Assimilative Capacity of Riparian Zones, Floodplains and Channels for Phosphorus

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Presentation Overview

- What is assimilative capacity?
- Forms and reactions of phosphorus (P)
- Physical capacity of
  - Riparian buffers
  - Floodplains
  - Channels
- Biological processes
- Cumulative benefits

What is Assimilative Capacity?

- General:
  - The ability of a system to process a material or substance at a certain concentration without itself being degraded.
- Regulatory:
  - The load a stream can accept and assimilate and still maintain in-stream water quality criteria.
- Layman:
  - When calorie intake balance calories used weight is maintained. The calories used is the assimilative capacity of the body.

Stream Assimilative Processes

- Physical
  - Filtering, Deposition
  - Dilution
- Chemical
  - Sorption, release from sediment and organic matter
  - Transformation via reactions
- Biological
  - Sequestering
  - Transformation via microbes, vegetative biomass and animal biomass; nutrient spiraling

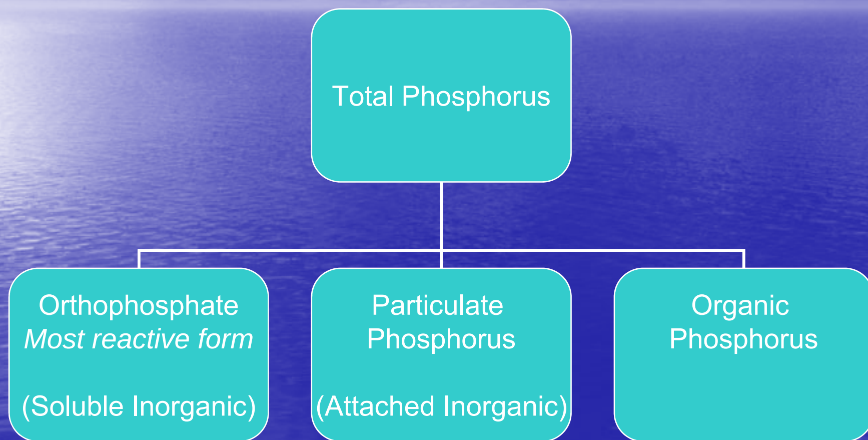
Stream Assimilative Processes

- The capacity of these processes to assimilate is interconnected and based on the features of the streamscape (the stream, floodplain, and riparian zone).
- Their abilities are compromised when natural features are removed.

A Management Goal

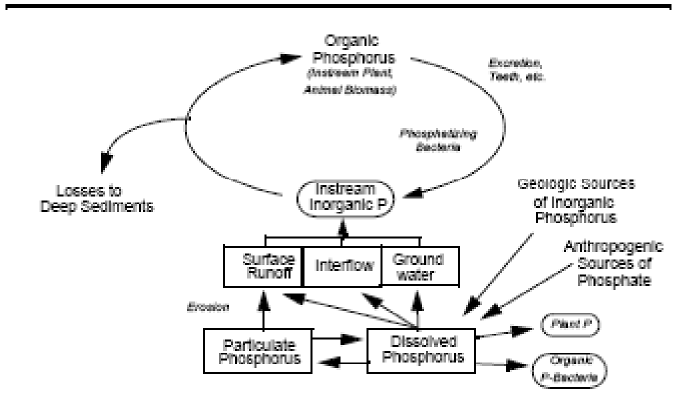
- Croplands need drainage and nutrient inputs which mean changes in hydrology and nutrient inputs to the stream.
- By recognizing and supplying the functions natural stream features provide, streams will balance the anthropomorphic changes and will protect downstream use.
- Some natural stream features include narrow low flow channels with connected floodplains and vegetated riparian areas.

