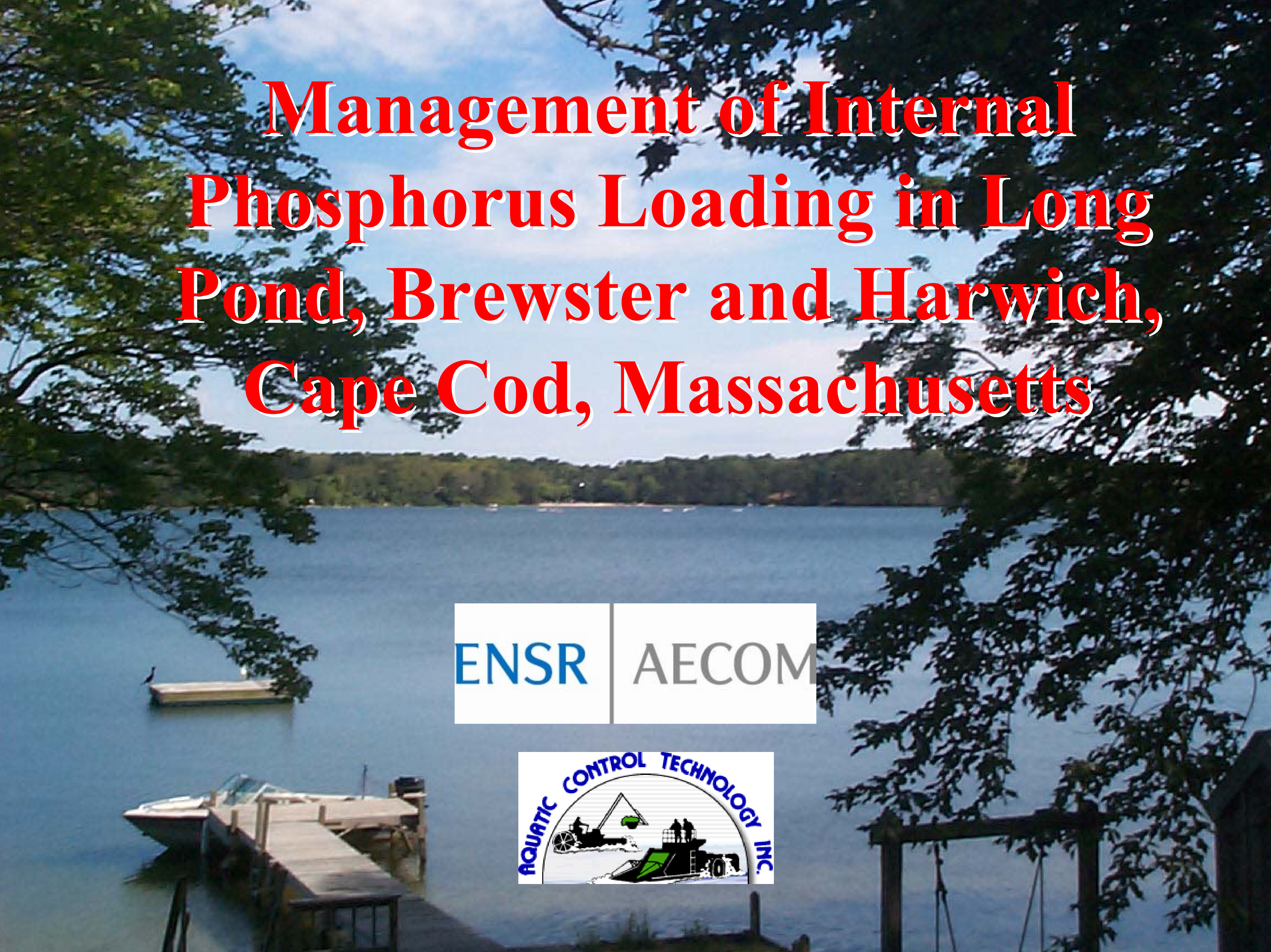
Management of Internal Phosphorus Loading in Long Pond, Brewster and Harwich, Cape Cod, Massachusetts



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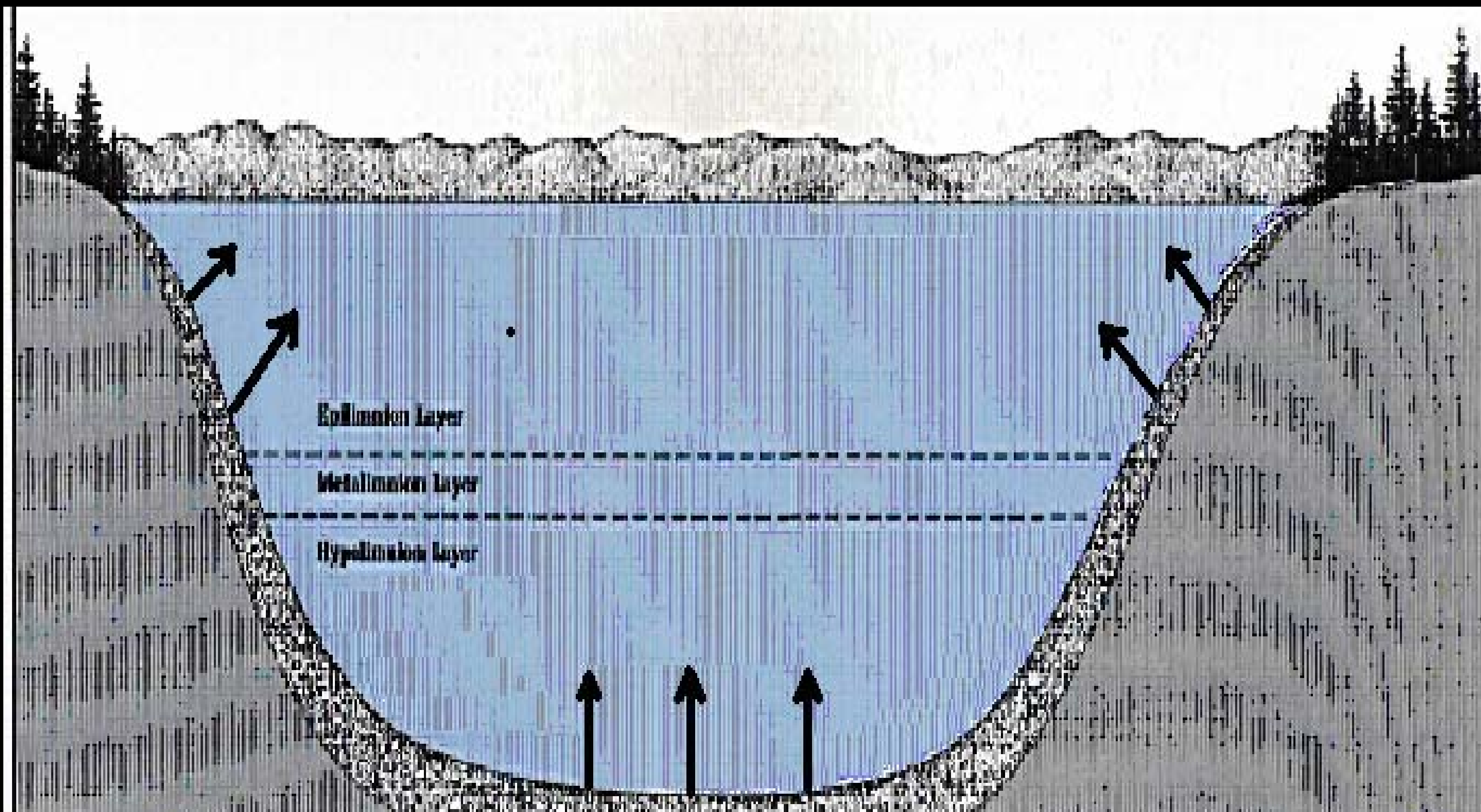
Water and P budgets for Long Pond

