PHASE 1
DIAGNOSTIC/FEASIBLITY STUDY OF LAKE ABSEGAMI

PREPARED FOR:
BASS RIVER STATE FOREST
BOX 118
NEW GRETNA, NEW JERSEY 08224

PREPARED BY:
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PROJECT NO. 209.01

SEPTEMBER 2002

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Consulting and Engineering Services For Water & Wetland Resources

PHASE I
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September 2002

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Section 1 Introduction

Lake Absegami is located in Bass River State Forest (Figure 1). The State Forest is 18,208 acres (7,369 ha) within the New Jersey Pinelands. Lake Absegami is the recreational focal point of the State Forest. The State Forest is about 25 miles north of Atlantic City and 6 miles west of Tuckerton. The forest is accessible from US Route 9 and the Garden State Parkway (S. Exit 52, N. Exit 50).

Lake Absegami, as well as a large portion of the Bass River State Forest, is located in Burlington County, the largest county in New Jersey. Specifically, the lake and park office are in Bass River Township, Burlington County, NJ. Burlington County is comprised of 40 municipalities, has a surface area of 827 square miles and extends the entire width of the state from the Delaware River to the Atlantic Coast. Burlington County is centrally located in the Boston-Washington D.C. Metropolitan Corridor. Eleven of the nation's largest cities are within overnight reach of the County.

The land for Bass River State Forest was acquired by the State of New Jersey starting in the early 1900's. Bass River State Forest was created for public recreation, water conservation and wildlife and timber management and research. Lake Absegami was created in the 1930's by the Civilian Conservation Corp when two streams that flow through the park were impounded (NJDEP Division of Parks and Forestry 1994). The lake is the center for most of the recreational activities in the State Forest. It is the only principal body of water within Bass River State Forest. However, other surface waters include the main branch of Bass River and its east and west branches. Bartlett's Branch feeds into the west branch of Bass River. The east branch of Bass River is fed by Dans Bridge Branch. Lake Absegami is fed by two tributaries on the east, Falkinburg Branch (southern branch) and Tommy's Branch (northern branch). Falkinburg Branch flows through the Absegami Natural Area near the office, while Tommy's Branch flows near the north shore camping area. The jurisdictional area of Bass River also includes headwater tributaries of the Wading River (Merrygold Creek, Ives Branch, and Beaver Branch). Other surface waters that extend into, or are located within, the State Forest include Pilgrim Lake, Timberline Lake, the cranberry reservoir on Beaver Branch, and former cranberry impoundments at Highland Park and Merrygold Estates.

Park activities include swimming, sun-bathing, picnicking, boating and canoeing, camping, hunting and fishing, hiking, horseback riding and the limited use of off-road motorized vehicles. The beach area is located along the eastern shore of the lake and has lifeguard supervision during the summer months. The area adjacent to the beach contains public parking, a bathhouse, a first aid station and a food/beach supply concession stand. A boat and canoe concession is also located along the eastern shore of the lake and is open during the summer months. Lake Absegami has a public boat launch just north of the concession stands. Powered boats are limited to electric motors.

The lake is open to both shoreline and boat-based recreational fishing, subject to New Jersey's Fish and Wildlife laws. However, only small baitfish and stunted chain pickerel are commonly found in the lake.

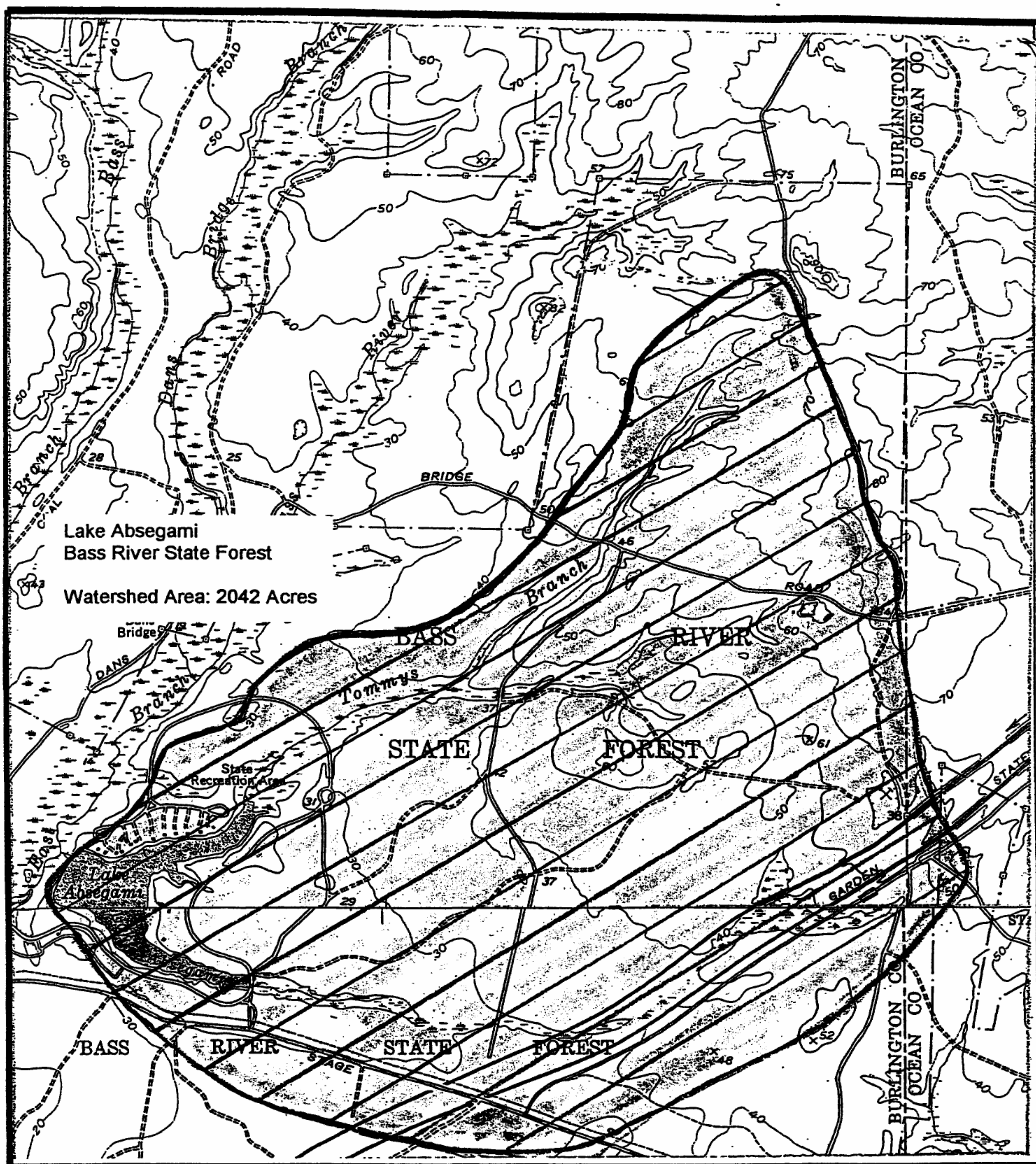


FIGURE NO.	PROJECT NAME/LOCATION:		DATE: 9/18/00	
1	DIAGNOSTIC FEASIBILITY STUDIES FOR THE RESTORATION OF FOUR LAKES		PROJECT NO.: 209.01	pH PRINCETON HYDRO, LLC
	DRAWING NAME: WATERSHED AREA MAP, LAKE ABSEGAMI BASS RIVER STATE FOREST, BURLINGTON COUNTY NEW GRETNA, NEW JERSEY		SCALE: 1" = 2000'	50 LAMBERT LANE LAMBERTVILLE, NJ 08530 PHONE: (609) 397.5335 FAX: (609) 397.5333
			DRAWN BY: MJB	
			CHECKED BY: GMG	

Lake Absegami is located within in the Mullica-Tom's Watershed. The surface waters of Bass River State Forest, include Tommy's Branch from the headwaters to Bass River State Forest Recreation Area service road, Falkinburg Branch of Lake Absegami from its headwaters to the lake, Lake Absegami proper, and other associated surface waters. All are classified as FW-1 waters by the State of New Jersey. FW-1 waters are those freshwaters designated as such in NJAC 7:9B-1.15(h). These waters are to be maintained in their natural state of quality (set aside for posterity) and not subjected to any man-made wastewater discharges or increases in anthropogenic activities (NJAC 7:9). Despite its "protected" status, Lake Absegami is still listed on the USEPA's 303(d) list (1998) of impaired waters. According to the USEPA, Lake Absegami's impairments include algal growth with elevated chlorophyll *a* concentrations and excessive aquatic macrophyte (plant) growth.

The New Jersey Pinelands or Pine Barrens, located in southeastern New Jersey, is a vast expanse of land containing towns, villages, farms, extensive unbroken forests of pine, oak and cedar, and the Pine Plains, the largest pigmy pine forest in the United States. It is comprised on upland, aquatic and wetland environments of approximately 400,000 contiguous hectares (988,400 acres) containing sandy, acidic, coastal plain soils. Bass River State Forest is located in the heart of the Pinelands (NJ Pinelands Commission, 1991). Thus, development within the forest must follow the guidelines established within the Pinelands Comprehensive Management Plan.

The Pinelands National Reserve, including the Pine Barrens, is located in southeastern New Jersey (http://www.burlco.lib.nj.us/pinelands/factsht.htm) (Figure 2). It is approximately 1.1 million acres in size and comprises 22% of the land in New Jersey land. The Pinelands National Reserve covers portions of 7 counties (Burlington, Ocean, Camden, Cape May, Cumberland, Gloucester and Atlantic counties) and all or parts of 56 municipalities (Figure 3). It is the largest tract of continuous open space in the mid-Atlantic region between Richmond and Boston. Almost 40% of the Pinelands National Reserve is in public ownership; the remaining land is privately owned (http://www.familyfishing.com/pbc/overview.asp). As of 1 January 1989, 308,000 acres were in State ownership, including the State parks and forests Wharton, Lebanon, Bass River, Belleplain, Island Beach and Colliers Mills. In addition, approximately 90,000 acres are in federal ownership and include Fort Dix, McGuire Air Force Base, NAVAIR Lakehurst, the NAFEC and the Forsythe and Cape May wildlife refuges.

The Pinelands National Reserve is located in the Atlantic Outer Coastal Plain. This geological formation is characterized by gently rolling terrain and sandy soils. (http://www.familyfishing.com/pbc/overview.asp; http://www.burlco.lib.nj.us/pinelands/plprofle.htm) Underlying the Pinelands National Reserve is the Kirkwood-Cohansey Aquifer System which consists of unconsolidated sand and gravel. The aquifer is estimated to hold 17 trillion gallons of very pure water (enough to cover the state of New Jersey in 10 feet of water); the aquifer is recharged by a long-term average of 45" of rainfall per year. Streams, rivers, bogs, marshes and swamps in the Pinelands National Reserve are fed by the aquifer. Major rivers include the Mullica, Great Egg Harbor, Maurice and Toms. The Great Egg Harbor and the Maurice River have been designated as wild and scenic rivers. The Preservation Area of Pines is transversed by the Mullica River. Lakes Lenape, Oswego, Absegami and Harrisonville are man-made and were created by damming streams and other wetlands.

The Pinelands National Reserve is home to over 1,200 plant and animal species (http://www.burlco.lib.nj.us/pinelands/plprofle.htm). Of these, 54 plant and 39 animal species are threatened with extinction in New Jersey. The reserve is home to the Pine Plains, the most extensive Pigmy Pine forest in the United States; Pigmy Pines are a dwarf variety of pitch pines. Other rare organisms found in the reserve include broom crowberry, timber rattlesnake, the Pine Barrens tree frog and the 3" curly grass fern (http://www.familyfishing.com/pbc/overview.asp). The fern grows only in shady cedar swamps and the only other place it is found is Long Island, NY.

In addition to native wild flora and fauna, the Pinelands area has been home to human habitation for thousands of years. Information collected from over 1,000 historic sites provides evidence of human habitation as early as 10,000 B.C. The landscape of the area at 10,000 B.C. was tundra-like. However, due to natural changes in global ecology (e.g. melting of glaciers, global warming and cooling, sea-level changes, etc.) by 5,000 B.C. the landscape had been modified to one similar to that existing today (http://www.familyfishing.com/pbc/ overview.asp). Europeans first inhabited the area in the 17th century. However, it was only after 1765 when furnaces were built to utilize natural iron deposits found in the bogs, that large amounts of human settlement occurred. Shortly thereafter, glass production using sands of the region began.

In the mid-19th century, iron and glass production declined, railroads were built and the berry and resort industries were established. Today, the Pinelands National Reserve area is home to about 700,000 people. Population densities range from 10 people per square mile in the interior regions to greater than 4,000 people per square mile in the developed communities along the edge of the region. Current industries in the reserve include agriculture, recreation, resource (sand and gravel) extraction and utilization, shell fishing, construction (in the periphery) and government organizations (i.e. military establishments). Agricultural activities include blueberry and cranberry production and row and field crop farming. New Jersey is among the top 3 states in blueberry and cranberry production and almost all of these berries are grown in the Pinelands region. Recreational activities important in the Pinelands include hiking, boating, fishing, camping, hunting, fishing, horseback riding and photography.

Due to the importance of the Pinelands as both a site of historical importance relative to human habitation and as the home of a richly diverse body of native flora and fauna, in 1978 and 1979 Congress and the State of New Jersey passed legislation to protect the area (http://www. familyfishing.com/pbc/overview.asp). Another sign of the ecological and biological importance of the Pinelands is its designation as a Biosphere Reserve by the United States Man and Biosphere Program and the United Nations Educational, Scientific and Cultural Organization (UNESCO). This designation illustrates the importance of the Pinelands as an indispensable example of one of the world's major ecosystem types. The Pinelands National Reserve is protected by, and its development guided by, the Pinelands Comprehensive Management Plan which is administered by the New Jersey Pinelands Commission in conjunction with local, state and federal government units. The Pinelands National Reserve is now divided primarily into 8 areas with development guidelines existing for each area type (http://www.familyfishing.com/pbc/factsheet.asp). These areas are:

1. Preservation Areas, approximately 294,000 acres in size, in which resource related uses and limited residential development are allowed,

2. Special Agriculture Production Areas, approximately 36,300 acres in size, in which berry agriculture uses and related development are allowed,

3. Agriculture Production Areas, approximately 67,300 acres in size, in which agricultural uses and related development are allowed,

4. Forest Area, approximately 246,800 acres in size, in which resource related industries and low density residential development are allowed,

5. Rural Development Area, approximately 116,700 acres in size, in which moderate density development is allowed,

6. Regional Growth Area, approximately 77,100 acres in size, in which moderately high residential development and commercial and industrial development is allowed,

7. Military and Federal Institutional Area, approximately 461,000 acres, in which appropriate use development is allowed,

8. Towns and Municipalities-56 throughout the Pinelands in which development consistent with existing character is allowed.

In addition to guidelines associated with these development areas, there are management programs designed to help protect the Pinelands. Resource protection programs are designed to protect natural resources including wetlands, vegetation, fish and wildlife, water resources, air quality, science resources and cultural resources. Development management programs related to forestry, resource extraction, waste management, recreation and fire management exist. Finally, there are management programs designed to guide agricultural development and activities.

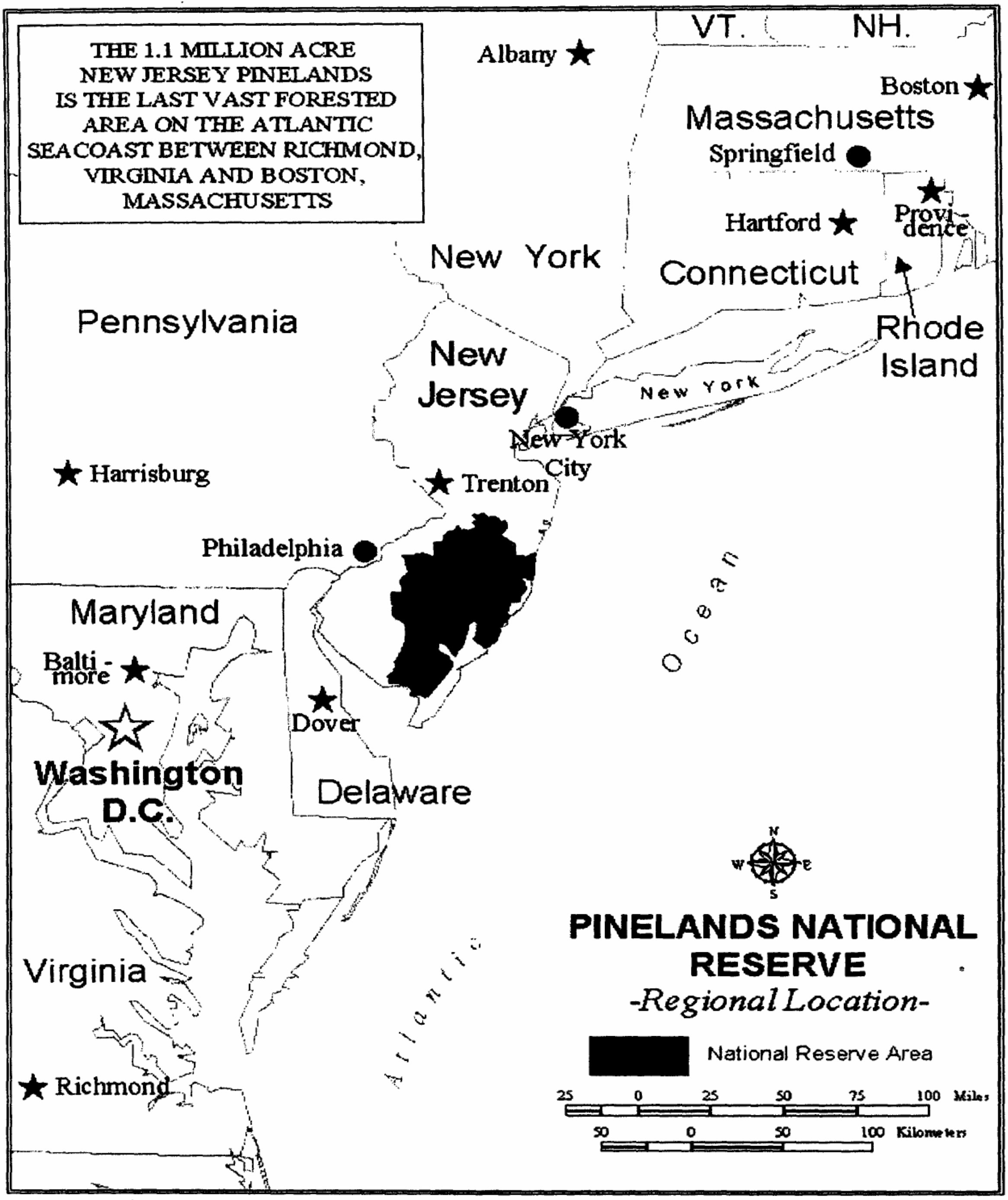


Figure 2: Regional Location of Pinelands National Reserve
(http://www.state.nj.us/pinelands/pinecur/rlm.htm)

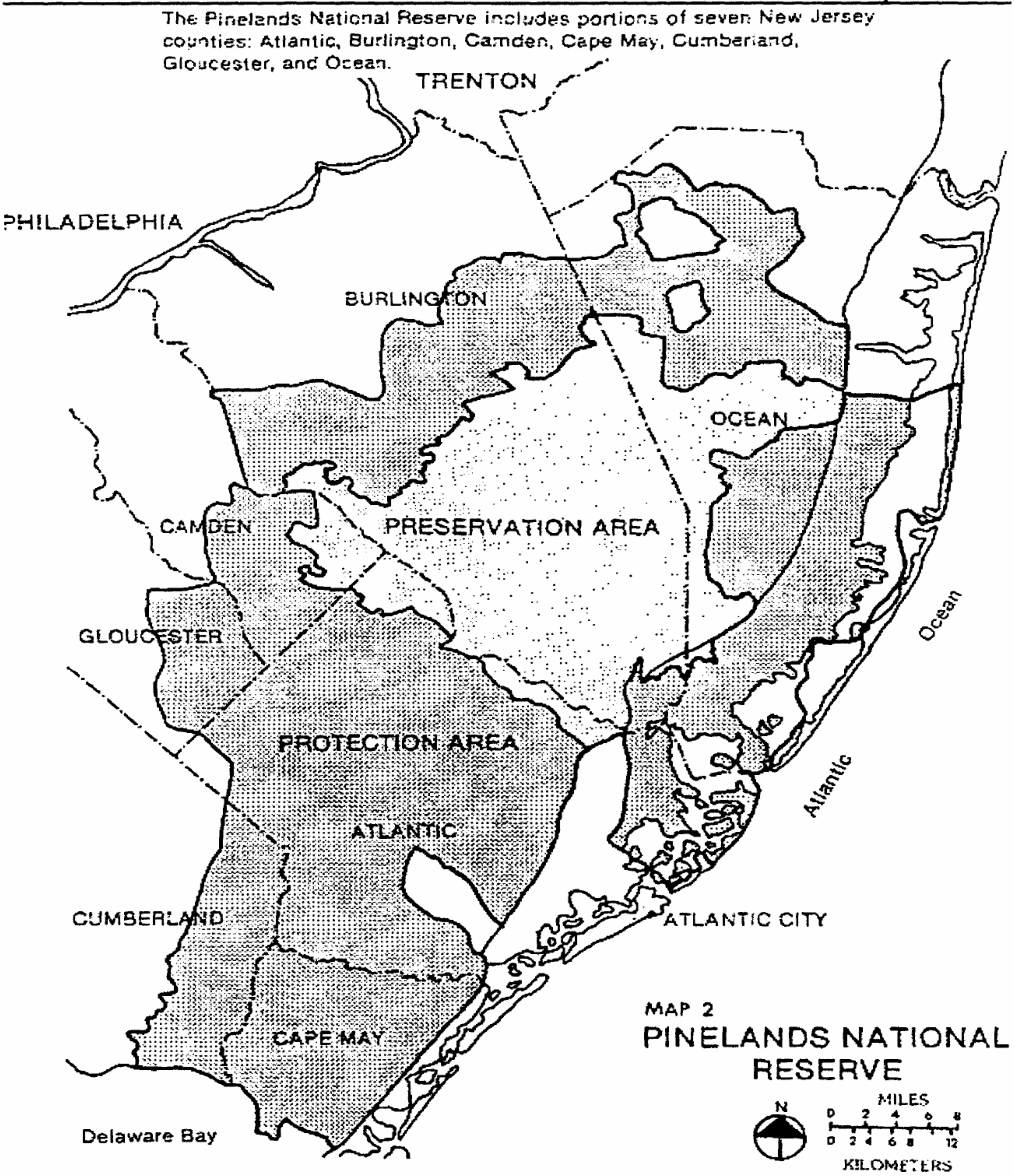


Figure 3: Location of Pinelands National Reserve in southeastern New Jersey
(http://www.state.nj.us/pinelands/pinecur/presmap.htm

Section 2 Characterization of Lake Morphometry

Lake Absegami has a surface area of 52.6 acres (21.3 hectares) (Figure 4; Table 1). It has a northeast and southeast branch of elliptical shape with a length of approximately 6,000 feet (1.83 x 10^3 m) running north-south and a width of approximately 3,500 feet (1.07 x 10^3 m) running east-west. The shoreline of the lake is very regular with no major cove areas.

A bathymetric survey of the lake was conducted by Princeton Hydro on 11 September 2001. A series of transects was surveyed with either a continuous recording fathometer or, in the more shallow areas, a graduated sounding rod. The data were used to generate a bathymetric map (Figure 5), representing water depths throughout the entire lake.

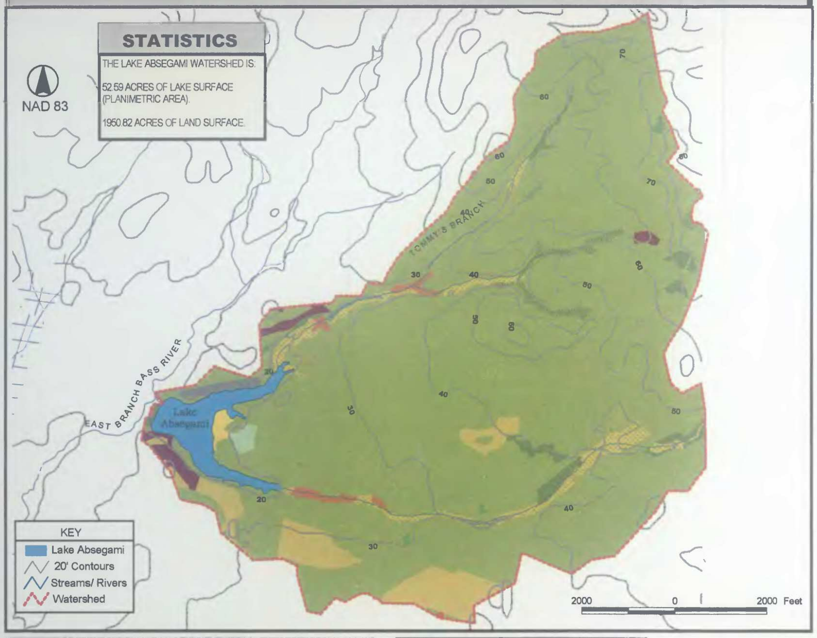
The bathymetric data reveals Lake Absegami is a shallow system with a mean depth of 3.25 ft (0.99 m) and a maximum depth of 7.44 ft (2.27 m). The volume of water was calculated to be 98.37 acre-feet (1.21 x 10^5 m^3).

In addition to water depth, data were collected on the depth or "thickness" of the unconsolidated sediments in Lake Absegami (Figure 6). Such data are absolutely essentially in order to quantify the costs associated with dredging the lake. The quantified sediment thickness data was used to calculate the total volume of 1.7 x 10^5 m^3 (136.35 acre-ft) of unconsolidated sediments in Lake Absegami. Please note this quantified volume of unconsolidated sediments is limited to those areas of the lake that were survey in detail (Figure 6).

Finally, the morphometric data were combined with select hydrologic data to calculate Lake Absegami's hydraulic residence time and annual flushing rate (Table 1), two important parameters with regard to management of a lake. The hydraulic residence time is the amount of time required to completely replace the lake's current volume with "new" water. It can also be thought of how long one molecule of water will be in the lake before it leaves via the main outflow. The annual flushing rate, which is the inverse of the hydraulic residence time, is the rate at which water enters and leaves a lake relative to its volume. As will be shown in Sections 5 through 7, these parameters assist in determining how efficiently incoming nutrients will be assimilated by algae and plants. In turn, this will influence in-lake water quality conditions through the growing season.

