PHOSPHORUS CONTROL ACTION PLAN

and Total Maximum Daily (Annual Phosphorus) Load Report

DUCKPUDDLE POND

Lincoln County, Maine

Duckpuddle Pond PCAP-TMDL Report

Maine DEPLW 2005 - 0706

Maine Department of Environmental Protection

and

Maine Association of Conservation Districts

Final EPA Submittal - 8 August, 2005

DUCKPUDDLE POND Phosphorus Control Action Plan (PCAP)

Table of Contents

APPENDICES

DUCKPUDDLE POND

Total Maximum Daily (Annual Phosphorus) Load

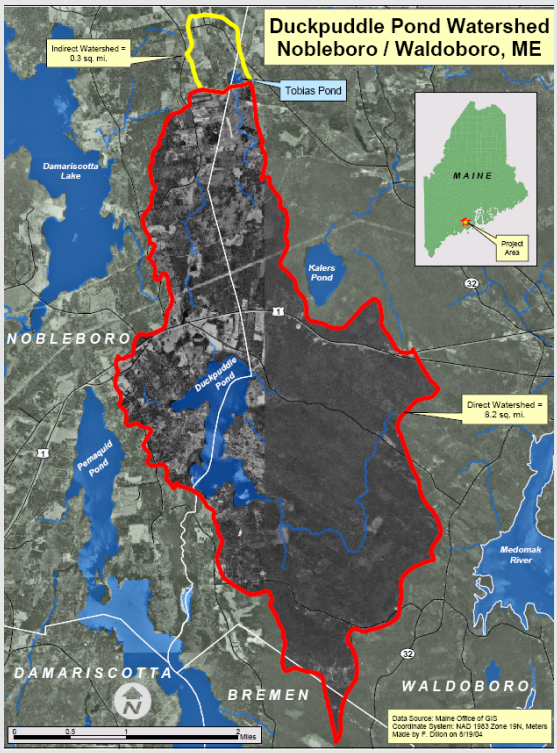
ACKNOWLEDGMENTS

In addition to Maine DEP and US-EPA New England Region I staff, the following individuals, groups and agencies were instrumental in the preparation of this combined Duckpuddle Pond Phosphorus Control Action Plan-Total Maximum Daily (Annual Phosphorus) Load report: MACD staff (Forrest Bell, Jodi Federle, and Fred Dillon); Knox-Lincoln Soil & Water Conservation District (Christie Monroe); Town of Waldoboro; Town of Nobleboro; Rosemary Mosher & Kirsten Boettcher (Orbis Mapping); Maine VLMP (Scott Williams), Maine Department of Inland Fisheries and Wildlife (Bill Woodward, Region B, Sidney Office), Maine Forest Service (Chris Martin) and Maine Department of Agriculture (Dave Rocque).

Duckpuddle Pond Phosphorus Control Action Plan Summary Fact Sheet

Background

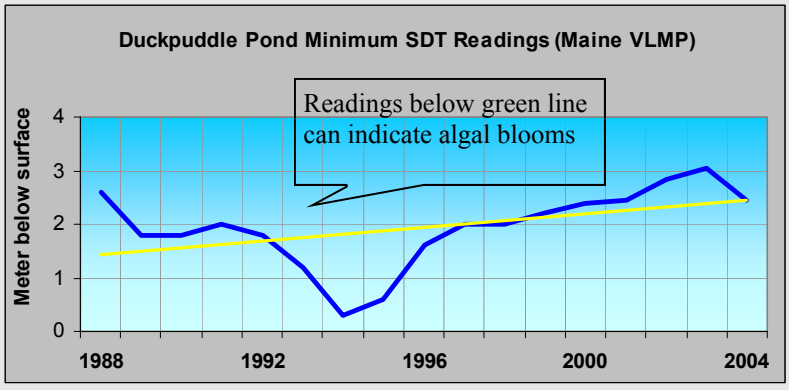
DUCKPUDDLE POND is a 242 acre (98 hectare) waterbody located in the towns of Waldoboro and Nobleboro in Lincoln County, southwestern Maine. Duckpuddle Pond has a direct **watershed** area (see map) of 8.2 square miles; a maximum depth of 23 feet, a mean depth of 14 feet (4.4 meters); and a **flushing rate** of 3.1 flushes per year. The total Duckpuddle Pond watershed drainage area, inclusive of associated sub-watersheds (Tobias Pond - see figure to right), is 8.5 square miles.



Duckpuddle Pond experienced nuisance summertime algal blooms during the 1989 to 1998 time period. This was likely caused by the contribution of **phosphorus** that is prevalent in area soils and is effectively transported to Duckpuddle Pond via storm flow runoff. Excessive soil erosion in lake watersheds can have far-reaching water quality consequences. Soil particles transport phosphorus, which annually accumulate in lake bottom sediments and essentially "fertilizes" the lake, feeding algal blooms and decreasing water clarity. Studies on lakes in general have also shown that as lake water clarity decreases, lakeshore property values decline. Excessive phosphorus can also stimulate the growth of non-indigenous aquatic invasive plants such as variable leaf milfoil, which, fortunately has not yet been found to occur in Duckpuddle Pond.

Stakeholder Involvement

Federal, state, county, and local groups have been working together to effectively address this nonpoint source water pollution problem in Duckpuddle Pond. During 2004 and 2005, the Maine Department of Environmental Protection funded a project in cooperation with the Maine Association of Conservation Districts to identify and quantify the potential sources of phosphorus and identify the **Best Management Practices** needed to be implemented in the Duckpuddle Pond watershed. A final report, completed in the spring of 2005, is entitled "Duckpuddle Pond Phosphorus Control Action Plan (PCAP)" and doubles as a **TMDL** report, to be submitted to the US-EPA, New England Region, for their final review and approval.

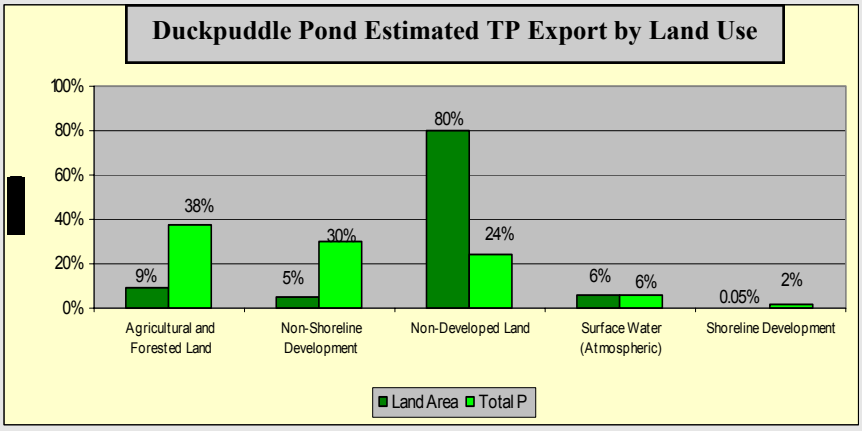


Duckpuddle Pond water transparency has gradually improved following a major decline during the early- mid 1990s

What We Learned

A land use assessment was conducted for the Duckpuddle Pond watershed to determine possible sources of phosphorus that may run off from land areas during annual storm events and springtime snow melting. This assessment utilized many resources, including a review of past watershed survey reports, generating and interpreting maps, inspecting aerial photographs, and carrying out field surveys.

Phosphorus Reduction Needed



Duckpuddle Pond is a well-colored lake which can naturally process up to 335 kg of total phosphorus on an annual basis (target concentration of 16 ppb) without harming water quality. Duckpuddle Pond's average summertime TP concentration is 22 ppb—equal to an additional 126 kg (6 ppb x 21 kg). Accounting for a 10 kg allocation for future watershed development, the total amount of phosphorus needed to be reduced to attain water quality standards (nuisance algal bloom-free conditions) in Duckpuddle Pond approximates 136 kg.

How to Address Duckpuddle Pond Phosphorus Loading

Based on a separate, land use model, it is estimated that 353 kilograms (kg) of phosphorus per year is "exported" to Duckpuddle Pond from the direct watershed. Reducing phosphorus input from the surrounding watershed is a scientifically proven way to improve lake water quality. By promoting best management practices to treat runoff from contributing watershed land uses, reductions approaching 136 kg may be attained The bar chart (above) illustrates the land area for land use groups in the Duckpuddle Pond watershed compared to the estimated total phosphorus export load. There are also phosphorus inputs to Duckpuddle Pond from indirect sources (associated waterbodies) and in-lake phosphorus recycling - see page 18 and the appendices of the full PCAP – TMDL report for more information on other nutrient loading models.

What You Can Do To Help!

As a watershed resident, there are many things you can do to protect the water quality of Duckpuddle Pond. Lakeshore owners can use phosphorus-free fertilizers and maintain natural vegetation adjacent to the lake. Agricultural and commercial land users can consult the Pemaquid Watershed Association, Knox-Lincoln County Soil and Water Conservation District or Maine Department of Environmental Protection for information regarding Best Management Practices (BMPs) for reducing phosphorus loads. All stakeholders and watershed residents can learn more about their lake and the many resources available, including review of the Duckpuddle Pond Phosphorus Control Action Plan. Following final EPA approval, copies of this detailed report, with recommendations for future NPS/BMP work, will be available online at www.maine.gov/dep/blwq/docmonitoring/tmdl2.htm, at the Nobleboro and Waterboro town offices, or can be viewed and/or copied (at cost) at Maine DEP offices in Augusta.

Key Terms

- ***Watershed*** *is a drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*
- ***Flushing rate*** *refers to how often the water in the entire lake is replaced on an annual basis.*
- ***Phosphorus****: is one of the major nutrients needed for plant growth. It is naturally present in small amounts and limits the plant growth in lakes. Generally, as phosphorus increases, the amount of algae also increases.*
- ***Best Management Practices*** *are techniques to reduce sources of polluted runoff and their impacts. BMPs are low cost, common sense approaches to reduce storm runoff and velocity to keep soil out of lakes and tributaries.*
- ***TMDL*** *is an acronym for* ***Total Maximum Daily Load****, representing the total amount of a pollutant (e.g., phosphorus) that a waterbody can annually receive and still meet water quality standards.*

Project Premise

This project, funded through a Clean Water Act section 319 grant from the United States Environmental Protection Agency (EPA New England Region), was directed and administered by the Maine Department of Environmental Protection (Maine DEP) in partnership with the Maine Association of Conservation Districts (MACD) from the fall of 2003 through the spring of 2005.

The objectives of this project were twofold: first, a comprehensive land use inventory was undertaken to assist Maine DEP in developing a Phosphorus Control Action Plan (PCAP) and a Total Maximum Daily Load (TMDL) report for the Duckpuddle Pond watershed. Simply stated, a TMDL is the total amount of phosphorus that a lake can receive without harming water quality. Maine DEP, with the assistance of MACD, will address and incorporate public comments before final submission to the U.S. Environmental Protection Agency (New England Region I).

Project partners combine efforts on a shoreline survey of the pond in 2004

Secondly, watershed survey work, including a shoreline survey, was conducted by the Maine DEP-MACD project team to help assess total phosphorus reduction techniques that would be beneficial for the Duckpuddle Pond watershed. Watershed survey work included assessing many direct drainage **nonpoint source (NPS) pollution** sites that were not previously identified.

