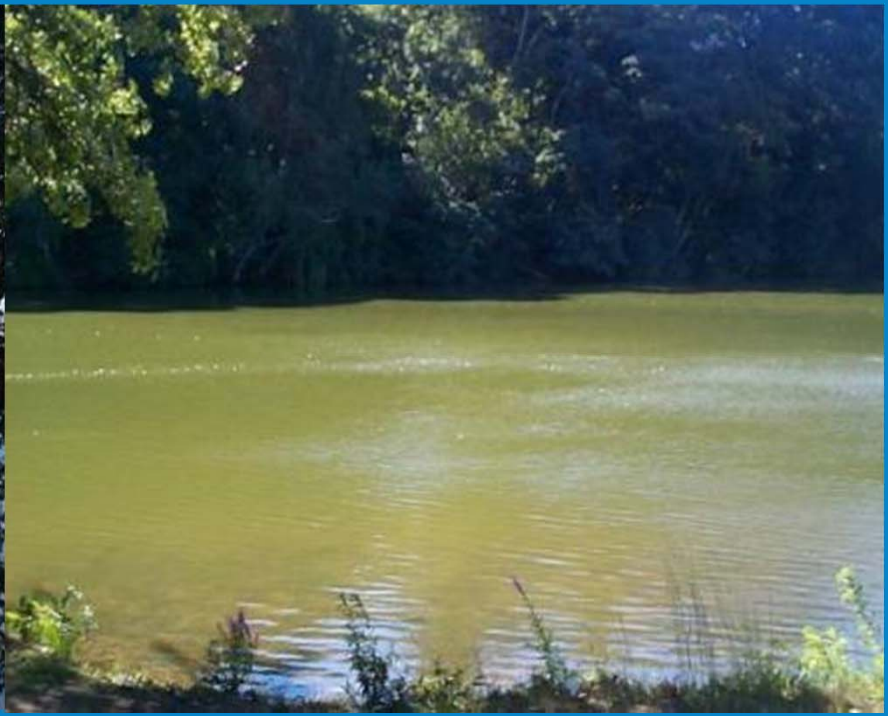
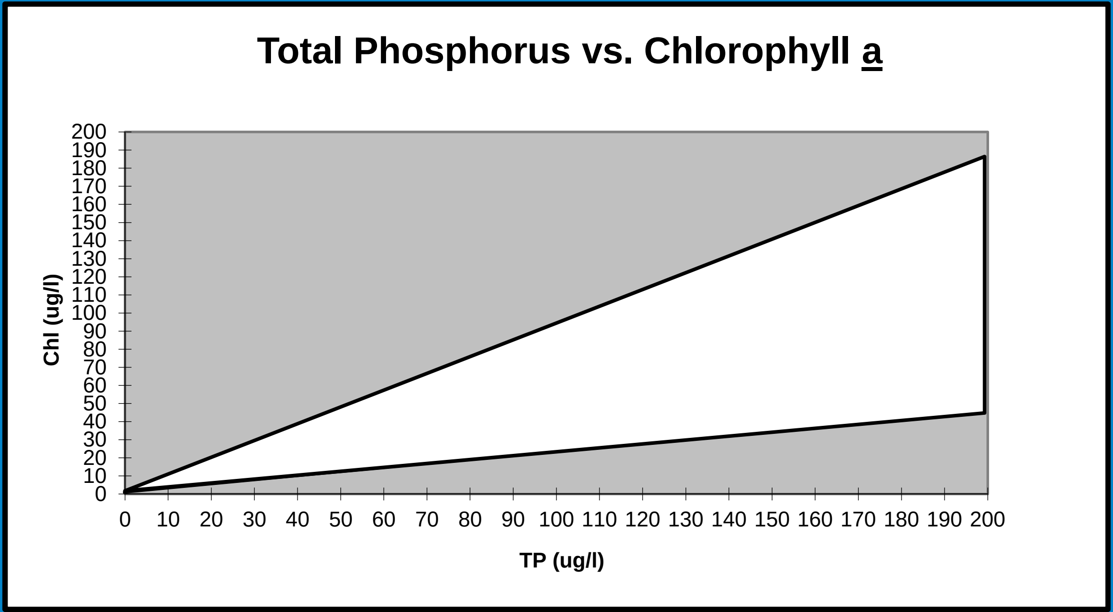
Seeing the Big Picture: Options and Limits for Management of Urban Lakes