LAKE ABSEGAMI WATERSHED

WATERSHED AREA / LAND USE & LAND COVER

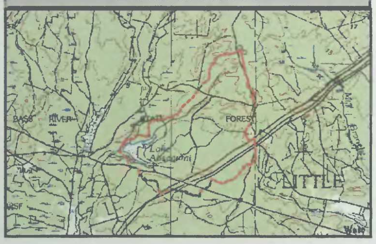


COLOR AERIAL PHOTOGRAPHY

LEGEND

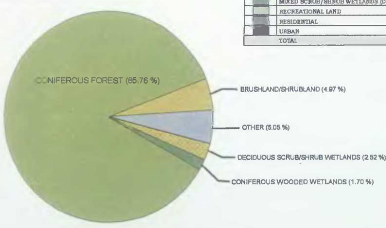
KEY	DESCRIPTION	NWI LABEL	GROUPING	ACREAGE	PERCENTAGE
	ATLANTIC WHITE CEDAR WETLANDS	PFO8E	WETLANDS	14.53	0.74
	BARREN LAND		BARREN LAND	4.86	0.25
	BRUSHLAND/SHRUBLAND		FOREST	96.87	4.97
	CONIFEROUS FOREST		FOREST	1673.04	85.76
	CONIFEROUS WOODED WETLANDS	PFO4B	WETLANDS	33.09	1.70
	CONIFEROUS/DECIDUOUS FOREST		FOREST	0.21	0.01
	DECIDUOUS SCRUB/SHRUB WETLANDS	PSS1E	WETLANDS	49.18	2.52
	DECIDUOUS WOODED WETLANDS	PFO1E	WETLANDS	1.32	0.07
	EXTRACTIVE MINING		BARREN LAND	0.40	0.02
	MIXED FORESTED WETLANDS (CONIFEROUS DOM.)	PFO4/1B	WETLANDS	18.45	0.95
	MIXED FORESTED WETLANDS (DECIDUOUS DOM.)	PFO1/4E	WETLANDS	22.10	1.13
	MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS DOM.)	PSS1/8E	WETLANDS	2.85	0.15
	RECREATIONAL LAND		URBAN	5.71	0.29
	RESIDENTIAL		URBAN	8.53	0.44
	URBAN		BARREN LAND	19.70	1.00
	TOTAL			1950.84	100.0

LAKE VICINITY



DATA SOURCES

1. New Jersey, Department of Interior, Geologic Survey, GIS Data Downloads, Elevation Models of New Jersey, New Jersey. Scale 1:100,000, 1986
2. New Jersey, Department of Environmental Protection, GIS data Web Site Downloads State Municaplities of New Jersey &Land Use/ Land Cover of Burlington County Scale 1:100,000, 1995-1997
3. New Jersey, Department of Interior, Geologic Survey, GIS Data Downloads, Monochromed Bitmapped Elevation Images of Burlington County, New Jersey. Scale 1:24,000, 1986
4. Color Aerial Photography, NJDEP GIS Digital Data, but this secondary product has not been verified by NJDEP and is not state authorized. Scale 1:24,000, 1995 - 1997



PERCENTAGE OF LAND TYPES

FIGURE 4: BASS RIVER STATE FOREST NEW GRETNA, BURLINGTON COUNTY NEW JERSEY, LAKE ABSEGAMI

NOTES:
1.) DATA ACCURACY IS LIMITED TO THE ACCURACY AND SCALE OF THE ORIGINAL DATA SOURCES.

2.) THIS MAP IS PART OF A DIAGNOSTIC FEASABILITY STUDY, AND SHOULD BE USED IN CONJUNCTION WITH THE ASSOCIATED TEXT.

pH

Project No.: 209.01

DRAWN BY:	KJM.CW
CHECKED BY:	FSL

Table 1

Lake and Watershed Statistics for Lake Absegami

Parameter	Value
Lake Surface Area	52.6 acres (21.3 hectares)
Watershed Area	1,950.8 acres (789.46 hectares)
Mean Depth	3.25 ft (0.99 m)
Maximum Depth	7.44 ft (2.27 m)
Lake Volume	98.37 acre-ft (1.21×10^5 m^3)
Annual Discharge	3.7×10^6 m^3/yr
Hydraulic Residence Time	0.033 yr (12 days)
Flushing Rate	30.5 times/yr
Watershed Area/Lake Surface Area Ratio	37.10

LAKE ABSEGAMI SEDIMENT THICKNESS

STATISTICS

CONDITIONS AT TIME OF SURVEY:

1.) THE LIMITS OF THE SURVEY ARE DUE TO HIGH QUANTITIES OF BIOLOGICAL INTERFERENCE, AND LOW WATER LEVELS, MAKING ACCESS TO THE OUTER-MOST PORTIONS OF THE LAKE IMPOSSIBLE.

2.) THE WATER LEVEL AT THE TIME OF SURVEY IS 4.75'. MEASURED FROM THE TOP OF THE DAM ON THE NORTHERN SIDE AT THE CONFLUENCE WITH BASS RIVER.

INLAKE DATA AT TIME OF SURVEY:

1.) VOLUME OF WATER:
98.37 ACRE-FT

2.) MEAN DEPTH:
3.25 FT

3.) MAXIMUM DEPTH:
7.44 FT

4.) PLANIMETRIC AREA:
44.85 ACRES

5.) TOTAL VOLUME OF SEDIMENT:
136.35 ACRE-FT

6.) MEAN SEDIMENT THICKNESS:
3.18 FT

STATE OF NEW JERSEY

BURLINGTON COUNTY

BURLINGTON COUNTY, NJ

Bass River Township

DATA SOURCES

1.) IN WATER DEPTH SURVEY CONDUCTED ON SEPTEMBER 11, 2001, BY PRINCETON HYDRO, LLC, 1108 OLD YORK ROAD SUITE 1, P.O. BOX 720, RINGOES, NJ 08551.

2.) METHODS USED TO CONDUCT THE BATHYMETERIC SURVEY CONFORM TO CLASS 1, USACE PROCEDURES ARE ACCURACIES.

KEY

Lake Absegami
Streams/ Rivers

SEDIMENT THICKNESS CONTOURS

SEDIMENT THICKNESS IN FEET
1

100 0 100 200 300 Feet

Scale: 1 : 400

NAD 83

FIGURE 6: BASS RIVER STATE FOREST NEW GRETNA, BURLINGTON COUNTY NEW JERSEY, LAKE ABSEGAMI

NOTES:
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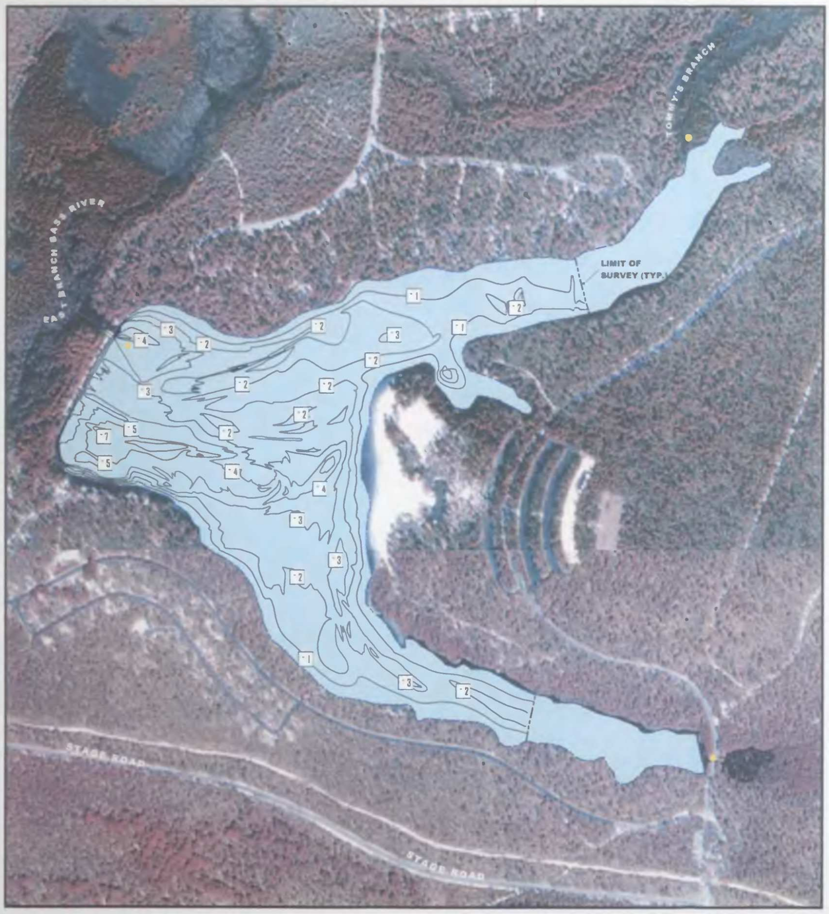
LAKE ABSEGAMI WATER DEPTH



STATISTICS

CONDITIONS AT TIME OF SURVEY:

1.) THE LIMITS OF THE SURVEY ARE DUE TO HIGH QUANTITIES OF BIOLOGICAL INTERFERENCE, AND LOW WATER LEVELS, MAKING ACCESS TO THE OUTER-MOST PORTIONS OF THE LAKE IMPOSSIBLE.

2.) THE WATER LEVEL AT THE TIME OF SURVEY IS 4.75'. MEASURED FROM THE TOP OF THE DAM ON THE NORTHERN SIDE AT THE CONFLUENCE WITH BASS RIVER.

INLAKE DATA AT TIME OF SURVEY:

1.) VOLUME OF WATER: 98.37 ACRE-FT

2.) MEAN DEPTH: 3.25 FT

3.) MAXIMUM DEPTH: 7.44 FT

4.) PLANIMETRIC AREA: 44.85 ACRES

5.) TOTAL VOLUME OF SEDIMENT: 136.35 ACRE-FT

6.) MEAN SEDIMENT THICKNESS: 3.18 FT

KEY

Lake Absegami
Streams/ Rivers
Sampling Points

BATHYMETRIC CONTOURS

IN FEET BELOW WATER SURFACE
-1

100 0 100 200 300 Feet

Scale 1 : 400

NAD 83

DATA SOURCES

1.) IN WATER DEPTH SURVEY CONDUCTED ON SEPTEMBER 11, 2001, BY PRINCETON HYDRO, LLC, 1108 OLD YORK ROAD SUITE 1, P.O. BOX 720 RINGOES, NJ 08551.
2.) METHODS USED TO CONDUCT THE BATHYMETERIC SURVEY CONFORM TO CLASS 1, USACE PROCEDURES ARE ACCURACIES.

FIGURE 5: BASS RIVER STATE FOREST NEW GRETNA, BURLINGTON COUNTY NEW JERSEY, LAKE ABSEGAMI

NOTES:
1.) DATA ACCURACY IS LIMITED TO THE ACCURACY AND SCALE OF THE ORIGINAL DATA SOURCES.

2.) THIS MAP IS PART OF A DIAGNOSTIC FEASABILITY STUDY, AND SHOULD BE USED IN CONJUNCTION WITH THE ASSOCIATED TEXT.

pH

Project No.: 209.01

DRAWN BY:	KJM,CW
CHECKED BY:	FSL

Section 3 Water Quality Data

Princeton Hydro, LLC conducted seven (7) in-lake water quality monitoring events at Lake Absegami between 22 September 2000 and 10 October 2001. In addition, three storm water monitoring events were also conducted on 30 May 2001, 15 September 2001 and 20 March 2002 These monitoring events were conducted to document the general "health" of the lake and aid in the quantification and refinement of its annual pollutant budget. In addition, stormwater monitoring focused on the inlet stations during or immediately following a storm event to provide information on the magnitude of the storm-associated pollutant loading. Both *in-situ* monitoring and discrete water quality sampling were conducted for a variety of physical, chemical and biological parameters.

3.1 In-situ Water Quality Data

During the in-lake monitoring events, temperature, dissolved oxygen, pH and specific conductance were measured at 0.5 to 1.0 meter intervals from surface to bottom at the mid-lake sampling station and, when applicable, at the surface of the two inlet stations. The three sampling stations are shown in Figure 5. Routine (non-storm event) monitoring data were collected from the mid-lake and inlet sampling stations from 22 September 2000 to 13 June 2001. Only the mid-lake station was monitored on the remaining routine monitoring dates due to the severe drought experienced during the summer and fall of 2001. Storm event monitoring occurred on 30 May 2001, 15 September 2001 and 20 March 2002; only the inlets were monitored on these dates.

Temperature

Temperature is one of the most important water quality parameters since it controls the rate of all chemical and biological reactions and influences the physical structure of a lake or pond. As the air temperature increases through the growing season, the temperature of the surface layers of water increases. This results in the surface layers being warmer than the bottom layers of water. Once the temperature difference between the surface and the bottom layers is large enough (e.g. a difference of > 1 °C per meter), thermal layering of a water body can occur. After the temperature difference exceeds 3 °C, a water body can become strongly thermally stratified. Stratification substantially minimizes the transfer of material and gases between the surface layers (the epilimnion) and the bottom layers (the hypolimnion). For example, in productive waterbodies, once the hypolimnion is cut off from the epilimnion, atmospheric oxygen can not enter the deeper waters, resulting in anoxia (dissolved oxygen concentrations < 1 mg/L). Such conditions have a substantial impact on the overall water quality of a lake.

The temperature of Lake Absegami ranged from 14.54 °C to 29.64 °C, with an average of 23.2 °C (Appendix A). The inlet temperatures were approximately 5 °C cooler than the lake, ranging from 14.89 °C on 22 September 2000 to 20.78 °C on 13 June 2001; the corresponding average lake temperatures on those dates were 21.4 °C and 26.2 °C, respectively.

Large differences between the surface and bottom layers of Lake Absegami were not observed during six of the seven in-lake monitoring events (Appendix A). Only on 3 May 2001 did the lake appear to be slightly layered, with a temperature difference of 1.28 °C between the surface and 1 m deep waters; the temperature difference between the 1 m and 2 m depths was only 0.45 °C. The relatively shallow depth of the lake prevented the establishment of strong temperature differences, thereby allowing the water column to continually mix. Thus, thermal stratification was extremely rare in Lake Absegami.

Dissolved Oxygen

In order to maintain a healthy and diverse aquatic ecosystem, the minimum dissolved oxygen (DO) concentration should be 5.0 mg/L. While many organisms can tolerate relatively low DO concentrations, 4.0 mg/L is the absolute minimum for more sensitive organisms including most species of trout. At no time were DO concentrations in Lake Absegami as low as 4.0 mg/L; the lowest concentration measured was 4.93 mg/L and the mean concentration was 7.63 mg/L (Appendix A). Based on these data, it is unlikely that the aquatic organisms of Lake Absegami were stressed by low DO levels.

On 13 June 2001 and 10 October 2001, the DO concentrations of the bottom layers of Lake Absegami were greater than those of the surface layers. This was most likely due to high rates of photosynthesis by rooted aquatic plants and/or benthic algae. On 28 September 2001, the DO concentration of the surface layers was greater than that of the bottom layers. Higher DO concentrations at the surface are common during the summer months due to algal photosynthesis in the upper waters and elevated bacterial decomposition in the deeper waters. Algal and aquatic plant photosynthesis produce dissolved oxygen as a by-product. Thus, the higher the rate of photosynthesis, the more DO being produced. Conversely, bacterial decomposition of organic matter requires DO, so elevated rates of bacterial decomposition immediately over the sediments tends to reduce DO concentrations.

pH

The acidity or alkalinity of a waterbody is measured in units called pH. Essentially, pH is a measurement of the concentration of the hydrogen ion (H^+). Alkalinity is a commonly used term describing the basicity of water, typically representing a pH greater than 7. Generally, the basic species responsible for alkalinity in water are bicarbonate ion (HCO_3^-), carbonate ion (CO_3^{2-})and hydroxide ion (OH^-). Conversely, waters with a pH of less than 7 are acidic waters, in which case pH is dominated by the presence of hydrogen ions (H^+). A pH of 7 is considered neutral (i.e. distilled water has a pH of 7.0).

Overall, the pH of Lake Absegami and its tributaries was moderately acidic (Appendix A). The mid-lake pH varied from 4.55 to 5.70 through the course of the Phase I monitoring program. The inlet pH varied from 4.79 to 5.1.

On 22 September 2000, the mid-lake pH ranged from 5.18 to 5.28. The pH values of inlet streams #1 and #2 were 5.10 and 5.04, respectively. On 3 May 2001, the mid-lake pH ranged from 4.71to 4.75; inlet streams #1 and #2 were similar to the mid-lake values at 4.79 and 4.84, respectively. On 13 June 2000, the mid-lake pH varied between 4.92 and 5.70; the pH of inlet streams #1 and #2 was slightly lower at 4.90-4.91. Only the mid-lake pH was measured for the duration of the sampling dates. Overall, the pH measurements taken on these four sampling dates were similar to those measured during the first three sampling events.

The optimal range of pH for most aquatic organisms is generally between 6.0 and 8.0. However, this is not always the case, as demonstrated in Lake Absegami. Due to Lake Absegami's proximity to the NJ Pine Barrens, its water are more naturally acidic and, therefore, its organisms are well adapted to tolerate these conditions. Therefore, it is unlikely that the organisms within and around Lake Absegami are stressed by its relatively low acidity.

Specific Conductance

Specific conductance (a.k.a. conductivity) is a measurement of a solution's resistance to electrical current/flow with higher conductivity measurements indicating lower resistance. The resistance of a solution decreases with increasing solute (e.g. salt) concentration. Therefore, conductivity can be used as an indirect measurement of the concentration of dissolved substances in water, with higher conductivity values indicating greater solute concentrations.

The conductivity values of Lake Absegami varied between 0.0530 and 0.4515 mmhos/cm (Appendix A). Conductivity values of 0.0530 mmhos/cm can be considered to be very low which is not unusual for waters associated with the Pine Barrens. However, values of 0.4515 mmhos/cm can be considered to be high and values > 0.5 mmhos/cm in New Jersey freshwaters are usually associated with productive waters. Conductivity levels of this magnitude can also reflect higher solute concentrations due to higher nutrient loads from runoff/leaching of fertilizers. High conductivity values may also be the result of industrial air pollution which results in the contamination of surface waters through atmospheric precipitation. In addition, higher conductivity (solute concentrations) values may be the result of the movement of road salts into receiving surface waters following snow melt. The transport of road salts, and other possible contaminates, to receiving waterways may also be facilitated by the subsequent movement of groundwater into surface water.

Secchi Depth and Water Color

The water clarity of Lake Absegami was measured with a Secchi disk, which is a weighted circular disk 23 cm in diameter with four alternating black and white sections painted on the surface. The disk is attached to a measured line that is marked off either in meters or feet. The disk is slowly lowered into the water until it can no longer be seen. At this point the observer records the depth with the calibrated line. The disk is then slowly raised until it reappears. Once it reappears, this depth is recorded. The average of the two values is the Secchi depth. The clearer the water, the greater the Secchi depth value. Secchi depth was measured at the mid-lake station during each in-lake sampling event.

Secchi depth was measured at the mid-lake sation during each in-lake monitoring event. On each of these dates, Secchi depth was equal to the depth of the lake. Therefore, visibility was to the bottom of Lake Absegami (Appendix A). Observations made during the monitoring events revealed that there was little aquatic vegetative growth within the lake. Some benthic algae and various rushes were identified in the littoral zone, while some submerged aquatic vegetation were observed in the more shallow waters of the lake. Thus, the relatively low amount of algal and aquatic plant growth in Lake Absegami contributed toward the clear water conditions.

While the water of Lake Absegami is relatively clear, it also tends to have a dark or brownish or black color. Such "tea" or dark colored waters are typical for surface waters within the Pine Barrens, especially for non-flowing waters. As will be described in detail later in this report these darker waters are attributed to elevated concentrations of iron and/or humic acids. While these observed conditions may give the water a perceived unpleasant or unattractive appearance, it is the natural color of the water. Given the unique appearance and value of the Pine Barren ecosystem, visitors to the State Forest should be educated on why the waters of Lake Absegami are dark in color.

3.2 Discrete Water Quality Data

In addition to the *in -situ* monitoring, discrete samples were collected from the mid-lake and inlet stream stations for the analysis of a variety of chemical and biological parameters. Samples were transported to a State-certified laboratory for chemical analysis. Mid-lake and inlet samples were analyzed for nitrate-N (NO_3^-), nitrite-N (NO_2^-), total Kjeldahl nitrogen (TKN), total phosphorus (TP), total suspended solids (TSS) and total iron. Samples were also analyzed for chlorophyll *a* and fecal coliform. . In addition, mid-lake samples were analyzed for alkalinity, hardness, ammonia, soluble reactive phosphorus (SRP), arsenic, zinc and lead. Inlet water samples were also collected during or immediately after three storm events. These samples were analyzed for nitrate-N, nitrite-N, TKN, TP, TSS, arsenic, lead, and zinc.

Additional biological sampling included the enumeration and identification of phyto- and zooplankton. On each sampling date, a sub-surface sample was collected for phytoplankton, while a Schindler-plankton trap was used to collect a sub-surface sample for zooplankton. The phyto- and zooplankton samples were preserved with Lugol's solution and transported to Princeton Hydro's biological laboratory where the dominant organisms were identified to the lowest practical taxon (genus or species). The resulting microscopic data were used to calculate the abundance and biomass of each identified organism, during each sampling event.

Nitrogen

While phosphorus tends to be the primary nutrient limiting algal and aquatic plant growth in lakes and ponds, nitrogen is another extremely important nutrient. Nitrogen can be found in an aquatic system in a variety of forms; particulate and dissolved, inorganic and organic. However, the two forms that are most easily utilized by algae and aquatic plants are ammonia-N and nitrate-N. Both are dissolved, inorganic forms of nitrogen. In addition to these forms of nitrogen, nitrite-N and total Kjeldahl nitrogen (TKN) were also measured as part of this Phase I Study. For the purpose of this report, ammonia-N is a measurement of N in total ammonia (ammonia (NH_3) and ammonium (NH_4)).

Ammonia-N (NH_3 and NH_4^+), the most reduced form of inorganic N, is a common by-product of the bacterial decomposition of organic matter. Thus, ammonia-N has the potential to accumulate in a lake or pond. However, since algae and aquatic plants easily assimilate ammonia-N for growth, concentrations tend to be low (< 0.05 mg/L) in most natural ecosystems. Ammonia (NH_4^+) concentrations in unpolluted waters tend to range between < 0.05 to XX mg/L. Mid-lake ammonia-N concentrations ranged from 0.03 to 0.1 mg/L through the course of the Lake Absegami monitoring program (Appendix B). Thus, ammonia-N concentrations in Lake Absegami were relatively low and did not pose a treat in terms of algal blooms or excessive aquatic plant growth.

When ammonia-N concentrations are low to moderate and the pH varied to acidic to neutral, ammonia (NH_4^+) is not very toxic to aquatic organisms. Ammonium hydroxide, a third form of ammonia-N, is highly toxic to aquatic organisms. However, this form of ammonia-N is not present in high concentrations under acidic to neutral pH conditions (Goldman and Horne, 1983). However, ammonium hydroxide increases with an increase in pH and water temperature. Given the naturally acidic state of Lake Absegami, the potential for ammonium toxicity is extremely low, even during the hot summer season.

Even under acidic or neutral pH conditions, ammonium hydroxide is highly toxic to young rainbow trout fry when ammonia-N concentrations exceeds 0.3 mg/L. The highest in-lake ammonia-N concentration measured during the Phase I monitoring program was 0.1 mg/L, so potential ammonium toxicity, even to young rainbow trout, was extremely unlikely in Lake Absegami.

Nitrate-N is another form of dissolved, inorganic nitrogen that is readily utilized by algae and aquatic plants for growth. Nitrate-N tends to be more mobile in surface- and groundwater relative to ammonia-N and can be generated through microbial activities such as nitrification. However, bacterial decomposition of organic matter does not produce nitrate-N. Thus, in the absence of other input sources, algal and aquatic plant uptake of nitrate-N tends to keep its concentration relatively low in lakes and ponds.

Nitrate-N concentrations in Lake Absegami were < 0.04 mg/L on all sampling dates except 23 September 2000 when the measured nitrate-N concentration was 0.06 mg/L (Appendix B). Inlet #1 and #2 concentrations varied between non-detectable (< 0.04 mg/L) and 0.08 mg/L. The concentration of nitrate-N in storm event samples ranged from < 0.04 mg/L to 0.27 mg/L.

For sources of potable water, the Federal and State limit for nitrate-N is 10 mg/L. In addition, summer nitrate-N concentrations greater than 1.0 mg/L can generate excessive amounts of algal and aquatic plant biomass. Mid-lake and inlet nitrate-N concentrations during the non-storm event sampling event were less than or equal to 0.08 mg/L through the course of the monitoring program (Appendix B). Thus, nitrate-N concentrations were well below both the potable water and ecological nitrate-N threshold values. The higher storm event nitrate-N concentrations of 0.11 and 0.27 mg/L from inlet #2 most likely reflect the movement of nitrogen into the lake via storm associated runoff.

Nitrite-N, a dissolved, inorganic form of N, concentrations were also measured in Lake Absegami and its inlets. Nitrite-N is highly unstable and is quickly converted into nitrate-N in surface waters through the microbial process of nitrification. Thus, the presence of relatively elevated concentrations of nitrite-N in a lake or pond may indicate that a large portion of the incoming hydrologic load originates from groundwater.

The nitrite-N concentrations of Lake Absegami and its inlets were not detectable, being < 0.003 mg/L on all sampling dates except on 23 September 2000 when the mid-lake nitrite-N concentration was 0.01mg/L (Appendix B). Nitrite-N concentrations in the storm event samples varied between non-detectable (< 0.003 mg/L) and 0.03 mg/L. Therefore, the nitrite-N concentrations of Lake Absegami and its inlets can be considered low, even during storm events. Also, groundwater does not appear to contribute significant amounts of nitrite-N to the system. In terms of toxicologic concerns, the Federal and State limit for nitrite-N in drinking water sources is 1.0 mg/L. Additionally, nitrite-N can be toxic to aquatic organisms, usually at concentrations of 0.06 mg/L. Since the concentration of nitrite-N did not exceed 0.03 mg/L during the Phase I Study, the nitrite-N concentrations were well below both the potable water and ecological nitrite-N threshold values.

TKN is a measurement of both the ammonia and organic forms of nitrogen. Of these two types of nitrogen, only ammonia can contribute to eutrophication of waterbodies. Furthermore, ammonia is toxic to aquatic life at high concentrations. However, since TKN measures all organic forms of nitrogen, it can be used as an indirect indicator of total nitrogen.

The TKN concentrations of Lake Absegami and its inlets during the non-storm event sampling events ranged from non-detectable (< 0.06 mg/L) to 0.36 mg/L (Appendix B). The inlet concentrations during storm events ranged from non-detectable (< 0.06 mg/L) to 2.3 mg/L. TKN concentrations in unpolluted, natural waters tend to vary between 0 and 5 mg/L. Thus, even inlet concentrations during a storm event at Lake Absegami had lower TKN concentrations than the maximum TKN concentration expected for unpolluted waters.

Phosphorus

Phosphorus tends to be the primary limiting nutrient for most freshwater waterbodies within the mid-Atlantic section of the United States. In other words, it takes very little phosphorus to stimulate large amounts of algal and/or aquatic plant growth; as phosphorus concentrations increase, the amount of algal and/or aquatic plant biomass will also increase. Thus, reducing current phosphorus loads, as well as controlling future loads, is an effective, long-term strategy in improving and preserving the water quality of a lake or pond.

Two forms of phosphorus were measured in Lake Absegami. The first was total phosphorus (TP), which measures all the phosphorus in the water; inorganic and organic, particulate and dissolved. Most water quality models are based on in-lake TP concentrations. If TP is considered "food" for algae and aquatic plants, then SRP can be considered "candy". Soluble reactive phosphorus (SRP) measures the dissolved inorganic forms of phosphorus that are easily assimilated by algae and aquatic plants for growth. Other forms of phosphorus, such as organic phosphorus, can also be utilized, however, more energy must be exerted to assimilate such forms. Thus, the first type of phosphorus that algae and aquatic plants will utilize is SRP. This provides a valuable means of assessing potential water quality problems; elevated SRP concentrations may indicate a potential algal bloom in the near future.

It has been well documented that in-lake TP concentrations greater than 0.03 mg/L can stimulate high levels of algal and/or aquatic plant growth. Under such conditions, a lake or pond is described as being eutrophic, meaning it is highly productive. Thus, such waterbodies have the potential to experience algal blooms and excessive densities of aquatic plants. Based on Princeton Hydro's in-house database, if in-lake TP concentrations are greater than 0.06 mg/L, and no large storms are expected within the next week, nuisance-level algal blooms will more than likely occur sometime over the next few days. This threshold of 0.06 mg/L is based on our in-house project experience of lakes located throughout New Jersey, New York and Pennsylvania.

