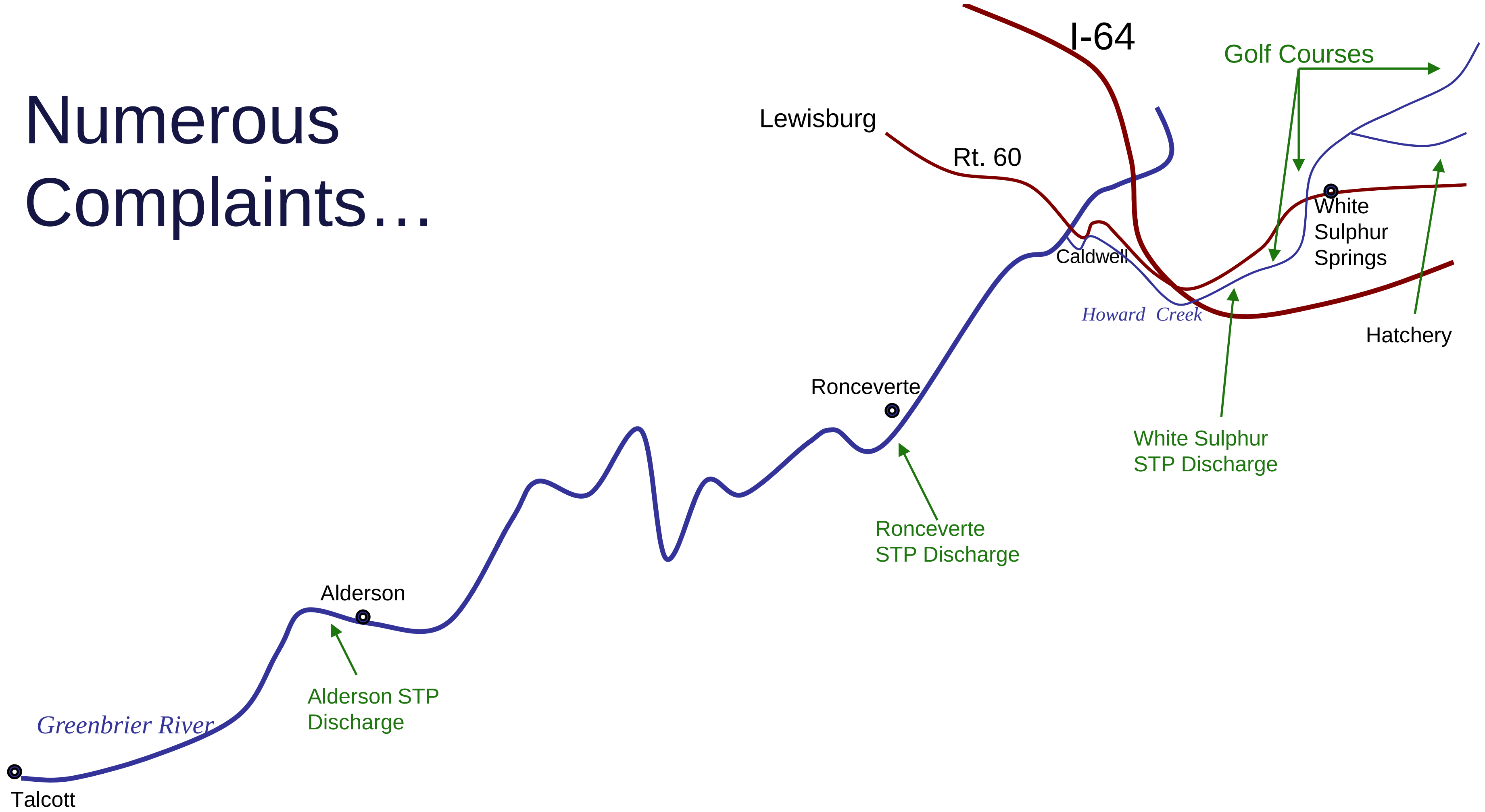
Nutrient Impacts in West Virginia Rivers and Streams

The Importance of Hardness in Developing Phosphorus Criteria

Numerous Complaints…



Greenbrier @ Howard Creek

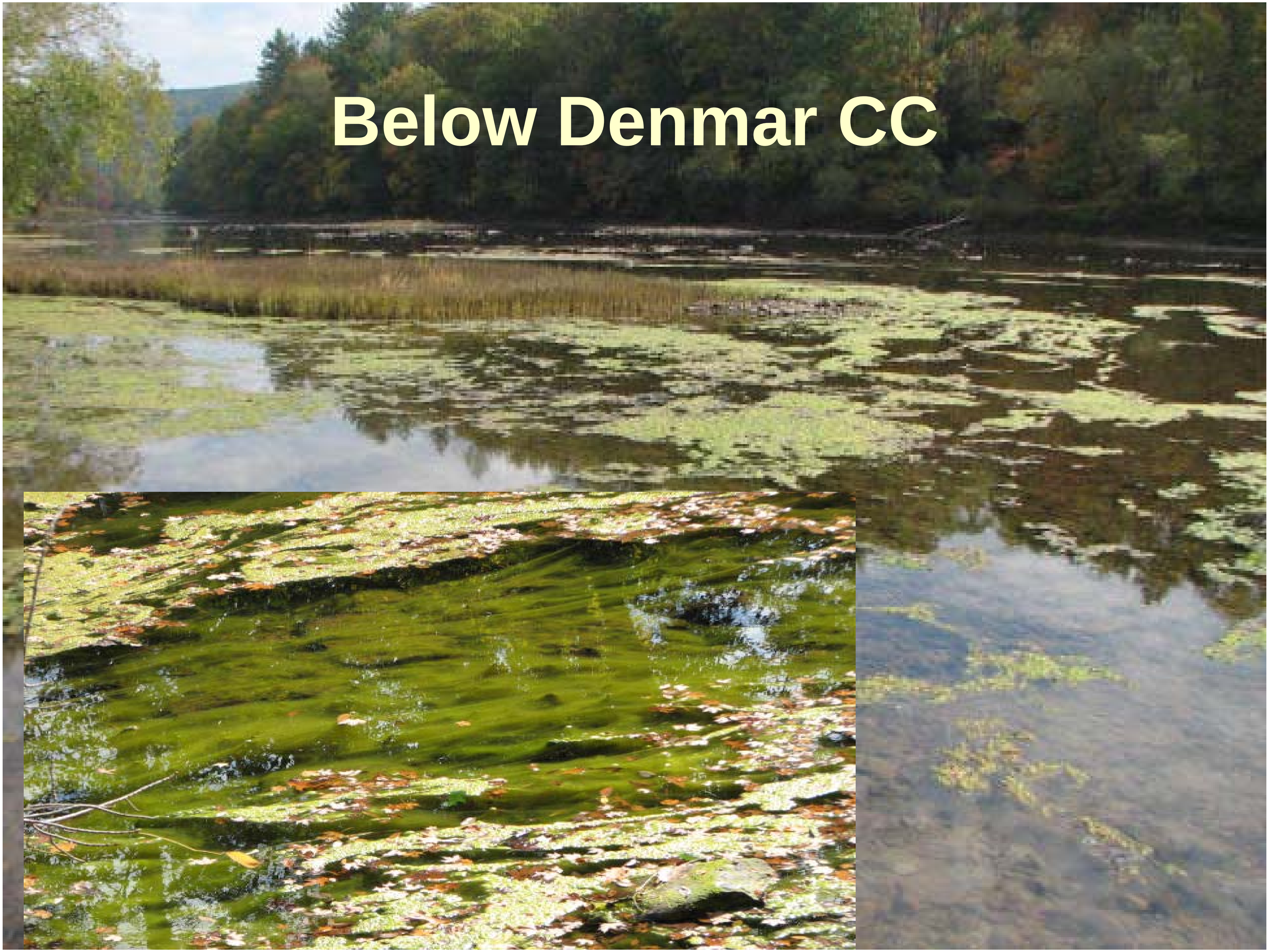
The river is about 3-4 feet deep, and the water column is full of algae on this side of the river.

