Development of a watershed ecoregion to protect water supply impoundment from ecological collapse by cyanobacteria blooms

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What is eutrophication?

- Natural and anthropogenic process of enrichment of water bodies by organic particulates stimulated by nutrient inputs and recycling
- Eutrophication progresses over the historic times in various stages
  - Oligotrophic
  - Mesotrophic
  - Eutrophic
- A hyper-eutrophic water body classification was added about twenty – thirty years ago
- End of the process is disappearance of the water body and its conversion into a wetland and ultimately dry land

Eutrophication Characteristics

Quality Water	Oligotrophic	Mesotrophic	Eutrophic	Hyper-eutrophic*
Total P (µg/L)	<10	10-20	>20	> 50
Chlorophyll - *a*	<4	4-10	>10	>20
Secchi disc transparency depth (m)	>4	2-4	<2	<1
Hypolimnetic oxygen (% saturation)	>80	10-80	<10	0

Based on US Environmental Protection Agency

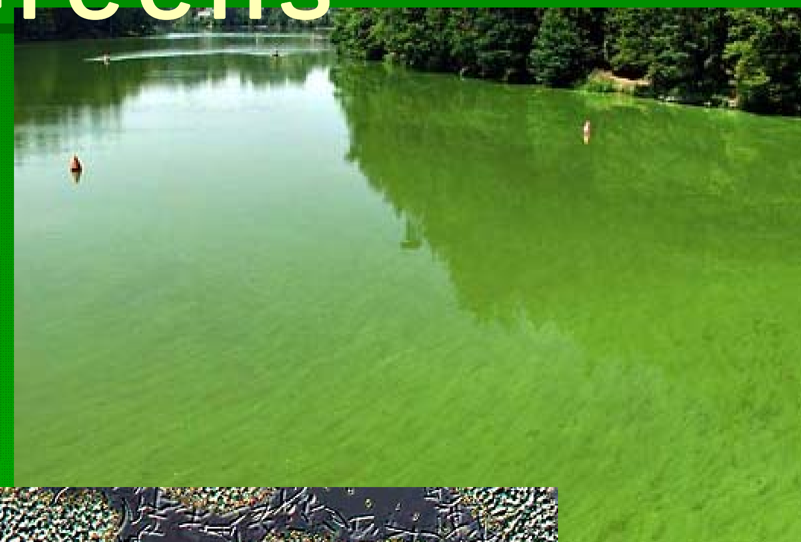
NUTRIENT IMPACT

- Photosynthesis is the driving process
- Photosynthesis occurs in the water layer where light can penetrate (euphotic zone)
- In the layer with insufficient light, on cloudy days and during night algae respire and impose oxygen demand (the equation is reversed)
- Other limiting factors are light (shading), hydraulics and alkalinity