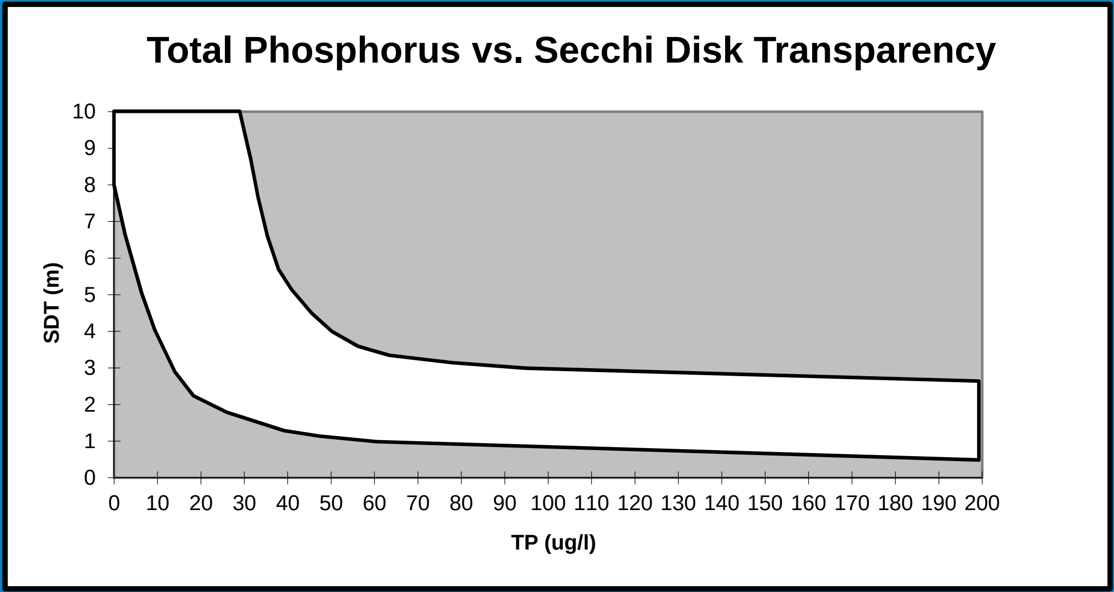


Ken Wagner, PhD, CLM

Water Resource Services

The impact of phosphorus

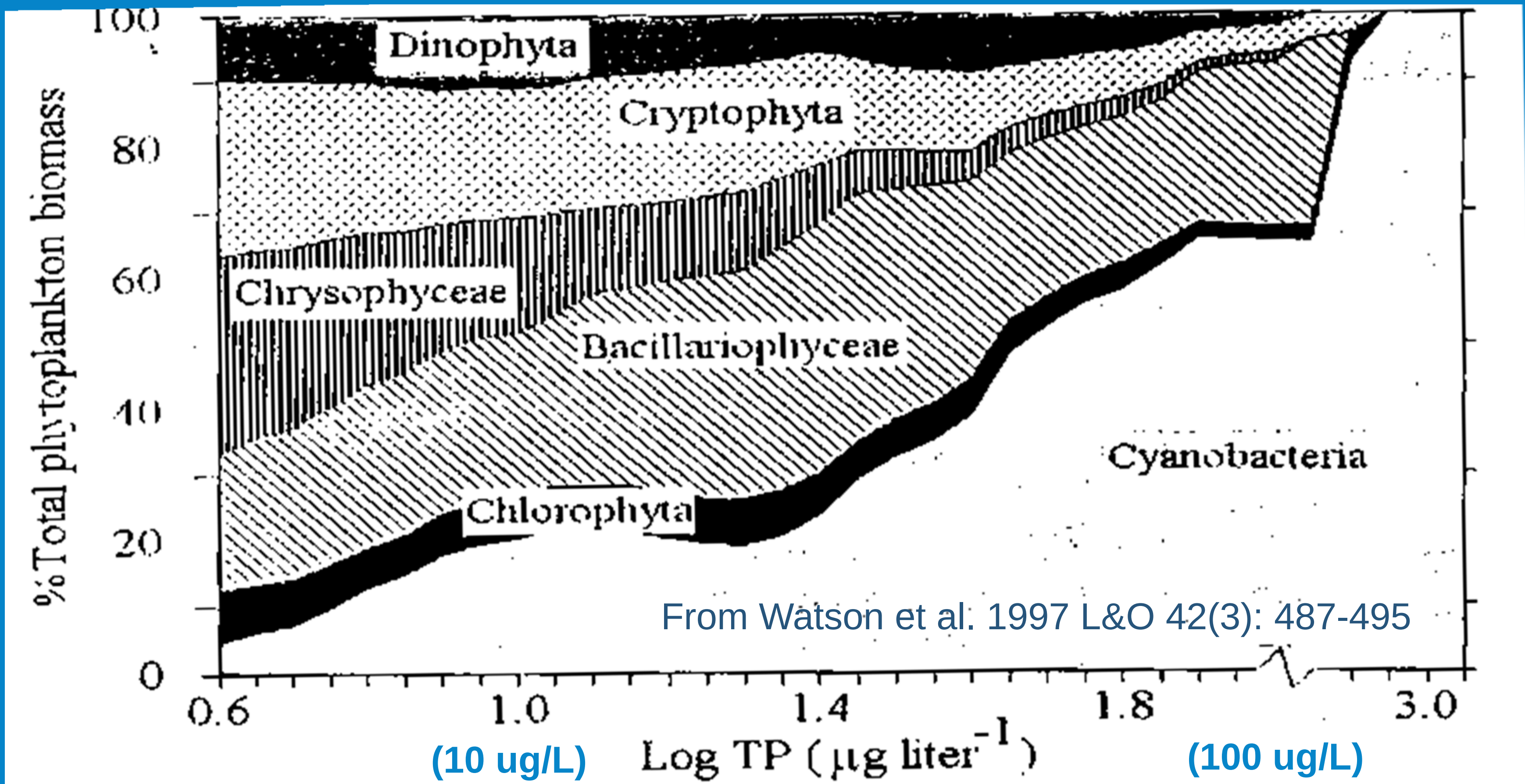




– More P leads to more algae

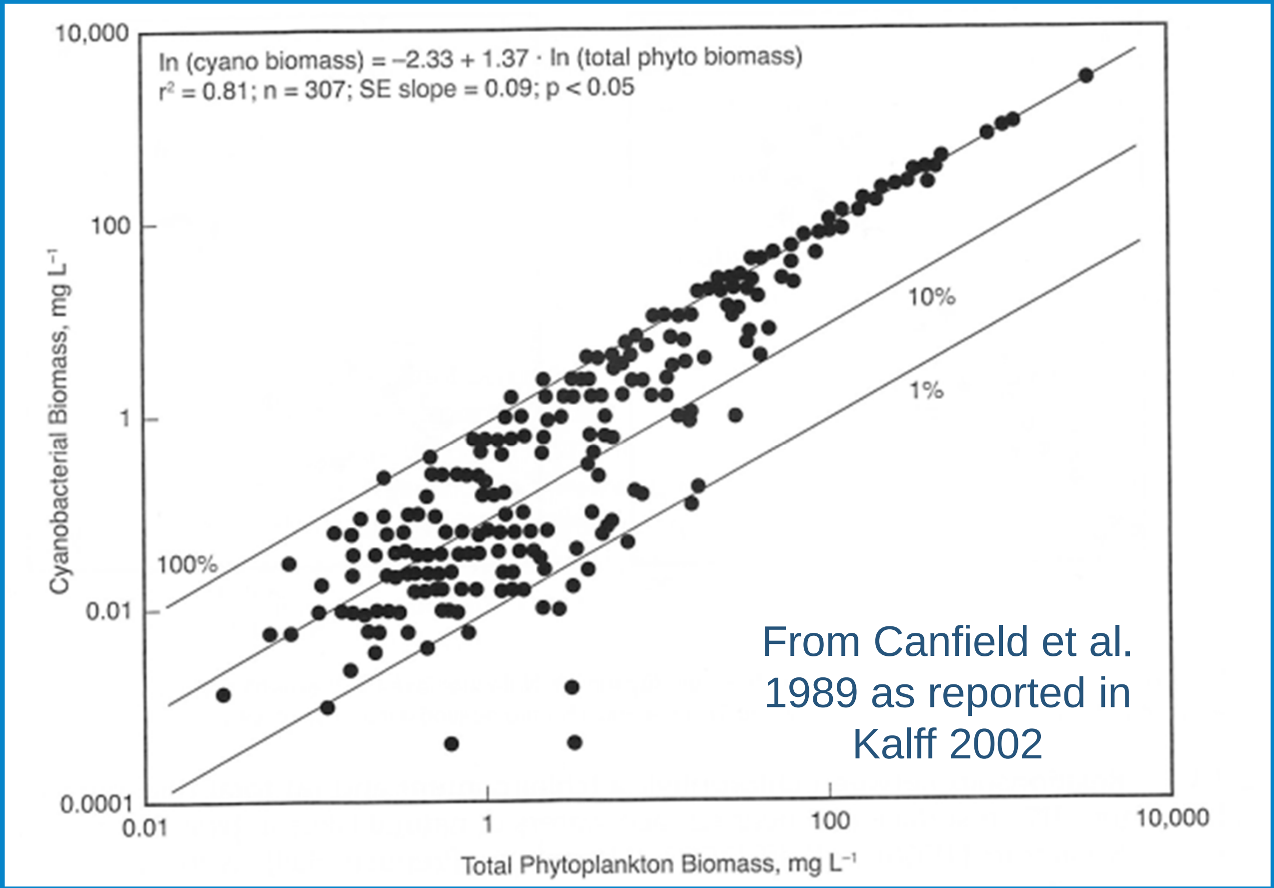
– More algae leads to lower water clarity

The impact of phosphorus



– High P also leads to more cyanobacteria, possible health effects therefore linked to high P

The impact of phosphorus



– As algal biomass rises, a greater % of that biomass is cyanobacteria. So more P = more algae = more cyanobacteria.