Below Ronceverte

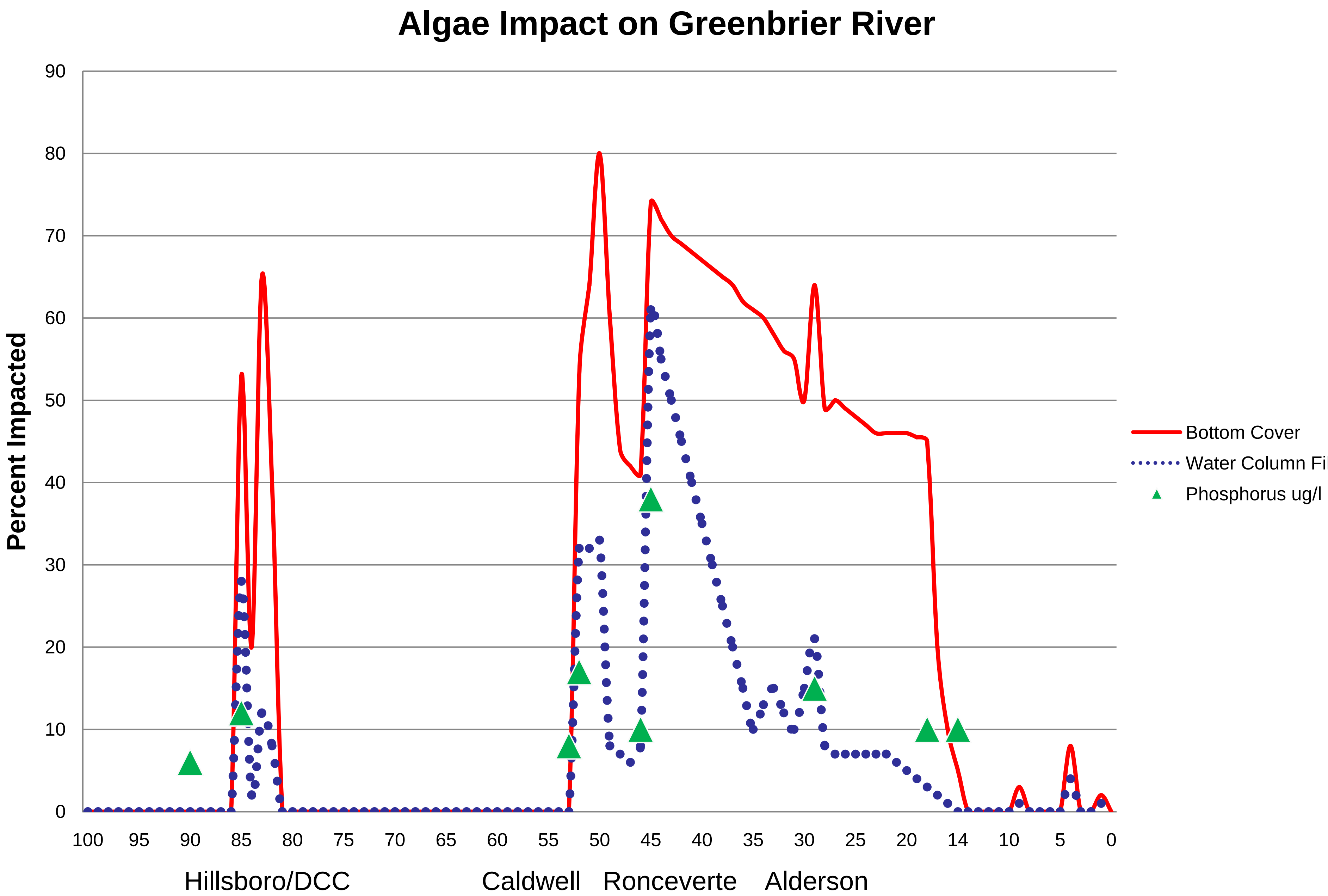
Above Davis Spring (2008)

Upstream….