Total phosphorus concentrations were low in Lake Absegami and its inlets, being non-detectable (< 0.02 mg/L) during all non-storm event sampling dates (Appendix B). Total phosphorus concentrations associated with the documented storm events were also non-detectable (< 0.02 mg/L) with the exception of inlet #2 on 15 September 2001 which had a concentration of 0.11 mg/L. Thus, TP concentrations at Lake Absegami were less than the 0.03 mg/L ecological threshold, with the exception of the above mentioned storm event sample.

Based on the measured TP concentrations, Lake Absegami was not seriously threatened by algal blooms, however the potential for occasional algal blooms exists, especially immediately after a storm event. In addition, in-lake TP concentrations did not exceed the 0.06 mg/L threshold of extreme nuisance conditions. The higher TP concentration in inlet #2 during the 15 September 2001 storm event was most likely the result of surface runoff. As will be discussed below, the TSS level of this same storm water sample was high (25 mg/L). The elevated TSS concentration provides evidence that surface runoff transported soils to the lake. Phosphorous is typically transported to surface waters by being adsorbed onto eroding soil/sediment material.

In most freshwater systems, SRP concentrations > 0.01 mg/L are enough to stimulate elevated amounts of algal and/or aquatic plant growth. The SRP concentrations of Lake Absegami were all below the analytical detection limit of 0.003 mg/L except on 23 September 2000 (Appendix B). On this date, the concentration was 0.01 mg/L. Thus, on this date, the SRP concentration of Lake Absegami was sufficient to potentially stimulate elevated algal/aquatic plant growth. However, during a majority of the study, SRP concentrations were more than likely not high enough to stimulate elevated levels of algal/aquatic plant growth.

Total Suspended Solids

Total suspended solids (TSS) is a measure of the amount of particulate matter in water. The State limit for TSS under baseline (non-storm event) conditions is 25 mg/L. TSS concentrations greater than 25 mg/L, under baseline conditions, can negatively impact aquatic habitats. Some of these negative impacts include in-filling of wetlands, lakes and waterways, the destruction of spawning habitat and added physiological stress on fish and benthic macroinvertebrates through suspended sediments settling on their gills. In addition, waterbodies with TSS concentrations greater than 25 mg/L are perceived by the layperson as being "dirty" or "muddy".

Mid-lake and inlet TSS concentrations were low in Lake Absegami, varying between non-detectable (< 2 mg/L) and 5 mg/L, with the exception of the inlet #2 sample collected during the 15 September 2001 storm event (Appendix B). These low TSS concentrations correspond to the high degree of water clarity in Lake Absegami, as was evident by the fact that the Secchi depth was always to the bottom of the lake. Therefore, high TSS concentrations did not threaten the integrity of Lake Absegami during the period in which the lake was being sampled. The TSS concentration of inlet #2 sample during 15 September 2001 storm event was 25 mg/L. The elevated TSS concentration of the 15 September 2001 inlet #2 sample was the result of storm-related surface runoff and/or the mixing of sediments within the water column.

pH

Iron

Iron is the fourth most abundant element, by weight, in the earth's crust and is a natural component of surface- and groundwaters. Water percolating through soil and rocks can carry iron in solution to natural waters. In addition, under anoxic conditions, iron can be released from sediments into overlying waters, thereby adding to their iron content.

Iron is not considered to pose a risk to human health. Instead, it is considered to be a nuisance rather than a health hazard. Elevated concentrations of iron give water a brown, rusty or dirty appearance, as well as produce taste problems in potable water. Iron is considered a secondary drinking water contaminant since its negative impacts are associated with the cosmetic and/or aesthetic quality of potable water. Thus, the US EPA drinking water limit for iron is 0.3 mg/L.

In addition to problems associated with taste, odor and appearance, iron deposits can form in pipelines, pressure tanks, and water heaters and softeners, decreasing the quantity and pressure of the water supply. Nonpathogenic iron bacteria levels can increase in iron rich waters. These bacteria can form a slime in toilet tanks and clog water systems.

Besides its potential to be a water quality nuisance, iron is an important nutrient for algal growth. Iron is an essential component of many enzymatic reactions and other cellular processes. In fact, under particular circumstances, iron can be the dominant nutrient limiting algal growth. However, such conditions are relatively unique and tend to be found in lakes located in the western portion of the United State.

Total iron concentrations in Lake Absegami ranged from below the limit of detection (< 0.10 mg/L) to 0.36 mg/L (Appendix B). Baseline inlet total iron concentrations varied between 0.14 and 0.22 mg/L. Therefore, in general, total iron concentrations of Lake Absegami and its inlets were less than the USEPA potable drinking water limit. The exception to this was on 23 September 2001 when the total iron concentration was the 0.36 mg/L, which slightly exceeded the USEPA's limit. Such elevated total iron concentrations can give the waters a dark or brownish color, as has been observed in Lake Absegami. In addition, Kentucky Water Watch reports an aquatic life standard of 1.0 mg/L using data on toxic effects. Based on this information, it does not appear that the iron concentration of Lake Absegami was great enough to pose risks to aquatic organisms.

Fecal Coliform

Coliform bacteria area group of bacteria that belong to the family Enterobacteriaceae. These bacteria consist of species found in the environment and in the intestinal tract of warm-blooded animals. Fecal coliform are a sub-group of the coliform group that are derived from the feces of warm-blooded animals. While fecal coliform themselves are not a pathogenic group of bacteria, they are indicators of such organisms and therefore make excellent water quality indicators in terms of general health.

Fecal coliform bacteria concentrations were measured at the mid-lake and inlet sampling stations, at a schedule similar to that used for the other discrete water quality parameters. For bathing beaches within the State of New Jersey, the level of fecal coliform deemed to pose a potential problem in terms of public health is 200 colonies per 100 mLs filtered. All of the lake and inlet samples had fecal coliform counts below this threshold with the highest concentration being 30 cells/100 mL (Appendix B).

In addition, the fecal coliform concentration of the inlet samples collected during the storm events were below the 200 colonies per 100 mLs filtered threshold. In fact, the fecal coliform counts during the first two stormwater events were below the analytical detection limit of 1 colony per 100 mLs filtered (Appendix B). Given the low fecal coliform counts, measured during baseline conditions as well as during storm events, there were no human health risks posed by the presence of elevated fecal coliform in Lake Absegami during the Phase I Study.

Hardness and Alkalinity

Hardness is a measure of cation concentration. In natural waters, hardness is a measure primarily of the concentration of calcium and magnesium ions, but also includes iron and manganese ion concentrations. Specifically, "hard water" refers to the large amounts of soap needed to produce a lather or that, on evaporation, a deposit forms on the sample container. In terms of lake management, information on the hardness of a waterbody is particularly useful, especially when considering the use of copper-based algicides. Hardness is measured as mg $CaCO_3$/L. One commonly used classification for hardness is as follows: 0-60 = soft, 61-120 = moderately hard, 121-180 = hard and >181 = very hard.

Alkalinity is a measurement of the concentration of carbonates (CO_3^{2-}), bicarbonates (HCO_3^-)and hydroxides (OH^-) in water. The alkalinity of water is indicative of its capacity to resist a change in pH. It is also known as the buffering capacity of a waterbody. Alkalinity is expressed in terms of mg $CaCO_3$/L with concentrations typically ranging from 20 to 200 mg/L in most natural freshwater ecosystems.

Soft waterbodies have less buffering capacity and are more susceptible to fluctuations in pH from acid rain and acid contamination. In addition, the softer the water, the greater the toxicity of metals such as lead, cadmium, chromium and zinc on aquatic life. Therefore, to protect aquatic organisms from the potential environmental impacts associated with shifts in pH, the alkalinity of a waterbody is preferred to be at least 20 mg/L.

pH

The highest hardness value of Lake Absegami was 7.9 mg/L with most measurements being < 5 mg/L. Alkalinity measurements were consistently below the analytical detection limit (< 1.7 or 5 mg/L) with most measurements being < 1.7 mg/L (Appendix B). These measurements of hardness and alkalinity indicate that Lake Absegami is a soft waterbody with a limited buffering capacity.

Such soft water conditions were expected, since the in-situ dataset revealed that the pH of Lake Absegami was consistently less than 6.0. These conditions indicate that Lake Absegami is extremely sensitive to changes or shifts in pH. Consequently, the level of potential heavy metal toxicity, relative to a New Jersey waterbody not located within the Pine Barrens, in Lake Absegami is low. Thus, preventative measures must be in place in order to avoid possible environmental problems in the future. Given the high level of sensitivity Lake Absegami has with regard to heavy metals, some of the more common metals were monitored as part of this Phase I Study.

Arsenic

Arsenic occurs naturally in rocks, soil, air, water, plants and animals. However, human activities, including burning of fossil fuels and wastes, paper production, glass and cement manufacturing, mining and smelting and the historical use of arsenic-containing pesticides, can release arsenic into the environment and provide a source for water contamination. The NJ water quality standard for surface waters limits arsenic to 0.017 mg/L. The USEPA's current limit for arsenic in drinking water is currently 0.05 mg/L, but will be lowered to 0.01 mg/L in the near future. The concentrations of arsenic in Lake Absegami and inlet storm event samples were consistently below the laboratory's limit of analytical detection, which varied from 0.005 to 0.01 mg/L. Therefore, the concentration of arsenic in Lake Absegami and its tributaries did not exceed either NJ surface water standards nor the USEPA's drinking water standards.

Lead

Lead contamination of waterbodies, primarily those providing drinking water, can pose substantial health risks, especially to children. Lead poisoning can cause damage to the brain, kidneys, nervous system and red blood cells. Lead rarely occurs naturally in water. Instead, lead contamination is mainly the result of the corrosion of lead containing structures such as lead pipes, solder and brass fixtures in water delivery systems.

The New Jersey Surface Water Quality Standards have established the lead limit at 0.005 mg/L; the USEPA's drinking water standard for lead is 0.015 mg/L. The concentration of lead in Lake Absegami and its tributaries, during both baseline conditions and storm events, were consistently below the analytical detection limit of 0.005 mg/L (Appendix B). Thus, lead concentrations within the lake and its tributaries did not exceed either State nor Federal limits.

Zinc

Zinc is not naturally found in high concentrations in New Jersey waters. However, it is abundant in minerals, so it is used to galvanize steel and is a component of batteries, plastics, wood preservatives, antiseptics and rodenticides (zinc phosphate). Zinc is also used in the vulcanization of rubber (including tires). Therefore, zinc is often found in higher concentrations near roadsides, the result of the degradation of tires. The release of zinc due to the breakdown of zinc-containing products, especially tires, is one source of waterbody contamination. In addition, zinc is also released into waterbodies through industrial discharges.

Zinc is not considered to be very toxic to humans or aquatic organisms. The USEPA drinking water limit for zinc is 5 mg/L. The concentration of zinc in Lake Absegami was 0.02 mg/L or less, while the concentration in the baseline and stormwater tributary samples varied between < 0.02 mg/L and 0.06 mg/L (Appendix B). Therefore, the concentrations of zinc in Lake Absegami and its tributaries were lower than Federal standards and not high enough to pose danger to human or aquatic organisms.

Chlorophyll a

Mid-lake and inlet samples were analyzed for chlorophyll *a*, a photosynthetic pigment all plants and algal groups possess. Since all algal groups contain chlorophyll *a*, measuring its concentration in lake water is an excellent means of quantifying the relative biomass of phytoplankton within the open waters of a waterbody. Concentrations of chlorophyll *a* are also used to assess the in-lake productivity associated with the phytoplankton. In turn, this information can be used to quantify the trophic state of a waterbody, as well as measure the relative effectiveness of an implemented in-lake restoration technique.

To the layperson, chlorophyll *a* concentrations greater than 30 mg/m^3 produce algal blooms and surface scums that are considered unpleasant for recreational waterbodies. The highest mid-lake chlorophyll *a* concentration in Lake Absegami was 7 mg/m^3 with most concentrations being much lower. Inlet chlorophyll *a* concentrations were below the analytical detection limit of 0.20 mg/m^3. Thus, planktonic (open water) algal blooms were not a major nuisance at Lake Absegami through the course of the Phase I Study.

3.3 Plankton Sampling

As mentioned previously, phytoplankton and zooplankton samples were collected at the in-lake station during each sampling event. Samples were taken to Princeton Hydro's biological laboratory and organisms were identified down to the practical taxon (genus or species). The resulting data were used to calculate organism abundance and biomass for each sampling event (Appendix B).

Phytoplankton

On 22 September 2000 the green algae (Chlorophyta) was the only algal group identified in Lake Absegami. The dominant green alga, in terms of both abundance and biomass was the thin, filamentous alga *Rhizoclonium* (Appendix C). This alga is well known to prefer acidic environments such as the Pinelands. Thus, any nuisance mat algae observed in Lake Absegami may be *Rhizoclonium*.

Both algal diversity and biomass were higher on 3 May 2001, relative to 22 September 2000, while algal abundance was lower (Appendix C). Four algal groups were identified in Lake Absegami at this time, including green algae, diatoms (Bacillariophtya), chrysophytes and dinoflagellates (Pyrrhopyta). The chrysophytes were the dominant group in terms of abundance, while the diatoms were the dominant group in terms of biomass. The assemblage of phytoplankton at this time, were typical of an algal community in a temperate lake during the spring season.

From May to June, both algal abundance and biomass declined (Appendix C). On 12 June 2001, algal abundance was less than 150 cells per mL, while algal biomass was less than 250 ug/L. The chrysophytes remained as the dominant group in terms of abundance, while the dinoflagellate *Peridinium* was the dominant alga in terms of biomass. Many species of *Peridinium* thrive in acidic environments.

Algal abundance and biomass slightly increased from June to July in Lake Absegami (Appendix C). In terms of abundance, the green algae were the dominant group, while the blue-green alga (Cyanobacteria) *Anabaena* was the dominant alga in terms of biomass (Appendix C). The identification of a blue-green alga in Lake Absegami was not expected since most blue-green algae prefer more neutral or alkaline pH environments, rather than acidic.

Algal abundance and biomass continued to increase; both parameters slightly increased from July to August (Appendix C). Similar to July, the green algae were the dominant algae in terms of abundance, while the blue-green alga *Anabaena* was the dominant alga in terms of biomass on 9 August 2001.

From early August to 10 October 2001, both algal abundance and biomass sharply declined in Lake Absegami (Appendix C). Such seasonal declines from summer to fall are common, especially in shallow, temperate waterbodies. At this time, algal abundance was only 66 cells per mL, while biomass was only 21 ug/L (Appendix C). The phytoplankton community on 10 October 2001 was composed primarily of green algae and chrysophytes, while the green algae accounted for the largest proportion of the community in terms of biomass.

In general, overall algal abundance and biomass were low throughout the course of the Phase I monitoring program. These relatively low algal values in Lake Absegami were attributed to its low pH and nutrient concentrations. However, in spite of the general low abundance and biomass of algae in Lake Absegami, the presence of *Anabaena* in July and August warrants some concern over the future management of the lake.

Typically, most blue-green algae can not tolerate acidic conditions; they tend to prefer more alkaline conditions. The fact that a few *Anabaena* were found in Lake Absegami indicates that this alga has the potential to bloom if more favorable conditions develop. *Anabaena*, like many blue-green algae, are well documented to produce unpleasant algal blooms/surface scums that have the potential to produce recreational, ecological and health-related problems. An increase in the pH of the lake and/or an increase in nutrient loading would create conditions would favor an increase in the growth of blue-green algae such as *Anabaena*. Thus, in order to preserve current water quality conditions and avoid blue-green algal blooms, the Bass River State Forest must continue to protect and preserve the land surrounding Lake Absegami.

Zooplankton

Zooplankton are micro-animals that live in the open waters of lakes and ponds. Many zooplankton are a source of food for forage or young game fish. Some types of zooplankton are herbivorous (eat algae) and thus can provide a natural means of controlling excessive algal growth. Therefore, given the important role of zooplankton within the aquatic food web, the Lake Absegami monitoring program included these organisms.

Similar to the phytoplankton, zooplankton abundance and biomass were generally low in Lake Absegami. On 22 September 2000, only 50 zooplankton per L were observed in Lake Absegami. At this time, the dominant zooplankton in terms of abundance and diversity were the rotifers, a group of small animals that feed primarily on bacteria and/or detritus. The dominant zooplankton at this time were nauplii, were are young copepods (Appendix C).

By 3 May 2001 zooplankton abundance and biomass remained low, with only 39 animals identified per L (Appendix C). Copepods were the dominant zooplankton in terms of both abundance and biomass. In addition, one herbivorous (algae eating) copepod, *Diaptomus*, was identified in the 3 May 2001 Lake Absegami sample.

From May to June, zooplankton numbers declined with only 7 animals per L (Appendix C). Similar to May, the dominant zooplankton on 12 June 2001 in terms of both abundance and biomass were the copepods.

From June to July, zooplankton abundance and biomass substantially increased. This strong increase in the zooplankton of Lake Absegami was attributed to a "bloom" of the small-bodied cladoceran *Bosmia*. This genus was the dominant zooplankton in both abundance and biomass at this time. *Bosmia* feeds primarily on bacteria and/or detritus but not on algae. Two herbivorous zooplankton were identified in Lake Absegami at this time; a cladoceran (*Daphnia*) and a copepod (*Diaptomus*). Combined, these two herbivorous zooplankton accounted for only 11 animals per L or 5% of the total number of zooplankton.

From July to August, zooplankton abundance and biomass continued to increase, primarily as a result of the cladoceran *Bosmina*. On 9 August 2001, over 480 *Bosmia* per L were identified in Lake Absegami (Appendix C). Once again, the herbivorous zooplankton *Daphnia* and *Diaptomus* were identified in Lake Absegami, an addition to another herbivorous cladoceran *Diaphniosoma*. In August, these three herbivorous zooplankton accounted for 20 animals per L or only 4% of the total number of zooplankton.

Both zooplankton abundance and biomass declined from August to October. On 10 October 2001, *Bosmia* remained the dominant zooplankton in terms of abundance and biomass, however, relative to August, its values substantially declined (Appendix C). At this time, the only herbivorous zooplankton identified in Lake Absegami was *Daphnia* at 3 animals per L.

In general, zooplankton abundance and biomass were low in Lake Absegami, relative to other temperate waterbodies in New Jersey. Similar to the phytoplankton, the low zooplankton values were attributed to the low pH. The dominant zooplankton in Lake Absegami was the cladoceran *Bosmina*. While a few herbivorous (algae eating) zooplankton were identified in Lake Absegami, they typically accounted for a minor proportion of the total zooplankton community. For example, in terms of abundance, herbivorous zooplankton only accounted for between 3 - 5% of the total number of zooplankton identified in Lake Absegami.

3.4 *Sediment Chemistry*

Sediment samples were collected from Lake Absegami by Princeton Hydro on 10 October 2001 for the purpose of identifying potential sediment contaminants and their concentrations. This information was needed to determine the feasibility and cost of dredging Lake Absegami. The costs associated with handling and disposing of the dredged material are significantly influenced by the presence of contaminants. In addition, specific disposal sites have to be identified for contaminated sediments.

Five separate boring samples were collected from numerous areas of the lake. One sample was collected from each of the branches of Lake Absegami; in addition, one sample was collected from the beach area, the mid-lake station and the boat launch cove. The five samples were then combined to generate a composite sample.

Core samples were collected using a stainless steel auger which cored to a depth of approximately four (4') feet. Each collected core was observed and physical characteristics such as color, texture and thickness were recorded. The core was then emptied into a stainless steel bowl and stirred until uniform soil color and texture were achieved. The soil was then placed into appropriate, laboratory-supplied containers, labeled and shipped at 4°C to the New Jersey certified laboratory, Integrated Analytical Laboratories, LLC (IAL). IAL analyzed the composited sediment sample for Priority Pollutants + 40 (PP+40), a common analysis used to identify potential soil contamination, and sediment composition.

Laboratory analysis of the sediments revealed non-detectable concentrations of volatile organics, semi-volatile organics, PCB's, pesticides, total cyanide and total recoverable phenols (Appendix D). Several metals and volatile solids were detected in the sample. The percent total volatile solids was 7.41%.

The metals that had non-detectable concentrations were antimony, arsenic, beryllium, cadmium, chromium, nickel, selenium, silver and thallium. Copper had a concentration of 10.1 mg/kg (ppm), while the concentration of lead was 21.5 mg/kg. The concentration of mercury was 0.0467 mg/kg. Finally, measured concentration of zinc was 12.9 mg/kg. The copper, lead, mercury and zinc concentrations did not exceed either the residential direct contact (RECSCC) or non-residential (NRDSCC) soil cleanup criteria (New Jersey Department of Environmental Protection Soil Cleanup Criteria (NJDEP-SCC) 1992).

In addition to the PP+40 analysis, sediment composition was also reported. Sieve analysis determined that 100.0% of the sediments were finer than 3/8" diameter. In addition, 96.6% of the sediments passed through sieve #10, while only 22.1% passed through sieve #100. Thus, most of the sediments were medium and fine sands. Hydrometer data revealed that only 3.9% of the sediments were finer than 0.039" in diameter. Almost 84% of the composited sediments in Lake Absegami were identified as sand (Appendix D).

Section 4 Watershed Characteristics

4.1 Geology

The Lake Absegami watershed is located within Burlington County, NJ which, in turn, is located within the Coastal Plain province. Specifically, the Lake Absegami watershed is located in the Cohansey formation of Coastal Plain province. The topography of the Coastal Plain is flat to very gently undulating. The geology of the Coastal Plain province is unconsolidated sediments consisting of layers of sand, silt and clay deposited alternatively in deltaic and marine environments, as sea levels fluctuated during the Cretaceous and Tertiary periods. The upland areas are underlain by erosion-resistant gravel and iron cemented sediments. The land which contains the Lake Absegami watershed is estimated to have formed 5.3 million years ago.

The Cohansey formation sediments are composed of white to yellow sand, with local gravel and clay. They are locally stained red or orange brown with iron oxides and ironstone. They also include marine and non-marine sediments. The sand is primarily medium grained, but ranges from fine to course, and is composed of quartz and siliceous rock fragments. Minerals found in this formation include pseudorutile, leucoxene, zircon, tourmaline, rutile, staurolite, sillimanite, monazite, kaolinite and ilmenite. Of these minerals, five contain iron in appreciable amounts; hence providing a natural source of iron for surface- and groundwater through chemical breakdown. Coastal Plain sediments have been mined for bog iron, glass sand, foundry sand, ceramic and brick clay, glauconite for fertilizers and titanium from ilmenite in sand deposits.

4.2 Soils

The Lake Absegami watershed straddles the Downer-Sassafras-Woodstown association and the Lakehurst-Lakewood-Evesboro association. According to the Soil Conservation Service (USDA SCS/NJAES 1971), soils occurring in these associations are characterized as *nearly level to gently sloping, well drained and moderately well drained soils that are moderately and moderately slowly permeable and have a sandy loam and fine sandy loam subsoil.* The soil types found in the Lake Absegami watershed, and some of their characteristics, are found in Table 2(a). Additional soils located within Bass River State Forest (NJDEP Division of Parks and Forestry 1994) include Alluvial, Berryland, Fallsington, Klej, Tidal Marsh and Muck. These soils belong to the Woodmansie-Lakehurst association and Atsion-Muck-Allivial land association. The characteristics of these additional soils are described in Table 2(b).

The Downer-Sassafras-Woodstown association occurs at relatively high elevations of about 80 to 120 feet in the central section of Burlington County and 40 to 60 feet in the southern and eastern section of the county. It can be found scattered throughout the county and accounts for approximately 6% of the county. Downer soils constitute 60% of the association, Sassafras soils are 20%, Woodstown soils are 10% and the remaining 10% are minor soils.

The well drained Sassafras and Downer soils are found in higher areas. Downer soils are somewhat sandier than the Sassafras soils and are less well suited to crops. The moderately well drained Woodstown soils lie below the Downer and Sassafras soils. In most areas, Woodstown soils have been improved by drainage. The minor soils in the association are sandy and are poorly drained in some areas.

The Lakehurst-Lakewood-Evesboro association is found in relatively high positions of the Coastal Plain, which in Burlington County, is primarily within the Pine Barrens. Approximately 22% of Burlington County is composed of soils of this association. The association is 40% Lakehurst soils, 30% Lakewood soils, 20% Evesboro soils and 10% minor soils including the Downer, Woodmansie and Atsion soils. The Lakehurst-Lakewood-Evesboro association is found on nearly level to strongly sloping land. The soils are somewhat poorly drained to excessively drained and are rapidly and moderately rapidly permeable. The subsoil or underlying material is a loamy sand or sand.

The Lakehurst soils are moderately well to somewhat poorly drained. The water table associated with these soils is high in the winter and low in the summer. Lakewood and Evesboro soils are excessively drained. All major soils in the association are low in natural fertility and the sands are subject to soil blowing.

The Woodmansie-Lakehurst association is located on nearly level to gently-sloping land. The association includes well-drained to somewhat poorly drained soils that are rapidly and moderately rapidly permeable. The subsoil is sand to sandy loam. This association is located on high areas of the outer Coastal Plain and includes the Pine Barrens. The major soils are Woodmansie (50%), Lakehurst (15%); the remaining 15% is minor soils

The Atsion-Muck-Alluvial land, sandy, association includes nearly level soils. The soils are poorly drained and moderately rapidly permeable. The subsoil is sand and loamy sand. The lands associated with the very poorly drained Muck and Alluvial soils are subject to frequent flooding from streams. This association occupies low positions in the Coastal Plain. The major soils are Atsion (50%), Muck (15%)and Alluvial (10%). Minor soils are Berryland, Lakehurst, Fallsington, Pocomoke and Klej.

4.3 Geology/Soils and Land Use Practices

The geology of an area influences not only its soil type and composition, but also has environmental implications, especially with respect to fate and transport of pollutants. When soils are comprised of larger particles (sand, gravel) instead of finer ones (silts, clay), water tends to leach through the soil. Water leaching through the soil horizon can carry with it contaminants, particularly soluble ones such as nitrate, into groundwater. When the soils are primarily composed of finer particles, the particles tend to pack together, thereby inhibiting the movement of water through the soil layers. In this situation movement of pollutants through runoff is the main concern, especially when the runoff has the opportunity to move into surface waters leading to surface water contamination. When the soils contain clays, and to some extent silts, many pollutants, including insoluble pesticides and phosphorus, will tend to bind to these particles. In this situation, the primary concern related to pollutant fate and transport is the movement of these chemicals with eroding sediments in runoff which is a primary mechanism of surface water contamination. The problem of pollutant movement via eroding sediments in runoff is exacerbated in regions which are comprised of soils that easily erode. Therefore, when developing land use practices and guidelines, the geology and soils of the region need to be considered in order to minimize the potential of pollutant contamination of groundwater via leaching and surface waters through runoff and input of contaminated groundwater.

The Coastal Plain geology of the Lake Absegami watershed includes soils composed of sand, silt and clay. As a result, the soil associations found in the watershed are sandy and/or loamy sandy soils. The soil associations of the area were described the Soil Conservation Service survey (USDA SCS/NJAES 1971) as well drained and moderately well drained. Furthermore, the Coastal Plain includes sand formations which contain productive aquifers and important groundwater reservoirs, providing further evidence that percolation of water through the soil horizon in this province is significant. Therefore, the potential for pollutants to leach through the soil horizon and contaminate groundwater is considerable. Thus, land use practices which minimize the use of soluble chemicals are prudent in order to minimize potential groundwater contamination.

Additionally, it has been noted that the Cohansey formation has been extensively eroded. The loose, sandy composition of the formation causes it to erode easily. While pollutants (especially phosphorus and insoluble pesticides) do not easily bind to sand, they easily bind to the clay, silt and organic material mixed in sands and loamy sands. Therefore, the potential for contamination of surface waters via eroding soils exists. In addition, pollution of surface waters through sediment loading, leading to higher concentrations of total suspended solids, can result from the erosion of soils. Therefore, land use practices in areas where sediment erosion is a concern should include those designed to reduce erosion (such as contour tilling) or prevent the movement of sediments into surface waters, primarily through the development or maintenance of riparian buffer zones.

