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Lovers Lake and Stillwater Pond Eutrophication Mitigation Plan

presented by David Mitchell, PhD

ENSR Corporation

February 15, 2007

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Presentation Overview

- Introduction to ENSR and Project Team
- Project Tasks and Schedule
- Defining the Problem
  - Available Data and Information
  - Defining Management Objectives
- Potential Pond Management Options
  - Dredging
  - Circulation/Aeration
  - Nutrient Inactivation
- Next steps

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ENSR Corporation – Lake Management

- Working in New England lakes and ponds for 20+ years
  - Conducted 250+ Diagnostic/Feasibility (D/F) Studies
  - Four Certified Lake Managers (CLM) on Staff
  - Published and presented extensively
- Have worked with MA agencies on Lake Management Issues
  - EOEA "*Final Generic Environmental Impact Report on Eutrophication and Aquatic Plant Management in MA*"
  - MA DEP guidance for rapid response for aquatic invasive species
- Familiar with Cape Cod lakes and ponds:
  - Long Pond (Harwich), Ashumet Pond (Mashee/Falmouth), Hamblin Pond (Barnstable), Great Pond, Herring Pond (Eastham)
  - Many other waterbodies as well

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Lovers Lake/Stillwater Pond Project Team

- David F. Mitchell, PhD, CLM – Project Manager
- Ken Wagner, PhD, CLM – Senior Technical Reviewer
- Wendy Gendron, CLM – Limnology Field Support
- Matt Kennedy, PE – Project Engineer
- Teresa McGovern PE – Engineering Support

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Chatham Ponds Project Tasks – Phase 1

- Evaluate available water quality data, reports and other relevant information to assess nutrient stations
  - identify critical data gaps
  - coordinate any needed sampling.
- Develop hydrologic (water) budget for two Ponds
- Develop nutrient budget for two Ponds
  - investigate internal nutrient recycling
  - compare with other potential watershed sources
- Characterize biota of Ponds
  - macrophyte community
  - fish (herring)

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Chatham Ponds Project Tasks – Phase 2

- Evaluate potential lake management options
  - dredging
  - circulation
  - aeration
  - nutrient inactivation (alum treatment).
- Select management options to alleviate eutrophication, considering:
  - technical feasibility
  - expected water quality or recreational improvements
  - longevity
  - cost-effectiveness
  - permitting issues
- For recommended option, develop specifications, permits and detailed cost estimates
- Identify funding sources for implementation

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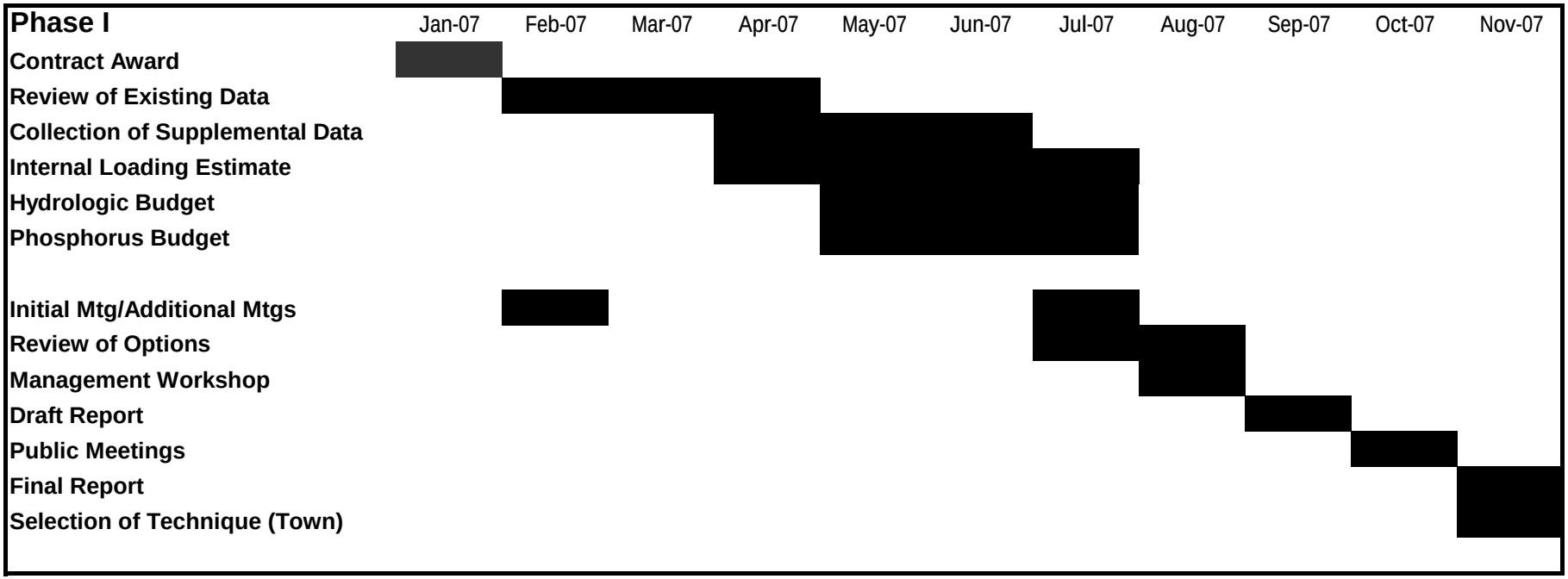
PROJECT SCHEDULE – PHASE 1 TASKS



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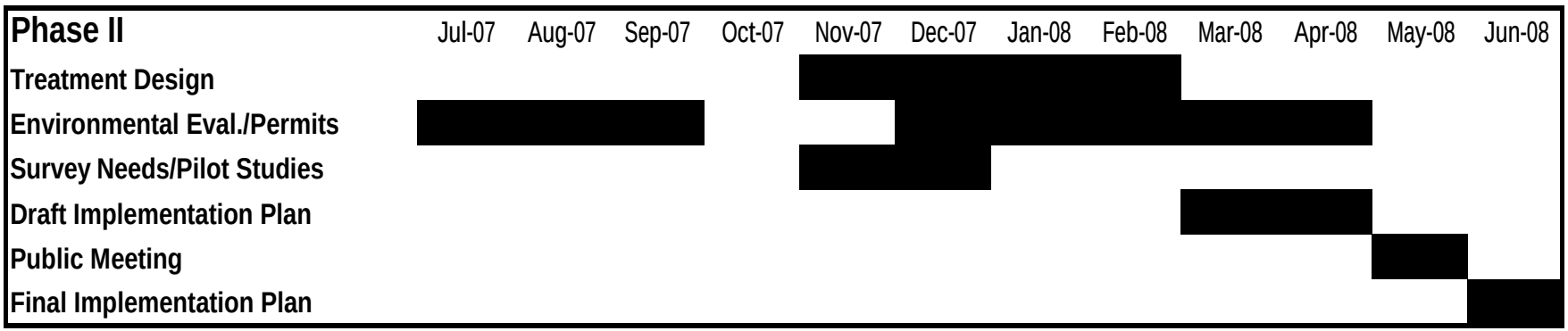
PROJECT SCHEDULE – PHASE 2 TASKS



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Data Evaluation for Lovers Lake & Stillwater Pond

- Describe physical attributes of the two ponds
  - Basin shape and bathymetry
  - Watershed size and land use
  - Flow characteristics
- Characterize current water quality
  - recent water chemistry results
  - secchi disk observations
  - observations of temperature and dissolved oxygen (DO) profiles
- Characterize biota
  - plankton (algae and zooplankton)
  - macrophyte and shoreline vegetation
  - wildlife (fish and waterfowl)

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Data Sources for Lovers Lake and Stillwater Pond

- Pond and Lake Stewards (PALS) volunteer monitoring data. 2000-06.
- Horsley and Witten, Inc. 2003. *A Qualitative Survey of Pond Shoreline Vegetation and Anthropogenic Threats at Eleven Freshwater Ponds in the Pleasant Bay Area of Critical Environmental Concern*. February 2003
- Cape Cod Commission. 2003. *Cape Cod Pond and Lake Atlas* - section on Chatham ponds. May 2003
- Ecologic, LLC. 2003. *Action Plan for Town of Chatham Ponds*. November 2003.
- Massachusetts Estuaries Project (MEP) *Linked Watershed-Embayment Model to Determine Critical Nitrogen Thresholds for Pleasant Bay System*. May 2006.
- Massachusetts Natural Heritage Endangered Species/Habitat maps
- Additional Town files and data from watershed groups