Below Denmar CC



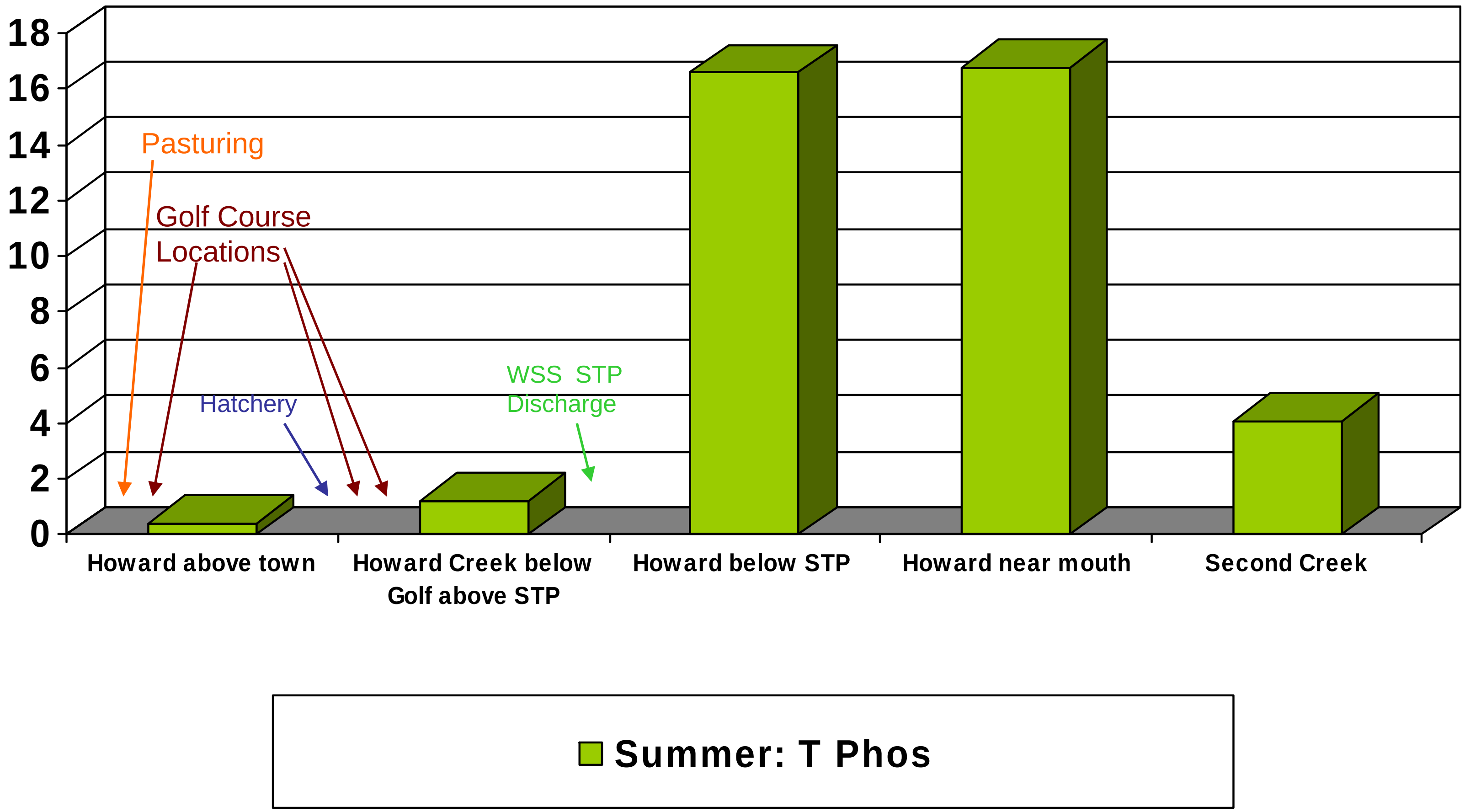

Hillsboro STP



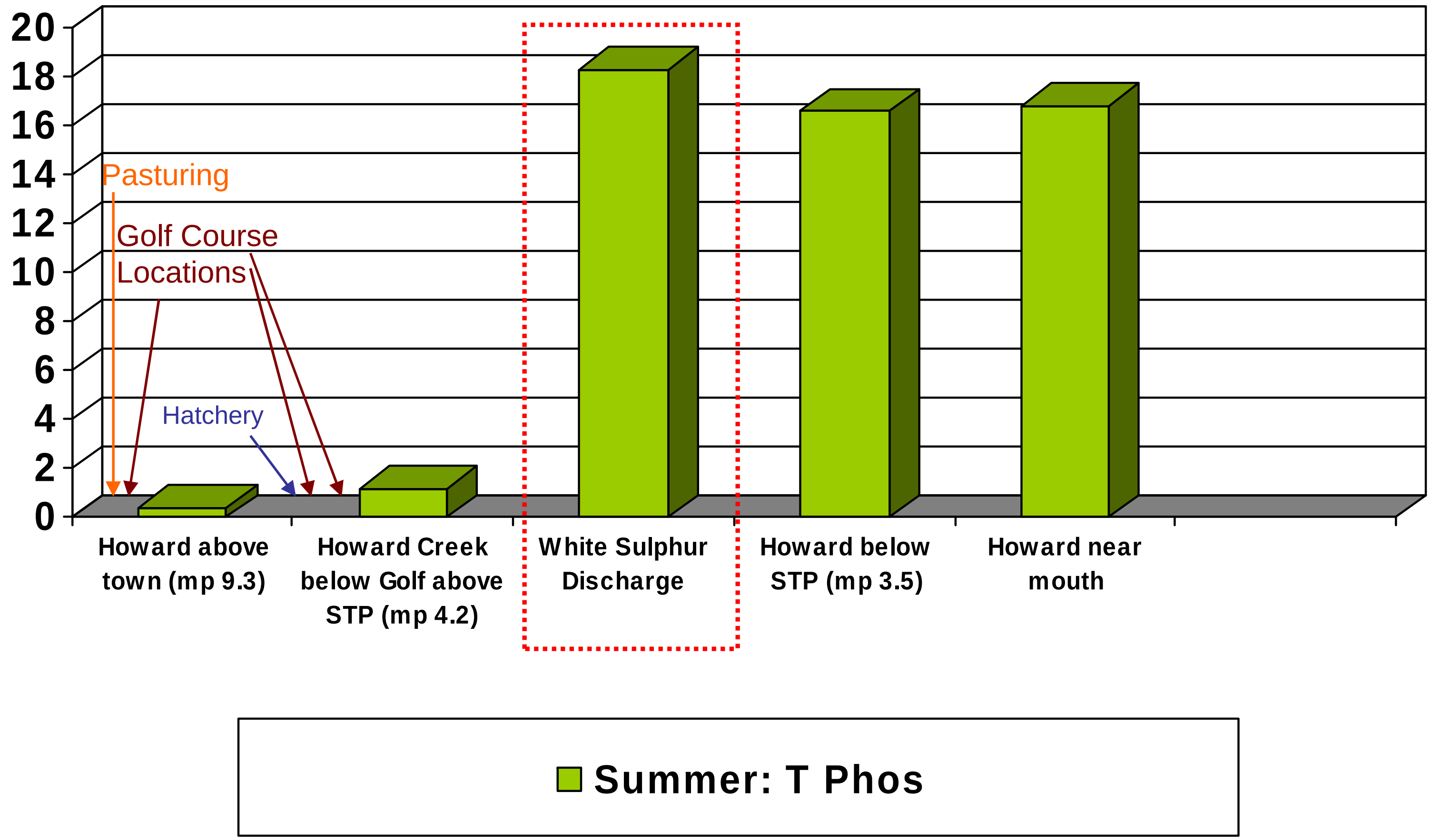
Algae Impact on Greenbrier River
Percent Impacted
90
80
70
60
50
40
30
20
10
0
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
14
10
5
0
Hillsboro/DCC
Caldwell
Ronceverte
Alderson
Bottom Cover
Water Column Fill
Phosphorus ug/l