Desirable P load target = <461 kg/yr

Input Source	Water (Million m^3/yr)	% of Total water	P (kg/yr)	% of Total P (Average)
Precipitation	3.6	51	50	8.0
Runoff	0.32	5	86-131	17.3
Inseepage	3.1	44	59	9.4
Discharge	0	0	0	0
Waterfowl	0	0	6	0.9
Regeneration	0	0	405	64.4
Total	7.0	100	606-651	100
Output Source				
Evaporation	2.0	29	0	0
Outflow	5.0	71	93	15
Outseepage	0	0	0	0
Withdrawal	0	0	0	0
Sedimentation	0	0	558-513	85
Total	7.0	100	606-651	100

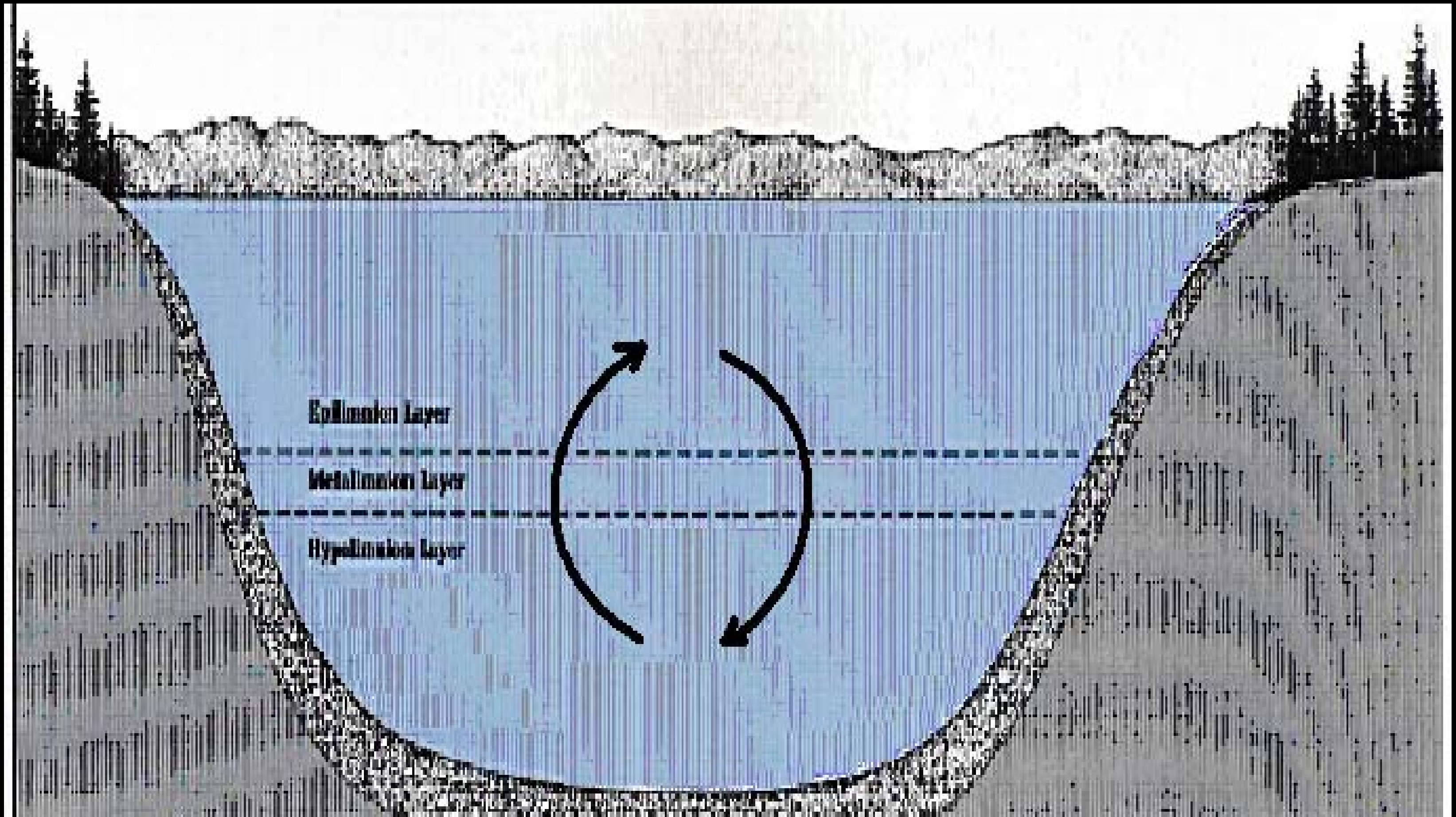
Internal P Loading

- Sources of internal loading



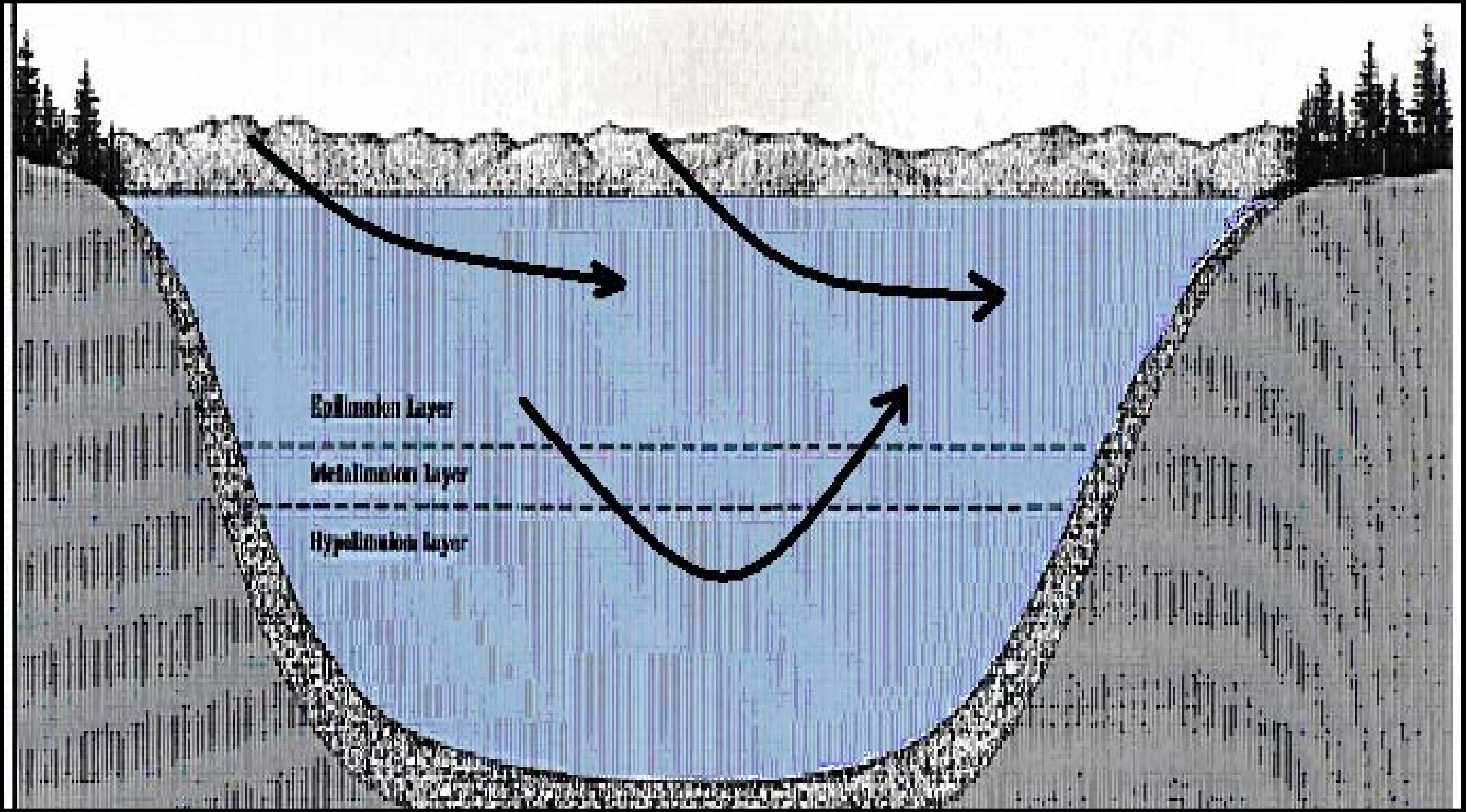
