Devol Pond Study

Presentation to

Devol Pond Association
Westport, Massachusetts

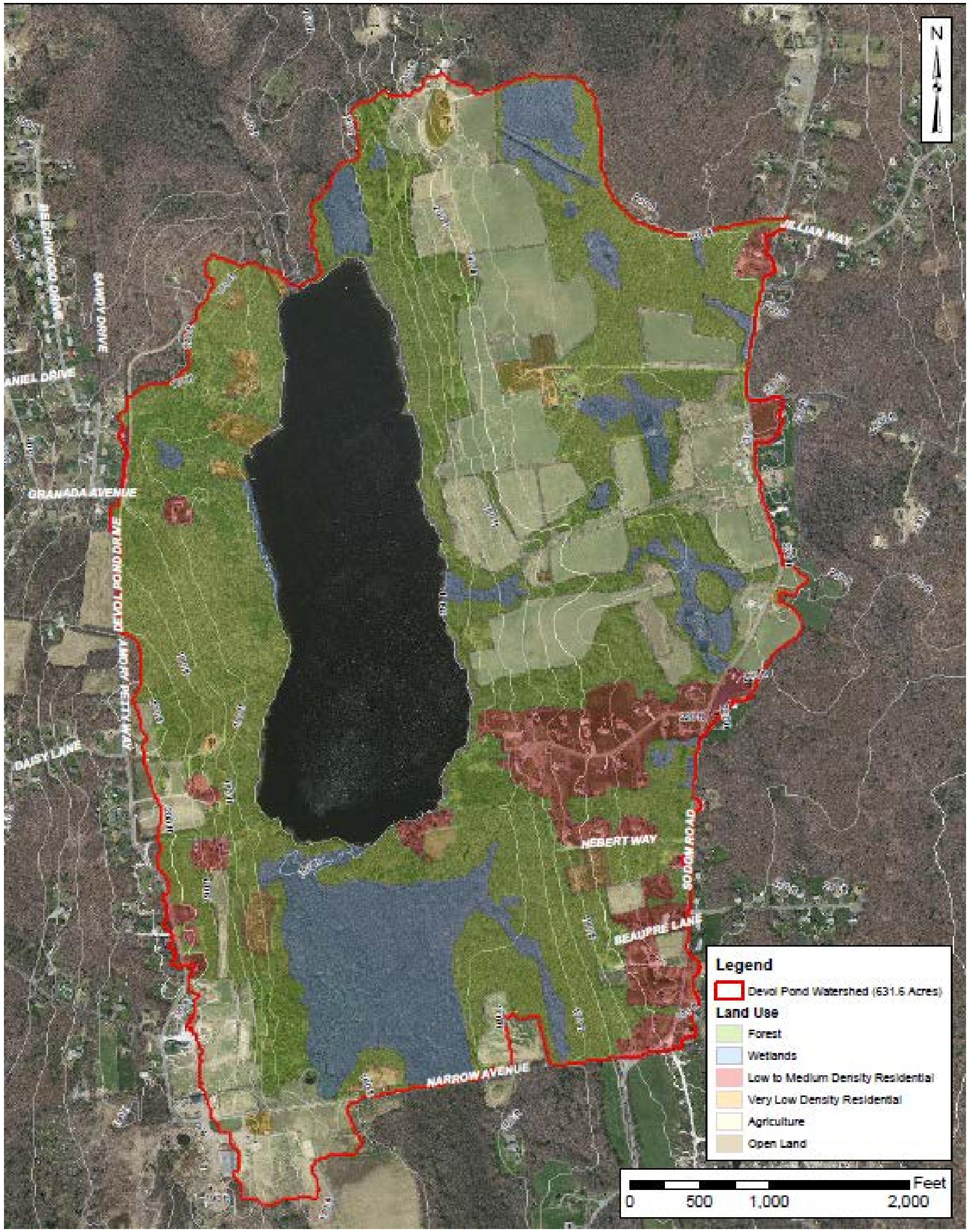
Carl Nielsen, CLM

May 18, 2013

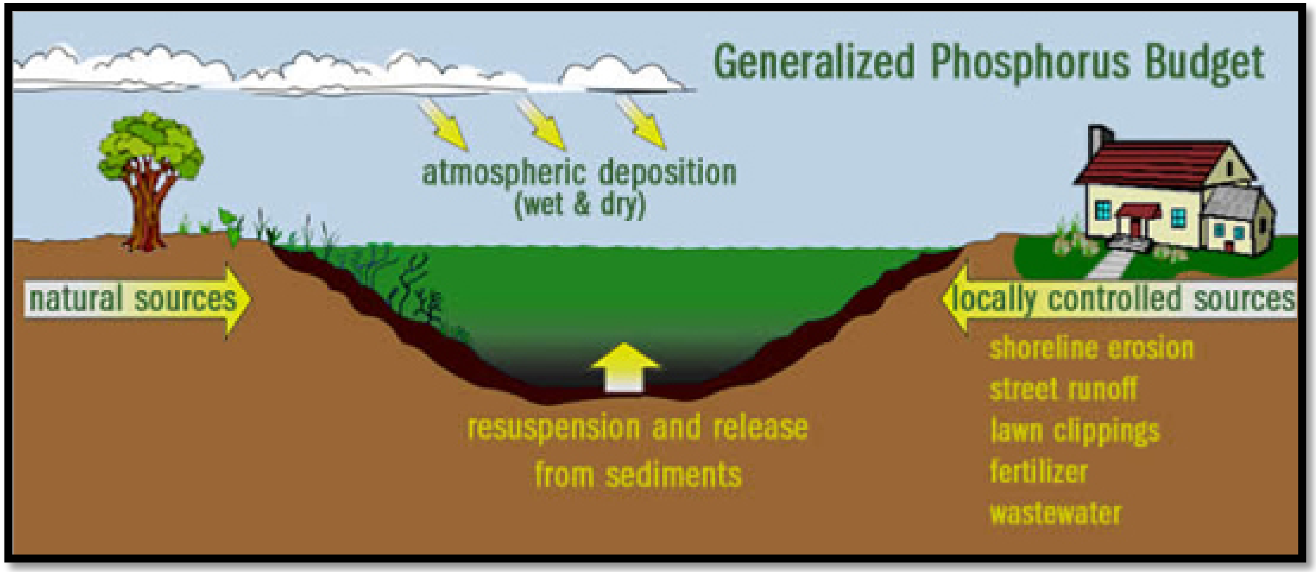
- **Purpose of Study**: To develop recommendations for solving the severe algae blooms that have occurred in recent years based on a limited amount of additional study.
- **Existing Data Review**: Reviewed Umass-Dartmouth study and WQ data collected by DPA. Used existing land use and LIDAR maps for our analysis.