File name

Lover’s Lake and Stillwater Pond Watersheds

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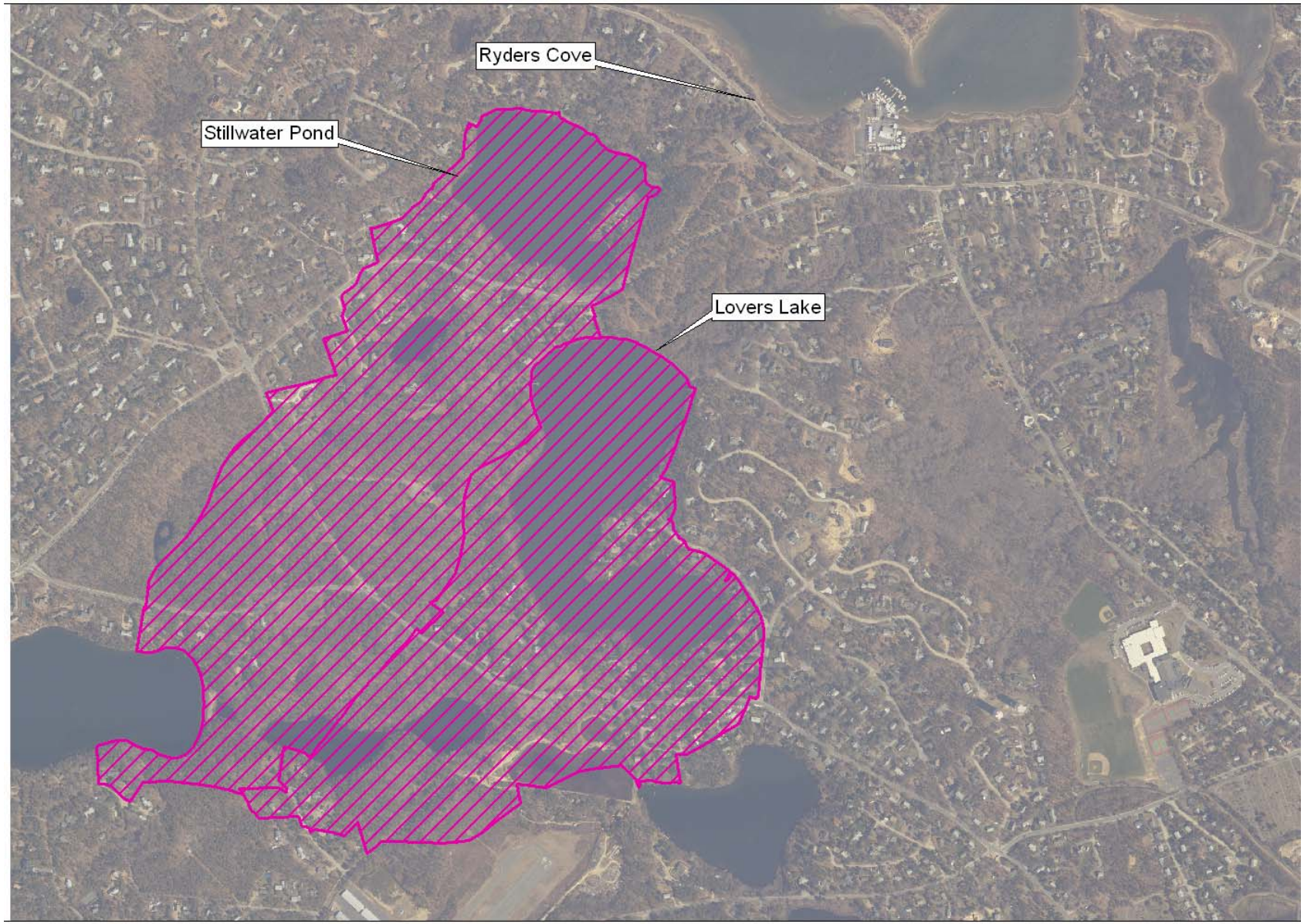

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General characteristics of Lovers Lake and Stillwater Pond

LOVERS LAKE

- Kettlehole Pond; MA-designated Great Pond
- Size is 37.7 acres
- Maximum depth about 32 feet
- Connected to Stillwater Pond and Frost Fish Creek
- No public access to pond
- Recreational uses
  - swimming, boating, fishing
  - passive recreational
- Herring run present

STILLWATER POND

- Kettlehole Pond; MA-designated Great Pond
- Size 18.7 acres
- Maximum depth about 46 feet
- Connected to Lovers Lake and Ryders Cove
- Unimproved boat launch
- Recreational uses
  - swimming, boating, fishing
  - passive recreational
- Herring run present

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What is the significance of being a kettlehole pond ?

- Formed by retreat of glacial ice sheet and remnant block of ice in sandy basin
- Deep central basin, often subject to thermal stratification
- Restricted number of tributaries and often only seasonal outflow
- Groundwater is most important portion of hydrologic budget
- Flushing rate is slow, nutrients are retained and promote growth
- Typically have diverse biotic communities

Lovers Lake Basin Bathymetry

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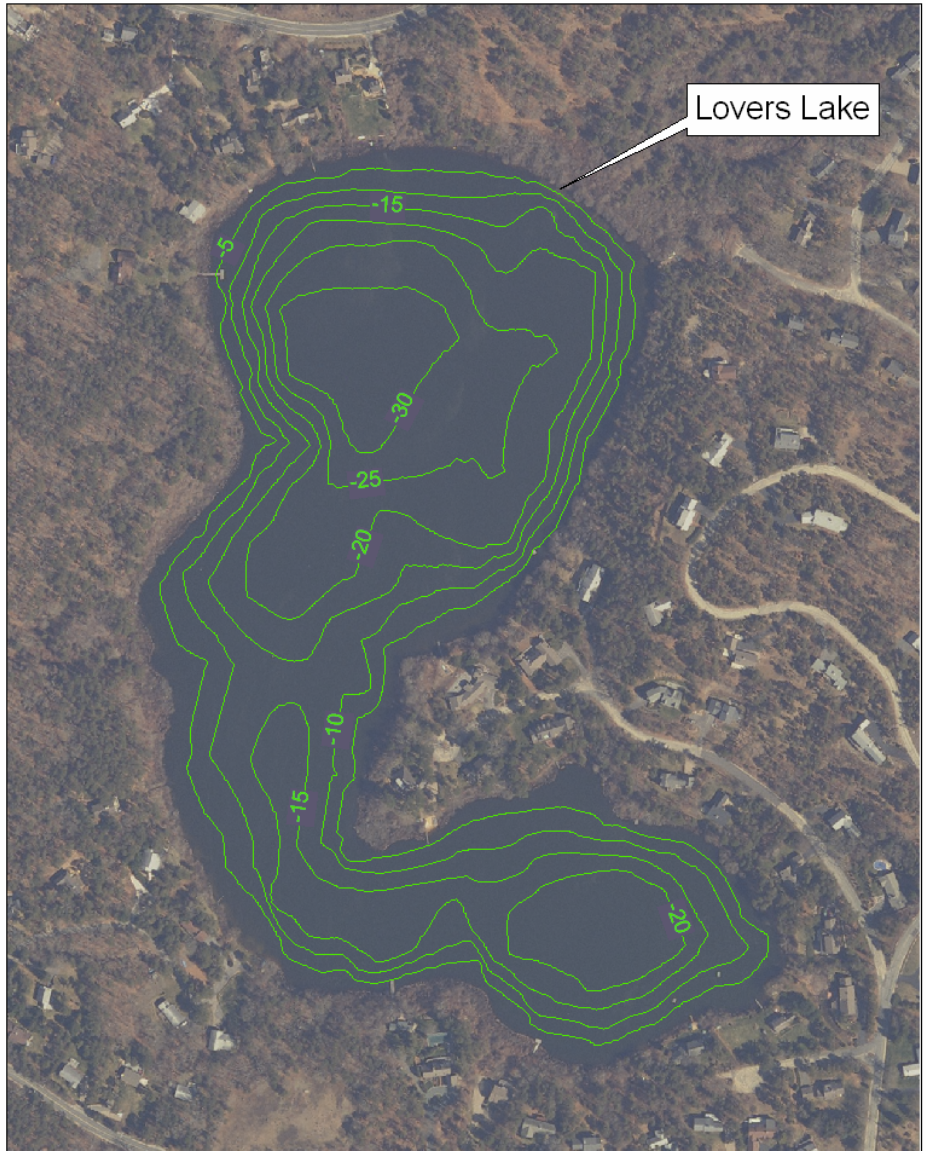

