Green Pond Oil Spill Site Revegetation/ Restoration Project

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1

Removing spilled oil from the environment is difficult; time consuming and expensive especially if a critical habitat or ecologically sensitive area has been affected. Past removal practices have had extreme deleterious effects on the ecosystem both immediate and long-term to such extent as to question whether removing oil from these sensitive systems was environmentally wise in the first place. This presentation will attempt to show that a carefully supervised cleanup followed by a scientifically driven monitoring program can be effective in removing oil from a sensitive wetland followed by a program to restore the wetland to its original scrub-shrub plant community and associated ecological function.

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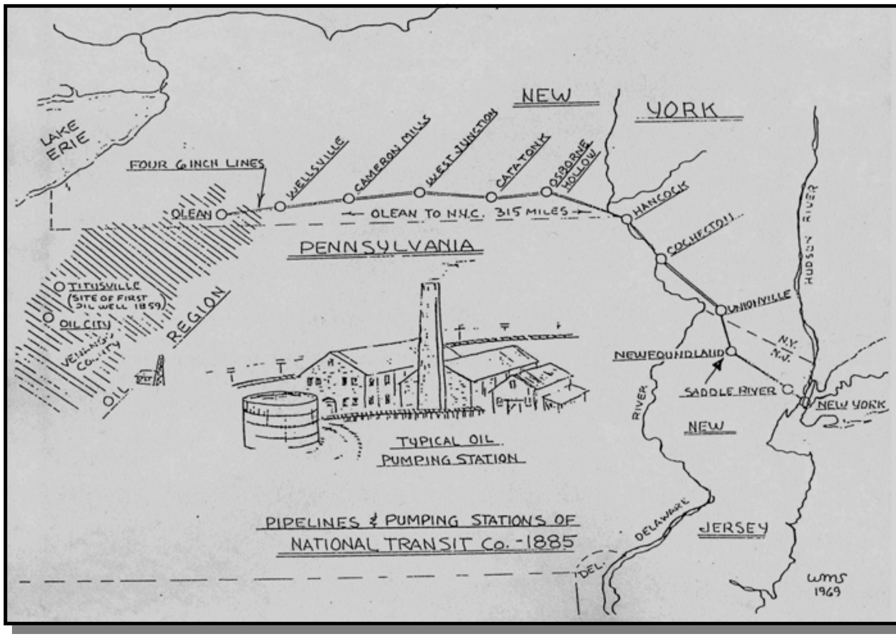

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Sketch of original pipeline route from southern Tier to Bayonne, NJ showing locations of pumping stations. Total length = 315 miles construction started in 1881 with final fourth line installed in late 1880’s, , making the total capacity of the system over 50,000 barrels a day. The lines were buried to a depth of eighteen inches in the ground, In very cold weather the oil would thickened and movement would be slow especially in the exposed stretches but the hot salt brine coming up with the oil in the well would be carried in the pipe along with the oil to help keep the oil flowing.

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Relict Pumping Station at Unionville, New York similar to Newfoundland Pumping Station

+ Eleven stations, 28 miles apart, over a 315 mile distance with 4 six inch diameter pipelines

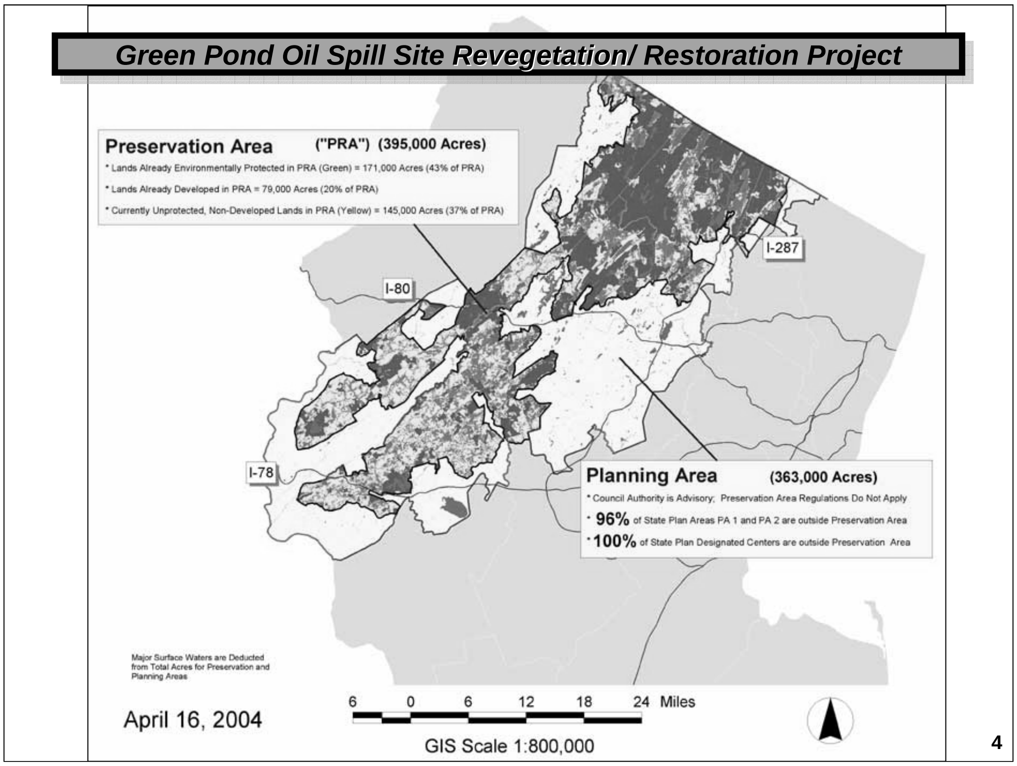
+ Maximum capacity of 50K barrels a day (2.1 million gallons).

+ Operation period: 1881-1920.

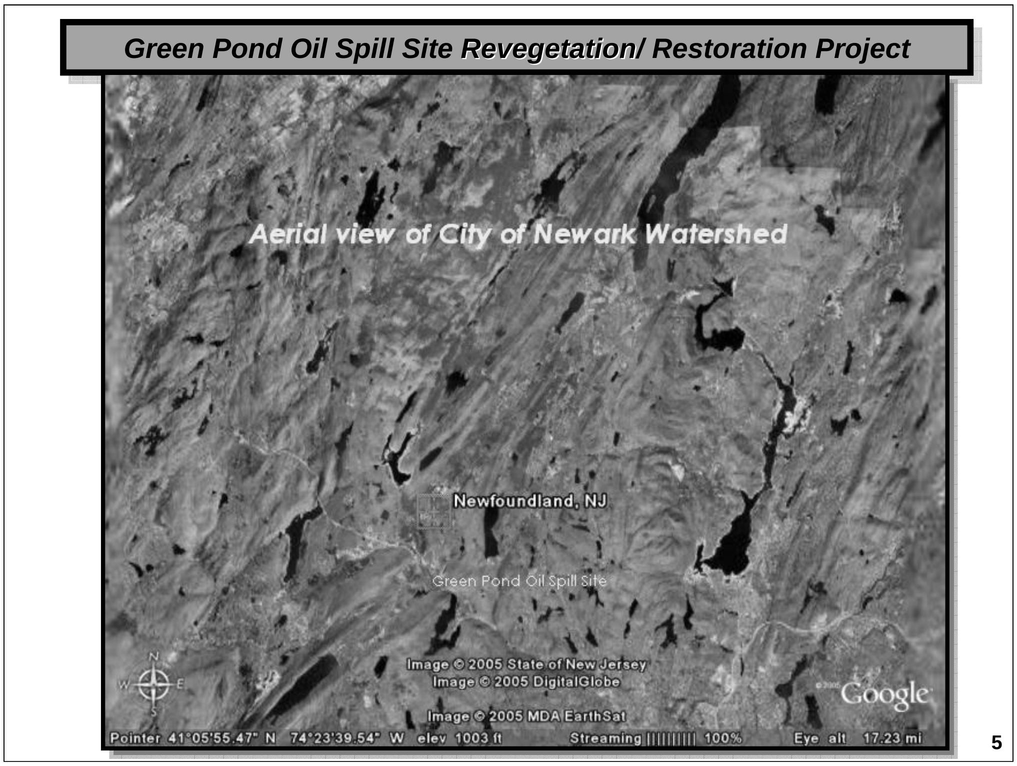
3

One of the few if not only remaining pumping stations in existence. The buildings are intact but the pumps and boilers have been removed to make room for the present day utilization. The pipeline contained eleven efficiently constructed pumping stations along the way, each one approximately 28 miles apart from the last. The significant NY pumping stations were in Olean, Wellsville, Cameron Mills, West Junction, Catatonk, Osborne Hollow, and Hancock. The NJ stations were located in Newfoundland, Saddle River, and Bayonne. The stations were equipped with duplicate boilers, engines, and Worthington pumps so that in the event of a breakdown, the oil would continue to flow without interruption.

Along with the actual pumping machinery were a number of large cast iron tanks that held the oil before it was pumped into the next portion of the pipe. The problem, we learned, was that these tanks were constructed without any bottoms other than compacted earth. The oil/water mixture was pumped into the tanks with the hope that the oil would separate and float on the water in the tank. Unfortunately, this bottom water did not always serve as a seal and oil seeped into the soil beneath. Over the forty year operation of the pipeline, unknown quantities of oil were lost to the underlying soils.



On August 10, 2004, the *Highlands Water Protection and Planning Act* went into effect. This historic law will protect drinking water for over 5.4 million people, preserve open space and provide effective regional planning for the Highlands region. In addition to water resources, the Highlands Region contains exceptional natural resources such as contiguous forest lands, wetlands, pristine watersheds and plant and wildlife species habitats. The region contains many sites of historic significance and provides abundant recreational opportunities.



Newark's Pequannock Watershed is located 35 miles northwest of the City of Newark in portions of Morris, Passaic and Sussex Counties. The area consists of approximately 35,000 acres and contains five major reservoirs.

Regarded by many as the "Heart of the Highlands" the Pequannock watershed provides critical water supplies to more than half-a-million New Jersey citizens and serves as a refuge for sensitive wildlife from otters and eagles to bears and bobcats.

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6

An aerial view of the Green Pond Oil Removal Site and Wetland. The wetland is 1.3 acre (.53 hectare) in size and borders the Pequannock River which serves as the connecting stream for the reservoir system of the City of Newark's water supply. The stream volume and current is regulated, especially during the summer months by the City of Newark water supply managers when the demand is greatest.

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February 1996 Initial Response

7

Background: In the winter of 1996, the water table was higher than usual from all the previous rain events and melting snow. The water table and oil surfaced on to the adjacent wetland located between pump station site and the Pequannock River ultimately discharging into the river. It is uncertain how often this phenomenon had occurred previously but apparently this time the severity was such as to initiate reporting to the National Response Center and ultimately a response by state and federal officials.

In the winter of 1996, the water table was higher than usual from all the previous rain events and melting snow. The water table and oil surfaced on to the adjacent wetland located between pump station site and the Pequannock River ultimately discharging into the river. It is uncertain how often this phenomenon had occurred previously but apparently this time the severity was such as to initiate reporting to the National Response Center and ultimately a response by state and federal officials.

In February of 1996, the United States Environmental Protection Agency (EPA) was notified by the National Response Center and the New Jersey State Department of Environmental Protection (NJDEP) of an oil discharge in to the Pequannock River from property owned by the City of Newark (Newark Water Authority) located near the intersection of the Pequannock River and Green Pond Road (State Route 513) in Jefferson Township, City of Newfoundland, Morris County, New Jersey.

At the Newfoundland pumping station, it took nearly a hundred years for this subterranean oil sitting on the groundwater to finally make its way out to the adjacent marsh and subsequently into the nearby Pequannock River.

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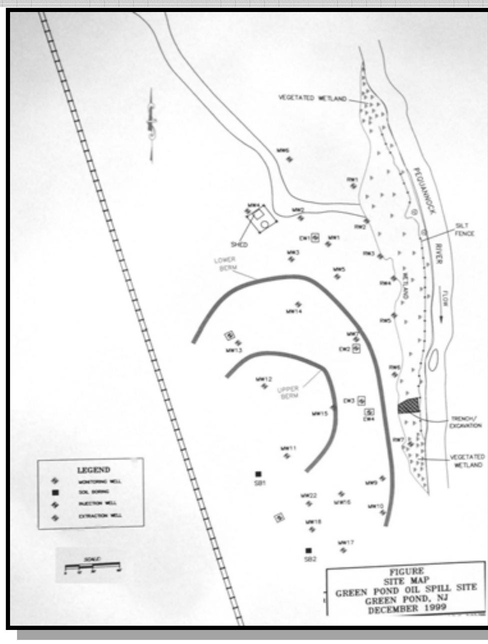

8

Later that Spring, twenty small diameter monitoring wells (piezometers) were drilled and sampled to locate the boundary of the subsurface oil deposit. Eventually, additional wells were installed to better locate the area of greatest concentration of subsurface oil. An upland recovery well was installed at this point using a bi-phase pumping system that skimmed and pumped the surface oil into a storage tank while the bottom pump created a zone of depression by pumping water to a injection pit 46 meters west of the recovery well location.