The impact of development

– Background concentrations for P: 5-50 ppb, with an apparent threshold of impact between 10 and 20 ppb

– Runoff P concentrations: 50 to 5000 ppb, median >370 ppb

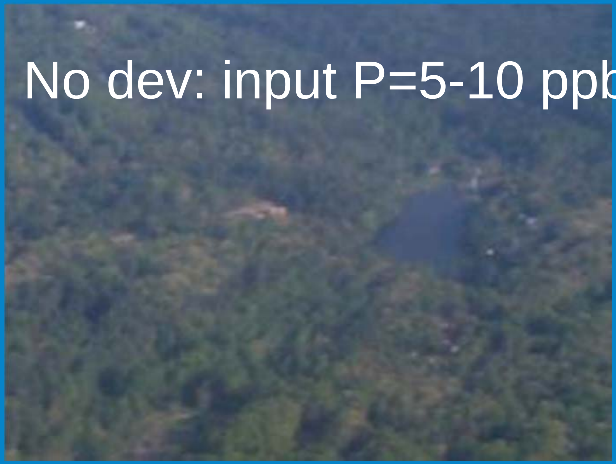
– Wastewater treatment effluent P: usually 300 to 6000 ppb, very best treatment achieves 20 to 50 ppb

5-50 ppb

50-5000 ppb

300-6000 ppb

The impact of development



Lake George,NY: 5% developed watershed contributes same P load as remaining undeveloped 95%

75% dev:
input P= >140 ppb

Watershops Pond, MA has 75% developed watershed, input P averages 193 ppb.

The impact of development

- How lakes process the incoming P varies substantially; flushing rate, depth, internal recycling, biological structure, inorganic suspended solids load, and other factors affect in-lake P concentration and related algal densities
- Nevertheless, higher input P leads to higher in-lake P and the problems related thereto; it is desirable to address the problems in the watershed rather than in the lake
- Urbanization has a major impact on lake quality

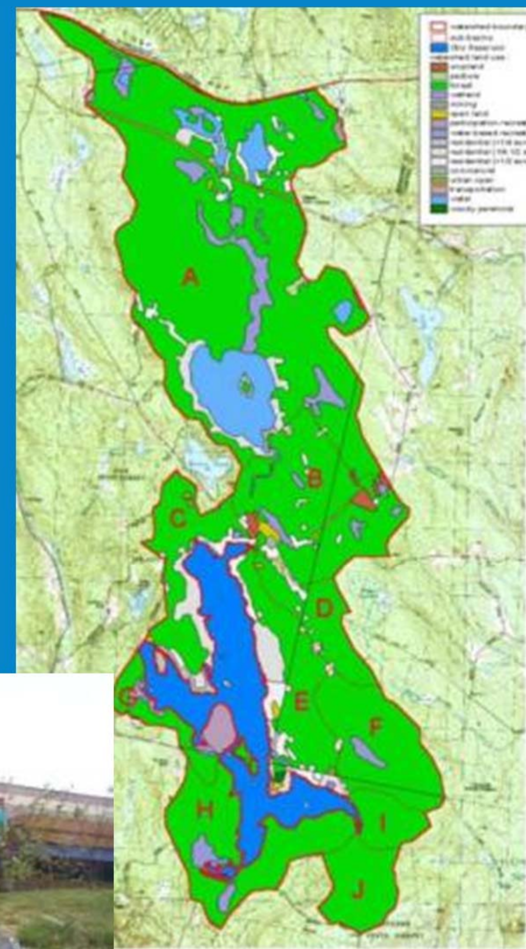


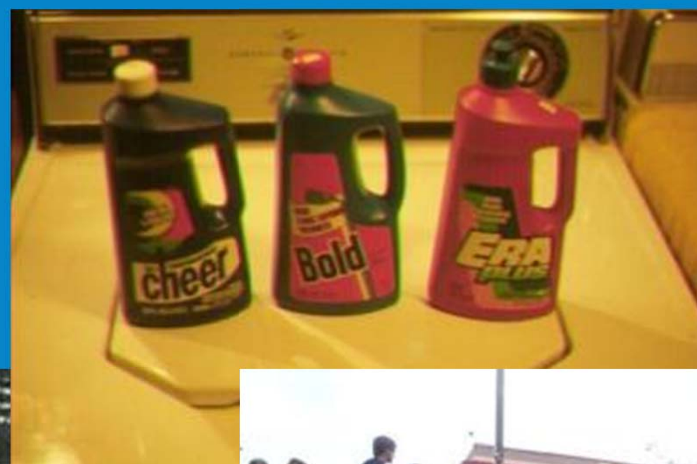
How do we counter development impacts?

- Source and Activity Controls - Eliminate or reduce sources which generate pollutants
- Transport Reduction - Capture and remove or convert pollutants before they enter target resource
- Instream/Inlake Treatments– enhancing internal processes for pollutant inactivation
- **Ecosystem Restoration- Repair damage to resources when controls fail**

Source Controls

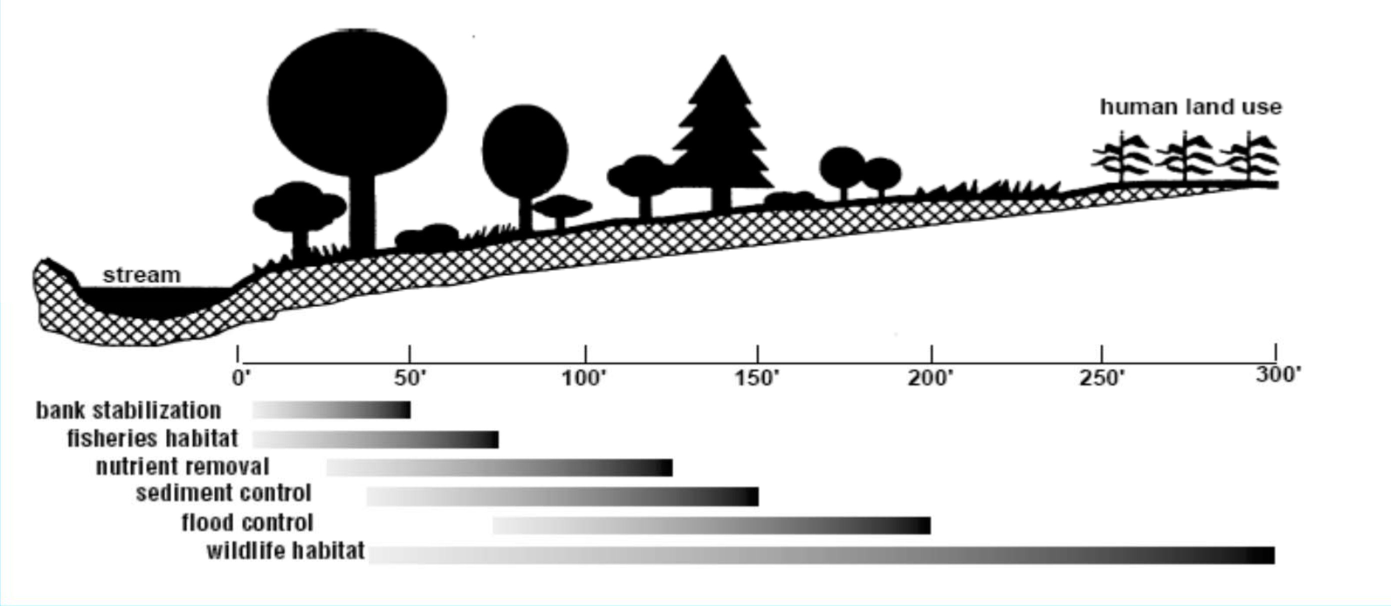
- Land use restrictions
- Material storage restrictions
- Product use limitations
- Education