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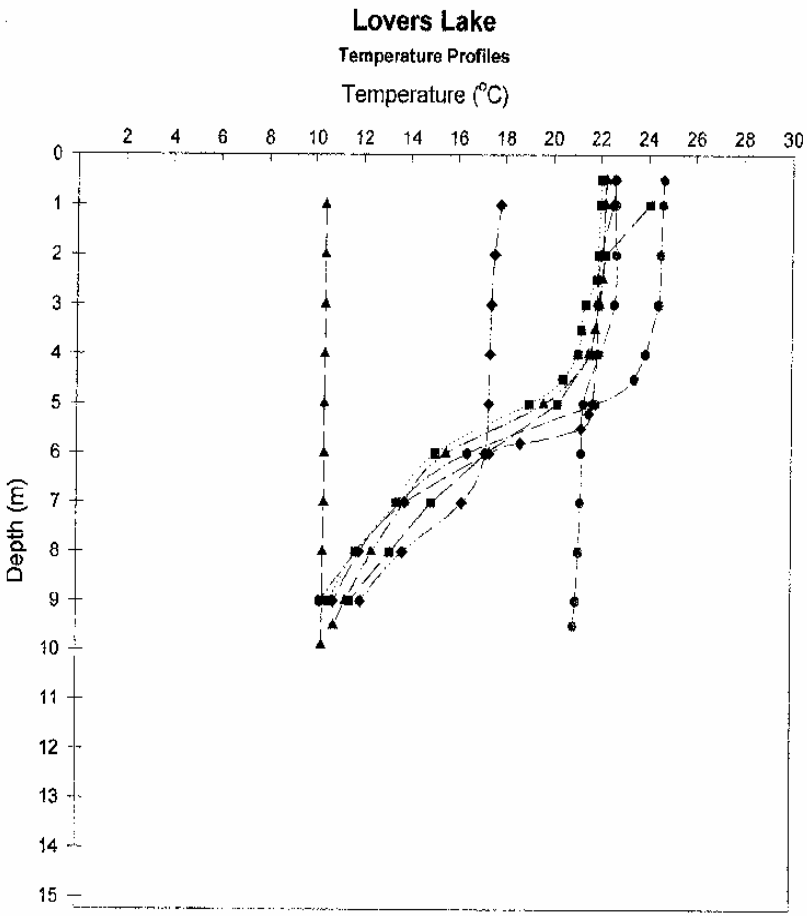
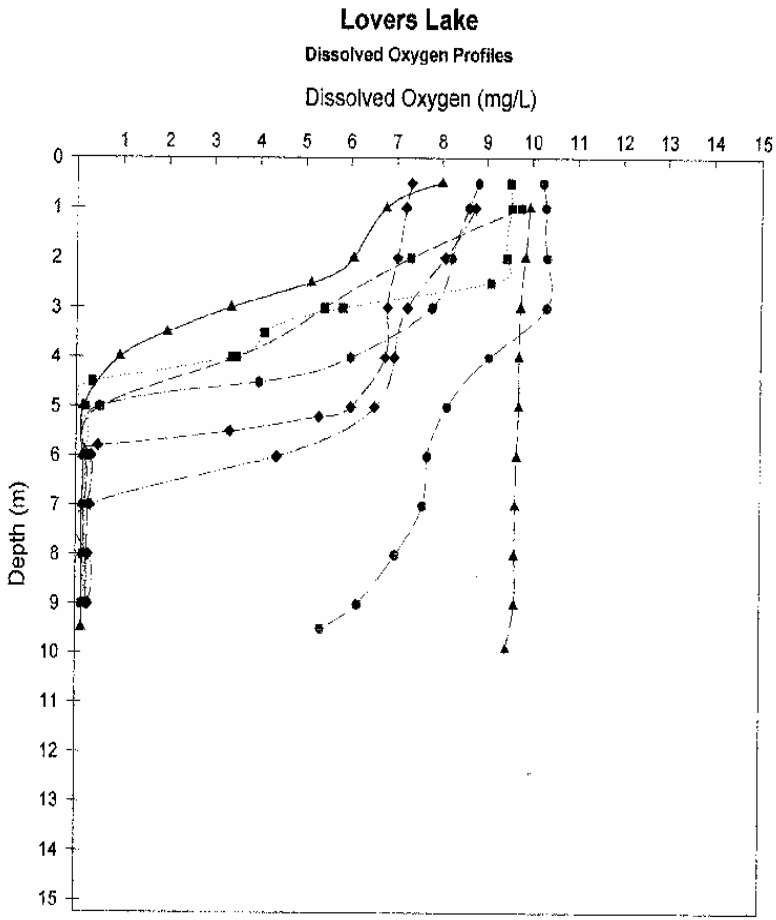
Lovers Lake Temperature and DO Profiles





Stillwater Pond Basin Bathymetry

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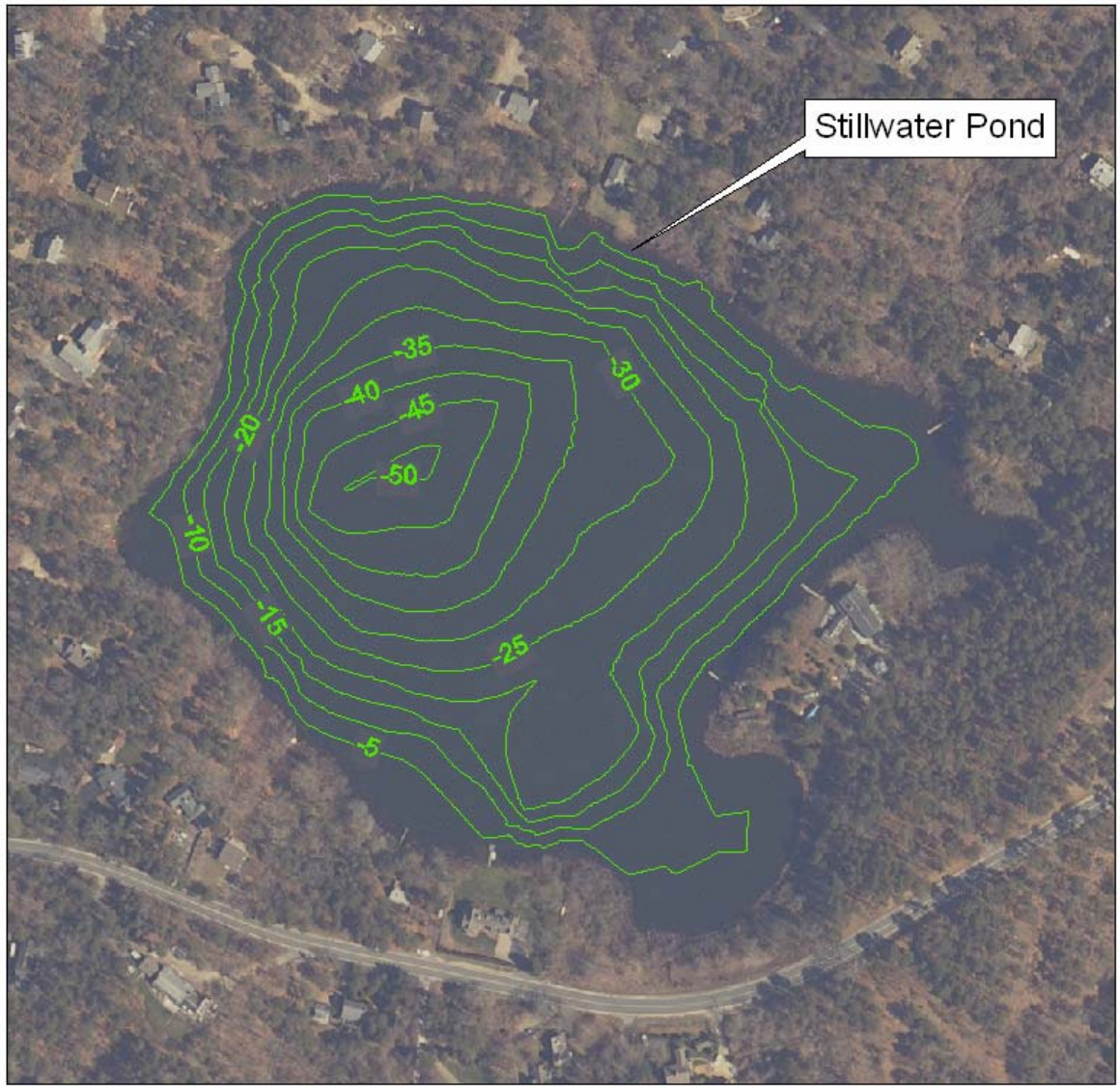