TABLE 2: Soil Characteristics [a]

Table 2(a): Soil Characteristics of Lake Absegami Watershed

Soil Name	Erodibility	Slope (%)	Depth to seasonal water table (feet)	Depth to bedrock (feet)	Risk of Septic
Atsion sand (At)	NA	NA	1	>5	severe
Downer loamy sand (DoA)	NA	0 - 2	>5	>5	slight
Downer loamy sand (DoB)	NA	2 - 5	>5	>5	slight
Keyport loamy sand (KeB)	Moderate	0 - 5	1.5 - 2.5	>5	severe
Lakehurst sand (LaA)	NA	0 - 3	1 - 3	>5	moderate
Lakewood sand (LtB)	NA	0 - 5	>5	>5	slight
Pits, sand and gravel (Pt)	NA	NA	0 - 5	4-20	slight
Woodmansie sand loamy substratum (WhB)	NA	0 - 5	>5	>5	slight
Woodstown loamy sand loamy substratum (WIA)	Moderate	0 - 2	1.5 - 2.5	>5	moderate
Woodstown loamy sand (WkA)	Moderate	0 - 2	1.5 - 2.5	>5	moderate

Table 2(b): Soil Characteristics of Lake Absegami Watershed

Soil Name	Erodibility	Slope (%)	Depth to seasonal water table (feet)	Depth to bedrock (feet)	Risk of Septic
Alluvial [b]	NA	Level to gentle slope.	0-3	Not Available	Severe
Berryland [c]	Low	0-2	0	>5	Not Available
Fallsington [d]	NA	0-5	0-1	>5	Severe
Klej [e]	NA	0-5	1-2 ½	>6	Moderate
Muck [b]	NA	Nearly level.	NA	<1 to >3	Severe
Tidal Marsh [b]	NA	NA	NA	NA	NA

a) NA denotes information Not Available.
b) Soil characteristics vary from site to site, thus only generalizations are available.
c) Berryland Official Series Description
http://www.statlab.iastate.edu/soils/osd/dat/B/BERRYLAND.html
d) Fallsington Official Series Description
http://www.statlab.iastate.edu/soils/osd/dat/F/FALLSINGTON.html
e) Klej Official Series Description http://www.statlab.iastate.edu/soils/osd/dat/K/KLEJ.html

4.4 Land Use

Land use within the Lake Absegami watershed was identified and mapped with the aid of the New Jersey Department of Environmental Protection Geographic Information System digital data (integrated terrain unit) and U.S. Geological Survey digital data (digital line graph). The land use categories, and their respective percent contributions to total watershed area, are listed in Table 3.

The dominant land type, by far, within the Lake Absegami watershed was coniferous forest, which accounted for slightly greater than 85% of the total land area (Table 3 and Figure 4). Brushland/shrubland and wetlands accounted for approximately 5% and 7% of the total watershed area, respectively. The remaining land use categories each accounted for 1% or less of the total area within the Lake Absegami watershed.

TABLE 3

Lake Absegami Watershed Land Use

Land Use	Acres	Hectares	Percentage
Atlantic White Cedar Wetlands	14.53	5.88	0.74
Barren Land	4.86	1.97	0.25
Brushland/Shrubland	96.87	39.20	4.97
Coniferous Forest	1673.04	677.06	85.76
Coniferous Wooded Wetlands	33.09	13.39	1.70
Coniferous/Deciduous Forest	0.21	0.08	0.01
Deciduous Scrub/Shrub Wetlands	49.18	19.90	2.52
Deciduous Wooded Wetlands	1.32	0.53	0.07
Extractive Mining	0.40	0.16	0.02
Mixed Forested Wetlands (Coniferous Dominant)	18.45	7.47	0.95
Mixed Forested Wetlands (Deciduous Dominant)	22.10	8.94	1.13
Mixed Scrub/Shrub Wetlands (Deciduous Dominant)	2.85	1.15	0.15
Recreational Land	5.71	2.31	0.29
Residential	8.53	3.45	0.44
Urban	19.70	7.97	1.00
Total	**1,950**	**789.46**	**100**

Section 5 Hydrologic Budget

The hydrologic budge, or water balance, of a lake is the net difference between total inflow, total out-flow and evaporative loss. There are a number of water sources and water losses which must be accounted for if an accurate representation of the hydrologic budget is to be obtained. Tributary inflow, surface runoff, precipitation and groundwater infiltration are all sources of water inputs. Evaporation, out-flow and seepage are representatives of water losses. The methods and results of this analysis to quantify each of the above applicable water sources and losses, are presented in the following sub-sections.

5.1 Precipitation/Evaporation

The average precipitation for the Lake Absegami watershed was obtained from the 30 year historical average provided by the Rutgers University New Jersey Climate database (http://climate.rutgers.edu/stateclim/data/coast_njhistprecip.html). For this long-term, monthly precipitation database, the State was divided into three regions: northern New Jersey (Division 1), southern New Jersey (Division 2)and coastal New Jersey (Division 3). The Lake Absegami watershed is located in coastal New Jersey, so the precipitation data used for its hydrologic budget were derived from Division 3.

The long-term mean amount of annual rainfall for the coastal portion of New Jersey was 106.8 cm (42.04 in). In order to develop a Management Plan for Lake Absegami, long-term, normalized precipitation records, such as those provided by Rutgers, were used to develop the lake's hydrologic budget. The normalized database included precipitation data from 1971 to 2000. Thus, based on an mean annual rainfall of 106.8 cm, the gross hydrologic load resulting from direct precipitation onto the lake's surface totals 1.9×10^5 m^3/yr.

Evaporation from the surface of the lake must be accounted for in order to accurately calculate the hydrologic budget. Water loss due to evaporation is dependent upon a number of variables, the most important being ambient temperature, intensity of sunlight and relative humidity. From this, it can be seen that evaporative losses are seasonally dependent. Utilizing a State-wide estimate of evaporative loss for the appropriate range of latitudes, and a lake surface area of 52.59 acres (21.28 hectare), the hydrologic loss attributable to evaporation totals 8.5×10^4 m^3/yr. Adjusting the gross precipitation load for evaporative loss yields a net annual direct surface precipitation load of 1.1×10^5 m^3/yr (Table 4).

TABLE 4

Precipitation/Evaporative Water Loss Over the Surface of Lake Absegami

Surface Area of Lake	52.59 Acres (21.28 ha)
Precipitation on Lake's Surface [a]	1.9×10^5 m^3/yr
Evaporative Loss	8.5×10^4 m^3/yr
Annual Net Gain Due to Direct Precipitation	1.1×10^5 m^3/yr

a) Based on normalized rainfall data.

5.2 *Surface Runoff*

The Lake Absegami watershed was divided into the land use categories identified in Figure 2 and Table 3. The division of the watershed into land use categories was used to determine the fate of precipitation falling within each area. In addition to land use, soil types, slopes, and local topography contribute in determining the percentage of precipitation that reaches Lake Absegami as surface runoff.

Total annual runoff within the Lake Absegami watershed was calculated using a modified version of the Rational Method. The Rational Method formula is:

$$q = C * i * A$$

where q is the peak discharge, "C" is a runoff coefficient determined by land use and soil types, "i" is rainfall intensity, and "A" is the watershed area. This formula is an approximate deterministic model representing the flood peak that results from a given rainfall. For Lake Absegami, an estimate of the total annual runoff load was required. Therefore, the rainfall intensity, "i", was replaced by the total yearly rainfall, "I". The equation was then modified to:

$$V = C * I * A$$

where "V" equals total volume of runoff per year.

To quantify the annual surface runoff that enters Lake Absegami, a runoff coefficient "C", was selected for each land use category. These runoff coefficients were obtained from various sources, but most were derived from Maidment (1993). The total annual surface runoff budget for each land type was arrived at by substituting the appropriate values into the corresponding variables (C, I and A) in the modified rational runoff equation. These land use runoff values were then summed to obtain the total annual surface runoff load for Lake Absegami (Table 5). Thus, the annual surface runoff load for Lake Absegami, during an average year, was estimated to be 1.3×10^6 m^3/yr (1.1×10^3 acre-ft/yr).

5.3 *Baseline Tributary Flow/Groundwater*

Of all the components of a hydrologic budget, the most difficult to measure and/or model is groundwater. Groundwater is the hydrologic load that originates from sub-surface water movement within a watershed. Groundwater has been known to account for up to 89% of the total hydrologic load in certain watersheds within the Pine Barrens region. Thus, efforts were made to quantify the groundwater contribution to the annual hydrologic load for Lake Absegami.

Initially, groundwater flow and input to Lake Absegami was to be determined using baseline (non-storm event) streamflow measured at gauging stations in each of the lake's inlets. These measurements were to be taken during lake and inlet sampling events. However, the latter half of 2001 was unusually dry, thus typical baseflow stream measurements could not be obtained. In addition, on several instances, the streamflow was so great that hazardous conditions existed which prevented measuring flow at the stream gauging stations. Therefore, baseflow at the two inlets could only be measured on three dates in 2000 and 2001 (Appendix A). Predictions of groundwater input to the lake, based on only three, varying baseflow estimates, could lead to an under- or over-estimation of the magnitude of the groundwater input. Thus, in order to provide a more accurate prediction of the groundwater contribution to Lake Absegami, it was determined that groundwater input should be calculated using a simplified mass balance approach. Groundwater inputs were calculated by subtracting water loss due to evapotranspiration and runoff from the gross precipitation input onto Lake Absegami watershed (excluding the lake, itself).

Using the annual, long-term rainfall value of 106.8 cm (42.04 in), the gross hydrologic load intercepted by the Lake Absegami watershed, excluding the lake itself, was estimated to be 8.4 x 10^6 m^3/yr. The effect of land use on the fate of precipitation was considered in the hydrologic load calculations, especially with respect to evapotranspiration. For the sake of these calculations the land use of Lake Absegami were divided into "vegetated" and "non-vegetated" categories. Vegetated land included land use categories such as forested and wetlands. Non-vegetated land use included categories such as commercial, industrial and residential.

Using a simple spreadsheet method (www.wxsystems.com/terms/potent.html), the relative rate of evapotranspiration was calculated. Evapotranspiration is the total loss of water by evaporation from the watershed and transpiration of water through the vegetation. The annual loss of water through evapotranspiration was estimated to be 61.7%. This percent value was used to calculate the amount of water loss through evapotranspiration over the vegetated land within the Lake Absegami watershed. Thus, based on the vegetated land within the Lake Absegami watershed, approximately 4.8 x 10^6 m^3/yr of the water was estimated to be lost through evapotranspiration.

The calculated amount of surface runoff and loss through evapotranspiration was subtracted from the gross, watershed-based hydrologic load. The volume of water remaining after these two components were subtracted from the gross load accounts for the water that infiltrates into the soil and becomes groundwater. Thus, the annual groundwater load for the Lake Absegami watershed was estimated to be 2.3 x 10^6 m^3/yr.

5.4 Hydrologic Budget Summary

Summing the various components of the hydrologic budget yields an annual water balance for Lake Absegami of 3.7 x 10^6 m^3 (Table 5). Groundwater inputs accounted for the largest component of the hydrologic load of Lake Absegami (62%). Net precipitation accounted for the smallest input at 2.9%. It was assumed, based on observations made during the sampling events, that Lake Absegami suffers no significant drop in water level through the seasons. Since no substantial loss due to seepage was anticipated, the annual outflow was assumed equal to the annual inflow, or 3.7 x 10^6 m^3/yr. Given a lake volume of 1.21 x 10^5 m^3, the hydraulic retention time is 0.033 years. The inverse of the hydraulic retention time, know as the flushing rate, was calculated to be 30.5 times/year.

TABLE 5

Annual Hydrologic Budget of Lake Absegami

Hydrologic Source	Annual Load (m^3)	Percent Contribution
Net Precipitation	1.1 x 10^5	2.9 %
Surface Runoff	1.3 x 10^6	35.1 %
Groundwater	2.3 x 10^6	62.0 %
Total	**3.7 x 10^6**	**100.0 %**

Section 6 Pollutant Budget

Pollutants can enter a lake either as discrete discharges from known sources or through discharges from a variety of sources within a watershed. Discrete discharges are referred to as point sources, and all other sources of pollutants are referred to as non-point sources. Non-point sources (NPS) contribute pollutants through stormwater runoff, precipitation on the lake surface and internal sources, such as groundwater inputs and release from lake sediments. By quantifying all of the pollutant sources for a lake, a pollutant budget can be developed. This pollutant budget is absolutely necessary in assessing the ecological and recreational health of a waterbody. In addition, pollutant budgets are also used to develop and/or evaluate various in-lake and watershed management strategies. For the purposes of this study, the term pollutant refers to suspended sediments and the nutrients nitrogen and phosphorus.

Typically, the largest source of pollutants originates from within a lake's watershed. Therefore, land use practices impact a lake as observed in extensive sedimentation and/or heavy nutrient loading. Most of this loading occurs during storm events; eroded soils, fertilizers, heavy metals and petroleum hydrocarbons are all constituents of storm runoff. A large majority of these storm runoff pollutants are either absorbed or adsorbed onto the surface of eroding sediment particles (Wanielista et al. 1982).

As a watershed becomes more developed, the amount of impervious surfaces increases. Such conditions substantially reduce the opportunity for stormwater to percolate through the soil. Thus, more watershed-generated pollutants will be directly discharged into receiving waterbodies through runoff. As such, developed (i.e. urban, residential) areas will contribute, on an unit area basis, more nutrients and suspended sediments than forested areas.

There are also internal processes that contribute to a lake's annual pollutant load. Die back of weeds and algae can generate a considerable amount of nitrogen and phosphorus as a result of bacterial decomposition of plant tissue and algal cells. This process can also lead to the accumulation of organic sediments. As detailed below, it is also possible, under anaerobic conditions, to liberate phosphorus from the sediments into the overlying water column. Depending on certain physical factors, this internally regenerated phosphorus can be a significant component of a lake's total annual phosphorus load, especially during the dry summer season.

Intuitively, pollutants are generally thought of as having harmful impacts on organisms and the environment. In contrast, relatively low levels of nitrogen and phosphorus enrichment can stimulate algal and aquatic plant growth, which can result in an increase in the biomass and growth of other organisms. However, excessive inputs of nutrients can cause eutrophication of lakes and its associated problems (e.g. anoxia, fish kills).

In contrast to nitrogen and phosphorus, total suspended solids (TSS) does not stimulate excessive algal or aquatic plant growth. In fact, elevated TSS concentrations inhibit algal/aquatic plant growth by limiting the amount of light available for photosynthesis. Elevated TSS concentrations can also destroy fish habitat (i.e. spawning beds), directly impact the health of fish and invertebrates (e.g. through covering the surface of the gills)and accelerate the rate of in-filling of aquatic ecosystems. Similar to nitrogen and phosphorus, the impacts of TSS concentrations are cumulative in nature. As the TSS load increases, its impact on the environment increases. As such, the impacts of the NPS pollutants nitrogen, phosphorus and TSS on aquatic ecosystems needs to be evaluated with a cumulative perspective in mind.

It is thus important, when preparing a lake's nutrient and sediment budget, to properly account for all the site specific factors which can contribute to pollutant loads. An assessment of the relative effects of such factors as lake morphometry, land use, slope, soil type, wastewater treatment practices and stormwater management is presented in this report. In this study, four main components of the Lake Absegami nutrient and sediment budget are analyzed:

1. Surface Runoff,
2. Internal Phosphorus Loading,
3. Groundwater Loading, and
4. Atmospheric Deposition.

The methods used to calculate the loads associated with each of these components, as well as the results of these analyses, are presented in this section of the report.

6.1 NPS Loading from Surface Runoff

Overland runoff contributions from the lake's immediate watershed were calculated using field validated, USEPA modified, unit area loading (UAL) coefficients (Table 6). Appropriate UAL coefficients were selected for each land type listed in Table 6. For the sake of the unit area loading analysis, the land use categories listed in Table 3 were condensed into larger land use groups as listed in Table 6.

Selected UAL coefficients, as developed by USEPA (1980) and Souza and Koppen (1983), were used to compute the lake's annual nitrogen (TN), phosphorus (TP)and total suspended sediment (TSS) loads. Table 7 displays the land use categories, their respective areas and pollutant loadings through runoff within the Lake Absegami watershed. The results of this analysis show that the annual TN load is 2,098 kg (4,625 lbs), the annual TP load is 150.4 kg (331.6 lbs)and the annual TSS load is 2.4×10^5 kg (5.2×10^5 lbs).

The dominant land use category within the Lake Absegami watershed is forested, accounting for approximately 86% of the total land area within the watershed (Table 7). Consequently, forested land was the largest annual contributor of TP, TN and TSS for Lake Absegami in terms of surface runoff. In contrast, developed, impervious land categories, such as residential and urban land, accounted for only 1.4% of the total land area, yet still contributed sizable pollutant loads to the lake relative to the forested land. As will be shown later, the land use within the Lake Absegami watershed will have a significant impact on the observed and predicted water quality of the lake as it influences pollutant transport and fate.

TABLE 6

Non-point Source (NPS) Loading Coefficients (kg/ha/yr) for Lake Absegami

Non-point Source	TN	TP	TSS
Barren Land	10	0.6	4000
Brushland/Shrubland	7	0.3	750
Extractive Mining	10	0.6	4000
Forested	2.5	0.2	250
Recreational	5	0.3	400
Residential	5	0.8	2000
Urban	10	1.6	4000
Wetlands	0	-0.25	-200
Precipitation on Lake [a]	10	0.25	NA
Dryfall on Watershed [b]	0.4	0.002	NA

a) Precipitation related pollutant load that fall is directly on the lake's surface.
b) Dust and other atmospheric-borne dryfall pollutants deposited on the watershed.

TABLE 7

NPS Unit Areal Loadings (kg/yr) for Lake Absegami

Land Use	Percentage Acreage	TN	TP	TSS
Barren Land	0.25	20	1.2	7,867
Brushland/Shrubland	4.97	274	11.8	29,402
Forested	85.77	1,693	135.4	169,291
Extractive Mining	0.02	2	0.1	648
Wetlands	7.26	0	-14.3	-11,455
Recreational	0.29	12	0.7	924
Residential	0.44	17	2.8	6,904
Urban	1.00	80	12.8	31,890
Total	**100**	**2,098**	**150.5**	**235,471**

6.2 *Internal Regeneration of Phosphorus*

As previously mentioned, internal regeneration is another source of phosphorus loading to lakes. Examination of Lake Absegami's dissolved oxygen and temperature profiles (Appendix A) and morphology indicates the lake is generally a well mixed waterbody that rarely develops a large anoxic zone immediately above the sediments (see Section 3.1 for details). Thus, anaerobic (no oxygen) mechanisms of phosphorus release from the sediments did not contribute to the lake's total phosphorus load. However, phosphorus release from the sediments can still occur under aerobic (with oxygen) conditions, contributing to a lake's phosphorus load, as was the case with Lake Absegami.

A number of TP release rates for aerobic sediments were reviewed and a flux rate of 0.6 mg/m/day^{-1} was selected (Nurnberg 1984). Accounting for temperature effects on bacterial and chemical activity, it was determined that aerobic TP release would most likely occur from mid-May through mid-September (120 days). Aerobic internal regeneration was estimated to annually contribute 13.1 kg (28.9 lbs) of phosphorus to Lake Absegami (Table 8).

6.3 *Groundwater Loading*

As demonstrated in the hydrologic budget of Lake Absegami, groundwater is the dominant source of water, accounting for over half of the lake's annual hydrologic load (Table 5). While sub-soil sampling for pollutants such as nitrogen and phosphorus was beyond the scope of this Phase I Study, a set of very simple mass balance calculations were conducted to provide an estimate of the possible contribution of groundwater to the lake's annual pollutant (nutrient) loads. The soils of a watershed function as a filter, removing particulate matter. Therefore, the contribution of groundwater to the lake's annual TSS pollutant load is expected to be negligible.

Phosphorus concentrations in groundwater are typically low since a large portion of the total phosphorus is adsorbed onto soil particles. However, under hydrologically stressed conditions (i.e. frequent flooding, inundation of brackish water and the possible development of anoxia in the interstitial groundwater within the local soils), the horizontal movement of groundwater directly into a receiving waterbody can be a source of phosphorus.

In contrast to TSS and most forms of phosphorus, nitrate-N and nitrite-N are highly mobile and are easily transported to receiving waterbodies through the groundwater.

A limited amount of water quality data were collected during the Lake Absegami monitoring program. The lake was monitored seven times from September 2000 to October 2001. In spite of this limited dataset, the collected data can be used to calculate a general estimate of the potential groundwater TP and TN contributions to Lake Absegami's annual pollutant load.

Under many conditions, groundwater contributions can be estimated using collected samples of baseflow entering a waterbody. Baseflow is essentially the flow of water in the absence of a storm event and can be described as an "outcropping of groundwater". Unfortunately, baseflow was only observed during three of the seven non-stormwater sampling events. Therefore, measured pollutant concentrations from within the lake and the inlets during measured baseflow, were used to estimate potential groundwater nitrogen and phosphorus contributions.

Combining the in-lake and baseflow inlet concentrations, the mean annual TN load entering the lake via groundwater was calculated. However, prior to this simple mass balance calculation, TN was calculated by combining TKN, nitrate-N and nitrite-N. The mean TN concentration, derived from in-lake and baseflow inlet concentrations, was estimated to be 0.173 mg/L which, in turn, was identified as the average TN concentration for groundwater entering Lake Absegami. Multiplied by the annual hydrologic load originating from groundwater (2.3 x 10^6 m^3), the annual TN load originating from groundwater was estimated to be 397 kg (875.2 lbs) (Table 8). This accounts for approximately 13% of the lake's total annual TN load.

The methodology described above was also used to calculate the annual groundwater TP concentration entering Lake Absegami. The average groundwater TP concentration was estimated to be 0.01 mg/L. This estimated mean was multiplied by the annual hydrologic contribution of groundwater to produce an estimated annual groundwater TP load of 23 kg (50.7 lbs) (Table 8). Based on this estimate, groundwater accounted for approximately 12% of the lake's total annual TP load (Tables 8 and 9).

Finally, a word of caution with regard to the estimated TN and TP contributions of groundwater to Lake Absegami. These estimates are based on a very small set of data and may not accurately represent annual conditions under more normal, long-term conditions. Thus, if a more accurate estimate of the groundwater contribution to the lake's annual TN and TP pollutant loads is desired, Princeton Hydro strongly recommends the implementation of a groundwater sampling program for the Lake Absegami watershed.

6.4 Atmospheric Deposition

The final source of pollutants is atmospheric deposition (precipitation and atmospheric dryfall). Once again, USEPA loading coefficients were used (Table 6). These contributions of nutrients, especially TP, were relatively minor, but were included in order to increase the accuracy of the budget. It was calculated that direct precipitation accounted for 213 kg TN per year and 5.3 kg TP per year, while atmospheric dryfall accounted for 316 kg TN per year and 1.6 kg TP per year (Table 8).

6.5 Pollutant Budget Summary

All of the pollutant sources of Lake Absegami were categorized into one of four (4) main sources and their percent contributions are shown in Table 8. These four sources were drainage from the watershed (surface runoff), internal phosphorus regeneration, groundwater and atmospheric deposition. Surface runoff accounts the majority of the nitrogen (almost 70%) and phosphorus (almost 78%), as well as practically all of the TSS, entering Lake Absegami on an annual basis (Table 8).

Given the importance of phosphorus in terms of driving whole lake primary productivity (the amount of algae and aquatic plant growth over time), the annual TP loads were separately broken into pounds, as well as kilograms and percent contributions (Table 9). The goal of such an exercise is to demonstrate that it take very little phosphorus to stimulate a lot of biological growth. For example, based on data firmly established within the scientific literature, it has been established that one (1) pound of phosphorus has the potential to generate 1,100 pounds of wet algae biomass. Thus, with an annual TP load of approximately 426 pounds, Lake Absegami has the potential to generate as much as 468,600 pounds of algae per year. Such conditions emphasis the need to implement in-lake and watershed-based management measures that minimize, as is feasibility possible, the magnitude of the lake's annual TP load.

Since nitrogen has a gaseous phase and is extremely difficult to control, most pollutant control measures focus on phosphorus and suspended sediments. It should be emphasized that many of the control measures implemented for phosphorus and suspended sediments will, to a certain degree, also aid in controlling the size of nitrogen load. Therefore, most of the recommended measures in this Study's Management Plan focuses on phosphorus and suspended sediment control.

TABLE 8

Annual Pollutant Budget for Lake Absegami

Sources of Pollutants	TN		TP		TSS	
	kg	%	kg	%	kg	%
Surface Runoff	2,098	69.4	150.4	77.8	235,473	100
Internal Phosphorus Regeneration	NA	NA	13.1	6.8	NA	NA
Groundwater	397	13.1	23	11.9	NA	NA
Atmospheric Deposition	529	17.5	6.9	3.5	NA	NA
Total	**3,023**	**100**	**193.4**	**100**	**235,473**	**100**

NA = not applicable

TABLE 9

Phosphorus Budget for Lake Absegami

Source of Pollutants	kg	lbs	Percent
Surface Runoff	150.4	331.6	77.8
Internal Regeneration	13.1	28.9	6.8
Groundwater	23	50.7	11.9
Atmospheric Deposition	6.9	15.2	3.5
Total	**193.4**	**426.4**	**100.0**

Section 7 Trophic State Modeling Analysis

Trophic state modeling is essentially the quantification of a lake's potential productivity by regression analysis of nutrient, hydrologic and morphometric data (Uttormark et al. 1974). A variety of models have been developed for this purpose but most are very similar in their mathematical origin. The modeling not only quantifies the productivity of a waterbody, but it may also be used to make predictions of changes in water quality (i.e. transparency, productivity, frequency and magnitude of blooms, etc.) arising from changes in land use, pollutant loading, climatic variability and the implementation of lake management strategies. As such, these models serve as valuable planning and management tools.

Most trophic state models are based on field measurements and empirical data. Since such data can be very site specific, the use of a model for a region or waterbody type other than where it has been verified can generate erroneous information. In order to minimize the degree of error, extremely generalized trophic state models were used in this study. These models were primarily derived from natural and man-made lakes in the United States and Canada. A more site specific model could be developed for Lake Absegami if a multi-year, long-term dataset (i.e. chlorophyll *a*, total phosphorus) was available. However, for the purposes of this study, the generalized models cited below will serve as an effective means of predicting the trophic state and algal productivity and biomass in Lake Absegami.

The data collected as part of this Phase I Diagnostic/Feasibility Study were used to model Lake Absegami's phosphorus retention (Kirchner and Dillon 1975), spring TP concentration (Dillon and Rigler 1974), trophic state (Carlson 1977) and mean annual chlorophyll *a* concentrations (Carlson 1977, Schindler 1978 and Vollenweider 1976).

The first step in the assessment and modeling process involved the calculation of the phosphorus retention coefficient; that is, the percentage of the annual phosphorus load that is retained in the lake. This value is important in that it largely determines the amount of phosphorus available for plant and algal uptake. Waterbodies with a substantial annual hydrologic load flush frequently, typically have a lower phosphorus retention, and usually, but not always, support less dense assemblages of weeds and/or algae then do infrequently flushed waterbodies.

The importance of flushing on phosphorus availability and trophic state stems from its relationship with the areal waterload (q_s). The areal water load is a function of the lake's surface area and the annual amount of water outflow. The areal water load was used to calculate the phosphorus retention coefficient using Equation 1 (Kirchner and Dillon 1975):

Equation 1: $R = 0.426e^{(-0.271qs)} + 0.574e^{(-0.00949qs)}$

Where: R = Phosphorus Retention

q_s = Areal Waterload = $\frac{\text{Annual Outflow from Reservoir}}{\text{Surface Area of Reservoir}}$

e = 2.718 (natural log)

Based on normal, long-term, climatic conditions, the phosphorus retention of Lake Absegami was calculated to be 0.49; thus 49% of the phosphorus entering the lake was predicted to remain while the remaining portion would leave the lake and enter the East Branch of the Bass River (Figure 4).