In mid-summer 1998, marsh soil cleanup operations commenced with the removal of oiled woody debris (deadfalls, etc). Once these materials were removed then a minimum amount of oily marsh soil was removed, sufficient only to remove the upper most oiled portion (10-15 cm). Most of the released oil had been trapped and sorbed on to the vegetative mat.

Although revegetation of the marsh was always considered, the main emphasis at this phase was on restoring and stabilizing the stream bank. Coconut fiber matting was installed adjacent to the stream to stabilize the soils and prevent erosion and possible further contamination of the Pequannock River. Erosion Control Fencing had been installed prior to the surface removal procedure but was removed to install the matting. This fencing was re-installed as an extra measure of protection of the stream.

Rebecca Hoff at NOAA's Hazardous Materials Response and Assessments Division in Seattle, Washington produced a succinct comprehensive treatment of the various response treatment options used on coastal marshes from historical spills ranging from the Torrey Canyon in 1969 to the mid 1990's (Hoff, 1995). Most of the spills addressed in the report involved coastal marshes which are unique compared to fresh water marshes but similar response techniques are used for both environments. Here you see the roll off containers that transported all the contaminated soil and debris off site…

Of the various cleanup techniques Hoff mentioned, removing contaminated sediments (soil) was considered to be the most detrimental to the marsh in terms of long term alteration of the ecology and impeding recovery.

Contaminated soil removal was the cleanup technique used at the Green Pond Oil Spill Site in Green Pond, New Jersey.

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11

Here is a view of the wetland from across the Pequannock River in the Autumn of 1998 following the removal of the oil contaminated soils. The white absorbent and containment boom can be seen along the streambank to collect oil that might still be leaching out of the marsh surface and subsurface deposits. Streambank stabilization was completed in the Autumn 1988 to protect from soil erosion and loss during the spring thaw and high water events. 12 inch diameter coir logs were installed along the entire length of the site behind the oil collection boom.

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How did we initiate the Restoration Process?

First we formed a Restoration Team comprised of Stakeholders and Restoration experts using the existing framework of federal and local expertise.

US Fish & Wildlife Service
Natural Resources Conservation Service
Morris County Soil Conservation Service

12

For the Green Pond Restoration project, OSC Mike Solecki utilized the experience and talents available through the National Contingency Plan to access experts from various Federal, state and local agencies to initiate the Restoration Process. Mike used an Memorandums of Understanding already in place to bring in the Natural Resources Conservation Service (NRCS) and the United States Fish & Wildlife Service. Another important stakeholder,The Morris County Soil Conservation, was brought in under the auspices of the NRCS. This group of experts coupled with the EPA's Environmental Response Team formulated a Restoration Plan that was provided to Mike for implementation.

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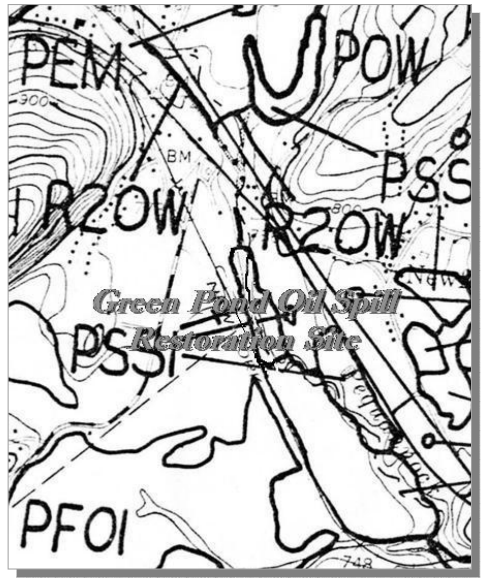
The Process starts with a search for historical knowledge of surrounding wetlands

PSS1 = Palustrine Scrub Shrub Broad leaved Deciduous e.g. Red Maple swamp



13

The Restoration Team using the National Wetland Inventory Map was able to determine that the Green Pond site was considered a Palustrine Scrub Shrub Broad-leaved Deciduous wetland (PSS1). Before the contaminated soil removal, some shrubs had been observed but had not been identified to species. Using the Inventory Map list and visiting the undisturbed floodplain wetland across the stream from the site, the Restoration Team generated a list of candidate species for restoration.

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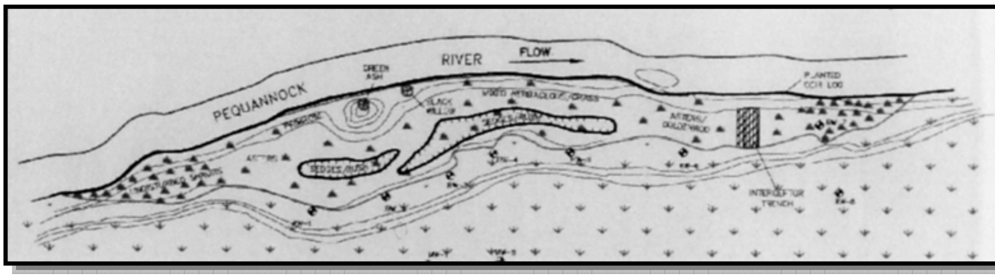
A Sketch Map



14

A Sketch Map showing some essential features of the wetland was drawn. This map served as the basis for all the subsequent restoration depictions for the site for the remainder of the project as it showed the locations of wetland vegetation that survived the soil removal effort. It also indicated rough topographical contours that later were useful in locating the plant materials.

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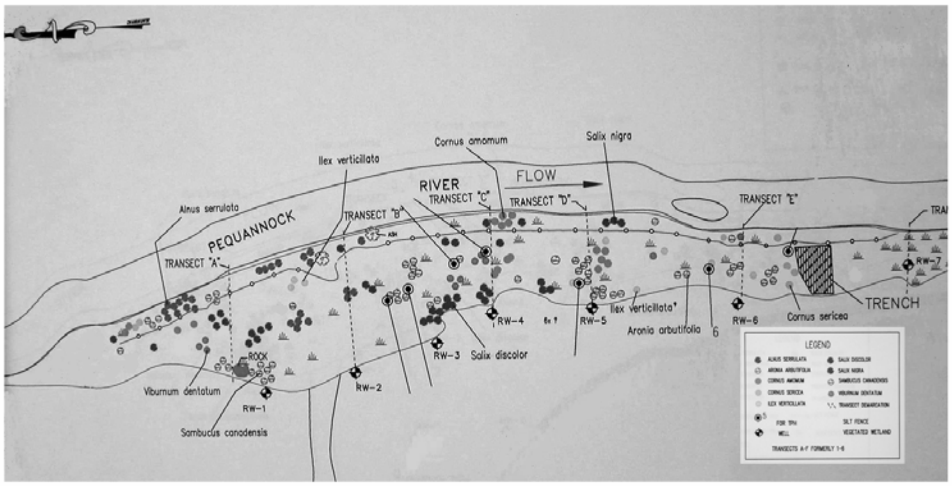
The PLAN



15

The NRCS drafted a Species List and Planting Scheme based on the area and topographical features of the site. The Plan was presented to the Restoration Team and after review and minor revisions forwarded to EPA's On-Scene Coordinator.

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The PLAN

- **ZONE A --** Streambank Coir Log Plantings

Juncus effusus (softrush)	224 units
Scirpus cyperinus (wool grass)	150 units
Carex lurida (shallow sedge)	150 units
Carex crinita (fringed sedge)	150 units
Iris versicolor (blue flag iris)	132 units
Eupatorium purpurea (Joe Pye Weed)	90 units

- **Zone B**

Cornus amomum (silky dogwood)	160 units
Salix serecia (silky willow)	160 units
Cephalanthus occidentalis(button bush)	64 units
Alnus serrulata(smooth alder)	64 units

- **Zone C**

Salix discolor (pussy willow)	225 units
Aronia arbutifolia (red chokeberry)	87 units
Cornus amomum (silky dogwood)	225 units

- **Zone D**

Cornus amomum(silky dogwood)	24 units
Ilex verticillata(Winterberry)	24 units
Sambucus canadensis (elderberry)	24 units
Viburnum dentatum(Arrowwood)	24 units

16

The Statement of Work with the Bid Package included plant descriptions and quantities required. The species list conforms with those species associated with **Palustrine Scrub-Shrub Broad Leaved Deciduous (PSS1)** wetlands as delineated and mapped by the National Wetland Inventory. The Palustrine System descriptor used within the Inventory refers to vegetated wetlands traditionally called marshes, swamps, bogs, and fens. It also includes small, shallow, permanent or intermittent water bodies e.g. ponds. The Scrub-Shrub class describes areas that are dominated by woody vegetation less than 20 feet tall. Broad-leaved Deciduous is self explanatory.

On Earth Day 1999, the plant materials and installers arrived on site. A Bid Package with Specifications had been prepared by the Restoration Team and submitted to the EPA OSC. A landscape firm who specialized in native plant installation was selected from three firms who had submitted bids.

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18

Originally the Statement of Work in the Bid Package called for live stakes for the shrubs but due to the lateness in the season, potted materials were substituted instead to insure greater survivability of the plants. Here you see the placement of the individual plants on the marsh surface. All the plant materials were installed within a two day time frame in mid April 1999 followed by deer fencing surrounding the entire site. A suggestion was made by the installation crew chief, Bill Young to the Restoration Committee as to the exact location and number of plants needed. Instead of grouping the plantings in clusters as originally proposed in the NRCS Plan, Mr. Young suggested that the plantings be distributed in smaller but more numerous clusters throughout the entire site. Two major advantages of this scheme would be that the deer fencing required to protect the new plantings (seen here being installed) could then encompass the entire rather than the clusters as previously proposed. The other advantage was that only two-thirds of the plant materials would be required to fulfill the objectives of the project.

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Monitoring for Adaptive Management

Table

Species	Number Live	Number Dead
V. dentatum	21	
Aronia	55	
Alnus	59	
Cornus (2 species)	15/69	
Sambucus	26	1
Ilex	18	
Salix discolor	52	
Salix nigra	19	
Total	334	Total 1
Coir Logs		
Lobelia cardinalis		13
Other herbaceous plants		45

19

A Monitoring program is useful for many purposes but primarily to implement an Adaptive Management Program: 1) to determine "success" of the restoration project; 2) to determine if additional plants are needed to fill in blank or die-off areas; 3) to implement an invasive or alien species program. A photodocumentation effort was implemented immediately to document the progress of the restoration. Survival tallies for the planted materials were performed in October 1999 by Chris Miller (NRCS) and are posted in this Table.

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Monitoring for Adaptive Management

Table	Average Height Measurements			
	Year1999		Year2000	
	Inches	Std Dev	Inches	Std Dev
Alnus	19	6.79	35.05	13.23
Aronia	19.67	3.78	30.83	10.87
Cornus	25	10.87	23.53	9.21
Ilex	20.17	2.23	23	5.78
S. discolor	40	11.59	32	15.21
S. nigra	27.13	11.38	27.28	10.37
Sambucus			52	
Vibernum			46	

20

During the years following the installation of the woody stemmed plant materials, observations were made to evaluate the growth and survival of these materials. The planted shrubs were documented by species and actual location within the wetland. (see Figure 12). Vertical growth measurements were made at the end of the growing season in 1999 and 2000. During one years growing season, Alders (Alnus sp.) and Chokeberry (Aronia) grew vigorously while the other species did not add significant height. This was an interesting and surprising observation as willows (Salis sp) are known to be very fast growers.

Every Spring the wetland at the Green Pond site is flooded varying from days to weeks at a time depending on the snow melt and rain events. The Pequannock River serves as the main conduit for water movement in the City of Newark Water Supply network. The Green Pond site is located on the stretch of the river several miles upstream from the Charlottesburg reservoir, the most downstream reservoir of the seven reservoirs that make up the Newark water supply. Once containment booms were installed by EPA, the threat to the water supply from the oil was reduced such that oil sheens were not observed downstream from the site. However, some oil could be observed remaining in the standing water pools after the water levels subsided. There was a concern that these periodic oilings could affect the survival and growth of the planted materials and possibly native plants already established.