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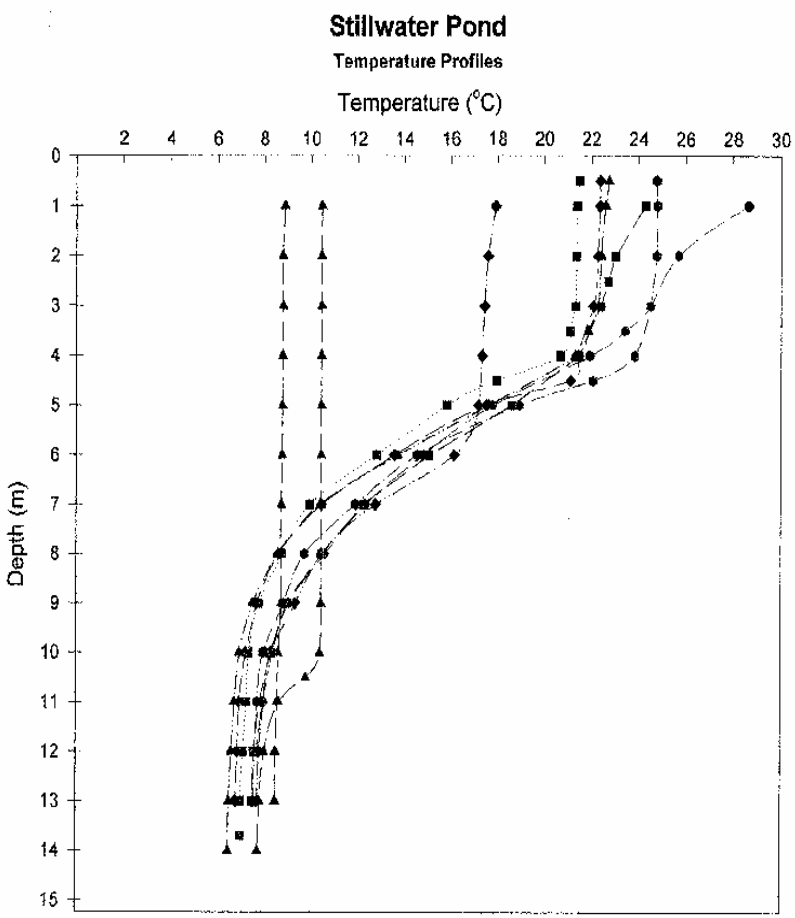
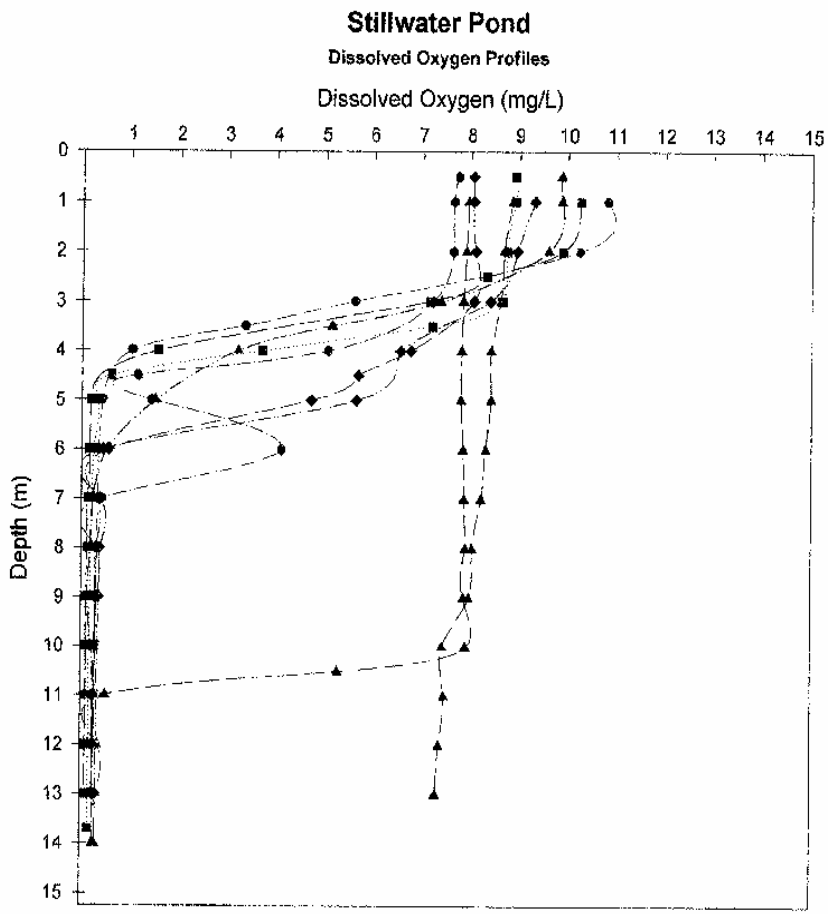
Stillwater Pond Temperature and DO Profiles





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What is Eutrophication and why do we want to mitigate it?

- Eutrophication is caused by an overabundance of nutrients
  - High levels of organic production – phytoplankton and macrophytes
  - Low water transparency
  - Large variation in DO over day and from top to bottom
  - Undesirable appearance, tastes, and odors
- Results of Eutrophication
  - Impaired water quality
  - Shift in biotic community
    - Loss of sensitive species
    - Potential fishkills
  - Impacted recreational uses
  - Unaesthetic conditions

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Current water quality in Lovers Lake and Stillwater Pond

LOVERS LAKE

- Surface total phosphorus (TP) levels about 38.9 ug/L; bottom TP is approximately 125 ug/L
- Secchi disk transparency (SDT) depth ranges from 1.5 to 5.6 ft
- Summer chlorophyll a ranges from 5.4 to 73.3 ug/L with average of 32,2 ug/L
- Anoxic conditions below 12-15 ft in late summer
- Water quality conditions are consistent with eutrophic classification

STILLWATER POND

- Surface total phosphorus (TP) levels about 25 ug/L; bottom TP is approximately 312 ug/L
- Secchi disk transparency (SDT) depth ranges from 2.2 to 10 ft
- Summer chlorophyll a ranges from 4.3 to 56.1 ug/L with average of 21.6 ug/L
- Anoxic conditions below 15-18 ft in late summer
- Water quality conditions are consistent with eutrophic classification

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Evidence of Internal Phosphorus Recycling

- Strongly anoxic hypolimnion, lack of oxygen in bottom releases phosphorus from iron-complex into overlying water
- Observations of elevated amounts of TP in bottom water - difference most profound in late season observations
- Lack of significant surface tributaries or obvious overland routes
- Persistent phosphorus levels despite watershed management BMPs
- Nutrient control is the key to long-term control of algae problems; watershed management has top priority, but in-lake controls may be expedient and/or necessary.