Internal P Loading

- Cycling upon turnover – not a major problem for Long Pond



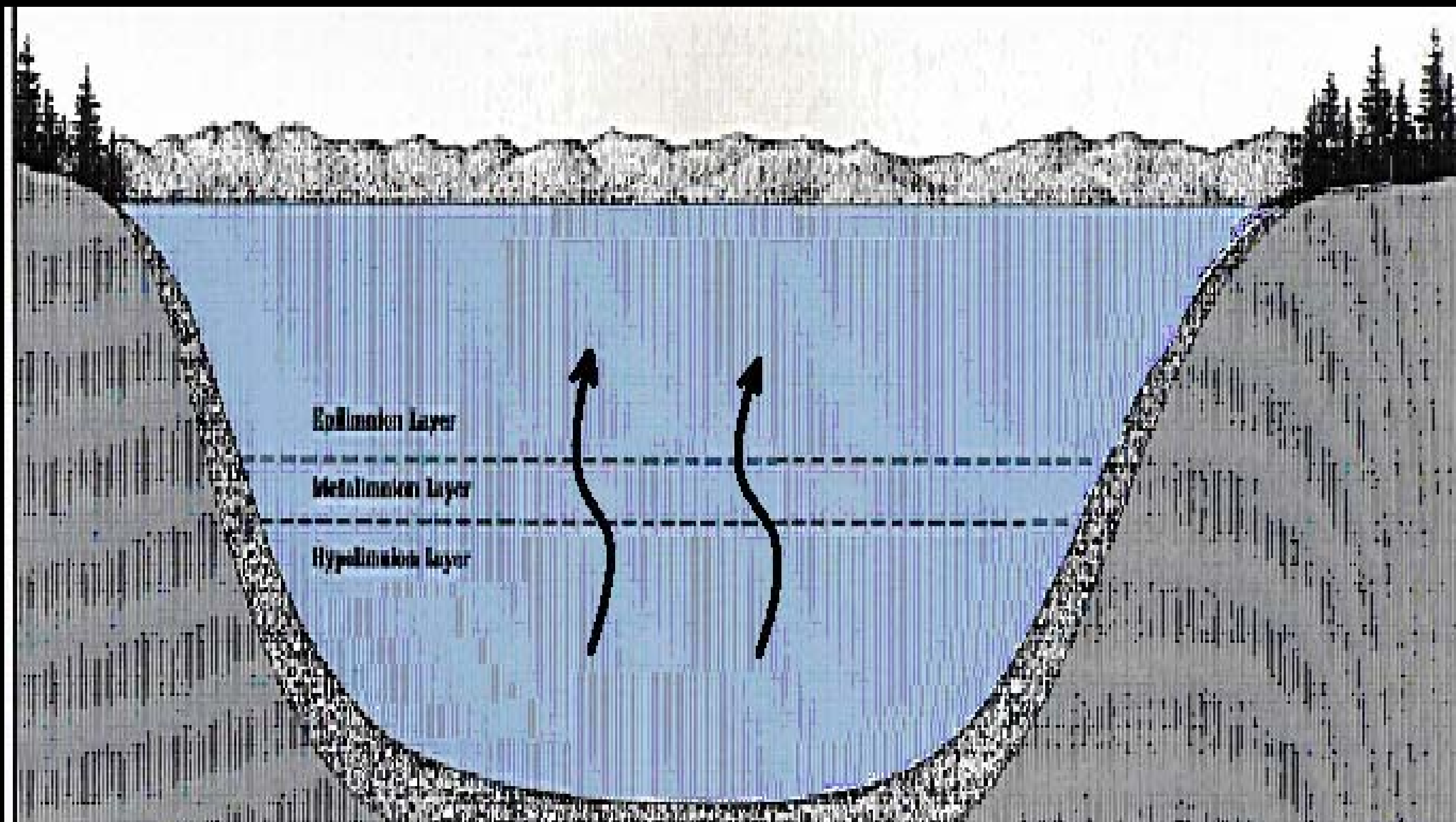
Internal P Loading

- **Metalimnetic erosion – a distinct problem for Long Pond**



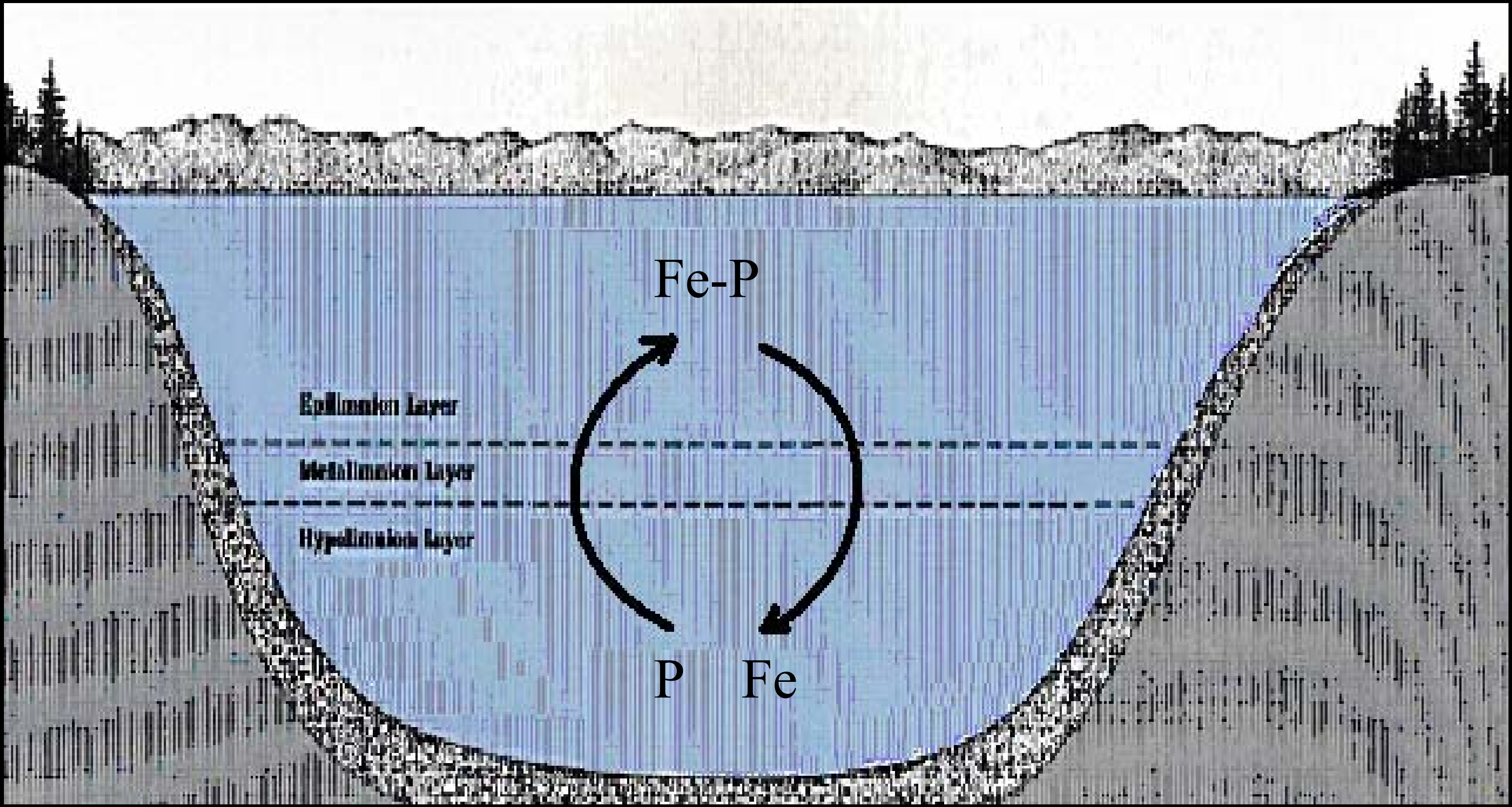
Internal P Loading

- Upward diffusion



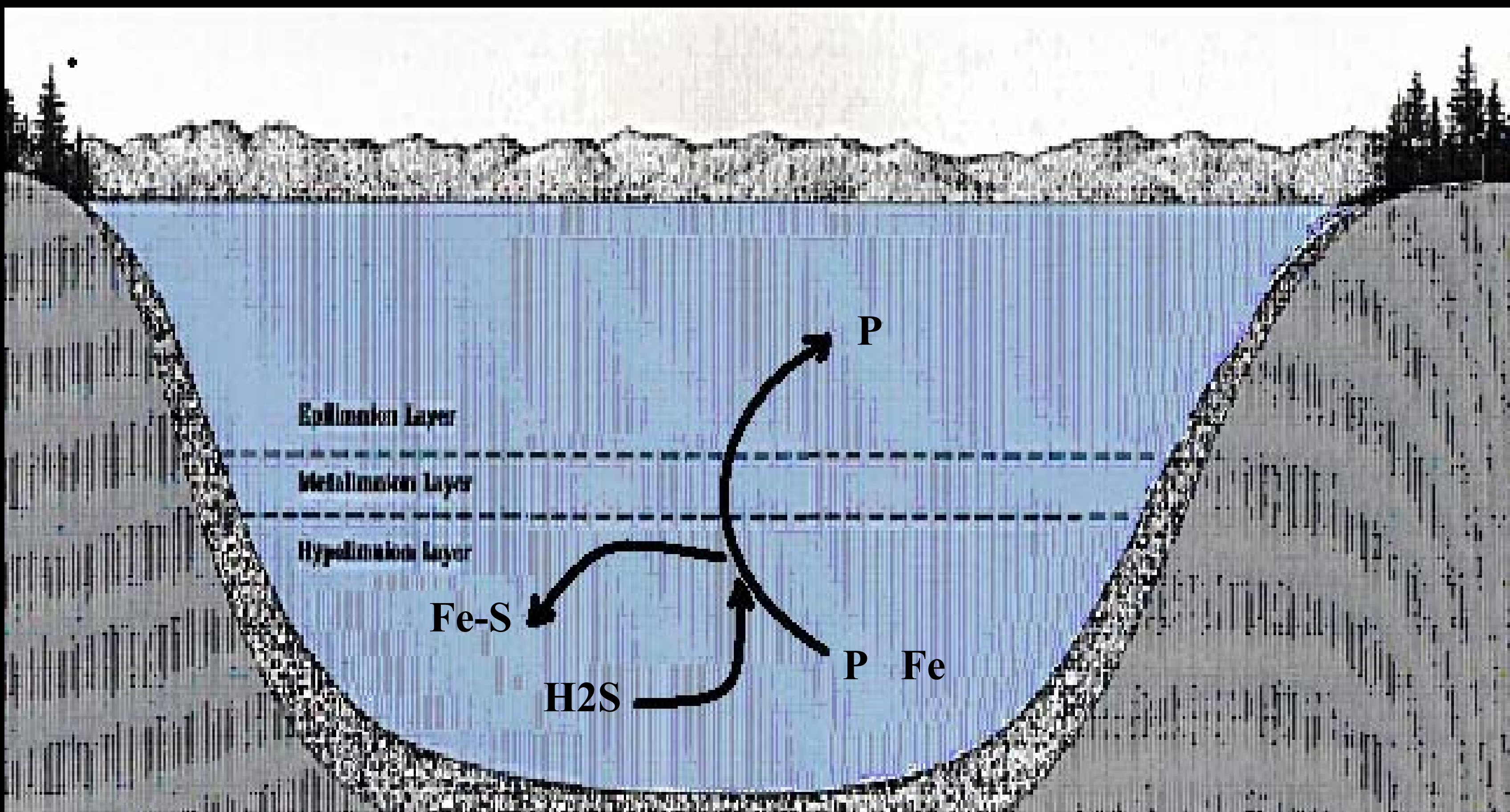
Internal P Loading

- The “ferrous” wheel



Internal P Loading

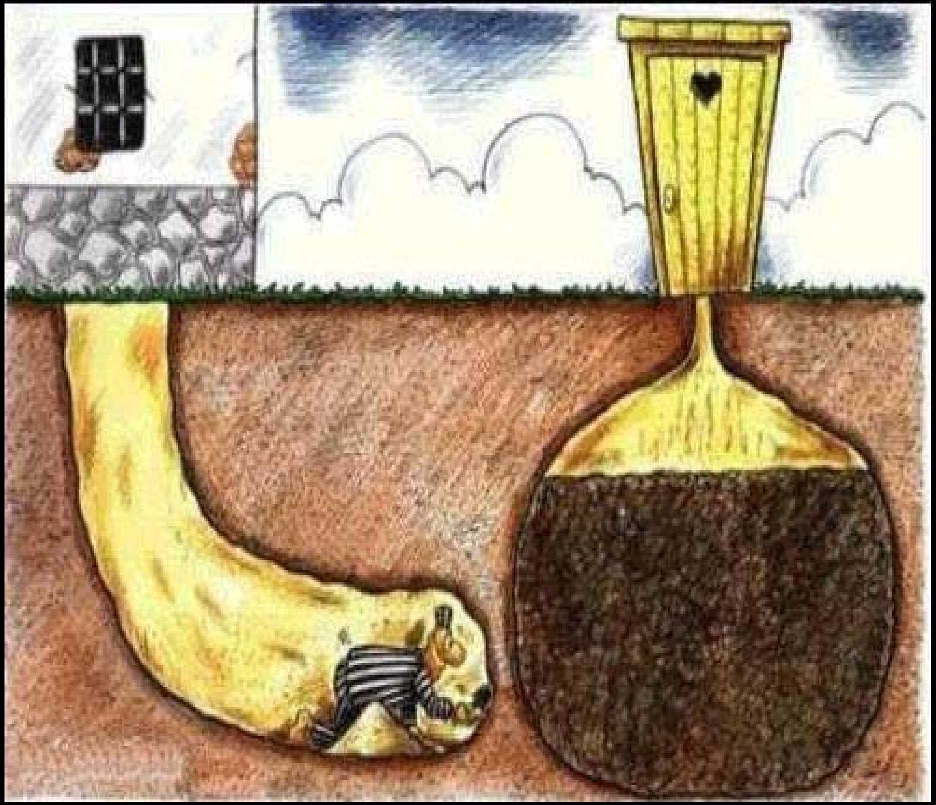
- Sulfate capture of iron



Internal P Loading

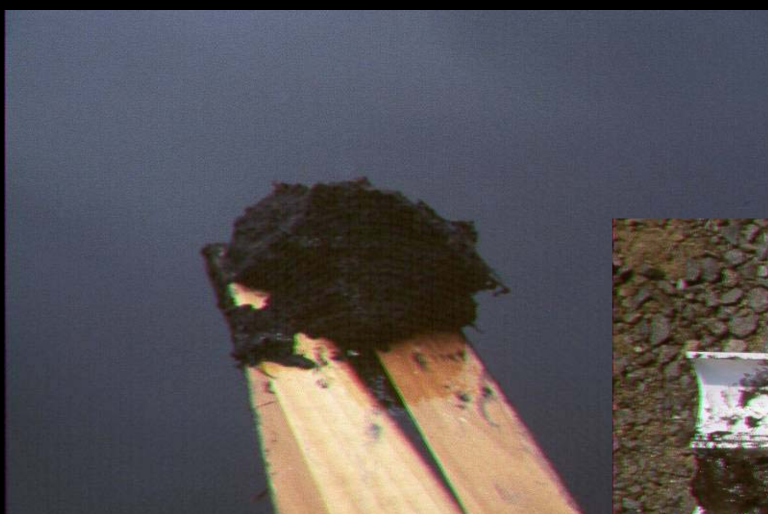
It is critical to know where you are going to avoid unpleasant surprises:

- **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 P Loading

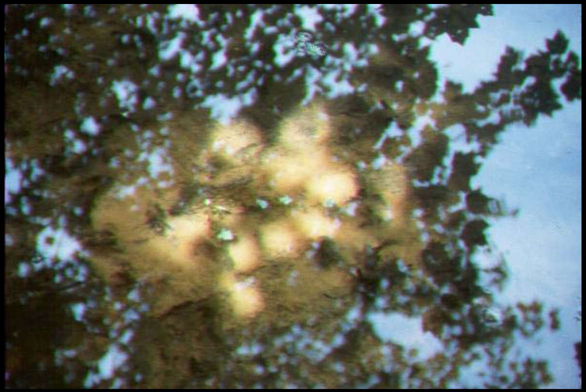
Phosphorus from past loadings can pass through the lake or become part of the sediment base; whether the P accumulating as sediment is bound as organic matter or complexes of iron, calcium or aluminum is important to recycling potential



Internal P Loading

Key processes in internal loading:

- P bound as organic matter may be released upon decay
- P bound as calcium may be released under low pH
- P bound as iron may be released under low oxygen
- P bound as aluminum tends not to be released
- Rooted plants can extract P from most sediment forms, and may release some of it into the water column



Internal P Loading

Evaluating internal loading:

- 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

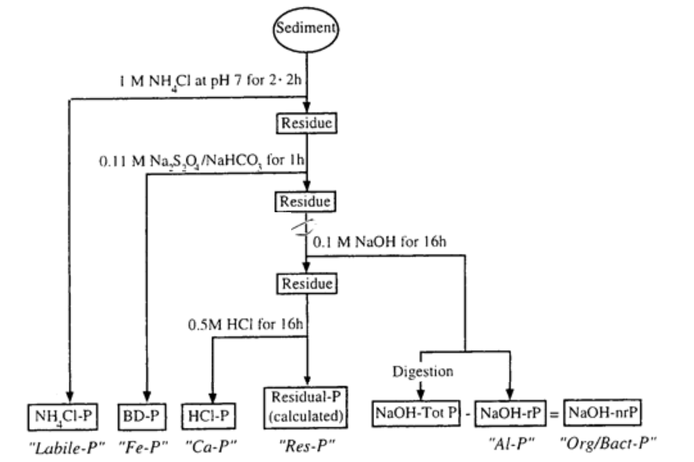
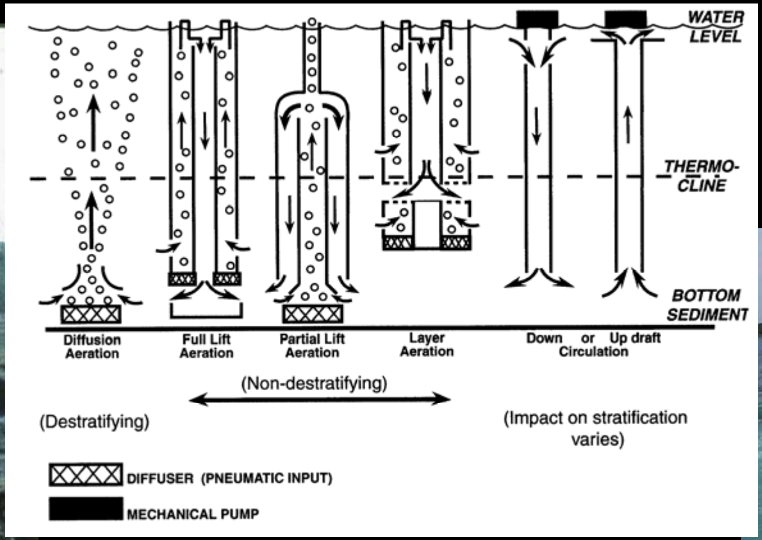


Fig. 2. The modified Hieltjes and Lijklema (1980) scheme used for phosphorus fractionation, including a dithionite/bicarbonate step to separate BD–P and also including a digestion step to distinguish reactive P (rP) from non-reactive P (nrP) in the NaOH extracted P.