In general, waterbodies with phosphorus retention coefficients greater than 0.6 (60%) should be productive and prone to excessive algal blooms and/or nuisance densities of weed growth. Thus, according to the calculated phosphorus retention coefficient, Lake Absegami is not likely to experience excessive algal blooms under typical climatic conditions.

The next step was to determine if well established water quality models could be used to predict conditions in Lake Absegami. The first of these models was the Dillon and Rigler (1974) mechanistic model, designed to predict spring TP concentrations (Equation 2):

Equation 2: $[TP] = L * (1-R) / \rho * z$

Where:
[TP] = Predicted spring total phosphorus concentration (mg/L)
R = Phosphorus Retention
L = areal phosphorus loading ($g/m^2/yr$)
ρ = flushing rate (yr^{-1})
z = mean depth (m)

Based on equation 1, the phosphorus retention of Lake Absegami is 0.49. The areal phosphorus load was calculated by dividing the lake's annual phosphorus load (193.4 kg/yr) by its surface area. Using the flushing rate and mean depth for Lake Absegami, the predicted spring TP concentration was calculated to be 0.015 mg/L.

Only one spring in-lake TP sample was collected during the Lake Absegami Phase I study. On 3 May 2001 the in-lake TP concentration was <0.02 mg/L (Appendix B). In order to make a comparison between the measured and predicted spring TP concentrations, half of the detection limit, 0.01 mg/L, was used to represent the measured spring TP concentration. Thus, the measured spring TP concentration was within 67% agreement with the predicted spring TP concentration.

In-lake TP concentrations were consistently below the analytical detection limit (< 0.02 mg/L) during all seven water quality monitoring events (Appendix B). Thus, the annual average measured TP concentration for Lake Absegami resulted in the same level of agreement with the predicted spring TP concentration. Based on these results, seasonal fluctuations in the phosphorus load entering Lake Absegami, at least during the spring and summer seasons, are expected to be minimal.

The trophic state of a lake is a way of describing its biological productivity on a relative basis and the Trophic State Index (TSI) is one of the most commonly used indicators in limnology (Carlson 1977). The index is based on three water quality parameters, total phosphorus, chlorophyll *a* and Secchi depth, from a variety of lakes. Total phosphorus is used since it is commonly the most limiting nutrient for algal growth. Chlorophyll *a* is a pigment used in photosynthesis that all algal groups possess and therefore is an excellent means of measuring algal biomass. Secchi depth is a common measurement of water clarity.

Mean values of TP, chlorophyll *a* and Secchi depth for a lake are logarithmically converted to a scale of relative trophic state (TSI) ranging from 1 to 100, where increasing values are indicative of increasing trophic state. A TSI of less than 35 indicates oligotrophic conditions, a TSI between 35 and 50 indicates mesotrophic conditions, and a TSI greater than 50 indicates eutrophic conditions. Higher numbers are associated with increased probabilities of encountering nuisance conditions such as algal scums and blooms.

The trophic state indices for Lake Absegami are shown in Table 10. These values were calculated using the in-lake water quality data that were collected as part of this Phase I Study.

The three TSIs for Lake Absegami were indicative of varying degrees of mesotrophy, or a moderate level of productivity. Based on the total phosphorus TSI, Lake Absegami can be described as nearly oligotrophic. This indicates that Lake Absegami tends to be a phosphorus limited system. In other words, an increase in the lake's annual phosphorus load would stimulate algal, and perhaps aquatic plant, growth. In turn, such conditions would negatively impact the recreational use of Lake Absegami.

Table 10 - Trophic State Indices for Lake Absegami

Trophic State	Water Quality Parameter		
	Mean Total Phosphorus (mg/L)	**Mean Chlorophyll *a* (mg/m^3)**	**Mean Secchi Depth (meters)**
Lake Absegami mean water quality value	0.01[a]	2.6	1.6[b]
Lake Absegami TSI values (log value)	37	40	53

a In-lake TP concentrations were consistently below the analytical detection limit of 0.02 mg/L. Thus, half of the detection limit was used to represent the in-lake TP concentration.

b The Secchi depth during each sampling event was to the bottom of the lake.

The chlorophyll *a* TSI value was higher, being indicative of a truly mesotrophic condition. The higher chlorophyll *a* TSI value, relative to the total phosphorus TSI value, indicates that the algae in Lake Absegami are either resident algae that obtain phosphorus from an additional source such as the sediments or they are algae that enter Lake Absegami from its inlets. More than likely, both mechanisms are true. Filamentous mat algae was observed growing along the bottom of Lake Absegami. Such bottom dwelling algae obtain the majority of their needed phosphorus from the sediments, at least while they form a low-lying carpet. Through the course of the growing season, these mats can become extensive in size and, as gases (dissolved oxygen and/or carbon dioxide) accumulate within and among the algal filaments, these mats float to the surface and can become a recreational/aesthetic nuisance. In addition, algal mats were observed in both of the lake's main inlets. During a storm event, these mats could easily wash into the main body of the lake. Thus, algal mats originating from the sediments and/or the main inlets account for the higher chlorophyll *a* TSI value relative to the total phosphorus TSI value.

Based on the Secchi disk TSI value, Lake Absegami was qualified as mildly eutrophic or meso-eutrophic. However, the Secchi disk TSI value can be misleading. Lake Absegami is a relatively shallow waterbody, with a mean and maximum depth of 1.0 m (3.25 ft) and 2.3 m (7.44 ft), respectively. During each sampling event, Secchi depth was to the bottom of the lake. Thus, the slightly higher Secchi disk TSI value, relative to the total phosphorus and chlorophyll *a* values, was a limitation of the application of the model in a clear but shallow waterbody. Given this limitation, this study, as well as future studies, should focus on total phosphorus and chlorophyll *a* as the primary water quality indicators, that should be used in describing the relative level of productivity in Lake Absegami.

7.1 Trophic State Modeling

Three empirical models were used to predict chlorophyll *a* concentrations in Lake Absegami. The first is a simple regression model that predicts the mean summer chlorophyll *a* concentration in the lake with the predicted spring TP concentration as shown in Equation 3 (Carlson 1977):

Equation 3: ln Chl *a* = (1.449 * ln TP) - 2.442

Where:	TP	=	predicted spring phosphorus concentration (mg/m^3)
	ln	=	natural log
	Chl *a*	=	mean summer chlorophyll *a* concentration (mg/m^3)

This equation is frequently used in lake restoration and management plans, since it predicts mean chlorophyll *a* over the summer season. The model was applied to Lake Absegami since the highest chlorophyll *a* concentrations were measured during the later half of the growing season (late summer through fall).

With a predicted spring TP concentration of 0.015 mg/L, or 15 mg/m^3, the mean summer chlorophyll *a* concentration in Lake Absegami was predicted to be 8.9 mg/m^3. Three samples, collected on 12 June 2001, 19 July 2001 and 9 August 2001, were used to calculate the summer chlorophyll *a* mean for Lake Absegami. The mean of these three chlorophyll *a* concentrations was 2.4 mg/m^3. Since there was only 27% agreement between the predicted (8.9 mg/m^3) and observed (2.4 mg/m^3) mean summer chlorophyll *a* concentration in Lake Absegami, the Carlson regression model may not be appropriate for this lake. However, the lack of agreement between predicted and observed values may have been due to the extreme environmental conditions experienced during the summer of 2001 (i.e. severe drought).

The measured mean summer chlorophyll *a* concentration was substantially lower than the predicted concentration. This general lack of agreement between predicted and observed mean summer chlorophyll *a* concentrations in Lake Absegami, via the Carlson model, may have been the result of the extremely severe drought experienced through 2001. The predicted spring TP load is based on findings of the pollutant budget analysis which, in turn, is based on long-term normal or average conditions. Under drought conditions, such as those experienced in 2001, the pollutant contribution from stormwater runoff is lower than under normal conditions. Thus, drought conditions result in a lower pollutant load which places a higher degree of limitation on in-lake algal growth. The net impact is a lower amount of algal biomass generated during a drought. Such conditions indicate that the Carlson trophic model may be more applicable to Lake Absegami under more normal climatological conditions.

The second trophic state model used to predict chlorophyll *a* concentrations in Lake Absegami was a more robust model based on a large, global database with the vast majority of the limnological data obtained from waterbodies in North America and Europe (Schindler 1978). As shown in Equation 4, this model is very similar to the Carlson model. The major difference is that this model predicts mean annual chlorophyll *a* concentrations from annual mean total phosphorus concentrations.

Equation 4:	log Chl *a*	=	1.213 * log TP - 0.848
Where:	TP	=	mean annual phosphorus concentration (mg/m^3)
	log	=	log base 10
	Chl *a*	=	mean annual chlorophyll *a* concentration (mg/m^3)

The mean annual phosphorus concentration for Lake Absegami was 0.01 mg/L, 10 mg/m^3. With the Schindler model, the predicted mean annual chlorophyll *a* concentration was 2.3 mg/m^3, while the observed mean annual chlorophyll *a* concentration was 2.6 mg/m^3. predicted mean value. Unlike the Carlson model, the level of agreement between the predicted and observed annual chlorophyll *a* concentrations for the Schindler model was relatively high at 88%. Thus, the Schindler model was a better predictor of the annual chlorophyll *a* concentration in Lake Absegami, than the Carlson model was for the summer chlorophyll *a* concentration.

The ecological impacts associated with the drought were particularly severe during the summer of 2001, relative to the rest of the year. Thus, a model that predicts annual chlorophyll *a* concentrations seemed to be more appropriate for Lake Absegami than a model that predicts summer chlorophyll *a* concentrations. This seems to be especially the case for drought conditions.

The final model (Equation 5) is a generalized trophic state model from Vollenweider (1976). An important component that this model includes that the other two did not is the hydraulic residence time of the waterbody.

Equation 5:	Chl *a*	=	$0.367 * \{(L/q_s)(1/[1+\surd(z/q_s)])\}^{0.91}$
Where:	q_s	=	areal water load (m/yr)
	z	=	mean depth (m)
	L	=	areal phosphorus load ($g/m^2/yr$)
	Chl *a*	=	mean annual chlorophyll *a* concentration (mg/m^3)

Based on an areal water load of 18.46 m/yr, a mean depth of 1.0 m and an areal phosphorus load of 0.909 g of $TP/m^2/yr$, the mean annual chlorophyll *a* concentration was estimated to be < 1.0 mg/m^3. Based on the six in-lake samples collected through the course of the Phase I Study of Lake Absegami, the observed mean annual chlorophyll *a* concentration was 2.6 mg/m^3.

The observed annual chlorophyll *a* mean was substantially higher than the predicted annual chlorophyll *a* mean. This difference was more than likely the result of the unusual climatic conditions experienced through the course of 2000 and 2001. Both years were dry, with 2001 experiencing a particularly severe drought toward the later half of the year. Such drought conditions reduce the annual hydrologic load which, in turn, allows resident algae to more completely utilize the available phosphorus. In contrast, the Vollenweider model is based on long-term, normal hydrologic conditions. Therefore, under near normal hydrologic conditions, the mean annual chlorophyll *a* concentration should be lower in Lake Absegami that what was measured during the 2000-2001 Phase I Study.

A review of the three trophic state models indicates that the Schindler model was the most useful model in predicting mean annual chlorophyll *a* concentrations in Lake Absegami. It should be emphasized that this conclusion is based on the limited amount of water quality data that were collected in 2000 and 2001. Annual TP concentrations were more useful in predicting chlorophyll *a* concentrations relative to spring TP concentrations. In contrast to what is typically experienced, incorporating the areal water load into these modeling efforts resulted in a lower degree of predictability. However, if additional water quality data were collected, especially during more normal climatological conditions, the level of agreement between predicted and observed annual chlorophyll *a* concentrations may have been higher with the Vollenweider model. In conclusion, based on the limited amount of data collected during this Phase I study, the Schindler model is recommended for future management use at Lake Absegami.

8.0 Management Plan

The data compiled and computed in Sections 2 through 6 were utilized to prepare a Management Plan for Lake Absegami. This Plan provides specific objectives and recommendations for the short and long-term management of Lake Absegami. Both in-lake and watershed management techniques are provided in the Plan. In-lake techniques tend to focus on symptomatic problems such as algal blooms and the accumulation of sediments, while watershed techniques tend to focus on reducing pollutant loads through the use of structural and non-structural Best Management Practices (BMPs). The management techniques were priority ranked, with these rankings being dependent upon applicability, regulatory constraints, technical feasibility, degree of effectiveness, initial implementation costs, and operations and maintenance costs.

8.1 In-lake Restoration Techniques

In-lake restoration techniques are designed to improve the water quality and/or aesthetics of a waterbody by alleviating the specific impacts of pollution. Although these measures typically provide only short-term relief without controlling the source of the pollutants, they can substantially improve the aesthetics of a lake while the long-term, watershed-based management practices are being implemented.

8.1.1 Dredging

Dredging is the removal of settled or accumulated material (i.e. sediments) from a waterbody. Surface runoff transports soil and other particulate matter to receiving waterbodies such as Lake Absegami. The Lake Absegami watershed is heavily forested; approximately 86% of the total area within the Lake Absegami watershed is forested. Therefore, surface runoff TSS loads are not particularly high due to stabilizing and soil retaining vegetation. However, there are sites along the shoreline that are prone to erosion via wave action. One of the more prominent of these sites is the beach located along the east-central shoreline (Figure 5). There are also a number of streambank sites along north and south Tommy's Branch, the main inlets to Lake Absegami, that are prone to severe streambank erosion. In addition to eroded soils, another potential source of accumulated sediments is partially decomposed organic matter such as aquatic plants, algal cells and fallen leaf litter.

In spite of the well vegetated watershed, a dredging project would enhance the ecological and recreational value of Lake Absegami. Specifically, the dredging and/or reclamation of some of the unconsolidated material immediately off the beach would increase the depth of the bathing area and improve circulation. The upper reaches of the northern and southern branches of Lake Absegami would also benefit from dredging. Deepening the upper reaches and increasing the amount of open water habitat would increase recreational assess into these areas via canoes and increase the amount of spawning habitat for fish. Given these potential benefits, there was a considerable amount of effort in assessing the possible implementation of a dredging project for Lake Absegami.

Bathymetric Survey

A bathymetric survey of Lake Absegami was conducted on 11 September 2001. From the data collected during the bathymetric survey, approximately 1.68 x 10^5 m^3 (136.4 acre-ft) or 220,000 cubic yards of unconsolidate sediments are estimated to exist within Lake Absegami. It should be noted that this estimate is for the portion of the lake actually surveyed (Figure 6). The upper reaches of the northern and southern branches were inaccessible due to extremely low water depths, which were at least partially attributed to the severe drought of 2001.

In order to obtain a general estimate of unconsolidated sediments within the entire lake, a series of discrete measurements were taken within the upper reaches of the northern and southern branches of Lake Absegami. Sediment thickness within these upper reaches were typically between 0.6 and 0.9 m (2 and 3 feet). Thus, the amount of unconsolidated sediments within the upper reaches of the two branches of Lake Absegami was estimated to be 0.28 x 10^5 m^3 (22.5 acre-ft) or 36,350 cubic yards. The amount of unconsolidated material within the upper reaches of the branches of Lake Absegami was estimated to account for approximately 14% of the total amount of material within the entire lake. Combined, the estimated amount of unconsolidated sediments within all of Lake Absegami was 1.96 x 10^5 m^3 or 256,350 cubic yards.

Over the entire lake the average sediment thickness was 1.0 m (3.2 feet), with some areas having sediment depths of up to 1.8 m (5.9 feet). The northern branch of the lake tended to have a thicker depth of unconsolidated sediments relative to the southern branch (Figure 6). In addition, the central and northwestern sections of the main body of the lake tended to have the thickest depth of unconsolidated sediments (Figure 6).

Physical and Chemical Testing of the Sediments

Sediment sampling of Lake Absegami was conducted by Princeton Hydro on October 10, 2001. Five separate grab samples were taken from within different areas of the lake. Sediment grab samples were collected just off the swimming beach, from the northern and southern branches, from the middle of the lake and from the boat launch cove. The grab samples were collected using an acetate core tube, approximately 10 feet in length. Each grab sample was observed and details such as color, texture, and thickness were recorded. The sample was then emptied into a stainless steel bowl where it was stirred to a uniform color and texture.

Upon compositing, the sediment sample was placed into the appropriate laboratory supplied containers, labeled, and shipped at 4 °C to a New Jersey certified laboratory, Integrated Analytical

Laboratories, LLC (IAL). IAL chemically analyzed the composite sediment sample for Priority Pollutant + 40 (PP+40) and the physical characteristic analyses of grain size, percent organics, and percent solids. The results of these sediment analyses are provided in Appendix D.

The laboratory analyses revealed non-detectable levels of volatiles, semivolatiles, PCBs, pesticides, total cyanide, and phenols. Nine of the thirteen heavy metals for which the sample was analyzed also revealed non-detectable results. These nine metals were antimony, arsenic, beryllium, cadmium, chromium, nickel, selenium, silver and thallium. Detectable results were revealed for copper, lead, mercury and zinc. The New Jersey Department of Environmental Protection Soil Cleanup Criteria (NJDEP-SCC) were utilized to provide guidelines regarding contaminated sites in New Jersey, and contains values for both Residential Direct Contact Criteria and Impact to Groundwater Criteria. The copper, lead, mercury, and zinc levels detected in the sediment sample were well below both sets of their respective values.

The physical characteristics of the sediments were determined via laboratory methods. These physical characteristics revealed that the sediments were 7.41% volatile solids (organics) and 33% solids. A grain size particle distribution analysis was also conducted on the composited sample and revealed the sediments to be 0.5% gravel, 83.7 % sand and 15.8 % fines. Essentially, these results indicate the majority of the sediment to be comprised mainly of coarse, medium and fine sand. In any event, the sandy composition of the unconsolidated sediments indicates that handling and transportation of the material should not be extremely difficult, especially if the material is de-watered.

Proposed Implementation

If a dredging project is implemented in Lake Absegami, a number of project issues will need to be resolved. Some of the major issues that need to be considered in planning for the proposed dredging project include:

1. The method of dredging to be utilized (mechanical vs. hydraulic),
2. Access for the dredging equipment,
3. Identification of disposal sites for the material, and
4. Round trip distance for the transport the material to the disposal site.

There are a variety of methodologies and strategies that could be used to implement a dredging project at Lake Absegami. The following describes the approach Princeton Hydro recommends for the dredging of the lake. These recommendations are based on Princeton Hydro's experience in the design, implementation, and management of dredging projects throughout New Jersey.

There are two primary dredging methods, mechanical and hydraulic. Mechanical dredging utilizes earth-moving equipment (i.e. backhoe, trackhoe, dragline bucket) to remove lake sediments. Hydraulic dredging mixes the sediments with water and removes the slurry via suctioning with pumps. Hydraulic dredging requires two distinct storage sites; the temporary storage site is where the slurry is allowed to dry, and the final disposal site is where the dried material will be permanently deposited. The mechanical approach to dredging tends to be slightly more expensive than the hydraulic dredging approach, simply based on dredging costs alone. However, the added permitting issues, handling of the liquid sediment slurry, and the need for both temporary and final disposal sites, typically increases the total price of hydraulic dredging beyond that of the mechanical approach. Due to the higher costs and space limitations with respect to temporary and final storage of dredged materials, hydraulic dredging is not recommended for Lake Absegami.

Sites of access for dredging equipment is dictated by the location of the specific areas being dredged and the total amount of material to be removed. Based on the fact that the majority of the shoreline is highly vegetated, the primary site of access for a dredging project at Lake Absegami would be the beach. If the dredging project is very selective in nature, the complexities associated with access may be minimal. However, as the scope and size of the project increases, the complexities associated with access will also increase. For example, dredging the northern and/or southern branches of Lake Absegami would more than likely require the construction of temporary haul roads from beyond the beach to the branches, in order to allow access for the dredging equipment.

It is absolutely critical that the disposal site(s) be clearly identified and established. In addition, the disposal site(s) must be large enough to appropriately contain the dredged material. In order to minimize permitting issues and general project logistics, the most effective strategy is to have an on-site (i.e. within the State Forest) disposal site. Based on the chemical analyses conducted as part of this Phase I study, the sediments of Lake Absegami are not deemed as hazardous and thus do not require to be disposed of at a landfill specially identified for hazardous materials. Thus, the dredged material could be transported to an on-site location for permanent disposal.

Since Lake Absegami is located in Bass River State Forest, the potential for nearby land that can be used for the final disposal of the dredged material should be high. Ballparks, abandoned fields, grasslands and meadows are excellent sites for disposal. Once the material has had an opportunity to settle, the site can easily be restored (i.e. stabilized and re-vegetated). The dredged material can be used for general non-structural purposes, such as landscaping. However, the material may have to be augmented with mulch or lime for landscaping. Obviously, the material can not be placed in wetlands nor back into the lake. The material should be placed in an upland area and stabilized in order to ensure that it does not once again impact the aquatic resources within Bass River State Forest.

The most important component of a dredging project, which dictates the costs associated with the entire project and is commonly overlooked, is the transportation and disposal of the sediments. For example, for a 25,000 yd^3 dredging project, a 5 mile round trip to the final disposal site can be expected to cost approximately $75,000.00 in trucking. In contrast, a 25 mile round trip to the final disposal site for the same amount of dredged material can be expected to cost approximately $200,000.00 in trucking. Therefore, in order to minimize trucking costs, the final disposal site should be located as close to Lake Absegami as is logistically possible.

Costs and Permitting

Based on the scenario described above, the dredging of Lake Absegami is expected to cost between $11.00 and $13.00 per cubic yard. Thus, dredging the lake, excluding the upper reaches of the northern and southern branches of Tommy's Branch that could not be surveyed, is estimated to cost between $2.4 and $2.9 million dollars. If the approximated amount of unconsolidated sediments within the upper reaches of both branches are included in the proposed whole-lake dredging of Lake Absegami, the estimated cost is between $2.8 and $3.4 million dollars. Both estimated costs include the actual dredging, transportation of the material to an on-site disposal site, all of the associated permitting and environmental monitoring / management, and the restoration of the site after the project is complete. It should be emphasized that if the upper reaches of the two branches are included in a dredging project, additional bathymetric data will need to be collected. This additional field work is included in the price quoted above for a whole-lake dredging project.

The actual price of a Lake Absegami dredging project will be chiefly dependent upon the round trip distance trucks would have to make from the lake to the final disposal site. Another, although smaller contributing, factor that dictates the actual price, is the size and extent of any temporary haul roads that need to be constructed and disassembled.

As mentioned above, in order to dredge Lake Absegami, both State and local permits will be required. Given the objective of the dredging of Absegami, as well as the size and scope of such an endeavor, via any of the scenarios listed in Table 11, a State General Permit-13 (Lake Dredging) would be required for the project. If the dredging would focus solely on material that has accumulated within the basin proper over time, a Minor Stream Encroachment permit will be required. The local permit will include, at a minimum, an Erosion and Sediment Plan approved by the Burlington County Soil Conservation District.

Given the extremely high costs associated with dredging most or all of the lake (> $2 million dollars), a more selective dredging of Lake Absegami is recommended. Such an alternative would make obtaining funds to actually implement the project more attainable. Given the existing conditions within the lake and the recreational and ecological needs of the system, we recommend selectively dredging a section of the lake just off the beach, as well as within the upper reaches of both branches which are currently inaccessible to both fish and canoes during the dry summer season.

The total bottom area from along the length of the beach, out to a distance of 500 feet, is approximately 12.5 acres. The average thickness of unconsolidated sediments within this section of the lake averaged 3.7 feet. Based on these measurements, the amount of unconsolidated sediments within this 12.5 acre area immediately off the beach is estimated to 5.8×10^4 m^3 (46.85 acre-ft) or 75,619 cubic yards.

Similar calculations for along the length of the beach and out to a distance of 200 feet, resulted in an in-lake dredging area of approximately 4.9 acres. In turn, the amount of unconsolidated sediments within this area is estimated to be 2.3×10^4 m^3 (18.58 acre-ft) or 29,989 cubic yards.

As mentioned earlier, the upper reaches of both the northern and southern branches of Lake Absegami are almost completely filled in with unconsolidated material. The amount of unconsolidated sediments within the upper reaches of both branches was approximated to be 0.28×10^5 m^3 (22.5 acre-ft) or 36,350 cubic yards. Again, it should be emphasized that these branch values were approximated with a limited amount of survey data and more detailed information would be required for the implementation of a dredging project.

With the estimated amount of unconsolidated sediment within selected areas of Lake Absegami, the associated costs of the various alternatives to a whole-lake dredging are provided in Table 11. Table 11 contains the information needed to make an objective evaluation of the cost effectiveness of the various dredging scenarios.

Table 11

A Number of Possible Dredging Scenarios and Their Associated Costs for Lake Absegami, Burlington County, NJ

Dredging Scenario	Estimated Amount of Unconsolidated Sediments	Associated Cost of Dredging[a]
Whole lake dredging within the bounds of the survey	220,000 yd^3	\$2.4 to \$2.9 million
Whole lake dredging, including the upper reaches of both branches of Lake Absegami[b]	256,350 yd^3	\$2.8 to \$3.9 million
An area approximately 200 ft beyond the Lake Absegami beach	29,989 yd^3	\$330,000.00 to \$390,000.00
An area approximately 500 ft beyond the Lake Absegami beach	75,619 yd^3	\$832,000 to \$983,000.00
Approximately 200 ft off the beach and the upper reaches of both branches of Lake Absegami[b]	66,339 yd^3	\$730,000 to \$862,000.00
Approximately 500 ft off the beach and the upper reaches of both branches of Lake Absegami[b]	111,969 yd^3	\$1.2 to \$1.5 million

a) The associated cost includes all additional survey work, permitting, environmental monitoring, dredging and site restoration. The quoted costs also take into account an approximately 5 mile round trip to the sediment disposal site.

b) The upper reaches of the northern and southern branches of the lake were inaccessible during the bathymetric survey. Therefore, the amount of unconsolidated sediments within these sections of the lake were estimated, based on a limited number of sediment probes.

8.1.2 Removal of Old Cedar Stumps

One specific issue of concern with regard to the recreational use of Lake Absegami has been the large number of cut, old cedar stumps distributed throughout the lake. Atlantic white cedar (*Chamaecyparis thyoides*) is found in wet areas near streams or within swamps throughout the Pine Barrens. Lake Absegami was created in the 1930's when the two branches of Tommy's Branch were impounded. The area that was impounded was a swampland, dominated by Atlantic white cedar. Most of these trees were cut down prior to the damming of the streams, however, the stumps continue to exist in Lake Absegami. Atlantic white cedar are well known to be highly resistant to rotting, which is partly due to the fact that they prefer acidic soils and waters. Such acidic conditions severely limit the ability of bacteria to decompose organic matter. Thus, the net effect is that the majority of these cedar stumps are still present in Lake Absegami.

The continued presence of these old cedar stumps has raised some issues of concern over the potential impacts they may exert on Lake Absegami. In terms of possible chemical contaminants due to the decomposition of the cedar stumps, any such impacts would be negligible. The only potential impact associated with the presence of the cedar stumps would be associated with a decline in DO concentrations, as a result of bacterial decomposition. However, as previously mentioned, white cedar has a very slow rate of decomposition. In addition, the pH of Lake Absegami varied from 4.55 to 5.70 through the course of the Phase I monitoring program. These acidic pH values severely limit rates of decomposition, since most bacteria can not tolerate such conditions. Thus, the rates of decomposition of the organic matter associated with the cedar stumps is extremely low which, in turn, results in an extremely minor demand for DO. Thus, the potential chemical impacts of the cedar stumps are deemed negligible.