Howard Creek

Summer T. Phos Loading (lbs/day)

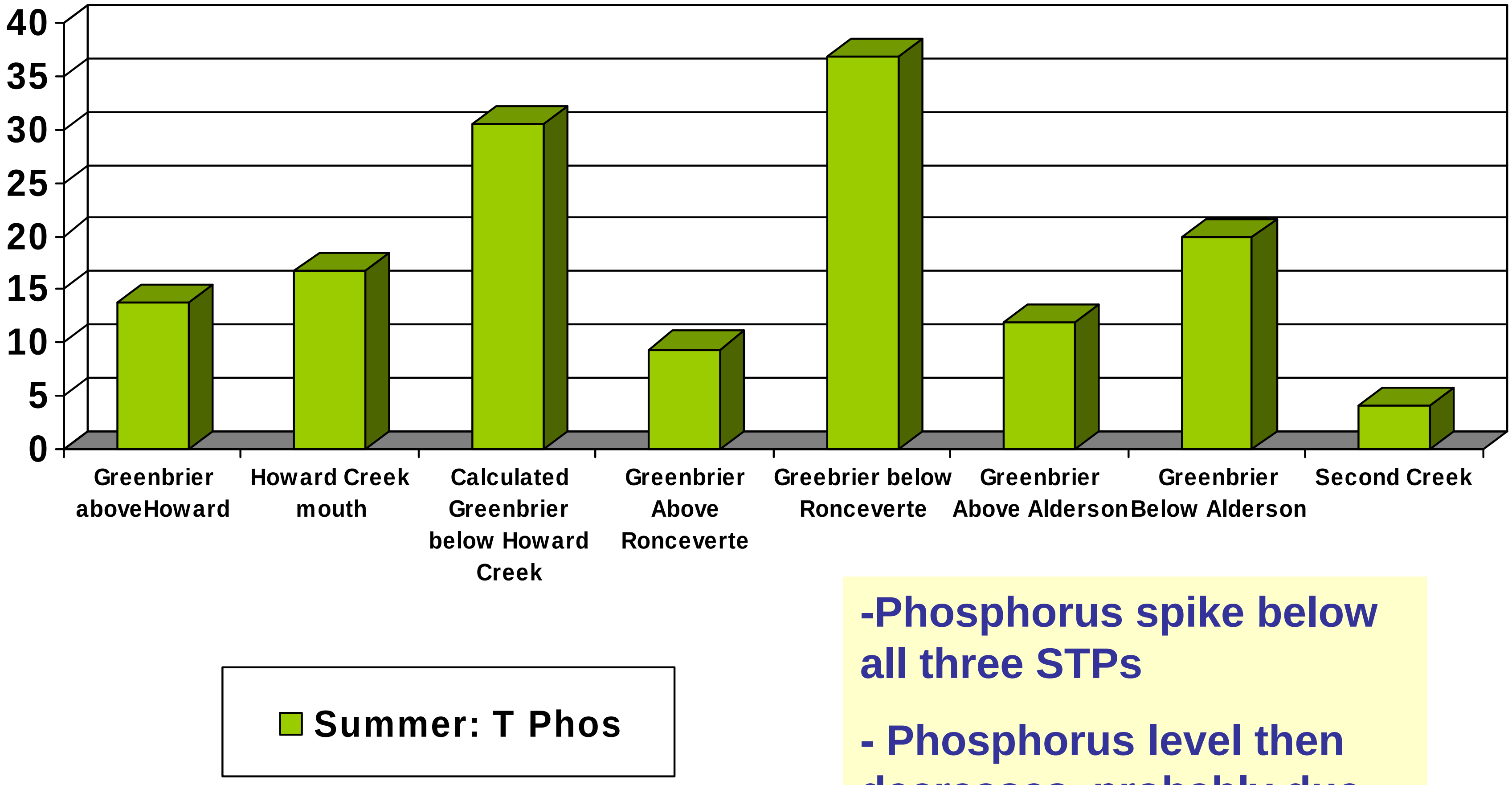


Summer T. Phos Loading (lbs/day)



An average of the Total Phos in the STP discharge seems to account for the majority of the phosphorous addition at this point in the stream.

Summer T. Phos Loading *(lbs/day)*



-Phosphorus spike below all three STPs

- Phosphorus level then decreases, probably due to algae uptake.

Source Tracking Conclusions

- Filamentous algae clearly correlated with P-discharge from WWTPs along the Greenbrier River