Cyanobacteria in Lake Mendota (Madison, WI) in 1970s

Hyper-eutrophic catastrophe in Czech Republic Blue Greens

Orlík



Sedlice

75% of reservoirs in Czech Republic have been infested

Losses of recreation, water supply, toxins, taste and odor, skin rash

PEA SOUP IN CHINA

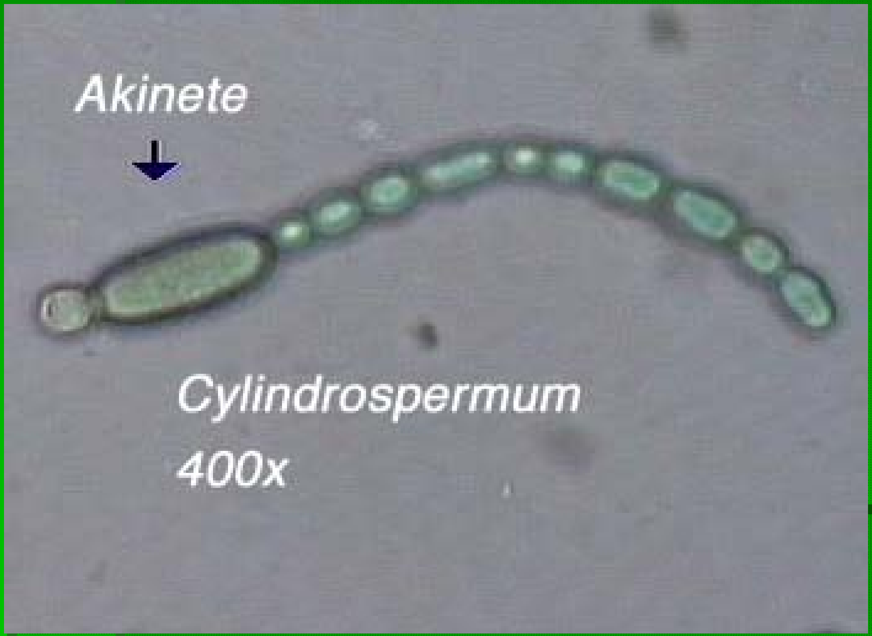
VICIOUS ALGAL BLOOMS

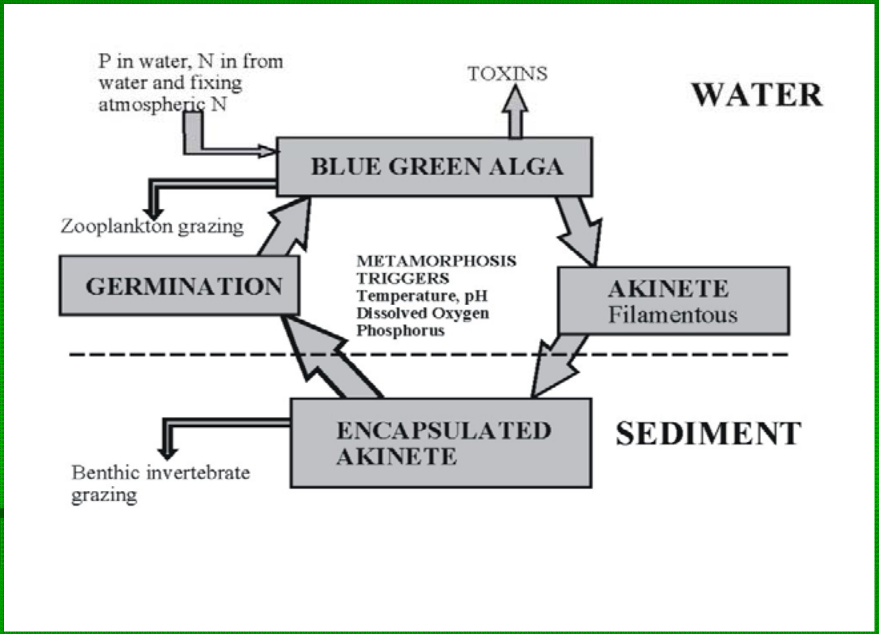
COMMON RESERVOIR MODELS BASED ON PHOSPHORUS MASS BALANCE DO NOT WORK

Cyanobacteria (Blue Green Algae)

- Cyanobacteria have been around for more than 3 billion years
- These microorganisms are responsible for atmospheric dissolved oxygen
- Some species can assimilate atmospheric nitrogen
- They are ubiquitous to nature
- They prefer warmer water bodies
- They produce toxins and impair taste and odor
- They form noxious algal blooms

Some cyanobacteria fix atmospheric nitrogen and encapsulate into akinetes





Akinetes settle into sediments where they overwinter and can take up phosphorus. They can stay in the sediment for several years and rise into water when conditions are favorable. They have a preference for higher temperatures (impact of global warming)

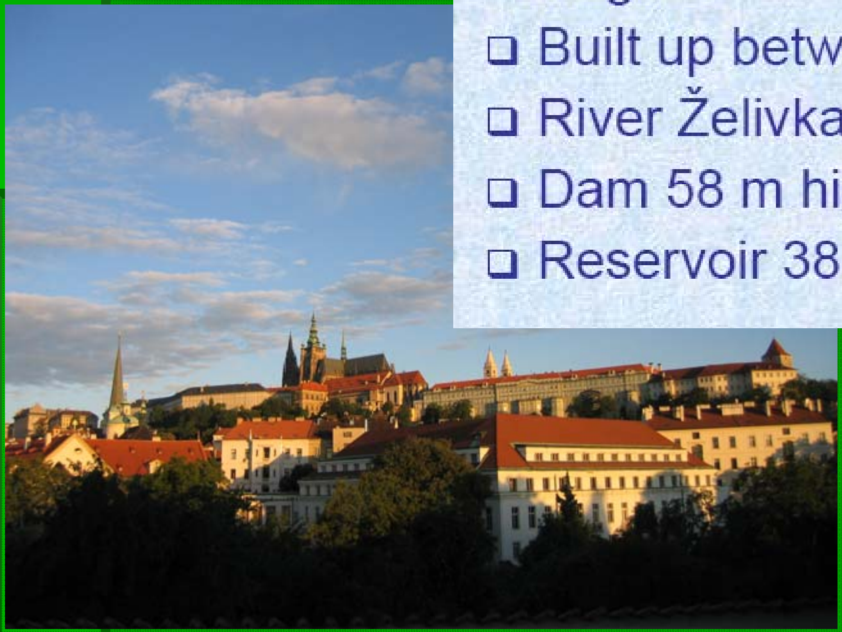
Conditions affecting cyanobacteria (Kravchuk, 2006)

- Temperature
- Phosphorus concentration
- Hydraulic conditions
- Light
- Grazing by zooplankton

Algal blooms occur suddenly even when nutrients controls have been implemented (Lake Delavan, Charles River). Once they occur they are extremely difficult and costly to control.