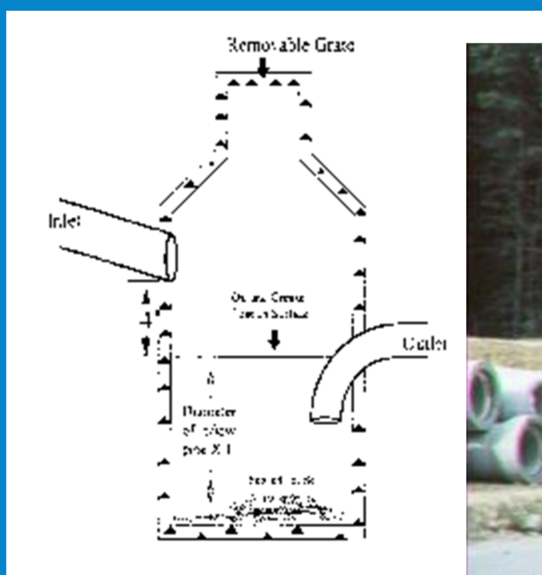
Pollutant Trapping

– Buffer strips: a lot more to know than just leaving some vegetated land



Pollutant Trapping

– Wide range of structural options – construction aids like silt fence, passive guards like swales, range of stormwater processing devices



Pollutant Trapping

– Detention systems, infiltration basins, filtration systems

Instream/Inlake Treatment

Creating detention within a lake or chemically treating runoff or streamflows

Aluminum treatments becoming more common and fairly effective in short and intermediate timeframes

Doing the math on watershed controls

– Can we get the land on the right to act like it is land on the left?

Doing the math on watershed controls

- USEPA 1999 – summarizes capture efficiency of many pollutant trapping devices
- Center for Watershed Protection 2003 – more summary, rationale and key factors
- USEPA stormwater management database – current – documented case histories from which one can infer reliable results

Wide range of possible outcomes, means and medians provide a feel for likely results, range shows importance of understanding key factors

Boiling it down

With reasonable implementation of Best Management Practices in a watershed, one can expect to achieve about a 50% reduction in P loading, with a probable maximum around 67%, unless extreme measures like chemical treatment or extensive infiltration are applied

Range and Median ( ) for Expected Removal (%) for Key Pollutants by Selected Management Methods, Compiled from Literature Sources for Actual Projects and Best Professional Judgment Upon Data Review.

	TSS	Total P	Soluble P	Total N	Soluble N	Metals
Street sweeping	5-20	5-20	<5	5-20	<5	5-20
Catch basin cleaning	5-10	<10	<1	<10	<1	5-10
Buffer strips	40-95 (50)	20-90 (30)	10-80 (20)	20-60 (30)	0-20 (5)	20-60 (30)
Conventional catch basins (Some sump capacity)	1-20 (5)	0-10 (2)	0-1 (0)	0-10 (2)	0-1 (0)	1-20 (5)
Modified catch basins (deep sumps and hoods)	25 (25)	0-20 (5)	0-1 (0)	0-20 (5)	0-1 (0)	20 (20)
Advanced catch basins (sediment/floatables traps)	25-90 (50)	0-19 (10)	0-21 (0)	0-20 (10)	0-6 (0)	10-30 (20)
Porous Pavement	40-80 (60)	28-85 (52)	0-25 (10)	40-95 (62)	-10-5 (0)	40-90 (60)
Vegetated swale	60-90 (70)	0-63 (30)	5-71 (35)	0-40 (25)	-25-31 (0)	50-90 (70)
Infiltration trench/chamber	75-90 (80)	40-70 (60)	20-60 (50)	40-80 (60)	0-40 (10)	50-90 (80)
Infiltration basin	75-80 (80)	40-100 (65)	25-100 (55)	35-80 (51)	0-82 (15)	50-90 (80)
Sand filtration system	80-85 (80)	38-85 (62)	35-90 (60)	22-73 (52)	-20-45 (13)	50-70 (60)
Organic filtration system	80-90 (80)	21-95 (58)	-17-40 (22)	19-55 (35)	-87-0 (-50)	60-90 (70)
Dry detention basin	14-87 (70)	23-99 (65)	5-76 (40)	29-65 (46)	-20-10 (0)	0-66 (36)
Wet detention basin	32-99 (70)	13-56 (27)	-20-5 (-5)	10-60 (31)	0-52 (10)	13-96 (63)
Constructed wetland	14-98 (70)	12-91 (49)	8-90 (63)	6-85 (34)	0-97 (43)	0-82 (54)
Pond/Wetland Combination	20-96 (76)	0-97 (55)	0-65 (30)	23-60 (39)	1-95 (49)	6-90 (58)
Chemical treatment	30-90 (70)	24-92 (63)	1-80 (42)	0-83 (38)	9-70 (34)	30-90 (65)

Doing the math on watershed controls

– So if we have a 20% developed watershed that has gone from 5 ppb to 50 ppb as a consequence of runoff impacts, and we apply reasonable BMPs, we expect to lower P to about 25 ppb – not bad, but hardly back to "natural" – we can flirt with restoring function in watersheds with low development %

Dev.

BMPs

– If we have a 75% developed watershed, P will be >140 ppb (could be >300 ppb), and even a 67% reduction by BMPs will not be adequate to reduce P to any desirable level

???

Can we achieve our goals?

