# Watershed Protection from the Top to the Bottom

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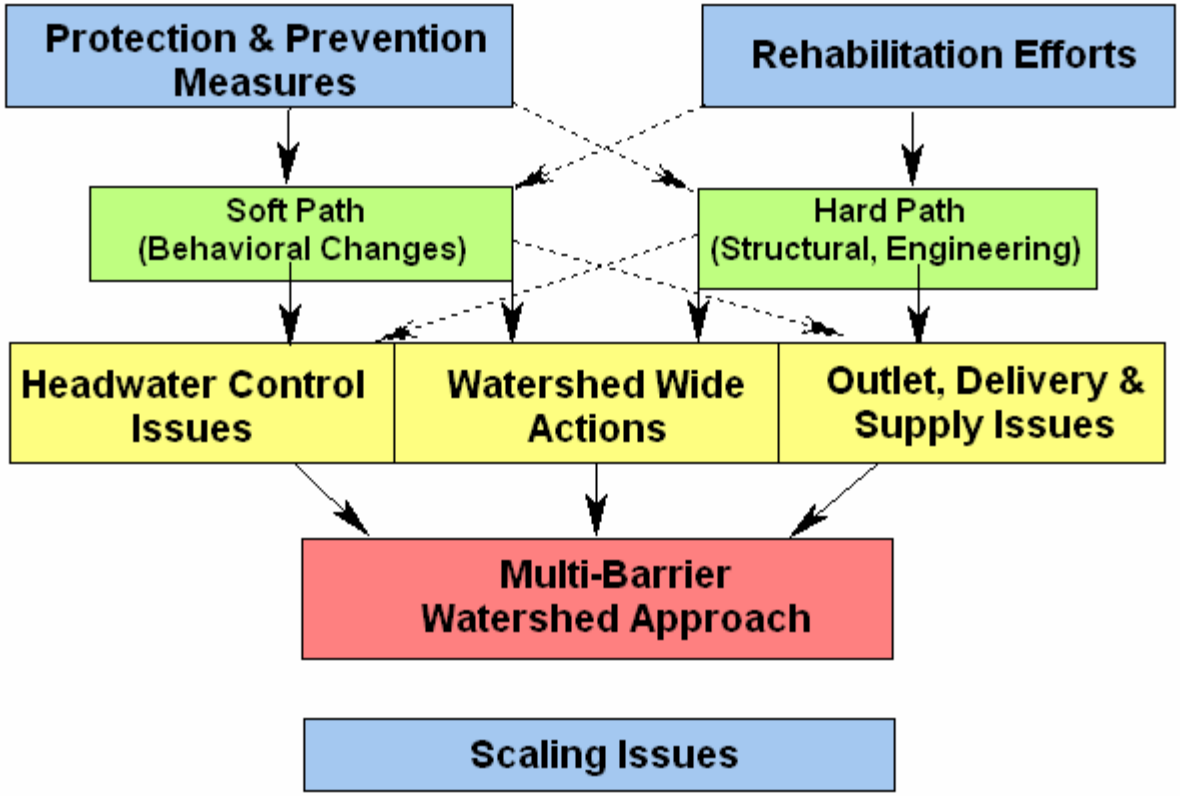
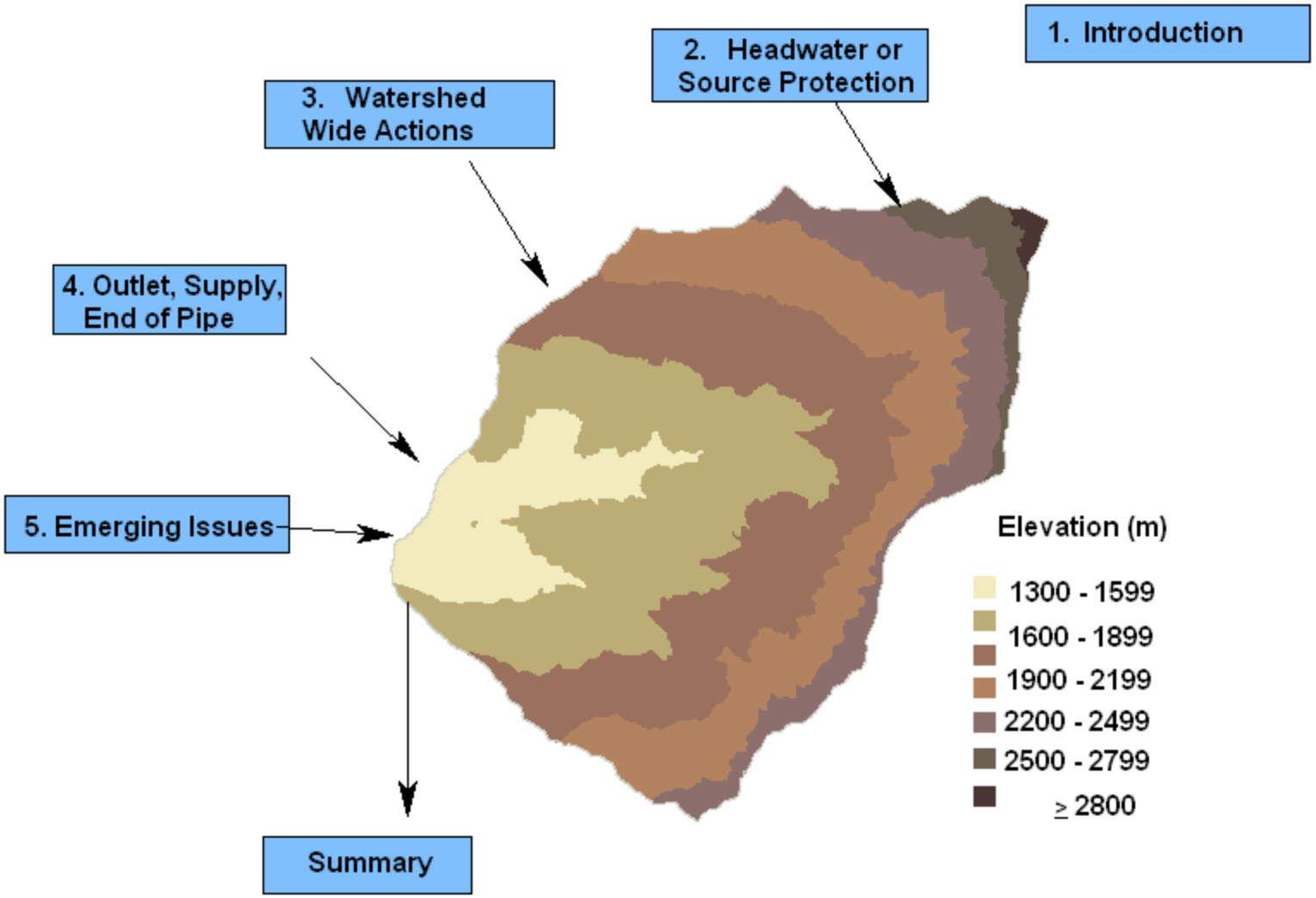
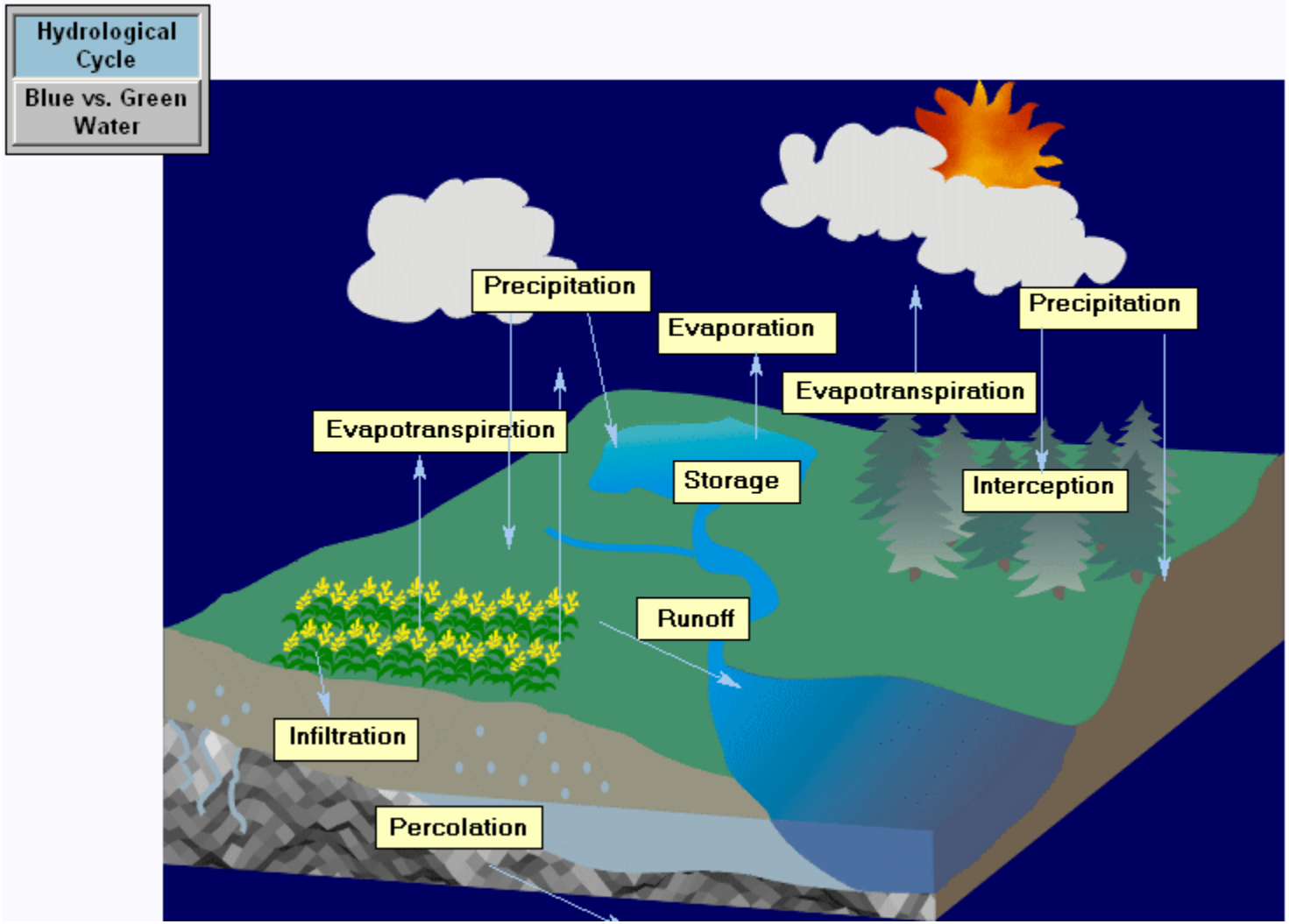
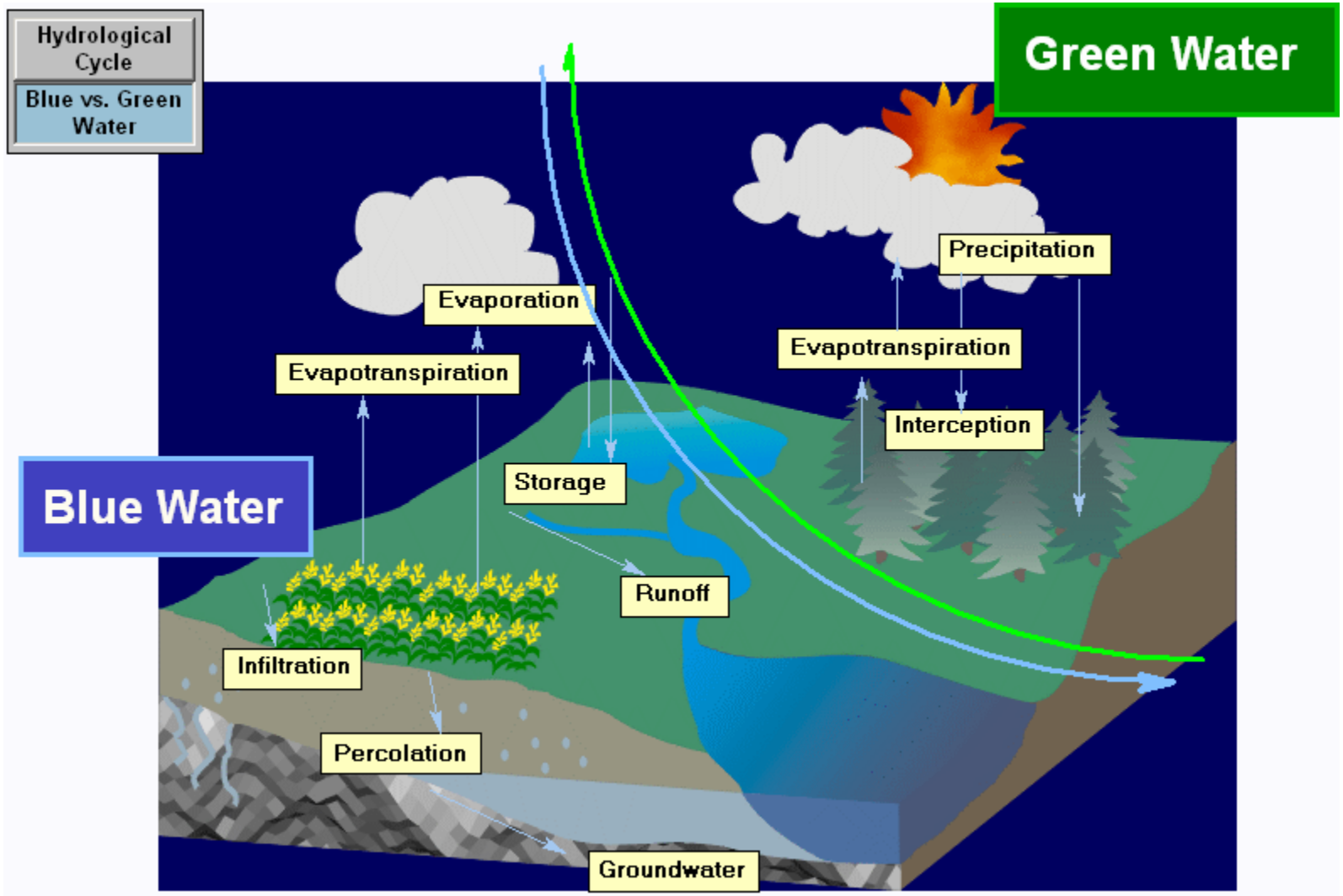
# A Multi-Barrier Approach to Watershed Management

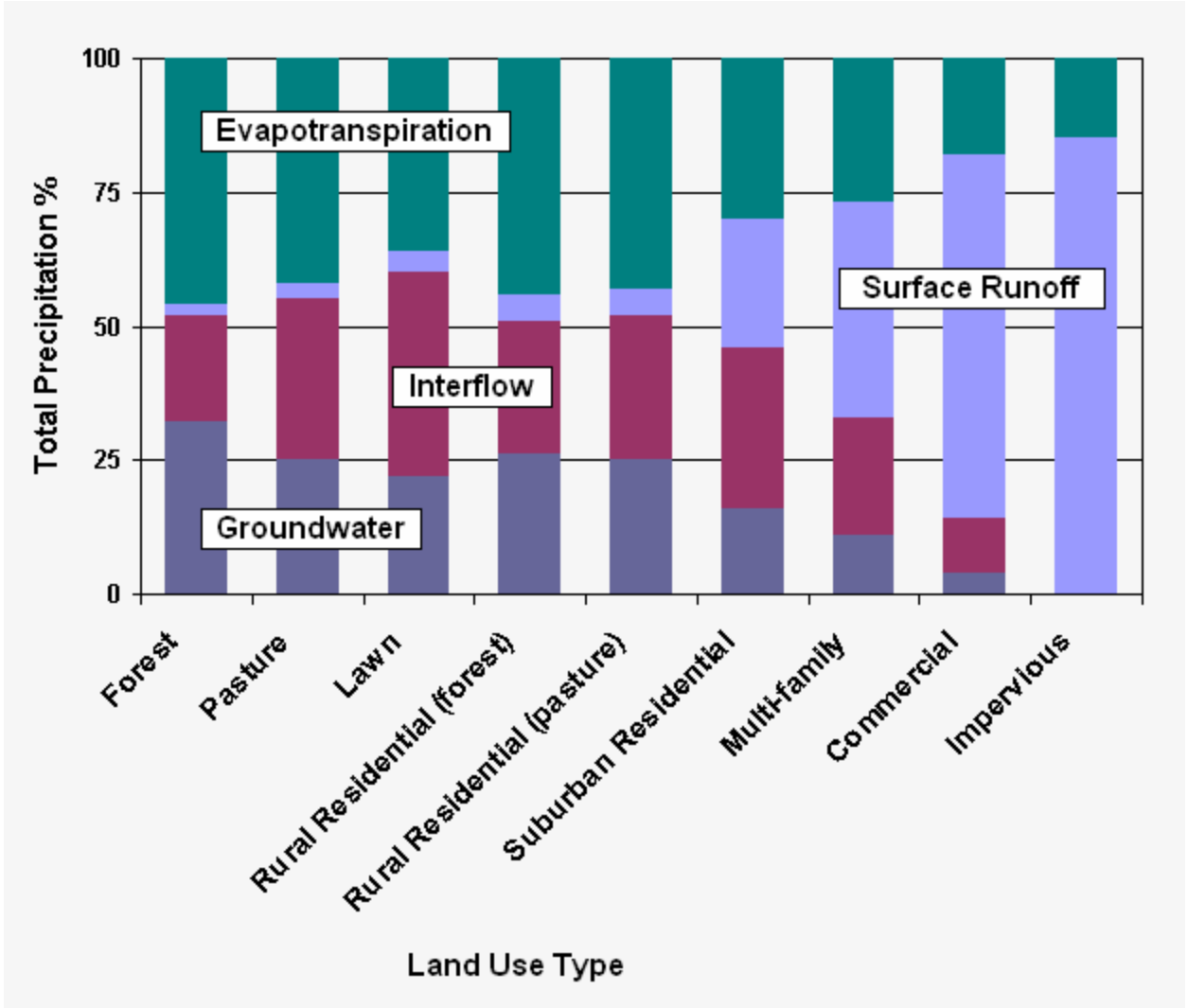



1. Introduction
2. Headwater or Source Protection
3. Watershed Wide Actions
4. Outlet, Supply, End of Pipe
5. Emerging Issues
Summary
Elevation (m)
1300 - 1599
1600 - 1899
1900 - 2199
2200 - 2499
2500 - 2799
≥ 2800