Švihov Reservoir in Czech Republic

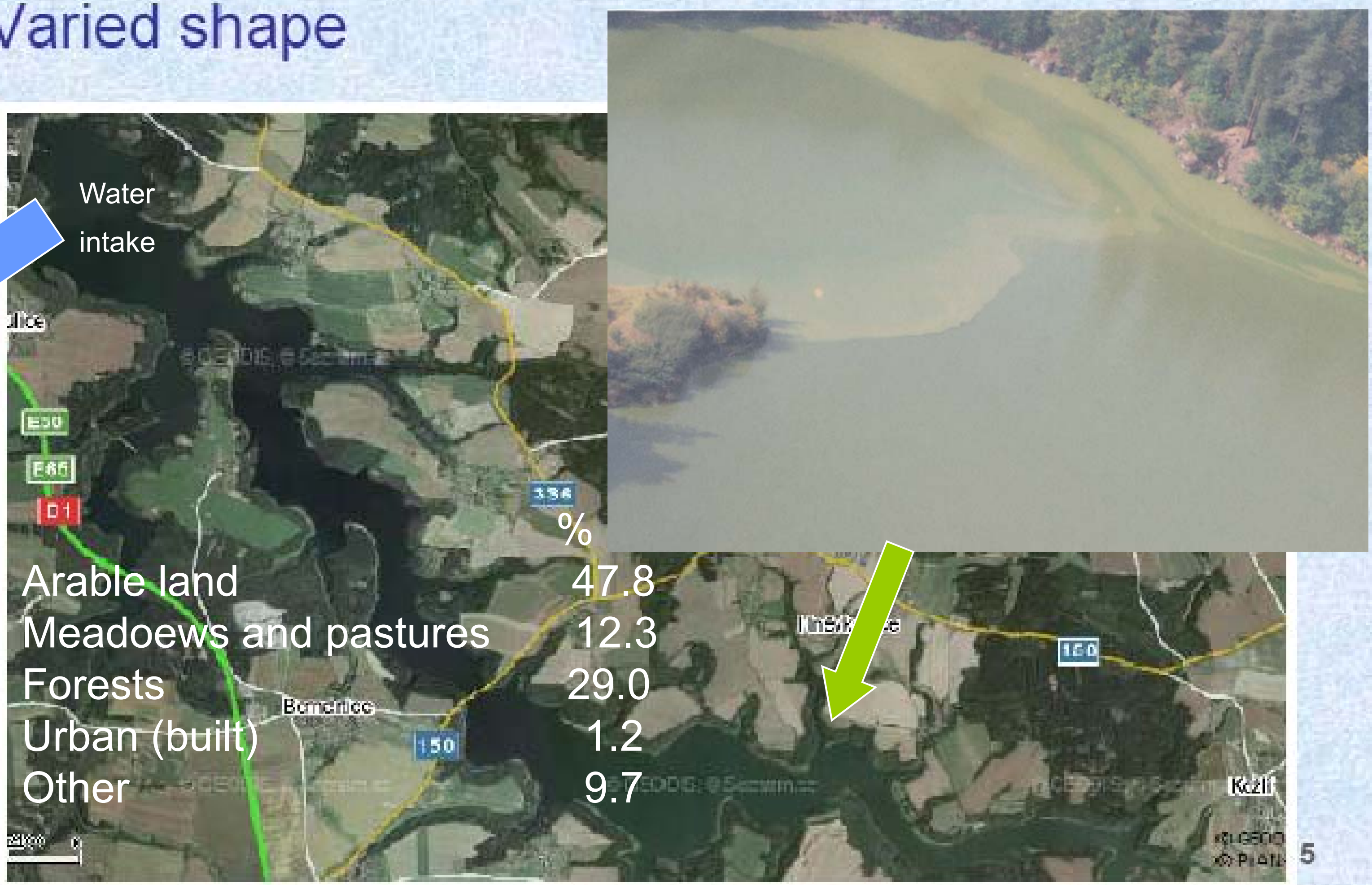
- The largest drinking water reservoir in the Czech Republic
- The most important source of drinking water for Prague (over 1 milion citizens)
- Partly for Vysočina region and Central Bohemia Region
- Built up between 1965 – 1972
- River Želivka
- Dam 58 m high, 850 m long
- Reservoir 38 km long, area 1432 ha