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22

Over the winter, the recovery system was not in operation and “spooges” occurred at the same locations due to the Spring high water table. The soil contamination levels in the soils reflected the influence of these various “spooge” events. When the oil recovery systems had been shut down during the winter and during high ground water conditions, oil had surfaced in specific locations in the marsh. Much of this oil was trapped in the vegetation mat and the rest was trapped by the absorbent booms stretched along the shoreline.

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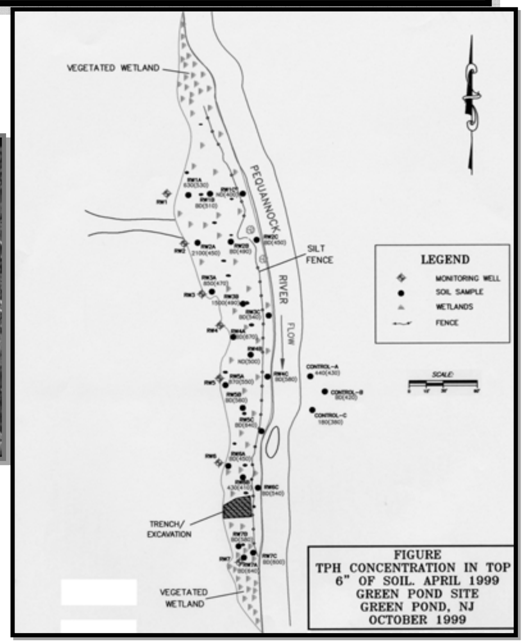
Monitoring Oil Levels in the Soils



23

At the outset of the study in order to determine the impact of the cleanup operations at the Green Pond Oil Spill Site, it was determined that soil samples should be collected and analyzed for residual petroleum hydrocarbons. Following the installation of plant materials in April 1999, soils were collected from selected sites within the restored wetland and a control site across river.The residual TPH levels in the soils were important to document any potential toxic effects to the newly installed plants in terms of mortality and/or growth patterns.

Sampling Location	TPH	Apr-99	Sampling Location		TPH	May-00	Sampling Location		TPH	Jun-01	TPH	Jun-02
	Conc.	MDL			Conc.	MDL			Conc.	MDL	Conc..	MDL
RW1-A	630	530					Near Rock		220	44	370	41
RW1-B	140J	510							250	45		
RW1-C	ND	400					Close to RW1-C		110	40	100	42
							Close to RW1-C		52	43		
							Near "Spooge"		120	39		
							Near "Spooge"		1800	520	7700	510
							Near Ash		120	48	230	44
RW2-A	2100	450										
RW2-B	83J	490					Close to RW2-B		2100	520	1900	490
RW2-C	140J	450					Close to Above				2100	560
			Between RW2&3		2300	510	Between RW2&3		560	220	1300	520
			Close to Above		1300	550	Close to Above		1500	510	1700	480
RW3-A	850	470										
RW3-B	1500	490	Close to RW3-B		4400	630	Close to RW3-B		110	49	1400	500
RW3-C	260J	540	Close to RW3-C		1400	520	Close to RW3-B		330	47		
RW4-A	480	670										
RW4-B	ND	500										
RW4-C	120J	580										
RW5-A	870	550	Close to RW5-A		960	550	Close to RW5-A		200	62	1900	540
RW5-B	490J	560					Close to RW5-B		180	61	430	58
RW5-C	420J	640										
RW6-A	140J	450	Close to RW6-A		1800	420	Close to RW6-A		340	43	510	48
RW6-B	430	410					Close to RW6-B		310	46	360	50
RW6-C	210J	540	Close to RW6-C		1300	550	Close to RW6-C		230	40	580	210
							Close to RW6-C		150	55	830	60
RW7-A	430J	640										
RW7-B	300J	580					Close to RW7-B		300	66	470	59
RW7-C	400J	600	J = estimated value below the detection limit									
Across River -A	440	430	MDL = Method Detection Limit									
Across River -B	260J	420	Across River -C	180J	380							

24

It is extremely important to analytically be able to distinguish naturally occurring organic compounds from the more toxic petroleum derived compounds. Most soil cleanup standards are predicated on levels which are petroleum in origin. Wetlands, in particular, have such high biomass productivity of plant materials and naturally occurring organics. At Green Pond, the levels of extracted organics increased from the initial sampling in May 1999 to June 2002 although the petroleum content diminished substantially. Looking at the TPH levels alone can be quite misleading and possibly trigger unnecessary additional soil removal which would be ecologically devastating to a recovering marsh.

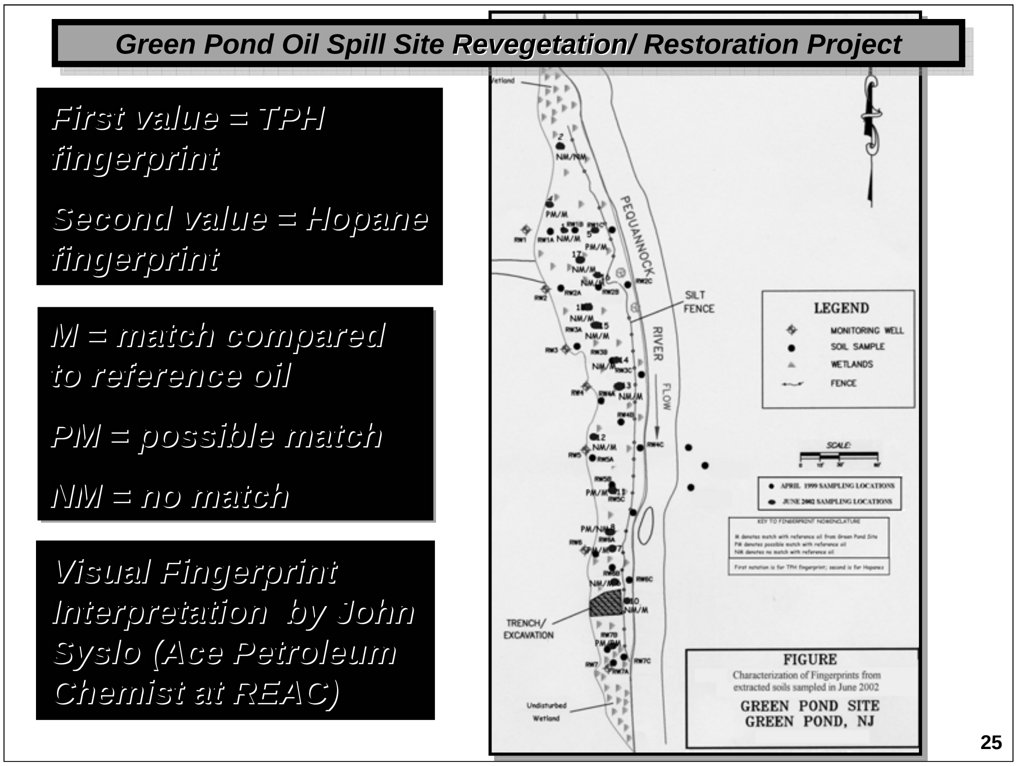
At Green Pond, the TPH levels increase represent the increase in vegetative cover from May 1999 to June 2002 more so than from crude oil contamination from the “spooges.” It is extremely important to be able to distinguish naturally occurring organic compounds from the more toxic petroleum derived compounds. Most soil cleanup standards are predicated on levels which are petroleum in origin. Wetlands, in particular, have such high biomass productivity of plant materials and naturally occurring organics. At Green Pond, the levels of extracted organics increased from the initial sampling in May 1999 to June 2002 although the petroleum content diminished substantially. Looking at the TPH levels alone can be quite misleading and possibly trigger unnecessary additional soil removal which would be ecologically devastating to a recovering marsh.

During this time, the petroleum component of the extractable organics has been altered by the physical weathering process which includes evaporation, dissolution and photo-oxidation. Once the oil is exposed to the elements and sunlight, the specific compounds will evaporate while others are changed chemically from exposure to direct sunlight.

Microbial action helps diminish the amount of oil remaining in the wetland as well. The same organisms that decompose or mineralize the lipids and oils in the marsh plants will act upon the petroleum under aerobic conditions. Under anerobic conditions, the degradation process involves a different suite of organisms and takes longer to mineralize the petroleum. At oil spills that have occurred decades ago, relatively fresh oil can still be found in the wetland and beaches where it was covered by sediments and sand

in storm events. In these circumstances, where the oil is incarcerated and not posing a threat to the ground water or surface natural resources, it is environmentally prudent to leave the oil as is.

The Green Pond Oil Spill site, represents an unusual case, where the oil after a hundred years of being in the ground actually surfaces and presents a threat to natural resources .



The hopane fingerprint from the Green Pond samples consisted of analyses of fifteen dominant hopanes. Unfortunately, the hopane pattern for the original Green Pond oil had low concentrations of indigenous hopanes which caused some difficulty in discerning a pattern in those samples with low concentrations. The pattern noted in many Green Pond samples was not typical to crude oil and therefore was speculated to be from naturally occurring organics, probably derived from plant materials common to marsh soils. In addition to the TPH levels in the soils using GC/MS SIM (modified EPA Method 8015B; Nom-Halogenated Hydrocarbons using GC/FID), visual fingerprinting matching was performed by REAC Senior Analytical Chemist John Syslo. The samples were compared to reference oil collected from the Green Pond site early in the recovery operation. The oil detected was identified as either an old weathered crude oil or a mixture of the weathered crude and other organic materials. The TPH pattern or fingerprint did not match the original oil collected from the site which contained only moderately weathered and many of the saturated hydrocarbons. The oil in the wetland soils displayed an unresolved complex mixture (UCM) of many unidentifiable hydrocarbons.

Prior to the Transects being established, photodocumentation was initiated as a regular activity to document the growth of the herbaceous plant community. A single reference location, called the Photo Rock located in the northwest corner of the wetland, was used consistently to photograph growth and successional changes.

It is during this wettest period of the season usually in the spring that more obligate wet species will be observed. At Green Pond, skunk cabbage, *Symplocarpus foetidus* is the earliest plant noticed followed by Jack-in-the-Pulpit . *Arisaema triphyllum stewardsonii* and the buttercups *Ranunculus abortivus*, & *Ranunculus septentrionalis*

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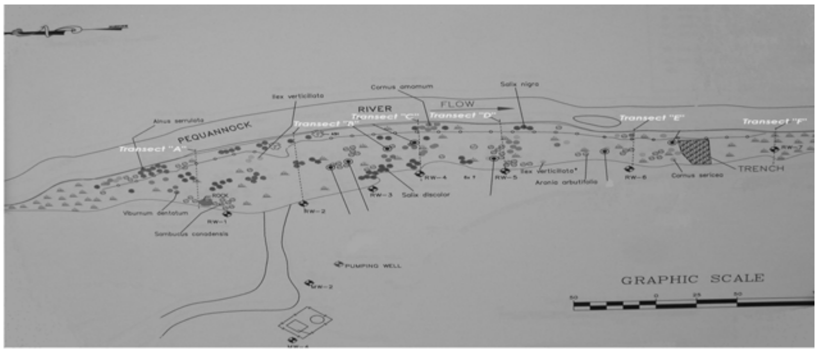
Monitoring the Wetland Plant Community



28

Six transect lines were established running east to west from the initial Recovery Wells. Plant species were identified at four foot intervals within six inch radius of each location and identified to the lowest taxonomic level possible. Any plants discovered within this radius were included in the survey. This type of survey is called **Point Intercept Sampling** and is one of the methods recommended in the 1989 manual for delineating wetlands (Tiner, R.W. 1999). It is a plot based method with a point on the transect representing the smallest plot which was used primarily for characterizing grassland plant communities. At the Green Pond site, we use the six inch radius as the plot size. A Spring survey was performed to document the spring ephemeral plants which likely would not be present in the Fall. The Fall survey was performed to document those plants which develop later in the growing season. Each location along each transect was marked and delineated with a red flag. Transect F is considered a control as it located in an area that had not cleared during the site work and is considered representative of an undisturbed area.