Forms of Phosphorus



Summary Diagram of Phosphorus Delivery and Processing

Phosphorus Sources	Phosphorus Input Forms	Phosphorus Transformations	Phosphorus Regulation	Phosphorus Sinks
Precipitation	Orthophosphate (Inorganic Phosphorus)	Phosphatizing Bacteria	Light	Groundwater
Groundwater			Fertilizers	Surface Water
Point Sources	Particulate Phosphorus (Attached Inorganic)	Anaerobic reduction of ferric hydroxides and release of Inorganic P	Point Sources	Vegetation (Riparian & Aquatic Macrophytes)
Runoff			Riparian Uptake	
Natural Decay (organic)	Organic Phosphorus		Groundwater	Animal Biomass (Bones & Teeth)
			Overland Flow	
			Stream Morphology	



Modified from Novotny and Chesters (1981)

Vegetated Riparian Buffers – Sediment Traps

- Vegetation traps terrestrial sediment and PP in surface runoff.
- Buffers retain the majority of the input P.
- Retention increases with buffer width.
- 30 m (98 ft) generally accepted as a target width with 85% TP removal.
- Results of studies vary widely.
- Both grassed and forested areas are effective.

Vegetated Riparian Buffers – Dissolved P Filters

- Roots in the buffer uptake dissolved P if contact occurs; note, subsurface drainage bypasses this.
- 50 – 83% removal of dissolved P from 100 ft vegetated buffers documented.
- Both grassed and forested areas effective; however, deeper roots provide increased opportunity for contact.

Vegetated Riparian Buffer – Direct P Removal Processes

- Buffer areas saturate & all soil binding sites are filled;
  - additional P inputs are exported as DP.
- P does not have an escape route;
  - unlike nitrate that can be denitrified and release as nitrogen gas.
- A combination of a wide zone of harvested, un-fertilized grass and at least 30’ of undisturbed forest riparian buffer may be most effective buffer combination for P removal.
  - harvesting can permanently remove P.

Vegetated Riparian Buffers – Other P Removal Processes & Benefits

- Highly enhanced soil microbial activity increase nutrient assimilation & degradation of pesticides
- Stabilize banks and reduce stream bank erosion
- Set back sediment producing activities from streams
- Contribute large woody debris (snags) to trap sediment in stream
- Provide water retention and infiltration area
- Provide aquatic and terrestrial habitat and food
- Provide shade to cool water and light limit algal growth
- Filter polluted air, improve near-field microclimate
- Create migration corridors and are aesthetically pleasing

Effects of Riparian Buffers on Reductions of Sediment and Nutrients from Field Runoff

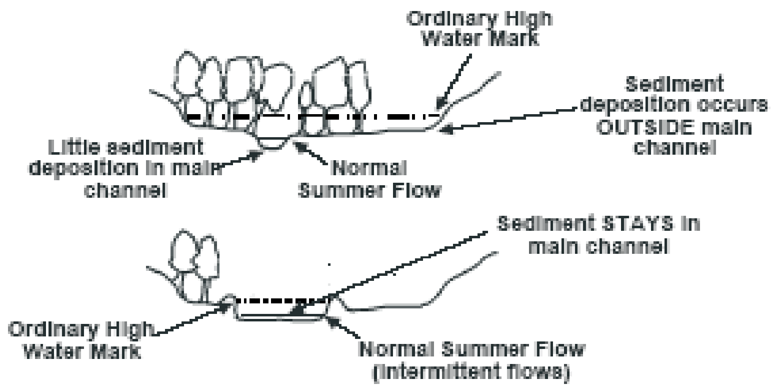
Buffer Width	Buffer Type	Sediment Input Conc.	Sediment Output Conc.	Sediment Reduction[4]	Nitrogen Input Conc.	Nitrogen Output Conc.	Nitrogen Reduction[4]	Phosphorus Input Conc.	Phosphorus Output Conc.	Phosphorus Reduction
m		--mg L^{-1}--		%	--mg L^{-1}--		%	--mg L^{-1}--		%
4.6[1]	Grass	7284	2841	61.0	14.11	13.55	4.0	11.30	8.09	28.5
9.2[1]	Grass	7284	1852	74.6	14.11	10.91	22.7	11.30	8.56	24.2
19.0[2,3]	Forest	6480	661	89.8	27.59	7.08	74.3	5.03	1.51	70.0
23.6[5]	Grass/ Forest	7284	290	96.0	14.11	3.48	75.3	11.30	2.43	78.5
28.2[6]	Grass/ Forest	7284	188	97.4	14.11	2.80	80.1	11.30	2.57	77.2