Landscape

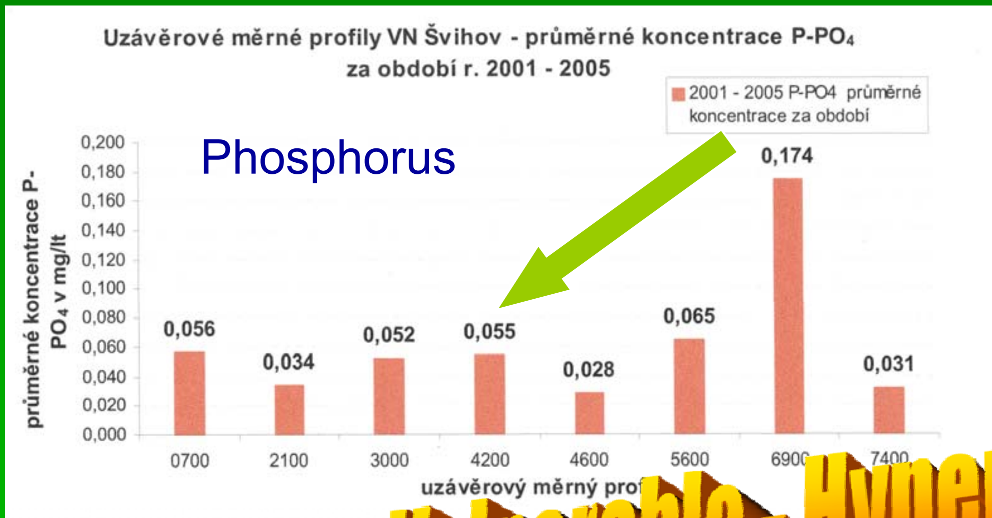
- Varied shape

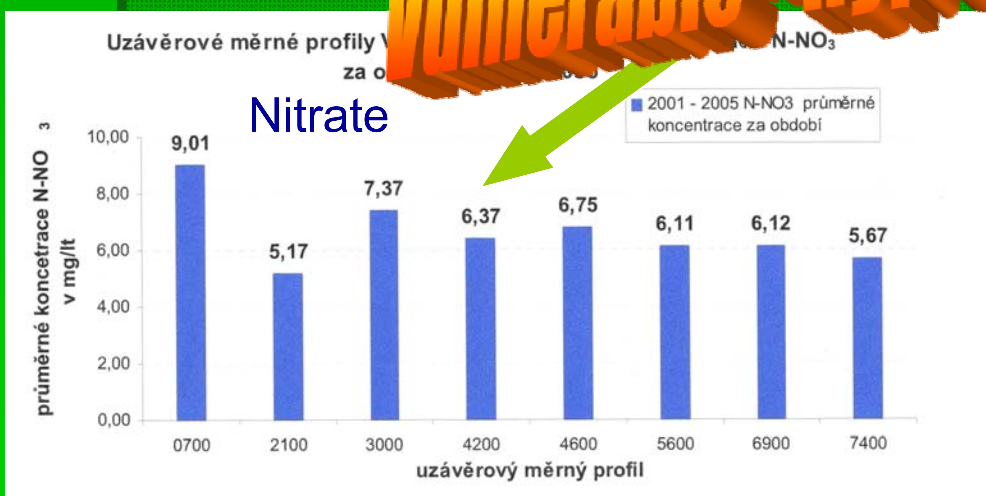
Dam



	%
Arable land	47.8
Meadoews and pastures	12.3
Forests	29.0
Urban (built)	1.2
Other	9.7

N & P in Švihov Reservoir Tributaries





Vulnerable - Hyper-eutrophication

CURRENT CONCENTRATIONS IN ŽELIVKA

N --- 6.37 mg/L

P --- 0.055 mg/L

DESIRABLE TO CONTROL EUTROPHICATION

N --- < 1 mg/L

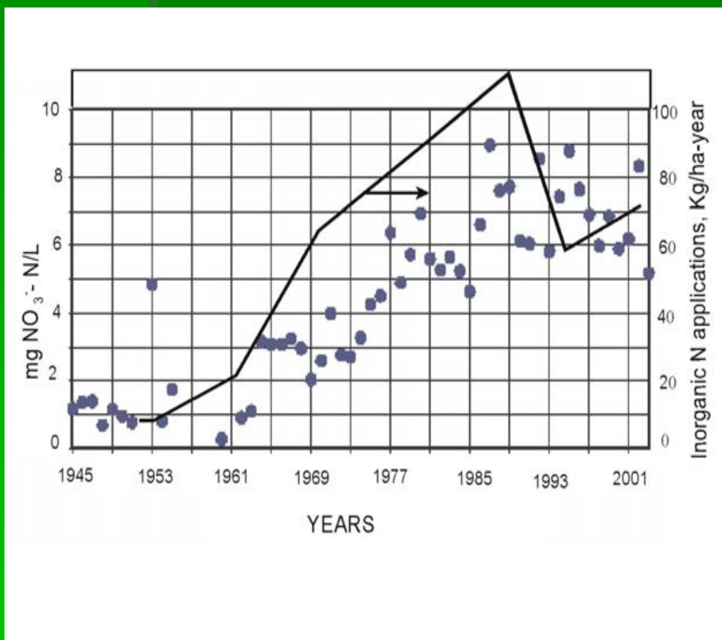
P --- < 0.015 ,g/L

Average annual **water quality characteristic throughout the Švihov reservoir. Data from the Vltava Watershed (Povodi) Agency by Hejzlar at al. (2006)**