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Monitoring the Wetland Plant Community

- Importance of taxonomic accuracy and consistency
- Familiar with wetland plants in the area

29

It goes without saying that to accurately delineate wetland plant communities, it is important to know the plants and their specific ecological niche requirements. At the Green Pond site, we were able to access the talents and time of a number of experts throughout the study period but primarily relied on Dr Gerry Moore, a research plant taxonomist from the Brooklyn Botanic Garden

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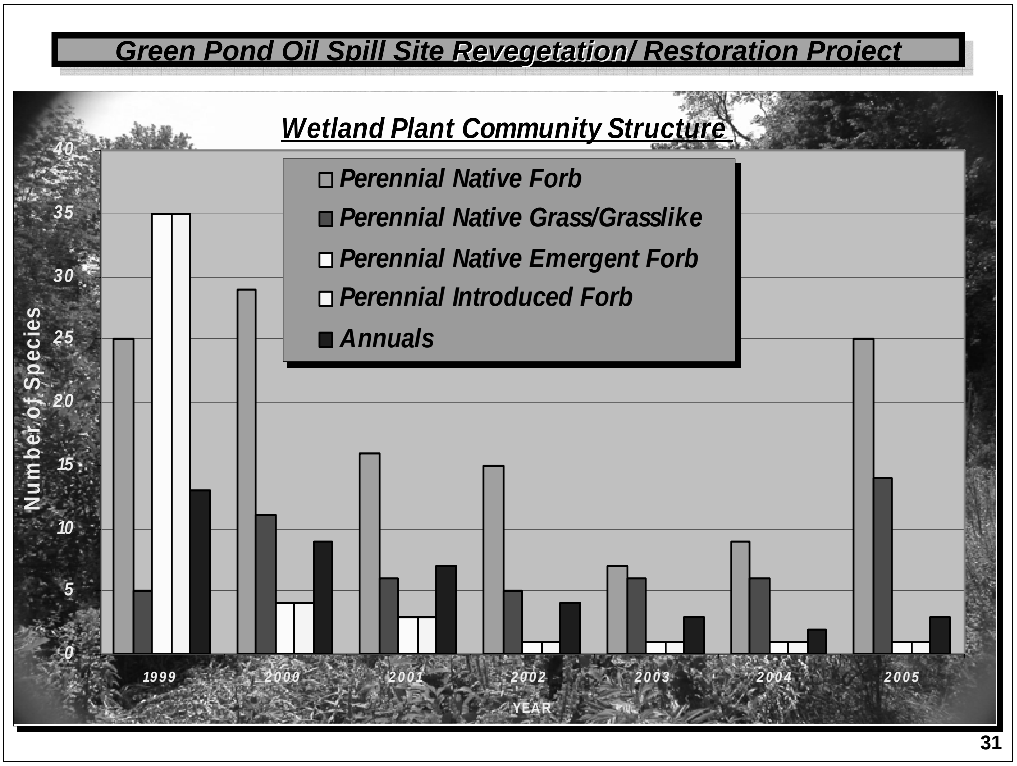
Monitoring the Wetland Plant Community

- Explanation of Plant Type Symbols
  - **P=perennial (survives longer than one season)**
  - **I=introduced (includes aliens, invasives)**
  - **N=native (occurs naturally in the NE.)**
  - **G=grass**
  - **Gl=grasslike**
  - **F=forb (includes herbs, non-woody species)**
  - **B=biennial (survives no longer than two seasons)**
  - **S=shrub (woody plants less than 50 feet in height)**
  - **A=annual (survives for a single growing season)**
  - **E=emergent (root systems are submerged)**

30

These are the Plant Type Symbols that are used in the National Wetland Inventory by the USF&W Service to describe and characterize wetlands in the US.



Mitsch & Gosselink (1993) compare horticulture techniques to natural succession for long term success of attaining a healthy ecosystem. They have observed that to develop a low maintenance wetland, natural successional processes need to be allowed to proceed.

The species composition of the plant community at the Green Pond Oil Spill site has changed since the contaminated soil was removed in July 1998. At the end of the 1999 growing season when the first plant survey was performed, the community was well established with an abundance of perennial plants. Native and Introduced forbs were predominant with a large portion of annuals present as well. The annuals decreased in number in subsequent years as well as the introduced species. At the Green Pond Oil site, the number of annual species decreased. Likewise, the emergents and introduced species has decreased which indicates that the growing conditions have become more conducive for a smaller number of more ubiguitous species. Shading from the growth of the planted shrubs are changing the sunlight availability such that the sunloving species are not thriving as in the early years of the project.

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Wetland Plant Species Indicator Categories*

OBL = Obligate Wetland

Occur almost always (>99% Probability) under natural conditions in wetlands.

FACW = Facultative Wetland

Usually occur in wetlands (67–99% Probability), but occasionally found in non-wetlands.

FAC = Facultative

Equally likely to occur in wetlands or non-wetlands (34-66% Probability).

FACU = Facultative Upland

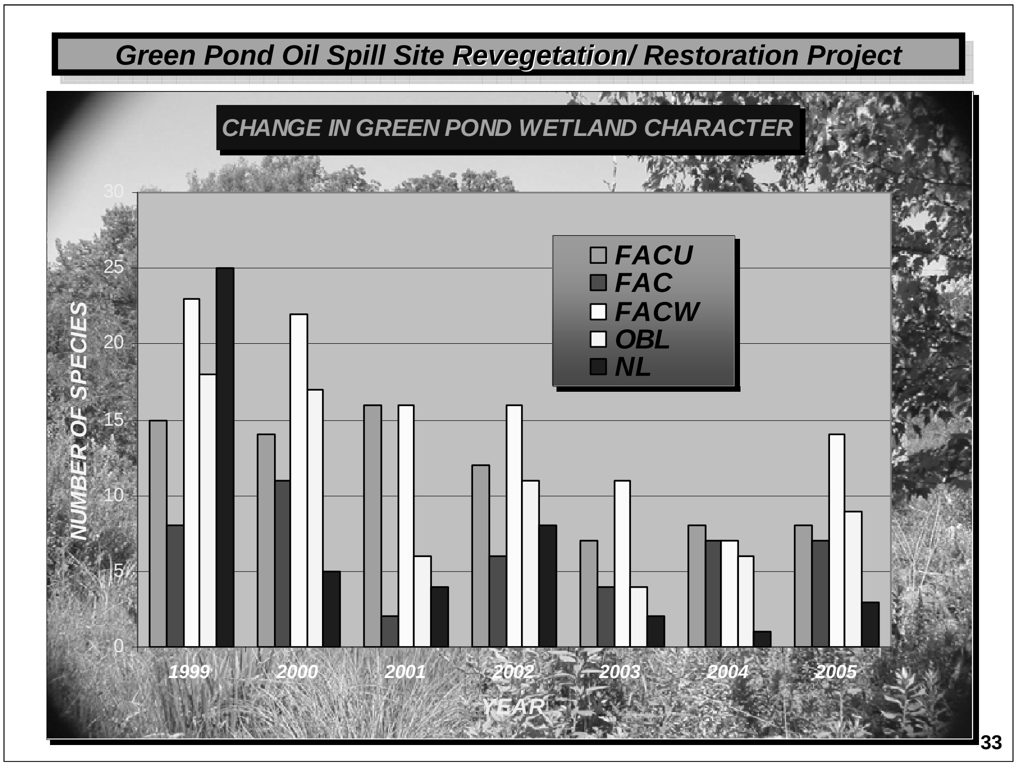
Usually occurs in non-wetland (67-99% Probability). But occasionally found in wetlands (1-33% Probability).

NL = not listed

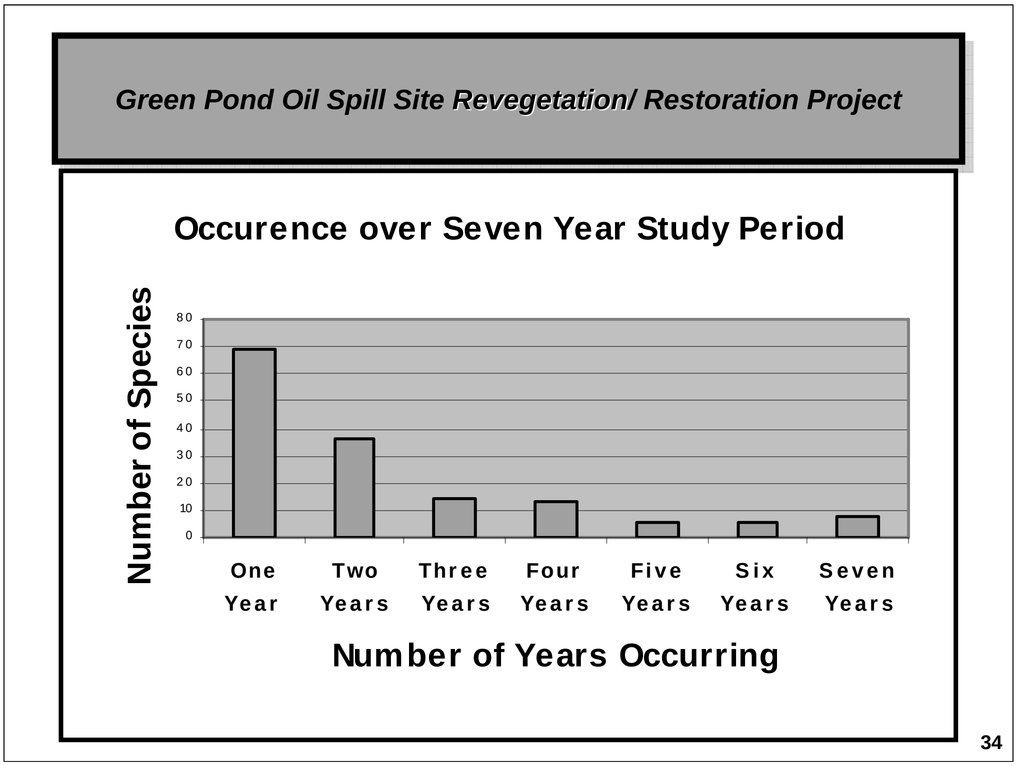
**National list of Plant Species that occur in Wetlands: Northeast Region (Region 1)*

USF&W Biological Report 88(26.1) MAY 1988

From a national list of vascular plants of over 7000 plants associated with wetlands, four wetland indicator categories were developed (Reed, 1997). Presently, the wetland plants for each USF&W Service Region has been compiled and catagorized. The list for Region 1 was used to determine the categories for the plants found at the Green Pond site.



Changes in the wetland character of the Green Pond Oil Spill site has also occurred over the seven years of observations. The first growing season had the greatest number of wetland species only because of the high number of Not Listed species. Not Listed means that a large number of species present at the Green Pond site are not found in the National List List of Plant Species that occur in Wetlands: Northeast (Region 1) (Reed, 1988). At the end of the second growing season, the number of Not Listed species dropped to less than ten from twenty-five; likewise the number has remained low for subsequent years. The number of species in the other categories of wetland species has varied during this same time period. Upland species (FacU) have been present throughout the entire period indicating the mixed nature of the habitat at the site. The number of wetland species (Fac, FacW and Obligate) comprises more than fifty percent of the overall species present on site. Using these categories indicates that the wetland at Green Pond has changed but has never lost its wetland character, using the USACE rules and regulations for wetland designation. The Green Pond restoration will likely retain these characters for many years without some catastrophic event.



This chart shows how long certain species have been present at the Green Pond site. It should be noted that nearly half of the total species observed at the Green Pond site only were present for one year. This transientness could be attributed nature of the species e.g. annual vs perennial and the environment changing such that site conditions where no longer conducive for that species to exist on site.