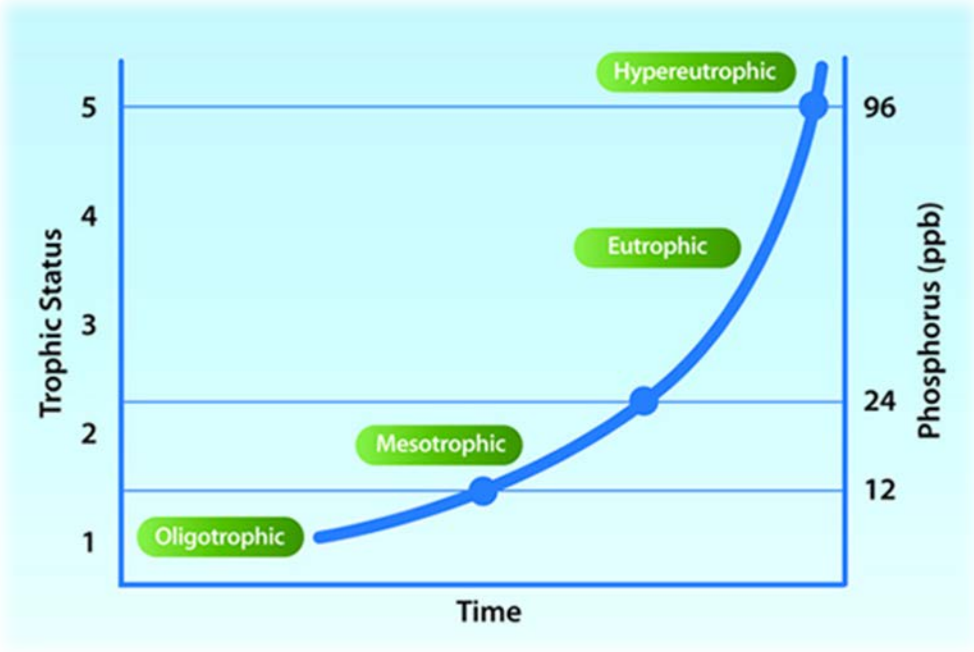
Watershed Facts:

- 632 acres with 103 acres of pond area.
- ~6:1 ratio is very good
- This means nutrient control can be achieved reasonably well
- It also means that the Enemy is Us!



Phosphorus Budget





Hydrologic Modeling for Devol Pond

Devol Pond - HYDROLOGIC ASSESSMENT

								Source:
Watershed for Devol Pond =		632.0	acres		27,529,920	SF	1 mi2	ESS delineation based on LIDAR
Pond Area		103.0	acres		4,486,680	SF	416,826 meters2	ESS, 2013, calculation in GIS
Area of Watershed - Pond Area		529.0	acres		23,043,240	SF		
Lake Circumference		8,500.0	feet					ESS, 2013, calculation in GIS
Lake Volume		26,955,682.0	cubic feet				763,300.0 meters3	ESS, 2013, calculation based on GIS and field data
Area influenced by seepage		1,062,500.0	ft2	=	98,709	m2		ESS estimate derived from pond circumference
Groundwater (data)		15	l/m2/day	=	0.530	cf/m2/day		ESS estimate for kettle hole ponds in SE Mass
				=	52,266.6	cf/day		Calculation
				=	0.605	cfs		Calculation
Annual PPT/yr		44.49	inches					Mean of Providence and Boston annual precip
Annual PPT - ET	29.81	2.48	ft/yr		0.35	cfs		Precip on pond minus regional ET
Runoff (watershed)	14.68	1.22	ft/yr		0.89	cfs		Calculation
Base Flow (Streams) as measured during dry weather - Average =					0.10	cfs		ESS measurement, 2013

	Ground	PPT	Surfacewater	Total
Dry	0.605	0.000	0.100	**0.705**
Wet	0.000	0.353	0.894	**1.247**
Total	**0.605**	**0.353**	**0.994**	**1.952** cfs

Estimated range of total annual input into lake:
(1.5 to 2 cfs/sq mi of watershed) =
1.48 to 1.98 cfs

Hydrologic Loading

Source	Load (cfs)	(m3/yr)	(%)
Direct Precipitation w/ Evapotranspiration	0.35	312,550	18.0
Ground Water Inseepage	0.61	540,265	31.0
Surface Water	0.99	887,642	51.0
Dry Weather*	0.10	89,300	5.1
Wet Weather*	0.89	798,342	45.9
Total Annual	1.95	1,740,457	100.0

*Subset of surface water total

Devol Pond Statistics:

Volume	26,955,682	cu. ft
Mean Depth	6.0	ft
Detention Time	160.1	days (0.44 yrs)
Flushing Rate	2.3	times/year
Response Time	284-473	days

Nutrient Modeling for Devol Pond

Devol Pond, Westport, Massachusetts - Existing Conditions

IN-LAKE MODELS FOR PREDICTING PHOSPHORUS LOADS AND CONCENTRATIONS

THE TERMS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE
TP	Lake Total Phosphorus Conc.	ppb	From data or model	70
L	Phosphorus Load to Lake	g P/m2/yr	From data/hydro model	0.14
TPin	Influent (Inflow) Total Phosphorus	ppb	From data	400
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data	70
I	Inflow	m3/yr	From data	1,660,814
A	Lake Area	m2	From data	416,826
V	Lake Volume	m3	From data	763,300.0
Z	Mean Depth	m	Volume/area	1.831219
F	Flushing Rate	flushings/yr	Inflow/volume	2.175833
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.175
Qs	Areal Water Load	m/yr	Z(F)	3.984427
Vs	Settling Velocity	m	Z(S)	0.320463
R	Retention Coefficient (from TP)	no units	(TPin-TPout)/TPin	0.825
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.629171
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.404029

Nutrient Modeling for Devol Pond

THE MODELS

NAME	FORMULA	PREDICTION CONC. (ppb)	PREDICTION LOAD (g/m2/yr)
Mass Balance	TP=L/(Z(F))*1000	35	
(minimum load)	L=TP(Z)(F)/1000		0.28
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	13	
(K-D)	L=TP(Z)(F)/(1-Rp)/1000		0.75
Vollenweider 1975	TP=L/(Z(S+F))*1000	33	
(V)	L=TP(Z)(S+F)/1000		0.30
Reckhow 1977 (General)	TP=L/(11.6+1.2(Z(F)))*1000	6	
(Rg)	L=TP(11.6+1.2(Z(F)))/1000		1.15
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	21	
(L-M)	L=TP(Z)(F)/(1-Rlm)/1000		0.47
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	23	
(J-B)	L=TP(Z)(0.65+F)/0.84/1000		0.43
Average of Model Values		19	
(without mass balance)			0.62
Reckhow 1977 (Anoxic)	TP=L/(0.17(Z)+1.13(Z(F)))*1000	29	
(Ra)	L=TP(0.17(Z)+1.13(Z(F)))/1000		0.34
From Vollenweider 1968			
Permissible Load	Lp=10^(0.501503(log(Z(F)))-1.0018)		0.20
Critical Load	Lc=2(Lp)		0.40

LOAD ANALYSIS

MODEL	ESTIMATED LOAD (kg/yr)	ESTIMATED LOAD (mg/L)
Phosphorus		
Mass Balance (no loss)	116	
Kirchner-Dillon 1975	314	
Vollenweider 1975	126	
Reckhow 1977 (General)	478	
Larsen-Mercier 1976	195	
Jones-Bachmann 1976	180	
Model Average		
(without mass balance)	258	0.1556
Reckhow 1977 (Anoxic)	140	
Permissible Load	83	0.0500 Permissible Conc.
Critical Load	166	0.1000 Critical Conc.

PREDICTED WATER CLARITY

PREDICTED CHL AND WATER CLARITY

MODEL	Value
Mean Chlorophyll (ug/L)	
Dillon and Rigler 1974	5.2
Jones and Bachmann 1976	6.0
Oglesby and Schaffner 1978	8.0
Modified Vollenweider 1982	9.5
"Maximum" Chlorophyll (ug/L)	
Modified Vollenweider (TP) 1982	28.3
Vollenweider (CHL) 1982	21.1
Mod. Jones, Rast and Lee 1979	24.7
Secchi Transparency (M)	
Oglesby and Schaffner 1978 (Avg)	2.4
Modified Vollenweider 1982 (Max)	4.3