Parameteer	Profile and River Km (from the Sázava River)				
	Dam (0099) RKm. 4.7	Kralovice (0899) RKm. 15	Budeč (1699) RKm. 24.2	Zahrádka (2099) RKm 29.2	Vojslavice (2699) RKm 36.5
Transparency, meters	5.1	4.3	3.4	3.2	2.0
pH	8.1	8.1	8.1	8.4	8.2
Total P, µg/L	20	24	32	28	61
Chlorophyll *a*	8	7	10	21	15
Classification	MT	MT-E	MT-E	E	HT

MT-mesotrophic, E-eutrophic, HT-hypertrophic

Main Causes of the Problem



- Green revolution in agriculture based on unbalanced overuse of industrial fertilizers
- Monocultural agriculture fed by industrial chemicals
- Plowing up an down the slope all the way to the water bodies
- No best management practices to control nonpoint sources of N & P
- Discharges from point sources of nutrients with no P and N removals. Combined sewers with CSOs/
- Phosphate detergents
- Soil and groundwater contamination by N and P

Develop a plan – main proposed goals

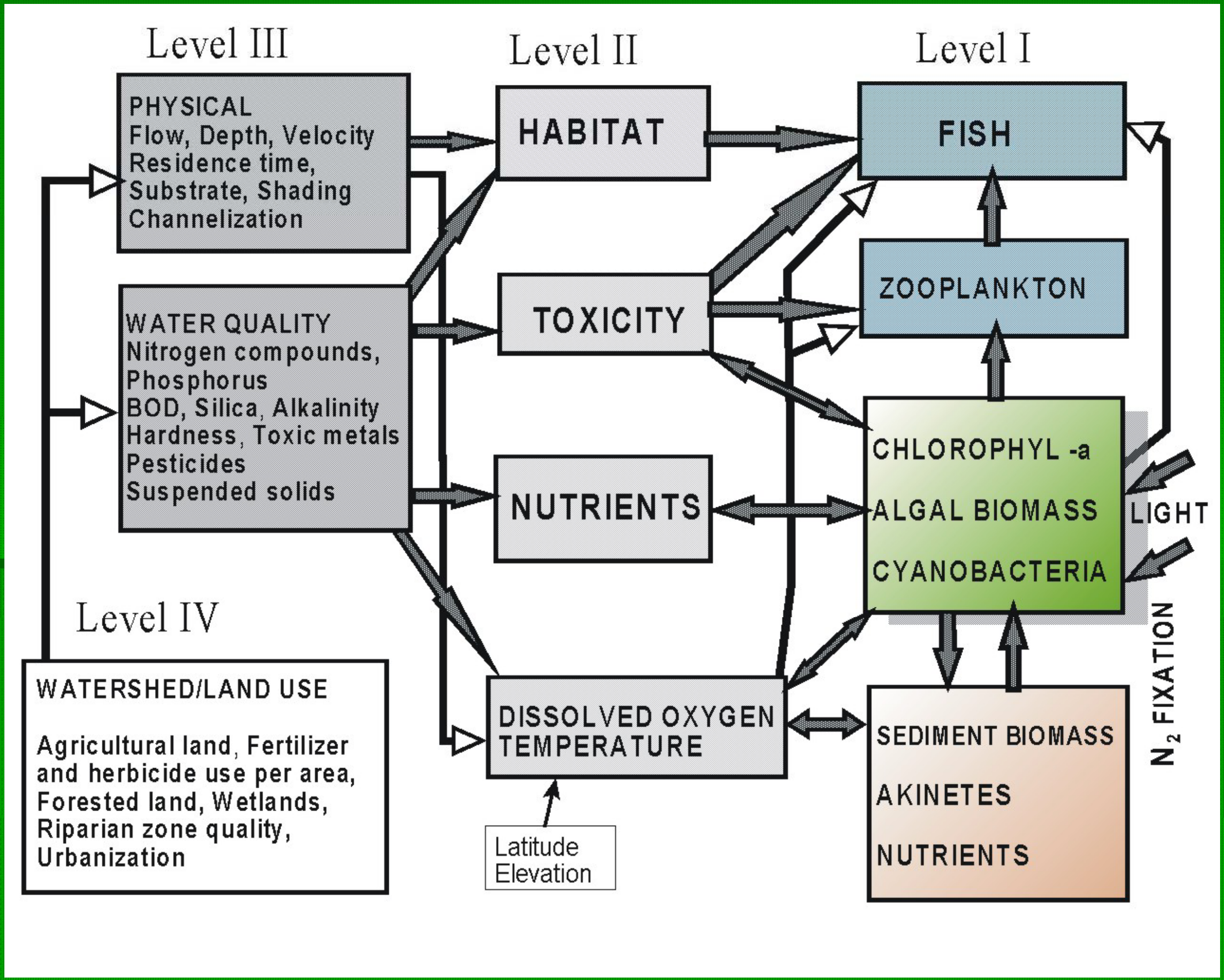
- Reversing the progress of hypertrophy
- Reduce point and diffuse source pollutant loads (combined sewers, feedlots)
- Protective zones (have been established by law but protection is lagging)
- Restoring the land ecology to provide barriers to pollution and buffering throughout the watershed
- Identify hazardous lands and buffer zones to be converted to a new sustainable use