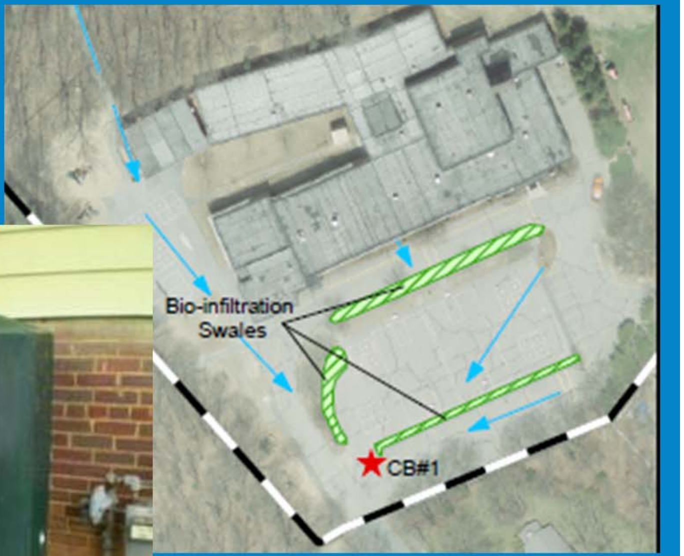
- If we are to achieve lake quality targets through stormwater management, we have to do way better than even the highest “reasonable” level expected based on experience to date
- We are going to need a different approach, an emphasis on the techniques that yield very high removal rates (= infiltration or chemical treatment), and dependence on in-lake techniques

Lawn fertilizer issue

- Dodson 2008 in Lake and Reservoir Management: Watershed feature most correlated to poor conditions was % lawn
- Lehman et al. 2009 in Lake and Reservoir Management: Ban on P in fertilizer produced 25% decrease in stream P concentration in first year. Follow up research in review, supports this assessment
- Cities banned or reduced fertilizer P starting in 1990s, whole states moving toward restrictions in 2000s, Scotts to remove P from most lawn fertilizer in next few years.

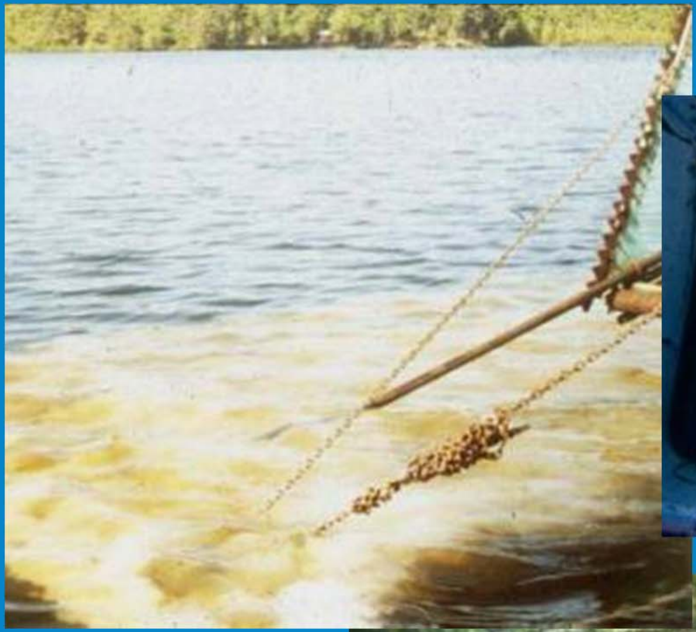
Low Impact Development (LID)

- LID techniques seek to minimize the generation of runoff and transport of pollutants off properties
- Focus on the source, widespread application, and creativity of approaches are important aspects of LID
- A lot of good work being done, suggests higher “removal” rates than conventional pollutant trapping
- Likely to be essential if we are to counter impacts of existing and future development



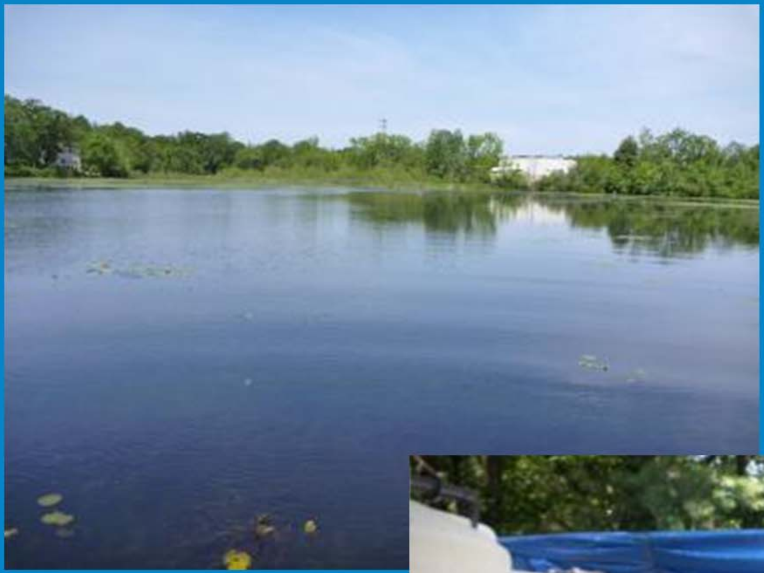
In-lake Options

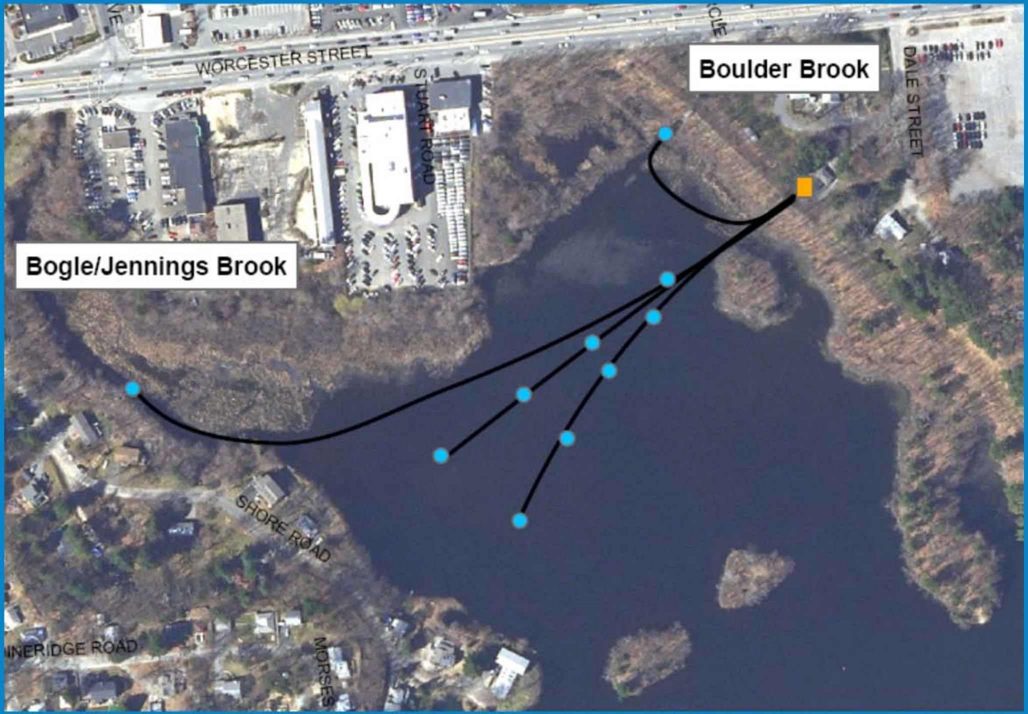
- P inactivation has proven useful in many cases
- Internal load control quite achievable, but only temporary if external load is substantial
- Can be used to treat incoming storm water to reduce peak and overall loading