Green Pond Oil Spill Site Revegetation/ Restoration Project

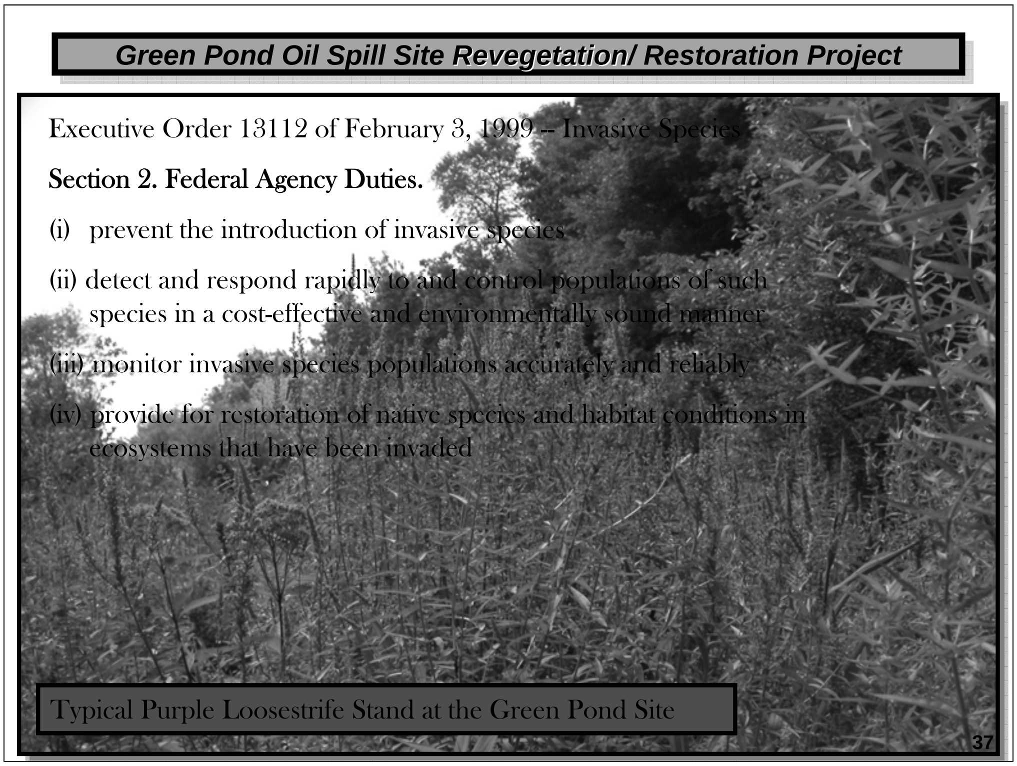
Introduced Species

Scientific Name	Common Name	Sep-99	Sep-00	Sep-01	Sep-02	Sep-03	Sep-04	Sep-05	Type
Agropyron repens	Quack Grass		X						PIG
Agrostis alba	Red Top	X							PIG
Alliaria petiola	Garlic Mustard				X	X	X		BIF
Barbarea vulgaris*	Yellow Rocket	X	X						BIF
Berberis thunbergii	Japanese Barberrry	X	X			X	X		IS
Cerastium vulgatum*	Mouse-eared Chickweed	X							PIF
Cirsium sp. (poss. Vulgare)*	Bull Thistle	X	X						BIF
Echinochloa crusgalli*	Barnyard Grass	X			X				AIG
Glechoma hederaca	Ground Ivy			X					PIF
Lysimachia nummularia	Creeping Jennie		X						PIF
Lythrum salicaria	Purple Loosestrife		X	X	X	X	X	X	PIF
Microstegioum vimeneum	Nepal Microstegium				X	X	X	X	G
Myosotis scorpioides	True Forget-me-not								PIF
Oenothora biennis	Evening Primrose.	X			X				BIF
Polygonum hydropiper*	Marshpepper Smartweed	X	X				X		AIEF
Rosa multiflora	Multiflora Rose		X		X		X	X	IS
Rumex crispus	Curly dock	X							PIF
Rumex obtusifolius*	Bitter Dock	X							PIF
Setaria glauca	Yellow bristle Foxtail			X					AIG
Urtica diocia	Stinging Nettle		X	X					PIF
Veronica officinalis	Common Speedwell		X						PIF
Vitus labrusca	Fox Grape	X	X	X	X	X	X	X	IWV

35

This table depicts the introduced species as defined in the National List of Plant Species that occur in Wetlands (Reed, 1988). Introduced means that man has been involved somehow in the species being introduced into the North America most likely from another continent; in many cases for agronomic purposes. Most introduced species were introduced since Colonial Times by man, advertently or inadvertently; such being the case for Purple Loosestrife, Multiflora Rose and Japanese Barberry. At the Green Pond site, the presence of introduced species(invasives would certainly be included in this category) are more numerous through the first two seasons but decreased dramatically by the end of the second year. Nevertheless a program for management of the remaining species was introduced to discourage the growth on-site and spread of these species off-site.

We know from the photo below taken before contaminated soil removal in July 1998 that Purple Loosestrife (***Lythrum salicaria)*** was present at the Green Pond site.



OSC Mike Solecki under Executive Order 13112 was able to justify the use of Federal funds to detect, monitor and remove all the Invasive Species on the Green Pond site, including Purple Loosestrife. Purple loosestrife is a serious invader of many types of wetlands, including wet meadows, prairie potholes, river and stream banks, lake shores, tidal and non-tidal marshes, and ditches. It can quickly form dense stands that displace native vegetation. Purple loosestrife can spread very rapidly due to its prolific seed production; one plant can produce as many as 2-3 million seeds per year. Purple loosestrife is native to Europe and Asia. It was first introduced into America in the early 1800s for ornamental and medicinal purposes. It has also been used as a nectar plant for bee-keeping.

Green Pond Oil Spill Site Revegetation/ Restoration Project

Invasive Species Management for Purple Loosestrife 2000

38

nvasive species control was instigated early in 2000 in the project during the growing season following the installation of the shrubs. A limited spraying program using a glyphosate herbicide (Roundup) on a small stand of Loosestrife that had survived the previous years soil removal operations. This test was abandoned after it was realized that the amount of Roundup needed to control the Loosestrife might possibly impact the water quality of the nearby Pequannock River.

A hand extraction effort was tried in a small area. This involved physically removing individual plants by hand which is considered an effective control technique (Malecki, et al. 1993). However at Green Pond, this technique was also abandoned as being too labor intensive.

Green Pond Oil Spill Site Revegetation/ Restoration Project

Invasive Species Management for Purple Loosestrife also included :

- ***Seed head clipping in Spring.***
- ***Clipping Flowering structures in late summer before seed maturation***

40

Clipping the seed bearing structures prior to the release of seeds helps deter the spread of Purple Loosestrife to new locations. At the Green Pond site, the most likely seed spreading vector would be the Pequannock River during spring flood conditions. A single plant may produce as many as two million seeds, a very prolific species indeed.

Green Pond Oil Spill Site Revegetation/ Restoration Project

41

By 2001, we had learned of the Biological Control Program that the State of New Jersey's Department of Agriculture had in place for Purple Loosestrife and contacted the appropriate officials about the Green Pond site as a possible candidate for biological control. In June 2001 Tom Scudder, State Entomologist, visited the site to evaluate the potential for biological control and later in the summer released 3000 *Galerucella calmariensis* and *pusilla* at the Green Pond site in the densest stands of Purple Loosestrife. Mr. Scudder marked these locations with blue and white tape to be visited in subsequent years to monitor the *Galerucella* populations.

Green Pond Oil Spill Site Revegetation/ Restoration Project

Invasive Species Management for Purple Loosestrife 2002

Adding more Galerucella beetles

42

On July 24th, 2002, 3000 Galerucella adults were added to the existing Green Pond population by Craig Bitler, The Eco-Strategies Group's Biological Control expert. Mr. Bitler, shown here, distributing the beetles to areas of loosestrife growth that had not been assaulted by the beetles introduced in June 2001. Although the "2001 class" has performed admirably in the biological control program, the loosestrife was extremely prolific in seed production with new plants becoming established in other areas of the wetland, thus the need for introducing additional beetles. The new recruits were supplied by the State of New Jersey Department of Agriculture's Bureau of Biological Control Laboratory. According to Craig Bitler, these recruits will eat their fill, drop to the ground, hibernate just below the soil surface and will emerge next spring (2003).

Green Pond Oil Spill Site Revegetation/ Restoration Project

Invasive Species Management for Purple Loosestrife

Biological Control with Galerucella beetles 2002 & 2003

43

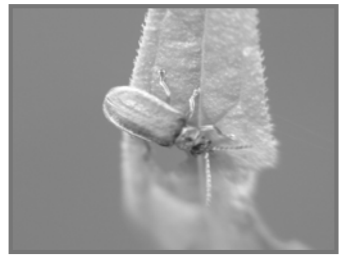
A minimum of 2,000 to 3,000 beetles per site are recommended. Releases in successive years will improve the chance for establishment. As the population increases, beetles may move larger distances (up to a few miles). Beetles may be released at any time after purple loosestrife emerges in the spring until late August. Beetles released prior to the summer solstice (June 21) may reproduce and show significant increase in the year of release. Beetles released after the summer solstice are likely to feed and overwinter without reproducing. These same beetles will reappear the following spring to restart the cycle. A measure of success of introducing a bio-control agent is when the agent is able to reproduce, over-winter and emerge the following season in numbers sufficient to be effective against the target plant species.

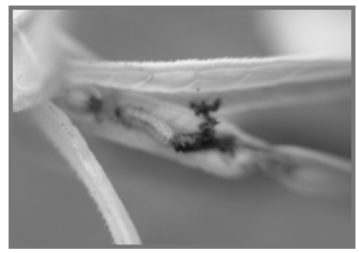
Green Pond Oil Spill Site Revegetation/ Restoration Project

Invasive Species Management for Purple Loosestrife 2001, 2002 & 2003 Galerucella spp. (calmariensis and pusilla)

Life Stages: Eggs laid in May, June , August and hatch in ten days. Larvae feed on young buds, leaves and stems up to 14 days. Pupation occurs in soil lasting about seven days.

Adults over winter and emerge in May and June. First generation adults emerge in July and August and relocate to new areas (hopefully).





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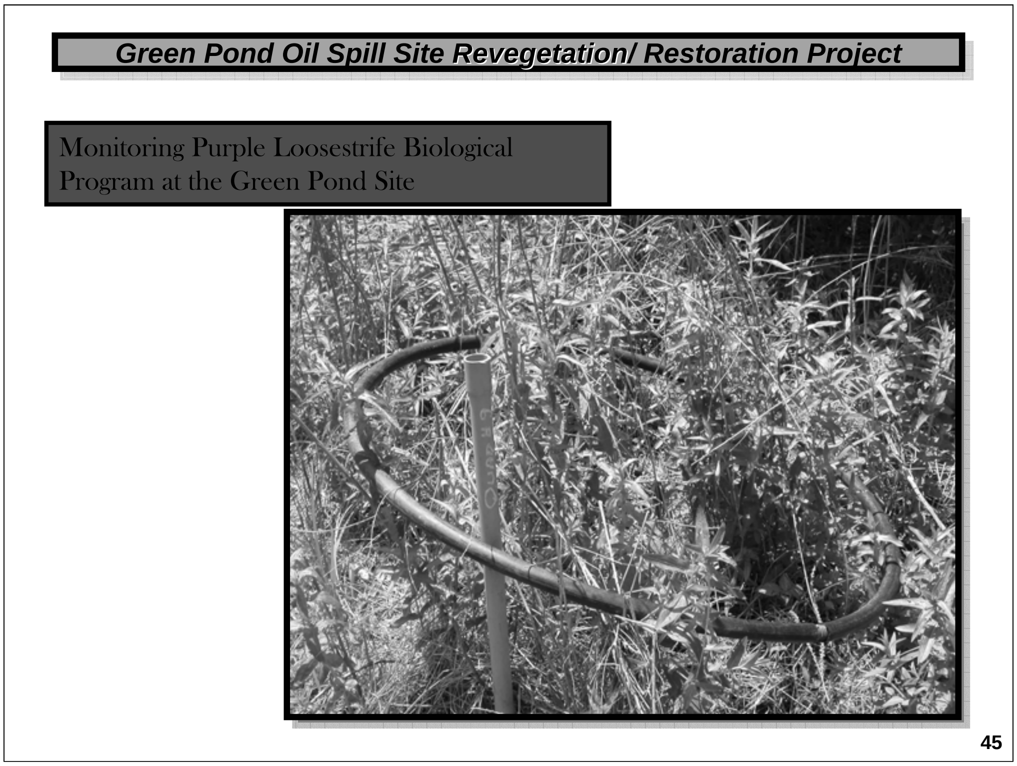
The two species of *Galerucella* beetles look very similar in the field and are nearly identical in their life cycles and morphology. Adults over winter in the upper most soil litter layer and emerge in the spring shortly after the new Loosestrife foliage emerge. Feeding begins immediately and continues several days before reproduction occurs. The egg masses (2-10/clump) are laid along the stems and in the leaf axils. Egg laying peaks in May and June and each female is capable of producing 500 eggs during a 45-day period. Larvae emerge within 7-10 days after egg-laying and migrate to the shoot tips (Figue 22.) The larval stage lasts about three weeks and then drops to the ground to pupate in the litter. Pupation lasts about two weeks and in mid-summer, the adults emerge as a F2 generation and feed for 7-10 days before returning to the litter for overwintering.