Floodplain Services

- Floodplains provide similar services as the riparian buffers
- Floodplains slow storm flow
  - fine sediment and P settle outside of the main channel
- Energy is decreased
  - reducing bank scour from shear stresses
- Floodplains buffer hydrologic changes
  - such as those associated with agriculture by providing flood flow storage which is slowly released as flow levels recede
- Floodplains provide lateral pathways for nutrient spiraling
- Floodplains provide a refuge for aquatic life during high flow events
- Accessible floodplain is essential to morphologic stability

Channel Modifications

- Channel modification affects how and where fine sediment is deposited



Natural Channels

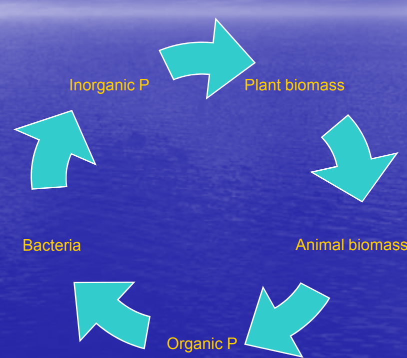
- Narrow low flow channel
  - Increase velocity and reduce nutrient retention time in the water
  - Have coarser substrates with less DP sorption potential
  - Increased interstitial flow and anaerobic assimilation of nutrients
- Sinuosity
  - Reduces stream power and energy
  - Increased surface area and habitat per unit distance
- Wider overflow area
  - Increases depositional area
- Pool, riffle, run complexes
  - Each are important to aquatic life
- Favor complex and diverse trophic state
  - Increases assimilation of nutrients

Modified Channels

- Wider, low energy channels
  - increase retention and contact time with DP leading to production of excess algae & simplified trophic levels
  - nutrients retained in the most available form (on fines and algae)
  - Sediments become saturated and will release DP when water column concentration decreases.
  - High water concentrations just exported downstream; no assimilative capacity left in channel.
- Self-forming channels estimated to remove 74% TP in first 39 years over traditional ditch maintenance (McKibbin Ditch)

Biological Processes

- Phosphorus spiraling in a stream
- Natural cycles are long (slow) and biomass diverse
  - Increases assimilation
- Modified cycles are short (fast) and P is readily available
  - Decreases assimilation



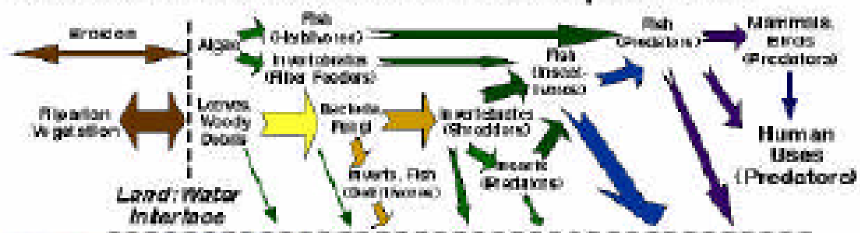
Cumulative Effects

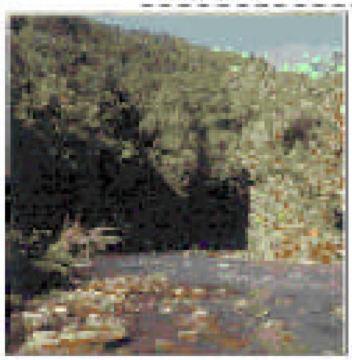
- Forested riparian zones, accessible floodplains, and natural channels provide good habitat and diverse aquatic communities
- TP is more efficiently converted to desirable aquatic biomass which impedes entry of available P
- Modified streamscapes favor a trophic shift to less desirable biomass
  - Increase algal and macrophyte production
  - Increase turbidity
  - Lower DO and wider diel DO and pH fluctuations