Nonpoint Source (NPS) Pollution *- is polluted runoff that cannot be traced to a specific origin or starting point, but appears to flow from many different sources.*

Note: *To protect the confidentiality of specific landowners in the Duckpuddle Pond watershed, actual site-specific watershed survey information is not identified as part of this report.*

This Phosphorus Control Action Plan (PCAP) report compiles and refines land use data derived from various sources, including the municipalities of Nobleboro and Waldoboro; the Maine Office of GIS; and the Knox Lincoln Soil & Water Conservation District (KL-SWCD). Local citizens, watershed organizations, and conservation agencies should benefit from this compilation of data as well as the watershed assessment and the NPS Best Management Practice (BMP) recommendations. Above all, this document is intended to help Duckpuddle Pond stakeholder groups to effectively prioritize future BMP work in order to obtain the funding resources necessary for NPS pollution mitigation work in their watershed.

For more specific information on this process, please refer to the appendices or contact Maine Lakes PCAP-TMDL Program Manager Dave Halliwell at the Maine DEP Augusta Office at 287-7649 or at david.halliwell@maine.gov).

Study Methodology

Duckpuddle Pond background information was obtained using several methods, including a review of previous studies of the lake and watershed area, numerous phone conversations and personal interviews with municipal officials, regional organizations and state agencies, and field observations of the watershed, including boat reconnaissance of the lake and shoreline.

Land use data were determined using several methods, including (1) **Geographic Information System (GIS)** map analysis, (2) analysis of topographic maps, (3) analysis of town property tax maps and tax data, (4) analysis of aerial photographs and (5) field surveys. Much of the undeveloped land use area (i.e., forest, wetland, reverting fields) was interpreted from GIS maps created by Orbis Mapping Services using the 2001 "ortho-hfs" aerial photographs available from the Maine Office of GIS. The developed land use areas were obtained using the best possible information available through analysis of methods 2 through 5 listed above. Necessary adjustments to the GIS data were made using best professional judgment.

> ***GIS**—or **geographic information system** combines layers of information about a place to give you a better understanding of that place. The information is often represented as computer generated maps.*

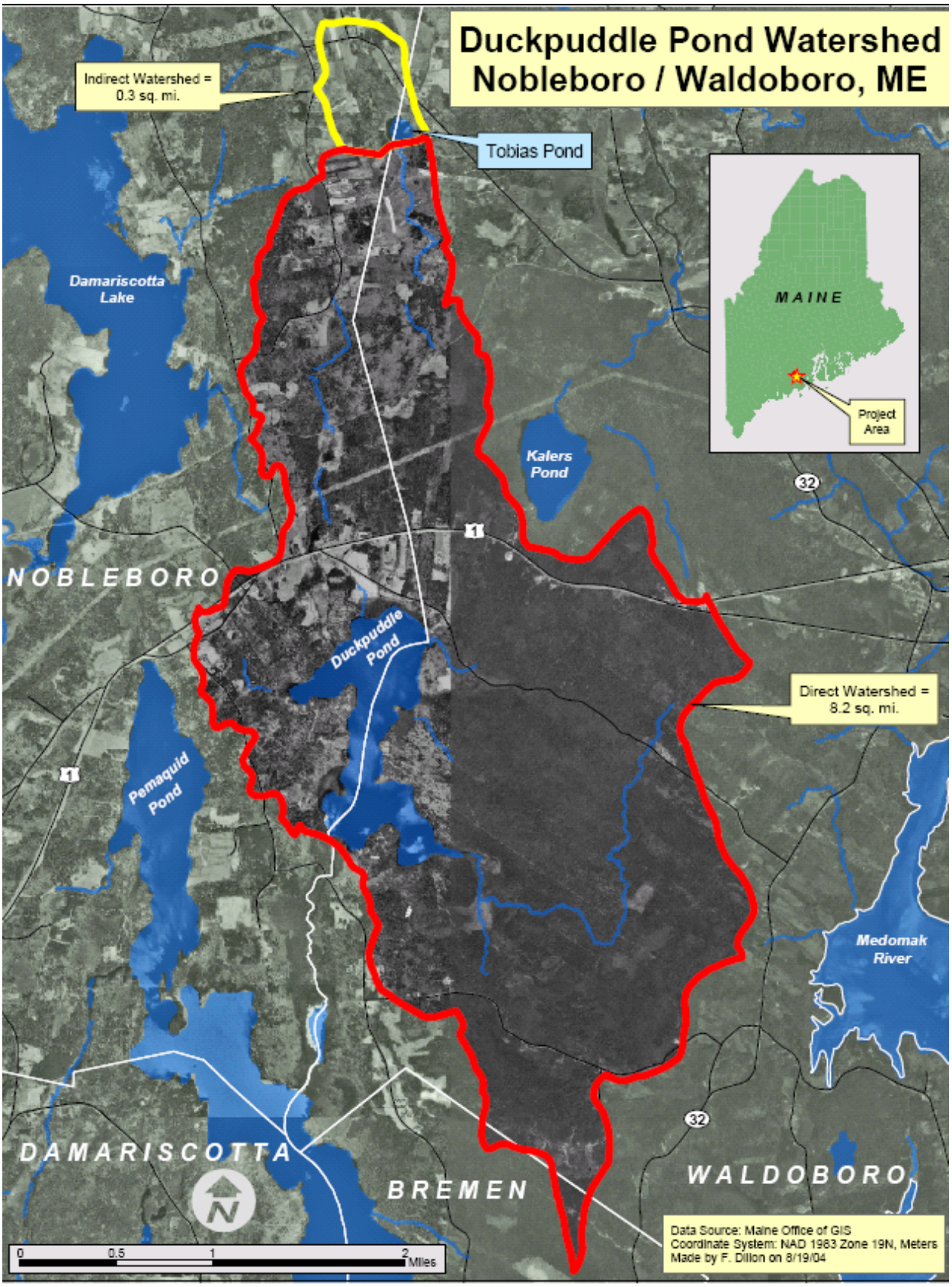
Roadway data were gathered by taking actual road width measurements of the various types of roads (state, town, private/camp) in the watershed. Roads were measured between the two outer edges of the roadside ditches or berms. An average width was used for each of the three road types. Final measurements for all roadways within the watershed were extrapolated or screen digitized using GIS (aerial photo data from the Maine Office of GIS). Roadway area was determined using GIS area calculations for the final road polygons.

Additional land use data (i.e. non-shoreline residential, institutional, operated forestland) were determined using GIS cover mapping, aerial photos, topographic and property tax maps, personal consultation and field visits.

Study Limitations

Land use data gathered for the Duckpuddle Pond watershed is as accurate as possible given available information and resources utilized. However, the final numbers for the land use analysis and phosphorus loading numbers are approximate, and should be viewed as carefully researched estimations.

Figure 1. Map of Duckpuddle Pond Direct Watershed



DUCKPUDDLE POND Phosphorus Control Action Plan

DESCRIPTION of WATERBODY (MIDAS Number 5702) and WATERSHED

DUCKPUDDLE POND is a relatively small, **well-colored** 242 acre waterbody, located within the towns of Waldoboro and Nobleboro (DeLorme Atlas, Maps 7,13), in Lincoln County, located in the mid-coast region of southern Maine. Duckpuddle Pond has a **direct watershed** area (see Figure 1) of 5,241 acres (8.2 square miles), within the Pemaquid River drainage system. Duckpuddle Pond has a maximum depth of 7 meters (23 feet), an overall mean depth of 4.4 meters (14 feet) and has a flushing rate of 3.1 times per year. The total Duckpuddle Pond watershed drainage area, including the upstream sub-watershed of Tobias Pond is 5,555 acres (8.5 square miles).

Scott Williams, aquatic biologist, views lake water taken from Duckpuddle Pond in 2004.

*The **direct watershed** refers to the land area that drains to the lake without first passing through another lake or pond.*

Drainage System – In the northern portion of the indirect watershed, Tobias Pond drains into a stream which flows approximately three miles through a series of wetlands, then outlets into Duckpuddle Pond. There is no dam at the outlet of Duckpuddle Pond, which flows in a southerly direction directly into Pemaquid Pond.

Water Quality Information

Duckpuddle Pond is listed on the Maine DEP's Clean Water Act section 303(d) list of lakes that do not meet State water quality standards, hence, the preparation of a Phosphorus Control Action Plan (and TMDL) was prepared, publicly reviewed, and submitted to EPA for final approval in the early summer of 2005.

***Secchi Disk Transparency** - a measure of the ability of light to penetrate water obtained by lowering a black and white disk into the water until it is no longer visible.*

Water quality monitoring data for Duckpuddle Pond has been collected since 1976. Chemical sampling including total phosphorus and chlorophyll-a, temperature, dissolved oxygen, color, pH, conductivity, and total alkalinity have been collected regularly since 2000 and measures of **Secchi disk transparency** have been collected regularly since 1988. Together, these data document an overall trend of increasing **trophic state,** in direct violation of the Maine DEP Class GPA water quality criteria requiring a stable or decreasing trophic state.

***Trophic state**—the degree of eutrophication of a lake. Transparency, chlorophyll-a levels, phosphorus concentrations, amount of macrophytes, and quantity of dissolved oxygen in the hypolimnion can be used to assess trophic state.*

Nonpoint source pollution is the main reason for declining water quality in Duckpuddle Pond. During storm events, nutrients such as phosphorus - naturally found in Maine soils - drain into the lake from the surrounding watershed by way of streams and overland flow - and annually

accumulate in lake bottom sediments.

Phosphorus is naturally limited in lakes and can be thought of as a fertilizer, a primary food for plants, including algae. When lakes receive excess phosphorus from NPS pollution, it "fertilizes" the lake by feeding the algae. Too much phosphorus can result in nuisance algae blooms, which can damage the ecology/aesthetics of a lake, as well as the economic well-being of the entire affected watershed community.

Principle Uses: The dominant human uses of the Duckpuddle Pond shoreline are residential (both seasonal and year-round occupancy) and recreational—boating, fishing and swimming/beach use.

Human Development: The Duckpuddle Pond shoreline is sparsely developed. Of the 35 shorefront lots (MACD shoreline survey on 9/30/04), ten lots are only used with tents or pop-up campers and there are several large, undisturbed shorefront areas.

The direct watershed of Duckpuddle Pond is located within the towns of Nobleboro and Waldoboro. Nobleboro and Waldoboro are rural, residential towns, located in northern Lincoln County. Commercial and employment centers are located in and around the Waldoboro, concentrated primarily along Route 1. Waldoboro is situated in mid-coast Maine, 15 miles southwest of Rockland, 66 miles northeast of Portland and 28 miles south of Augusta and has a population of 4,916. The Town consists of 73 square miles of area, making it one of the largest towns in the region, including many miles of coastline, acres of forest and abundant open fields.