Restoring wetlands and buffer strips as well as vigorous soil erosion control will be necessary, including taking some hazardous agricultural land out of production

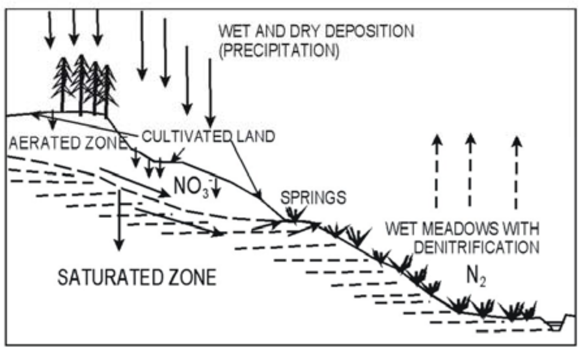
Buffer zones in Iowa

Erosion BMPs in Wisconsin

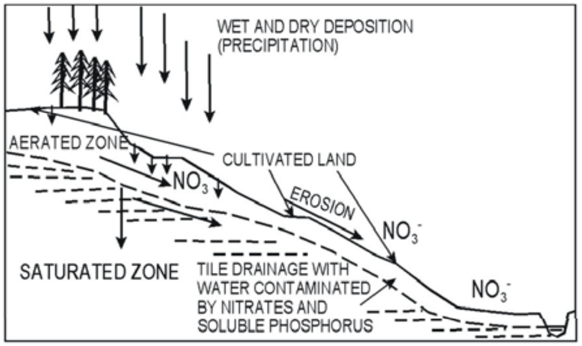
Finding relationship between many factors and loads is not easy but it can be done



