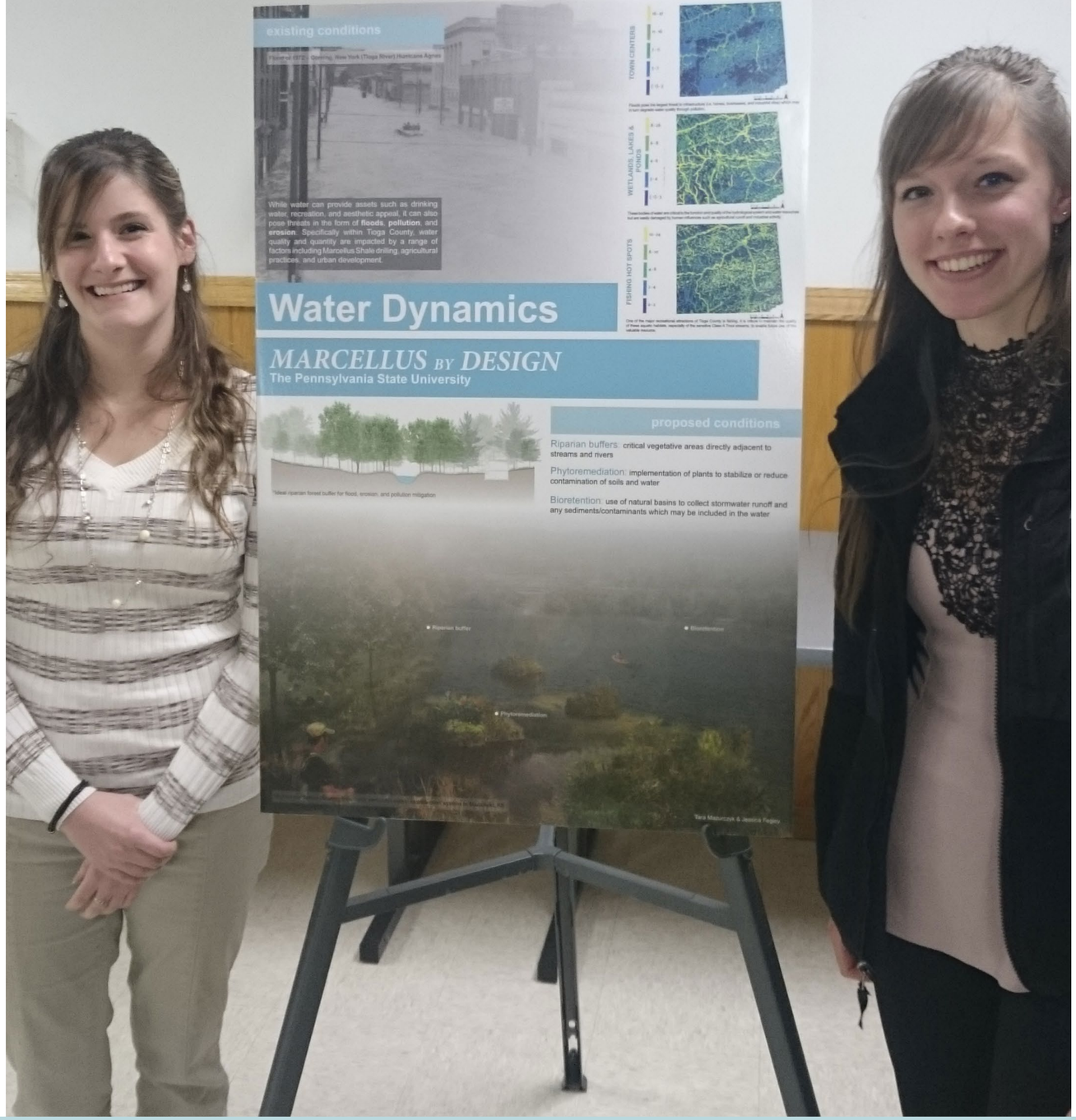
Library

Provided are PDFs of papers and other resources that provide valuable background material as well as links to other related websites and websites of groups associated with this project proposal.

References

Here is a bibliography with full citation information for all the resources used in making the Water Dynamics Project.

Water Dynamics - Resources



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