While cedar stumps may not negatively impact Lake Absegami in terms of water quality, they can exert a negative impact on its recreational use. The lake is relatively shallow with a mean depth of only 3.25 ft (Table 1). Thus, the cedar stumps can be potential navigational hazards for canoes and fishing boats that use electric motors, especially during particularly dry conditions, such as those experienced during the summer and fall of 2001. Thus, in order to address these conditions, a survey of the stumps located throughout Lake Absegami was conducted on 27 November 2001. Specially, GPS technology was used to identify and locate submerged cedar stumps.

Given the large number of stumps distributed throughout the lake, the survey focused on those sections of the lake where the stumps could directly impact recreational activities such as boating, fishing and swimming. Extremely large stumps were sited and specifically located on the map, while particular areas where large densities of stumps were distributed along the lake bottom were identified (Figure 7). Essentially, large isolated stumps were found within the northern and southern branches of the lake. In addition, two stump fields were located just beyond the Lake Absegami beach (Figure 7).

The removal of these cedar stumps will be an extremely difficult and time consuming task. Lowering the lake will provide easier access to the stumps. A combination of shoreline and bargebased equipment could be used to remove the stumps. While a price estimate on a per stump basis would be extremely difficult to quantify, estimated prices were developed for the major stump fields located in Figure 7. It should be emphasized that the prices quoted below are based on a partial drawdown of the lake and the removal of most, but not all, of the stumps within each field.

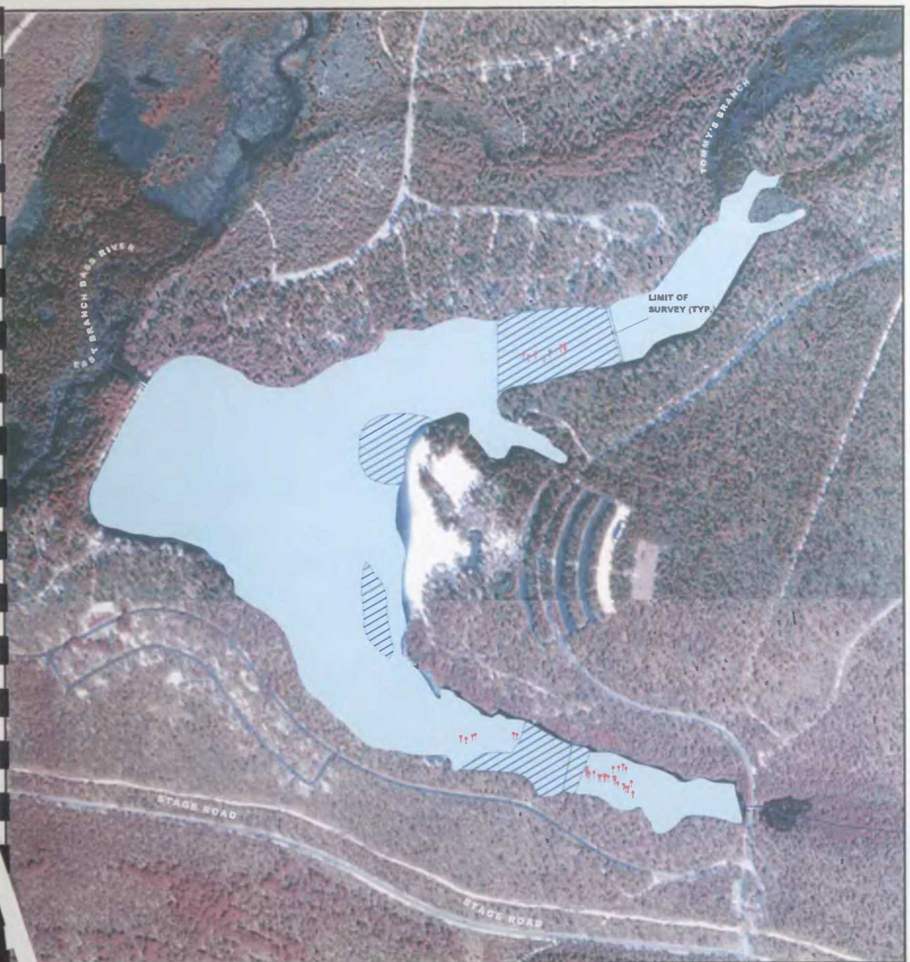
The material and labor associated with the removal of a large number of the stumps within the fields identified in the northern and southern arms of the lake (Figure 7), are estimated to cost $5,000.00 per field. Most of the stumps in the two stump fields located immediately beyond the beach could be removed for approximately $7,500.00.

While the prices quoted above include the actual removal of the stumps, they do not include their transport to a final disposal site. Given the size of the Bass River State Forest, there may be areas within the State lands available for the disposal of these stumps. In fact, the stumps can be used to aid in stabilizing some localized areas of exposed soils. In any event, if the State Forest disposed of the removed stumps, the associated costs of such a project would be close to those already quoted. Thus, assuming the Bass River State Forest transports the removed stumps to an on-site disposal site, the removal of a large portion of the cedar stumps identified in the four fields shown in Figure 7 is estimated to cost approximately $17,500.00.

There will be a certain degree of permitting associated with the removal of the cedar stumps. NJ DEP may require an Individual Permit to removal the stumps or may simply ask for a General Permit-13 with a Minor Stream Encroachment. Given the uniqueness of the proposed task, a pre-application meeting is recommended between the State Forest and NJ DEP to determine the exact course of action in terms of obtaining the State permits. Thus, an exact cost associated with the this component of the project is difficult to quantify. Depending on the require scope of permitting (i.e. general permit vs. an individual permit), the range of permitting costs vary between $2,000.00 to $10,000.00.

In addition to the State permit, a drawdown permit would have to be filed with the New Jersey Division of Fish, Game and Wildlife, Bureau of Freshwater Fisheries. An Erosion and Sediment Plan would have to be submitted to the Burlington County Soil Conservation District. This E&S Plan would have to address both the removal of the stumps, and the stabilization efforts at the final disposal site of the stumps. These additional permitting issues are estimated to cost another $3,000.00.

Finally, it should be noted that the removal of cedar stumps is not strongly recommended given their potential environmental benefits. Specifically, the stumps serve as structural habitat and refuge for macroinvertebrates and forage fish. Thus, if stumps are removed from Lake Absegami, only those that pose a navigational and/or recreational hazard should be targeted for removal.



LAKE ABSEGAMI STUMP FIELDS

STATISTICS

CONDITIONS AT TIME OF SURVEY:

1.) THE LIMITS OF THE SURVEY ARE DUE TO HIGH QUANTITIES OF BIOLOGICAL INTERFERENCE, AND LOW WATER LEVELS, MAKING ACCESS TO THE OUTER-MOST PORTIONS OF THE LAKE IMPOSSIBLE.

2.) THE WATER LEVEL AT THE TIME OF SURVEY IS 4.75'. MEASURED FROM THE TOP OF THE DAM ON THE NORTHERN SIDE AT THE CONFLUENCE WITH BASS RIVER.

INLAKE DATA AT TIME OF SURVEY:

1.) VOLUME OF WATER:
98.37 ACRE-FT

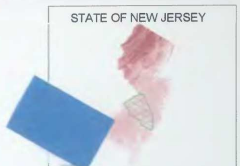
2.) MEAN DEPTH:
3.25 FT

3.) MAXIMUM DEPTH:
7.44 FT

4.) PLANIMETRIC AREA:
44.85 ACRES

5.) TOTAL VOLUME OF SEDIMENT:
136.35 ACRE-FT

6.) MEAN SEDIMENT THICKNESS:
3.18 FT



DATA SOURCES

1.) IN WATER DEPTH SURVEY CONDUCTED ON SEPTEMBER 11, 2001, BY PRINCETON HYDRO, LLC, 1108 OLD YORK ROAD, SUITE 1, P.O. BOX 720, RINGOES, NJ 08551.

2.) METHODS USED TO CONDUCT THE BATHYMETERIC SURVEY CONFORM TO CLASS 1, USACE PROCEDURES ARE ACCURACIES.

KEY

- Lake Absegami
- Streams/ Rivers
- Large Tree Stumps
- Survey Limit
- Stump Field

BATHYMETRIC CONTOURS

100 0 100 200 300 Feet

Scale: 1 : 400

NAD 83

FIGURE 7: BASS RIVER STATE FOREST NEW GRETNA, BURLINGTON COUNTY NEW JERSEY, LAKE ABSEGAMI.

NOTES:
1.) DATA ACCURACY IS LIMITED TO THE ACCURACY AND SCALE OF THE ORIGINAL DATA SOURCES.

2.) THIS MAP IS PART OF A DIAGNOSTIC FEASABILITY STUDY, AND SHOULD BE USED IN CONJUNCTION WITH THE ASSOCIATED TEXT.

pH

Project No.: 209.01

DRAWN BY:	KJM,CW
CHECKED BY:	FSL

8.1.3 Circulator Systems

Submersed circulator systems are designed to constantly move water to prevent the establishment of stagnant or still water conditions. These still water conditions, or "dead zones" are primarily the result of prevailing winds. Usually circulator systems are installed in small coves or shoreline areas on the windward side of a lake. Algae, floating fragments of weeds and debris accumulate within these areas during windy conditions and will remain there during stagnant, windless conditions. A properly installed circulator system will prevent the accumulation of such material by constantly circulating or moving the water away from the shoreline. Another advantage that may be realized with the use of a circulator system is a reduction in accumulated, near-shore pathogenic bacteria. Thus, the objective of a circulator system is to strategically place a number of circulator units within the area of concern to prevent the development of stagnant conditions.

The only section of shoreline at Lake Absegami that would directly benefit from the use of a circulator system would be the beach along the east-central shoreline (Figure 5). Based on the morphometric attributes of the lake, as well as the total length of the shoreline, three circulator units (Appendix E) would more than likely be required to eliminate, or at least substantially minimize, the accumulation of floating debris along the beach shoreline. Depending on the prevailing winds, the circulator units would be positioned to direct the flow of air and water toward the northwest or southwest.

If a circulator system is seriously considered for the beach area of Lake Absegami, the following aspects of such a project need to be addressed:

1. Shoreline based electrical connections are required for the circulator unit. As shown in the simple diagram provided in Appendix E, a water-safe electrical cable connects each circulator unit with a source of energy located on the shoreline. Specifically, the circulator system's electrical panel(s) must be connected to a reliable source of electricity. Thus, in order to minimize the costs associated with this management technique, the system must be connected to the closest source of electricity.

2. The services of a certified electrician are required for the installation of the electrical panels.

3. The units need to be placed in the properly identified positions to ensure optimal efficiency of the system.

4. The units should be placed in the lake sometime in the spring and should be removed in late fall, to prevent potential ice damage during the winter.

5. The length of electrical cable needs to be accurately calculated to ensure that there is adequate cable for proper installation and positioning of the units.

The purchase of the equipment (three circulator units, associated electrical cable and panels), is estimated to cost between $25,500.00 and $27,000.00, dependant upon the total length of electrical cable needed for each circulator unit, and the subsequent price per linear foot. This estimated range in cost does not include the costs associated with unit / cable installation, freight and shipping. Additional factors not included in this price range are the required services of a certified electrician and any supplemental shoreline-based modifications required to provide the system with a safe and dependable source of electricity.

One of the primary factors dictating the installation and equipment costs of installing a circulator system, is how close the shoreline electrical source is to the circulator units. The farther away the units are from the electrical source, the more electrical cable is required. The price of the electrical cable is expensive and typically costs between $2.50 and $3.00 per foot of cable. The anticipated amount of electrical cable, as well as the number of circulator units, is one of the primary factors responsible for the wide variation in the estimated costs of installing a circulator system in Lake Absegami. Given the associated cable costs, the circulator units and shore-based electrical panel(s) should be as close to the shoreline as possible, to minimize the distance between these two components of the circulator system (Appendix E).

Finally, it should again be emphasized that while such a circulator system would improve the overall aesthetics of the beach area of Lake Absegami, it will not improve the water quality conditions of the lake and does nothing to reduce the lake's pollutant (phosphorous, nitrogen and TSS) loads. While a circulator system may aid in reducing concentrations of fecal coliform, such results have not been quantitatively documented as this time.

8.1.4 Fishery Management

During the 2000-2001 sampling program, Princeton Hydro personnel qualitatively assessed the fish community of Lake Absegami. Only small baitfish (primarily minnows) and a few small, stunted chain pickerel were observed in the lake. From these data, it was concluded that the recreational fishery of Lake Absegami is sub-optimal. To improve the lake's fishing potential, Princeton Hydro recommends managing the lake as a warm-water fishery, taking into account the lake's inherent shallow depth, acidic pH, and overall limited productivity.

Since ample nursery, foraging, and refuge habit exists in Lake Absegami, no augmentation nor modification of the current in-lake habitat / structure is required. However, as described earlier in Section 8.1.1, the dredging of the arms of the lake would increase and enhance viable aquatic habitat.

The primary activity needed to improve upon the lake's current recreational fishery is the stocking of game fish and enhancement of the forage fish population. The fish recommended for stocking include largemouth bass (*Micropterus salmoides*) and fathead minnows (*Pimephales promelas*).

Largemouth bass are generally classified as a warmwater fish species. While largemouth bass are adaptable to a wide range of conditions and inhabit a variety of aquatic habitats, they are most commonly found in small, shallow lakes or the shallow bays of larger lakes. They are usually found associated with soft sediment bottoms, stumps and stands of emergent and submergent aquatic vegetation. Largemouth bass tolerate waters of moderate turbidity. Feeding rates of largemouth bass are extremely limited when temperatures fall below 10 °C.

The optimal range of pH for most aquatic organisms tends to be between 6.0 and 9.0. In contrast, the pH of Lake Absegami was typically measured to vary from the upper 4.0's to the upper 5.0's (Appendix A). Thus, the acidic conditions of Lake Absegami contribute toward limiting its biological productivity. Fortunately, largemouth bass are extremely tolerate of a wide range in pH. For example, in Florida, some bass have been found in lakes with pH values as low as 4.3. Thus, given the existing structural habitat and shallow mean depth, as well as the acidic waters, largemouth bass were selected as the primary gamefish for Lake Absegami.

Largemouth bass reproduce over a variety of substrates as long as firm, silt-free nests can be built. However, they prefer rocky/gravelly substrates with cover (logs, stumps, vegetation). They can also spawn in a variety of substrates including mud, gravel, and sand, but their nests are usually located near cover such as stands of aquatic plants, stumps, and brushpiles. Largemouth bass typically reproduce sometime between late-spring and early-summer. Reproduction commences when water temperatures are between 13 and 16 °C, with optimal rates attained at water temperatures between 18 and 21 °C.

Largemouth bass are top piscivores (fish-eating fish). They primarily feed on forage fishes, including young sunfish, shad, and fathead minnows. Given the anticipated low number of forage fish in Lake Absegami, some supplemental stocking should accompany the stocking of largemouth bass. Fathead minnows are the recommended forage fish species for stocking. Unlike many species of sunfish (i.e. bluegill, pumpkinseed), fathead minnows do not compete for spawning habitat with largemouth bass, nor do they compete for food with young bass. Therefore, no panfish species should be stocked in Lake Absegami as forage fish.

Several types of escoids (pickerel and pike) are also tolerant of the environmental conditions characteristic of Lake Absegami, especially in regards to pH. However, their forage needs have to be met before they can be successfully integrated into a stocking program. Pike and pickerel are highly efficient predators and are strongly piscivorus. Adults will consume almost any living vertebrate in the size range they can engulf. Therefore, an adequate forage fish population must be present in order to minimize interspecific competition among largemouth bass, pike, and pickerel for prey items (i.e. forage fish). Large pike and pickerel can also feed on smaller-sized largemouth bass, which could compromise the establishment of a stable population of largemouth bass in Lake Absegami. Given such potential inter-relationships among the various gamefish species, stocking Lake Absegami with pike or pickerel is not recommended at this time.

Over time a secondary gamefish species (i.e. pike) may be included in the Lake Absegami stocking program. However, the addition of another gamefish species is not recommended until a more detailed fishery survey and habitat assessment is completed. In addition, it should be noted that it is difficult to obtain escoid fishes from hatcheries, adding to the complications associated with initiating an escoid stocking program. Thus, given what is known about current in-lake conditions, the Lake Absegami fishing stocking program should initially focus solely on the establishment of largemouth bass and fathead minnows.

It is tentatively recommended that two size classes of largemouth bass are considered for the stocking program: a) 4-6" size class at a density of 100 fish per acre, and b) 8-10" size class at a density of 10 fish per acre. Fathead minnows, which will serve as the primary forage fish for the largemouth bass, should be stocked at a density of 2,000 fish per acre. Given these recommended stocking rates, 5,260 (4-6") largemouth bass, 526 (8-10") largemouth bass and 105,200 fathead minnows are proposed for the Lake Absegami stocking program.

In order to optimize the stocking program, two separate stocking events are recommended. The first stocking event should be conducted in the spring. At this time, the 4-6" largemouth bass should be added to Lake Absegami. Stocking the smaller largemouth bass in Lake Absegami in the spring will provide the fish with the subsequent growing season to become familiar with the in-lake habitat and increase in size. In addition, 1,000 of the 2,000 fathead minnows should be added at this time.

The second stocking event should be scheduled in the fall following the first stocking event. For the fall stocking event, the 8-10" largemouth bass and the remaining 1,000 fathead minnows should be added to the lake.

The exact price for the fish identified above is dependent upon the relative availability of each species and size class. However, based on recently implemented stocking programs, the following estimated price range was developed for Lake Absegami. The purchase of the fish (5,260 (4-6") largemouth bass, 526 (8-10") largemouth bass and 105,200 fathead minnows) is estimated to cost between $10,000.00 and $20,000.00. This price does not include the tax and transportation of the fish, however, these costs tend to be minor relative to the actual purchase of the fish.

The recommended stocking plan outlined above is tentative since a formal, quantitative assessment of the fish community of Lake Absegami has yet to be completed. It is possible that the stocking plan may be modified after a detailed fishery survey of the lake is complete. Therefore, as part of the fishery management program of Lake Absegami, a fishery survey should be conducted. Given the size and structural complexity of the lake's habitat, a detailed fishery survey would require three days of work and cost approximately $8,000.00. The methodology associated with such a survey would include, but not be limited to, electroshocking, shoreline siening, gill nets and trap nets. The resulting fishery dataset would serve as the baseline to establish pre-stocking conditions of Lake Absegami. Such data would allow the State Forest to quantitatively identify the recreational improvements associated with the implementation of the recommended stocking program.

The implementation of both the fishery survey and stocking program is estimated to cost approximately $18,000.00-$28,000.00. This price would include all required permitting, the pre-stocking fishery survey, the purchase and stocking of the fish, and a report on the fishery survey and the implemented stocking program. The estimated price assumes outside consultants and vendors would be used for conducting the fishery survey and the purchasing and stocking of the fish, respectively.

8.1.5 Chemical Control of Aquatic Plants

Princeton Hydro personnel made qualitative assessments of aquatic and semi-aquatic plant growth at Lake Absegami. An emergent rush, most likely spike rush, and stands of *Scirpus subtermindlis* (swaying rush, also know as water club rush), a form of submerged aquatic vegetation, were identified throughout a large portion of Lake Absegami. The emergent rush was found within the littoral zone of Lake Absegami, while the submerged rush, *Scirpus subtermindlis*, was more uniformly distributed throughout the lake bottom.

In addition to the emergent and submerged rushes, yellow water lily (*Nuphar spp.*) and, on occasion, coontail (*Ceratophyllum* spp.) and *Sphagnum spp.* moss were found in the northern branch. A similar aquatic plant community was found in the southern branch, with white water lily *Nymphaea* spp. also being observed. With the exception of the spring sampling dates (earlier than June 2001), the submerged rush was found in both branches during the entire monitoring program. Aquatic plant growth in the main body of the lake and the branches did not attain nuisance levels. Given these current conditions, chemical control of aquatic plants is neither needed nor recommended. In fact, the presence of the rush provides good habitat for fish and other aquatic organisms.

Fragments of aquatic plants may accumulate along the beach shoreline of Lake Absegami, however, such floating mats of vegetation could be physically harvested or raked off the beach. After aquatic plant biomass dries out, it is substantially lighter and easier to handle, and can be mixed into a mulch pile.

8.1.6 Chemical Control of Algae

A qualitative analysis of algal growth in Lake Absegami and its inlets was also made by Princeton Hydro personnel. While phytoplankton (free floating algae) abundance was relatively low in Lake Absegami, substantial amounts of filamentous mat algae were found along the lake bottom, especially within the two branches. These mats of filamentous algae were also observed floating on the water's surface. During the spring and early summer, most of this mat algae was the filamentous green alga *Spirogyra*. A substantial amount of *Spirogyra* were observed in the northern and southern branches during the early summer season, however, *Spirogyra* tends to prefer cooler water temperatures. Thus, *Spirogyra* proliferates in the spring and early summer and dies off by the mid-summer season. This preference for lower water temperatures indicates that by the time Lake

Absegami is being heavily used for recreation, *Spirogyra* is on the decline and any nuisance biomass will generally dissipate by the height of summer.

In addition to *Spirogyra*, a number of other filamentous mat algae were observed during the Phase I Study of Lake Absegami. Some of these algae included *Pithophora*, *Mougeotia* and *Rhizoclonium*. Unlike *Spirogyra*, these algae tend to proliferate in warmer waters. While these algae were common during the summer season, they did not attain densities high enough to be considered a major nuisance. Therefore, given the relative amount of filamentous algae biomass in Lake Absegami, chemical control with a copper-based algicide is not recommended as this time. Similar to the aquatic plants, any significant amount of filamentous mat algae that accumulates along the beach could be manually raked off the beach and allowed to dry for mulching.

As with all aquatic ecosystems within the Pinelands, nutrient concentrations are low in Lake Absegami. The Bass River State Forest should be cognizant of the fact that watershed-based activities can increase the nutrient (nitrogen and phosphorus) loads entering Lake Absegami. In turn, such an increase in the nutrient loads will result in an increase in algal growth. Elevated levels of algal growth, as a result of an increase in the lake's nutrient load, may produce nuisance conditions. Such an increase in nuisance conditions may result in the re-consideration of the use of copper-based algicides.

Although copper-based algicides may provide a limited amount of short-term control of excessive algal growth, the use of such products should be avoided. The hardness of Lake Absegami varied between < 5 to 7.8 mg of $CaCO_3$ per L (Appendix B). These hardness values are extremely low. The use of copper sulfate is generally limited to waterbodies where hardness is greater than 50 mg of $CaCO_3$ per L. Low hardness values essentially allows the copper to be more readily absorbed by non-target organisms such as fish and macroinvertebrates. Thus, the use of copper sulfate, even if algal growth begins to attain nuisance conditions, should be avoided in Lake Absegami in order to avoid toxicological impacts on non-target organisms.

8.2 Watershed Restoration Techniques

In contrast to in-lake restoration techniques, watershed based techniques focus on the causes of eutrophication rather than the effects. Watershed techniques are not as visible as in-lake techniques and tend to take more time to produce their desired results. However, they are absolutely vital in reducing the pollutant load, as well as producing and sustaining long-term improvements in surface water quality.

Watershed control measures are designed to reduce non-point source (NPS) pollution. NPS pollution is very diffuse, generated over a relatively large area, and is produced by a wide variety of sources. Some examples of NPS pollutant sources include lawn and garden fertilizers, waste generated from livestock, pets, and waterfowl, eroded shorelines / streambanks, surface runoff from paved surfaces and construction sites, and atmospheric deposition. This type of pollution is sharply contrasted to point source pollution, where pollutants are generated and discharged from a specific point or source. An example of a point source is the release of effluent from a sewage treatment plant. Relatively speaking, point source pollution is easy to control. If a sewage treatment plant is responsible for the problem, effort and money need only to control that one source. Unfortunately, NPS pollutants can often be more difficult and expensive to control. Nevertheless, where NPS pollution accounts for all or a large fraction of the total pollutant load, this source of pollution needs to be controlled if long-term improvements in water quality are to be realized.

The fundamental objective of watershed management is to reduce the external pollutant loads. Another, just as important objective, for the watershed-based management of Lake Absegami is to preserve and protect the existing natural resources of the lake through a series of land-based, pro-active techniques. Given the fact that forested land accounts for almost 86% of the total land use within the Lake Absegami watershed, most of the recommended watershed management techniques are very pro-active.

One of the reasons NPS pollution is difficult to control is that it does not respect municipal or property boundaries. Since it is generated over the entire watershed, as well from atmospheric sources, the organization concerned about the ability to adequately control pollutant loading may not be within the jurisdictional limitations of the affected community. However, most of the time the community concerned and responsible for the water quality of a given waterbody does have control over shoreline areas. Since the vast majority of the Lake Absegami watershed is located within the Bass River State Forest, the recommended watershed-based management techniques would be implemented by the State Forest. Given these conditions, the implementation of the watershed-based component of the Management Plan should be relatively easy to implement.

8.2.1 Public Education

The following NPS management techniques can be lumped into the general category of Public Education. Basically, these measures require voluntary implementation. To be successful, these measures must be embraced by the community and stakeholders. However, if rigorously implemented such measures can have a pronounced and positive impact on water quality, lake trophic state and general aesthetics. The aim of such non-structural NPS management techniques is to reduce pollutant loading before it occurs by controlling its generation at the point of origin.

Lake Absegami is a public lake located within Bass River State Forest. Since the lake is within public land, public education will be an important component of the Lake Absegami Management Plan. Such a public education program should have two major stakeholder groups in mind. The first stakeholder group should be the public who visits and recreates at Lake Absegami. The second stakeholder group should be local residents who may live within the Lake Absegami watershed, with an emphasis placed on local students (elementary, middle school and/or high school) who potentially have direct access to the lake and State Forest.

The visiting stakeholder component of the public education program should focus on producing and distributing literature to interested parties. Such literature could be similar to the brochure that was generated as part of this Phase I Diagnostic / Feasibility Study (Appendix E). Future informational brochures could include topics such as non-point source pollution, a summary of the general lake ecology of Lake Absegami and tips on what visitors can do to minimize their individual impacts on the water quality of Lake Absegami.

In addition to providing general information and useful tips, any management measures that are implemented at Lake Absegami should include a public education component. For example, if the lake is scheduled for dredging or stump removal, a pre- and post-project educational brochure should be developed and available for distribution. The pre-project brochure would explain what will be accomplished and the anticipated benefits. The post-project brochure would provide detailed information on what and how the project was accomplished, as well as document the lake's measured response to the project.

Educational brochures could be designed and developed by either employees of the State Forest and/or a hired consultant. The generated brochures can then be made available at the Bass River State Forest. The information could also be placed on the Internet at a State Forest web-site for general access. Funding for such projects could be obtained through the New Jersey Environmental Education program or the US EPA Environmental Education Grant Program. Another source of funding could be Lake Restoration funds that may be available in New Jersey sometime in the future. Typically, a public education task is included as part of a larger proposal to obtain funds for lake restoration. The design and development of such educational brochures typically varies between $800.00 and $1,000.00 per brochure, not including photocopying.

In order to instill a sense of ecological value and concern in NJ residents, some of which may utilize and manage the Lake Absegami ecosystem in the future, the Bass River State Forest may want to team with local schools in developing some student-based, public education projects or programs. For such an educational project to be successfully implemented, the State Forest would have to closely work with a local teacher(s) and school(s). As cited earlier, the New Jersey

Environmental Education program may provide the funds necessary to implement student-based activities such as water quality monitoring and shoreline plantings. Students could also assist in the development of educational material that could distributed by the State Forest. In any event, to implement this watershed measure, Bass River State Forest would need to establish a working relationship between themselves and a local school district.

8.2.2 Preservation of Existing Land

This Phase I Study revealed that approximately 95% of the Lake Absegami watershed is forested and/or some type of wetland. Such existing land conditions are optimal for water quality since forested land tends to generate the lowest surface runoff pollutant loads and wetlands can function to actually assimilate nutrients and other pollutants. Therefore, in order to prevent any future degradation of the water quality of Lake Absegami, the land within its watershed should remain forested. The majority of the Lake Absegami watershed is located within the Bass River State Forest, so preserving this land should not be problematic.