Buffering capacity of the watershed has to be restored



A) Water and nutrient regime before tile drainage

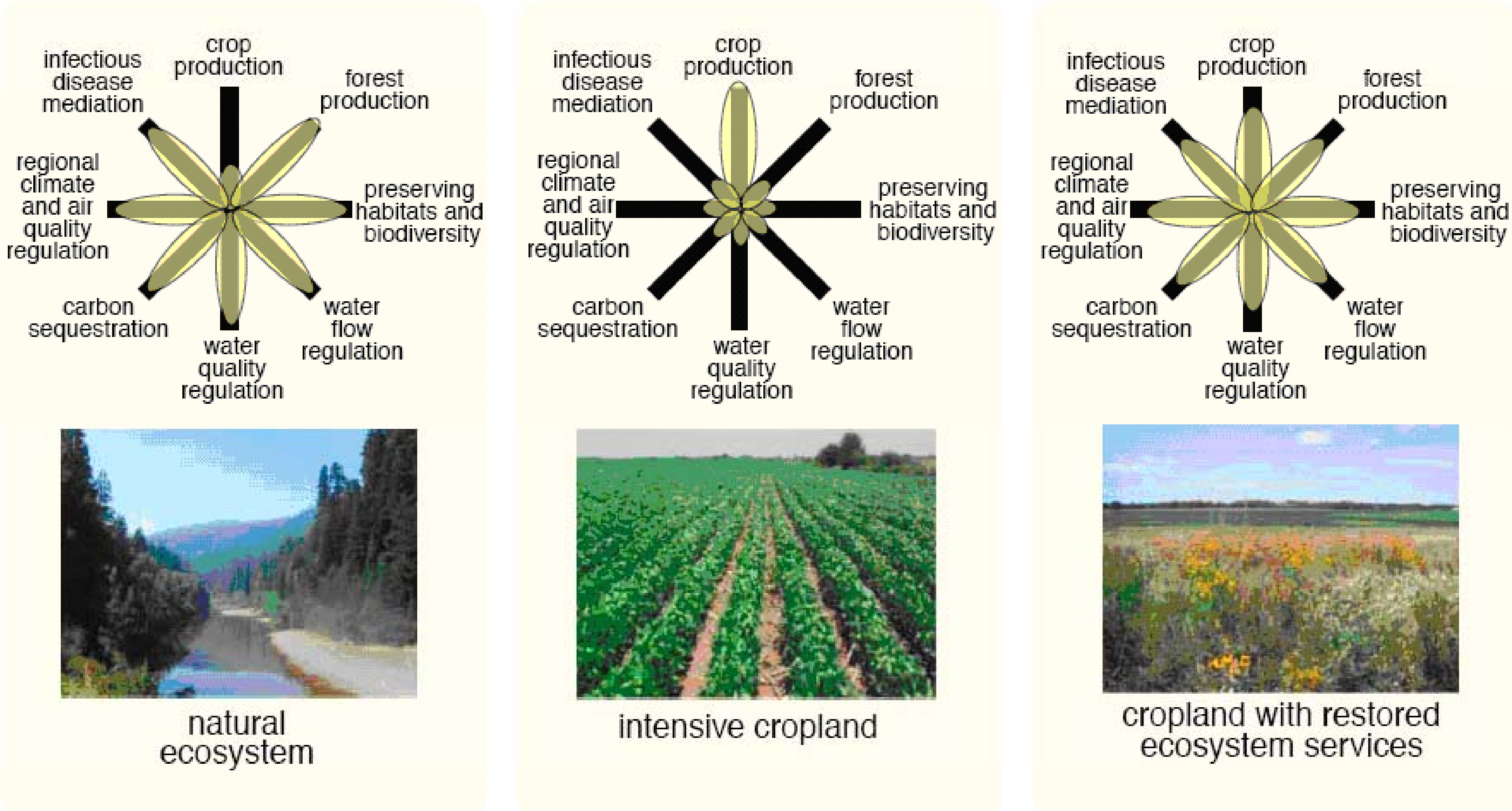


B) Water and nutrient regime after tile drainage

Source: Laxa at al (2008) *Vodni Hospodarstvi*

- Low land wetlands were drained (loss of denitrification)
- Riparian wetlands are natural sinks of nutrients (nitrates)