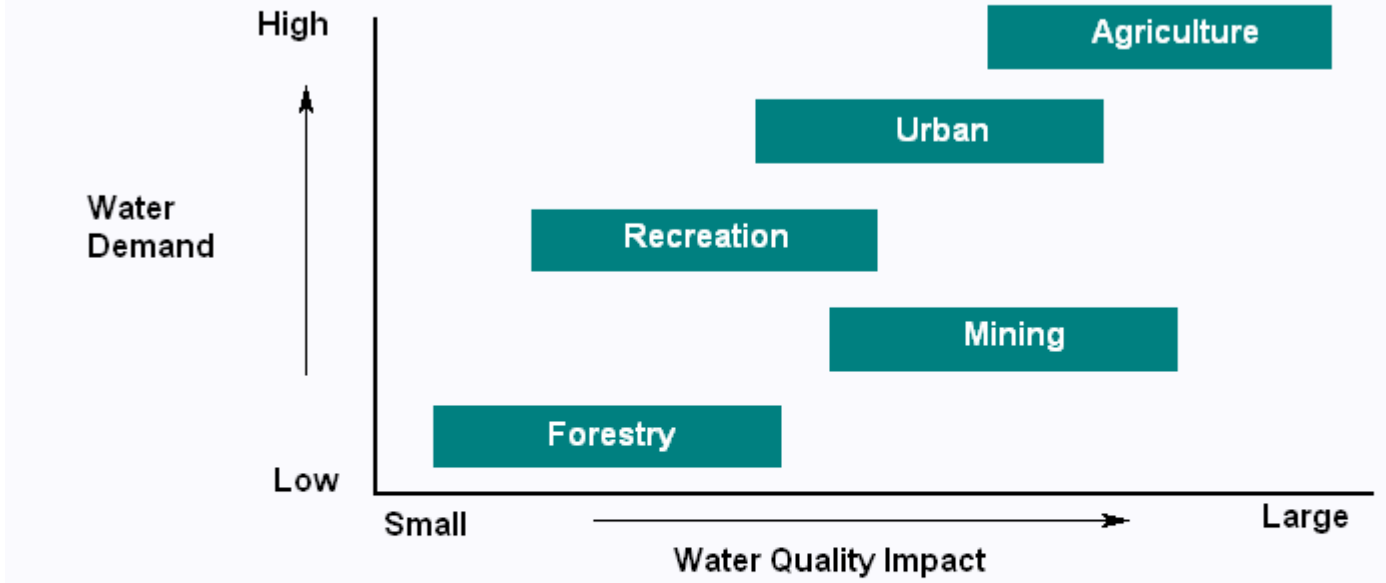
# Where is the Water Coming From

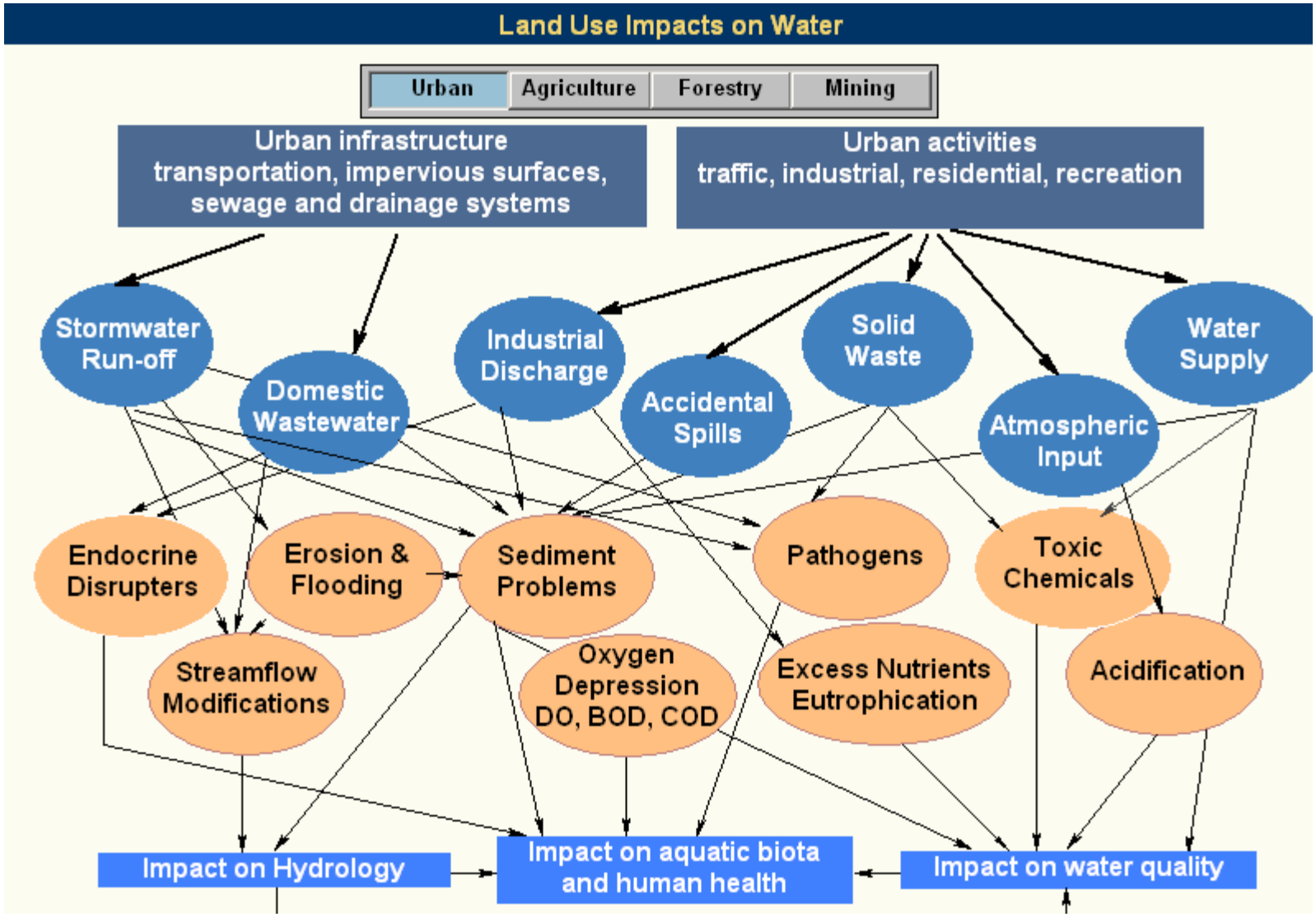

Hydrological Cycle
Blue vs. Green Water
Precipitation
Evaporation
Evapotranspiration
Precipitation
Evapotranspiration
Storage
Interception
Runoff
Infiltration
Percolation

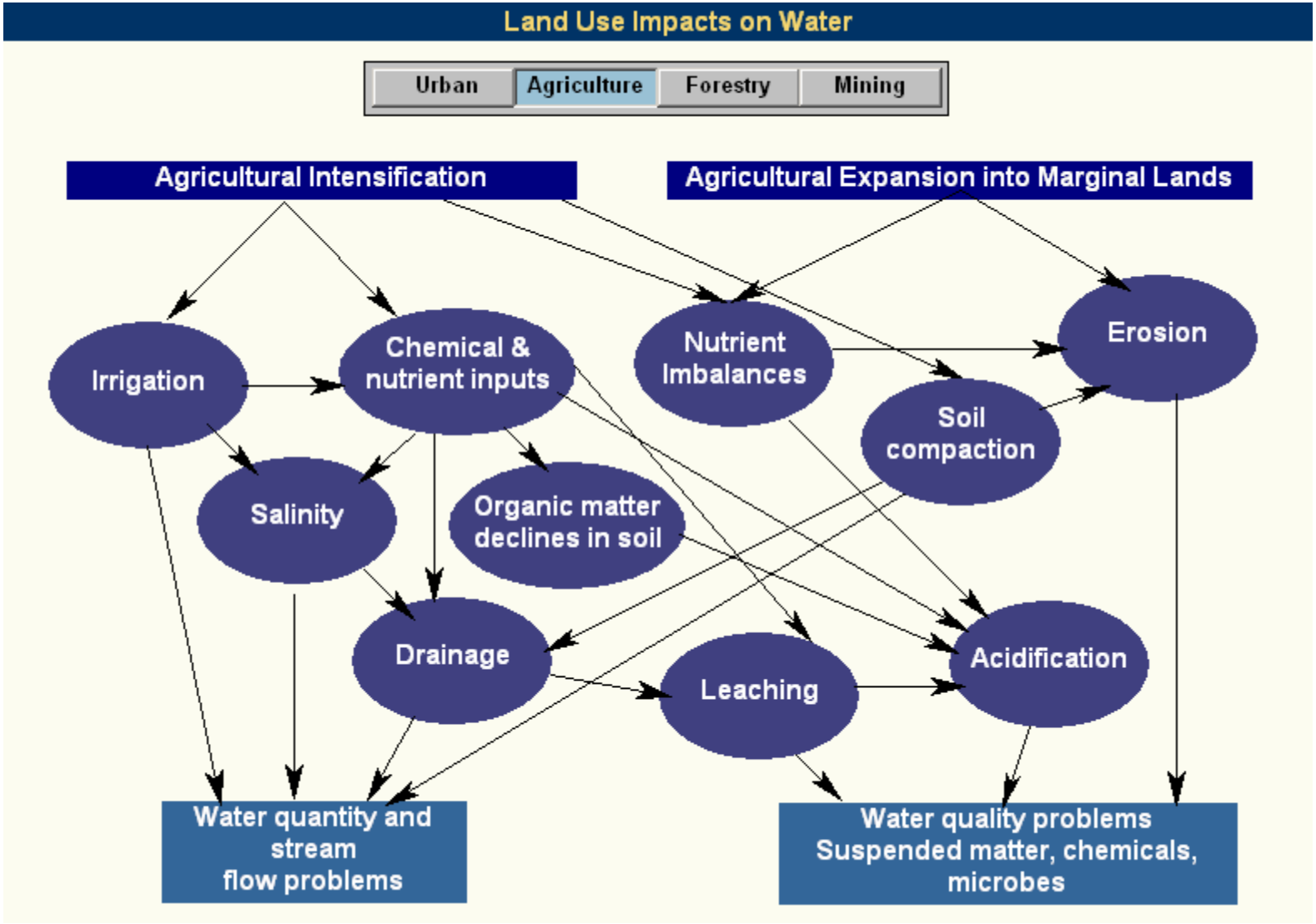

Hydrological Cycle
Blue vs. Green Water
Green Water
Blue Water
Precipitation
Evaporation
Evapotranspiration
Evapotranspiration
Interception
Storage
Runoff
Infiltration
Percolation
Groundwater

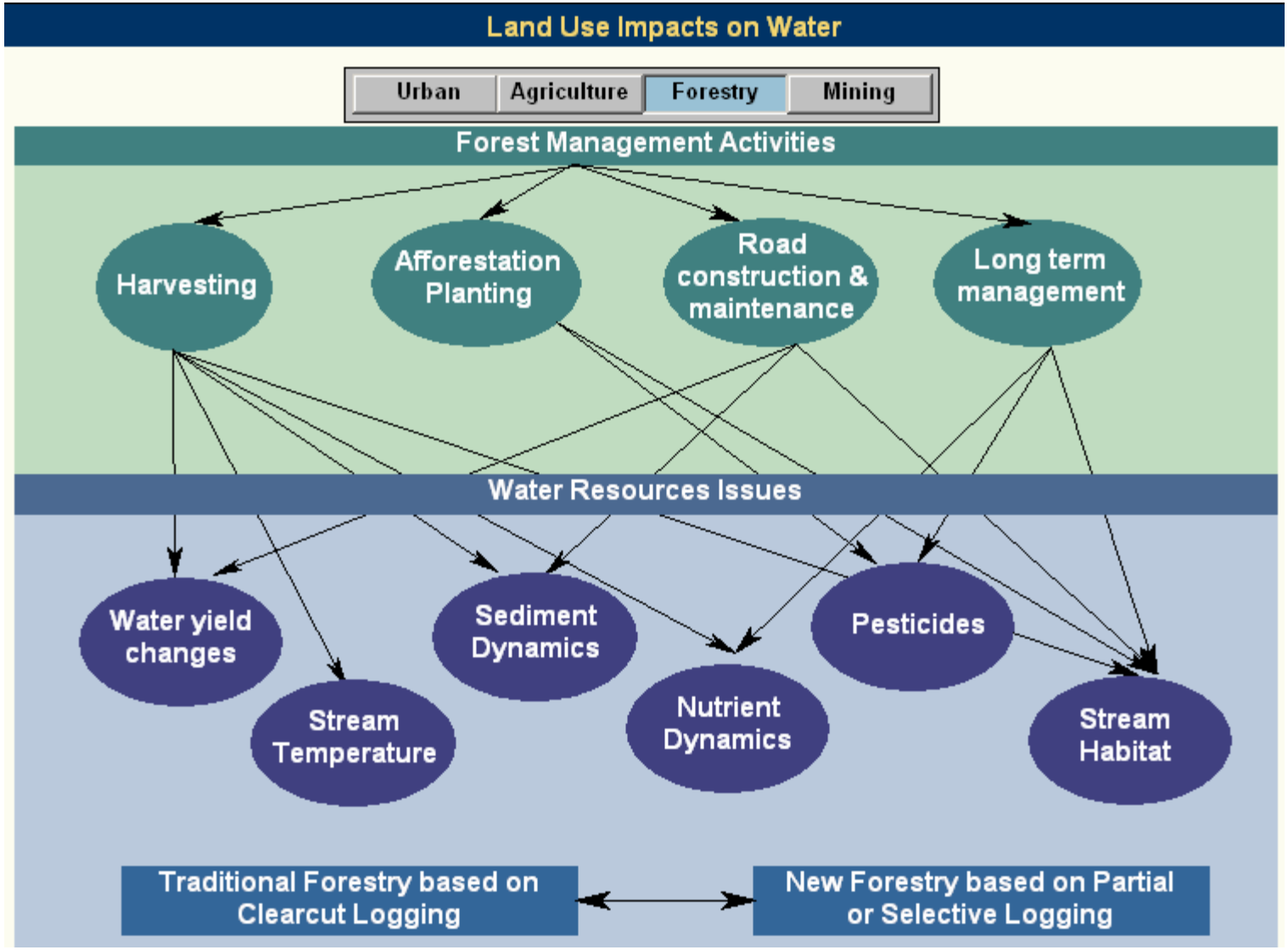

100
75
50
25
0
Total Precipitation %
Evapotranspiration
Surface Runoff
Interflow
Groundwater
Forest
Pasture
Lawn
Rural Residential (forest)
Rural Residential (pasture)
Suburban Residential
Multi-family
Commercial
Impervious
Land Use Type

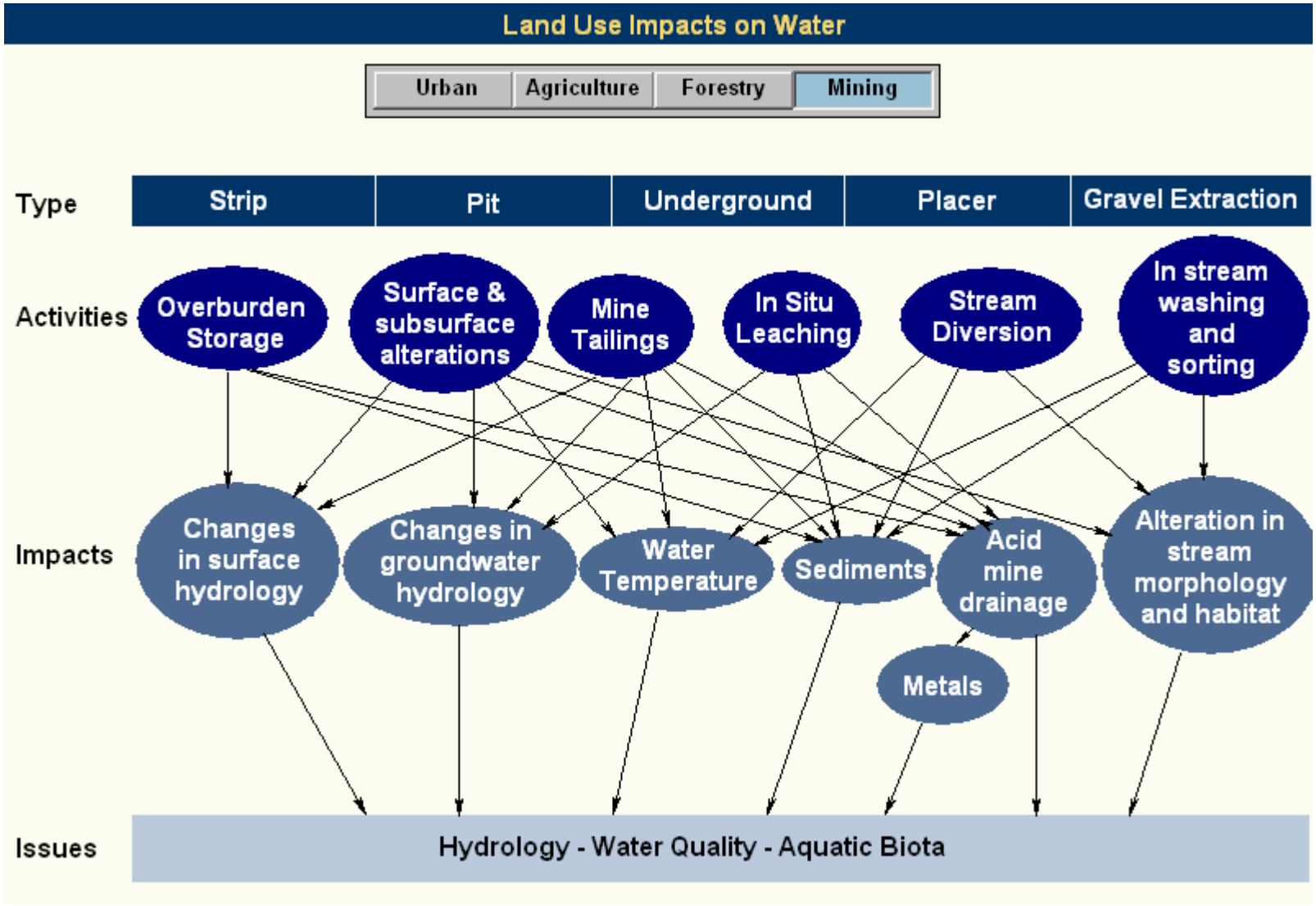
## Impacts on Water Quantity and Quality