Since Lake Absegami and the majority of its watershed is located within Bass River State Forest, concern over future development and/or earth-moving activities should be minimal. Any earth-moving activities that are implemented by the State Forest should closely follow Burlington County Soil Conservation District guidelines for soil and erosion control, to minimize any increase in the lake's current pollutant load. Additional guidance may be obtained through the Pine Lands Commission.

As long as the Lake Absegami watershed continues to remain preserved and protected by Bass River State Forest, large-scale structural best management practices (BMPs), such as sedimentation basins, grassed swales, sand filters, etc., will not be necessary for the lake. Reactionary measures, such as the implementation of structural BMPs, tend to be more costly than pro-active measures, such as preservation and protection of land. Therefore, it is in the best interest of both the State Forest and the stakeholders who use the lake for recreation, to preserve and protect the existing natural resources, rather than wait for water quality problems to develop and implement costly structural BMP projects.

8.2.3 Shoreline Stabilization

The majority of the shoreline of Lake Absegami is well stabilized. Relatively low slopes, combined with highly vegetation shorelines, resulted in a stabilized shoreline. The exception to these highly stabilized conditions is, as expected, the beach. Obviously, no stabilization efforts (i.e. rip-rap, plantings) are recommended for the beach, in order to allow access and the recreational use of the lake. While the shoreline of Lake Absegami was generally well stabilized, it is possible that some sections of the streambank along the northern and southern Tommy's Branch inlets are in need of stabilization.

To objectively implement a shoreline stabilization plan for the two main inlets of Lake Absegami, a set of protocol should be followed. Essentially, the protocol would be used to prioritize those sections of streambank with the highest need of stabilization. Available funds (i.e. grants or other sources) would then be used to implement those projects that would provide the highest degree of return per dollar spent. While the Bass River State Forest may want to develop their own set of protocol to prioritize potential streambank stabilization projects, the following proposed protocol are provided as a recommended means of initiating this watershed technique.

1. Conduct a stream walk along both the northern and southern branch of Tommy's Branch. Field notes and digital photographs should be taken of the streambank sites in need of stabilization. The linear length and slope of the identified sites should be estimated. Finally, data on the environment and habitat immediately surrounding each streambank site, both within the stream and adjacent to the stream, should be collected.

2. The data that were collected as part of the streambank survey should be complied into a database. The database would then be used to prioritize the projects. Prioritization parameters could include, but would not necessarily be limited to, length and slope of site, potential in-stream and riparian impacts if not stabilized, and possible impacts on property of the State Forest or any private stakeholders.

3. The results of the prioritization assessment would be placed into a final report, which would include the digital photographs and a long-term prioritization plan for the implementation of the identified projects. In turn, this document could be used to justify the need to provide the State Forest with Federal, State, County and/or local funds to implement the targeted projects.

Depending on site-specific conditions, standard structural (i.e. rip-rap, gabions) and/or bioengineering (i.e. biologs, installation of vegetation) technique may be used to implement the identified streambank stabilization projects. However, without any site-specific information, it is difficult to identify in detail which techniques should be used for which project. Thus, the prioritization assessment document should include guidance in the selection of the most appropriate stabilization technique(s).

Regardless of which technique or combination of techniques is implemented, the cost of stabilization tends to vary between $50.00 and $100.00 per linear foot. This estimated price range includes material and labor associated with implementing the project and ease of access to the site. However, the estimated price range does not include permitting and the development of design plans and bid specifications. The price per linear foot would decline if the State Forest used its own personnel and equipment to implement the projects. Another means of reducing the estimated cost is to have volunteers assist in some of the planting of vegetation. Such volunteer assistance may include boy or girl scouts, middle or high school students, concerned local citizens or members of Americorp.

The estimated cost of conducting the prioritization assessment is $11,000.00. This would include the field work, prioritization assessment procedure, and submission of a completed report.

8.3 Evaluation of Management Techniques

A feasibility matrix was developed to objectively evaluate the implementation of potential in-lake and watershed techniques. An ordinal ranking, based on a score of 1 to 5, was generated for each technique. Those techniques scoring the highest were given priority consideration. The feasibility of each option was judged on the basis of:

1. Pollutant reduction - How substantial a decrease in nutrient and/ or sediment loading could be expected from the implementation of this technique?

2. Practicality - Can the technique be practically implemented for Lake Absegami and/or its watershed?

3. Effectiveness - Based on the scientific literature, how effective is this technique in meeting desired management objectives?

4. Environmental Impacts - Are there any adverse environmental impacts associated with implementation of the technique?

5. Initial Costs - How much will it cost to design and initially implement the technique compared to expected returns?

6. Operations and Maintenance (O/M) Costs - How much will it cost to operate and/ or maintain the technique on a long-term, annual basis?

In terms of the in-lake management of Lake Absegami, the highest and second highest ranked management techniques were fishery management and dredging, respectively (Table 12). For fishery management, the high degree of practicality and negligible level of environmental impacts resulted in its high rank. The anticipated effectiveness, coupled with its low operation / maintenance costs, made dredging the second highest ranked in-lake management technique.

The installation of a circulator system at the beach of Lake Absegami was ranked third in the overall rating (Table 12). While a circulator system would substantially reduce the accumulation of floating debris and material along the beach, the initial and operational / maintenance costs and logistics of providing a source of near shore electricity, lowered the overall rating of this in-lake management technique.

The remaining in-lake management techniques, removal of the old cedar stumps, the chemical control of aquatic plants and the chemical control of algae, were all ranked with an overall rating of 12 (Figure 12). The low degree of practicality and high initial costs, resulted in the lower ranking for the removal of the old cedar stumps. Since boat traffic on Lake Absegami is limited to electric motors and canoes, justification for the removal of the old cedar stumps was low.

The level of nuisance aquatic plant and algae problems in Lake Absegami was generally limited by its acidic pH and relatively low level of productivity (i.e. nutrient loads). Given these current conditions, the level of practicality in initiating a plant or algae chemical control program in Lake Absegami was low. Obviously, the potential environmental impacts (i.e. toxicological impacts on non-target organisms, possible accumulation of copper in the sediments) contributed toward lowering the overall rating of these chemical-based, in-lake management techniques. It is possible that over time, as the nutrient load and/or pH increases, the level of productivity will increase which, in turn, will produce nuisance conditions on a more frequent basis. Under such future conditions, the overall ranking of the use of chemical products to control aquatic plants and/or algae may increase. However, under current conditions, such products are not recommended.

All of the watershed-based management techniques were ranked higher than the in-lake management techniques (Table 12). These higher values were primarily due to their higher pollution reducing capacities, as well as the low operation and maintenance costs and the negligible environmental impacts. Thus, the overall rankings of the watershed-based management techniques were higher than those identified for the in-lake management techniques (Table 12).

As previously mentioned, the Lake Absegami watershed is primarily composed of undeveloped land, located within the Bass River State Forest. Under such conditions, watershed-based management efforts need for focus on preserving current watershed and in-lake conditions through pro-active strategies, rather than reactive strategies which focus on reducing current pollutant loads through the installation of structural BMPs. Fortunately, the pro-active strategy is substantially lower in cost, as long as the proper planning and preservation measures are in place. Given the importance of such planning efforts, the preservation of existing in-lake conditions was ranked the highest of the watershed-based management techniques. Please note that the designated rating for the preservation of existing in-lake conditions is based on the assumption that no land needs to be purchased in order to continue such preservation efforts.

The implementation of a public education program was ranked as the second highest watershed-based management technique (Table 12). The slightly lower ranking of public education relative to preservation efforts was due to the difficultly of translating public education to reductions in pollutant loads, as well as the need for funds to continue educational efforts.

The implementation of a streambank stabilization project was the lowest ranked of the three watershed-based management techniques, but it was still higher than any of the in-lake management techniques. The lower rank of the streambank stabilization project was due to the additional level of assessment required to identify and prioritize streambank stabilization projects.

8.4 Proposed Management Plan for Lake Absegami

Using the information collected and analyzed as part of this Phase I Study, a specific Management Plan for Lake Absegami was developed and proposed. The actual implementation and associated costs of these management techniques are outlined in Table 13. The costs provided in Table 13 are for the first year of the Management Plan and do not include subsequent or maintenance costs. However, such maintenance costs will be substantially lower than the initial costs.

Table 12 - Management Alternatives Feasibility Matrix for Lake Absegami

Alternative	Pollutant Reduction	Practicality	Effectiveness	Initial Costs	Operation and Maintenance Costs	Environmental Impacts	Overall Rating
Dredging	1	2	3	2	4	3	15
Circulator System	1	2	3	2	2	4	14
Removal of Old Cedar Stumps	1	1	2	1	4	3	12
Fishery Management	1	4	3	2	3	5	18
Chemical Control of Aquatic Plants	1	1	4	2	2	2	12
Chemical Control of Algae	1	1	3	3	3	1	12
Public Education	3	4	3	4	4	5	23
Preservation of Existing Lake	5	3	4	4*	5	5	26
Shoreline / Streambank Stabilization	4	3	3	3	4	4	21

* Ranking value assumes no land will need to be purchased

Table 13 - Proposed Management Plan for Lake Absegami

In-Lake Management Techniques	
Selective Dredging Scenario I (Approximately 200 ft off the beach and the upper reaches of both branches of the lake - 66,000 cubic yards)	$796,000.00
OR	*OR*
Selective Dredging Scenario II (Approximately 200 ft off the beach - 30,000 cubic yards)	$360,000.00
Circulator System (three circulator units and associated materials)	$27,000.00
Fishery Management (one year of stocking program of largemouth bass and fathead minnows, as well as implementing a detailed fishery survey)	$23,000.00
Watershed-based Management Techniques	
Public Education Program	$3,500.00
Preservation Existing Lake Conditions[a]	$0.00
Streambank Stabilization Program (conducting the prioritization assessment and implementing of a 100 to 200 ft streambank stabilization project)	$21,000.00
Water Quality Monitoring Program (per year)	$5,000.00
Project Management and Documentation	$3,000.00
Total for the Management Plan, with Selective Dredging Scenario I	**$878,500.00**
Total for the Management Plan, with Selective Dredging Scenario II	**$442,500.00**

a) Assumes no land needs to be purchased by the Bass River State Forest.

8.5 Environmental Evaluation

Socio-economic and environmental impacts were considered in the analysis of the management techniques for the Lake Absegami Phase I study. The impacts and potential mitigation measures of implemented management practices are presented below, using the environmental evaluation checklist from the US EPA Clean Lakes Program Guidance Manual (1990).

1. *Will the project displace people?*

   No.

2. *Will the project deface existing residences or residential areas?*

   No. Lake Absegami is located in Bass River State Forest.

3. *Will the project be likely to lead to changes in established land use patterns or an increase in development pressure?*

   No. The Lake Absegami watershed is located within Bass River State Forest. Thus, the Lake Absegami watershed will remain predominantly forested.

4. *Will the project adversely affect prime agricultural land or activities?*

   No. There is no agricultural land within the Lake Absegami watershed.

5. *Will the project adversely affect park land, public land or scenic land?*

   No. While both Lake Absegami and most of its watershed are located within Bass River State Forest, the recommended management measures would beneficially affect the recreational use of the State Forest as well as the lake's water quality.

6. *Will the project adversely affect lands or structures of historic, architectural, archeological or cultural value?*

   No. The proposed management measures involve no modifications to existing structures or activities which will impact lands of historic, archeological or cultural value.

7. *Will the project lead to a significant long-range increase in energy demands?*

   The proposed circulator system would require a source of power and would result in an increase in energy demands. While the use of the a circulator system will increase the State Forest's energy demand, such a demand will not be considered major since the system would only be in operation from Memorial Day Weekend to Labor Day Weekend of each year.

8. *Will the project adversely affect short-term or long-term ambient air quality?*

No impacts to air quality are anticipated.

9. *Will the project adversely affect short-term or long-term noise levels?*

No.

10. *If the project involves the use of in-lake chemical treatments, will it cause any short-term or long-term effects?*

No algicides nor herbicides are being recommended as part of the Lake Absegami Management Plan. Thus, the impact of in-lake chemical treatments is not a concern.

11. *Will the project be located in a floodplain?*

Yes. Lake Absegami is an impoundment of the Tommy's Branch inlets, which are tributaries of the Bass River. Any implemented in-lake management techniques will occur within the floodplain.

12. *Will structures be constructed in the floodplain?*

No new structures would be constructed in the floodplain.

13. *If the project involves physically modifying the lake shore, its bed, or its watershed, will the project cause any short or long-term adverse effects?*

The recommended stabilization projects along select portions of the lake's inlets may involve the physical modification of some shoreline areas. However, such projects would not cause short or long-term adverse effects. Instead, these proposed projects would provide ecological and aesthetic benefits for the lake and its watershed.

14. *Will the project have a significantly adverse effect on fish and wildlife, wetlands or other wildlife habitat?*

No adverse impacts are expected.

15. *Have all feasible alternatives to the project been considered in terms of environmental impacts, resource commitment, public interest and cost?*

All feasible alternatives for the Management Plan of Lake Absegami have been thoroughly assessed. The recommended management techniques should result in an improvement in lake water quality, general aesthetics and recreation without creating any major adverse environmental impacts.

16. *Are there other measures not previously discussed which are necessary to mitigate adverse impacts resulting from the project?*

There are no necessary mitigation measures known at the present time which have not been discussed.

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APPENDIX A

IN-SITU DATA

In-situ **data measured in Lake Absegami on 22 September 2000**

Mid-lake

Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (mmhos/cm)
Surface	21.37	6.58	5.18	0.0984
0.5	21.37	6.73	5.22	0.0983
1.0	21.37	6.68	5.23	0.0979
1.5	21.32	6.71	5.28	0.0977

Inlets

Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (mmhos/cm)
		Inlet #1		
Surface	14.89	5.30	5.1	0.1231
		Inlet #2		
Surface	15.65	5.66	5.04	0.0944

In-situ **data measured in Lake Absegami on 3 May 2001**

Mid-lake

Depth (meters)	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**pH**	**Specific Conductance (mmhos/cm)**
Surface	22.41	8.54	4.71	0.3024
0.5	22.10	8.54	4.72	0.3062
1.0	21.13	8.68	4.73	0.3146
1.5	20.96	8.68	4.75	0.3180
2.0	20.68	8.79	4.74	0.3251

Inlets

Depth (meters)	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**pH**	**Specific Conductance (mmhos/cm)**
		Inlet #1		
Surface	15.51	7.13	4.84	0.4515
		Inlet #2		
Surface	15.51	6.40	4.79	0.4441

***In-situ* data measured in Lake Absegami on 13 June 2001**

Mid-lake

Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (mmhos/cm)
Surface	26.43	9.10	4.92	0.1156
0.5	26.34	9.66	5.00	0.1189
1.0	26.09	10.35	5.22	0.1216
1.5	26.00	12.34	5.70	0.1243

Inlets

Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (mmhos/cm)
		Inlet #1		
Surface	20.78	11.94	4.90	0.1108
		Inlet #2		
Surface	20.69	8.67	4.91	0.1167

In-situ data measured in Lake Absegami on 19 July 2001

Mid-lake				
Depth (meters)	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**pH**	**Specific Conductance (mmhos/cm)**
Surface	25.81	5.67	4.66	0.054
0.5	25.83	5.67	4.67	0.053
1.0	25.82	5.64	4.67	0.054
1.5	25.81	5.61	4.67	0.053

In-situ **data measured in Lake Absegami on 9 August 2001**

Mid-lake

Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (mmhos/cm)
0.5	29.64	8.47	4.55	0.062
1.0	29.30	8.54	4.57	0.062
1.5	29.27	8.30	4.62	0.062

***In-situ* data measured in Lake Absegami on 28 September 2001**

Mid-lake

Depth (meters)	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**pH**	**Specific Conductance (mmhos/cm)**
Surface	19.83	5.68	4.84	0.0662
0.5	19.75	5.67	4.89	0.0661
1.0	19.76	5.71	4.99	0.0662
1.5	19.70	4.93	5.25	0.0643

***In-situ* data measured in Lake Absegami on 10 October 2001**

Mid-lake				
Depth (meters)	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**pH**	**Specific Conductance (mmhos/cm)**
Surface	14.99	7.91	4.67	0.1070
0.5	14.81	8.27	4.67	0.1102
1.0	14.54	9.02	4.70	0.1132

Storm Event Monitoring
***In-situ* data measured in Lake Absegami on 15 September 2001**

Inlets

Depth (meters)	Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Specific Conductance (mmhos/cm)
		Inlet #1		
Surface	14.75	10.02	7.19	0.0655
		Inlet #2		
Surface	14.79	8.07	7.06	0.1304

Storm Event Monitoring
***In-situ* data measured in Lake Absegami on 20 March 2002**

Inlets

Depth (meters)	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**pH**	**Specific Conductance (mmhos/cm)**
		Inlet #1		
Surface	7.51	7.29	4.62	0.0385
		Inlet #2		
Surface	6.17	9.71	4.21	0.1752

Secchi depths for Lake Absegami

Date	Secchi Depth (m)	Total Depth (m)
22 September 2000	1.8	1.8
3 May 2001	2.2	2.2
13 June 2001	1.8	1.8
19 July 2001	1.5	1.5
9 August 2001	1.5	1.5
28 September 2001	1.5	1.5
10 October 2001	1.2	1.2

APPENDIX B

DISCRETE CHEMICAL DATA

AND

FECAL COLIFORM RESULTS

Discrete in-lake water quality data in 2001
from Lake Absegami

Mid-lake

Sample Date	Water Quality Parameters [a,b]														
	Chlorophyll *a* (mg/m^3)	Alkalinity	Hardness	Ammonia -N	Nitrate -N	Nitrite -N	Total Kjeldahl -N	SRP	TP	TSS	Iron (Total)	Iron (Dissolved)	Arsenic	Zinc	Lead
22 Sept '00	1.2	<1	4.0	0.06	0.06	0.01	0.07	0.01	<0.02	<3	0.36	0.36	<0.005	<0.01	<0.003
3 May '01	<0.3	<5.0	<5	0.06	<0.04	<0.003	0.25	<0.003	<0.02	<2	0.14	0.08	<0.005	0.02	<0.003
13 Jun '01	<0.3	1.7	7.8	0.03	<0.04	<0.003	0.27	<0.003	<0.02	5	---	---	—	—	---
19 Jul '01	0.5	<1.7	5.4	0.03	<0.04	<0.003	<0.06	0.006	<0.02	2	<0.1 [c]	0.1 [c]	<0.008	<0.02	<0.005
9 Aug '01	6.6	<1.7	<5	0.1	<0.04	<0.003	0.36	<0.003	<0.02	3	0.10	<0.10	<0.008	<0.02	<0.005
10 Oct '01	7	<1.7	<5	0.07	<0.04	<0.003	0.25	<0.003	<0.02	<2	<0.10	<0.10	<0.008	<0.02	<0.005

a) Parameters in mg/L unless otherwise noted.
b) Parameters reported as "less than" a value (e.g. <0.04) were non-detectable at a minimum detection level equal to that respective value.
c) Dissolved iron is reported as greater than total iron due to a data aberration since the concentration of both parameters were at the detection limit of 0.1 mg/L.

Discrete in-lake water quality data in 2001
from Lake Absegami

Inlet #1

Sample Date	Chlorophyll a (mg/m^3)	Nitrate-N	Nitrite-N	Total Kjeldahl-N	TP	TSS	Iron (Total)	Iron (Dissolved)
	Water Quality Parameters [a,b]							
22 Sept '00	<0.2	0.06	<0.003	0.14	<0.02	<3	0.22	0.13
3 May '01	---	<0.04	<0.003	0.11	<0.02	<2	0.21	0.14
13 June '01	---	<0.04	<0.003	0.12	<0.02	4	0.20	0.20

Inlet #2

Sample Date	Chlorophyll a (mg/m^3)	Nitrate-N	Nitrite-N	Total Kjeldahl-N	TP	TSS	Iron (Total)	Iron (Dissolved)
	Water Quality Parameters [a,b]							
22 Sept '00	<0.2	0.08	<0.003	0.07	<0.02	<3	0.22	0.22
3 May '01	---	0.06	<0.003	0.25	<0.02	2	0.14	0.13
13 June '01	---	<0.04	<0.003	0.08	<0.02	4	0.20	0.10

a) Parameters in mg/L unless otherwise noted.
b) Parameters reported as "less than" a value (e.g. <0.04) were non-detectable at a minimum detection level equal to that respective value.

Discrete in-lake water quality data from Lake Absegami for Storm Events in 2001 and 2002

Inlet #1

Sample Date	Water Quality Parameters [a,b]								
	Nitrate-N	Nitrite-N	Total Kjeldahl-N	TP	TSS	Petroleum Hydrocarbons	Arsenic	Zinc	Lead
30 March '01	<0.04	<0.003	<0.06	<0.02	<2	<0.41	<0.01	<0.02	<0.005
15 Sept. '01	<0.04	<0.003	0.22	<0.02	<2	<0.38	<0.008	<0.02	<0.005
20 March '02	0.06	<0.003	0.51	<0.02	<2	<0.38	<0.008	0.06	<0.005

Inlet #2

Sample Date	Water Quality Parameters [a,b]								
	Nitrate-N	Nitrite-N	Total Kjeldahl-N	TP	TSS	Petroleum Hydrocarbons	Arsenic	Zinc	Lead
30 March '01	0.27	<0.003	<0.06	<0.02	<2	<0.41	<0.01	<0.02	<0.005
15 Sept. '01	0.11	0.03	2.3	0.11	25	<0.38	<0.008	0.03	<0.005
20 March '02	<0.04	<0.003	0.27	<0.02	4	<0.38	<0.008	<0.02	<0.005

a) Parameters in mg/L unless otherwise noted.
b) Parameters reported as "less than" a value (e.g. <0.04) were non-detectable at a minimum detection level equal to that respective value.

Lake Absegami fecal coliform data from 2001 and 2002

Regular Sampling Events

Date	Fecal Coliform (CFU/100 ml)	Total Coliform (CFU/100 mL)
	Mid-lake	
3 May 2001	<1	<1
13 June 2001	0	---
19 July 2001	4	30
9 August 2001	30	30
	Inlet #1	
3 May 2001	<1	<1
13 June 2001	5	---
	Inlet #2	
3 May 2001	<1	<1
13 June 2001	8	---

Stormwater Sampling Events

Date	Fecal Coliform (CFU/100 ml)	Total Coliform (CFU/100 mL)
	Inlet #1	
30 March 2001	<1	---
20 March 2002	80	240
	Inlet #2	
30 March 2001	<1	---
20 March 2002	22	900

Lake Absegami beach fecal coliform data (cfu/100 mL)
(Data Collected by the State of New Jersey)

Date	Left Side of Beach	Center of Beach	Right Side of Beach
2 July 2001	8	60	13
10 July 2001	<3	5	5
17 July 2001	18	13	50
24 July 2001	3	110	480
25 July 2001	10	8	15
31 July 2001	20	3	18
7 August 2001	18	117	30
13 August 2001	30	36	50
21 August 2001	7	5	10
28 August 2001	5	3	8
5 September 2001	10	3	5

APPENDIX C

PLANKTON AND ZOOPLANKTON DATA

Lake Absegami Biological Analysis
22-Sep-2000

Phytoplankton

Organism	Cells/mL	µg/L
Chlorophyta		
Chlamydomonas	105	10.93
Scenedesmus	60	6.24
Dictyosphaerium	60	4.16
Rhizoclonium	449	70.16
Total	**674**	**91.49**

Zooplankton

Organism	Number/L	µg/L
Cladocerans		
Bosmina	5	5.0
Copepods		
nauplii	15	11.7
Rotifers		
Keratella	5	0.2
Polyarthra	5	4.8
Trichocera	10	3.3
Conochilus	10	1.2
Total	30	9.6
Total	**50**	**26.3**

Lake Absegami Biological Analysis
13-Jun-2001

Phytoplankton

Organism	Cells/mL	µg/L
Chlorophyta		
Chlamydomonas	17	1.81
Chlorella	6	4.58
Total	23	6.38
Bacillariophyta		
Tabellaria	23	68.06
Stephanodiscus	6	31.77
Synedra	2	8.27
Total	31	108.10
Chrysophyta		
Chromulina	40	9.49
Ochromonas	17	3.77
Total	58	13.26
Pyrrhophyta		
Peridinium	35	103.34
Total	**146**	**231.09**

Zooplankton

Organism	Number/L	µg/L
Copepods		
Cyclops	2	0.3
nauplii	3	2.5
Total	5	2.8
Rotifers		
Keratella	2	0.1
Total	**7**	**2.9**

Lake Absegami Biological Analysis
9-Aug-2001

Phytoplankton

Organism	Cells/mL	µg/L
Chlorophyta		
Chlamydomonas	49	5.07
Chlorella	5	4.28
Gloeocystis	157	87.11
Carteria	11	17.11
Total	222	113.57
Chrysophyta		
Chromulina	22	5.07
Cyanobacteria		
Anabaena	11	257.59
Total	**254**	**376.23**

Zooplankton

Organism	Number/L	µg/L
Cladocerans		
Bosmina	475	480.0
Chydorus	4	2.8
Daphnia	4	8.9
Diaphniosoma	4	5.1
Total	487	496.85
Copepods		
Cyclops	8	1.6
Diaptomus	12	19.5
Mesocyclops	4	8.3
Total	23	29.38
Total	**510**	**526.2**

Lake Absegami Biological Analysis
10-Oct-2001

Phytoplankton

Organism	Cells/mL	µg/L
Chlorophyta		
Chlamydomonas	15	1.52
Chlorella	15	11.52
Total	30	13.04
Chrysophyta		
Chromulina	29	6.83
Cryptophyta		
Rhodomonas	7	1.42
Total	**66**	**21.30**

Zooplankton

Organism	Number/L	µg/L
Cladocerans		
Bosmina	57	57.6
Chydorus	12	8.7
Daphnia	3	7.0
Total	72	73.3
Copepods		
Cyclops	15	3.0
nauplii	4	3.1
Total	19	6.2
Rotifers		
Keratella	8	0.3
Polyarthra	3	2.9
Total	11	3.2
Total	**102**	**82.6**

Lake Absegami Biological Analysis
3-May-2001

Phytoplankton

Organism	Cells/mL	µg/L
Chlorophyta		
Chlamydomonas	46	4.80
Chlorella	9	7.12
Gloeocystis	37	29.29
Scenedesmus	37	1.73
Total	129	42.94
Bacillariophyta		
Tabellaria	65	195.39
Synedra	28	96.19
Total	93	291.58
Chrysophyta		
Chromulina	102	23.92
Ochromonas	74	16.07
Dinobryon	112	39.40
Total	288	79.40
Pyrrhophyta		
Peridinium	19	56.61
Total	**529**	**470.53**

Organism	Number/L	µg/L
Copepods		
Cyclops	11	2.2
Diaptomus	5	8.5
nauplii	14	10.9
Total	30	21.7
Rotifers		
Keratella	6	0.2
Polyarthra	3	2.9
Total	9	3.1
Total	**39**	**24.8**

Lake Absegami Biological Analysis
19-Jul-2001

Phytoplankton

Organism	Cells/mL	µg/L
Chlorophyta		
Chlamydomonas	21	2.19
Chlorella	16	12.67
Gloeocystis	42	33.25
Chlorogonium	10	1.67
Total	89	49.77
Chrysophyta		
Chromulina	47	11.02
Pyrrhophyta		
Peridinium	5	14.90
Cyanobacteria		
Anabaena	10	238.37
Total	**151**	**314.06**

Zooplankton

Organism	Number/L	µg/L
Cladocerans		
Bosmina	165	166.6
Chydorus	11	8.0
Daphnia	7	16.3
Total	183	190.94
Copepods		
Cyclops	15	3.0
Diaptomus	4	6.8
nauplii	11	8.6
Total	30	18.43
Rotifers		
Keratella	26	0.9
Total	**239**	**210.2**

APPENDIX D

SEDIMENT DATA

INTEGRATED ANALYTICAL LABORATORIES, LLC.