*Waterbodies within designated **NPS priority watersheds** have significant value from a regional or statewide perspective and have water quality that is either impaired or threatened to some degree due to NPS water pollution. This list helps to identify watersheds where state and federal agency resources for NPS water pollution prevention or restoration should be targeted.*

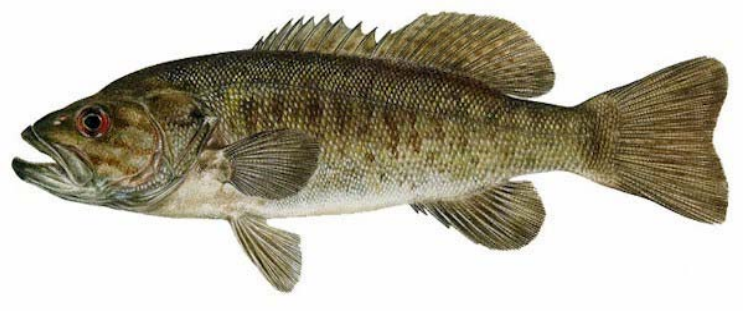
Duckpuddle Pond is on the State's **Nonpoint Source Priority Watersheds** list due primarily to excessive total phosphorus, lake enrichment, and the historical prevalence of late summer and early fall nuisance algal blooms (as occurred in 1989 through 1998).

Increase in human populations cause development to expand and generally increase the amount of NPS pollution in an area. For this reason, population growth rates are a concern for the watershed. Based on estimates from US census Waldoboro's population has increased by more than 8% since 1990 while Nobleboro's population has increased nearly 15% during the same time period. In addition, summer residents and visitors can cause the population to expand in both towns during peak summertime months (June, July, and August). Some of the population increase that has occurred during this time period involves the conversions from seasonal to year-round residences.

Duckpuddle Pond Fish Assemblage & Fisheries Status

Based on records provided by the Maine Department of Inland Fisheries and Wildlife (Maine DIFW) and a recent conversation with fisheries biologist Bill Woodward (Region B, Sidney office), Duckpuddle Pond (Nobleboro and Waterboro - Pemaquid River drainage) is managed primarily as a warmwater (smallmouth and largemouth bass and chain pickerel) fishery. Duckpuddle Pond was originally surveyed by Maine DIFW in 1941 and their lake fisheries survey report was last revised in 1982. A total of **14** fish species are listed, including: **10** native indigenous fishes (sea-run alewife, American eel, golden shiner, white sucker, brown bullhead, chain pickerel, banded killifish, pumpkinseed, redbreast sunfish and yellow perch); and **4** previously introduced fishes (white perch, smallmouth and largemouth bass, and brown trout - last stocked in 1978, however, associated Pemaquid Pond is stocked annually with brown trout).

Smallmouth bass



Chain pickerel

Given that the trophic state of Duckpuddle Pond has been disturbed by cumulative human impacts over the past several decades, a moderate reduction in the total phosphorus load in the Duckpuddle Pond watershed will lead to maintaining in-lake nutrient levels within the natural assimilative capacity of this lake to effectively process phosphorus resulting in the elimination of nuisance algal blooms.

Watershed Topography and Characteristic Soils (Source: USDA SCS 1974): The soils within the Duckpuddle Pond drainage area range from somewhat poorly to moderately well drained. The majority of the soils within the watershed fall within the "C" or "C/D" hydrologic group with many of the soils conducive to moderate amounts of runoff and moderate permeability. The somewhat excessively drained Lyman association accounts for 24% of the watershed area, while moderately well drained Peru soils (17%) and Boothbay (9%) are the other dominant soils of the watershed area. The remaining 50% of the watershed consists of more than 15 other soil types.

Land Use Inventory

The results of the Duckpuddle Pond watershed land use inventory are depicted in Table 1 (following page). The various land uses are categorized by developed land vs. non-developed land. Developed land area, including transitional conversion forest land and operated forest land, comprises approximately 14% of the watershed. Non-developed land, including the water surface area of Duckpuddle Pond, comprises the remaining 86% of the watershed. These numbers may be used to help make future planning and conservation decisions relating to the Duckpuddle Pond watershed. The information in Table 1 was also used as a basis for preparing the Total Maximum Daily (Annual Phosphorus) Load report (see Appendices).

Descriptive Land Use and Phosphorus Export Estimates

Agriculture: Non-manured hayland (98 acres) is the primary agricultural land use within the watershed. Most of the hayland is located in the northern and central portions of the watershed. There are some cultivated croplands (approximately 60 acres) within the Duckpuddle Pond watershed. There are larger farms located in the Tobias Pond watershed approximately 4 miles north of Duckpuddle Pond. These farms are actively working on conservation projects with the Knox-Lincoln Soil and Water Conservation District and Maine Department of Environmental Protection.

All agricultural land uses combined currently account for 481 acres or 9% of the total watershed area and approximately 35% of the watershed total phosphorus load. This proportionately large estimated phosphorus load is generally due to the fact it is the primary developed land use in the watershed.

Forest Lands: Of the total land area within the Duckpuddle Pond watershed approximately 66% (3,340 acres) is forested.

Actively Managed Forest Land **-** 270 acres (5%) are determined through GIS analysis to have been actively managed during the past five years. While poorly managed forestry operations have the potential to negatively impact a waterbody through erosion and sedimentation from logging sites, properly managed forestry operations generally do not. Sustainable forest management can enhance water quality through sequestering excess nutrients particularly in forested riparian areas. This land use type accounts for approximately 2.7% of the watershed total phosphorus export.

Inactive/Passively Managed Forests - 3,170 acres (61%) did not incur active management during this study period. Characterized by privately-owned non-managed deciduous and mixed

Table 1. Duckpuddle Pond Direct Watershed - Land Use Inventory and Phosphorus Loads

LAND USE CLASS	Land Area (Acres)	Land Area (% Total)	Total Phosphorus Export (% Total)
Agricultural and Forested Land			
Row Crops/Tillage/Corn	60.2	1.1%	17.8%
Manured Hayland	44	0.8%	8.8%
Non-manured Hayland	98	1.9%	7.9%
Actively Managed Forest Land	270	5.2%	2.7%
Pasture (grazed meadows)	8	0.2%	0.7%
Sub-Totals	**481**	**9%**	**38%**
Shoreline Development			
Septic Systems	**Duckpuddle Pond Septic Model**		1.7%
Private/Camp Roads	1	0.0%	0.3%
Low Density Residential	1	0.0%	0.1%
Sub-Totals	**2**	**0%**	**2%**
Non-Shoreline Development			
Public Roads	87	1.7%	16.6%
Low Density Residential	146	2.8%	9.4%
Commercial-Industrial	22	0.4%	4.2%
Medium Density Residential	1	0.0%	0.1%
Institutional	0	0.0%	0.1%
Parks & Cemeteries	0	0.0%	0.0%
Gravel Pits	5	0.1%	0.0%
Sub-Totals	**261**	**5%**	**30%**
Total: DEVELOPED LAND	**744**	**14%**	**70%**
Non-Developed Land			
Inactive/Passively Managed Forests	3,170	60.5%	16.7%
Grassland	248	4.7%	6.5%
Scrub/shrub	43	0.8%	0.6%
Wetlands	719	13.7%	0.0%
Total: NON-DEVELOPED Land	**4,180**	**80%**	**24%**
Total: Surface Water (Atmospheric)	**316**	**6%**	**6%**
TOTAL: DIRECT WATERSHED	**5,241**	**100%**	**100%**

forest plots, these forests may support active management in the future. Approximately 17% of the phosphorus load is estimated to be derived from inactive/passively managed forested areas within Duckpuddle Pond's direct drainage area.

Shoreline Development consists of all lands within the immediate shoreland area (250 feet) of Duckpuddle Pond. Some land uses extend both inside and outside of this area. The following section describes only those land uses (or parts of land uses) that are within 250 feet of Duckpuddle Pond.

A complete shoreline survey was conducted in September of 2004 by Maine DEP, MACD, Knox Lincoln SWCD, and Pemaquid Lake Association project staff. The survey was conducted from a boat, approximately 50 feet from the shoreline. The survey results provide a shoreline structure tally and qualitatively evaluates the nonpoint source pollution impact of each lot in regard to phosphorus loading. A total of 35 developed lots were evaluated during the shoreline survey. Most of Duckpuddle Pond is surrounded by low-density residential development. There are several large tracts of natural undeveloped shorefront. There are three no pubic boat launching facilities around the shore and only 16 private docks on shorefront lots.

To help characterize shoreline development and to assist stakeholders with targeting and implementation of future shoreline best management practices, each lot was assigned an NPS pollution impact rating using best professional judgment. The ratings range from 1 to 3, with 1 being very low impact (primarily natural vegetation with development set back from the lake) and 3 being high impact (little vegetation, development near the shoreline). Table 2 outlines the impact ratings assigned to each shoreline lot during the survey.

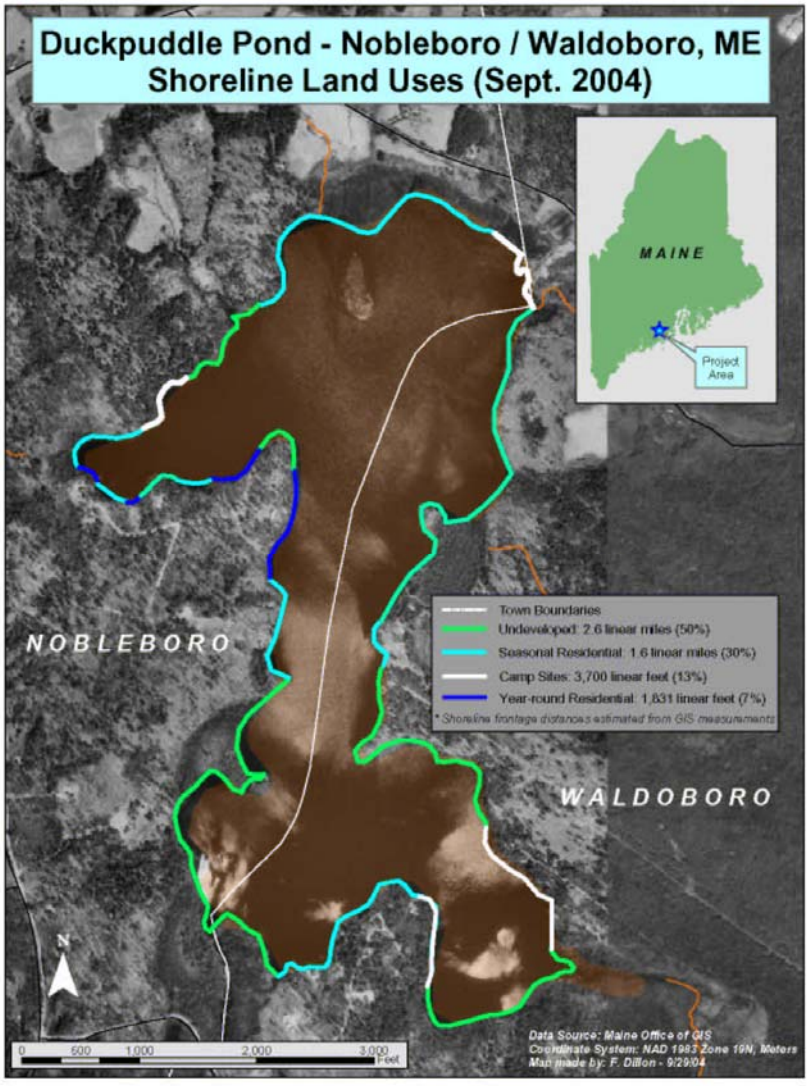


Table 2. Duckpuddle Pond Shoreline Survey Results (2004)			
NPS Pollution Potential Severity Score	**Impact rating characterized by one or more of the following:**	**Number of shoreline sites identified within each category**	**% of sites within each category**
1 = low impact	Good natural vegetation; good setback from lake	20	57%
2 = moderate impact	Lack of adequate buffer; close to lake	14	40%
3 = high impact	Lack of buffer; steep slopes; close to lake	1	3%

Overall, 40% of all shoreline lots that were surveyed on Duckpuddle Pond have a moderate impact due to inadequate vegetative buffers and/or close proximity to the lake. Some of the shoreline areas lack vegetative plantings other than mowed lawns. Vegetative buffers help to decrease the amount and flow of run-off from the sites. In addition, 3% of the lots surveyed have a high impact to the lake due to a lack of any vegetation or visual erosion on banks and access ways. On the positive side, 57% of the lots were rated as low impact. These lots retained a healthy buffer of natural vegetation between the lake and any substantial development. Overall, the impact of Duckpuddle Pond shoreline lots appears to be minimal.