In-lake Options

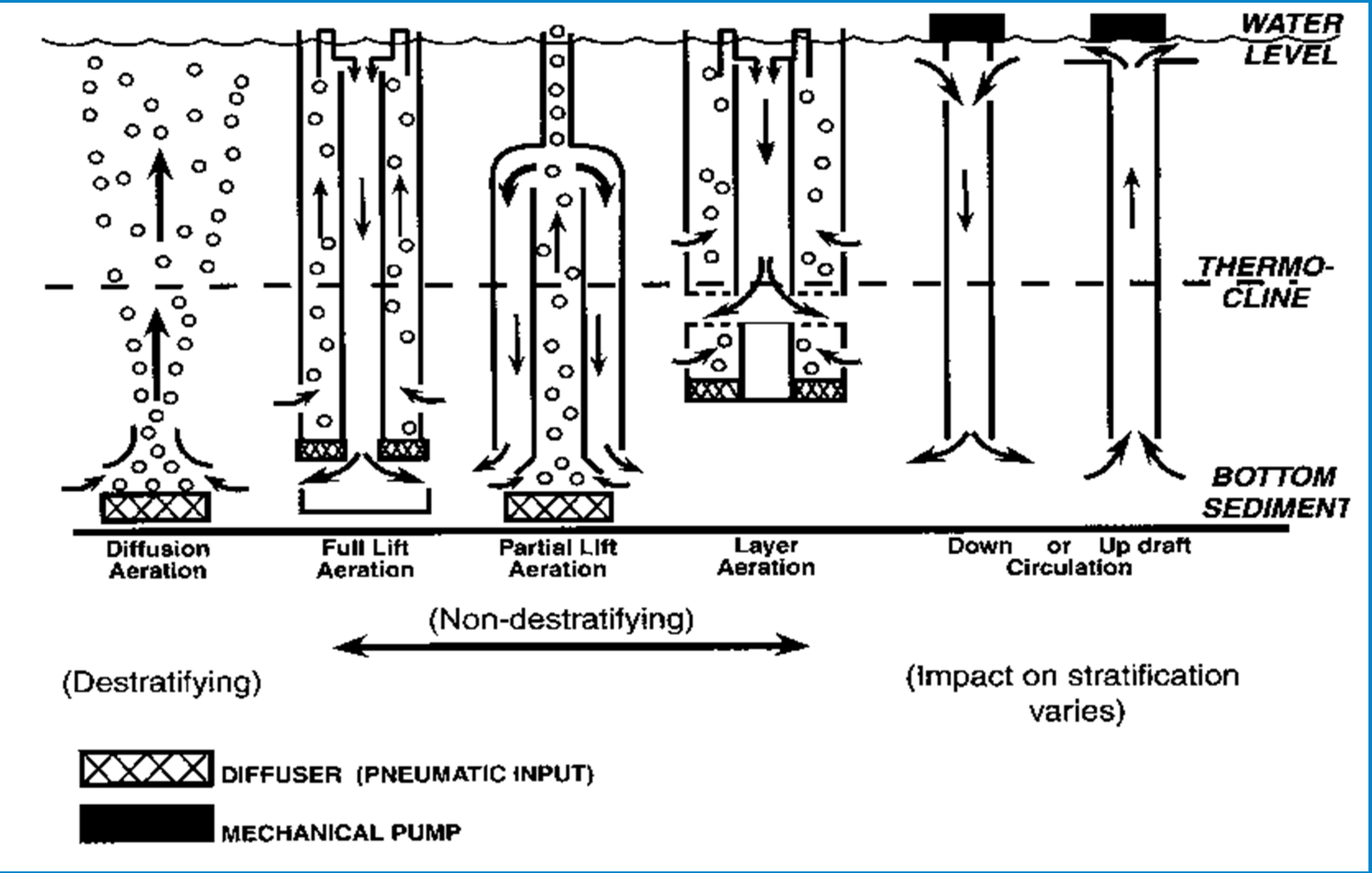
- Morses Pond effort includes P inactivation