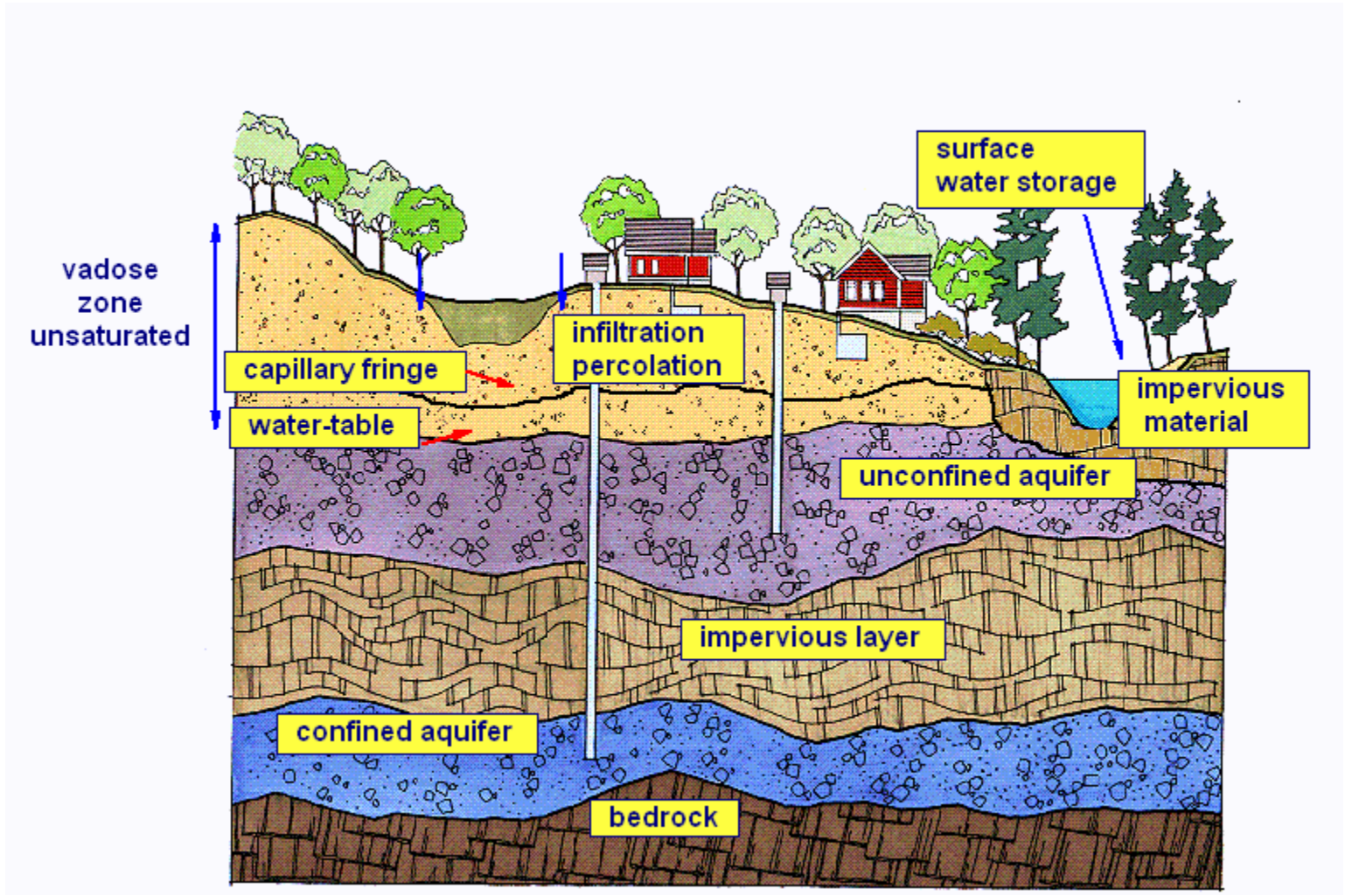




Land Use Impacts on Water
Urban
Agriculture
Forestry
Mining
Urban infrastructure
transportation, impervious surfaces,
sewage and drainage systems
Urban activities
traffic, industrial, residential, recreation
Stormwater
Run-off
Domestic
Wastewater
Industrial
Discharge
Accidental
Spills
Solid
Waste
Atmospheric
Input
Water
Supply
Endocrine
Disrupters
Erosion &
Flooding
Sediment
Problems
Pathogens
Toxic
Chemicals
Streamflow
Modifications
Oxygen
Depression
DO, BOD, COD
Excess Nutrients
Eutrophication
Acidification
Impact on Hydrology
Impact on aquatic biota
and human health
Impact on water quality

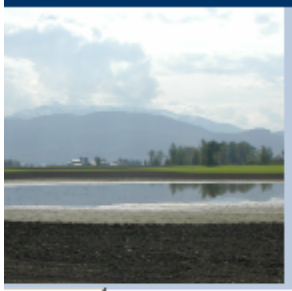

Land Use Impacts on Water
Urban
Agriculture
Forestry
Mining
Agricultural Intensification
Agricultural Expansion into Marginal Lands
Irrigation
Chemical & nutrient inputs
Nutrient Imbalances
Erosion
Soil compaction
Salinity
Organic matter declines in soil
Drainage
Leaching
Acidification
Water quantity and stream flow problems
Water quality problems Suspended matter, chemicals, microbes


Land Use Impacts on Water
Urban
Agriculture
Forestry
Mining
Forest Management Activities
Harvesting
Afforestation Planting
Road construction & maintenance
Long term management
Water Resources Issues
Water yield changes
Stream Temperature
Sediment Dynamics
Nutrient Dynamics
Pesticides
Stream Habitat
Traditional Forestry based on Clearcut Logging
New Forestry based on Partial or Selective Logging


Land Use Impacts on Water
Urban
Agriculture
Forestry
Mining
Type
Strip
Pit
Underground
Placer
Gravel Extraction
Activities
Overburden Storage
Surface & subsurface alterations
Mine Tailings
In Situ Leaching
Stream Diversion
In stream washing and sorting
Impacts
Changes in surface hydrology
Changes in groundwater hydrology
Water Temperature
Sediments
Acid mine drainage
Alteration in stream morphology and habitat
Metals
Issues
Hydrology - Water Quality - Aquatic Biota


vadose
zone
unsaturated
surface
water storage
infiltration
percolation
capillary fringe
water-table
impervious
material
unconfined aquifer
impervious layer
confined aquifer
bedrock

# Land Use Impacts on Water



Water Source

Interbasin Transfer

Watersheds

Groundwater Supplies

Water Availability

Use

Water Uses

Transportation

Agriculture

Health

Fisheries

Industry & Energy

Environmental Services

Municipalities & Cities

Tourism & Recreation

Impact

Impacts

Stormwater, Flooding, NPS Pollution, Channel Modifications Diversions

Storage, NPS Pollution, Obstructions, Temperature Effects

Modifications of Flow Shortages Recharge

Loss of Biodiversity Stream Health Pathogens Sediments

Disease, Illness, Wetland losses Water Quality Deterioration

Conflicts

Overall Results

Supply & Demand Imbalances

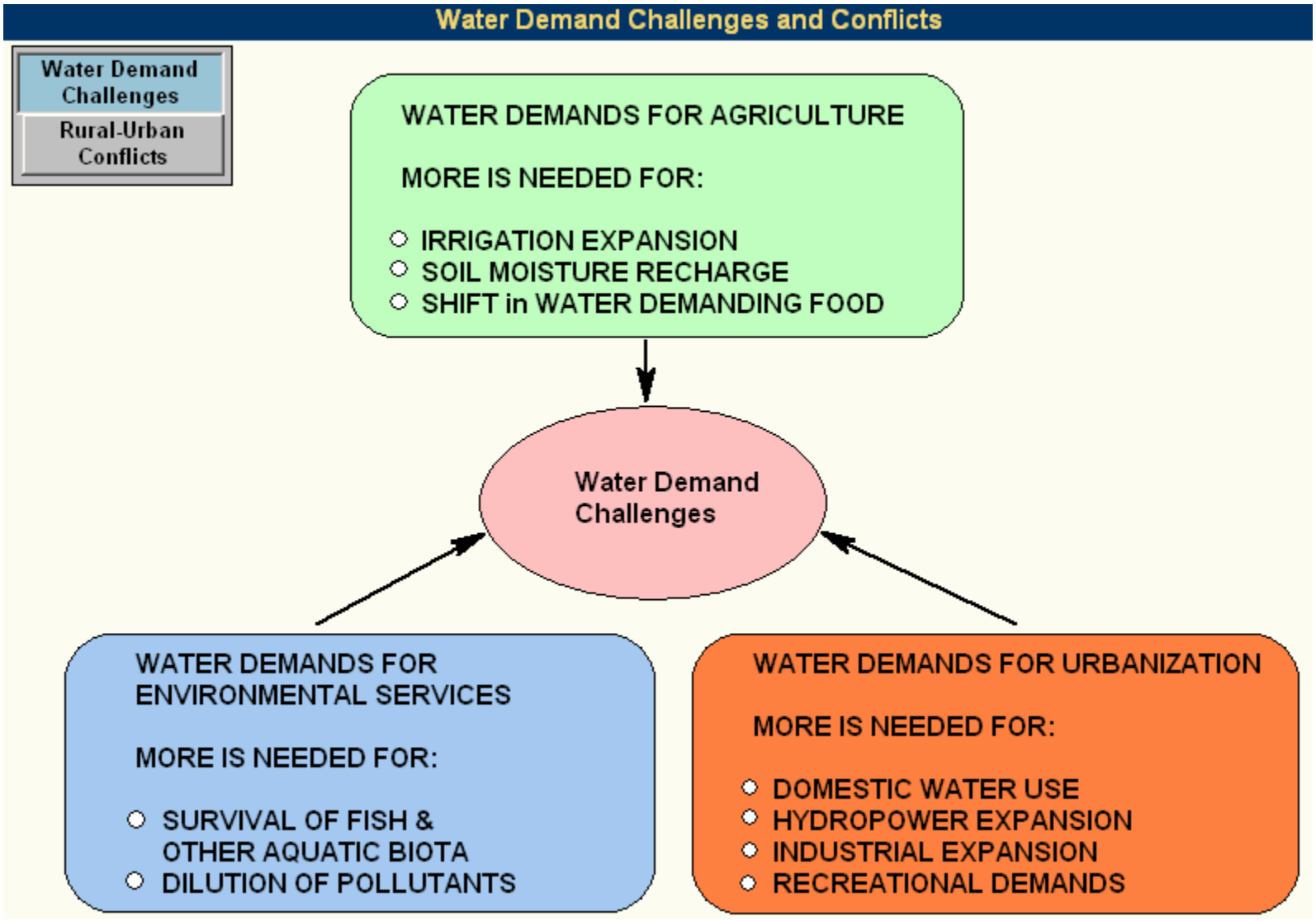
Jurisdictional Problems

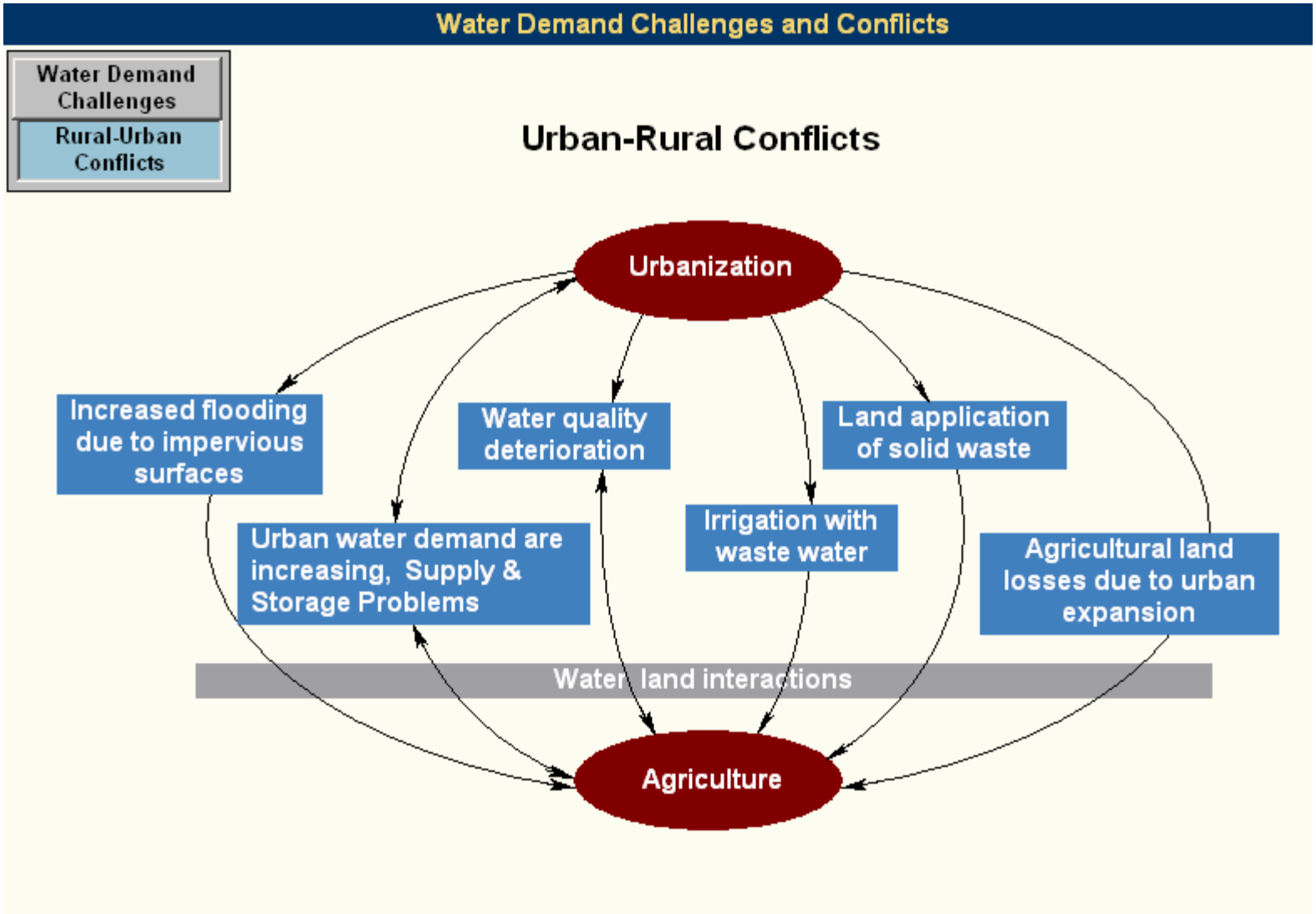
Conflicts over Use

Conflicts over Quality

Aquatic & Human Health

Ownership & Equity Problems


Water Demand Challenges and Conflicts
Water Demand Challenges
Rural-Urban Conflicts
WATER DEMANDS FOR AGRICULTURE
MORE IS NEEDED FOR:
IRRIGATION EXPANSION
SOIL MOISTURE RECHARGE
SHIFT in WATER DEMANDING FOOD
Water Demand Challenges
WATER DEMANDS FOR ENVIRONMENTAL SERVICES
MORE IS NEEDED FOR:
SURVIVAL OF FISH & OTHER AQUATIC BIOTA
DILUTION OF POLLUTANTS
WATER DEMANDS FOR URBANIZATION
MORE IS NEEDED FOR:
DOMESTIC WATER USE
HYDROPOWER EXPANSION
INDUSTRIAL EXPANSION
RECREATIONAL DEMANDS


Water Demand Challenges and Conflicts
Water Demand Challenges
Rural-Urban Conflicts
Urban-Rural Conflicts
Urbanization
Increased flooding due to impervious surfaces
Water quality deterioration
Land application of solid waste
Urban water demand are increasing, Supply & Storage Problems
Irrigation with waste water
Agricultural land losses due to urban expansion
Water land interactions
Agriculture

## Innovations and Need for Change

What have we been doing? **Changing Course** What should we be doing?