Internal P Loading Control

Reducing 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 may help too



Internal P Loading Control

Dredging:

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

- Removes nutrient reserves
- Removes "seed" bank
- Potential mat control

Internal P Loading Control

Dredging:

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

Internal P Loading Control

Info 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 P Loading Control

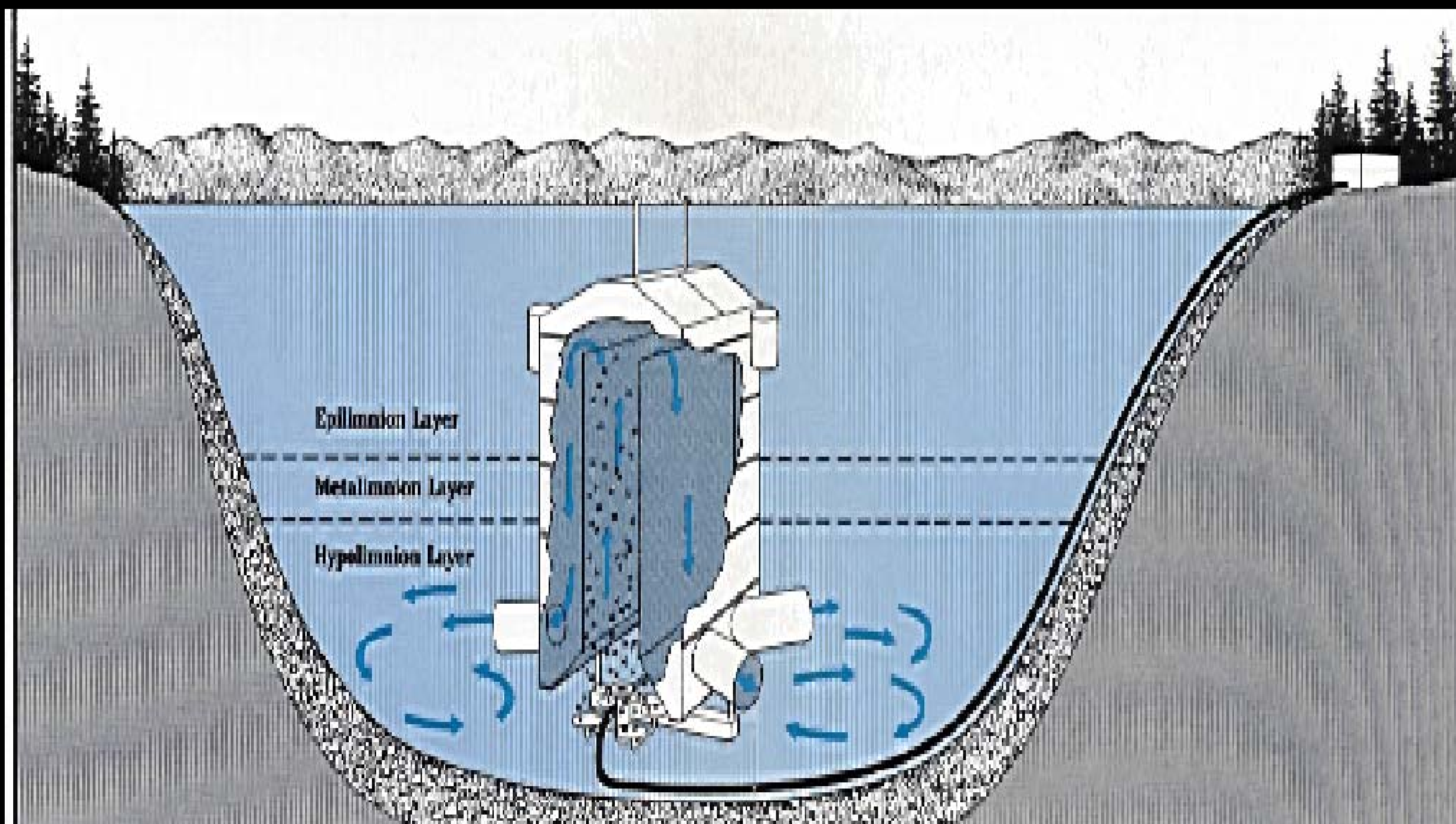
For dredging of Long Pond:

- Sediment quality – no reason to assume contamination, but would need about $20,000 of testing
- Sediment quantity – about 1 million cy @ $15/cy
- Flow control – no control, would have to be done hydraulically
- Disposal site features – would need about a 100 acre site
- Affected resources – limited in-lake issues
- Equipment access – no problem
- Relation to lake uses – would not be able to boat most of lake for at least 5 years!

Internal P Loading Control

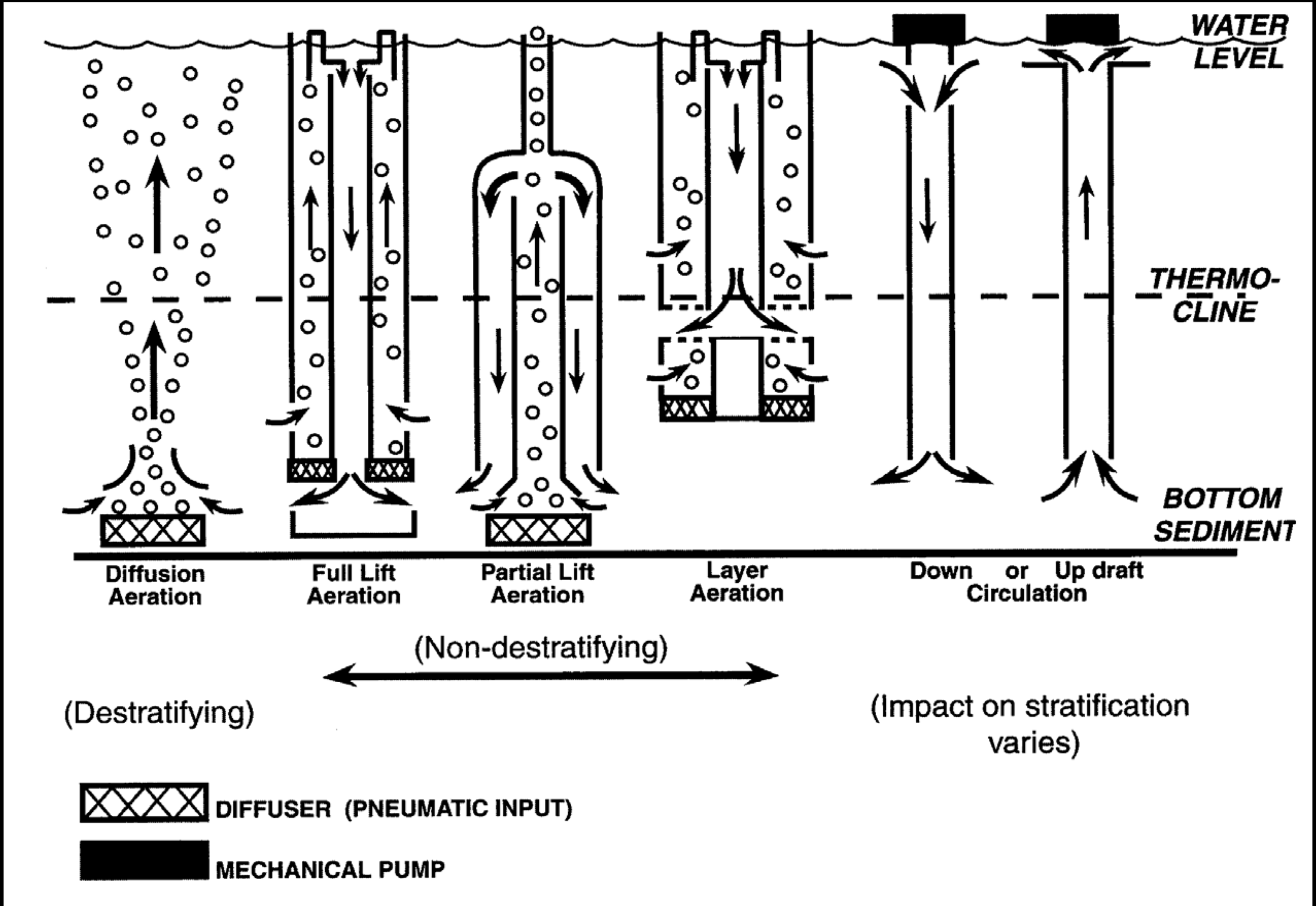
Non-destratifying aeration:

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



Internal P Loading Control

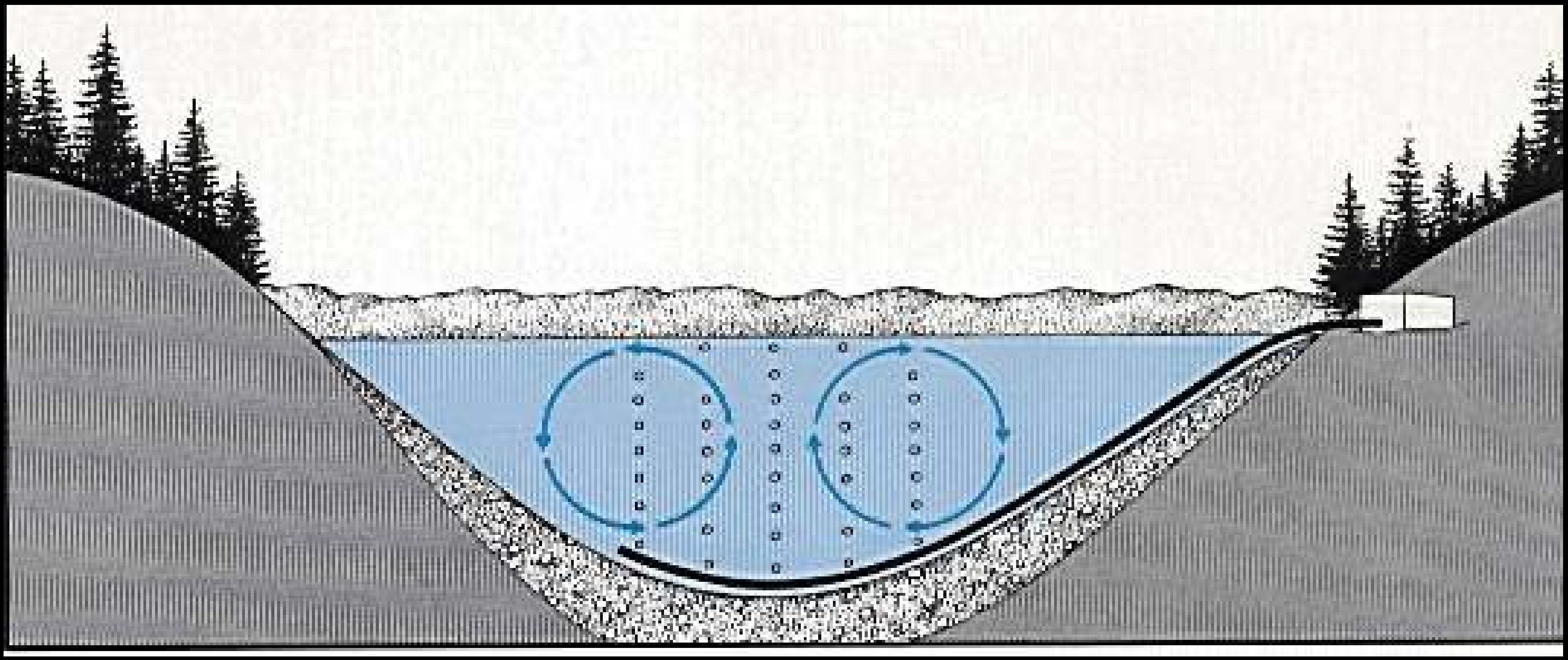
Aeration systems:



Internal P Loading Control

Destratifying aeration/mixing:

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



Internal P Loading Control

Mixing systems:

Internal P Loading Control

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 P Loading Control

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

Internal P Loading Control

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 P Loading Control

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 Loading Control

For aeration/mixing of Long Pond:

- Oxygen demand – sediment driven, need 3-4 large units for hypolimnetic aeration, $150,000 each
- Bathymetry – 3 separate basins, feeds into need for at least 3 units
- P binder – iron dominated, may need more added
- Energy necessary to destratify – could make it work with 1 cfm/ac – Solarbee estimates need for 25+ units @ $750,000 to $1 million
- Forms of algae and zooplankton – bluegreens are main problem group, susceptible; limited zoopl.
- Sensitive receptors – no flora/fauna problems, people issues with navigation and noise
- Power availability – need major source for hypolim. aeration, >$10,000/yr, none for Solarbees, assume 20+ yr lifespan (?)
- Nearby land availability – would have to give up part of Town beach complexes for hypolim.

Internal P Loading Control

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 Loading Control

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

Internal P Loading Control

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

Internal P Loading Control

To Avoid Toxicity:

Aluminum dose at any one time should be <10 mg/L, preferably <5 mg/L

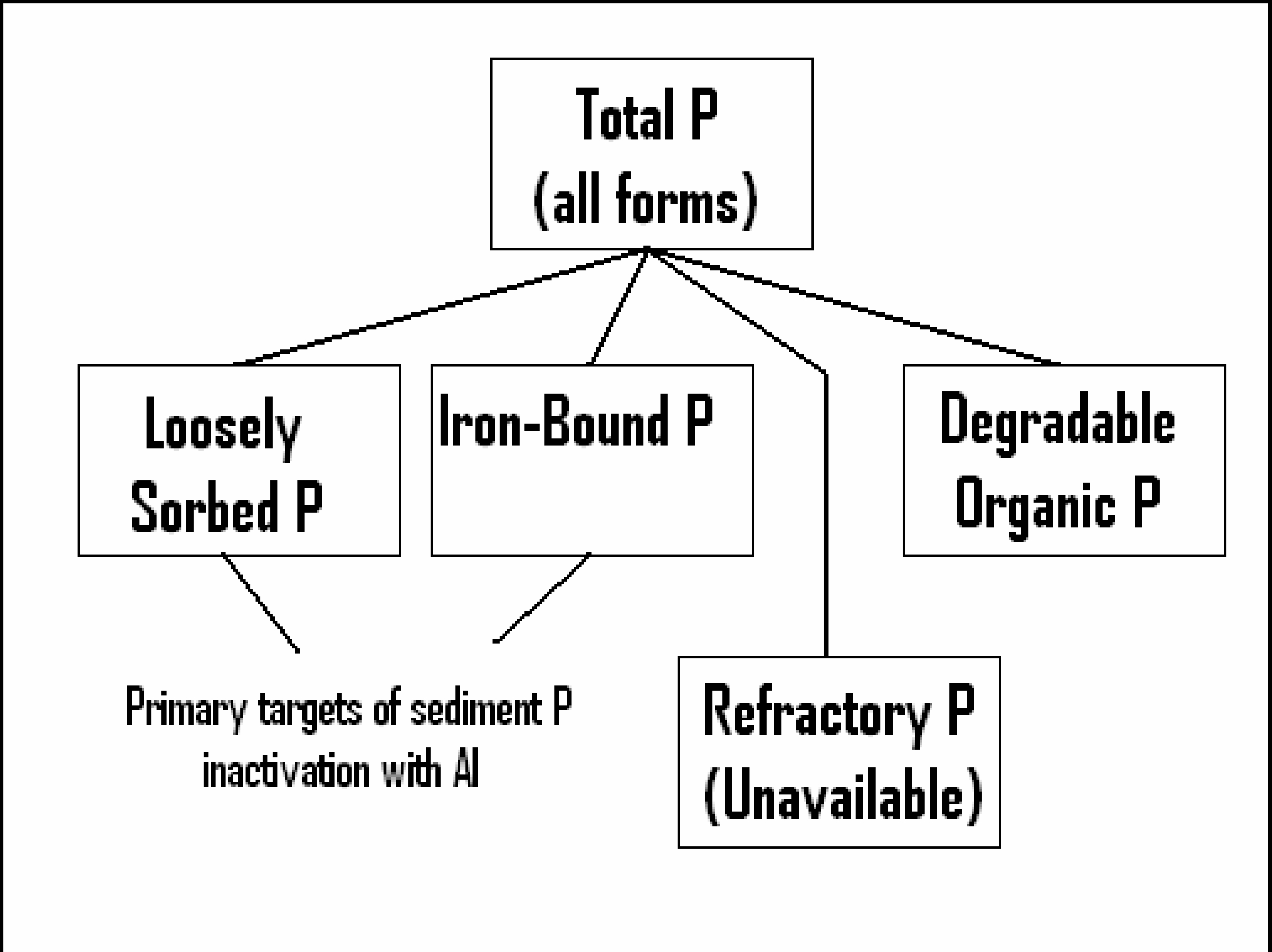
Treat defined areas of the lake in a pattern that minimizes contiguous area treated at once (patchwork with adjacent blocks not treated sequentially)