To estimate quantitative phosphorus loading from residential shoreline use, the shoreline area was classified as low, medium and high density development. Town tax records, property tax maps, high resolution aerial photos and GIS maps were used to determine low, medium and high density residential areas within the shoreland zone. Phosphorus loading coefficients were developed using information on residential lot stormwater export of algal available phosphorus (Dennis et al. 1992). Low density residential development is the dominant type of development along the shoreline. This low density residential development along the shoreline of Duckpuddle Pond comprises less than 1% of the land area in the watershed, which accounts for less than 1% of the estimated total phosphorus load.

Shoreline Septic Systems: It is important to consider the potential for phosphorus loading from septic systems around the immediate vicinity of Duckpuddle Pond. Antiquated and/or poorly designed and installed septic systems within the shoreland zone may contribute substantially to the annual total phosphorus load to adjacent lake water, adding to the cumulative phosphorus load to Duckpuddle Pond.

Total phosphorus export loading from residential septic systems within the 100-foot shoreline zone has been estimated for Duckpuddle Pond. The primary information source for this assessment originates from the shoreline survey that was conducted during the summer of 2002 by MACD and DEP. Duckpuddle Pond shoreline soils are classified for septic suitability based on the identified soil type's ability to filter and purify effluent in septic tank and drain field systems.

In order to estimate total phosphorus loading from shoreline septic systems, a simple model was used based on the following attributes: seasonal or year-round occupancy; estimated age of the

system; estimated distance of the system from the lake; and surveyed usage (derived from East Pond survey), while taking into account a groundwater phosphorus loading range based on low, medium and high flow estimates. These attribute values were determined by the shoreline survey and personal interviews with local officials.

For purposes of these calculations it was estimated that 50% of the dwellings along the shoreline had septic systems installed after 1974. Based on the results of the shoreline survey: 50% of residences (and their septic systems) were estimated to lie less than 50' from the shoreline while 50% were located 50 feet or greater from the shoreline; and, 75% of the structures were assumed to be seasonal residences (occupied 90 days/year) while 25% were assumed to be year-round residences (occupied most of the year). Estimates of the loading from residential septic systems on Duckpuddle Pond range from a low of 3 kg to a high of 10 kg total phosphorus per year. Based on best professional judgment, a medium groundwater flow estimate and annual phosphorus export of 6 kg was chosen, which is less than 2% of the total phosphorus export.

Private (Camp) and Public Roadways: There is approximately 1 acre of private (camp) and public roads within the immediate shoreland zone (250' from shore) of Duckpuddle Pond. These roadways adjacent to Duckpuddle Pond account for less than 1% of the watershed total phosphorus load.

Shoreline land uses: The combined export of all shoreline land uses accounts for approximately 2% of the total phosphorus load.

Other Development and Land Uses

Non-Shoreline Development consists of all lands outside the immediate shoreland area (250 feet) of Duckpuddle Pond. Some land uses extend outside the shoreland zone. The following section describes only those land uses (or parts of land uses) more than 250 feet away from Duckpuddle Pond.

Residential Homes: Town tax records, property tax maps, high resolution aerial photos and GIS maps were used to determine low, medium, and high density residential areas within the Duckpuddle Pond watershed. Low-density residential areas, characterized by dispersed, low-density single-family homes with less than one residence per acre, are scattered throughout the watershed and account for approximately 9% of the total phosphorus load to Duckpuddle Pond and 3% of the total watershed land area. Medium-density residential area areas are characterized by one or more single family residences per acre. Medium-density development accounts for less than 1% of the total watershed and less than 1% of the total phosphorus load. High-density residential development is found in eight areas within the watershed. There is no high-density residential development in the watershed.

Private and Public Roadways: There are 87 acres of public roadways outside the shoreland zone within the Duckpuddle Pond watershed. These roads contribute a larger phosphorus load (17%) versus their minimal land area (less than 2%) in the Duckpuddle Pond watershed.

Other Non-Shoreline Land Uses

Commercial-Industrial: There is a small amount of commercial development located primarily along the Route 1 corridor. This land use accounts for 22 acres within the watershed and approximately 4% of the total phosphorus load to Duckpuddle Pond.

Institutional Public: Institutional Public land uses account for less than 1% of the land use and less than 1% of the total phosphorus export to Duckpuddle Pond.

Gravel Pits: There is one 5-acre pit located in the watershed. Because many gravel pits are internally draining, there is limited phosphorus export associated with this land use category.

Non-Shoreline Land Uses: In total, these land uses comprise 5% of the land use area and an estimated 30% of the phosphorus load to Duckpuddle Pond.

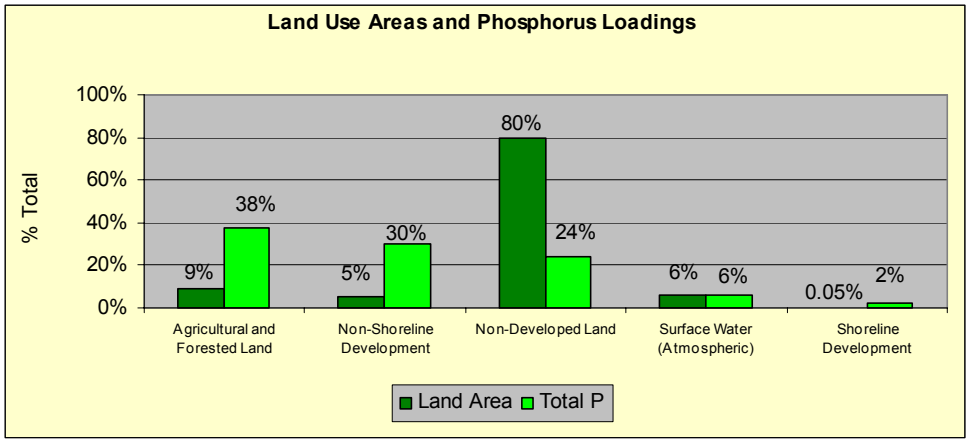
Phosphorus Loading from Non-Developed Lands and Water

Other Non-Developed Land Areas: Forested and open water wetlands are prevalent throughout the watershed. They range in size from over 150 acres to less than 1 acre. Wetlands filter and slow runoff, provide important wildlife habitat and help reduce flooding. There are 719 acres of wetland within the watershed. Of the approximately 200 acres of grassland and scrub shrub, the majority is found in the northern portion of the watershed adjacent to or nearby existing farmland and roadways. Combined wetlands, reverting fields and islands account for the remaining 19% of the land area and 7% of the total phosphorus export load.

Atmospheric Deposition (Open Water): Duckpuddle Pond's surface waters (242 acres) and other open waters comprise 6% of the total watershed area, and because of atmospheric deposition of sediment and particulate matter, account for 6% of the total phosphorus load entering the lake.

Figure 2 (below) depicts the percentage of land use areas and corresponding total phosphorus loadings.

Figure 2. Duckpuddle Pond Direct Watershed
Land Use Areas and Estimated Total Phosphorus Loadings



PHOSPHORUS LOAD Summary – Watershed, Sediment and In-Lake Capacity

Supporting documentation for the phosphorus loading analysis includes the following: water quality monitoring data from Maine DEP and the Volunteer Lake Monitoring Program, Orbis/MACD GIS analysis and field ground-truthing, and the development of a phosphorus retention model (see Appendices for detailed information). Please note that two methods were used in our analysis to assist with the preparation of this report. However, the phosphorus reduction needed for the Duckpuddle Pond TMDL was determined using only the in-lake concentration model.

1. Modeling total phosphorus input into Duckpuddle Pond

Watershed Land Use: Total phosphorus loadings to Duckpuddle Pond originate from a combination of external watershed and internal lake sediment sources. Watershed total phosphorus sources, totaling approximately **353 kg TP** annually have been identified and accounted for by land use (See Table 3 - page 27).

Loading from the Indirect Watershed: Total phosphorus loading from associated upstream sources (Tobias Pond) probably does not contribute a significant amount of phosphorus to Duckpuddle Pond at this time, taking into account its relative distance and small size. For the purposes of this report, the current indirect load from Tobias Pond is 0 Kg.

The sum of these two potential sources of TP indicates that an estimated 353 kg of TP/yr may be contributing to the current in-lake phosphorus levels of Duckpuddle Pond. However, these models do not take into account many of the complex factors that affect lake water quality. Instead, these figures provide stakeholders with estimates that should assist with targeting implementation measures in the watershed.

2. Modeling Duckpuddle Pond's in-lake concentrations of total phosphorus (TMDL)

Lake Capacity: The lake's assimilative capacity for all existing and future non-point pollution sources for Duckpuddle Pond is 335 kg of total phosphorus per year, based on a target goal of 16 ppb (see Phosphorus Retention Model - page 29).

Target Goal: A change in 1 ppb in phosphorus concentration in Duckpuddle Pond is equivalent to 21 kg. The difference between the target goal of 16 ppb and the measured average summertime total phosphorus concentration (22 ppb) is 6 ppb (6 x 21) or 126 kg.

Future Development: The annual total phosphorus contribution to account for future development for Duckpuddle Pond is 10 kg (see page 28 for more information).

Reduction Needed: Given the target goal and a 10 kg allocation for future development, the total amount of phosphorus needed to be reduced, on an annual basis, to maintain water quality standards in Duckpuddle Pond is estimated to be 136 kg (126 + 10).

PHOSPHORUS CONTROL ACTION PLAN

Recent and Current NPS/BMP Efforts

In 1995, the Knox Lincoln SWCD and Maine DEP surveyed the watershed. Several of the sites in this survey were addressed in a 2000—2003 319 project in the Duckpuddle Pond Watershed. The final report estimates that more than 446 tons per year of sediment and 524 lbs (238 kg) of phosphorus per year were mitigated through best management practices installed by the grant sponsors. BMPs included: a manure storage system for 150 dairy cows, permanent seeding on a 9 acre crop field, planting of winter cover crops on 37 acres for two years, and stabilizing 8 culverts near stream crossings. In addition to the Duckpuddle Pond Watershed Study, Knox-Lincoln SWCD and USDA NRCS field office offers free property consultations to help landowners with land erosion issues, low-impact development and ordinance interpretation. Over the past ten years, KL-SWCD has provided several individual consultations for landowners on Duckpuddle Pond.