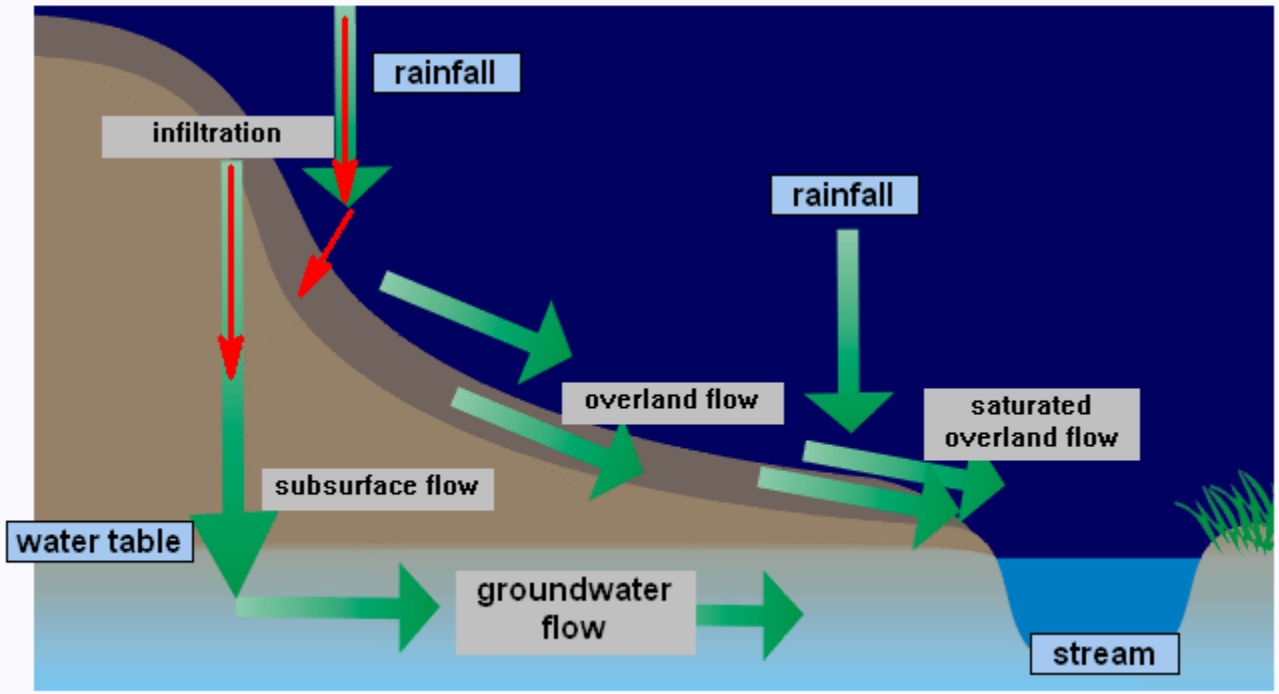
| Traditional Approach | Innovative Approach |
|---|---|
| Creating Impervious & Compacted Surfaces | Minimizing Imperviousness & compaction |
| Minimizing Buffer Zones | Maximizing Buffer Zones |
| Draining Wetlands | Creating Wetlands |
| Stormwater Piping | Detaining Stormwater |
| End of Pipe Treatment | Source Control |
| Point Source Pollution | Non-Point Source Pollution |
| Expanding Water Supplies | Controlling Demand (Water Smart) |
| Dealing with Single Pollutants | Cumulative Effects |
| Water Use for Human Activities | Water for Environmental Services |
| Flood Irrigation | Innovative Irrigation |
| Managing Blue Water | Managing Green Water |
| Government based Management | Community Involvement |

# Soil Infiltration & Filter Capacity

Infiltration

Retain/Filter

The portion of precipitation that runs off or infiltrates to the ground water table depends on the soils permeability rate, surface roughness, and the amount, duration and intensity of precipitation.



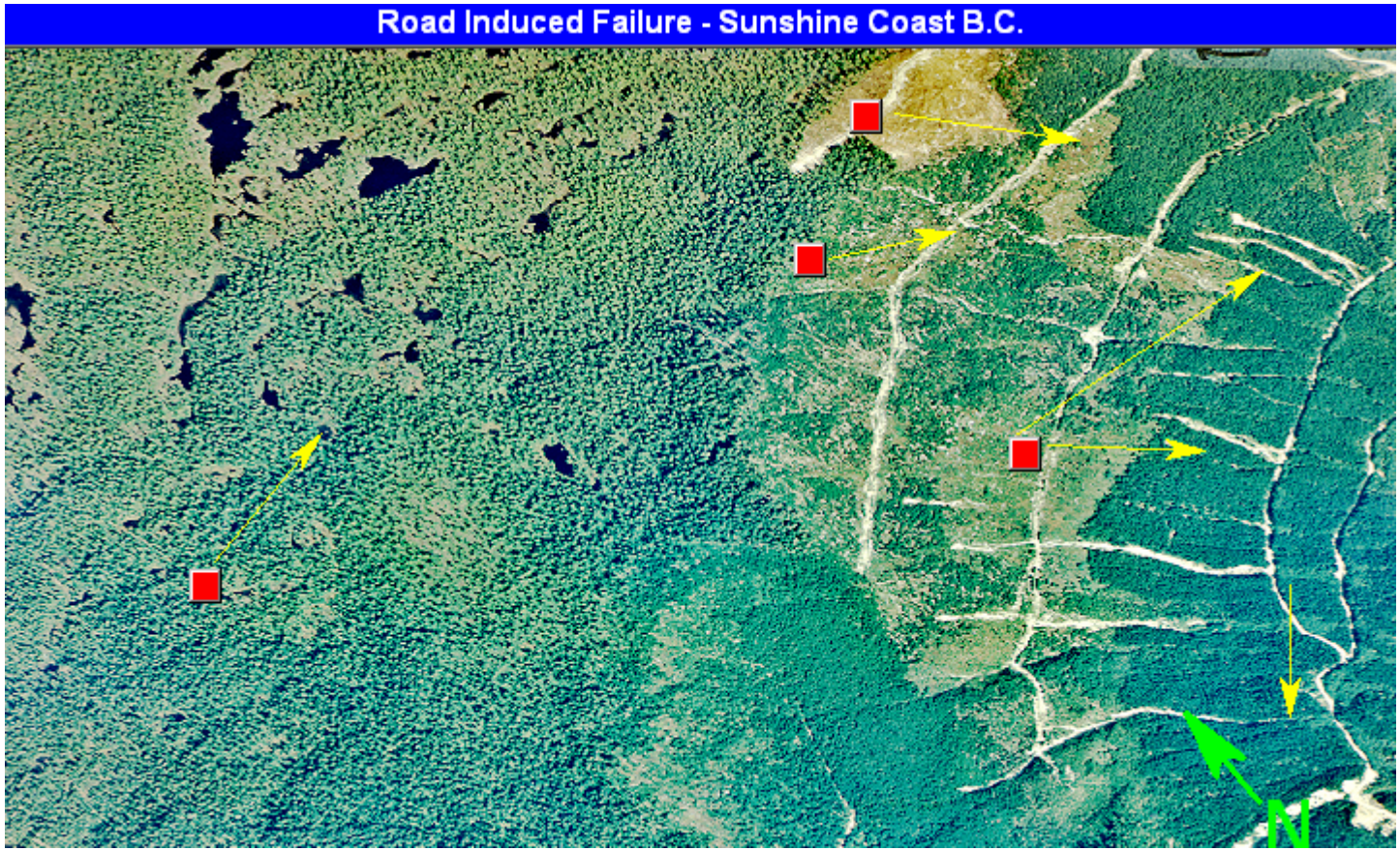
## Soil Infiltration & Filter Capacity

Infiltration

Retain/Filter

| Maximize water infiltration into soils | Minimize surface runoff & detain water in the mountains | Filter water through soil and surficial material |
|---|---|---|
| 1. Maintain vegetation cover<br>2. Avoid Soil compaction<br>3. Create surface roughness<br>4. Maintain surface litter and organic matter content in the soil<br>5. Prevent erosion, clogging and reduction of soil pore space<br>6. Manage land use to minimize reduction in hydraulic conductivity infiltration and percolation in soils | 1. Surface detention of water in ponds and wetlands<br>2. Maximize storage of water in soils and subsoils<br>3. Maximize water holding capacity<br>4. Maintain vegetation cover that assists in water detention<br>5. Find the right combination of conditions that allows good decomposition and chemical conversions | 1. Maintain a healthy and biologically active soil<br>2. Prevent soil clogging<br>3. Maintain physical and chemical filter capacity of soil<br>4. Maintain wetland systems and riparian buffers<br>5. Avoid alterations of surface conditions (litter layer, compaction, erosion) |

**A 10% INCREASE IN SOIL COMPACTION IN THE WORLD RESULTS IN A SOIL WATER LOSS EQUIVALENT OF ALL FRESHWATER IN RIVERS AND LAKES IN CANADA (LAVKULICH 1996)**


Road Induced Failure - Sunshine Coast B.C.
N

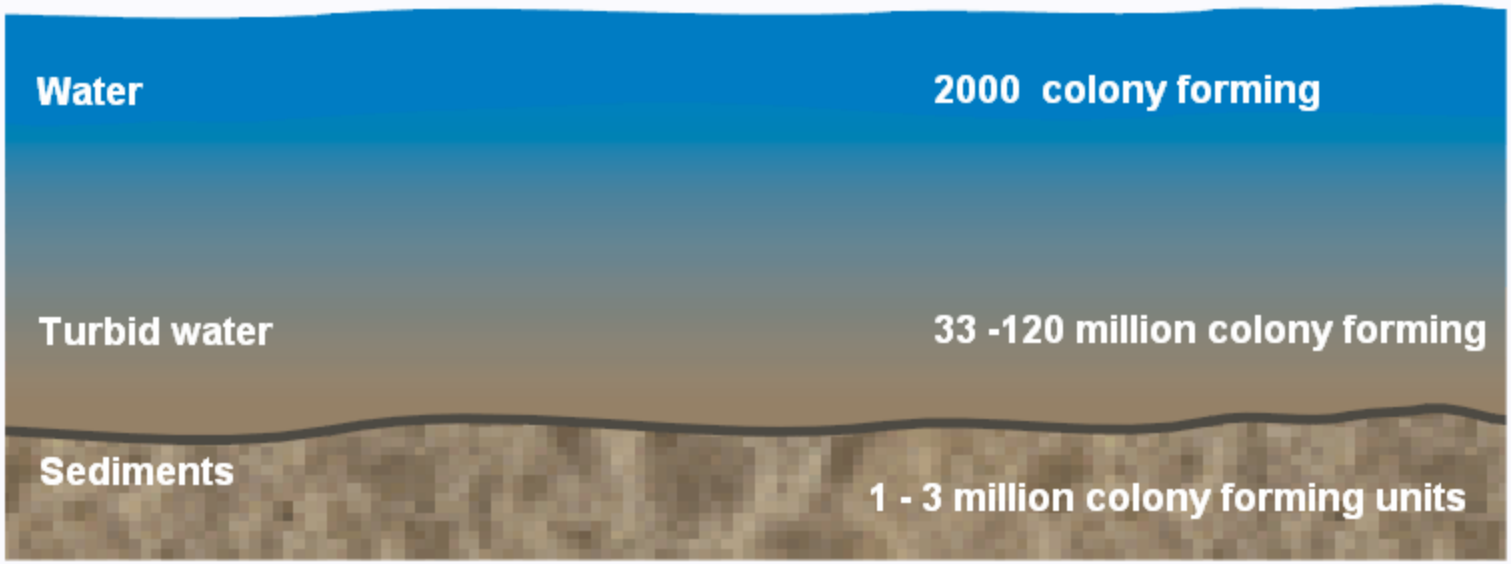
Sediment Sources

Sediments & Health


Sediment Sources

Sediments & Health

## Micro-organisms




The importance of sedimentary particles
in the water as a nursery for bacteria

Other WQ Issues

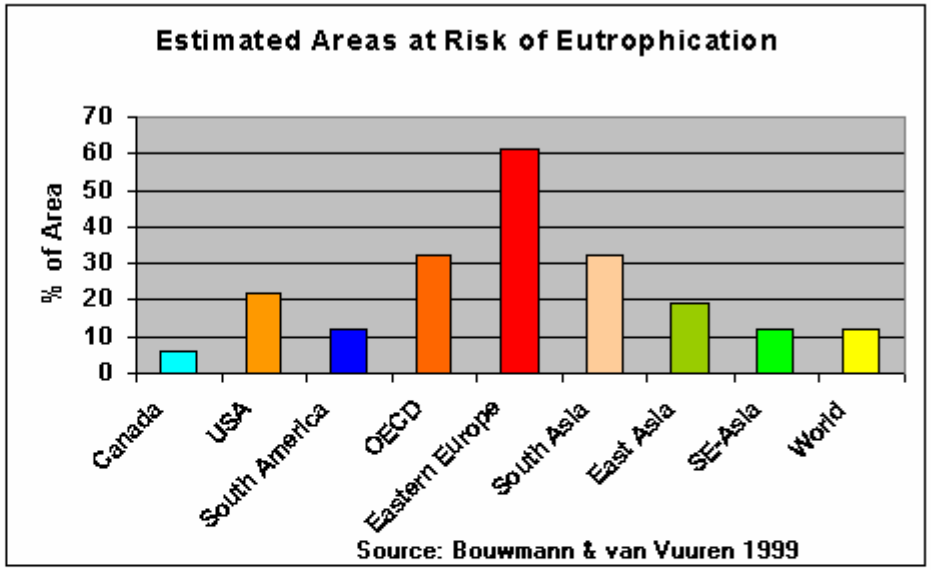
Eutrophication

THE MOST IMPORTANT WATER QUALITY ISSUES:

- EXCESS NUTRIENTS: LEADING TO EUTROPHICATION
- SOIL EROSION AND SEDIMENTATION LEADING TO STREAM DETERIORATION AND PATHOGEN PROBLEMS
- FATE of ANTIBIOTICS, HORMONES, PESTICIDE & PHARMACEUTICALS IN WATER

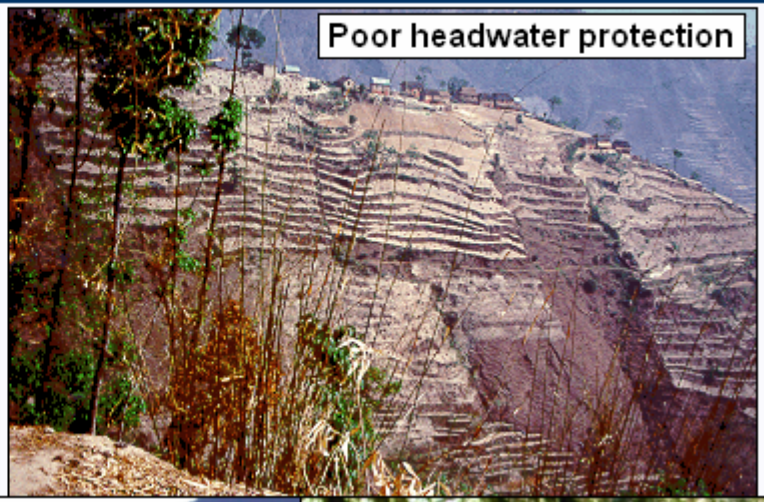
Other WQ Issues

Eutrophication

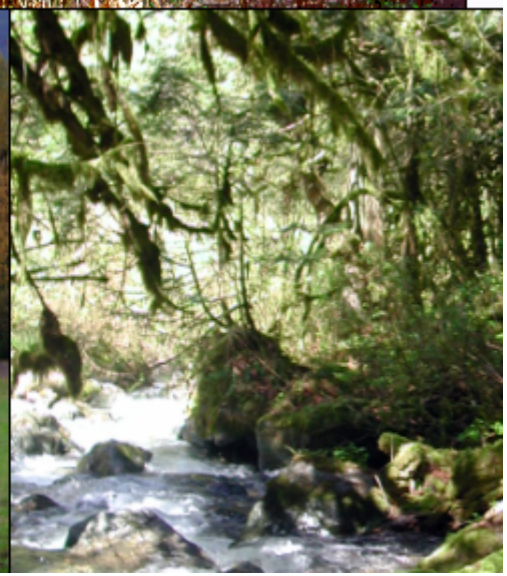




## Land Use Restrictions / Protection





# Watershed Wide Actions

- Land Use
- Stormwater Detention
- Riparian Buffer Zones
- Source Control = Budgets / Density