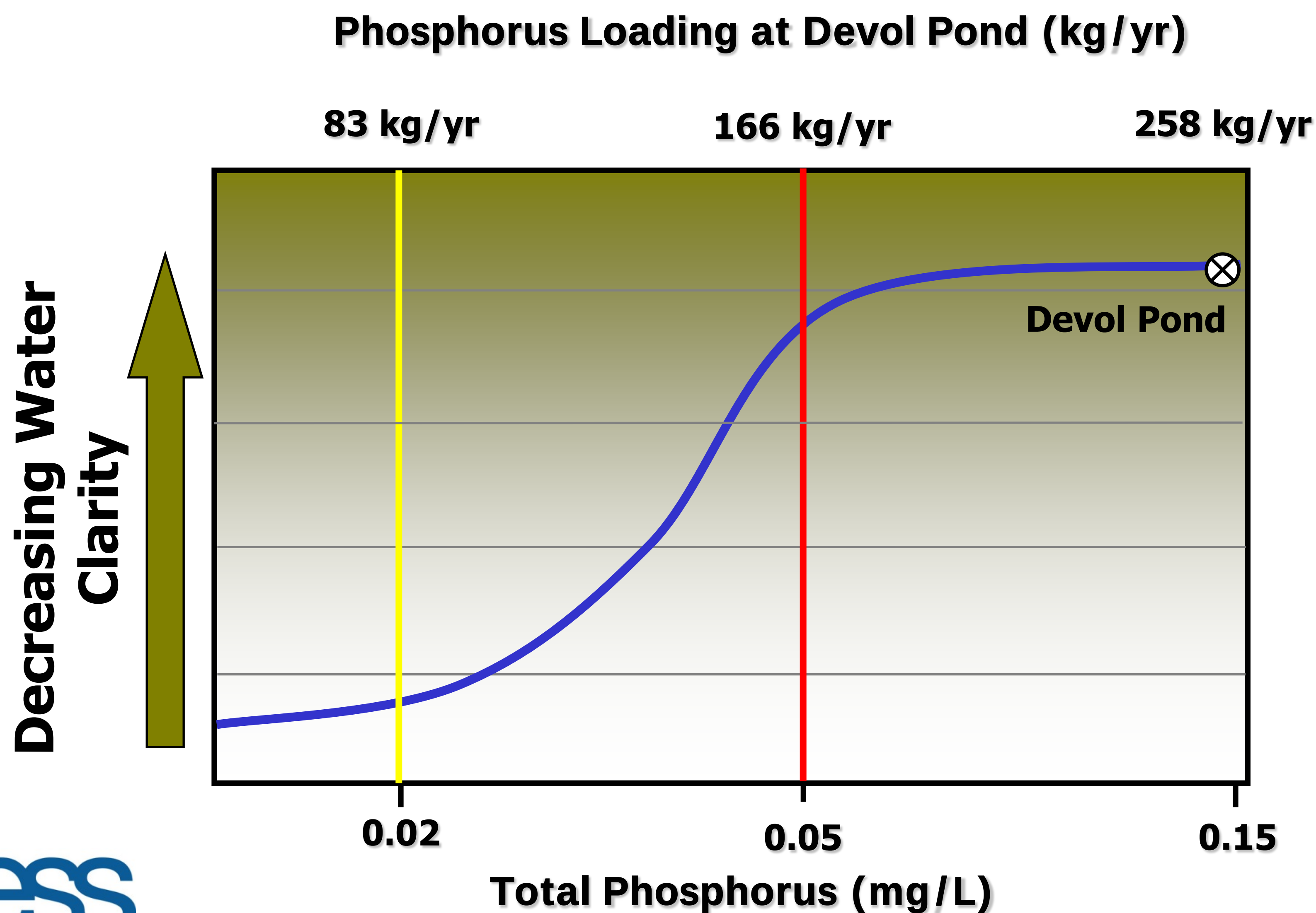
ess group

Modeled Phosphorus Loading

Nutrient loads for Devol Pond.	
Variable	**Total Phosphorus**
In-lake concentration (mg/l)	0.035
Min. load g/m2/yr	0.28
In-lake Predictive Models	
Kirchner-Dillon (P) g/m2/yr	0.75
Vollenweider (P) g/m2/yr	0.30
Reckhow (general P) g/m2/yr	1.15
Larsen and Mercier (P) g/m2/yr	0.47
Jones and Bachman (P) g/m2/yr	0.43
Average all phosphorus models g/m2/yr	0.62
Average all phosphorus models kg/yr	**258.0**
Vollenweider's permissible	
load g/m2/yr	0.2
load kg/yr	**83**
load mg/L	0.05
Vollenweider's critical	
load g/m2/yr	0.4
load kg/yr	**166**
load mg/L	0.10

Key!

Relationship Between Phosphorus and Water Clarity



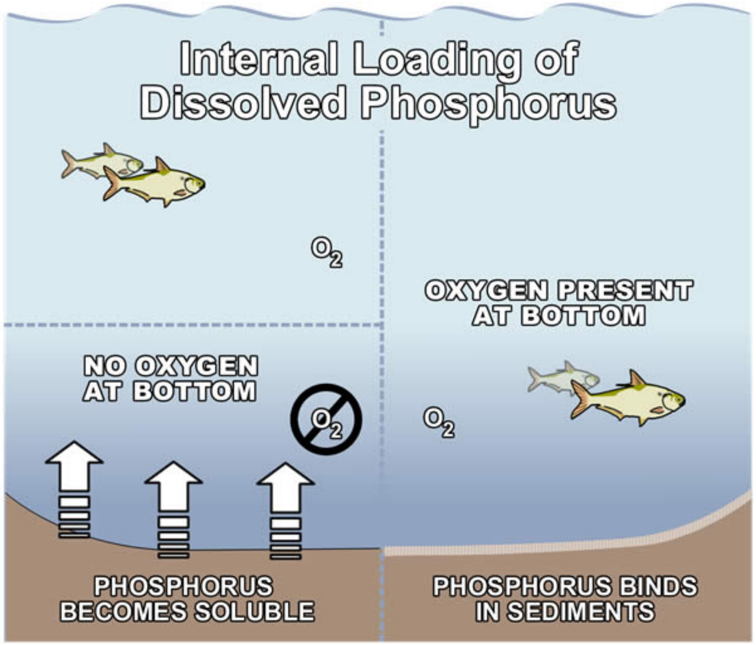
Phos Load by Source

Annual phosphorus loads (kg/yr) for Devol Pond listed by source as derived from in-field measurements, regional data, and hydrologic modeling.

Source	Phosphorus Loads (kg/yr)	(%)
Direct Precipitation*	6.30	2.4%
Ground Water Inseepage*	16.6	6.4%
Surface Water		
Dry Weather	66.0	25.6%
Wet Weather	72.0	27.9%
Internal Release (from lake sediments)*	97.1	37.6%
Total Annual	**258.0**	**100.0%**