Recommendations for Future NPS-BMP Work

Duckpuddle Pond is a waterbody that has impaired water quality due to dissolved oxygen depletion in the waters below the thermocline - originating from nonpoint source (NPS) pollution. Specific recommendations regarding recent and current efforts in the watershed, best management practices (BMPs), and actions to reduce external watershed total phosphorus loadings in order to improve water quality conditions in Duckpuddle Pond are as follows:

Existing erosion sites: Obtain funding to repair existing erosion sites for all land uses within the watershed. Some of the chronically eroding sites are associated with older public and private roads accessing the lake. Fixing these areas usually requires cooperation between multiple landowners, and/or a road association or municipality.

Action Item # 1: Fix existing watershed erosion sites		
Activity	**Participants**	**Schedule & Cost**
Repair or mitigate existing erosion sites within the watershed	Watershed residents, KL-SWCD, municipalities, camp road associations, local contractors	2006 - 2014 **$10,000 annually**

Roadways: Institute a series of inspections and technical assistance workshops for camp roads

Action Item # 2: Camp road inspections and enhanced phosphorus		
Activity	**Participants**	**Schedule & Cost**
1. Institute inspections and offer technical assistance for camp roads. 2. Require new public and private roads to meet phosphorus standards	Watershed municipalities, KL-SWCD, camp road associations, private landowners, developers, Maine DEP	Annually beginning in 2006 **$5,000/yr**

and road associations. Enhance shoreland zoning to require new public and private roads to meet the phosphorus control standards outlined in the DEP's Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development (1992).

Agriculture: Encourage conservation practices on agricultural lands that will be environmentally friendly and economically beneficial. Increase landowner awareness of agricultural BMPs.

Action Item # 3: Encourage conservation on agricultural lands		
Activity	**Participants**	**Schedule & Cost**
1. Encourage participation in agricultural conservation programs. 2. Promote nutrient management	Watershed municipalities, KL-SWCD, USDA NRCS, agricultural landowners	Annually beginning in 2006 **$2,000/yr**

Forestry: "Existing, voluntary state guidelines for simplified pre-harvest plans, filter areas and proper erosion control as described in Best Management Practices for Forestry: Protecting Maine's Water Quality would minimize erosion and sedimentation during harvesting. Watershed municipalities should adopt new Statewide Standards for Timber Harvesting and Related Activities in Shoreland Areas (see below)."

Action Item # 4: Promote Sound Forest Management in Shoreland Areas		
Activity	**Participants**	**Schedule & Cost**
1. Promote use of voluntary best management practices for forestry. 2. Encourage landowner participation in WoodsWISE, Maine Forest Service's financial assistance program for forest landowners.	Watershed municipalities, forest landowners, logging professionals, local land trusts, Maine Forest Service.	Beginning 2006 **Cost dependent on activities. Financial cost - share assistance available to develop long-term forest management plans.**

Individual action: Seek technical assistance through SWCD/NRCS programs. Monitor and maintain individual septic systems. Continue to support non-maintain and enhance downslope buffers for all development within the watershed.

Action Item # 5: Technical assistance and self monitoring for individuals		
Activity	**Participants**	**Schedule & Cost**
1. Seek technical assistance and include support of non-phosphorus fertilizer 2. Monitor septic systems 3. Establish and enhance vegetated buffers	Landowners, KL-SWCD, USDA-NRCS	Ongoing **May involve cost to landowners or technical assistance programs**

Municipal action: Implement town comprehensive plans and phosphorus control ordinances. Improve shoreland zoning standards and implement land use standards for non shoreline development.

WATER QUALITY MONITORING PLAN

Historically, the water quality of Duckpuddle Pond has been monitored since 1990, including Secchi disk transparencies, temperature and oxygen profiles, pH, alkalinity, color and some conductivity readings during the open water months. Chlorophyll-a has been monitored on the lake from the 2000 to the present. Total phosphorus has been measured regularly from 2000 to the present (VLMP and Maine DEP). Continued long-term water quality monitoring within Duckpuddle Pond will be conducted bi-monthly, from May to October, through the continued efforts of the VLMP monitors in cooperation with Maine DEP. Under this planned, post-TMDL water quality monitoring scenario, sufficient data will be acquired to adequately track seasonal and inter-annual variation and long-term trends in water quality in Duckpuddle Pond. A post-TMDL adaptive management status report will be prepared five to ten years following EPA approval of the Duckpuddle Pond PCAP-TMDL.

PCAP CLOSING STATEMENT

The Knox Lincoln Soil and Water Conservation District in cooperation with resident landowners, has worked since the mid 1990's to correct both point and nonpoint source pollution within the Duckpuddle Pond watershed. Today, point source pollution to Duckpuddle Pond is no longer a problem and efforts have been focused on correcting nonpoint source pollution problems. KL-SWCD is continuing to work with landowners, businesses, the towns of Nobleboro and Waterboro and state and federal agencies to help correct this problem. Through the KL-SWCD, property owners are able to receive technical assistance regarding erosion, land use standards and camp road maintenance. It is important to note that the recently completed 319 nonpoint project estimates a reduction of 238 kg/year of phosphorus entering Duckpuddle Pond waterways. This is an important step towards future protection of the Pond. With continued diligent watershed work by residents, towns, and local and regional organizations - the water quality of Duckpuddle Pond is apt to improve in future years to the benefit of sport fisheries and lake user groups.

APPENDICES

DUCKPUDDLE POND

Total Maximum Daily (Annual Phosphorus) Load

Introduction to Maine Lake TMDLs and Phosphorus Control Action Plans (PCAPs)

You may be wondering what the acronym 'TMDL' represents and what it is all about. TMDL is actually short for 'Total Maximum Daily Load.' This information, no doubt, does little to clarify TMDLs in most people's minds. However, when we think of this as an annual phosphorus load (*Annual Total Phosphorus Load),* it begins to make more sense.

Simply stated, excess nutrients or phosphorus in lakes promote nuisance algae growth/blooms - resulting in the violation of water quality standards as measured by water clarity depths of less than 2 meters. A lake TMDL is prepared to estimate the total amount of total phosphorus that a lake can accept on an annual basis without harming water quality. Historically, development of TMDLs was first mandated by the Clean Water Act in 1972, and was applied primarily to *point sources* (i.e. discharge pipes) of water pollution. As a result of public pressure to further clean up water bodies, lake and stream TMDLs are now being prepared for watershed-generated *Non-Point Sources* (NPS) of pollution.

Nutrient enrichment of lakes through excess total phosphorus originating from watershed soil erosion has been generally recognized as the primary source of NPS pollution. Major land use activities contributing to the external phosphorus load in lakes include residential-commercial developments, roadways, agriculture, and commercial forestry. Statewide, there are 38 lakes in Maine which do not meet water quality standards due to excessive amounts of in-lake total phosphorus.

The first Maine lake TMDL was developed (1995) for Cobbossee Lake by the Cobbossee Watershed District (CWD) - under contract with Maine DEP and US-EPA. TMDLs have been approved by US-EPA for Madawaska Lake (Aroostook County), Sebasticook Lake, East Pond (Belgrade Lakes), China Lake, Webber, Threemile and Threecornered ponds (Kennebec County), Mousam Lake, Highland Lake (Falmouth), Annabessacook Lake and Pleasant Pond (contract with Cobbossee Watershed District), Sabattus Pond, Highland Lake (Bridgton) and Long Lake with LEA, Unity Pond (Waldo County), Toothaker Pond (Franklin County), Upper Narrows Pond (CWD), and Little Cobbosee Lake (CWD). PCAP-TMDLs are presently being prepared by Maine DEP, with assistance from the Maine Association of Conservation Districts (MACD) and County Soil and Water Conservation Districts (SWCDs) - for Togus, and Lovejoy ponds. PCAP-TMDL studies have also been initiated for Lilly, Hermon-Hammond, and Sewall ponds, as well as two of the remaining seven 303(d) listed waterbodies in Aroostook County (Christina and Trafton lakes).

Lake PCAP-TMDL reports are based in part on available water quality data, including seasonal measures of total phosphorus, chlorophyll-a, Secchi disk transparencies, and dissolved oxygen-water temperature profiles. Actual reports include: a lake description; watershed GIS assessment and estimation of NPS pollutant sources; selection of a total phosphorus target goal (acceptable amount); allocation of watershed/land-use phosphorus loadings, and a public participation component to allow for stakeholder review.

PCAP-TMDLs are important tools for maintaining and protecting acceptable lake water quality and are designed to 'get a handle' on the magnitude of the NPS pollution problem and to develop plans for implementing Best Management Practices (BMPs) to effectively address the lake's water pollution problem. Landowners and watershed groups are eligible to receive technical and financial assistance from state and federal natural resource agencies to reduce watershed total phosphorus loadings to the lake.

For further information, you may contact Dave Halliwell, Maine Department of Environmental Protection, Lakes PCAP-TMDL Program Manager, SHS #17, Augusta, ME 04333 (287-7649).

Water Quality Monitoring: (Source: Maine VLMP and Maine DEP) Comprehensive water quality monitoring data for Duckpuddle Pond (Nobleboro) has been collected since 1976 (missing 1978-80 and 1982-87). This water quality assessment is based on 20 years of Secchi disk transparency (SDT) measures, combined with 10 years of oxygen and temperature profiles, 9 years of epilimnion core total phosphorus (TP) data, 10 years of water chemistry and chlorophyll-a monitoring data.

Water Quality Measures: (Source: VLMP and Maine DEP) Duckpuddle Pond is a highly colored lake (average color 58 SPU) with an average Secchi disk transparency (SDT) of 2.7 m (8.9 ft). The range of epilimnetic water column total phosphorus (TP) (from core samples only) for Duckpuddle Pond is 10 to 29 parts per billion (ppb) with an average of 19 ppb, while chlorophyll-a ranges from 4.2 to 17.9 ppb with an average of 10.1 ppb. Dissolved oxygen (DO) profiles show moderate to severe summertime DO depletion in deeper areas of the lake. Oxygen levels below 5 parts per million (ppm) stress most cold-water fish and a persistent loss of oxygen may eliminate habitat for sensitive cold-water species. The potential for TP to enter the water column from the bottom sediments and become available to algae (internal loading) is high (VLMP 2004). Together, these data indicate a historical minor trend of increasing trophic state and hence a violation of the Class GPA water quality criteria requiring a stable or decreasing trophic state.

Priority Ranking, Pollutant of Concern and Algal Bloom History: Duckpuddle Pond is listed on the State's 2002 303(d) list of waters in non-attainment of Maine state water quality standards and was moved up in the priority development order due to stakeholder interest and need to complete an accelerated approach to lakes TMDL development. The Duckpuddle Pond TMDL has been developed for total phosphorus, the major limiting nutrient to algae growth in freshwater lakes in Maine. Nuisance summertime algal blooms were prevalent in Duckpuddle Pond during the 1989 to 1998 (10-year) period, but did not occur prior (1976 to 1988) or since (1999 to 2004).