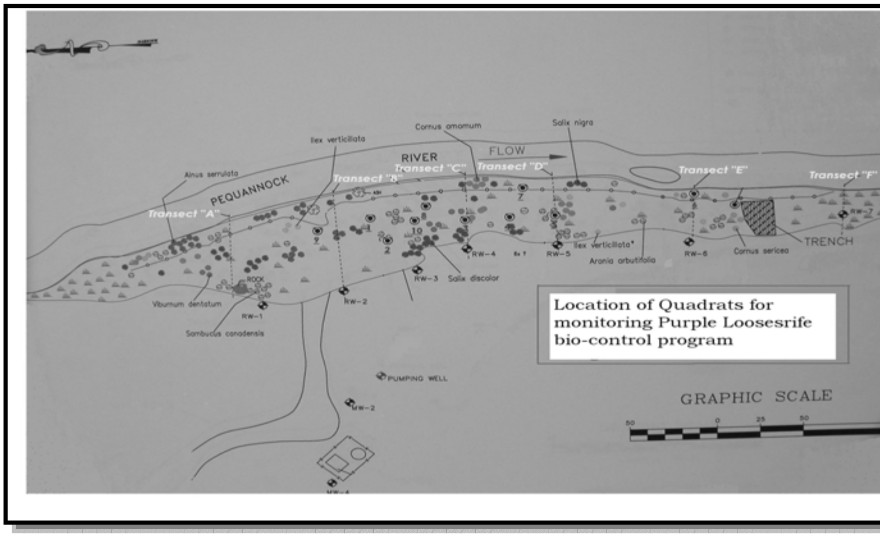
Typically it takes three to five years for populations of loosestrife beetles to build to levels that kill plants. In the first one to two years following release,



A monitoring program was initiated in June 2002 and carried out in 2002 and 2003 using the Protocol developed by Dr. Bernd Blossey of Cornell University. This entails ten randomly placed one-square meter plots being established within the site. Survey data is gathered in the spring and then in late summer. The purpose is to determine to what extent the beetles are having on the Loosestrife populations, if any. The results, shown below, are compiled and voluntarily submitted to Cornell University for their data base on overall Biological Control Program.

The monitoring program was not continued in years following 2002 as the program is very labor intensive. However additional releases of 3000 Gallerucella beetles were made in 2003 and 2004.

Green Pond Oil Spill Site Revegetation/ Restoration Project



46

Quadrats were placed at random **into the purple loosestrife infestation**. Ten quadrats were established at the Green Pond site in a randomized mannerto allow useful statistical analysis. We then marked the position of the quadrats on the vegetation map.

Green Pond Oil Spill Site Revegetation/ Restoration Project

Cornell Protocol for monitoring success of Galerucella beetles evaluates:

- Herbivory measures:

  number of flower heads (inflorescences)

Significant decrease in number of flower heads

  number of flowers per inflorescence

Significant decrease of Purple Loosestrife flower production

  number of stems and cover within each sampling quadrat

At many locations noticeable decrease in percent cover and stem numbers

  height of plants within each sampling quadrat

No significant decrease in height of Purple Loosestrife

- Beetle population levels e.g egg, larvae and adult stages

Significant of overwintering adults produced noticeable number of egg clusters and larvae

47

Since 1992, several insect species have been released in North America as biological control agents against purple loosestrife. To evaluate the success of the control program, Dr. Bernd Blossey at Cornell University initiated a scientific based protocol to document changes in target weed populations, control agent abundance, and changes in plant communities. Dr. Blossey was largely responsible for introducing the Gallerucella beetles to North America as a bio-control agent against Purple Loosestrife.

The attack of *Galerucella*, but especially of the flower feeders, will change the number of flower buds producing seeds. This measurement allows us to assess their impact.

A change in flower head number is an indication of the herbivory action of the Gallerucella larvae. The larvae prefer the soft tissue of the plant terminals as its food supply. Any damage to these tissues will result in a reduction in the formation of flower heads for a particular plant.

However, young larvae feed on shoot tips (apical meristems) of the purple loosestrife plant stunting its growth. However, The first couple of years the mean purple loosestrife stem height does not change significantly. Historically, the mean stem heights are reduced by about 50%, followed by elimination of purple loosestrife through beetle herbivory.

In order to better assess changes in plant diversity, a list of all plant species present in the sampling quadrats was required. At the Green Pond Site, Purple Loosestrife was a dominant member of the plant community but was the most dominating as many other wetland species co-existed within close proximity to the Purple Loosestrife.

Green Pond Oil Spill Site Revegetation/ Restoration Project

Other large plant species growing in close proximity to Purple Loosestrife at Green Pond

48

A main detractor characteristic of Purple Loosestrife in North America is its capacity to form pure stands and crowed out native species. At Green Pond, although a dominant member of the plant community, Purple Loosestrife has not created a monospecific plant community, largely due to the microhabitats present at the site.

Green Pond Oil Spill Site Revegetation/ Restoration Project

The Matter of Invasives at Green Pond, continued

Nepal Microstegium (Japanese Stiltgrass)

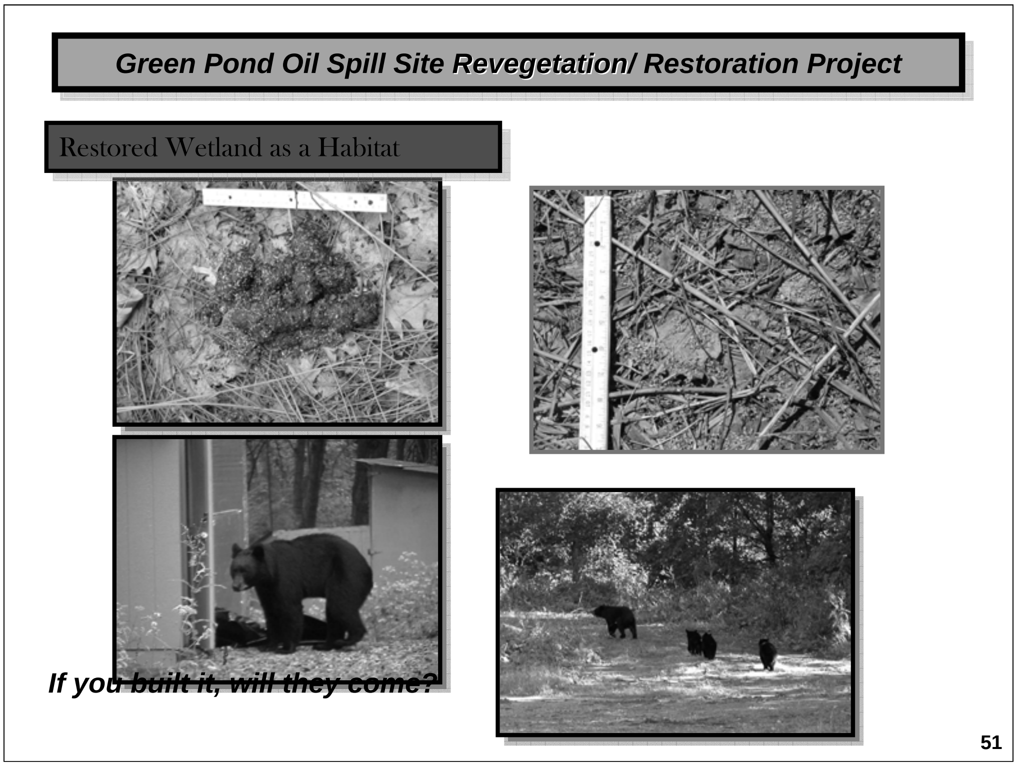
Japanese barberry

49

A number of alien invasives have been documented at the Green Pond site. Japanese Stiltgrass, once confined to a small clump in the southern end of the wetland has now spread to other locations. It has a sprawling habit and grows slowly through the summer months, ultimately reaching heights of 2 to 3 1/2 ft. Japanese stilt grass is especially well adapted to low light conditions. It threatens native plants and natural habitats in open to shady, and moist to dry locations. Stilt grass spreads to form extensive patches, displacing native species that are not able to compete with it. Japanese stilt grass is a colonial species that spreads by rooting at stem nodes that touch the ground. Stilt grass reproduces exclusively by seed. Individual plants may produce 100 to 1,000 seeds that fall close to the parent plant. Seed may be carried further by water currents during heavy rains or moved in contaminated hay, soil, or potted plants, and on footwear. Stilt grass seed remains viable in the soil for five or more years and germinates readily.

Japanese barberry is a dense, deciduous, spiny shrub that grows 2 to 8 ft. high. The branches are brown, deeply grooved, somewhat zig-zag in form and bear a single very sharp spine at each node. At Green Pond, only few individual plants were observed in the wetland close to the Pequannock River although it is abundant in the upland portion of the site. Japanese barberry forms dense stands in natural habitats including canopy forests, open woodlands, wetlands, pastures, and meadows and alters soil pH, nitrogen levels, and biological activity in the soil. Once established, barberry displaces native plants and reduces wildlife habitat and forage. White-tailed deer apparently avoid browsing barberry, preferring to feed on native plants, giving barberry a competitive advantage. In New Jersey, Japanese barberry has been found to raise soil pH (i.e., makes it more basic) and reduce the depth of the litter layer in forests. Japanese barberry spreads by seed and by vegetative expansion. Barberry produces large numbers of seeds which have a high germination rate, estimated as high as 90%. Barberry seed is transported to new locations with the help of birds (e.g., turkey and ruffed grouse) and small mammals which eat it.

Here you see Japanese barberry being sprayed in October 2003 by Craig Bitler, an invasive species specialist with TEG, using a solution of glyphosate. Chemical control is proven to be an effective control strategy. Whereas chemicals were not considered to be a control option in the wetland for Japanese barberry, they were considered to be safe and appropriate for the upland portion of the site. Glyphosate was very effective(99%) at Green Pond with only one application necessary.

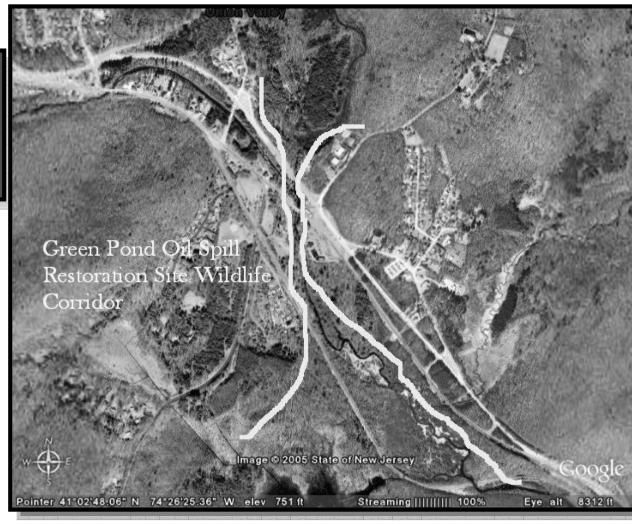


Black bears are the largest omnivore in the Green Pond area and frequented the site often in person or left their calling cards as shown on the left. The droppings were found in the Spring 2003 and contained sedge and rush seed heads remaining from the previous seasons growth as shown in the upper right photo. The seeds had been accumulated into a large mass in one area near Transect B from the Spring floods. Although the wetland was enclosed by a deer fence, the bear did not a problem of accessing the site at will. The bears became such frequent visitors that Mike Solecki named the large male; Ozzie and the female; Harriot after Ozzie and Harriot Nelson, TV personalities from the ’50’s. Ozzie, the TV personality, was a Rutgers graduate; we are not sure about the bear.

Green Pond Oil Spill Site Revegetation/ Restoration Project

Restored Wetland as a Habitat

Green Pond site located within riparian zone that serves as wildlife corridor



If you built it, will they come?

52

Wildlife corridors can help restore the proper ecosystem functions only if they are wide enough to constitute viable interior forest habitat. An "edge", such as between the forest and a maintained road or clearing, must be far enough away so that its various ecosystem effects do not reach all the way into the corridor. In addition to land-based wildlife corridors, stream-side corridors have been promoted as a means of linking isolated habitats of some species. The Pequannock River riparian zone serves this function as can be seen in the aerial photo. At the Green Pond site, the river provides a corridor for wildlife movement between the large tracts of natural areas north and south of the site. In the Northeast, where fragmentation of ecological landscapes and habitats are a serious problem, preserving and restoring natural corridors are important to maintain populations of animals, in particular the species which require large undisturbed natural habitat areas for feeding and breeding.

Green Pond Oil Spill Site Revegetation/ Restoration Project

Restored Wetland as a Habitat

If you built it, will they come?