Developing ecoregion

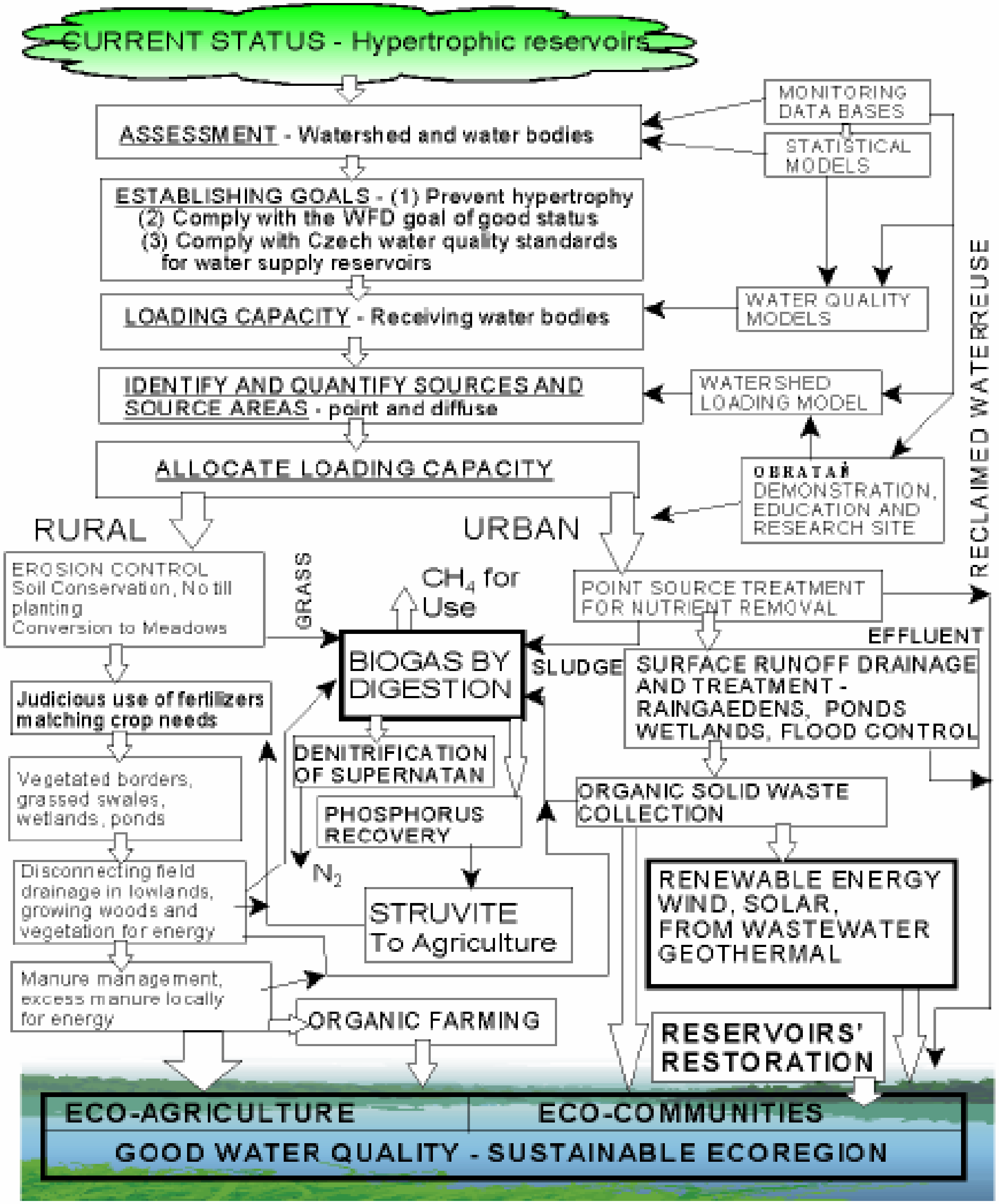


Alternatives

- Alternatives and development of water, used water, urban runoff and solids management in urban ecocities and ecovillages
- Alternatives for small unsewered settlements using natural systems for used water disposal and reclamation
- Crop selection, fertilizer management to bring the excess waste nutrients to zero, erosion control and soil conservation as well as reduction of delivery of nitrogen and phosphorus from the source area to the receiving water via surface (runoff) and subsurface (shallow groundwater) pathways.

Ecoregion alternatives

- Disconnection of old drainage systems and converting riparian zones into wetlands
  - selecting vegetation with a focus on vegetation energy (methane) production by digestion with treatment plant sludge and other organic solid waste
- Using the models evaluate feasibility and design of irrigation system using high nitrate groundwater for irrigation and considering, if necessary, groundwater recharge with highly treated and denitrified urban effluents and/or low nitrate (treated) urban and highway runoff
- Using modeling to design the digestion system for sludge and organic solids produced on converted lands (grass, woodchips) and organic solid (food waste, vegetation, leaves and debris, shredded woodchips from tree pruning)
- Develop a system for production, sale and distribution of biogas either in the form of a gas fuel or electricity.


CURRENT STATUS - Hypertrophic reservoirs
ASSESSMENT - Watershed and water bodies
MONITORING DATA BASES
STATISTICAL MODELS
ESTABLISHING GOALS - (1) Prevent hypertrophy
(2) Comply with the WFD goal of good status
(3) Comply with Czech water quality standards for water supply reservoirs
LOADING CAPACITY - Receiving water bodies
WATER QUALITY MODELS
IDENTIFY AND QUANTIFY SOURCES AND SOURCE AREAS - point and diffuse
WATERSHED LOADING MODEL
ALLOCATE LOADING CAPACITY
OBRATAŇ DEMONSTRATION, EDUCATION AND RESEARCH SITE
RECLAIMED WATER REUSE
RURAL
URBAN
EROSION CONTROL Soil Conservation, No till planting Conversion to Meadows
GRASS
CH_4 for Use
POINT SOURCE TREATMENT FOR NUTRIENT REMOVAL
EFFLUENT
BIOGAS BY DIGESTION
SLUDGE
SURFACE RUNOFF DRAINAGE AND TREATMENT - RAINGAEDENS, PONDS WETLANDS, FLOOD CONTROL
Judicious use of fertilizers matching crop needs
DENITRIFICATION OF SUPERNATAN
Vegetated borders, grassed swales, wetlands, ponds
PHOSPHORUS RECOVERY
ORGANIC SOLID WASTE COLLECTION
N_2
Disconnecting field drainage in lowlands, growing woods and vegetation for energy
STRUVITE To Agriculture
RENEWABLE ENERGY WIND, SOLAR, FROM WASTEWATER GEOTHERMAL
Manure management, excess manure locally for energy
ORGANIC FARMING
RESERVOIRS' RESTORATION
ECO-AGRICULTURE
ECO-COMMUNITIES
GOOD WATER QUALITY - SUSTAINABLE ECOREGION

Conclusions

- Protection of the Švihov reservoirs and Prague water supply from eutrophication requires a comprehensive watershed and water body management and protection
- The major problem threatening the reservoir are existing and increasing future occurrences of nuisance algal blooms of blue green algae (cyanobacteria).
- Significant reductions of N and P loads must be achieved.
- Because of uncertainty in models and estimates, the planning process and watershed and water body management must be adaptive, recurrent and include common sense immediate actions and also long term plans.
- There is not much time to wait

Credits and Collaborators

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Fulbright Program, USA

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