Natural Environmental Background Levels for Duckpuddle Pond were not separated from the total nonpoint source load because of the limited and general nature of available information. Without more and detailed site-specific information on nonpoint source loading, it is very difficult to separate natural background from the total nonpoint source load (US-EPA 1999). There are no known point sources of pollutants to Duckpuddle Pond.

WATER QUALITY STANDARDS & TARGET GOALS

Maine State Water Quality Standard for nutrients which are narrative, are as follows *(July 1994 Maine Revised Statutes Title 38, Article 4-A*): "Great Ponds Class A (GPA) waters shall have a stable or decreasing trophic state (based on appropriate measures, e.g., total phosphorus, chlorophyll a, Secchi disk transparency) subject only to natural fluctuations, and be free of culturally induced algae blooms which impair their potential use and enjoyment."

Maine DEP's functional definition of nuisance algae blooms include episodic occurrence of Secchi disk transparencies (SDTs) < 2 meters for lakes with low levels of apparent color (<26 SPU) and for higher color lakes where low SDT readings are accompanied by elevated chlorophyll a levels. This water quality assessment uses historic documented conditions as the primary basis for comparison. Given the context of "impaired use and enjoyment," along with a realistic interpretation of Maine's goal-oriented Water Quality Standards (WQS), Maine DEP has determined that episodic, non-cyanobacteria based algae blooms (e.g. diatoms), limited to the fall or spring periods only, are in WQS attainment for GPA waters. Currently, Duckpuddle Pond does not meet water quality standards due to excessive historical watershed phosphorus loading leading to severe dissolved oxygen (DO) depletion in deep areas of the lake and increasing trophic state.

Designated Uses and Anti-degradation Policy: Duckpuddle Pond is designated as a GPA (Great Pond Class A) water in the Maine DEP state water quality regulations. Designated uses for GPA waters in general include: water supply; primary/secondary contact recreation (swimming and fishing); hydro-electric power generation; navigation; and fish and wildlife habitat. No change of

land use in the watershed of a Class GPA water body may, by itself or in combination with other activities, cause water quality degradation that would impair designated uses of downstream GPA waters or cause an increase in their trophic state. Maine's anti-degradation policy requires that "existing in-stream water uses, and the level of water quality necessary to sustain those uses, must be maintained and protected."

Numeric Water Quality Target: The water quality goal for Duckpuddle Pond is to halt its current trend of increasing trophic state so that it can attain Maine DEP standards of stable or decreasing trophic state. The numeric (in-lake) water quality target for Duckpuddle Pond, to meet this goal, is conservatively set at 16 ppb total phosphorus (335 kg TP/yr). Since numeric criteria for total phosphorus do not exist in Maine's water quality regulations - and would be less accurate targets than those derived from this study - we employed best professional judgment to select a target in-lake phosphorus concentration that would attain the narrative water quality standard. Spring-time (early May) epilimnion core total phosphorus levels in Duckpuddle Pond approximate 16 ppb, while summer-time (July through September) in-lake epilimnion core total phosphorus levels measure 20-24 ppb. In summary, the numeric water quality target goal of 16 ppb for total phosphorus in Duckpuddle Pond was based on observed late spring – early summer mixed water column data, corresponding to continued maintenance of non-bloom conditions, as reflected in suitable (water quality attainment) measures of both Secchi disk transparency (> 2.0 meters) and chlorophyll-a (< 8.0 ppb).

ESTIMATED PHOSPHORUS EXPORT BY LAND USE CLASS

Table 3 details the numerical data used to determine external phosphorus loading for the Duckpuddle Pond watershed. The key below explains the columns and the narrative that follows the table (pages 28-29) relative to each of the representative land use classes.

Key for Columns in Table 3

Land Use Class: The land use category that was analyzed for this report

Land Area in Acres: The area of each land use as determined by GIS mapping, aerial photography, Delorme Topo USA software, and field reconnaissance.

Land Area %: The percentage of the watershed covered by the land use.

TP Coeff. Range kg TP/ha: The range of the total phosphorus coefficient values listed in the literature associated with the corresponding land use.

TP Coeff. Value kg TP/ha: The selected coefficient for each land use category. The total phosphorus coefficient is determined from previous research – usually the median value, if listed by the author. The coefficient is often adjusted using best professional judgment based on conditions including soil type, slope, and best management practices (BMPs) installed.

Land Area in Hectares: Conversion, 1.0 acre = 0.404 hectares

TP Export Load kg TP: Total hectares x applicable total phosphorus coefficient for each land use

GIS adjusted kg TP: Total hectares x land use coefficient x slope coefficient x soils coefficient (See Appendix A)

TP Export Total %: The percentage of GIS estimated phosphorus exported by the land use.

Table 3. Duckpuddle Pond Direct Watershed - Phosphorus Export by Land Use Class

LAND USE CLASS	Land Area Acres	Land Area %	TP Coeff. Range kg TP/ha	TP Coeff. Value kg TP/ha	Land Area Hectares	TP Export Load kg TP	GIS Ad-justed* kg TP	TP Ex-port Total %
Agricultural and Forested Land								
Row Crops/Tillage/Corn	60	1.1%	0.26 - 18.6	2.24	24.4	54.6	62.8	17.8%
Manured Hayland	44	0.8%	0.65 - 1.81	1.51	17.6	26.6	31.2	8.8%
Non-manured Hayland	98	1.9%	0.35 - 1.35	0.64	39.8	25.5	28.0	7.9%
Actively Managed Forest Land	270	5.2%	0.04 - 0.60	0.08	109.4	8.7	9.7	2.7%
Pasture (grazed meadows)	8	0.2%	0.14 - 4.90	0.81	3.3	2.7	2.4	0.7%
Sub-Totals	**481**	**9%**	**-**	**-**	**194**	**118**	**134**	**38%**
Shoreline Development								
Septic Systems		**Duckpuddle**	**Pond**	**Septic**	**Model**	6.0	6.0	1.7%
Private/Camp Roads	1.3	0.02%	0.60 - 10.0	2	0.5	1.0	1.0	0.3%
Low Density Residential	1.2	0.02%	0.25 - 1.75	0.5	0.5	0.3	0.3	0.1%
Sub-Totals	**2**	**0.05%**	**-**	**-**	**1**	**7**	**7**	**2%**
Non-Shoreline Development								
Public Roads	87	1.7%	0.60 - 10.0	1.5	35.3	52.9	58.8	16.6%
Low Density Residential	146	2.8%	0.25 -1.75	0.5	59.2	29.6	33.2	9.4%
Commercial-Industrial	22	0.4%	0.77 - 4.18	1.5	8.8	13.2	14.7	4.2%
Medium Density Residential	0.7	0.0%	0.40 - 2.20	1.0	0.3	0.3	0.4	0.1%
Institutional	0.4	0.0%	0.77 - 4.18	1.5	0.2	0.3	0.3	0.1%
Parks & Cemeteries	0.2	0.0%	0.14 - 4.9	0.8	0.1	0.1	0.1	0.0%
Gravel Pits	5	0.1%	0.00 - 0.05	0	2.0	0.0	0.0	0.0%
Sub-Totals	**261**	**5%**	**-**	**-**	**106**	**96**	**107**	**30%**
Total: DEVELOPED LAND	**744**	**14%**	**-**	**-**	**301**	**222**	**249**	**70%**
Non-Developed Land								
Inactive/Passively Mngd. Forests	3170	60.5%	0.01 - 0.08	0.04	1282.9	51.3	58.9	16.7%
Grassland	248	4.7%	0.10 - 0.20	0.2	100.5	20.1	23.0	6.5%
Scrub/shrub	43	0.8%	0.10 - 0.20	0.1	17.2	1.7	2.1	0.6%
Wetlands	719	13.7%	0.00 - 0.05	0	291.0	0.0	0.0	0.0%
Total: NON-DEVELOPED Land	**4,180**	**80%**	**-**	**-**	**1692**	**73**	**84**	**24%**
Total: Surface Water (Atmospheric)	**316**	**6%**	**0.11 - 0.21**	**0.16**	**128**	**20**	**21**	**6%**
TOTAL: DIRECT WATERSHED	**5,241**	**100%**	**-**	**-**	**2,121**	**315**	**353**	**100%**

Total Phosphorus Land Use Loads

Estimates of total phosphorus export from different land uses found in the Duckpuddle Pond are presented in Table 3, representing the extent of the current direct watershed phosphorus loading to the lake (353 kg TP/yr). Total phosphorus loading measures are provided as a range of values to reflect the degree of uncertainty generally associated with such relative estimates (Walker 2000). The watershed total phosphorus loading values were primarily determined using literature and locally-derived export coefficients as found in Schroeder (1979), Reckhow et al. (1980), Dennis (1986), Dennis et al. (1992), and Bouchard et al. (1995) for residential properties, roadways, agriculture and other types of land uses (e.g., recreational, commercial).

Agricultural and Operational Forest Lands: Phosphorus loading coefficients as applied to agricultural land uses were adopted, in part, from Reckhow et. al. 1980: livestock areas/pasture (0.81 kg TP/ha/yr), row crops/tillage/cultivation (2.24 kg TP/ha/yr) the Annabessacook Lake Model 1977: orchard (0.40 kg TP/ha/yr) Dennis and Sage 1981: low-intensity hayland (0.64 kg TP/ha/yr); and from past Maine DEP 1982 studies: farm buildings (used commercial-industrial coefficient) (1.5 kg TP/ha/yr).

The phosphorus loading coefficient applied to actively managed forest land (0.08 kg TP/ha/yr) was changed from previous PCAP-TMDL reports after consulting with LEA and Maine Forest Service staff. The rationale for this change is based on the fact that properly managed harvest areas will generally act as phosphorus sinks during periods of regeneration. According to the Maine Forest Service, nearly 3,500 water quality inspections conducted throughout the state in 2003, approximately 7% of the harvested sites posed "unacceptable" risks to water quality. Previous lake PCAP-TMDL reports identified a "worst case" upper limit phosphorus loading coefficient of 0.6 kg TP/ha/yr for operated forestland. We applied this "worst case" value to 7% of the 2,356 operated forestland hectares (165 ha) identified in the Duckpuddle Pond watershed. The "best case" passively managed forestland coefficient (0.04 kg TP/ha/yr) was then applied (per Jeff Dennis, Maine DEP and Chris Martin, Maine Forest Service) to the remaining 93% (2,191 hectares) of operated forestland - assuming that it had all been properly managed. The calculations to arrive at an average operated forestland coefficient of 0.08 kg TP/ha/yr are as follows:

Worst case operated forestland: 2,356 ha x 7% = 165 ha x 0.60 kg TP/ha/yr = 99 kg TP/ha/yr

Best case operated forestland: 2,356 ha - 165 ha = 2,191 ha x 0.04 kg TP/ha/yr = 88kg TP/ha/yr

New phosphorus loading coefficient for operated forestland: 187 kg TP / 2,356 ha= 0.08

Residential Lots (House and Camp): The range of phosphorus loading coefficients used (0.25 – 2.70 kg TP/ha/yr) were developed using information on residential lot stormwater export of phosphorus as derived from Dennis et al (1992). low density residential Development (0.50 kg TP/ ha/yr), medium density residential development (1.0 kg TP/ha/yr), and high density residential development (1.40 kg TP/ha/yr).