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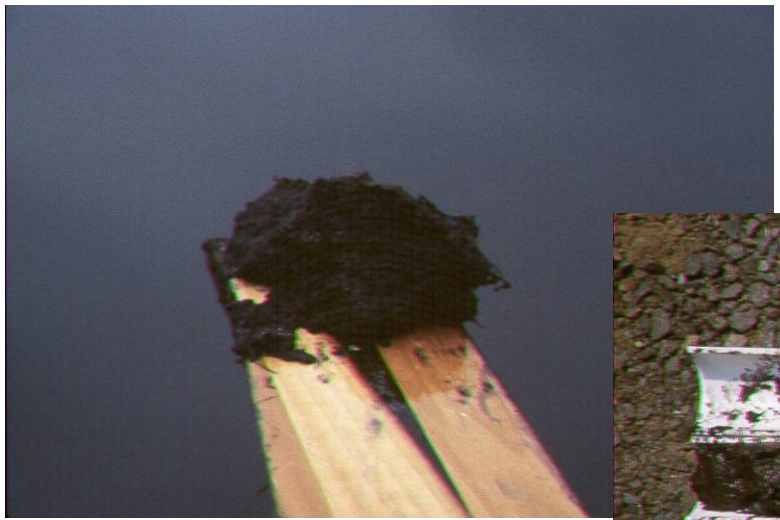
Internal Phosphorus Recycling

Phosphorus from past loadings can pass through the lake or become part of the sediment base; whether the P accumulating as sediment is bound as organic matter or complexes of iron, calcium or aluminum is important to recycling potential



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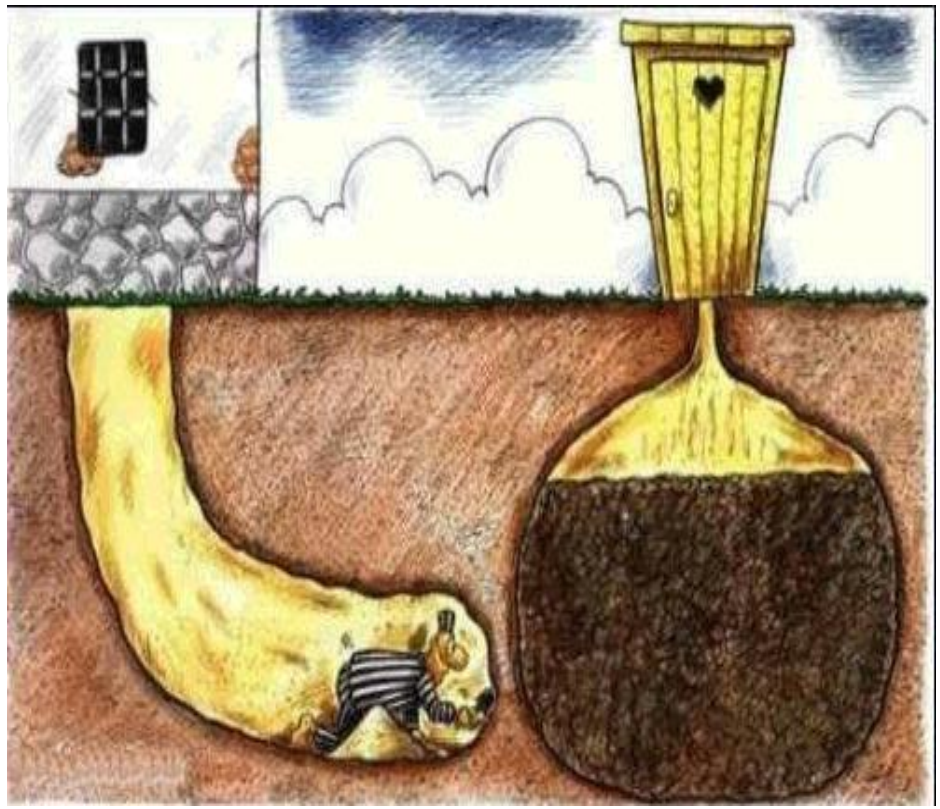
Internal Phosphorus Recycling

It is critical to know where you are going to avoid unpleasant surprises:

- **How much of total P load is internally generated?**
- **Does available P reach the photic zone during summer?**
- **Which P binder is dominant?**
- **How and where are algae utilizing available P?**



Internal Phosphorus Recycling

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Evaluating internal loading via sediment sampling/analysis :

- Measure P near the bottom and top, and preferably in between, to look for gradients
- Measure P over time to detect accumulation in bottom or surface waters
- Measure forms of P in the sediments; evaluate potential releases

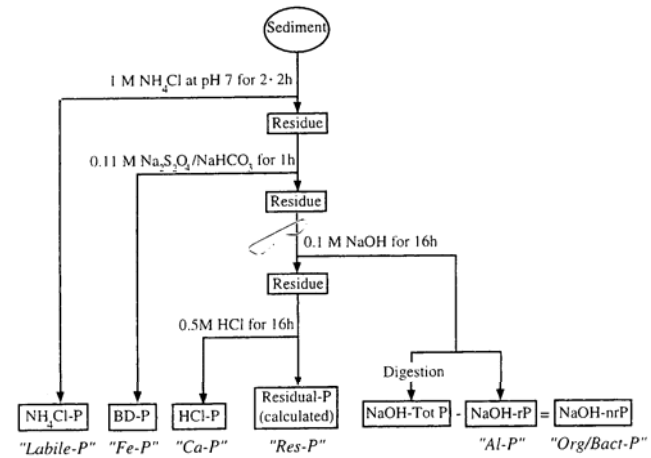
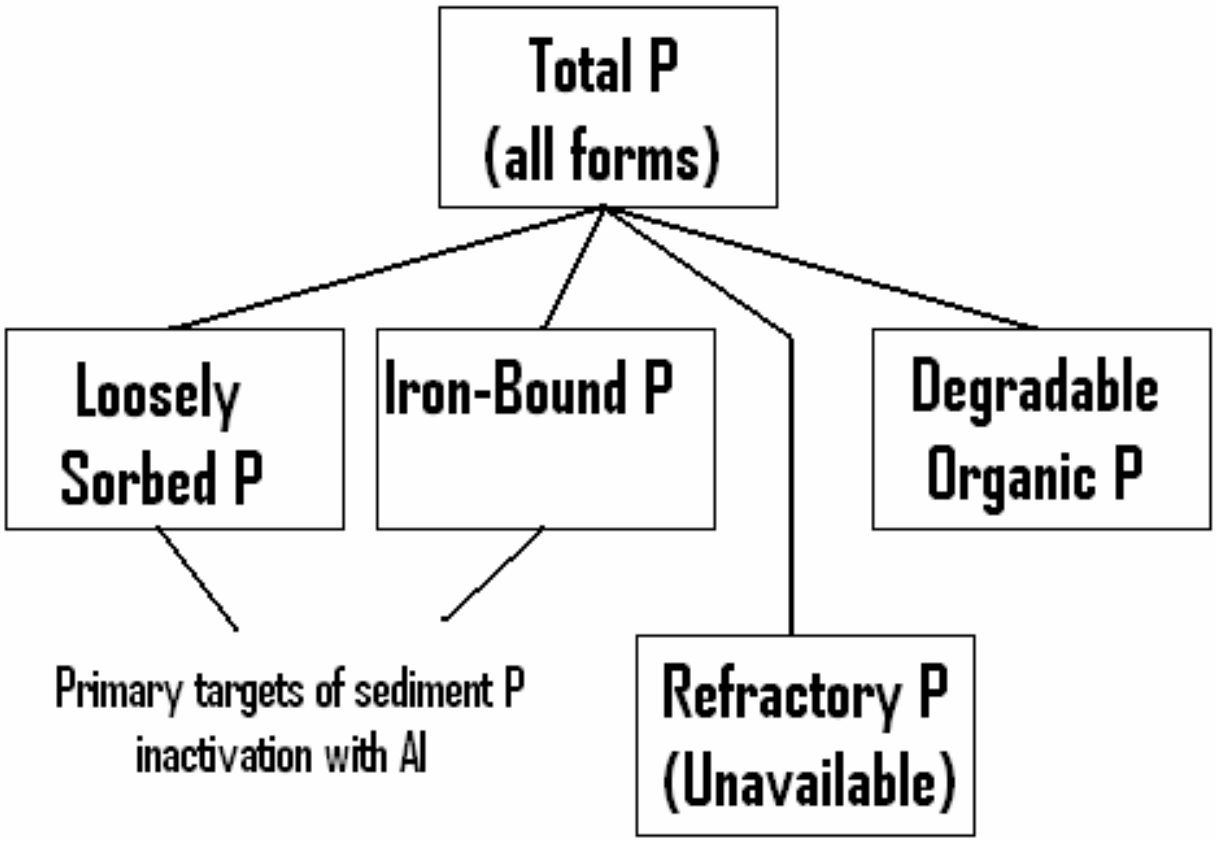