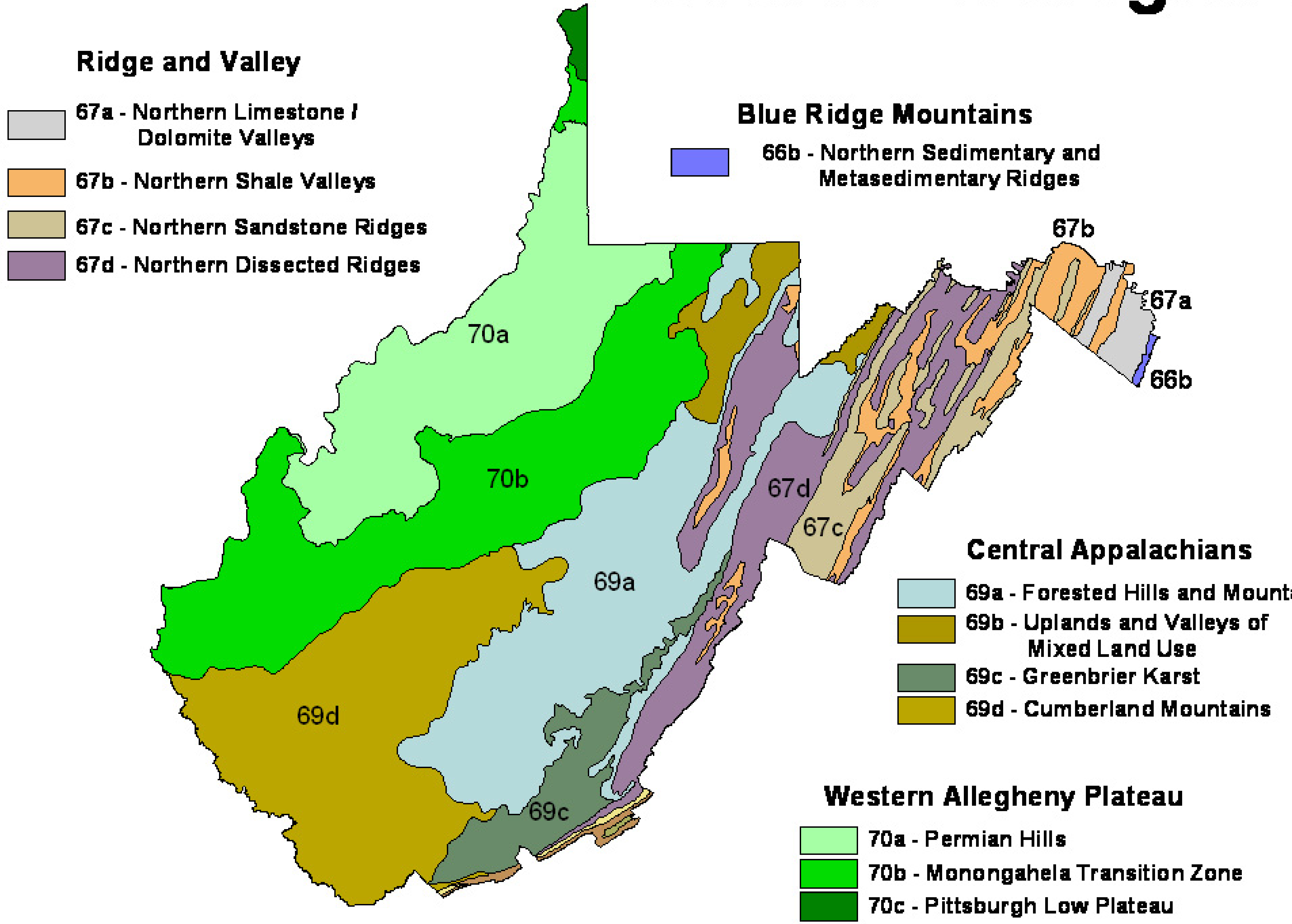
  http://www.wvdep.org/Docs/16873_Assessment_Filamentous_Algae_Greenbrie_%20River.pdf

- Why weren't other rivers experiencing similar problems???

Can you find what is different?

	hardness	Alk	pH	T. Phos	NO3-NO2
Tug Fork	220	124	6.8-8.3	0.052	0.56
Coal River	205	110	7.2-8.2	0.017	0.854
Dunkard Creek	134	89	7.2-8.6	0.06	0.57
West Fork River	252	68	6.7-8.0	0.06	0.56
South Branch of Potomac	105	85	7.4-9.1	0.075	0.5
Shenandoah River	175	117	7.7-8.8	0.07	0.98
Opequon Creek	292	211	7.3-8.5	0.25	2.1
Indian Creek	202	189	7.6-8.3	0.088	1.7
Greenbrier River	50	60	6.6-8.6	0.018	0.46

Level IV Ecoregion



Similar Chemistry…

Tygart Valley River
Cacapon River
Bluestone River
New River
NF Hughes River
Greenbrier River

Tygart Valley River

T. Phos	0.04
Alk	44
Hardness	71

Cacapon River

T. Phos	0 .021
Alk	56
Hardness	98

New River

T. Phos	0.03
Alk	60
Hardness	80



South Fork of South Branch Potomac

T. Phos	0.01
Alk	91
Hardness	130

South Branch-Franklin

T. Phos	0.01
Alk	123
Hardness	128

South Branch (OF)

T. Phos 0..43
Alk 97
Hardness 141

Shenandoah River

T. Phos	0.07
Alk	117
Hardness	174

River	Avg. Hardness (mg/l)	Algae Development
Greenbrier River	65	Severe
North Fork Hughes River	63	Low [T]
Tygart Valley River	70	High
New River	79	Moderate [D]
Kanawha River	85	None [T]
Cacapon River	96	High
South Fork/South Branch Potomac River	112	Moderate
Bluestone River	121	Moderate
South Branch Potomac River	130	Low-Moderate
Guyandotte River	145	None
West Fork River	190	None
Monongahela River	149	None
Tug Fork	178	None
North Branch Potomac River	214	None
Shenandoah River	174	None
Birch River	221	None
Coal River	284	None
Mud River	373	None

River	Avg. Hardness (mg/l)	Algae Development
Greenbrier River	65	Severe
Tygart Valley River	70	High
Cacapon River	96	High
South Fork/South Branch Potomac River	112	Moderate
Bluestone River	121	Moderate
South Branch Potomac River	130	Low-Moderate
Guyandotte River	145	None
West Fork River	190	None
Monongahela River	149	None
Tug Fork	178	None
North Branch Potomac River	214	None
Shenandoah River	174	None
Birch River	221	None
Coal River	284	None
Mud River	373	None

River	Avg. Alkalinity (mg/l)	Algae Development
Cheat River	17	None
Cherry River	18	None
Gauley River	24	None
Upper Greenbrier River	30	None
Lower Elk River	35	None
Tygart Valley River	44	Severe
Lower Greenbrier River	54	High
Cacapon River	56	High
South Branch Potomac River	97	Low-Moderate

Algae Limiting factors

	Alkalinity	Hardness	Turbidity
Cherry River	X		
Elk River	X		
Gauley River	X		
Cheat River	X		
Little Kanawha	X		X
Kanawha			X
Tug Fork		X	
West Fork		X	X
Shenendoah		X	
Opequon		X	X
Guyandotte		X	

What makes algae grow?