Private and Public Roads: The total phosphorus loading coefficient for private and public roads (2.0 TP/ha/yr for private and 1.50 kg TP/ha/yr for public) was chosen, in part, from previous studies of rural Maine highways (Dudley et al. 1997) and phosphorus research by Jeff Dennis (Maine DEP).

Other Developed Land Uses: Research from Wagner-Mitchell-Monagle 1989: parks and cemeteries (0.80 kg TP/ha/yr), from the original Cobbossee Lake TMDL (Monagle 1995) and total phosphorus recommendations by Jeff Dennis: institutional public (1.50 kg TP/ha/yr), commercial (1.50 kg TP/ha/yr), industrial (1.50 kg TP/ha/yr), gravel pits (0 kg TP/ha/yr), campgrounds (0.70 kg TP/ha/yr), boys and girls camps (used low density residential coefficient) from Bouchard 1995

utilities lines (used grasslands/reverting fields coefficient) (0.20 kg TP/ha/yr) from Dennis, Sage 1981; Annabessacook Lake 1990; and Reckhow et al 1980 landfill (used low intensity hayland coefficient) (0.64 kg TP/ha/yr)

Total Developed Lands Phosphorus Loading: A total of 70% (249 kg) of the phosphorus loading to Duckpuddle Pond is estimated to have been derived from the cumulative effect of the preceding cultural land use classes: agriculture and forestry (38% - 134 kg); non-shoreline development (30% - 107 kg) and shoreline development (2% - 7 kg), including septic systems (2% - 6 kg) as depicted in Table 3.

Non-Developed Lands Phosphorus Loading: The phosphorus export coefficient for forested land and islands (0.04 kg TP/ha/yr) is based on a New England regional study (Likens et al 1977) and phosphorus availability recommendation by Jeff Dennis. The phosphorus export coefficient for reverting fields is based on research by Bouchard in 1995 (0.20 kg TP/ha/yr). The export coefficient for wetlands is based on research by Bouchard 1995, and Monagle 1995 (0.0 kg TP/ha/yr). The phosphorus loading coefficient chosen for surface waters (atmospheric deposition) was (0.16 kg TP/ha) and was originally used in the China Lake TMDL (Kennebec County).

Shoreline Erosion: Undeveloped areas of the lake shoreline that may be eroding due to natural causes (i.e., wind, wave and ice action) are not included as a source of phosphorus due to the difficulty in quantifying impact area and assigning suitable phosphorus loading coefficients.

Phosphorus Load Summary

It is our professional opinion that the selected export coefficients are appropriate for the Duckpuddle Pond watershed. Results of the land use analysis indicate that a best estimate of the present total phosphorus loading from external nonpoint source nutrient pollution (direct and indirect drainages) approximates 353 kg TP/yr.

LINKING WATER QUALITY and POLLUTANT SOURCES

Assimilative Loading Capacity: The Duckpuddle Pond TMDL is expressed as an annual load as opposed to a daily load. As specified in 40 C.F.R. 130.2(i), TMDLs may be expressed in terms of either mass per unit time, toxicity, or other appropriate measures. It is thought appropriate and justifiable to express the Duckpuddle Pond TMDL as an annual load because the lake basin has an annual flushing rate of 3.1, just over two times the 1.50 average flushing rate for Maine lakes.

The Duckpuddle Pond basin lake assimilative capacity is capped at 335 kg TP/yr, as derived from the empirical phosphorus retention model based on a target goal of 16 ppb. This value reflects the modeled annual phosphorus loading responsible for current trophic state conditions, based on a goal of maintaining summertime phosphorus concentrations at or below 16 ppb.

Future Development: In order to effectively meet the stated goal of maintaining current trophic state conditions, further reductions in existing watershed phosphorus loading is necessary for two important reasons. First, Duckpuddle Pond has a flushing rate of only 3.1 times per year and is a well-mixed waterbody. Some development has occurred in the watershed over the past 5 years, no doubt resulting in an increase in annual phosphorus loading from the watershed. Given the lag time in lake response to this additional P-load, existing annual watershed phosphorus loads should be reduced by at least the amount of increase in P-load over the past 5 years (Jeff Dennis, DEP).

The Maine DEP water quality goal of maintaining a stable trophic state includes a reduction of current P-loading which accounts for both recent P-loading as well as potential future development in the watershed. The methods used by Maine DEP to estimate future growth (Dennis et al. 1992)

are inherently conservative, as they provide for relatively high-end regional growth estimates and largely non-mitigated P-export from new development. This provides an additional non-quantified margin of safety to ensure the attainment of state water quality goals.

This projected amount is a conservative estimate, since most of the development during this period (1999-2003) did in fact incorporate measures to mitigate phosphorus export from the Duckpuddle Pond watershed. The second reason for the need to further reduce existing watershed P-loads is that growth will, no doubt, continue to occur in the Duckpuddle Pond watershed, contributing new sources of phosphorus to the lake. Previously unaccounted P-loading from anticipated future development on the Duckpuddle Pond watershed is 10.5 kg (1 ppb change in trophic state = 21 kg x 0.50). Hence, existing phosphorus source loads must be reduced by at least 10.5 kg/yr to allow for anticipated new sources of phosphorus to Duckpuddle Pond. Reductions already underway in non-point source total phosphorus loadings are expected from the continued implementation of best management practices - primarily from improvements to roadways and residential shoreline vegetative buffer plantings (see NPS/BMP Implementation Plan and PCAP Summary, pp. 19-21).

Internal Lake Sediment Phosphorus Mass: The relative contribution of internal sources of total phosphorus within Duckpuddle Pond - in terms of sediment TP recycling - were analyzed (using lake volume-weighted mass differences between early and late summer) and estimated on the basis of water column TP data from 2000 to 2004 (not 2003). Estimated internal sediment TP loads for this 4-year period ranged from 12 to 18 with an average annual value of 15 kg. The amount of phosphorus being released from the sediments of Duckpuddle Pond, during the summer period, has been relatively low, however fairly regular during this time period. This value is not calculated into the model to determine the target goal for Duckpuddle Pond.

Linking Pollutant Loading to a Numeric Target: The basin loading assimilative capacity for Duckpuddle Pond was set at 335 kg/yr of total phosphorus to meet the numeric water quality target of 16 ppb of total phosphorus. A phosphorus retention model, calibrated to in-lake phosphorus data (springtime average, 2002 -2004), was used to link phosphorus loading to a numeric target.

Supporting Documentation for the Duckpuddle Pond TMDL Analysis includes the following: Maine DEP and VLMP water quality monitoring data and specification of a phosphorus retention model – including both empirical models and retention coefficients.

Total Phosphorus Retention Model (after Dillon and Rigler 1974 and others)

L = P (A z p) / (1-R) where: (1 ppb change = **21** kg)

335 = **L** = in-lake total phosphorus load capacity (kg TP/year) 12 = 251

16 = **P** = spring overturn total phosphorus concentration (ppb) 13 = 272

0.98 = **A** = lake basin surface area (km^2) 14 = 293

4.4 = **z** = mean depth of lake basin (m) **A z p = 13.4** 16 = 335

3.1 = **p** = annual flushing rate (flushes/year) 17 = 356

0.64 = **1- R** = phosphorus retention coefficient, where: 18 = 377

0.36 = **R = 1 / (1+ sq.rt. p)** (Larsen and Mercier 1976)

Previous use of the Vollenwieder (Dillon and Rigler 1974) type empirical model for Maine lakes, e.g., Cobbossee, Madawaska, Sebasticook, East, and China Lake TMDLs (2000-2001), and Long,

Webber-Threemile-Threecornered pond complex, Mousam, Annabessacook, Pleasant Pond, Unity, and Upper Narrows pond PCAP-TMDLs (Maine DEP 2003-2005) have shown this approach to be effective in linking watershed total phosphorus (external) loadings to existing in-lake phosphorus concentrations.

Strengths and Weaknesses in the Overall TMDL Analytical Process: The Duckpuddle Pond TMDL was developed using existing lake water quality monitoring data, derived watershed export coefficients (Reckhow et al. 1980, Maine DEP 1981 and 1989, Dennis 1986, Dennis et al. 1992, Bouchard et al. 1995, Soranno et al. 1996, and Mattson and Isaac 1999) and a phosphorus retention model which incorporates both empirically derived and observed retention coefficients (Vollenwieder 1969, Dillon 1974, Dillon and Rigler 1974 a and b, and 1975, Kirchner and Dillon 1975). Use of the Larsen and Mercier (1976) total phosphorus retention term, based on localized data (northeast and north-central U.S.) from 20 lakes in the US-EPA National Eutrophication Survey (US-EPA-New England) provides a more accurate model for northeastern regional lakes.

Strengths:

- Approach is commonly accepted practice in lake management
- Makes best use of available water quality monitoring data
- Based upon experience with other lakes in the northeastern U.S. region, the empirical phosphorus retention model was determined to be appropriate for the application lake.

Weaknesses:

- Inherent uncertainty of TP load estimates (Reckhow 1979, Walker 2000) and associated variability and generality of TP loading coefficients.

Critical Conditions - Occur in Duckpuddle Pond during the summertime, when the dissolved oxygen depletion in the bottom hypolimnetic waters is most pronounced. The lake target loading capacity of 16 ppb total phosphorus during this critical time period, will provide adequate seasonal protection, and will result in gradual water quality improvement over future years (see Seasonal Variation).

LOAD ALLOCATIONS (LA's) The annual load allocation for Duckpuddle Pond equals 335 kg TP and represents, in part, that portion of the lake's assimilative capacity allocated to non-point (overland) sources of phosphorus (from Table 3). Direct external TP sources (totaling 353 kg/yr - GIS adjusted) have been identified and accounted for in the land-use breakdown portrayed in Table 3. Further reductions in non-point source phosphorus loadings are expected from the continued implementation of NPS best management practices (see PCAP pages 23 –26). As previously mentioned, it was not possible to separate natural background from non-point pollution sources in this watershed because of the limited and general nature of the available information. As in other Maine TMDL lakes (see Sebasticook Lake, East Pond, China Lake and Webber-Threemile-Threecorner, Annabessacook, Pleasant, and Unity pond TMDLs), in-lake nutrient (phosphorus) loadings in Duckpuddle Pond originate from a combination of direct and indirect external (watershed + associated sub-watershed) and an accumulation of internal (sediment) sources of phosphorus.

WASTE LOAD ALLOCATIONS (WLA's): There are no known existing point sources of pollution (including regulated storm-water sources) in the Duckpuddle Pond watershed, hence, the waste load allocation for all existing and future point sources is set at 0 (zero) kg/year of total phosphorus.

MARGIN OF SAFETY (MOS): An implicit margin of safety was incorporated into the Duckpuddle Pond TMDL through the conservative selection of the numeric water quality target, as well as the selection of relatively conservative phosphorus export loading coefficients for cultural pollution sources (Table 3). Based on both the Duckpuddle Pond historical records and a summary of statewide Maine lakes water quality data for colored (> 30 SPU lakes) - the target of 16 ppb (335 kg TP/yr in Duckpuddle Pond) represents a highly conservative goal to assure attainment of Maine DEP water quality goals of non-sustained and non-repeated blue-green summer-time algae blooms due to NPS pollution or cultural eutrophication and stable or decreasing trophic state. The statewide data base for colored Maine lakes indicate that summer nuisance algae blooms (growth of algae which causes Secchi disk transparency to be less than 2 meters) are more likely to occur at 18 ppb or above.