Headwater Streams

- Strongly influence higher order streams by the cumulative cascading of nutrients
- Headwater streams represent 78% of the stream miles in Ohio
- Natural headwater streams
  - retain and process Coarse POM
  - export Fine POM
  - Provide high quality biomass in diverse aquatic communities in balanced trophic relationships
- Have the highest potential to be modified

Natural Stream Habitat with an Intact Riparian Zone





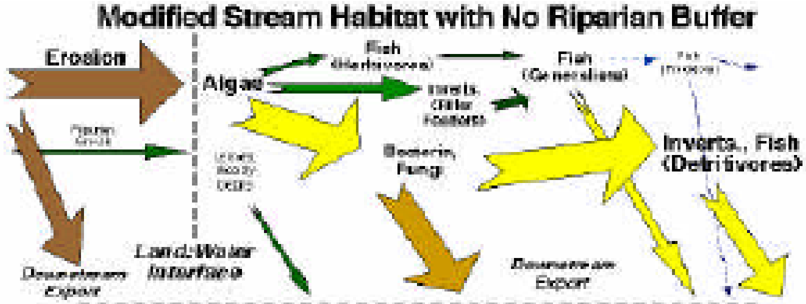
TANGIBLE PRODUCTS:

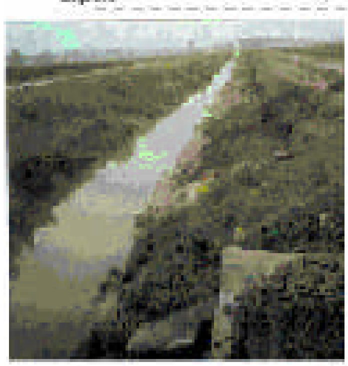
1. Desirable biomass (*e.g.*, game fish, biodiversity, sensitive species).
2. Water quality suitable for *all* uses.
3. Ability to assimilate background

KEY INDICATORS:

1. Higher biological index scores which attain beneficial use criteria.
2. Water quality comparable to reference conditions.

Modified Stream Habitat with No Riparian Buffer





TANGIBLE PRODUCTS:

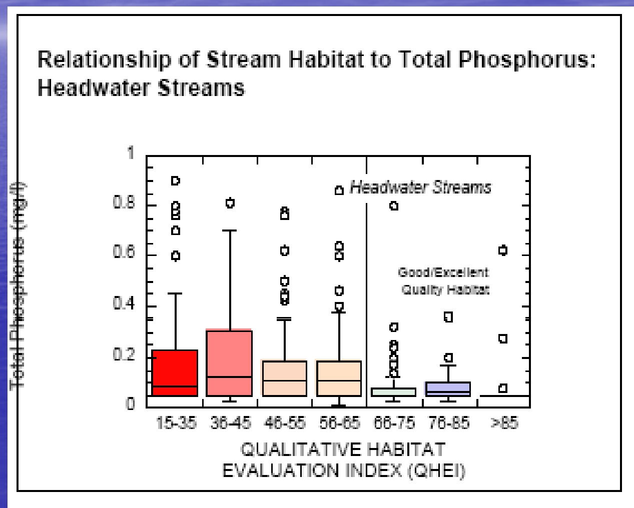
1. Low quality biomass (e.g., nuisance algae, tolerant species).
2. Water quality suitable for *few* uses.
3. Reduced capacity to assimilate nutrients and sediment from runoff.

KEY INDICATORS:

1. Low biological index scores which fail to attain beneficial use criteria.
2. Water quality poorer than reference

Biology, Habitat, and TP

- ICI, IBI, and QHEI highest in small streams where TP is lowest
- ICI, IBI decrease as TP increase



Conclusions

- Assimilative capacity of P in streams is high IF provided with natural stream features.
  - Narrow low flow channel
  - Accessible floodplains
  - Forested riparian zones
  - Cumulatively result in a longer, more natural nutrient spiral, buffered flows, stable geomorphology, and reduced export of P downstream
- Streams are dynamic and will adjust to watershed disturbance
  - Can adjust well with reduced downstream impact
  - Can ill adjust and exacerbate problems