- Physical Needs
  - Clear (shallow) water
  - Low silt accumulation (rocky bottom)
- Nutritional Needs
  - Carbon (106), Nitrogen (16), Phosphorus (1)
  - In most surface waters, phosphorus is the limiting nutritional factor for algae growth.
- Right Chemistry
  - Alkalinity >35-40
  - Hardness <150 (WV conditions)

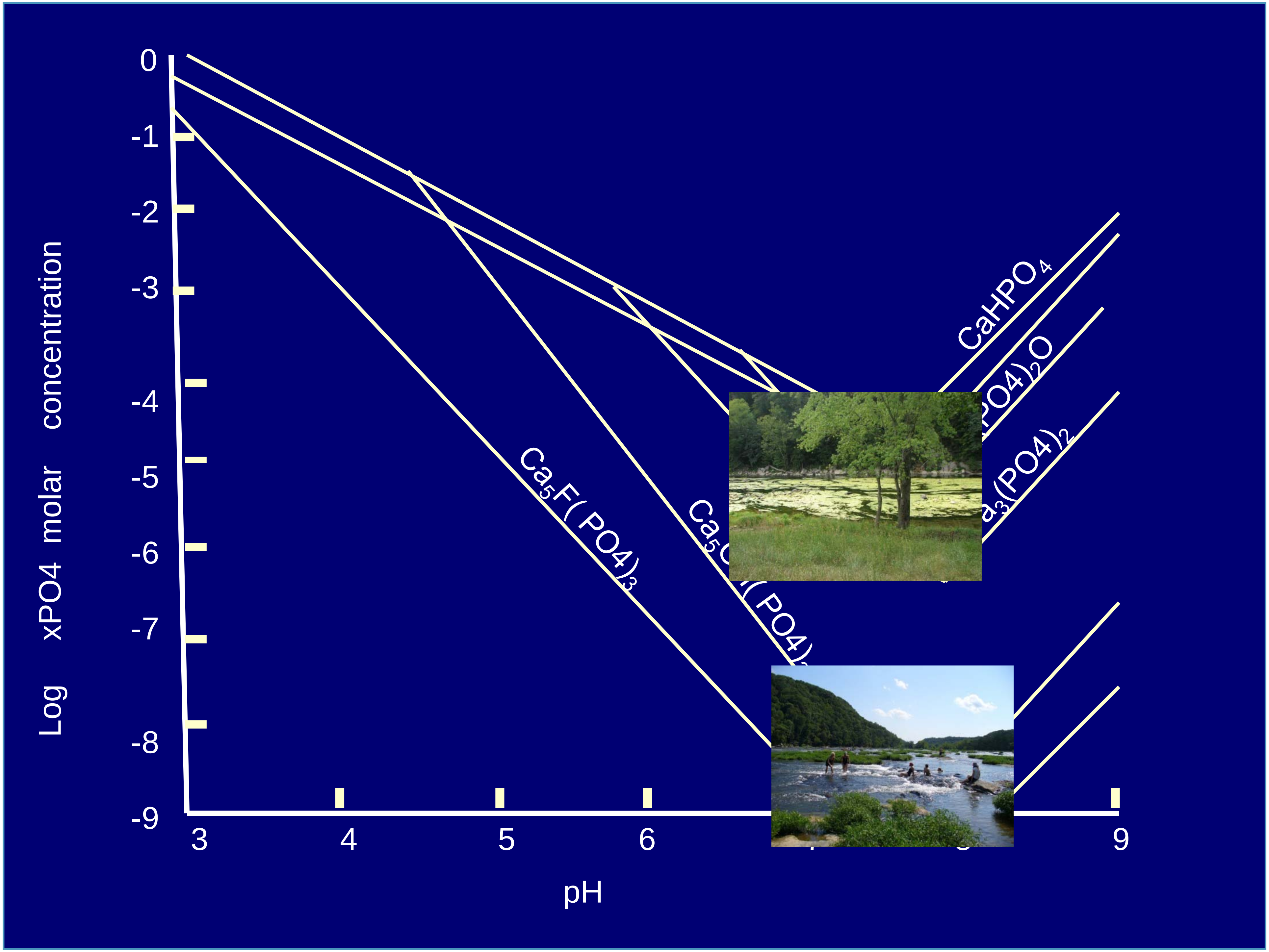
Hardness

- <60 mg/l - soft
- 60-120 - moderately hard
- 120-180 - hard
- >180 - very hard

The Chemistry...

- Ca^{+2} + PO_4^{-3} <==> $Ca_3(PO4)_2$

	$Ca(H_2PO4)_2 \cdot H_20$
$Mg(H_2PO_4)_2$	$Ca(H_2PO_4)_2$
$MgHPO_4$	$CaHPO_4$
$Mg_3(PO_4)_2$	$Ca_4(PO4)_2O$
$Ca_2Mg(PO_4)_2$	$Ca_5(PO_4)_3OH$
	$Ca(PO4)_2$-H_2O
	$Ca_4H(PO_4)_3$
	$Ca_5F(\ PO4)_3$


0
-1
-2
-3
-4
-5
-6
-7
-8
-9
Log xPO4 molar concentration
3
4
5
6
9
pH
CaHPO4
Ca5F(PO4)3

Sequestered P

- Magnesium can form dissolved complexes with $(PO_4)^{-3}$
  - Phos remains “dissolved” but not very reactive (for uptake)
- Adsorbed to silicates/carbonates

Researchers…

“results suggest that pH combined with **Ca and Mg activity are the dominant chemical controls on P chemistry** in this P enriched system.” (Bedore, 2008)

“Significant regression line” in relationship of *chlorophyll a* concentrations and Ca/Mg ratio (Kawaga et al, 1989)

Dissolved Ca and Mg have a “regulating effect” on P-nutrition (Neel, 1979)

A Ca/Mg ratio less than 4 had a negative effect on algal growth, and a Ca/Mg ratio greater than 5 enhanced growth (Masayoshi, 2000).