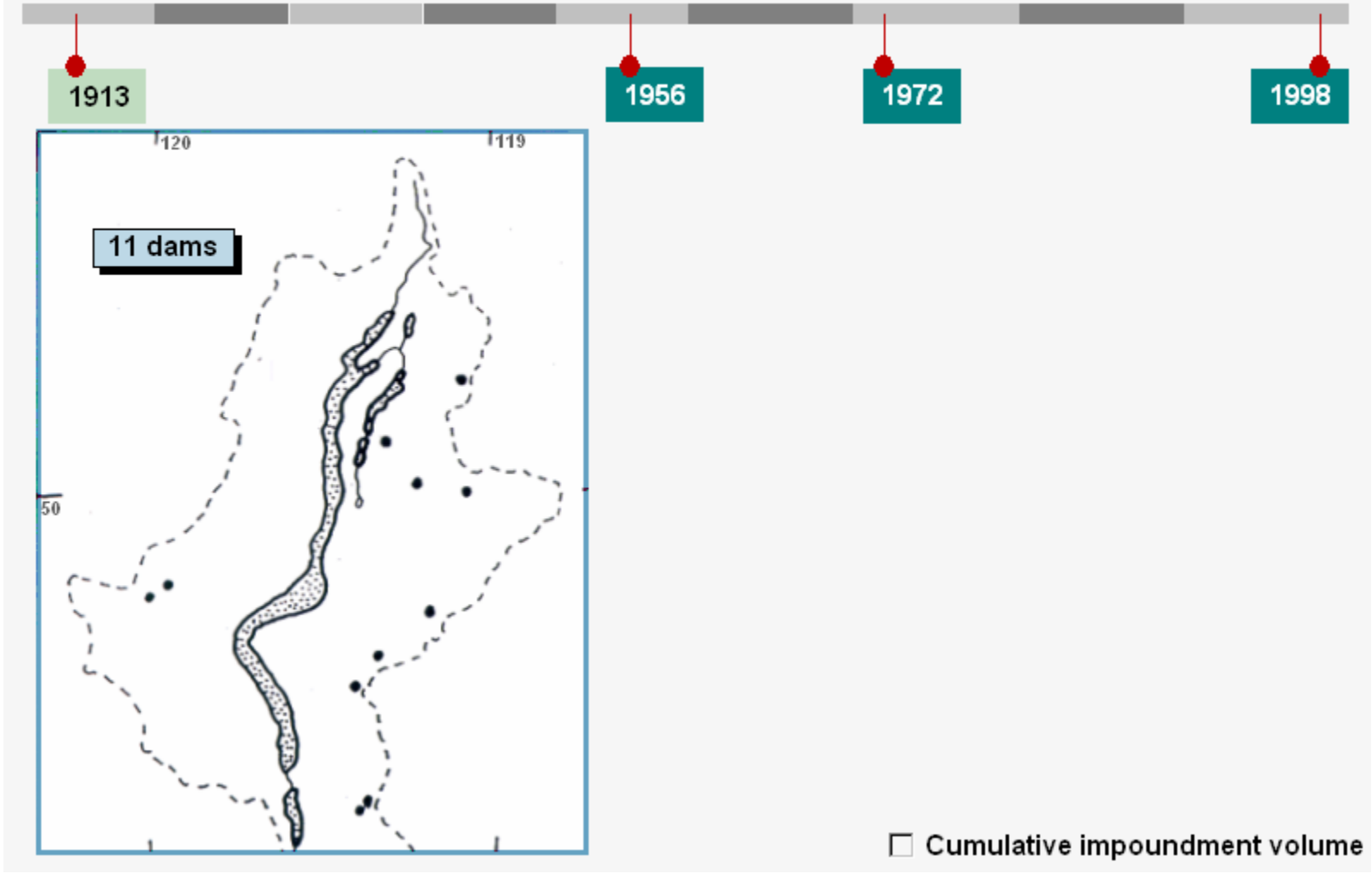
## Imperviousness

## Stormwater Detention

## Riparian Buffer Zones

## Source Control

## Sequential development of irrigation dams, drinking water reservoirs and diversions in the Okanagan



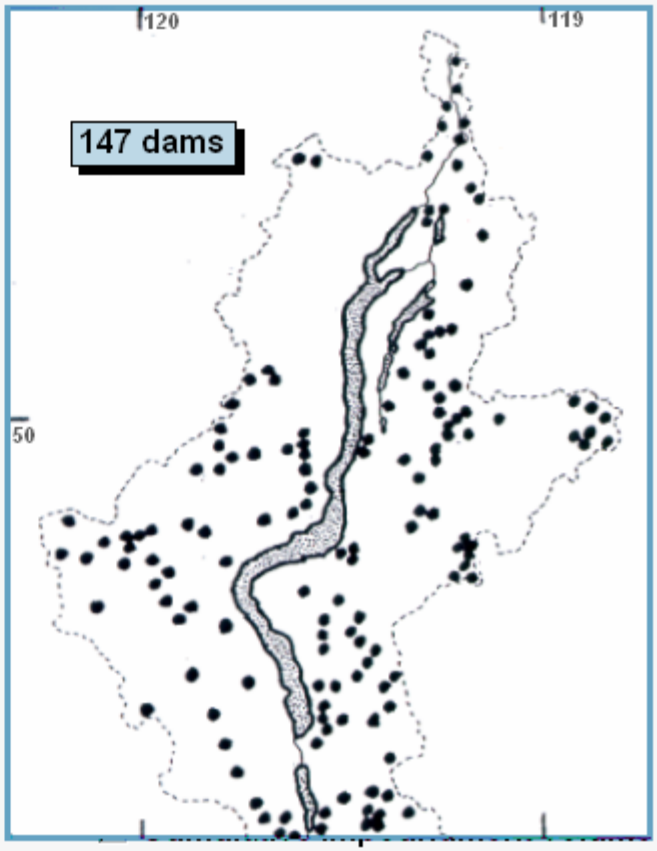
## Sequential development of irrigation dams, drinking water reservoirs and diversions in the Okanagan

1913

1956

1972

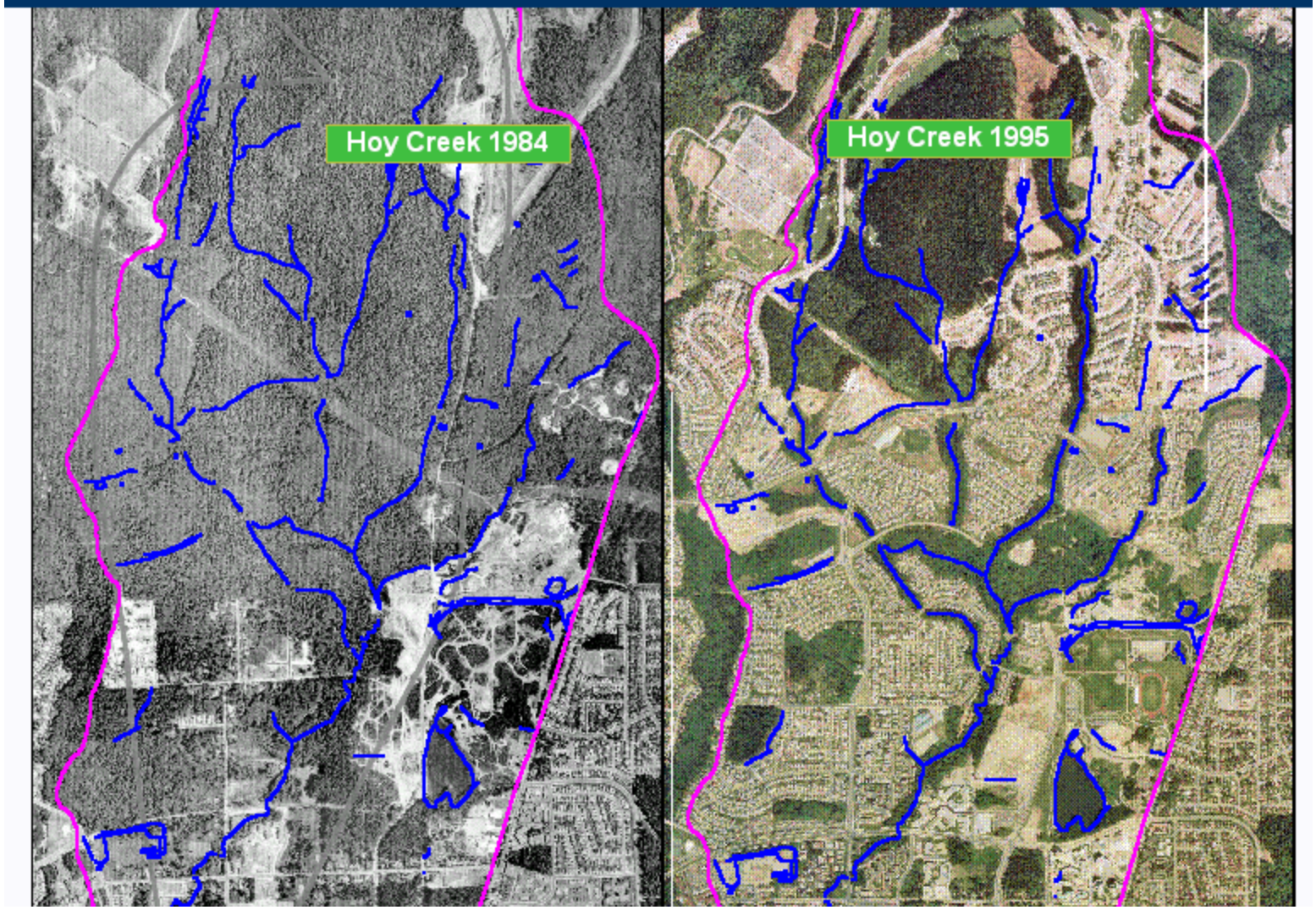
1998

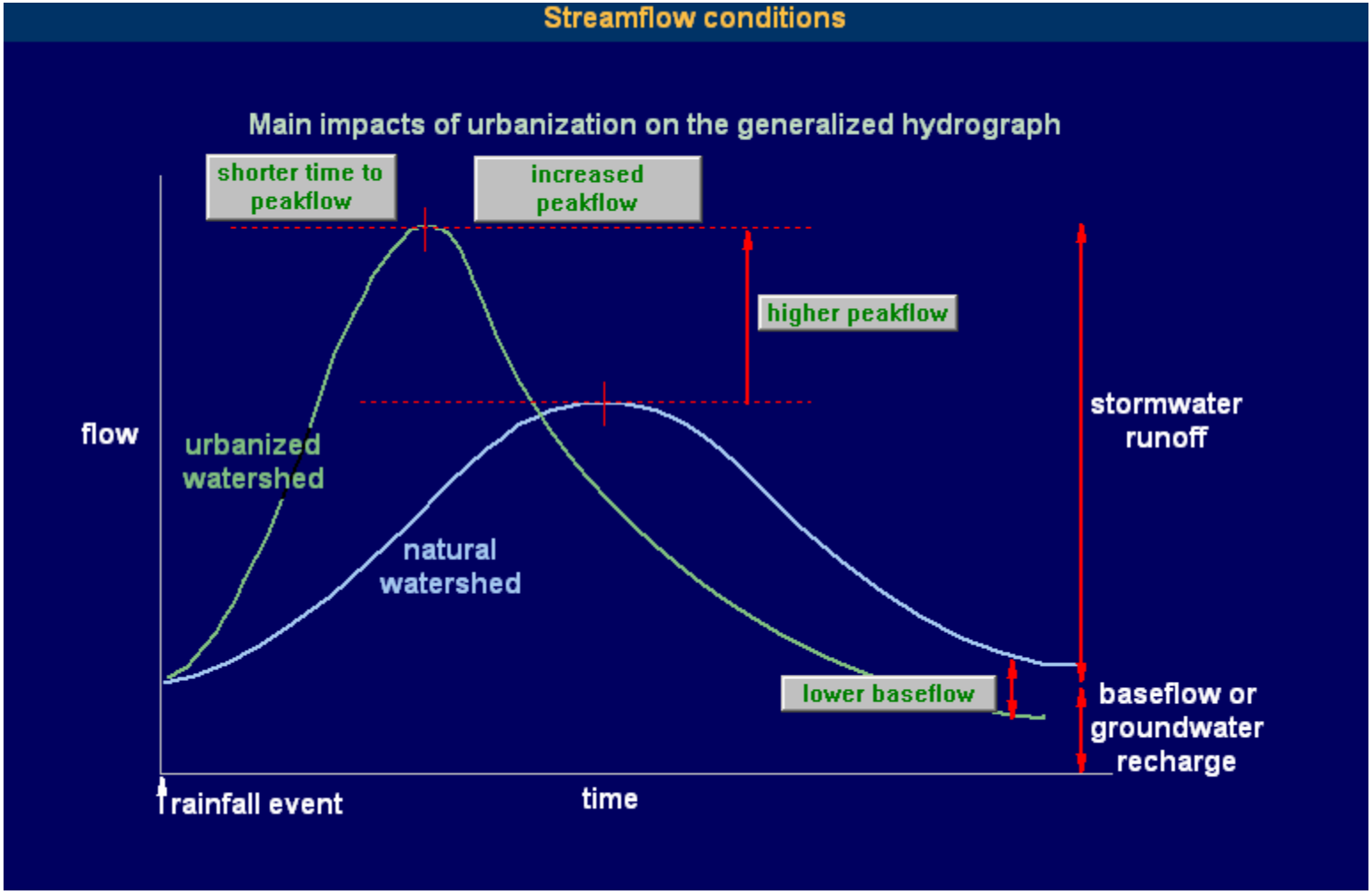


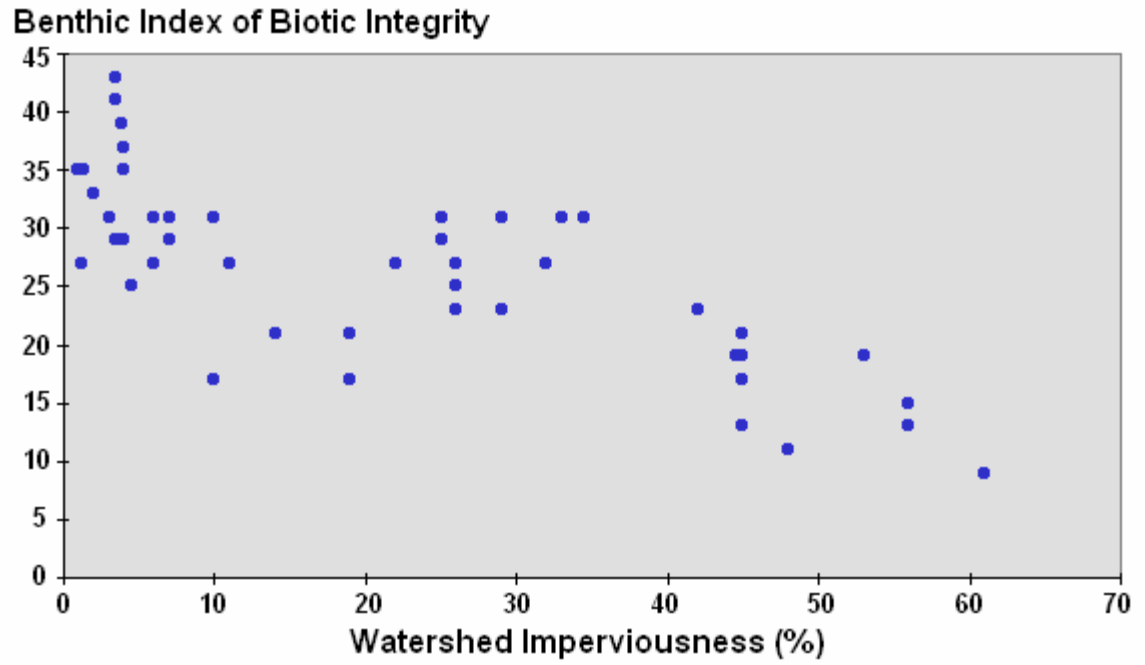
## MAJOR CHANGES IN LAND USE ACTIVITIES 1971-2001

| Growth Indicators | 1971 | 2001 | % Increase |
|---|---|---|---|
| Population | 115'000 | 317'000 | 175% |
| Golf Courses | 7 | 50 | 600 % |
| Ski Resorts | 4 | 8 | 100 % |
| Wineries | < 12 | 82 | 580 % |
| Grape Production Area | 955 ha | 2286 ha | 240% |
| Water Storage Systems | 81 | 147 | 81% |

## Imperviousness & Soil Compaction




Streamflow conditions
Main impacts of urbanization on the generalized hydrograph
shorter time to peakflow
increased peakflow
higher peakflow
stormwater runoff
flow
urbanized watershed
natural watershed
lower baseflow
baseflow or groundwater recharge
rainfall event
time


Benthic Index of Biotic Integrity
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
Watershed Imperviousness (%)

**May (1996)**


Imperviousness & Soil Compaction
Pervious Pavement
Pervious Options
Effective Reduction
CH

## Stormwater management

Before

After


Goal:
60% of rainfall detained in rock pits
30% of rainfall in infiltration galleries and detention ponds
Excessive storms into bypass storm system


CHILLIWACK Promotory Height

Low impact urban stormwater design

Minimum impact Street. No curbs or gutters, or drainage pipes. All surface runoff is infiltrated

# Buffers

Poor Buffers

Buffer functions

# Buffers

Poor Buffers

Buffer functions

Noise Reduction

Water Temperature Moderation

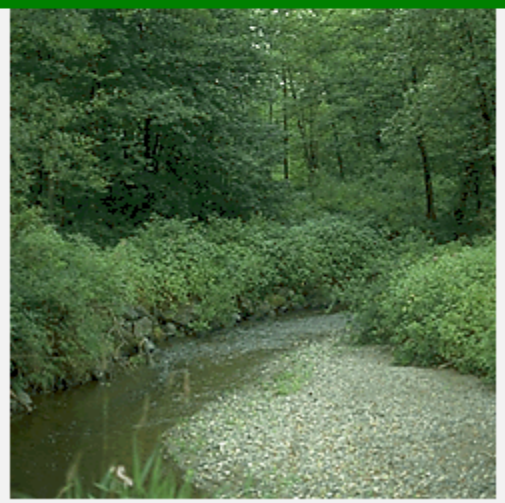
Sediment Removal

Pollution Reduction

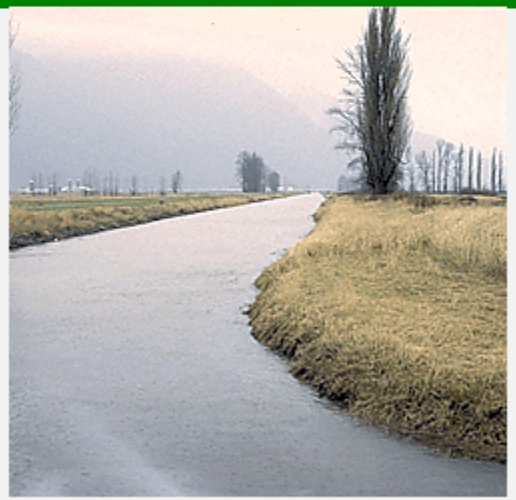
Species Diversity

Stormwater Retention and Wetland Protection

10 30 50 70 90 metres of buffer



Good Buffer



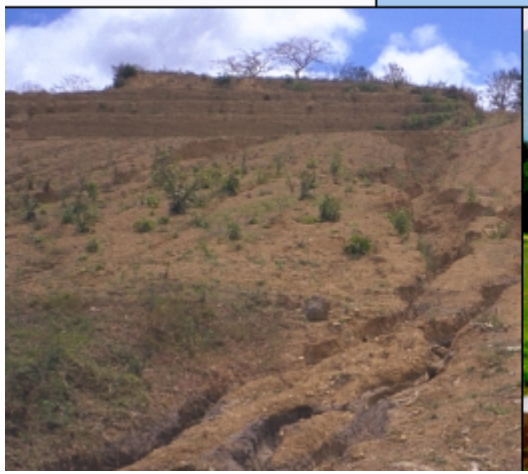
Poor Buffer

# Water quality

- Water Quality Issues
- Excess Nutrients
- Soil Erosion & Pathogens
- Antibiotics & Hormones