SEASONAL VARIATION: This Duckpuddle Pond TMDL is protective of all seasons, as the allowable annual load was developed to be protective of the most sensitive time of year – during the summer, when conditions most favor the growth of algae and aquatic macrophytes. With an average flushing rate of 3.1 flushes/year, the average annual phosphorus loading is most critical to the water quality in Duckpuddle Pond. Maine DEP lake biologists, as a general rule, use more than six flushes annually (bi-monthly) as the cutoff for considering seasonal variation as a major factor (to distinguish lakes vs. rivers) in the evaluation of total phosphorus loadings in aquatic environments in Maine. Nonpoint source best management practices (BMPs) proposed for the Duckpuddle Pond watershed have been designed to address total phosphorus loading during all seasons.

PUBLIC PARTICIPATION: Adequate ('full and meaningful') public participation in the Duckpuddle Pond TMDL development process was ensured - during which land use and phosphorus load reductions were discussed - through the following avenues from summer 2004 through summer 2005:

1. Initial (July 13, 2004) stakeholder meeting with Lake Association and municipal representatives
2. Consultations with Waldoboro and Nobleboro residents.
3. Draft reports were given to town officials in Waldoboro and Nobleboro
4. Duckpuddle Pond watershed stakeholder meeting (July 11, 2005) to review document
5. Extensive Duckpuddle Pond water quality monitoring with volunteers
6. Maine DEP, MACD and local stakeholder Duckpuddle Pond watershed and shoreline survey
7. Arial photo interpretation with Duckpuddle Pond watershed stakeholders

DUCKPUDDLE POND STAKEHOLDER REVIEW

A stakeholder review document was distributed to a list of fourteen stakeholders on Wednesday June 8, 2005. These stakeholders included the Knox Lincoln SWCD and NRCS, Pemaquid Watershed Association, Maine DEP, Maine Forest Service, Maine Department of Agriculture, Maine Department of Inland Fisheries and Wildlife, VLMP, local landowners, and municipal officials and staff. Three sets of brief comments were received (Bill Woodward, Maine DIFW; Chris Martin, Maine Forest Service; Christy Monroe, Knox Lincoln Soil and Water Conservation District). All of the suggested edits were minor and were incorporated into the public review document.

PUBLIC REVIEW PROCESS AND COMMENTS

PUBLIC REVIEW PROCESS: The public review process began on July 1, 2005 and ran for 1-month (4-weeks) through July 29, 2005. All stakeholder review participants were provided electronic versions of the public review document. A meeting was held on July 11th, 2005 at the Knox-Lincoln Soil and Water Conservation District to discuss and answer questions about the document. There were no formal questions posed as a result of this meeting. In addition, the following 'legal' advertisement was placed in the Kennebec Journal on the weekends of July 9/10 and July 23/24 of 2005:

DUCKPUDDLE POND (Knox and Lincoln Counties)

Watershed/Lake Nutrient Control/Management Report (PCAP-TMDL)

In accordance with Section 303(d) of the Clean Water Act, and implementation regulations in 40 CFR Part 130 - the Maine Department of Environmental Protection has prepared a combined **Phosphorus Control Action Plan (PCAP)** and **Total Maximum Daily Load (TMDL)** nutrient report for the **Duckpuddle Pond** (DEPLW 2005-0706) watershed, located within the towns of Waldoboro and Nobleboro. This **PCAP-TMDL** report identifies and provides best estimates of non-point source phosphorus loads for all representative land use classes in the **Duckpuddle Pond** watershed and the total phosphorus reductions required to restore and maintain acceptable water quality conditions. A Public Review draft of this report may be viewed at Maine DEP Central Offices in Augusta (Ray Building, Hospital Street - Route 9, Land & Water Bureau) or on-line: http://www.maine.gov/dep/blwq/comment.htm. Please send all comments, in writing - by July 29, 2005, to Dave Halliwell, Lakes TMDL Program Manager, Maine DEP, State House Station #17, Augusta, ME 04333. e-mail: david.halliwell@maine.gov.

PUBLIC REVIEW COMMENTS: Public review comments were submitted by David Rocque, Maine Department of Agriculture and Chris Martin, Maine Department of Conservation:

Hi Forrest: Just took a quick look at the TMDL for Duckpuddle Pond and had a question. I noticed that the land area for row crops/tillage/corn was 60.2 acres with 17.8% of the total phosphorous export. Public roads were 87 acres but only 16.6% of total P. Do you take into consideration that some crop land has a buffer and may be relatively flat (sheet flow and infiltration) whereas almost all roads have ditches which are concentrated flow direct conduits to the lake? I suspect you do and the numbers used are an average for average conditions. Could an adjustment be made upon ground truthing actual conditions? - Dave Rocque

Hi Dave: You ask a very good question. In our analysis of the Duckpuddle watershed, we do correct land use, adjust for soils, slope, and installed Best Management Practices utilizing our GIS-based mapping model. Therefore phosphorus export from a flat field may be adjusted downward, while a steep road would be adjusted upward. Even though we ground truth the watersheds that we work on, we are not able to dedicate the time necessary to make adjustments for which areas drain into buffers and which do not. We explored this a few years ago and determined that it would

take significant time and effort to properly adjust our model to account for all drainage patterns/buffers in a given watershed. Thank you for your inquiry, Forrest Bell, MACD Project Team

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David & Forest,

Thanks once again for opportunity to review and comment. The following are a few additional suggestions for clarification.

Page 12. Change "operated forested land to "actively managed forest land". Terminology parallels nicely when comparing passively managed verses actively managed land-use, similar to developed verse non-developed land.

Page 13, Table 1 - Same wording suggestions - "operated forested land to "actively managed forest land" under land-use class descriptions. Under "non-developed" category change undisturbed/ unmanaged forest to inactive/passively managed forests, provides consistency in wording for preceding definitions on page 12.

Page 20, Action Item # 4 – Suggested paragraph wording change from: Forestry: Municipal requirements for simplified pre-harvest plans, filter areas and proper erosion control as described in Best Management Practices for Forestry: Protecting Maine's Water Quality would minimize erosion and sedimentation during the harvesting period and help prevent negative impacts if the lot is developed in the future. Watershed municipalities should follow guidelines of LD 188 SWS (see below). to: Forestry "Existing, voluntary state guidelines for simplified pre-harvest plans, filter areas and proper erosion control as described in Best Management Practices for Forestry: Protecting Maine's Water Quality would minimize erosion and sedimentation during harvesting. Watershed municipalities should adopt new Statewide Standards for Timber Harvesting and Related Activities in Shoreland Areas (see below)." Direct references to LD 188 could be misleading - LD 188 deals only with implementation, the substance of the statewide standards lies within MFS Rule - Chapter 21. Statewide Standards for Timber Harvesting and relate activities in Shoreline Area.

Action Item 4, Page 20: Financial incentives are not listed. Maine Forest Service's WoodsWISE program cost-shares development of long-term forest management plans and water quality improvement projects, similar to NRCS EQUIP for landowners (see hyper link below). Suggested wording clarifications:

Action Item # 4: Promote sound forest management in shoreland areas

Activities:

1. Promote use of voluntary Best Management Practices for Forestry
2. Adopt Statewide Standards for Timber Harvesting and Related Activities in Shoreland Areas.
3. Encourage landowner participation in WoodsWISE, Maine Forest Service's financial assistance program for forest landowners: Be Woods Wise - The Maine Forest Service

Participants: Watershed municipalities, forest landowners, logging professionals, local land trusts, Maine Forest Service. Schedule & Cost: Beginning 2006 - Cost dependent on activities. Financial cost-share assistance available to develop long-term forest management plans and implement sustainable forestry projects including NPS corrective action.

Page 26, Table 3 – Same wording suggestions as page 13, Table 1
Page 27 – change "operated forest land" to "actively managed forest land"
Earlier suggested revision were duly noted….thanks for incorporating. Please do not hesitate to call or email with any questions on this latest round—Chris Martin.

Hi Chris - just a note to acknowledge receipt of your public review comments for the Duckpuddle Pond PCAP-TMDL draft report. We appreciate your considerable efforts and contributions in this timely process. We will incorporate your comments into the final document. - Dave

APPENDIX A - Steps in Creating the GIS Adjusted Total Phosphorus Export

To better quantify phosphorus export within the Duckpuddle Pond watershed, a GIS model was developed. The base for the model was a land use coverage created by Maine DEP using earlier land use coverage, high-resolution aerial photographs and field verification. Each individual land use was assigned a phosphorus export coefficient. The land use coverage was then "unioned" with slope, soil type and proximity coverage. The phosphorus export from the initial land use coverage was then modified by these additional coverage's. The result of the model was an estimation of the kilograms of phosphorus export for each land use incorporating the effects of slope, soil type and proximity. The steps for creating this model are outlined below.

1. An initial land use coverage was created (the coverage included roads and wetlands) for the watershed.
2. A soils coverage was unioned into the land use coverage.
3. A slope coverage was unioned into the land use and soil coverage. Before unioning the slope coverage, all slope classes were categorized. Slopes less than 8% were a slope class 1, slopes between 8 and 30% were a slope class 2 and slopes greater than 30% were a slope class 3.
4. A proximity coverage was created that extended 250 feet from Duckpuddle Pond . This coverage was then unioned into the land use/soils/slope coverage. All developmental land uses that were within close proximity to these lake were reclassified as "shoreline" land uses. For example, "medium density residential" development within 250 feet of Duckpuddle Pond was now classified as "shoreline medium density residential". As a result of these unions, each original land use polygon was broken down into smaller polygons that reflected a change in soil type, slope and proximity to the lake.
5. The land use/soil/slope/proximity coverage was then joined with a phosphorus export coefficient table. This table matched each land use with its estimated corresponding phosphorus export coefficient.
6. An additional field was added to the land use/soil/slope/proximity coverage called "Soils Adjust". This field assigned the following modifying coefficients for each soil type:

   A = 0.7
   B = 0.9
   C = 1.1
   C/D = 1.2
   D = 1.3
   Unknown or Blank = 1

7. An additional field was added to the land use/soil/slope/proximity coverage called "Slope Adjusted". This field assigned the following modifying coefficients for each of the 3 slope classes:

   Class 1 = 1.0
   Class 2 = 1.1
   Class 3 = 1.3
   Unknown or Blank = 1

8. A field was added called "Phosphorus Export Rate" to the land use/soils/slope/proximity coverage. This field takes the original land use coefficient and multiplies it by the "slope adjust" and "soil adjust" factors. (The proximity coverage is already factored in based on "shoreline" code in the land use classes.)
9. The final step was adding a field called "Phosphorus Export" to the coverage. This field multiplies the hectares of each unique polygon by the corresponding Phosphorus Export Rate. This column displays the kilograms of phosphorus exported from a specific soil type, for a particular slope range on a designated land use.

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