In-lake Options

– Aeration and mixing - overlapping but differing approaches



In-lake Options

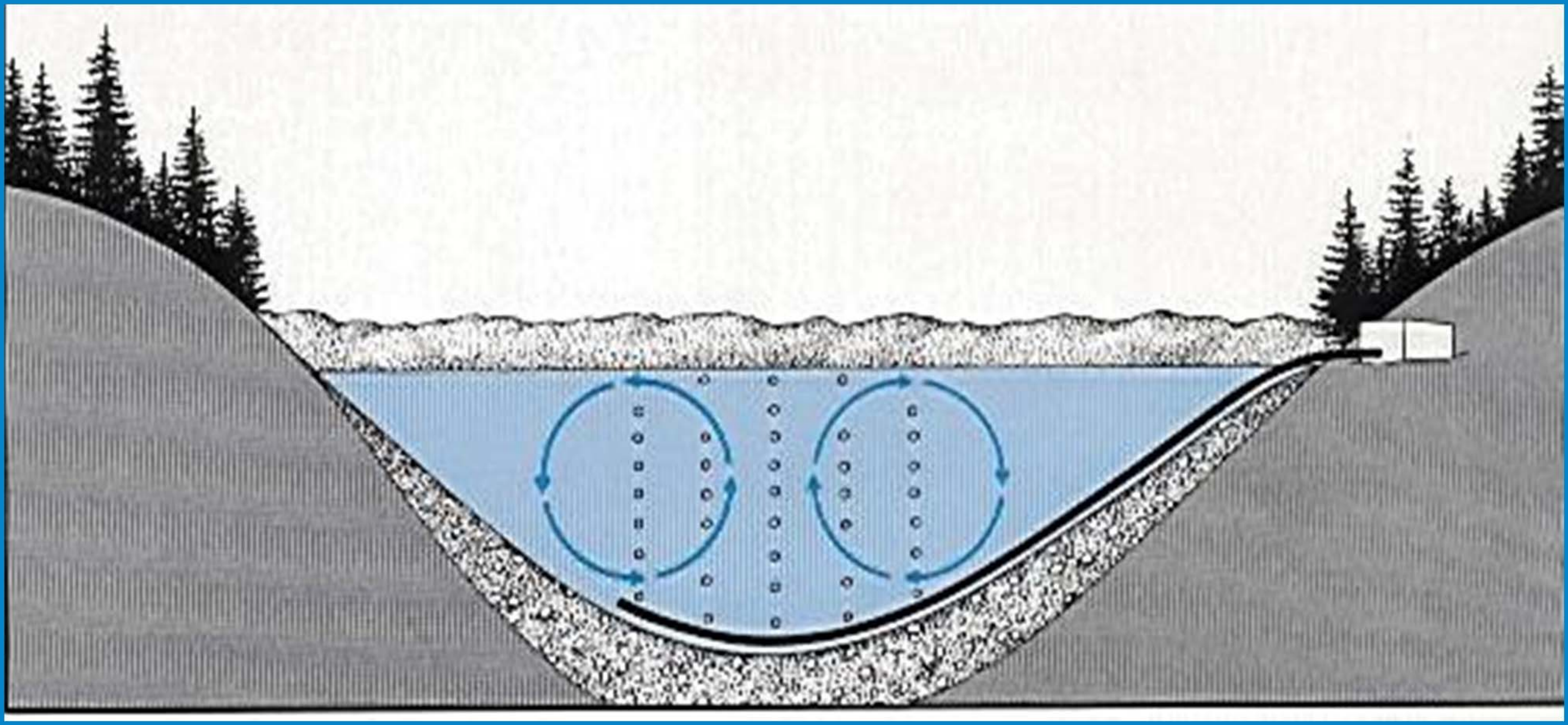
Key Factors in Aeration

- 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

In-lake Options

Destratifying aeration

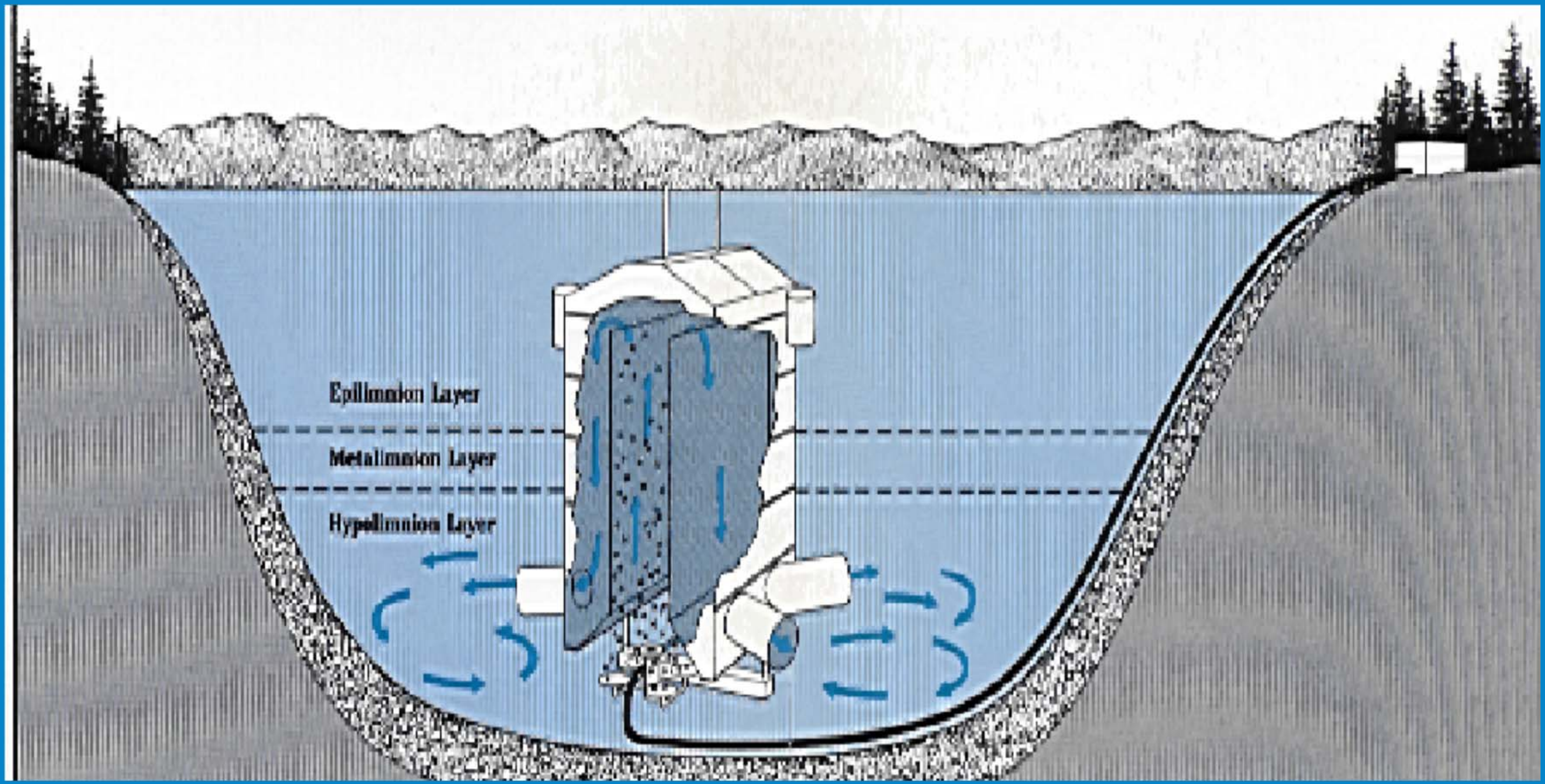
Lake is mixed completely or partially, input of oxygen comes from bubbles and interaction with lake surface



In-lake Options

Non-destratifying aeration:

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



In-lake Options

About Additives

- Basis in wastewater and sludge treatment
- Less research involved in lake applications
- Oxygen is most important, then nutrient balance
- Bacteria normally already present


In-lake Options

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, some potential to disrupt with only surface layer mixing

In-lake Options

Updraft Mixing

In-lake Options

Downdraft Mixing

In-lake Options

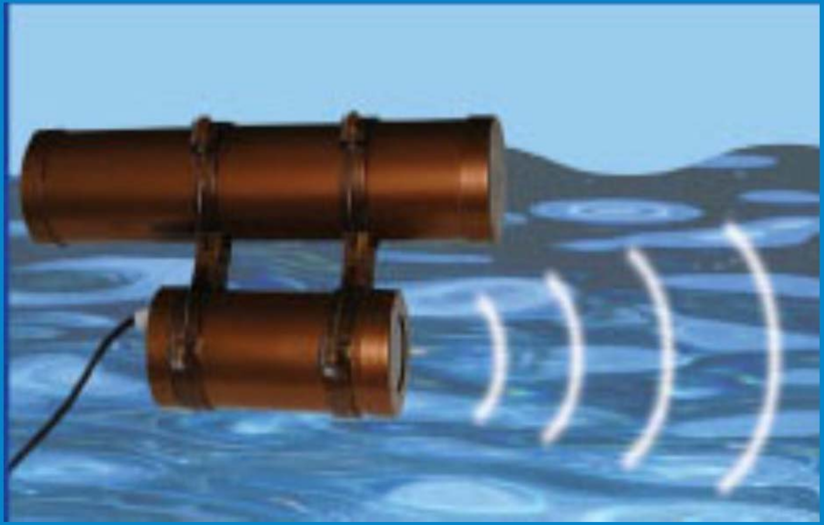
Sonication and Algaecides

Sonication

- "Line of sight technique"
- Rocks, plants, other obstructions interfere
- Not effective on all algae
- Gaining application experience