THE MOST IMPORTANT WATER QUALITY ISSUES:

- EXCESS NUTRIENTS: APPLICATION OF ACTIVE NITROGEN, P- MOBILISATION FROM MANURE - LEADING TO EUTROPHICATION AND BIODIVERSITY PROBLEM
- SOIL EROSION AND SEDIMENTATION LEADING TO STREAM DETERIORATION AND PATHOGEN PROBLEMS
- ANTIBIOTICS, HORMONES, AND PESTICIDE USE AND FATE OF THESE SUBSTANCES IN WATER

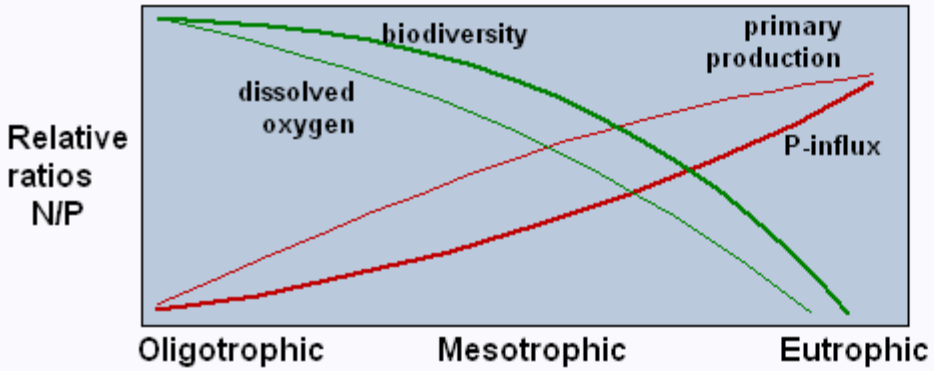


# Water quality

- Water Quality Issues
- **Excess Nutrients**
- Soil Erosion & Pathogens
- Antibiotics & Hormones

**Different Phytoplankton**

P-limitations regulate growth in most lakes and rivers
N-limitation are more common in estuaries and the ocean




| | |
|---|---|
| Low productivity | High productivity |
| Scarce littoral plants | Abundant littoral plants |
| Low nutrient levels | High nutrient levels |
| Oxygen in hypolimnion | Hypolimnion O depletion |
| Usually deeper lakes | Usually shallower lakes |
| Large diversity of plankton | Low diversity of plankton |

# Problems and options in manure management

Winter Manure Applications

Buffer Zones to Protect Waterways

Poor Soil Management

Animal Access to Streams

Improved Storage and Management

# Problems and options in manure management

Winter Manure Applications

Animal Access to Streams

Buffer Zones to Protect Waterways

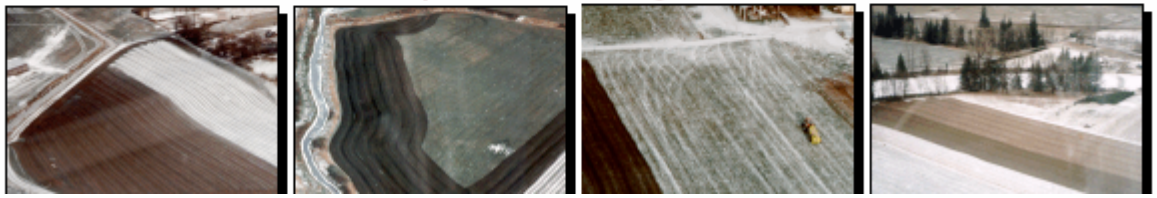
Poor Soil Management

Improved Storage and Management

In the Northern Hemisphere during the winter:
- soils are saturated resulting in surface runoff,
- plant growth is minimal, hence nutrient uptake is small,
- soils are often frozen leading to surface runoff.

Many farmers have insufficient manure storage capacity which leads to inappropriate winter applications. Resulting problem: sediment and excess nutrients in streams leading to eutrophication!

click photo to see enlarged version



# Problems and options in manure management

Winter Manure Applications

Animal Access to Streams

Buffer Zones to Protect Waterways

Poor Soil Management

Improved Storage and Management

Farmers should leave a sufficient buffer strip between fields and streams or ditches to reduce sediment inputs and the leaching of nutrients. Grassed buffer strips are effective in removing nutrients and sediments from streams.

The larger the buffer the greater the removal.

click photo to see enlarged version

# Problems and options in manure management

Winter Manure Applications

Animal Access to Streams

Buffer Zones to Protect Waterways

Poor Soil Management

Improved Storage and Management

Too many animals in confined spaces can lead to the loss of vegetation cover which, in turn, leads to soil compaction, surface erosion, changes in hydrology and water pollution.

The maintenance of vegetation cover is critical.

click photo to see enlarged version

# Problems and options in manure management


Winter Manure Applications

Buffer Zones to Protect Waterways

Poor Soil Management

Animal Access to Streams

Improved Storage and Management


**D**irect access to streams and ditches should be avoided because of nutrient and microbial problems. Fencing is a viable alternative.

click photo to see enlarged version

# Problems and options in manure management

Winter Manure Applications

Animal Access to Streams

Buffer Zones to Protect Waterways

Poor Soil Management

Improved Storage and Management

There are many innovative ways of improving the management of agricultural waste.

Increased storage capacity allows for the effective application of manure - when the soils can absorb it and when it is needed by the plants.

Moving manure to livestock poor areas is another viable option. This will improve the soil organic matter.

click photo to see enlarged version



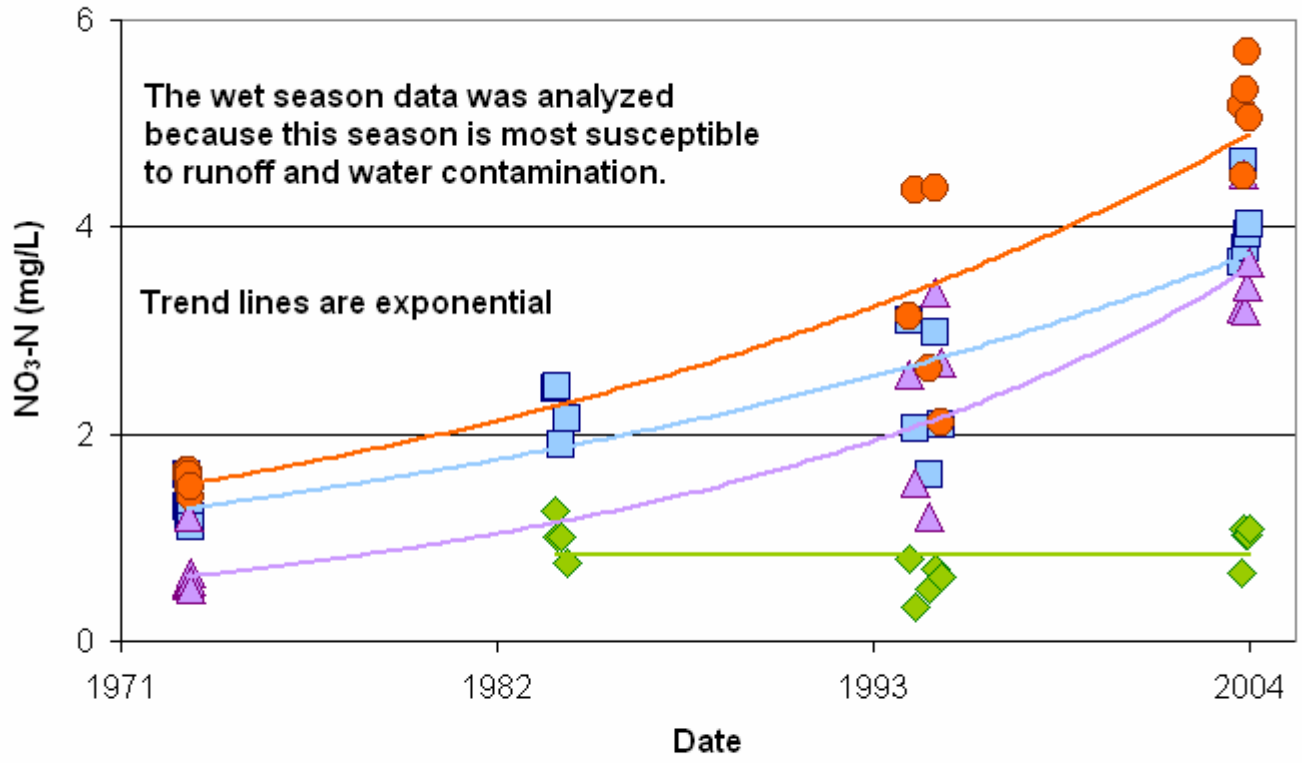

## Problems and options in manure management

Burial of dead chickens could be a significant source of nitrates and pathogens.

## Historical Nitrate Trends: Wet Seasons

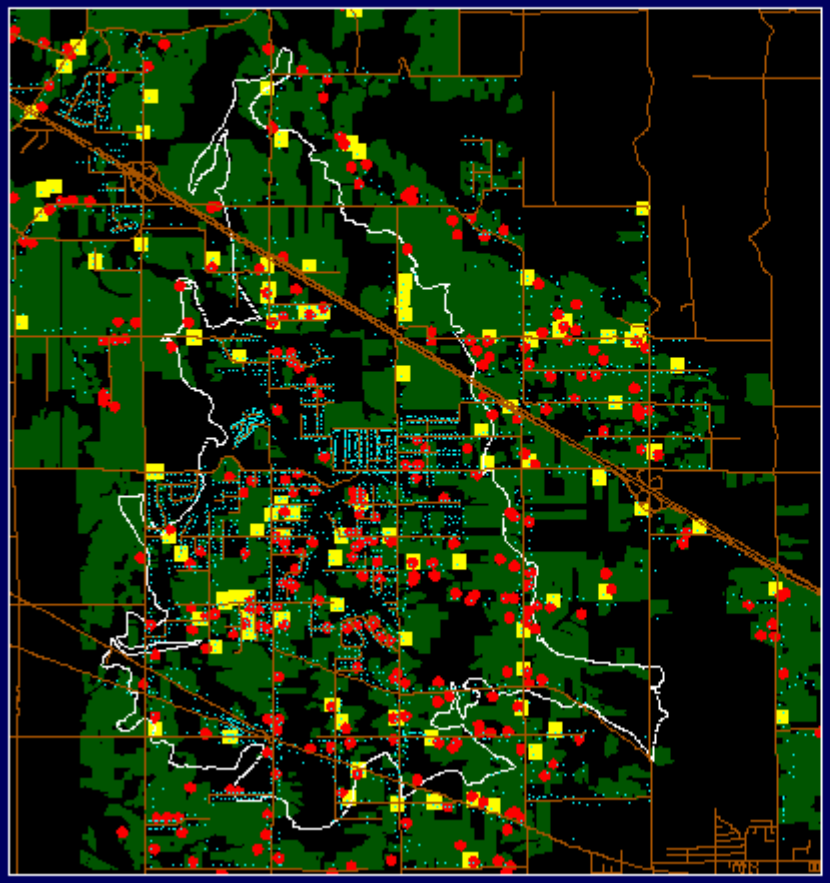
Nitrate Trends

Animal Trends




- Marshall Creek at North Parallel Road ($R^2$=0.901)
- Sumas River at International Border ($R^2$=0.833)
- Sumas River Downstream by Pump Station ($R^2$=0.888)
- Sumas River Headwaters (no significant change over time)

# Sources of nitrogen



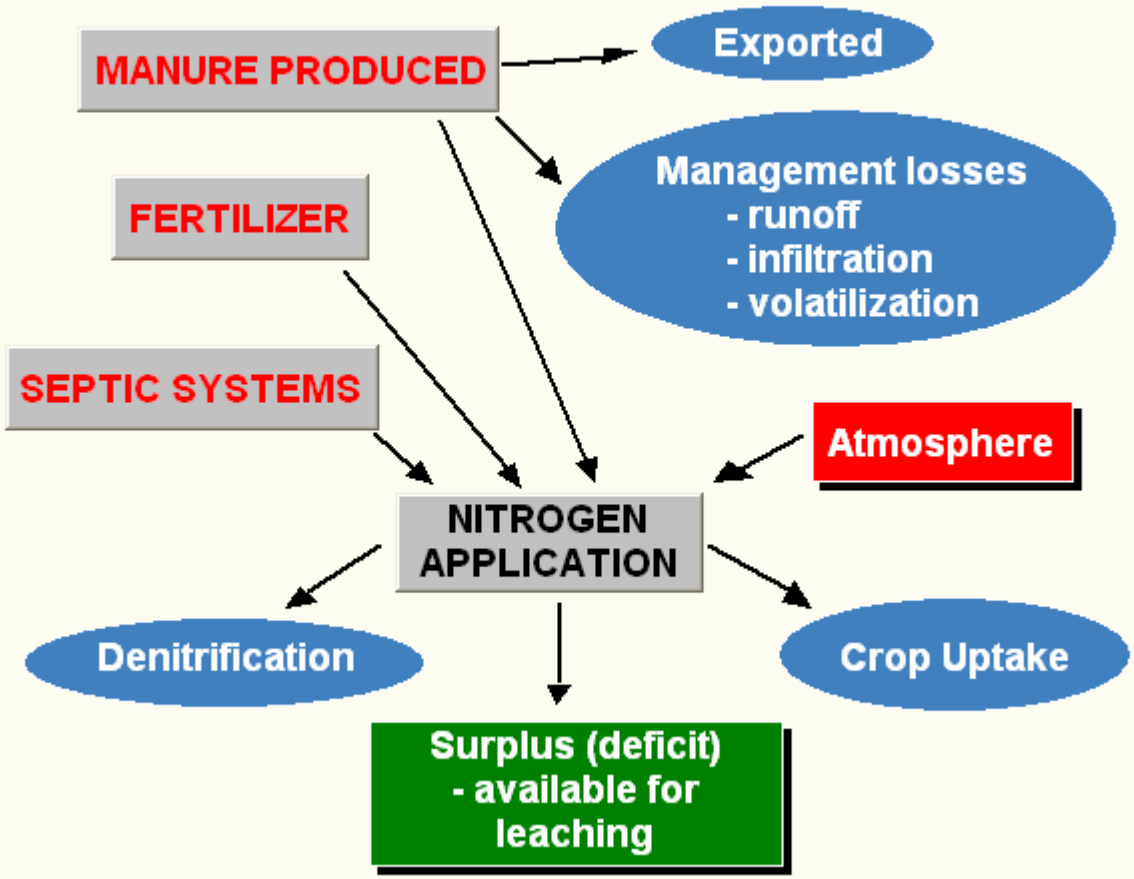
- septic systems
- farms
- horse farms
- farm land
- roads

click to show:

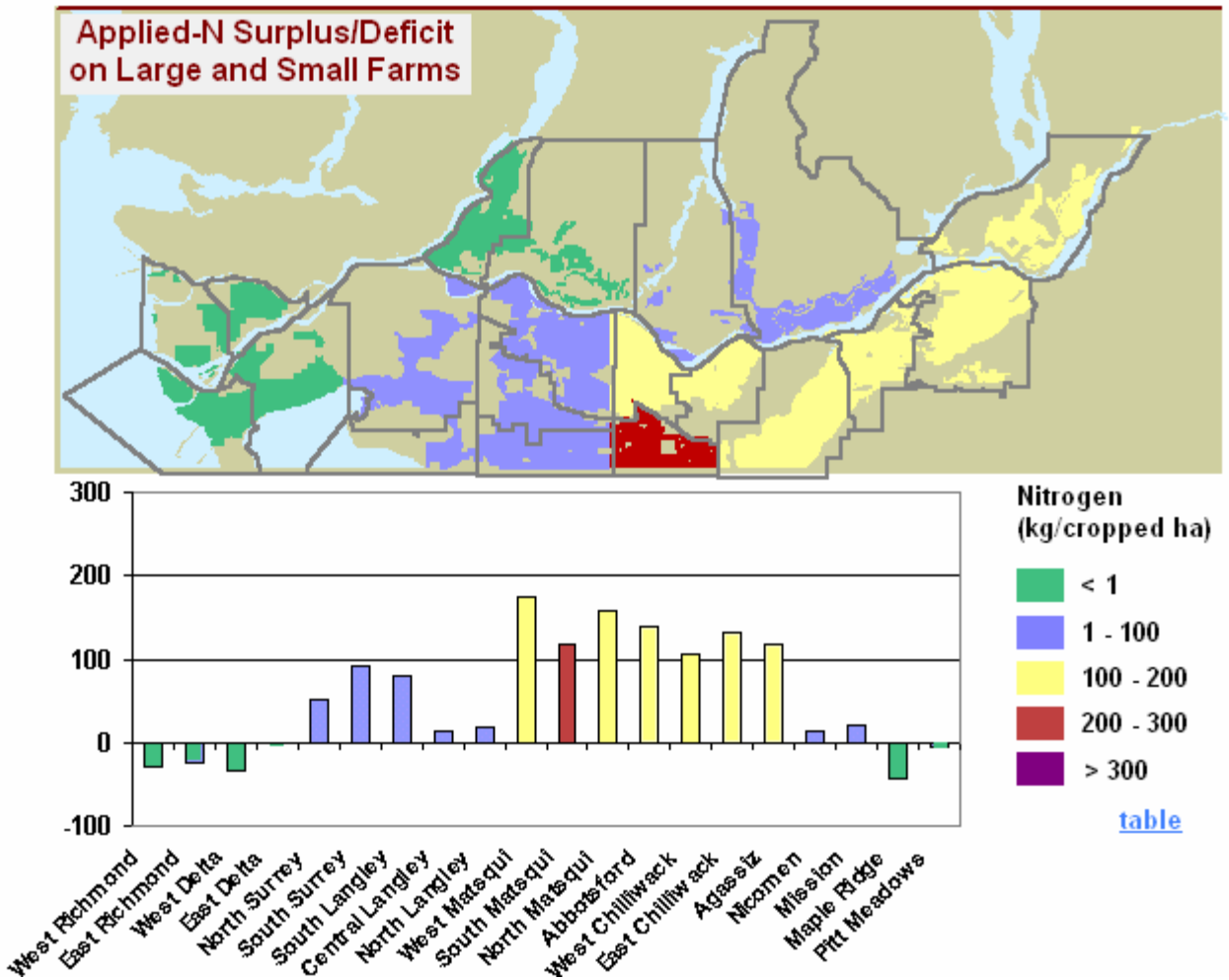
SEPTICS
FARMS
HORSE FARMS
FARM LAND
COMBINED

only the black areas do not receive any nitrogen input (except from rainwater)