* Modeled not measured

Measuring Phosphorus Release from Sediment



Assessment Needs:

a) Area that goes anoxic

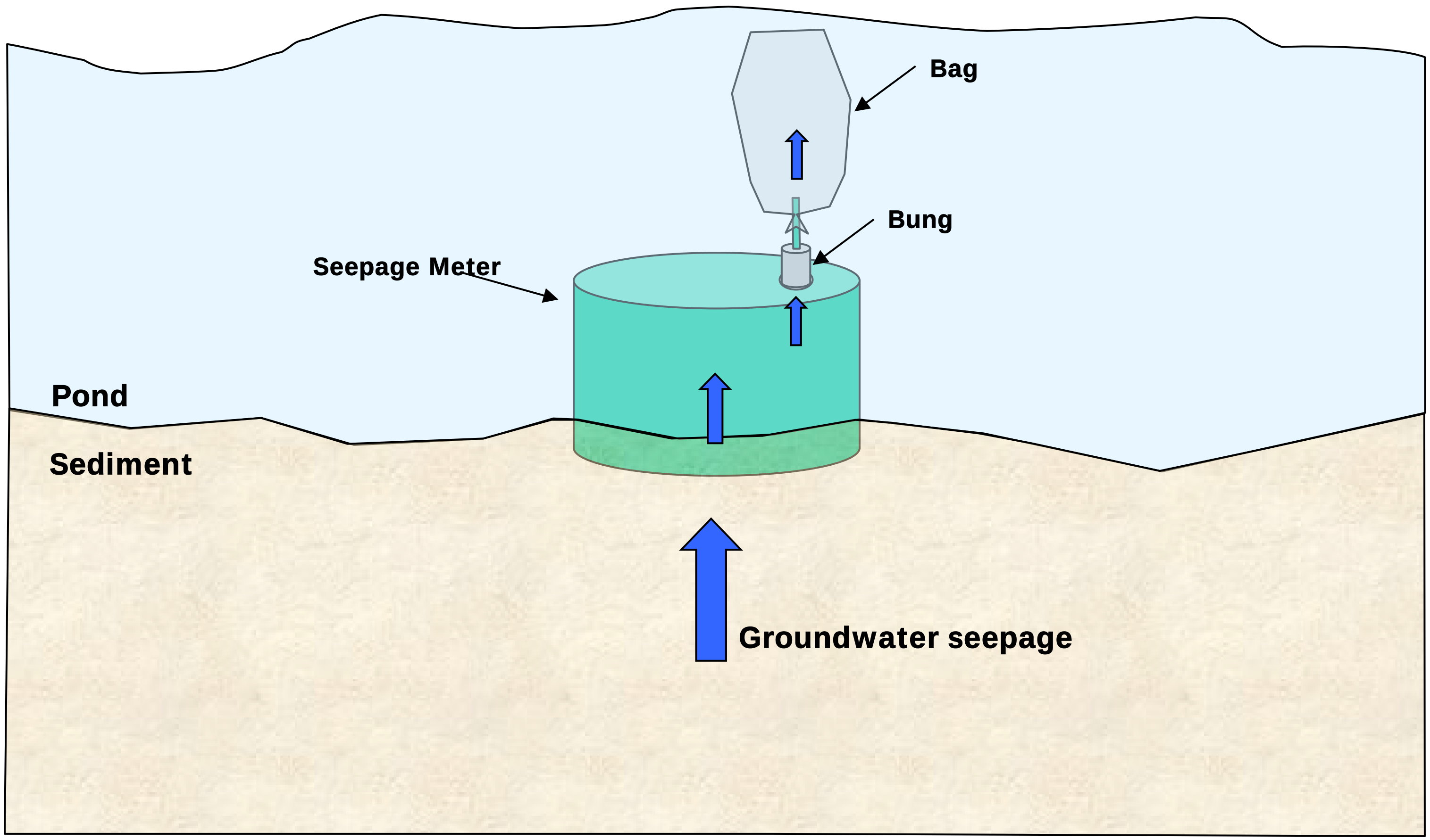
b) Length of anoxic condition

c) Phos release rate during anoxia

d) Alum dose needed – "jar testing"

ess group

Measuring Groundwater Quantity and Quality



Options and Recommendations

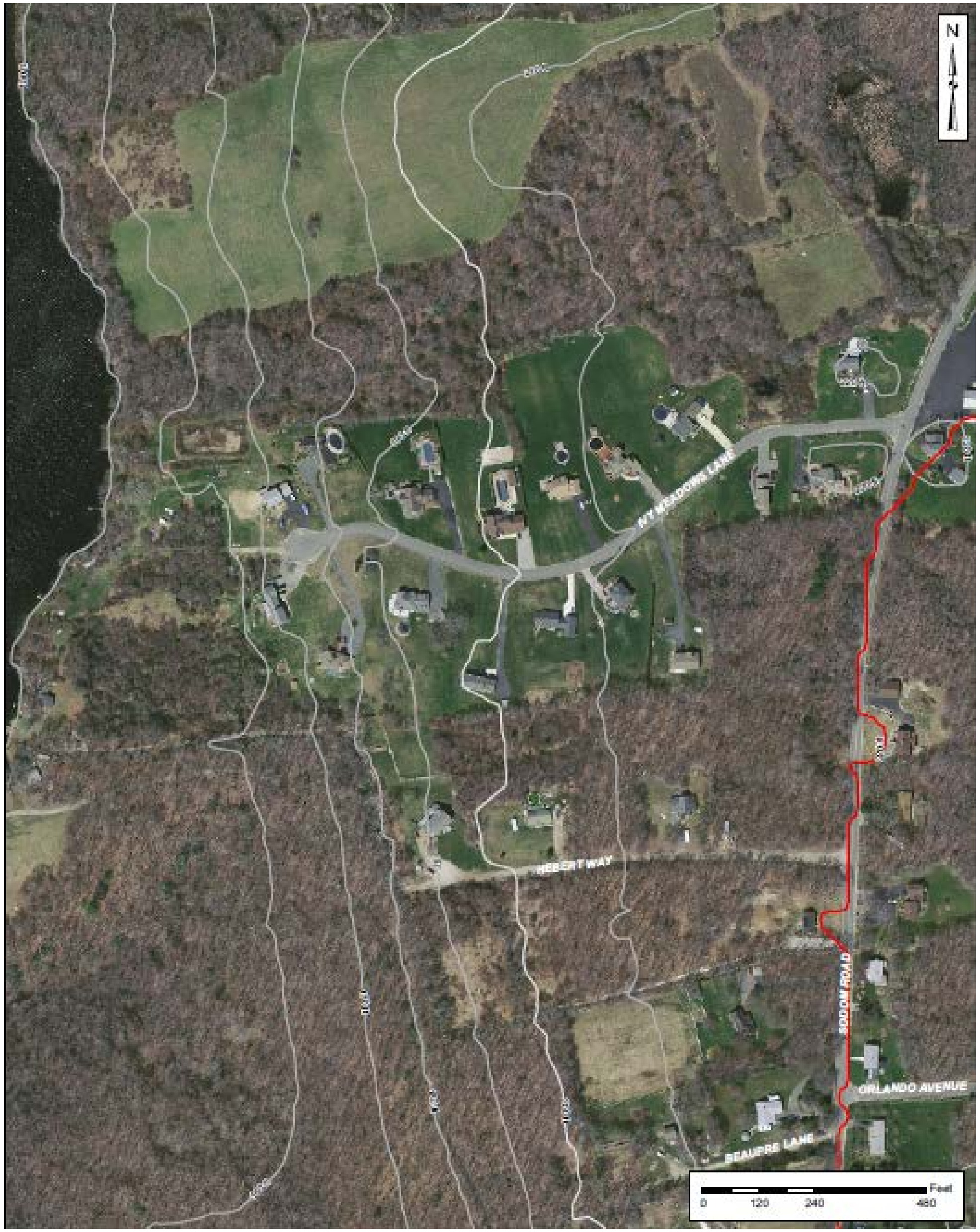
The Enemy is Us:

a) Most residential areas in watershed are over fertilized

b) Pasture lands need to have larger buffers between streams and shorelines

c) Street vacuum more frequently

d) Grade dirt roads to direct flow to wooded areas rather than streams or pond

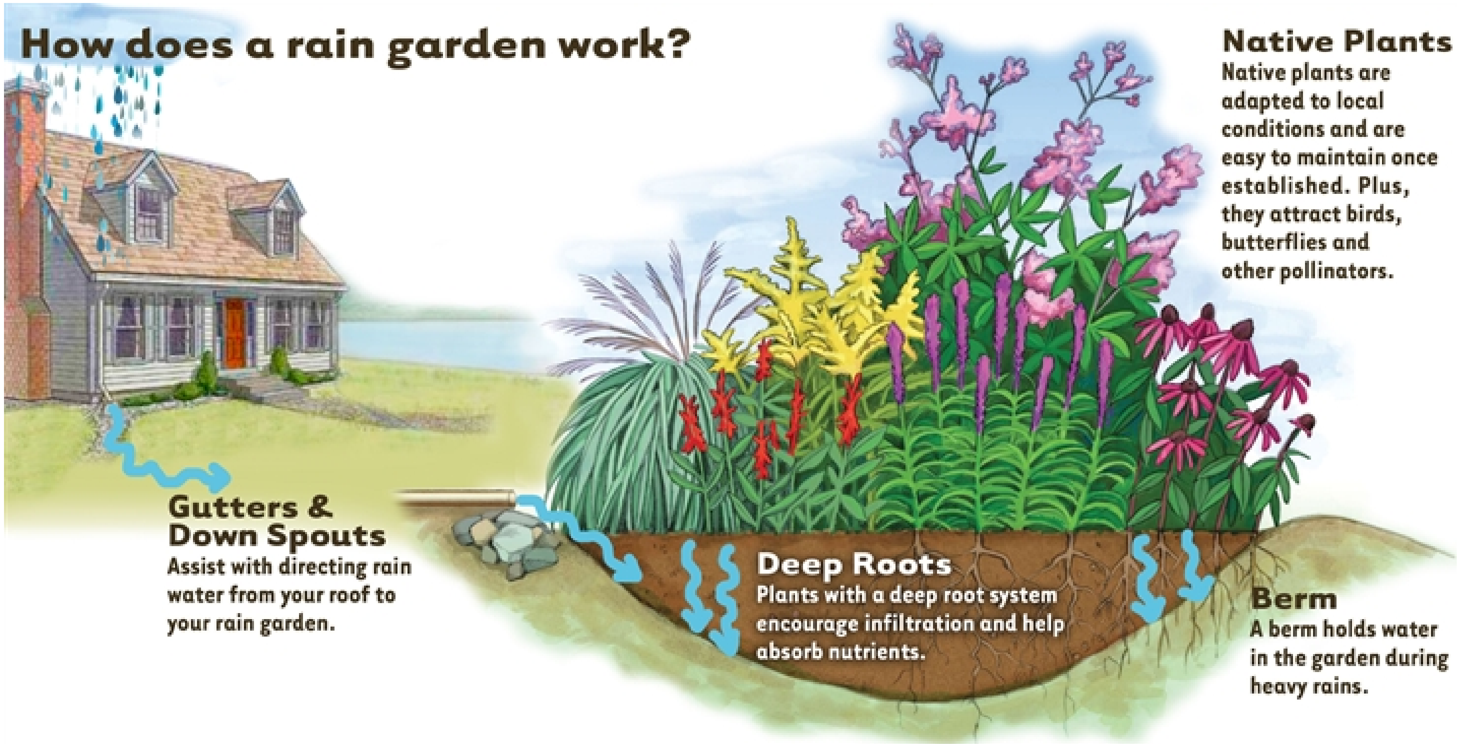


Structural BMPs

- **Stopping source always best option**
- **Swales and Check-dams:** Encourage infiltration and plant uptake