Apply aluminum at enough depth to create a surface refuge (can even treat below thermocline)

When buffering alum with aluminate, use a 2:1 ratio of alum to aluminate, by volume, to avoid pH change

Internal P Loading Control

Available Sediment P Determination:



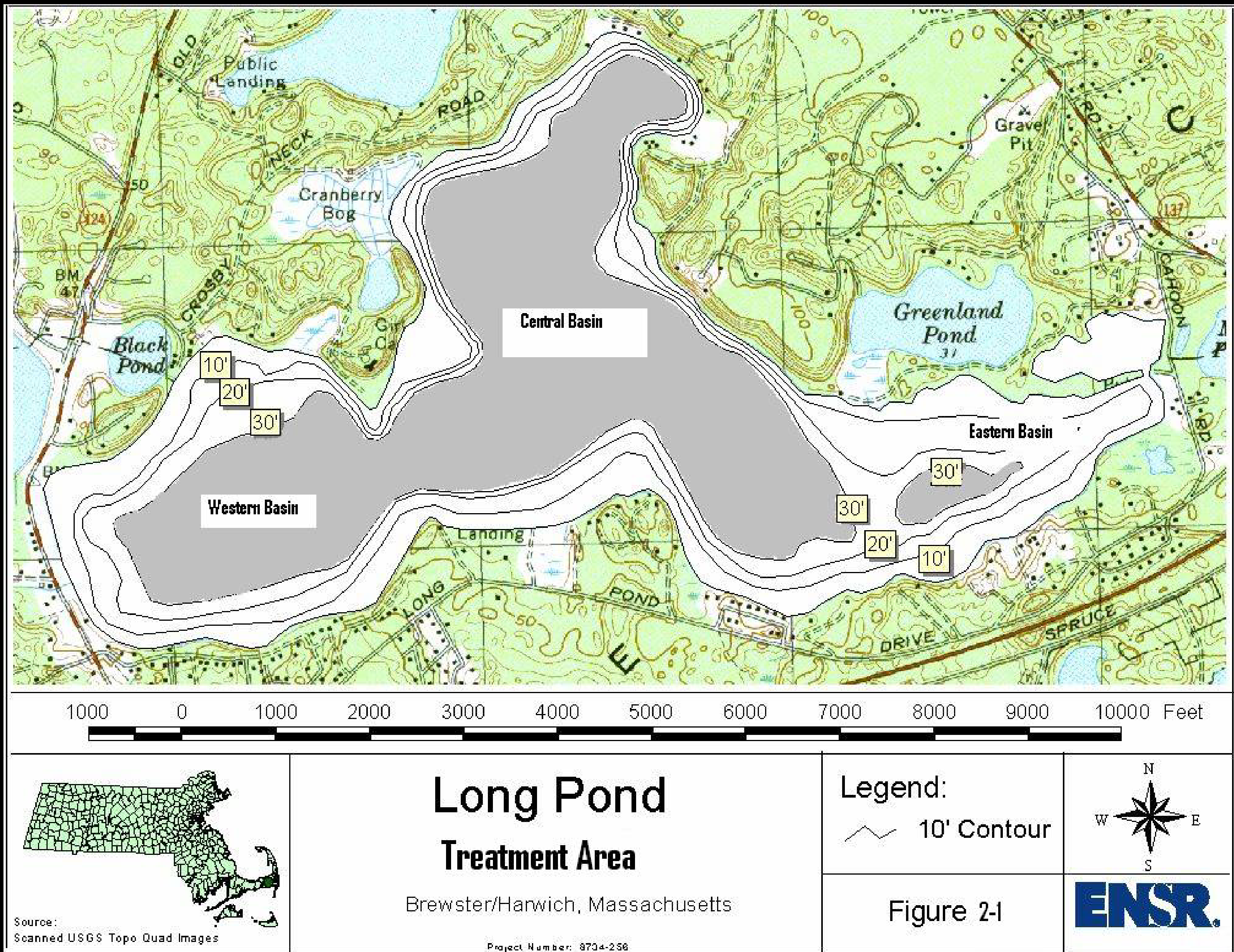
Sediment Dose Calculation:

West basin @ 15 g/m2 (1-2 mg/L)

Central basin @ 30 g/m2 (1.5-3 mg/L)

East basin @ 10 g/m2 (1-2 mg/L)

Internal P Loading Control



Internal P Loading Control

Conclusions for Lake Sediment Treatments:

Effective inactivation of sediment P can be achieved 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 at least 10 years in shallow lakes and 20+ years in deep lakes; extended by watershed management

Internal P Loading Control

Factors in Planning "Environmental" Treatments:

- Existing P load, sources and inactivation needs
- System hydrology – flow and flushing
- Potential water chemistry alteration - pH, metals levels, oxygen concentration
- Potentially sensitive receptors - fish, zooplankton, macroinvertebrates, reptiles, amphibians, waterfowl
- Presence of rooted plants or other interferences
- Fate and transport - future cycling, downstream movement, accumulation of sulfates in sediment
- Accumulated residues - quantity and quality

Internal P Loading Control

For alum treatment of Long Pond:

- Existing P load – dominated by internal recycling, external load is not large for a lake of this size
- Dose – total of 82,000 lbs @ total cost of $418,000
- System hydrology – long detention time
- Potential water chemistry alteration – need to control pH
- Potentially sensitive receptors – fish and molluscs are primary sensitive groups, not expected in target area, protective measures to be taken
- Presence of rooted plants or other interferences - minimal
- Fate and transport –mixed into deep bottom sediment after several weeks
- Accumulated residues – thin (<1 inch) layer of inert material in deep surficial sediments

Internal P Loading Control

	Long Pond Basin			
	West	Central	East	Total
Mean P (mg/kg DW)	1.5	3.0	1.0	
Area (ac)	106	251	13	
Area (m2)	427419	1012097	52419	
Dose (g/m2)	15	30	10	
Dose (kg/area)	6411	30363	524	37298
Dose (lb/area)	14105	66798	1153	82056
Dose (gal alum)	12594	59641	1030	73265
Dose (gal aluminate)	6297	29821	515	36632

110,000 gallons of liquid to be applied (<100 ft X 50 ft X 3ft volume)

What it looks like during treatment

Loading

What it looks like during treatment

Applying

The End