Researchers…

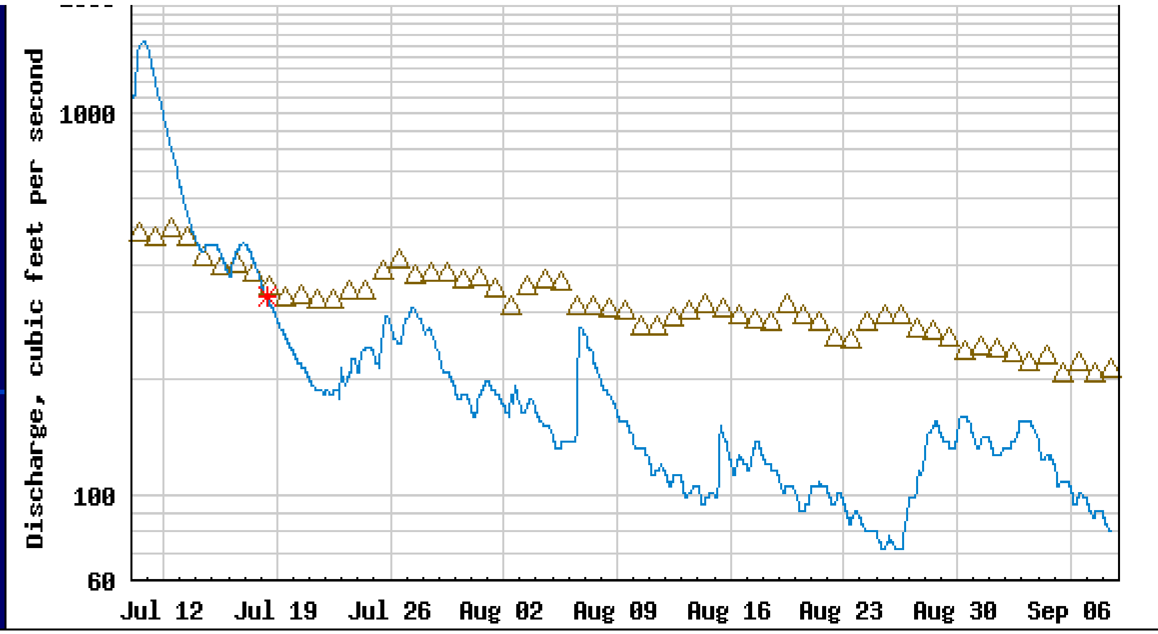
Phosphorus co-precipitates with calcite in highly alkaline aquatic environments. (Plant *et al*, 2002; Avimelech 1980; Salinger 1993)

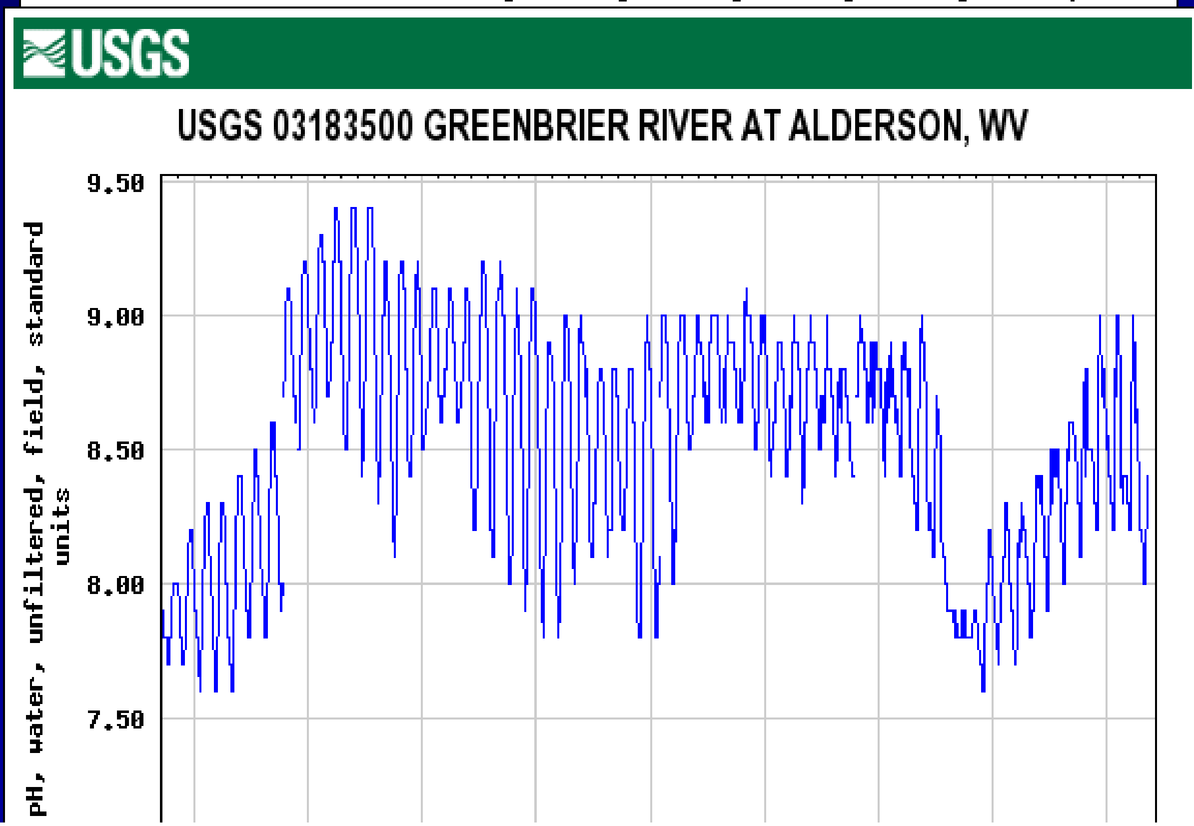
Long term P-accumulation in the Everglades was linearly correlated with Ca^{+2} accumulation (Reddy *et al* 1993).

Ca-P precipitation is a natural mechanism to control eutrophication in hard water lakes (Hartley, 1997)

Key question #1

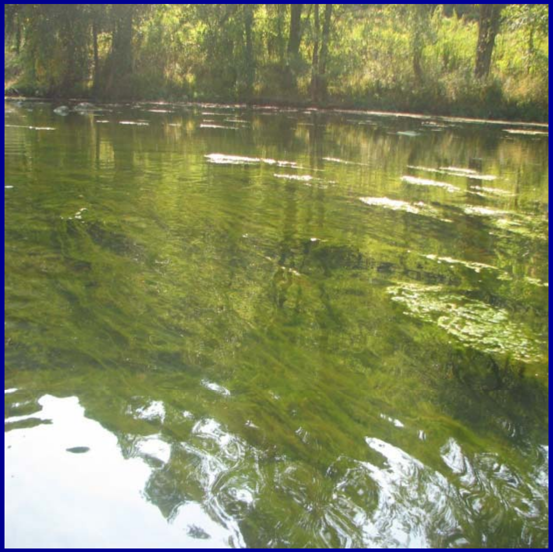
- Is there a threshold available phosphorus concentration for algae blooms to occur on “nutrient sensitive” streams?