Fig. 2. The modified Hieltjes and Lijklema (1980) scheme used for phosphorus fractionation, including a dithionite/bicarbonate step to separate BD-P and also including a digestion step to distinguish reactive P (rP) from non-reactive P (nrP) in the NaOH extracted P.

Available Sediment P Determination:



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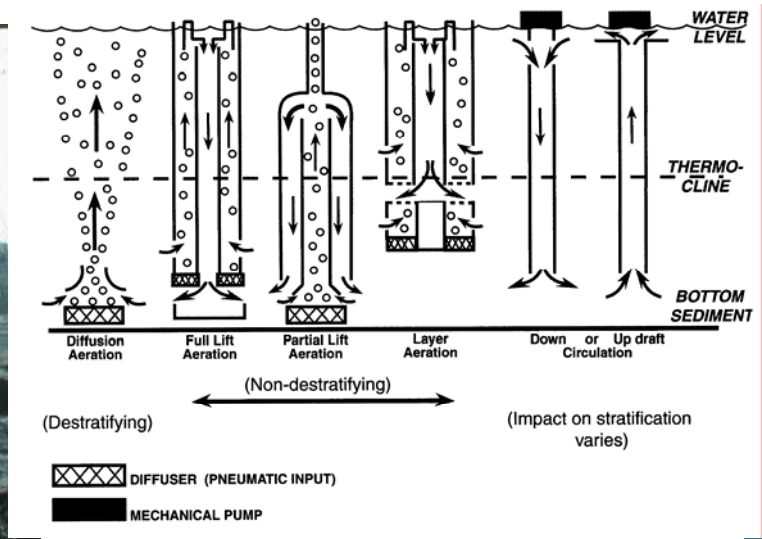
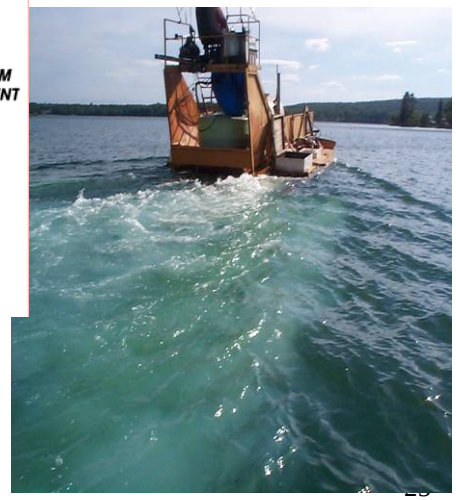
Internal P Recycling – Potential Restoration Approaches

Different methods to reduce internal loading:

- Dredging removes nutrient reserves
- Aluminum treatments bind P most permanently; iron or calcium may be appropriate in some cases
- Aeration will limit release by iron; mixing (circulation) may help too





Internal Phosphorus Recycling - Dredging

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Dredging:

- Dry (conventional)
- Wet (bucket/dragline)
- Hydraulic (piped)

- Removes nutrient reserves
- Removes “seed” bank
- Potential mat control

Internal Phosphorus Recycling - Dredging

Dredging:

- **Essential to remove all nutrient-rich sediment for maximum effect**

Information Needs in Planning to Dredge:

- Sediment quality – controls disposal
- Sediment quantity – affects cost and method
- Flow control – affects method
- Disposal site features – affects method and rate
- Affected resources – controls mitigation needs
- Equipment access – affects method
- Relation to lake uses – affects timing and interference

Internal Phosphorus Recycling – Aeration/Mixing

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Aeration/mixing can work by:

- Adding oxygen and facilitating P binding while minimizing release from sediments
- Physical mixing that disrupts growth cycles of some algae
- Alteration of pH and related water chemistry that favors less obnoxious algal forms
- Turbulence that neutralizes advantages conveyed by buoyancy mechanisms
- Creation of suitable zooplankton refuges and enhancement of grazing potential

Internal Phosphorus Recycling – Aeration/Mixing

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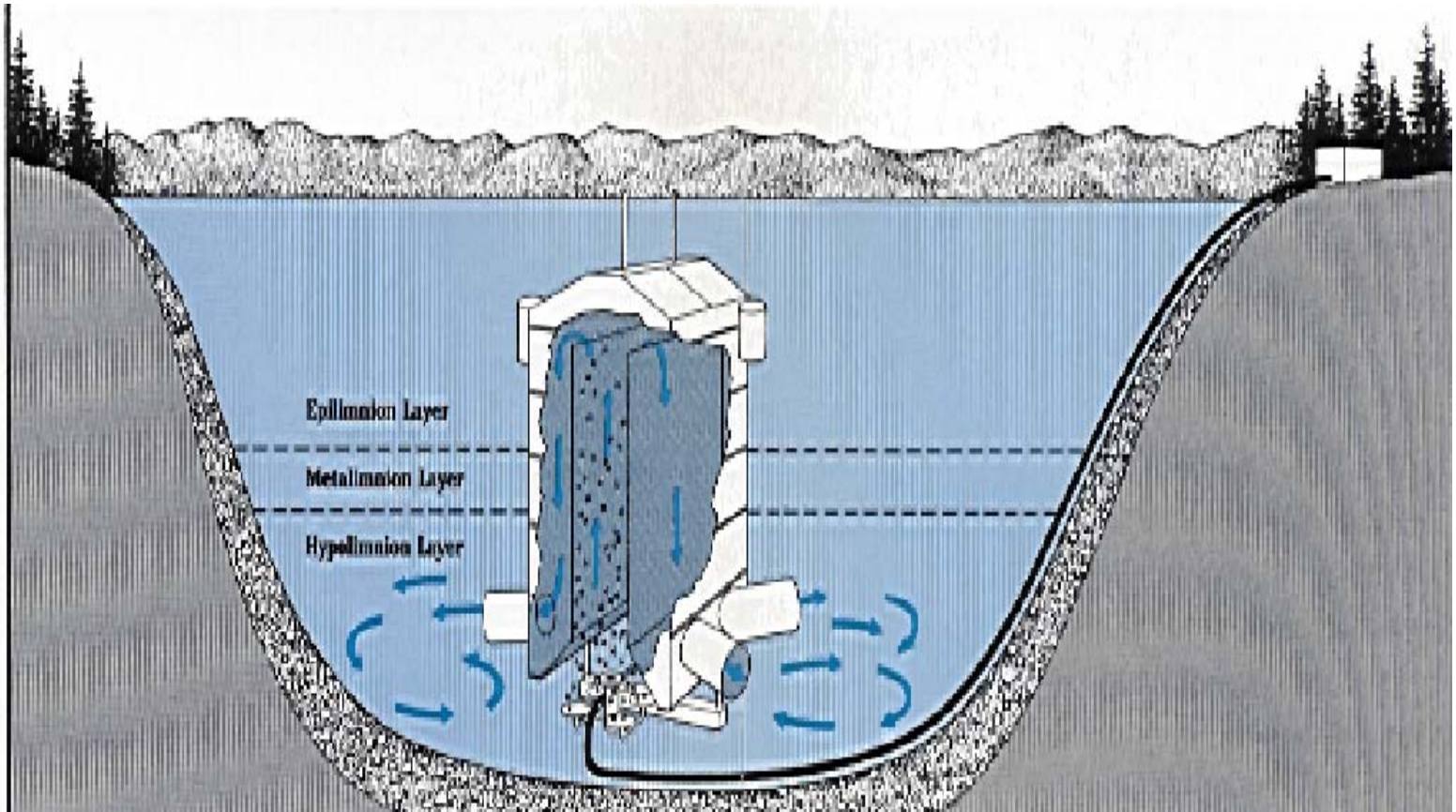
Non-destratifying aeration:

Bottom layer is aerated, but top layer is unaffected; oxygen input via bubbles (can be air or oxygen)



Internal Phosphorus Recycling – Aeration/Mixing

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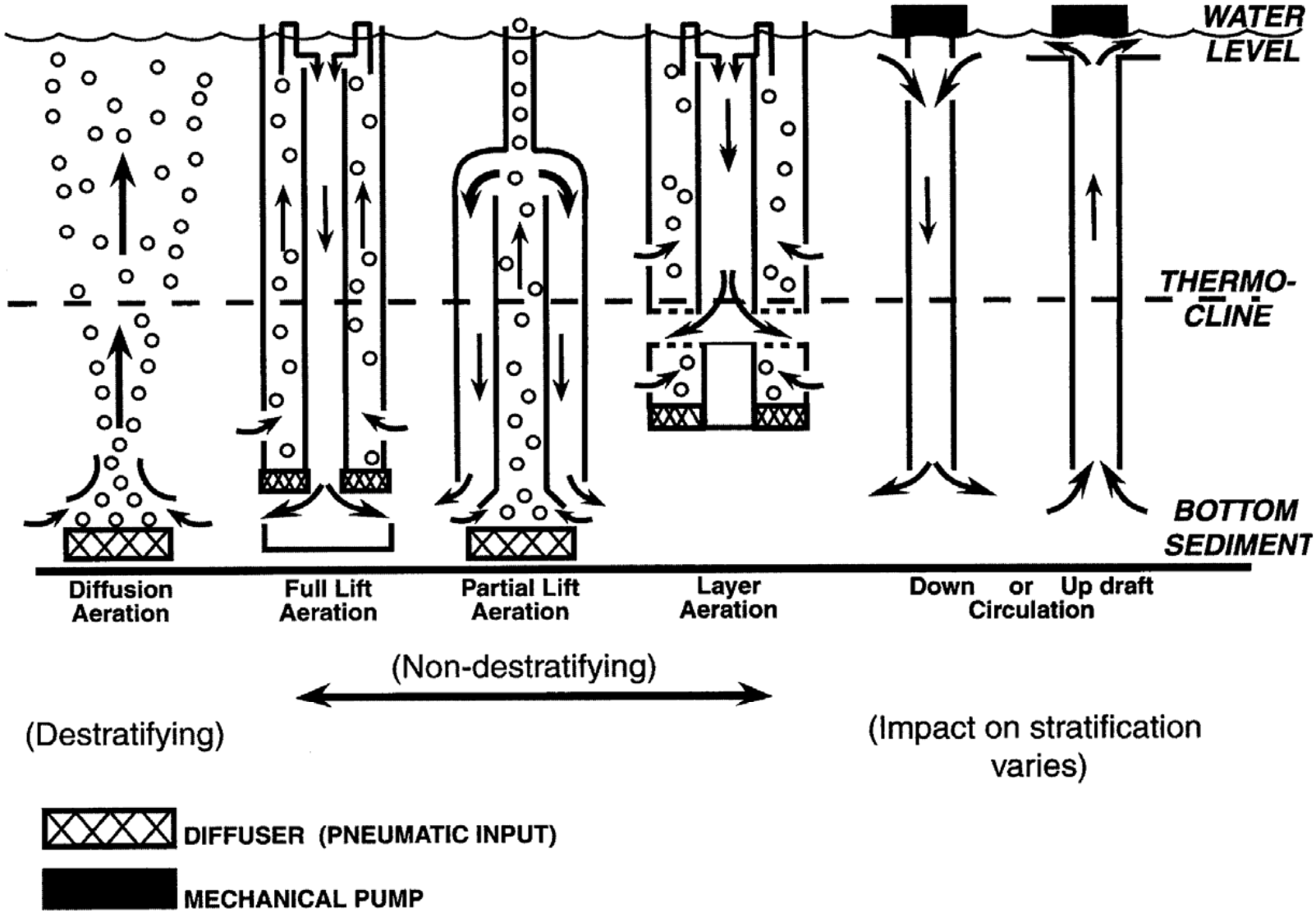
Aeration systems:



Key factors in aeration:

- Adding enough oxygen to counter the demand in the lake (usually about 75% from sediment) and distributing it where needed in the lake
- Maintaining oxygen levels suitable for target aquatic fauna (fish and invertebrates)
- Having enough of a P binder present to inactivate P in presence of oxygen
- Not breaking stratification if part of goal is to maintain natural summer layering of the lake

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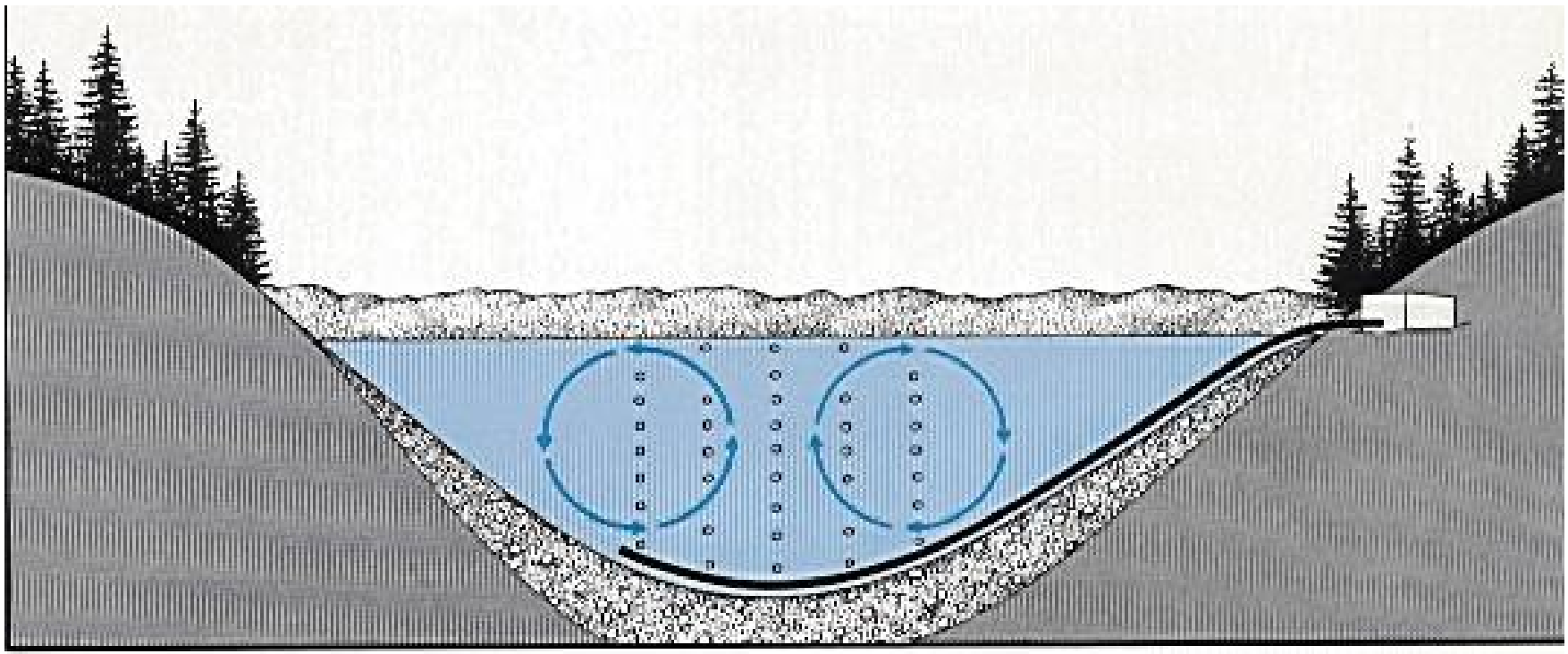
Destratifying aeration/mixing:

Lake is mixed, top to bottom, input of oxygen comes from bubbles and interaction with lake surface



Internal Phosphorus Recycling – Aeration/Mixing

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Mixing systems:

Key factors in mixing:

- Moving enough water to prevent stagnation; may mix whole lake or just the top layer (if any)
- Fostering greater homogeneity in mixed zone and greater interaction with the atmosphere (oxygen and pH effects may be large)
- Getting enough motion or change in water quality to disrupt target algal species; moving algae to dark zone helps, but may be possible to disrupt with only surface layer mixing

Internal Phosphorus Recycling – Aeration/Mixing

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Info needs for aeration/mixing:

- Oxygen demand and its component parts (sources)
- Bathymetry and light penetration
- P binder forms and abundance
- Energy necessary to destratify
- Forms of algae and zooplankton
- Potentially sensitive biological receptors
- Power availability
- Nearby land availability

Internal P. Recycling – Nutrient Inactivation

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Lake Sediment Treatment:

Reduce P release from sediment; can control P in lake if sediment is the major source

Normally planned to react with upper 2-4 inches of sediment, more if very loose

Dose usually 25-100 g/m^2 – based on amount and form in which P is bound in sediment

Phosphorus Inactivators:

Aluminum - Most permanent binder, works well at all DO levels and best at an initial pH range of 6.0-8.0

Iron - Most common natural binder, works well at high DO and moderate to high pH (>6.0)

Calcium - Precipitates at elevated concentrations at high pH (>8.0), not greatly affected by DO

Organic complexes - Most common at low pH (<6.0), may inactivate or chelate P

Synthetic polymers - May capture and inactivate P as part of flocculation process

Internal P. Recycling – Nutrient Inactivation

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When to Use Aluminum:

- Internal P load is high relative to external load, or external load is pulsed such that one treatment covers much of the annual load
- Detention time is high
- pH is 6-8 and alkalinity (buffer capacity) is high (>20 ppm, preferably >40ppm)
- Potentially sensitive receptors are few, or avoidable, or impacts are acceptable
- Rooted plant density in the targeted area at the time of treatment is low

Conclusions for Lake Sediment Treatments:

Effective inactivation of sediment P achievable with Al

Necessary dose should be determined from the mobile sediment P fraction (loosely sorbed and Fe-P) and expected stoichiometry of Al-P binding (10-100:1) or measured dose response curve; buffer treatment as necessary

Short-lived benefits are usually a function of continued large external P load or insufficient Al addition

Where sediment P is inactivated, internal P loading has declined by 50-90% and chl has declined proportionally

Benefits of proper treatment tend to last about 10 years in shallow lakes and 15-20 years in deep lakes

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Extra data may be needed to evaluate choices

- Lake volume and flushing rate estimates
- Water quality over season – spring TP concentrations
- DO concentrations in hypolimnion from spring turnover until mid-stratified period to document DO loss rate for estimate of aeration
- Sediment quality – to evaluate amount of desorbable phosphorus and calculate amount of alum inactivation
- Sediment characteristics to evaluate volume, handling, and disposal options for dredging
- Information on herring fishery, T/E species, any other special considerations

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Selection of the appropriate pond restoration method requires clearly-defined objectives

- What are current uses of pond and the desired endpoints.
  - Boating, swimming, fishing
  - Other types of uses ?
- What level of water quality improvement is needed to:
  - improve aesthetic appearance ?
  - meet all water quality standards
  - promote ecological health or biological diversity ?
  - enhance recreation ?
- How we will measure success ?
  - Increase SDT to allow swimming all summer ?
  - Decrease number and frequency of algal blooms ?
  - Property values increase ?

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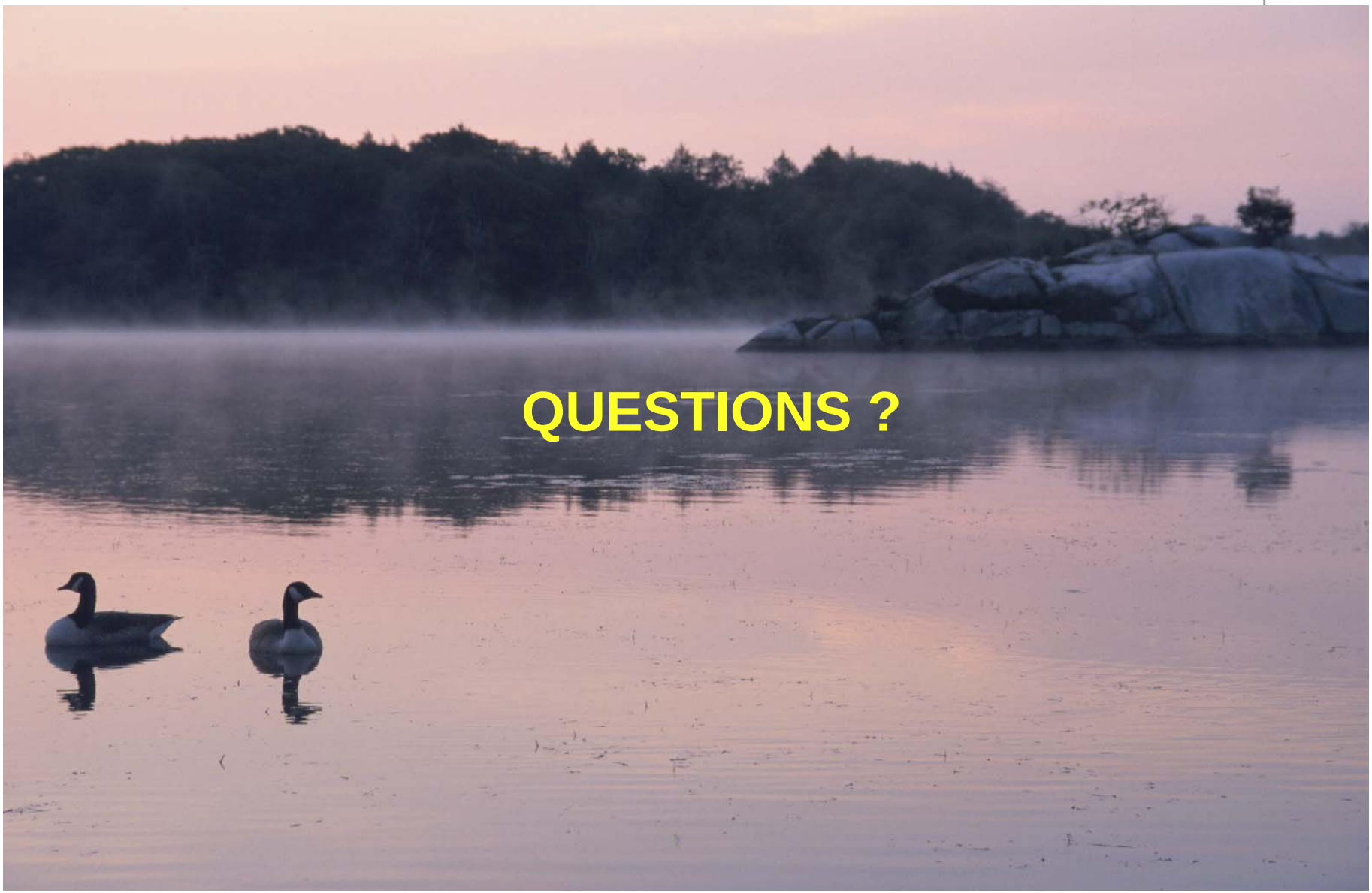
Next Steps Forward

- Review available pond and watershed data
- Conduct sediment sampling (late April) and coordinate with Town regarding additional pond observations of T°/DO
- Finalize diagnostic data and develop evaluation of various pond management options. Report back to Town with recommendations
- Public meeting to discuss recommended management option developed by ENSR and the technical review group
- Conduct Phase II design and permitting tasks

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