## Model used to calculate nitrogen mass balance



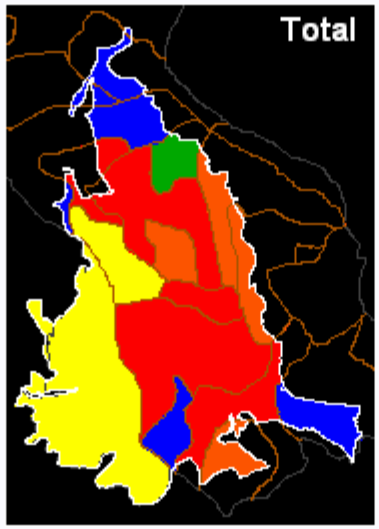
# Nitrogen Plots and Graphs for 2001



## Sources of nitrogen and other contaminants

Hobby
Commercial
Septic
Total

CUMULATIVE EFFECTS




Nitrogen Surplus Map
(After plant uptake and losses)

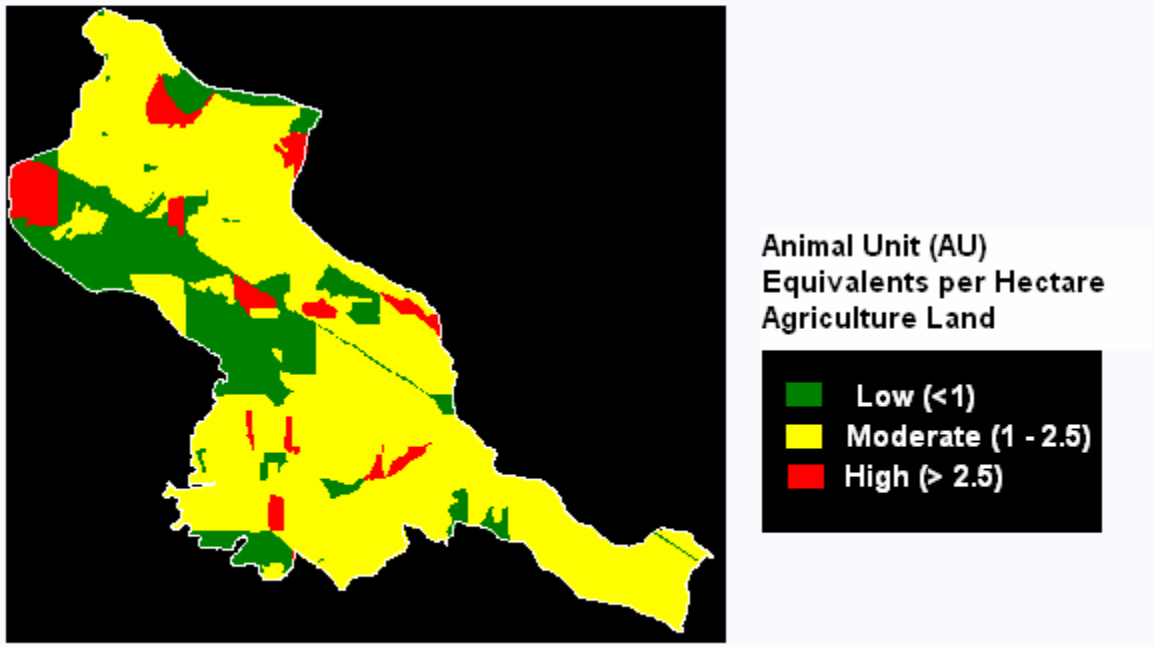
kg $ha^{-1}$ $year^{-1}$

- 0 - 20
- > 20 - 40
- > 40 - 60
- > 60 - 80
- > 80

| Surplus N Applied | Rate (kg $ha^{-1}$ $yr^{-1}$) | % of Surplus |
|---|---|---|
| From hobby farms | 12.2 | 18.0% |
| From commercial farms | 33.1 | 48.8% |
| From septic systems | 22.5 | 32.2% |
| Overall total | 67.8 | 100% |

## Animal Stocking Density Regulations in Denmark

Animal Unit density above 2.5 LUE is considered the point at which the risk of pollution to stream and groundwater may become critical (depending on soil permeability, slope and climatic conditions).




WETLANDS IN STORMWATER MANAGEMENT

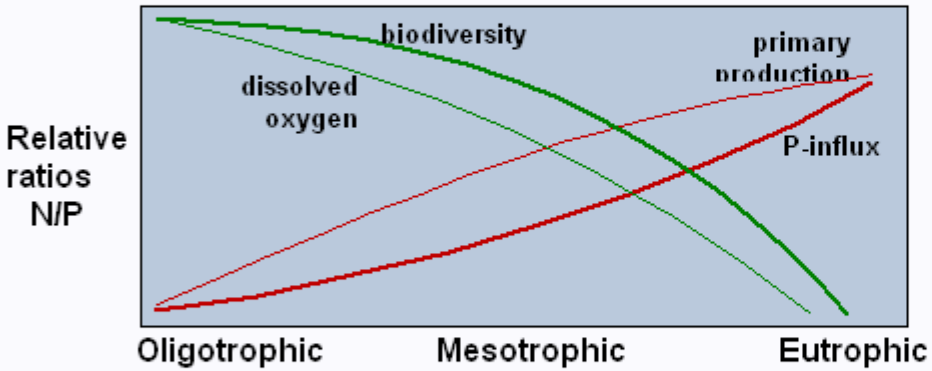
## Outlet, Delivery, Supply, Issues

- Why Treatment & Recycling
- Conservation (domestic, irrigation)
- Treatment

# Excess Nutrients & Eutrophication

Excess Nutrient, Pathogens and Organic Pollutantants from Agriculture and Urban Land Use need to be treated but the cost of treatment is increasing rapidly. Hence Source Control and reducing demand is essential.

**P-limitations regulate growth in most lakes and rivers**
**N-limitation are more common in estuaries and the ocean**



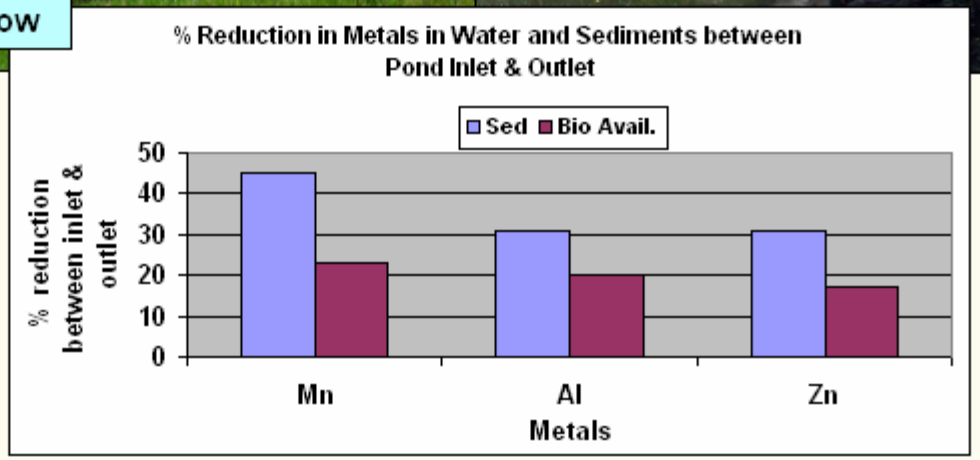

| | |
|---|---|
| Low productivity | High productivity |
| Scarce littoral plants | Abundant littoral plants |
| Low nutrient levels | High nutrient levels |
| Oxygen in hypolimnion | Hypolimnion O depletion |
| Usually deeper lakes | Usually shallower lakes |
| Large diversity of plankton | Low diversity of plankton |


# Innovations in Stormwater Management

PONDS

WETLANDS

(Highway Detention Pond North-Vancouver)

PONDS
WETLANDS

# WETLANDS IN STORMWATER MANAGEMENT

## Wetland (Honduras)

# Treatment

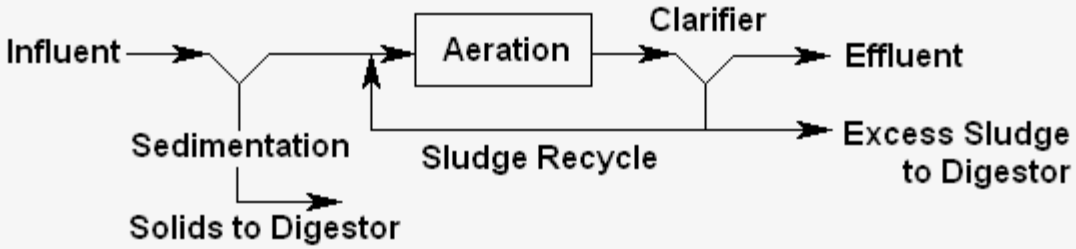
## Traditional

- Activated Sludge - Organic Matter Removal
- Trickling Filter - Organic Matter Removal