RECOMMENDED

Residential Rain Gardens

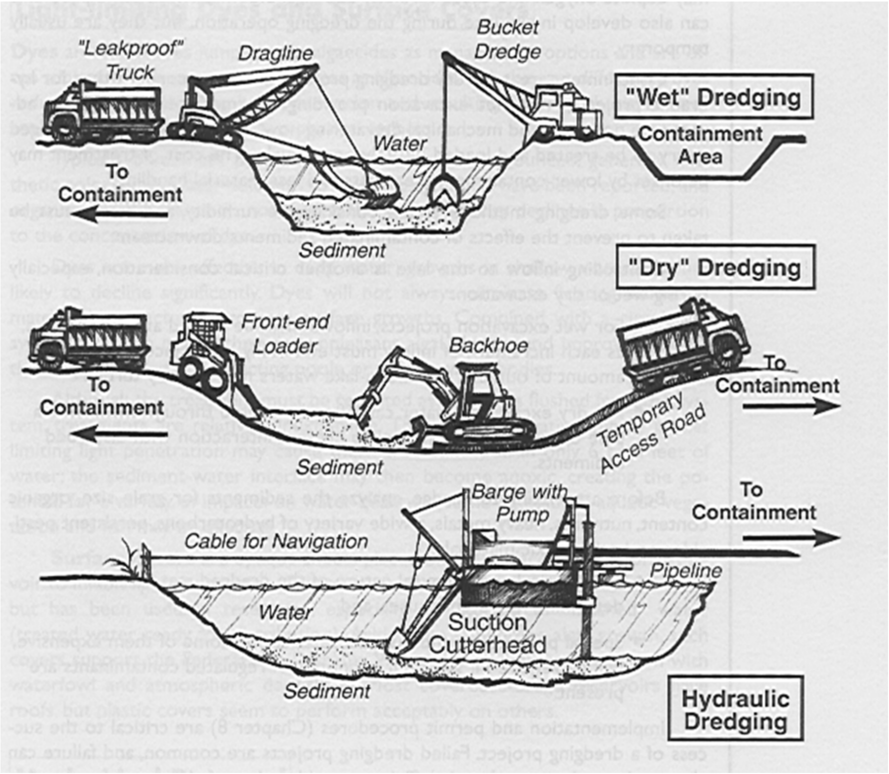


RECOMMENDED

ess group

Dredging

- Removal of sediment from the bottom of a lake, pond, or river
- Typically, only the overlying, unconsolidated soft sediments are removed, but deeper dredging can be done too.
- Dredging is most often used to increase depth for navigation; however, it can be used as a lake management technique to control aquatic invasive species and algae blooms
- Invasive plant populations are reduced through the removal of the nutrient-rich, unconsolidated sediment layer



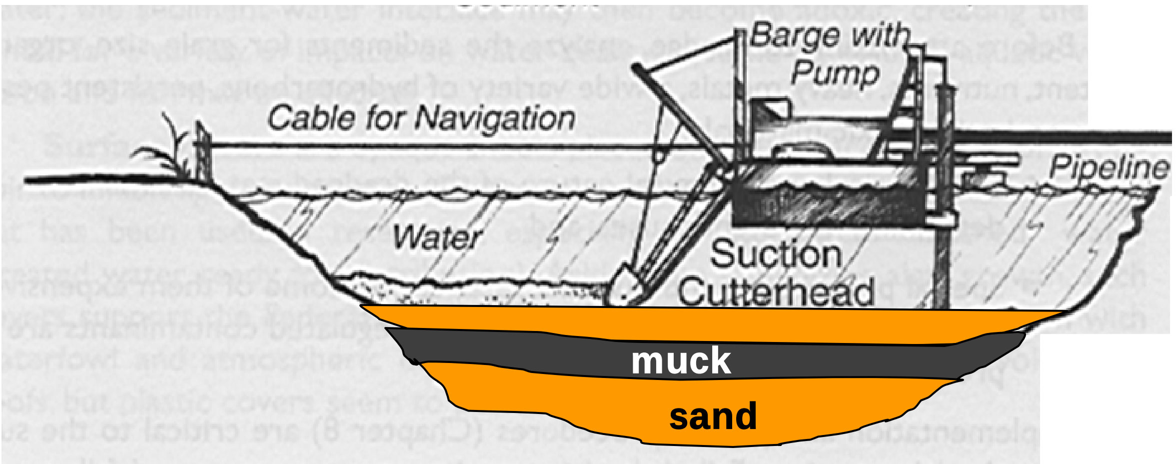
Not Ideal:

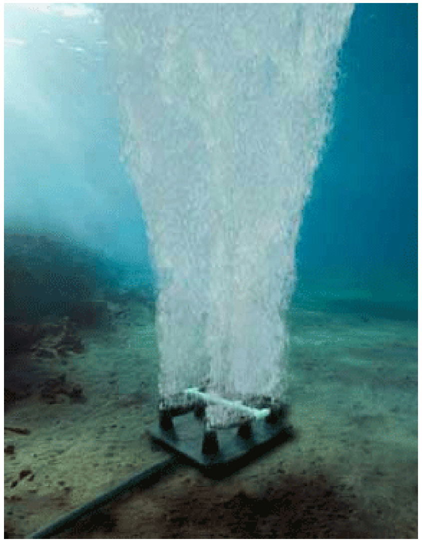
a) High initial cost

b) May not last long-term

Rejected

Sediment Inversion/Lake Aeration/Circulation





Rejected

Not Ideal:

a) High initial cost

b) Unproven results

c) Annual expense for maintenance and energy

d) Navigation issue

ess group

Algaecides:

a) Proven and quick

b) Very economical and generally easy to permit

c) Copper or alum are options, Alum better

d) Does not address underlying problems

e) Potential for long-term negative ecological impacts

f) Recommended as a short-term solution only

g) $12,000/yr for 1ppm alum

h) $5,000/yr copper

i) $4,000 one-time permitting

RECOMMENDED

Nutrient Inactivation - Alum

Alum Dosing Calculations and Cost for Devol Pond, Westport, MA

	Devol Pond			
Lake or Area	**Option 1**	**Option 2**	**Option 3**	**Notes:**
Mean Available Sediment P (mg/kg DW)	700.0	500.0	300.0	Final determination will be based on field testing of sediment prior to treatment
Target Depth of Sediment to be Treated (cm)	5	5	5	
Volume of Sediment to be Treated per m2 (m3)	0.050	0.050	0.050	
Specific Gravity of Sediment	1.10	1.10	1.10	
Percent Solids (as a fraction)	0.20	0.20	0.20	
Mass of Sediment to be Treated (kg/m2)	11.0	11.0	11.0	
Mass of P to be Treated (g/m2)	7.70	5.50	3.30	
Target Area (ac)	**50**	**50**	**50**	Area treated will depend on funding availability with 25 acre min and 75 acre max.
Target Area (m2)	201613	201613	201613	
Aluminum sulfate (alum) @ 11.1 lb/gal and 4.4% aluminum (lb/gal)	0.4884	0.4884	0.4884	
Sodium aluminate (aluminate) @ 12.1 lb/gal and 10.38% aluminum (lb/gal)	1.256	1.256	1.256	
Stoich. Ratio (ratio of Al to P in treatment)	10	10	10	
Resulting areal dose (g Al/m2)	77	55	33	
Ratio of alum to aluminate during treatment (volumetric)	2	2	2	
Aluminum Load				
Dose (kg/area)	15524	11089	6653	
Dose (lb/area)	34153	24395	14637	
Dose (gal alum) with Alum only	69929	49949	29969	
Application (gal/ac) for alum	1399	999	599	
Dose (gal alum) @ specified ratio of Alum to Aluminate	28793	20566	12340	
Dose (gal aluminate) @ specified ratio of Alum to Aluminate	15996	11426	6855	
Application (gal/ac) for Alum in Alum+Aluminate Trtmt	576	411	247	
Application (gal/ac) for Aluminate in Alum+Aluminate Trtmt	320	229	137	
Anticipated days of treatment in area	10	7	5	
Unit Cost				
Alum	$1.25	$1.25	$1.25	Rate set by market at time of treatment
Aluminate	$2.75	$2.75	$2.75	Rate set by market at time of treatment
Chemical Cost				
Alum only	$87,411	$62,436	$37,462	
Alum + Aluminate	$79,980	$57,129	$34,277	
Labor Cost				
Application (assumes 5,000 gal/day)	$49,789	$36,992	$24,195	
Mobilization/Contingencies (assumes 1 day/50 ac)	$5,000	$5,000	$5,000	
Monitoring (assumes 1 day/trtmt day + 12 days + 20% for lab costs)	$21,064	$17,686	$14,308	
Permitting (Studies/NOI)	$12,000	$12,000	$12,000	
In-Kind Design	$0	$0	$0	
Permitting Assistance, Volunteer Monitoring, Education	$0	$0	$0	
Cost Summary (alum only)	$175,264	$134,115	$92,965	
Cost Summary (alum + aluminate)	$167,834	$128,807	$89,780	
Cost Summary (Phoslock)	$247,814	$185,936	$124,057	

RECOMMENDED

Proposed Long-Term Monitoring Program for Devol Pond.

Parameter	Utility	Proposed Locations	Proposed Frequency
Secchi transparency	Water clarity	In-lake	2/yr, June, August
Total phosphorus	Fertility	In-lake (Surface) and tribs.	2/yr, June, August
Total nitrogen	Fertility	In-lake (Surface) and tribs.	2/yr, June, August
Temperature	Fish health	In-lake (Surface)	2/yr, June, August
Dissolved Oxygen	Fish health	In-lake (Surface)	2/yr, June, August
pH	Fish health	In-lake (Surface)	2/yr, June, August
Conductivity	Dissolved solids	In-lake (Surface)	2/yr, June, August
Turbidity	Suspended solids	In-lake (Surface) and tribs.	2/yr, June, August
Plant density/distrib.	Plant nuisances	In-lake	Annually, August

Each year conduct basic assessment to track trends, adjust management.

Cost of Annual Program: $2,500 or do with volunteers for $1,000

RECOMMENDED

ess group

Summary

- **Our Study Findings**:
  a) Phosphorus (the limiting nutrient) is off-the-charts high.
  b) Significant amount of P likely emanating from sediment
  c) Additional loading from watershed, although only a few direct surface water discharges to manage.
- **Modeling Results**:
  a) The pond is receiving 258 kg/yr P and needs to be well below 166 kg/yr to see marked improvement in WQ.
  b) 97 kg/yr is likely due to internal sediment releases although additional study is warranted to quantify accurately.

Recommendations

Watershed Actions

a) Reduce watershed loads through education of residents on fertilizer use – newsletter, brochures, workshops, etc.

b) Maintain or enhance buffers to streams in agricultural areas

c) Design and install rain gardens in residential areas

Short-term In-Pond

a) Consider low-dose alum annually in early June – 1ppm

b) Alternatively, cheaper copper treatments when blooms begin

Long-term In-Pond

a) Consider nutrient inactivation through high-dose alum treatment to reduce source of internal phosphorus load

ess group