53

A variety of snakes were freguent visitors to the Green Pond site. The black rat snake or pilot snake **_(Edaphe obsoleta)_** as the name states, is completely black except for their white chin. Hatchlings of the black rat snake have a pale grey background with black blotches along its back. Old timers sometimes refer to the Black Rat Snake as the "Pilot Snake" in the mistaken belief that this Snake pilots or guides the venomous rattlesnake to safe denning areas in the forest. Rat snakes are primarily known as rodent eaters, however, other food preferences do exist. As juveniles, rat snakes will eat small lizards, baby mice, and an occasional small frog. Adult rat snakes have a diet mainly consisting of mice and rats, but will also include chipmunks, moles, and other small rodents. Adults will also eat bird eggs and young birds that do not put up a strong fight. Rat snakes kill their prey by constriction. When this snake was sighted in the wetland as shown above, a large number of green frogs had just emerged from the vernal pool in the wetland.

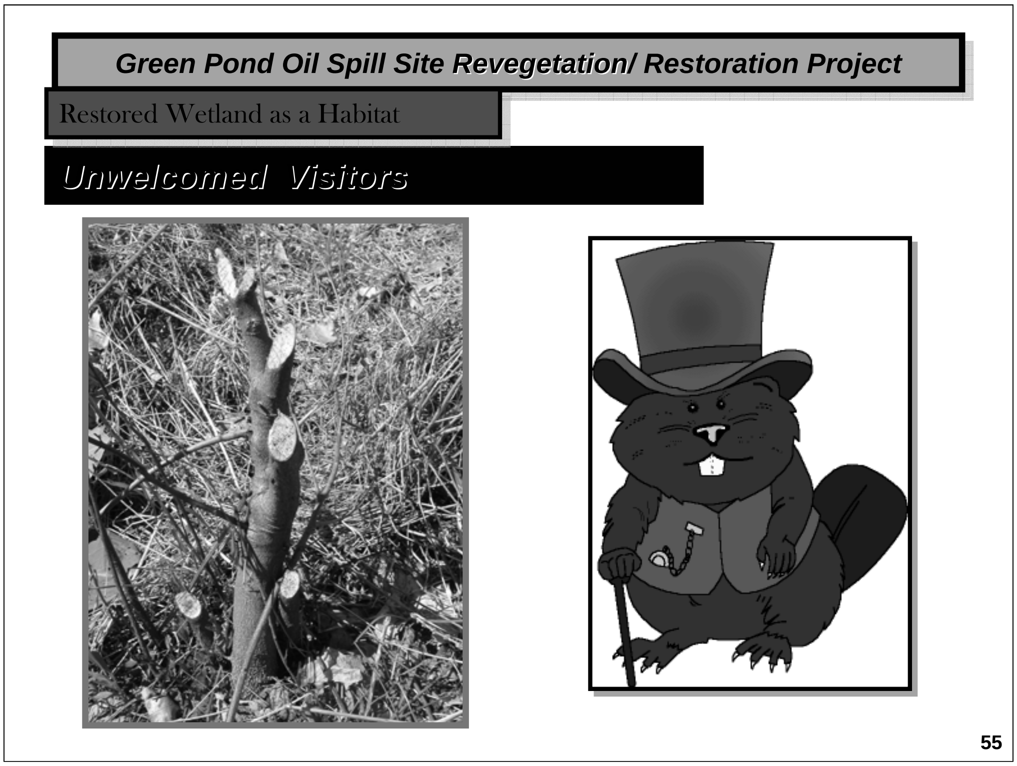
Green Pond Oil Spill Site Revegetation/ Restoration Project

Restored Wetland as a Habitat

If you built it, will they come?

54

The Green Pond Site wetland is home to a number of threatened and endangered species listed by the State of New Jersey. Here you see a female Wood Turtle (***Clemmys insculpta*****).** This turtle is a riparian species that uses a mosaic of wetland and upland habitats in the vicinity of its stream habitat. The Wood Turtle requires clean streams running through meadows, woods, and farmlands. However, it often can be found away from water, especially after warm spring rains or in the summer. It will rest in the shade of vegetation, fallen logs, or debris and can be found in all of the Northern Region, except the urbanized regions of the eastern counties. Because wood turtles commonly inhabit both aquatic and terrestrial environments, declines in their abundance can be attributed to both habitat loss and stream degradation. This species was listed as threatened in New Jersey in 1979 as a result of major decreases in its abundance and distribution in the state. The individual pictured here was a female 8-10 years old and was photographed at different locations at the Green Pond site over several years; apparently this species is fairly long lived.



In late winter of 2002, unwelcomed beavers clipped many of the willows and alders that had been planted in 1999. They removed the branches off site such that originally, we thought that the shrubs had been vandalized by humans but a closer look revealed who the vandals really were. These beavers were probably young adults who live in the streambank closeby. The Pequannock River is too large to dam and create beaver ponds but offers miles of streambank with abundant shrubbery for food.

A good measure of success for the revegetation efforts at the Green Pond Oil Spill site is the long term survival and growth of the shrubs that were installed. Before the start of the growing season of 2003, a survey was conducted that measured the height and number of stems of each of the shrubs present. During the winter and early spring of 2002, beavers had harvested most of the shrubs to such an extent that to perform a survey would have been futile. Beavers prefer willows and alders over other wetland shrubs but compensated by sprouting and producing more branches.

Green Pond Oil Spill Site Revegetation/ Restoration Project

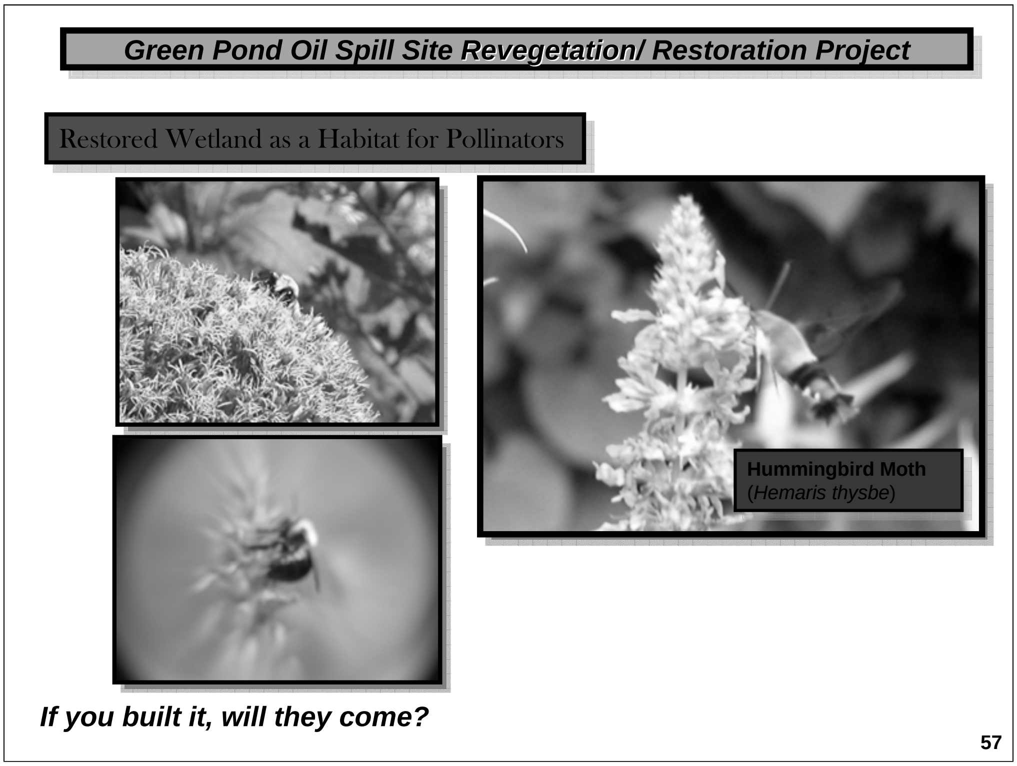
Restored Wetland as a Habitat

Shrub Recovery after Beaver Herbivory

56

However, by the end of the growing season of 2002, the shrubs had regained their original stature and density by base sprouting and growth. Beaver harvesting in 2003 was observed but was marginal compared to the harvesting that occurred in 2002 and none was observed in 2004 and 2005.

This is not uncommon and has been observed at other locations and may have some beneficial aspects as the number of stems per plant after harvesting is greater than without harvesting.



Pollinating insect populations, especially honeybees, have been in the decline. However the tall herbaceous plants at the Green pond site has served as a nectar source ever since the tall full flowered plants developed. One of the complaints from the apiarists about control Purple Loosestrife was that these programs would affect the honeybee populations. An important observation we made at Green Pond was that the bees were opportunists; meaning that as we removed Purple Loosestrife flower heads, the bees moved over to the Joe Pye Weed and New York Ironweed flower heads and continued feeding. As long as full flowered plants like the Joe Pye and Ironweed abound, concerns about impact of Purple Loosestrife on honeybee populations are not really founded.

The Hummingbird Moth (*Hemaris thysbe*) is a frequent visitor at the Green Pond site and feeds on a variety of tall composites and Purple Loosestrife as seen above. They are strong fliers, with a rapid wingbeat and heavy bodies; like hummingbirds, hovering in front of a flower and sipping nectar through the extended proboscis. The proboscis rolls up like a party noisemaker when not in use, and may not be readily evident in a resting moth. Some species lack scales on large portions of their wings, and therefore have transparent or clear wings. These are commonly referred to as "clearwing hummingbird moths," (Note however that the scientifically accepted common name of "Hummingbird clearwing" refers specifically to *Hemaris thysbe*.)

Domesticated honeybees are not the only pollinators in trouble these days. Many species of butterflies, moths, birds, bats and other mammals are also in retreat, threatening not only commercial crops but a wide range of flowering plants. Despite the importance of pollinators, the ever-expanding conversion of landscapes to human uses adversely affects their habitats. A growing body of evidence indicates that these beneficial creatures are in serious decline, due to loss, modification, and fragmentation of habitat, and the excessive use of pesticides. The risk of losing the essential role of pollinators, required for the successful propagation of native plant communities, wildlife habitats, and a range of food crops, is real.(1)

Butterflies are good pollinators; are diurnal and have good vision (can see red) but a weak sense of smell. They are perching feeders. Butterfly-pollinated flowers are brightly-colored but odorless. Often, these flowers occur in clusters (Compositae, milkweed) and/or are designed with a “landing platform.” Butterflies walk around on flower clusters probing the blossoms with their tongues. Each flower has a tube of suitable length for the butterfly’s tongue.

Moths are nocturnal, have a good sense of smell, and are hover-feeders. These flowers are white or pale colors so they are visible at night, and may only be open at night. Typically, these flowers have a strong, sweet scent (again, maybe only at night) and deep tubes to match the length of the appropriate moth’s tongue. The petals are flat or bent back (recurved) so the moth can get in.

We observed many additional butterfly species at Green Pond than depicted above e,g, white sulphurs, monarchs and viceroys but were not photographed and can safely conclude that the Green Pond Restoration site serves as a habitat and garden for butterflies from early summer into the late autumn.

1.Anonymous; http://pollinators.nbii.gov/declines.html

Green Pond Oil Spill Site Revegetation/ Restoration Project

Restored Wetland as a Habitat for Arachnids

Female Spined Micrathena

Black and Yellow Argiope

If you built it, will they come?

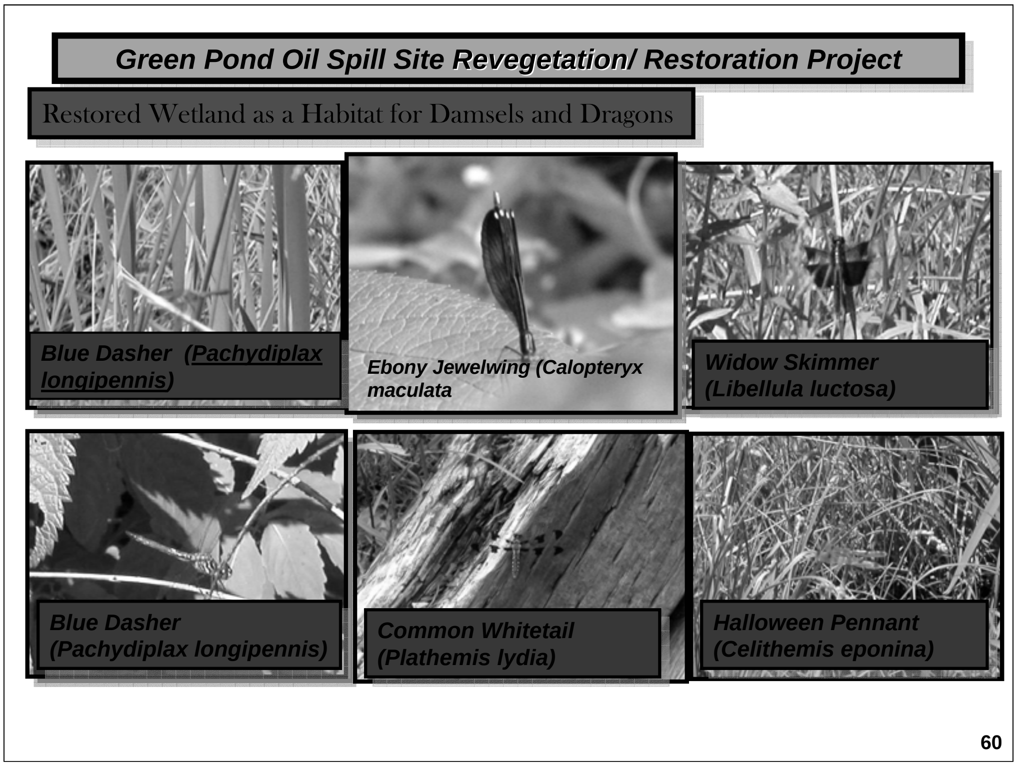
59

Both the Spined Micrathena and Black and Yellow Argiope spiders are orb web builders that have inhabited the Green Pond wetland since the vegetation has attained such heights as to make orb web building feasible for these spiders.