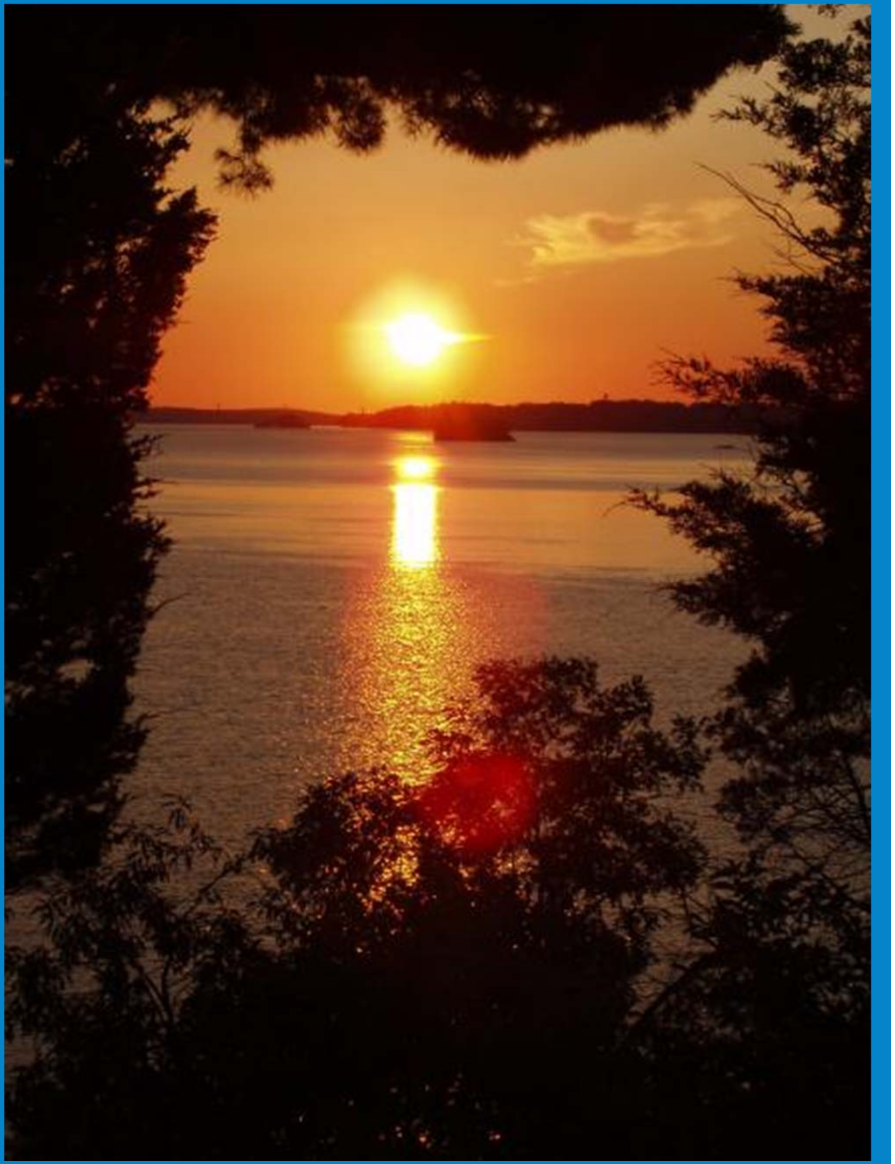
Proper Use of Algaecides

- Use to prevent bloom, not remove it
- Must know when algal growth is accelerating
- Must know enough about water chemistry to determine most appropriate form of algaecide
- If frequency of application becomes too high, recognize that the technique requires adjustment or will not be adequate for long-term use



Conclusions

- There is a mismatch between impacts of development and countermeasures as traditionally applied; degradation outstrips remedial actions most of the time
- Other than preventing development above some threshold (10%?), there are only a few options that provide the needed level of P control
- Targeted source control, LID, and in-lake treatments have the greatest applicability

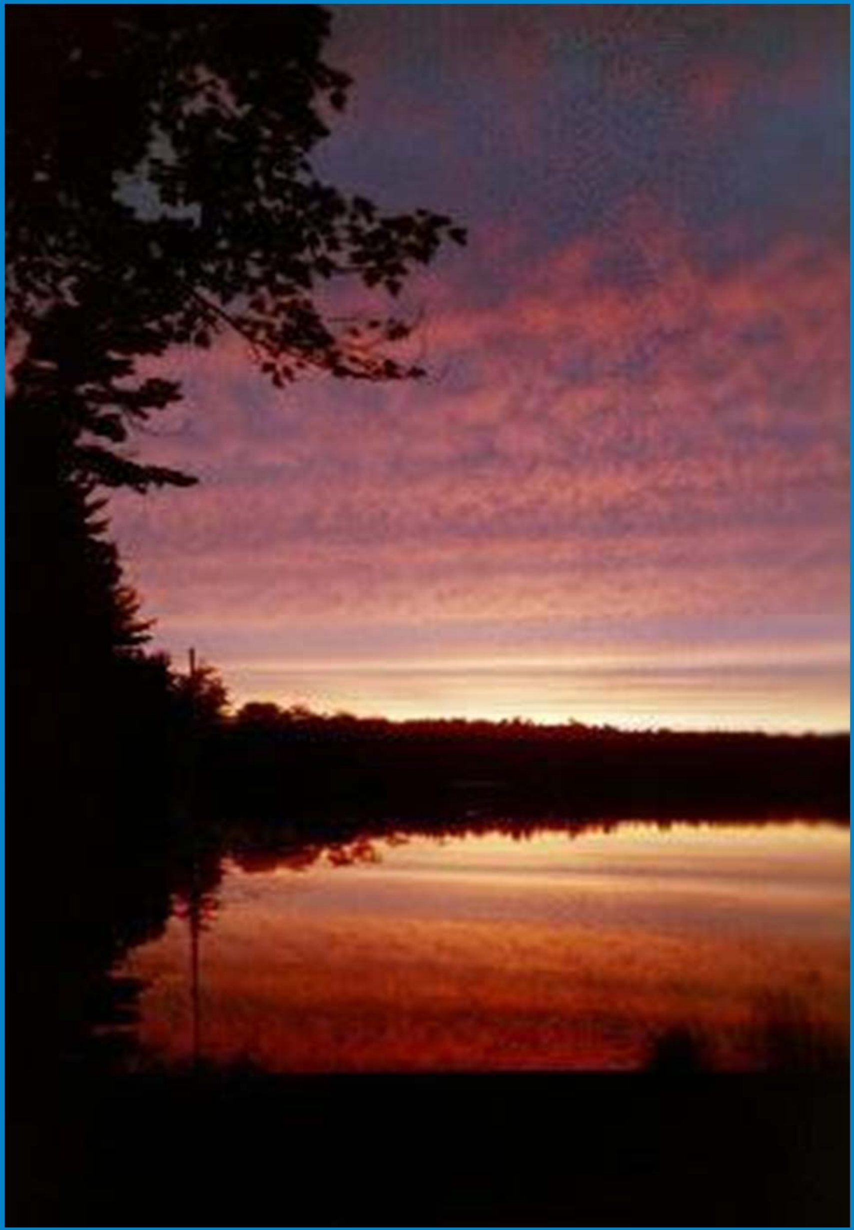


Conclusions

– Rehabilitation of severely eutrophied systems may not be realistically achievable with existing tools at application levels that are feasible and affordable

– Protecting lakes with currently desirable conditions would appear to deserve higher priority than some restoration efforts

– Rehabilitating lakes to meet designated uses may not always require extreme nutrient controls



The End

That was depressing. Shall we have another?

QUESTIONS?