Discharge, cubic feet per second
1000
100
60
Jul 12
Jul 19
Jul 26
Aug 02
Aug 09
Aug 16
Aug 23
Aug 30
Sep 06


USGS
USGS 03183500 GREENBRIER RIVER AT ALDERSON, WV
pH, water, unfiltered, field, standard units
9.50
9.00
8.50
8.00
7.50

Key question #2

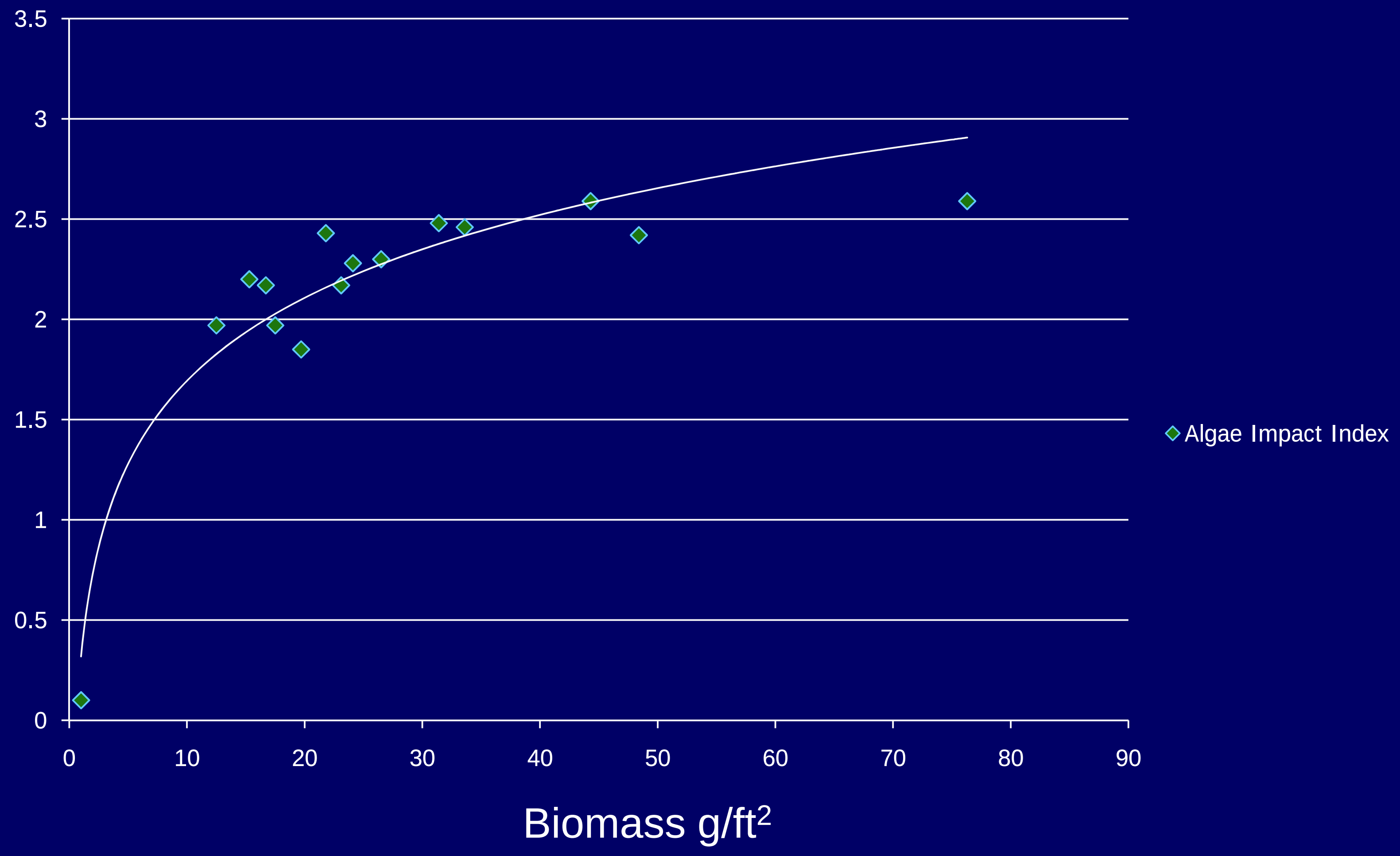
- What level of filamentous algae bloom is problematic?




TRIPLE BEAM BALANCE
OHAUS

River	Bottom Cover (%)	Water Column Fill (%)	Biomass (g/ft^2)	Impact Index
South Branch @ Old Fields	53	3.7	12.5	1.97
North Fork Hughes at North Bend	54	60	44.3	2.59
North Fork Hughes at Cairo	23	4	19.7	1.85
Greenbrier-Hillsboro 1	40	18	26.5	2.30
Greenbrier-Hillsboro 2	53	28	21.8	2.43
Greenbrier- Caldwell	53	32	33.6	2.46
Greenbrier –Coffman Hill Rd.	80	27	31.4	2.48
Greenbrier - near Rt 62 bridge 1	41	16	24.1	2.28
Greenbrier - near Rt 62 bridge 2	85	7	15.3	2.20
Greenbrier-Ronceverte	74	50	76.3	2.59
Greenbrier- US Alderson	64	23	48.4	2.42
Greenbrier- 1 mile below Alderson	39	10	23.1	2.17
Greenbrier-Lowell	46	9	16.7	2.17
Hypothetical	20	8	17.5	1.97

Algae Impact Index = $(1.5*\mathit{log}\ BC + \mathit{ln}\ WC)^{0.5}$



2009 Goals

- Investigate “threshold” P-concentration using low level analyses. (~15 sites with intensive monitoring through summer)
- Delineate algae development on Greenbrier and Tygart:
  – Spatially and chronologically
  – Relate to Nutrient concentrations
- Define “nuisance level” of filamentous algae (user surveys)