To trap prey, the Spined Micrathena builds her web between shrubs or small trees, three to seven feet off the ground. Insects that try to fly in between the trees don't see the web and get stuck. First, the micrathena weaves three main lines of web; then she builds her orb (circular part of the web). The orb is six to eight inches across. As soon as the sun goes down, she eats her web. When the sun comes up, she builds it again. Most of the prey that get caught in the web are small flies, such as mosquitoes and gnats. Small wasps, flying ants, and beetles also get caught. The micrathena hangs out in the center of her web, with her head pointing down. As soon as she feels the vibrations of prey trapped in her web, she runs to bite it. (1)

The Black and Yellow Argiope (Argiope aurantia) occur from southern Canada south through the lower 48 United States, Mexico, and Central America as far south as Costa Rica (2) . This species prefers sunny areas among flowers, shrubs, and tall plants. It can be found in many types of habitats. If the climate is suitable, _Argiope_ spiders may be active both day and night, attacking insects that are trapped in its web. They often construct and repair their webs after dark, but may do this in day time too. Once they find suitable sites for their webs, they will tend to stay there unless the web is frequently disturbed, or they can't catch enough food there. As noted earlier, adult males roam in search of potential mates, but once they find a female they build small webs nearby and court her. These spiders have relatively poor vision, but are quite sensitive to vibration and air currents. Males communicate with potential mates by plucking and vibrating the females' webs.

Many other Arachnids inhabit Green Pond but these two were the most photogenic.



The Green Pond wetland is home to a myriad of dragonfly and damselfly species, many more than the few that could be photographed easily. Dragonflies and damselflies are certainly species commonly associated with wetlands adjacent to streams. The nearby aquatic habitat serves as the hatchery for the larvae and nymphs of these species. The adult forms then use the wetland for feeding and mating followed by egg laying back into the aquatic environment. New Jersey is home to over a hundred species of Odonates, just a few pictured here. Having a diversity of Odonate species present in a wetland speaks well of the ecological conditions.

Green Pond Oil Spill Site Revegetation/ Restoration Project

- What have we learned so far..
  - The herbaceous plant community in a wet meadow stripped of surface soil (4-6inches) will recover providing root systems remain intact.
  - Low level soil TPH levels do not adversely affect potted shrub survival.
  - Occasional oil “spooges” do not affect the plant community as a whole.
  - Several seasons of drought have not altered plant community species from wet to upland dominance.
  - Invasive species management is a “must do” activity in a revegetation/restoration project.

  - ***WATCH OUT FOR THE BEAVERS, SNAKES AND BEARS, OH MY!***

61

Green Pond Oil Spill Site Restoration Project Scoresheet (How did we do)

Restoration Guiding Principles*

- ***Preserve and protect aquatic resources***
- ***Use reference sites***
- ***Restore ecological integrity***
- ***Anticipate future changes***
- ***Restore natural structure***
- ***Involve a multi-disciplinary team***
- ***Restore natural function***
- ***Design for self-sustainability***
- ***Use passive restoration, when appropriate***
- ***Restore native species, avoid non-native species***
- ***Address ongoing causes of degradation***
- ***Use natural fixes and bioengineering***
- ***Develop clear, achievable and measurable goals***
- ***Monitor and adapt where changes are necessary***
- ***Focus on feasibility***

**Watershed Ecology Team, US EPA Office of Wetlands, Oceans and Watersheds*

62

Preserve and protect aquatic resources. Existing, relatively intact ecosystems are the keystone for conserving biodiversity, and provide the biota and other natural materials needed for the recovery of impaired systems. Thus, restoration does not replace the need to protect aquatic resources in the first place. Rather, restoration is a complementary activity that, when combined with protection and preservation, can help achieve overall improvements.

Use a reference site. Reference sites are areas that are comparable in structure and function to the proposed restoration site before it was degraded. As such, reference sites may be used as models for restoration projects, as well as a yardstick for measuring the progress of the project. While it is possible to use historic information on sites that have been altered or destroyed, historic conditions may be unknown and it may be most useful to identify an existing, relatively healthy, similar site as a guide for your project. Remember, however, that each restoration project will present a unique set of circumstances. Therefore, it is important to tailor your project to the given situation and account for any differences between the reference site and the area being restored. That was the case at Green Pond where had the National Wetland Inventory and the Shrub community across the river to give us a hint of what was there prior to the spill and subsequent cleanup activities.

Restore ecological integrity. Restoration should reestablish insofar as possible the ecological integrity of degraded ecosystems. Ecological integrity refers to the condition of an ecosystem -- particularly the structure, composition, and natural processes of its biotic communities and physical environment. An ecosystem with integrity is a resilient and self-sustaining natural system able to accommodate stress and change. Its key ecosystem processes, such as nutrient cycles, succession, water levels and flow patterns, and the dynamics of sediment erosion and deposition, are functioning properly within the natural range of variability. Biologically, its plant and animal communities are good examples of the native communities and diversity found in the region.

Anticipate future changes. The environment and our communities are both dynamic. Although it is impossible to plan for the future precisely, many foreseeable ecological and societal changes can and should be factored into restoration design. For instance, long-term, post-project monitoring should take successional processes such as shrub regrowth that will change the light and shade characteristics of the wetland to where conditions mayh not be so conducive to the number and types of herbaceous plants now growing at the Green Pond site.

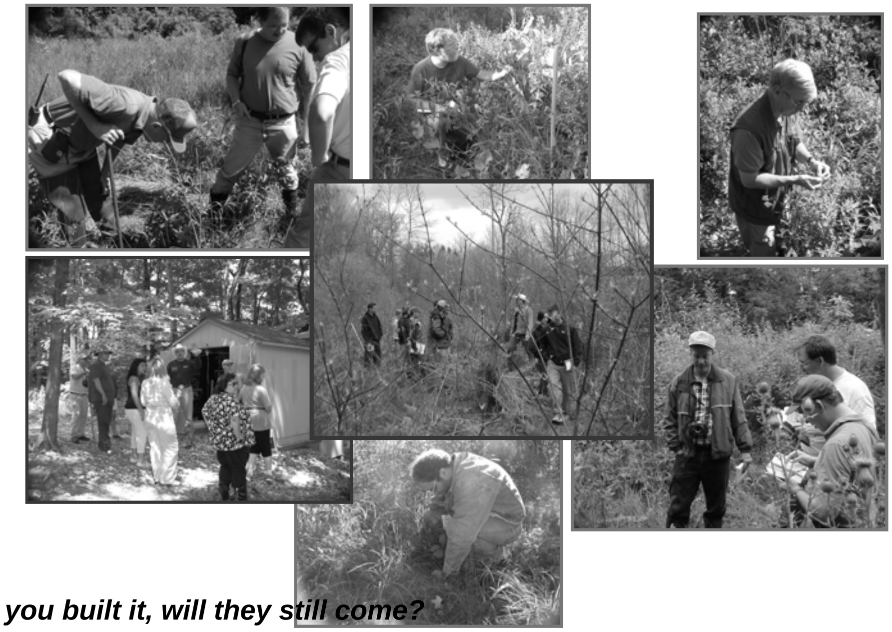
Restore natural structure. Restoring the original site morphology and other physical attributes is essential to the success of other aspects of the project, such as making conditions that are conducive to the health and survival of the native biota.

Involve the skills and insights of a multi-disciplinary team. Restoration can be a complex undertaking that integrates a wide range of disciplines including ecology, aquatic biology, hydrology and hydraulics, geomorphology, engineering, planning, communications and social science. It is important that, to the extent that resources allow, the planning and implementation of a restoration project involve people with experience in the disciplines needed for the particular project. Universities, government agencies, and private organizations may be able to provide useful information and expertise to help ensure that restoration projects are based on well-balanced and thorough plans. With more complex restoration projects, effective leadership will also be needed to bring the various disciplines, viewpoints, and styles together as a functional team. At Green Pond, we were fortunate to have so much expertise available within the government agencies as well as the hands on experience and knowledge of a very experienced landscape architect and landscaper.

Restore natural function. Structure and function are closely linked in river corridors, lakes, wetlands, estuaries and other aquatic resources. Reestablishing the appropriate natural structure can bring back beneficial functions. For example, restoring the bottom elevation in a wetland can be critical for reestablishing the hydrological regime, natural disturbance cycles, and nutrient fluxes. In order to maximize the societal and ecological benefits of the restoration project, it is essential to identify what functions should be present and make missing or impaired functions priorities in the restoration. Verifying whether desired functions have been reestablished can be a good way to determine whether the restoration project has succeeded.

Design for self-sustainability. Perhaps the best way to ensure the long-term viability of a restored area is to minimize the need for continuous maintenance of the site, such as supplying artificial sources of water, vegetation management, or frequent repairing of damage done by high water events. High maintenance approaches not only add costs to the restoration project, but also make its long-term success dependent upon human and financial resources that may not always be available. In addition to limiting the need for maintenance, designing for self-sustainability also involves favoring ecological integrity, as an ecosystem in good condition is more likely to have the ability to adapt to changes.

Green Pond Oil Spill Site Revegetation/ Restoration Project

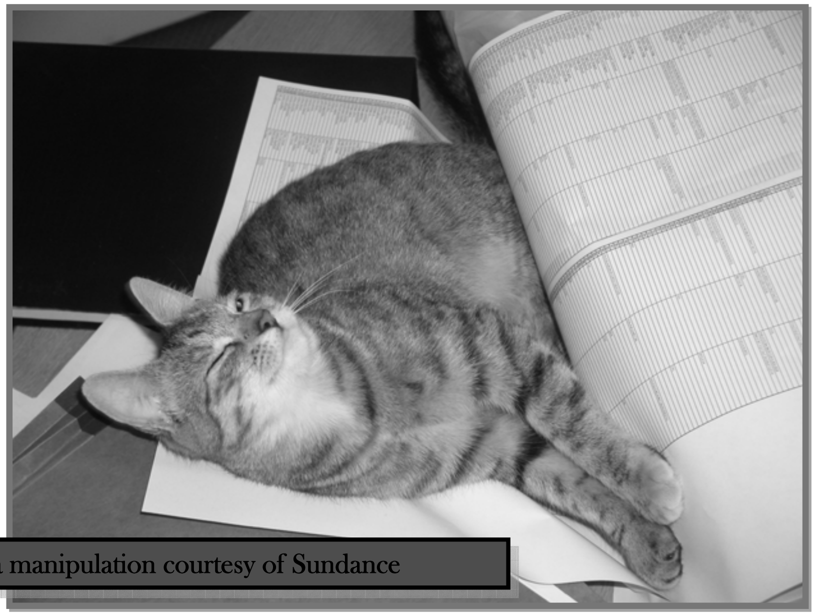


If you built it, will they still come?

63

Over the course of the years since the Green Pond Restoration project was initiated, we have had many groups visiting the restoration for educational and scientific purposes, including Wm Patterson and Rutgers Universities. Now that the oil removal program is completed, EPA will no longer have a presence at the site. We would like to have a group volunteer to continue the monitoring of the plant community and the Purple Loosestrife Bio-Control project.

Green Pond Oil Spill Site Revegetation/ Restoration Project



Data manipulation courtesy of Sundance

64

Need I say more……Thank You very much….

Thank You

After viewing the links to additional resources, please complete our online feedback form.

Thank You

Links to Additional Resources

65