CONFORMANCE / NONCONFORMANCE SUMMARY

Integrated Analytical Laboratories, LLC. received one (1) soil sample(s) from Princeton Hydro, LLC (Project: ABSEGAMI) on October 11, 2001 for the analysis of:

(1) Volatiles + 15
(1) Semivolatiles - BNA + 25
(1) PCB's
(1) Pesticides
(1) PP Metals
(1) Cyanide, Total
(1) Total Recoverable Phenols
(1) Total Volatiles Solids
(1) * Particle Size

*Subcontracted results from Golder Associates

A review of the QA/QC measures for the analysis of the sample(s) contained in this report has been performed by:

[signature] 6/26/01

Reviewed by — Date

SUMMARY REPORT
Client: Princeton Hydro, LLC
Project: ABSEGAMI
Lab Case No.: E01-7035

PARAMETER(Units)	Conc	Q	MDL
Lab ID:	7035-001		
Client ID:	ABSEGAMI		
Matrix:	Soil		
Sampled Date:	10/10/2001		
Volatiles (ppb)			
TOTAL VO's:	ND		15
TOTAL TIC's:	ND		
TOTAL VO's & TIC's:	ND		
Semivolatiles - BNA (ppb)			
TOTAL BNA'S:	ND		558
TOTAL TIC's:	30810		
TOTAL BNA'S & TIC's:	30810		
PCB's (ppb)	ND		440
Pesticides (ppb)	ND		10.9
Metals (ppm)			
Antimony	ND		2.96
Arsenic	ND		2.96
Beryllium	ND		1.48
Cadmium	ND		0.741
Chromium	ND		5.93
Copper	10.1		5.93
Lead	21.5		1.48
Mercury	0.0467		0.0371
Nickel	ND		2.96
Selenium	ND		5.93
Silver	ND		1.48
Thallium	ND		0.296
Zinc	12.9		5.93
General Analytical			
Cyanide, Total (ppm)	ND		3.00
Total Recoverable Phenols (ppm)	ND		7.51
Total Volatile Solids (%)	7.41		NA
***Particle-Size Distribution ASTM D 422**	¤		

ND = Analyzed for but Not Detected at the MDL
All qualifiers on individual Volatiles & Semivolatiles are carried down through summation.
*Subcontracted results from Golder Associates
¤Please refer to Particle-Size Distribution chart enclosed in report

INTEGRATED ANALYTICAL LABORATORIES

VOLATILE ORGANICS

Client/Project: PRINCETON/ABSEGAMI

Lab ID: 7035-001
Client ID: ABSEGAMI
Date Received: 10/11/2001
Date Analyzed: 10/21/2001
Data file: I2081.D

GC/MS Column: DB-624
Sample wt/vol: 5g
Matrix-Units: Soil-μg/Kg (ppb)
Dilution Factor: 1
% Moisture: 66.7

Compound	Concentration	Q	MDL
Chloromethane	ND		15
Vinyl Chloride	ND		15
Bromomethane	ND		15
Chloroethane	ND		15
Trichlorofluoromethane	ND		15
Acrolein	ND		30
1,1-Dichloroethene	ND		15
Methylene Chloride	ND		15
Acrylonitrile	ND		30
t-Butyl Alcohol(TBA)	ND		30
trans-1,2-Dichloroethene	ND		15
Methyl-t-Butyl Ether(MTBE)	ND		15
1,1-Dichloroethane	ND		15
Chloroform	ND		15
1,1,1-Trichloroethane	ND		15
Carbon Tetrachloride	ND		15
1,2-Dichloroethane(EDC)	ND		15
Benzene	ND		15
Trichloroethene	ND		15
1,2-Dichloropropane	ND		15
Bromodichloromethane	ND		15
2-Chloroethylvinyl Ether	ND		15
cis-1,3-Dichloropropene	ND		15
Toluene	ND		15
trans-1,3-Dichloropropene	ND		15
1,1,2-Trichloroethane	ND		15
Tetrachloroethene	ND		15
Dibromochloromethane	ND		15
Chlorobenzene	ND		15
Ethylbenzene	ND		15
Total Xylenes	ND		15
Bromoform	ND		15
1,1,2,2-Tetrachloroethane	ND		15
1,3-Dichlorobenzene	ND		15
1,4-Dichlorobenzene	ND		15
1,2-Dichlorobenzene	ND		15

Total Target Compounds: 0

INTEGRATED ANALYTICAL LABORATORIES

VOLATILE ORGANICS
Tentatively Identified Compounds

Client/Project: PRINCETON/ABSEGAMI

Lab ID: 7035-001
Client ID: ABSEGAMI
Date Received: 10/11/2001
Date Analyzed: 10/21/2001
Data file: I2081.D

GC/MS Column: DB-624
Sample wt/vol: 5g
Matrix-Units: Soil-μg/Kg (ppb)
Dilution Factor: 1
% Moisture: 66.7

CAS #	Compound	Estimated Concentration	Retention Time
	No peaks detected		

Total TICs = 0

INTEGRATED ANALYTICAL LABORATORIES

SEMIVOLATILE ORGANICS

Client/Project: PRINCETON/ABSEGAMI

Lab ID: 7035-001
Client ID: ABSEGAMI
Date Received: 10/11/2001
Date Extracted: 10/15/2001
Date Analyzed: 10/15/2001
Data file: B6860.D

GC/MS Column: DB-5
Sample wt/vol: 5.38g
Matrix-Units: Soil-μg/Kg (ppb)
Dilution Factor: 1
% Moisture: 66.7

Compound	Concentration	Q	MDL
N-Nitrosodimethylamine	ND		558
Phenol	ND		558
Aniline	ND		558
bis(2-Chloroethyl)ether	ND		558
2-Chlorophenol	ND		558
1,3-Dichlorobenzene	ND		558
1,4-Dichlorobenzene	ND		558
Benzyl alcohol	ND		558
1,2-Dichlorobenzene	ND		558
2-Methylphenol	ND		558
bis(2-chloroisopropyl)ether	ND		558
4-Methylphenol	ND		558
N-Nitroso-di-n-propylamine	ND		558
Hexachloroethane	ND		558
Nitrobenzene	ND		558
Isophorone	ND		558
2-Nitrophenol	ND		558
2,4-Dimethylphenol	ND		558
bis(2-Chloroethoxy)methane	ND		558
Benzoic acid	ND		558
2,4-Dichlorophenol	ND		558
1,2,4-Trichlorobenzene	ND		558
Naphthalene	ND		558
4-Chloroaniline	ND		558
Hexachlorobutadiene	ND		558
4-Chloro-3-methylphenol	ND		558
2-Methylnaphthalene	ND		558
Hexachlorocyclopentadiene	ND		558
2,4,6-Trichlorophenol	ND		558
2,4,5-Trichlorophenol	ND		558
2-Chloronaphthalene	ND		558
2-Nitroaniline	ND		558
Dimethylphthalate	ND		558
2,6-Dinitrotoluene	ND		558
Acenaphthylene	ND		558

INTEGRATED ANALYTICAL LABORATORIES

SEMIVOLATILE ORGANICS

Client/Project: PRINCETON/ABSEGAMI

Lab ID: 7035-001
Client ID: ABSEGAMI
Date Received: 10/11/2001
Date Extracted: 10/15/2001
Date Analyzed: 10/15/2001
Data file: B6860.D

GC/MS Column: DB-5
Sample wt/vol: 5.38g
Matrix-Units: Soil-µg/Kg (ppb)
Dilution Factor: 1
% Moisture: 66.7

Compound	Concentration	Q	MDL
3-Nitroaniline	ND		558
Acenaphthene	ND		558
2,4-Dinitrophenol	ND		558
4-Nitrophenol	ND		558
2,4-Dinitrotoluene	ND		558
Dibenzofuran	ND		558
Diethylphthalate	ND		558
Fluorene	ND		558
4-Chlorophenyl-phenylether	ND		558
4-Nitroaniline	ND		558
4,6-Dinitro-2-methylphenol	ND		558
N-Nitrosodiphenylamine	ND		558
1,2-Diphenylhydrazine/Azobenzene	ND		558
4-Bromophenyl-phenylether	ND		558
Hexachlorobenzene	ND		558
Pentachlorophenol	ND		558
Phenanthrene	ND		558
Anthracene	ND		558
Carbazole	ND		558
Di-n-butylphthalate	ND		558
Fluoranthene	ND		558
Benzidine	ND		558
Pyrene	ND		558
3,3'-Dimethylbenzidine	ND		558
Butylbenzylphthalate	ND		558
3,3'-Dichlorobenzidine	ND		558
Benzo[a]anthracene	ND		558
Chrysene	ND		558
bis(2-Ethylhexyl)phthalate	ND		558
Di-n-octylphthalate	ND		558
Benzo[b]fluoranthene	ND		558
Benzo[k]fluoranthene	ND		558
Benzo[a]pyrene	ND		558
Indeno[1,2,3-cd]pyrene	ND		558
Dibenz[a,h]anthracene	ND		558
Benzo[g,h,i]perylene	ND		558

Total Target Compounds: 0

INTEGRATED ANALYTICAL LABORATORIES

SEMIVOLATILE ORGANICS
Tentatively Identified Compounds

Client/Project: PRINCETON/ABSEGAMI

Lab ID: 7035-001
Client ID: ABSEGAMI
Date Received: 10/11/2001
Date Extracted: 10/15/2001
Date Analyzed: 10/15/2001
Date File: B6860.D

GC/MS Column: DB-5
Sample wt/vol: 5.38g
Matrix-Units: Soil-μg/Kg (ppb)
Dilution Factor: 1
% Moisture: 66.7

CAS #	Compound	Estimated Concentration	Retention Time
	Unknown aromatic	3570	6.04
	Unknown alkane	2620	6.32
	Unknown alkane	2850	6.84
	Unknown alkane	3460	7.37
	Unknown alkane	2460	8.06
	Unknown alkane	2400	8.17
	Unknown	6360	9.38
	Unknown aromatic	4630	9.73
	Unknown aromatic	2460	9.92

Total TICs = 30810

INTEGRATED ANALYTICAL LABORATORIES

PCB's

Client/Project: PRINCETON/ABSEGAMI

Lab ID: 7035-001
Client ID: ABSEGAMI
Date Received: 10/11/2001
Date Extracted: 10/15/2001
Date Analyzed: 10/16/2001
Data file: V6529.D

GC Column: DB-5/DB1701P
Sample wt/vol: 5.46g
Matrix-Units: Soil-µg/Kg (ppb)
Dilution Factor: 1
% Moisture: 66.7

Compound	Concentration	Q	MDL
Aroclor-1016	ND		440
Aroclor-1221	ND		440
Aroclor-1232	ND		440
Aroclor-1242	ND		440
Aroclor-1248	ND		440
Aroclor-1254	ND		440
Aroclor-1260	ND		440

INTEGRATED ANALYTICAL LABORATORIES

PESTICIDES

Client/Project: PRINCETON/ABSEGAMI

Lab ID: 7035-001
Client ID: ABSEGAMI
Date Received: 10/11/2001
Date Extracted: 10/15/2001
Date Analyzed: 10/16/2001
Data file: W8927.D

GC Column: DB-5/DB1701P
Sample wt/vol: 5.5g
Matrix-Units: Soil-μg/Kg (ppb)
Dilution Factor: 1
% Moisture: 66.7

Compound	Concentration	Q	MDL
alpha-BHC	ND		10.9
beta-BHC	ND		10.9
gamma-BHC	ND		10.9
delta-BHC	ND		10.9
Heptachlor	ND		10.9
Aldrin	ND		10.9
Heptachlor epoxide	ND		10.9
Endosulfan I	ND		10.9
4,4'-DDE	ND		10.9
Dieldrin	ND		10.9
Endrin	ND		10.9
Endosulfan II	ND		10.9
4,4'-DDD	ND		10.9
Endrin aldehyde	ND		10.9
Endosulfan sulfate	ND		10.9
4,4'-DDT	ND		10.9
Chlordane	ND		54.6
Toxaphene	ND		54.6

INTEGRATED ANALYTICAL LABORATORIES, LLC.

METALS

Client/Project: PRINCETON/ABSEGAMI

Lab ID: 7035-001
Client ID: ABSEGAMI
Date Received: 10/11/01
Matrix-Units: Soil mg/Kg (ppm)
% Moisture: 66.7
Batch #: 260

Compound	Result	Q	DF.	MDL	Date Analyzed	Method
Antimony	ND		1	2.96	10/15/01	6020
Arsenic	ND		1	2.96	10/15/01	6020
Beryllium	ND		1	1.48	10/15/01	6020
Cadmium	ND		1	0.741	10/15/01	6020
Chromium	ND		1	5.93	10/15/01	6020
Copper	10.1		1	5.93	10/15/01	6020
Lead	21.5		1	1.48	10/15/01	6020
Mercury	0.0467		1	0.0371	10/15/01	7471 A
Nickel	ND		1	2.96	10/15/01	6020
Selenium	ND		1	5.93	10/15/01	6020
Silver	ND		1	1.48	10/15/01	6020
Thallium	ND		1	0.296	10/15/01	6020
Zinc	12.9		1	5.93	10/15/01	6020

INTEGRATED ANALYTICAL LABORATORIES, LLC.

Total Cyanide

Client/Project: PRINCETON/ABSEGAMI

Date Received: 10/11/01

Lab ID	Client ID	Result	Q	DF	Matrix-Units	MDL	% Solids	Date Analyzed
7035-001	ABSEGAMI	ND		1	S-mg/Kg	3.00	33.3	10/19/2001

INTEGRATED ANALYTICAL LABORATORIES, LLC.

Total Recoverable Phenols

Client/Project: PRINCETON/ABSEGAMI

Date Received: 10/11/01

Lab ID	Client ID	Result	Q	DF	Matrix-Units	MDL	% Solids	Date Analyzed
7035-001	ABSEGAMI	ND		1	S-mg/Kg	7.51	33.3	10/15/2001

INTEGRATED ANALYTICAL LABORATORIES, LLC.

% TVS

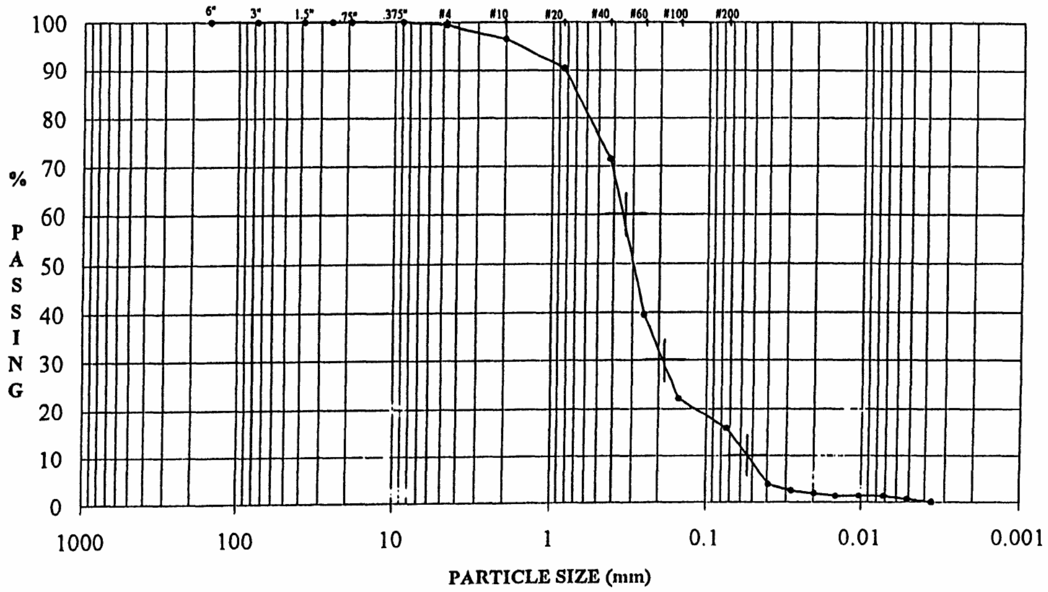
Client/Project: PRINCETON/ABSEGAMI

Date Received: 10/11/01

Lab ID	Client ID	Result	Q	DF	Matrix-Units	MDL	% Solids	Date Analyzed
7035-001	ABSEGAMI	7.41		1	S-% TVS	NA	33.3	10/17/2001

PARTICLE-SIZE DISTRIBUTION ASTM D 422

US STANDARD SIEVE OPENING SIZES



COBBLE	GRAVEL		SAND			FINES
	Coarse	Fine	Cor	Med	Fine	Silt or Clay

Sieve Data

Particle Diameter	% Finer
3"	100.0%
1 1/2"	100.0%
1"	100.0%
3/4"	100.0%
3/8"	100.0%
#4	99.5%
#10	96.6%
#20	90.3%
#40	71.5%
#60	39.5%
#100	22.1%
#200	15.8%

Hydrometer Data

Particle Diameter	% Finer
0.039	3.9%
0.028	2.6%
0.020	1.9%
0.014	1.3%
0.010	1.3%
0.007	1.3%
0.005	0.6%
0.004	0.0%

DESCRIPTION

Sample:	7035-001	Depth:	-
		USCS:	-
Wet Color:	Black		
Description:	m-f Sand, some fines, trace gravel		
Comments:			

SAMPLE DATA

W_C (%):	181.2		C_C	N/A
G_S:	2.65	(ASSUMED)	C_U	N/A
% Gravel	0.5		LL	-
% Sand	83.7		PL	-
% Fines	15.8		PI	-

Date:	10/23/01
Technician:	LDS
Reviewer:	RMW

IAL/LAB GEOTECH/NJ

GOLDER ASSOCIATES INC.
CHERRY HILL, NEW JERSEY

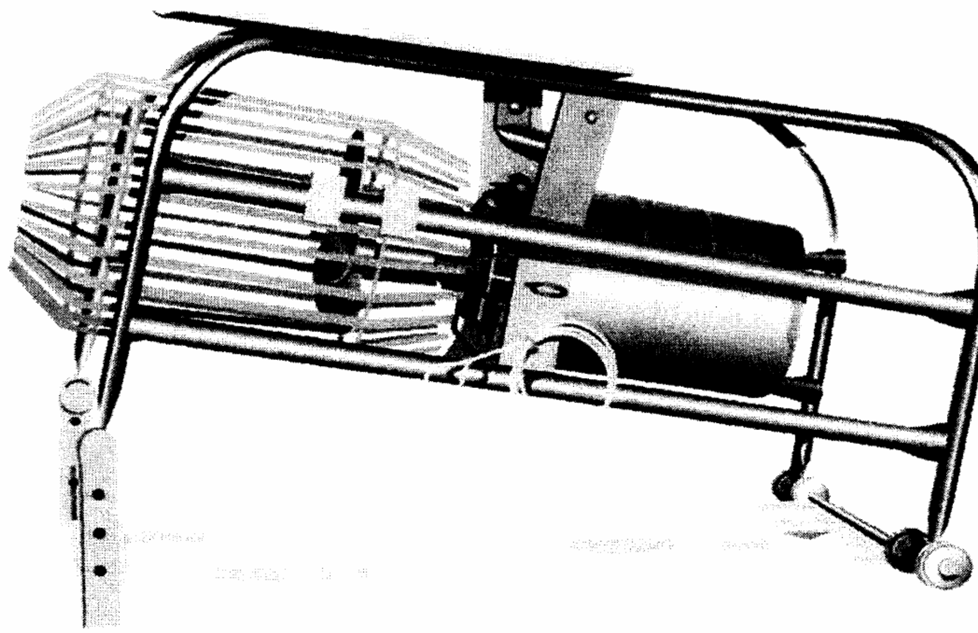
INTEGRATED ANALYTICAL LABORATORIES, LLC.

METHODOLOGY SUMMARY

Analytical Parameter	Aqueous Samples Method #	Soil/Other Samples Method #
Volatiles + 15	NA	EPA 8260B
Semivolatiles - BNA + 25	NA	EPA 8270C
PCB's	NA	EPA 8082
Pesticides	NA	EPA 8081A
P.P. Metals	NA	EPA 6020
Metals (Mercury)	NA	EPA 7471A
Cyanide, Total	NA	EPA 9012 A
Total Recoverable Phenols	NA	EPA 9066
Total Volatiles Solids	NA	EPA 160.4

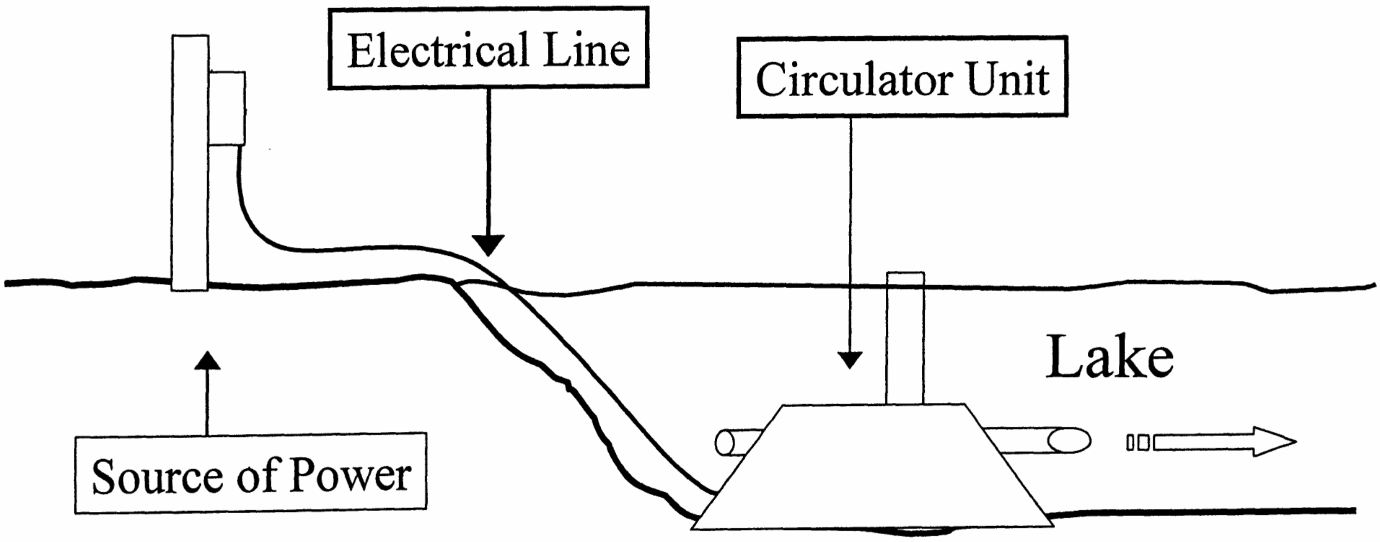
APPENDIX E

SUBMERSED CIRCULATOR SYSTEM



Sub-Triton submersed circulator system from Otterbine Barebo, Inc.

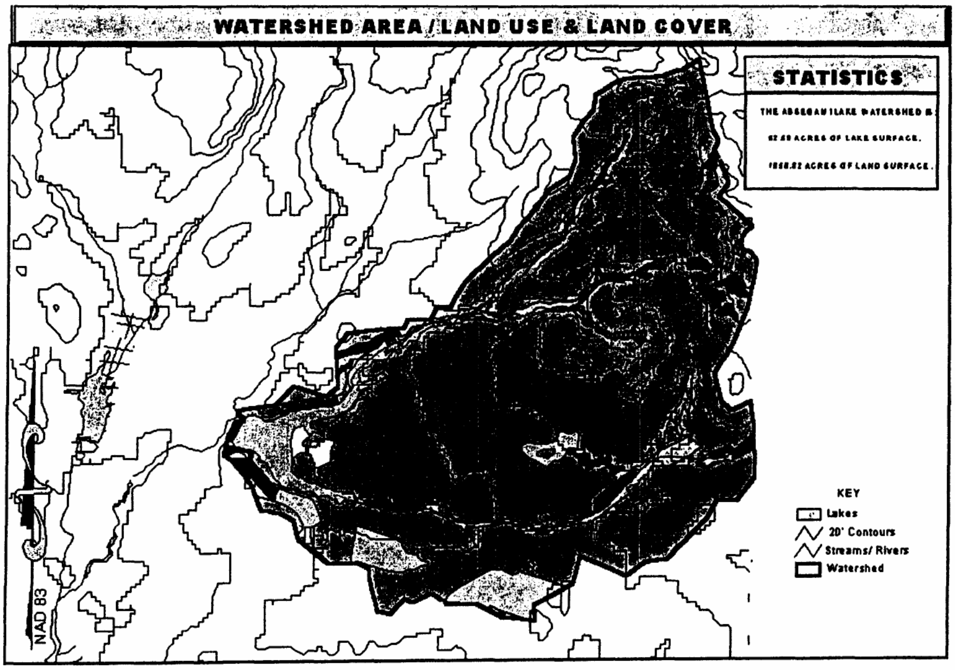
Submerged Circulators

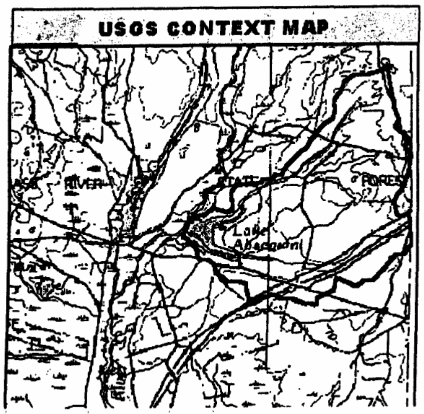


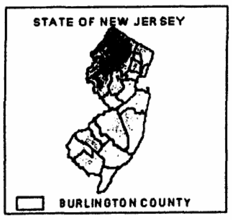
pH

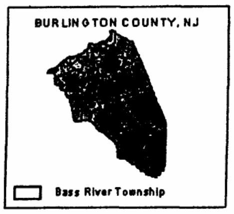
APPENDIX F

PUBLIC EDUCATION BROCHURES









Goals of the Diagnostic / Feasibility Phase I Study of Lake Absegami

- Delineate the Lake Absegami watershed.
- Collect site-specific in-lake and watershed information on Lake Absegami.
- Develop a hydrologic budget for the lake.
- Develop a pollutant budget for the lake, which focuses on nitrogen, phosphorus and suspended solids.
- Conduct a bathymetric survey of the lake.
- Develop a lake and watershed-based Management Plan.

Bass River State Forest and Lake Absegami

Bass River State Forest is located in Burlington County, within the New Jersey Pinelands. The land for the State Forest was acquired in 1905 and two streams flowing through the park were impounded in the 1930's to create Lake Absegami. This lake is the focal point of public recreation within the forest. The lake is used for a variety of recreational activities including swimming, fishing, and canoeing. Powered boats are limited to electric motors.

Identified Problems within Lake Absegami

In spite of the heavy amount of recreational use Lake Absegami receives, the lake does experience a number of water quality problems that need to be addressed. Some of these problems include the unpleasant brownish-black color of the lake, the accumulation of sediments, the high number of old cedar swamp stumps, and the excessive growth of algae and aquatic plants through the spring and summer months. Given these observed problems, the Bass River State Forest received funding through NJ Department of Treasury, administered by the NJ DEP Division of Parks and Forestry to conduct a Diagnostic / Feasibility Study of Lake Absegami and its surrounding watershed.

Bass River State Forest
Box 118
New Gretna, New Jersey 08224

LAKE ABSEGAMI STAKEHOLDER

The Diagnostic / Feasibility Phase I Study of Lake Absegami, Bass River State Park

Brought to you by the Bass River State Forest and the New Jersey Department of Environmental Protection, Division of Parks and Forestry

Funded by the New Jersey Department of the Treasury, Office of Design and Construction

Prepared by Princeton Hydro, LLC 80 Lambert Lane, Lambertville, New Jersey 08530 - (609) 397-5335