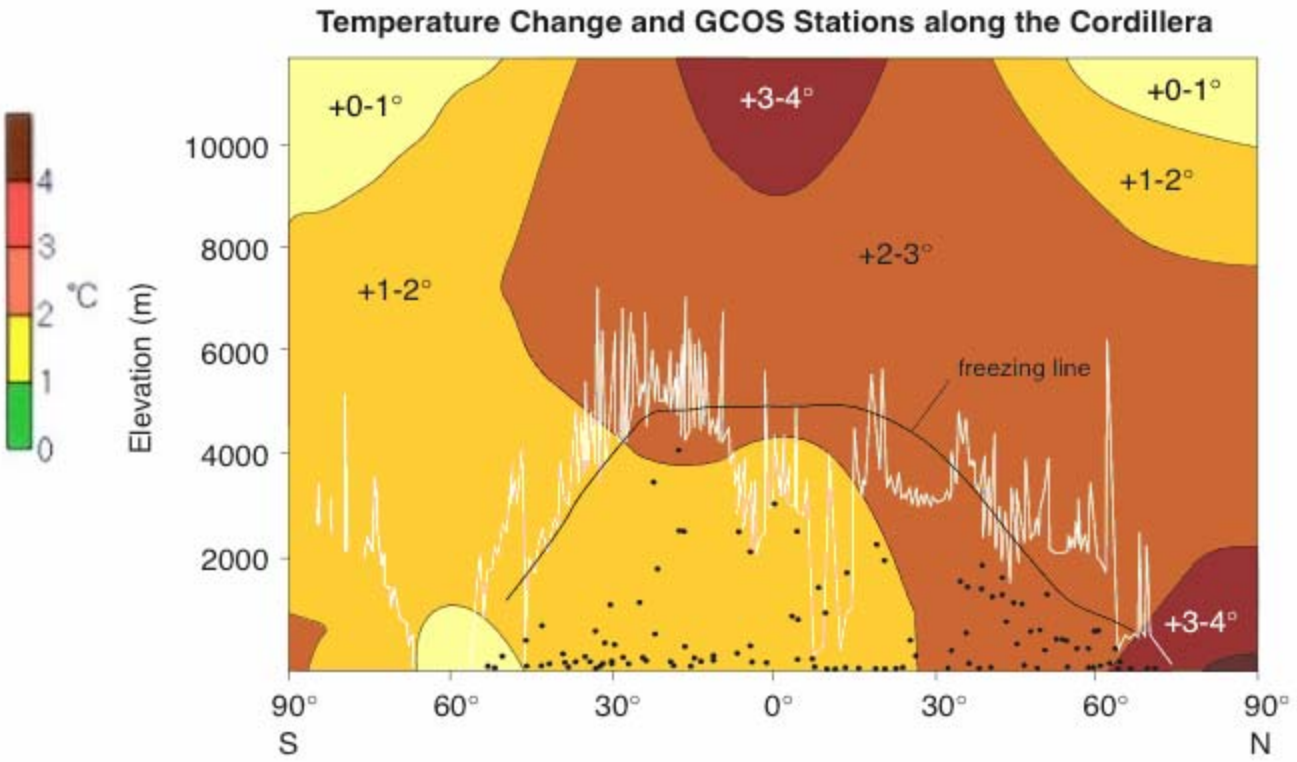
## Biological Nutrient Removal

- Biological Phosphorus Removal
- Biological Nitrogen & Phosphorus Removal

### Activated Sludge - Organic Matter Removal



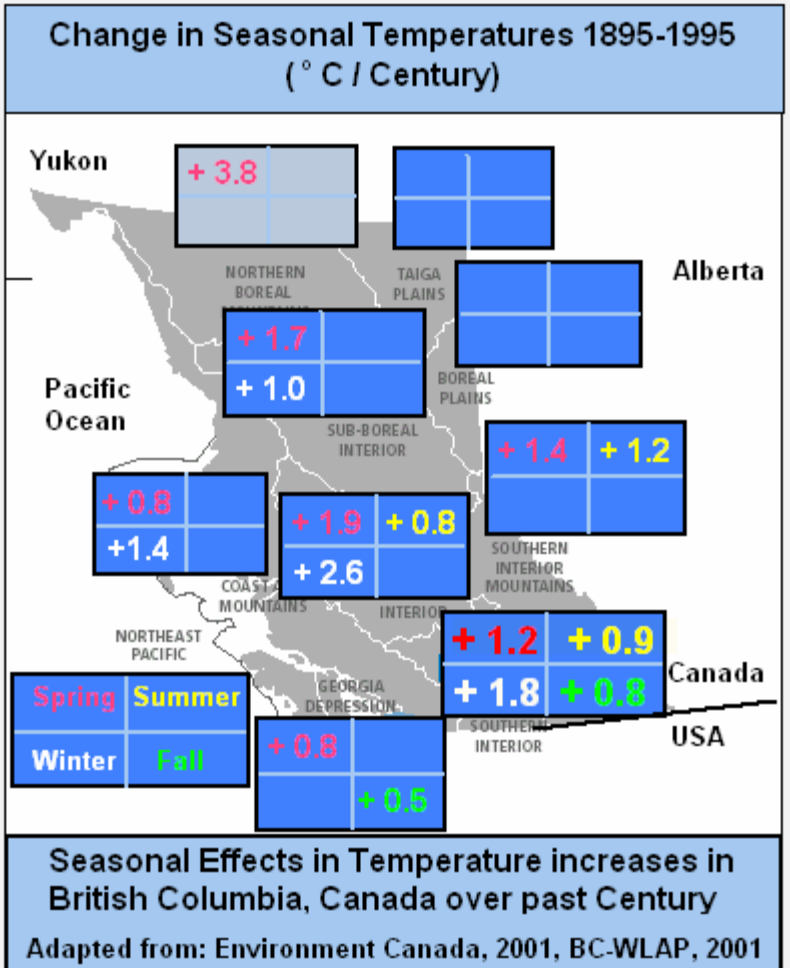

# Expected Temperature Increases by 2050

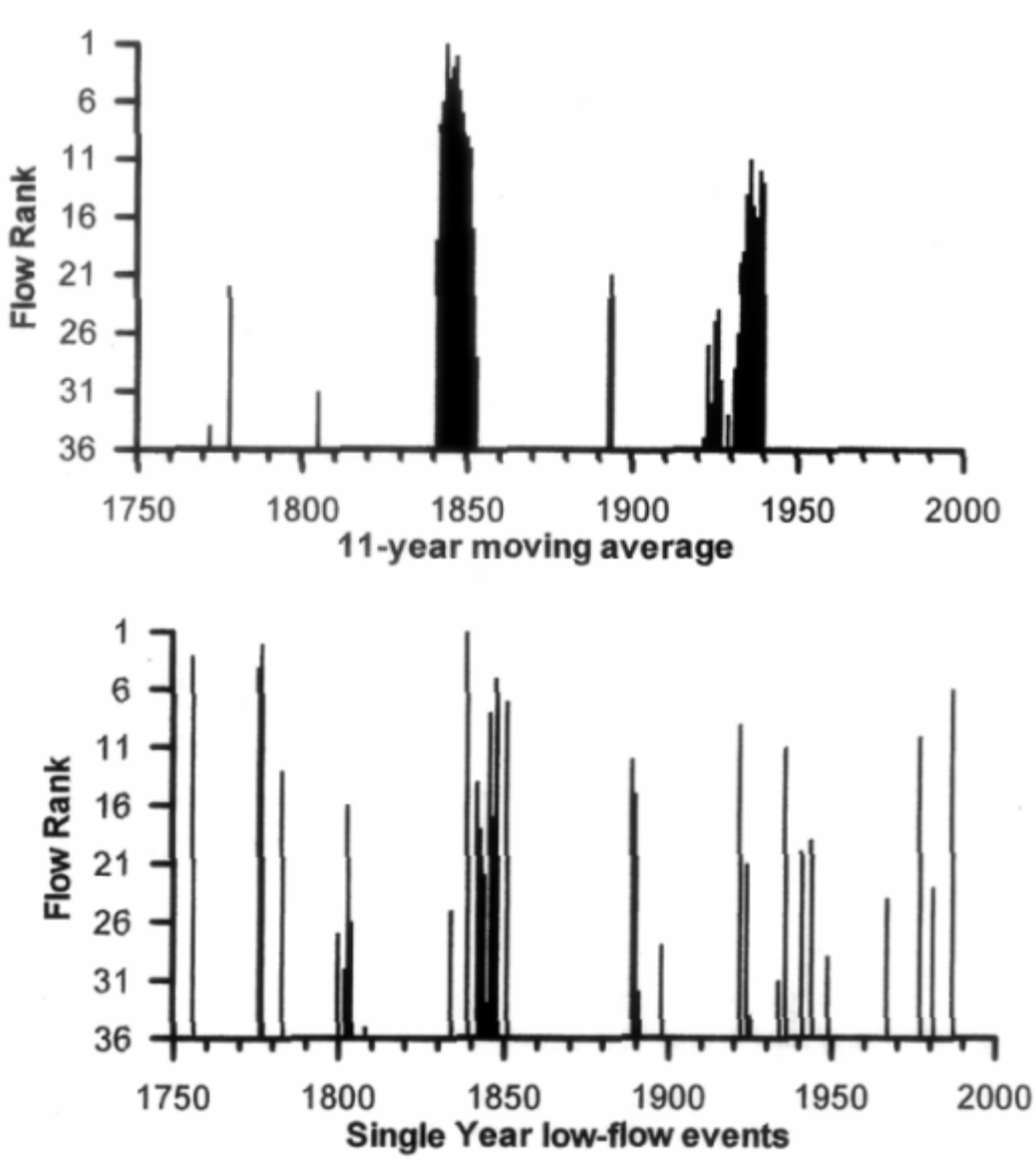


# Climate Change

## Seasonal Changes in Temperature in British Columbia, Canada

◉ Seasonal Temp. ○ Changes in Min. Temp. ○ River Water Temp. Changes




Flow Rank
1
6
11
16
21
26
31
36
1750
1800
1850
1900
1950
2000
11-year moving average
Flow Rank
1
6
11
16
21
26
31
36
1750
1800
1850
1900
1950
2000
Single Year low-flow events

# Pine Beetles and Fire

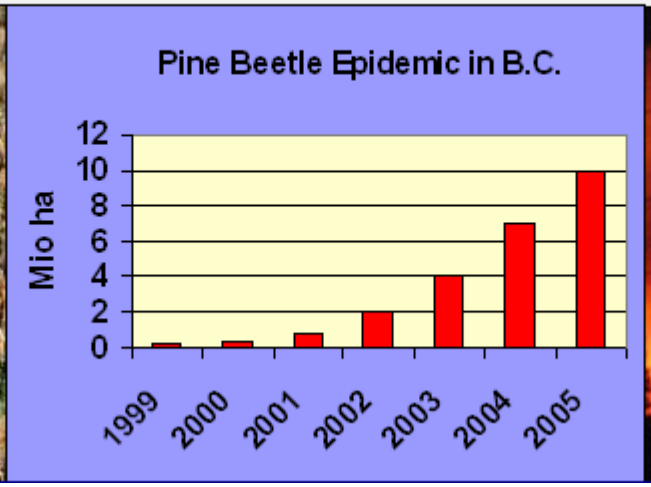
PINE BEETLES | HYDROLOGICAL RESPONSE

**Estimated Area Affected in 2005:**
**10 Mio ha (2 times the size of Denmark)**

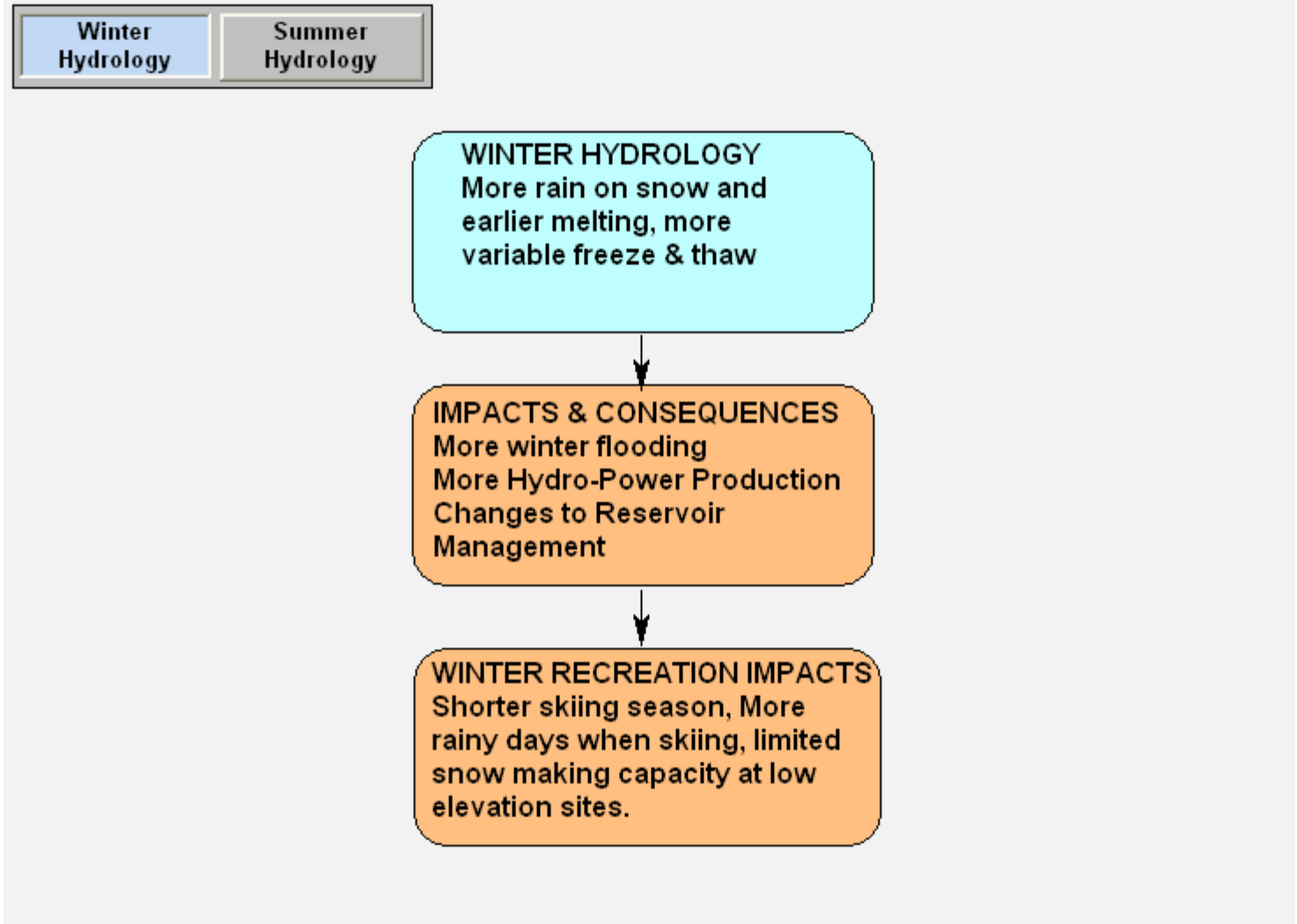
**Impact since 1994: 350 Mio $m^3$ of timber**

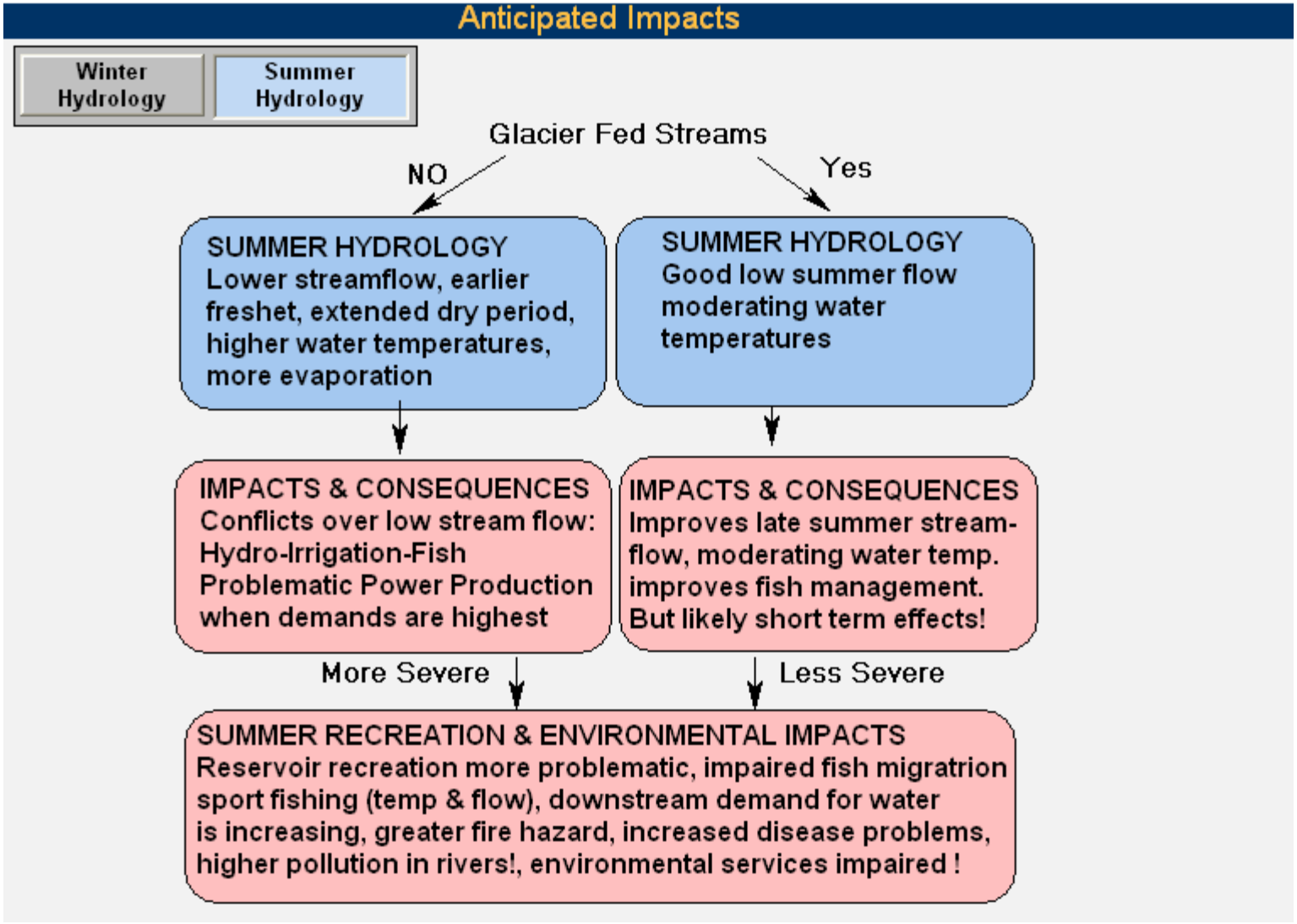
**Dilema:**

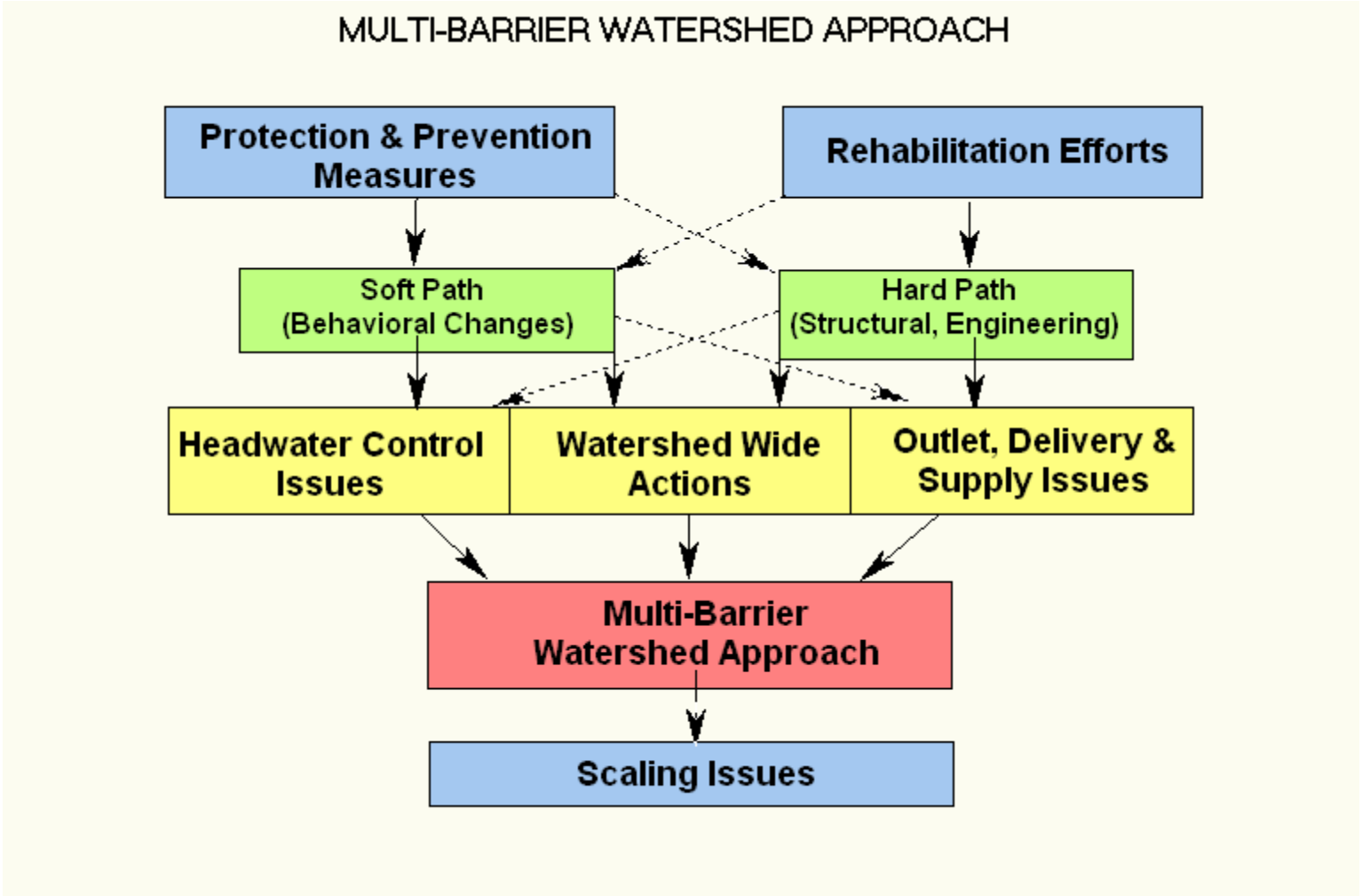
- Rapid Harvesting changes the Hydrological Cycle
- No havesting creates forest fire hazard & $CO_2$
- In both cases this will acelerate global warming




# Anticipated Impacts




Anticipated Impacts
Winter Hydrology
Summer Hydrology
Glacier Fed Streams
NO
Yes
SUMMER HYDROLOGY
Lower streamflow, earlier freshet, extended dry period, higher water temperatures, more evaporation
SUMMER HYDROLOGY
Good low summer flow moderating water temperatures
IMPACTS & CONSEQUENCES
Conflicts over low stream flow: Hydro-Irrigation-Fish
Problematic Power Production when demands are highest
IMPACTS & CONSEQUENCES
Improves late summer stream-flow, moderating water temp. improves fish management.
But likely short term effects!
More Severe
Less Severe
SUMMER RECREATION & ENVIRONMENTAL IMPACTS
Reservoir recreation more problematic, impaired fish migratrion sport fishing (temp & flow), downstream demand for water is increasing, greater fire hazard, increased disease problems, higher pollution in rivers!, environmental services impaired !


MULTI-BARRIER WATERSHED APPROACH
Protection & Prevention Measures
Rehabilitation Efforts
Soft Path (Behavioral Changes)
Hard Path (Structural, Engineering)
Headwater Control Issues
Watershed Wide Actions
Outlet, Delivery & Supply Issues
Multi-Barrier Watershed Approach
Scaling Issues

# Conclusions

**WATER CONSERVATION**

- **LOW IMPACT Urban Design to minimize amount of stormwater**
- **Water saving divices**
- **Rainwater collection**
- **More efficient use of water in urban and agriculture**
- **Better water pricing, metering, incentives**

**LAND USED & WATER QUALITY**

- **Minimize impervious surfaces to reduce quantity and quality of runoff**
- **Innovative Urban Stormwater management to detain pollutants in ponds and wetlands**
- **Agriculture needs better BMP's that are proactive :**
  **Nutrient Budgets, P-Index, Buffers, Stocking Densities, Source Control**

To implement all this will require vision and leadership but
most of all a basin wide organization needs to take the lead to puts science into action !

# WE NEED OF LEADERSHIP IN WATER GOVERNANCE

| GOVERNANCE | ENFORCEMENT | INCENTIVES |
|---|---|---|
| ARCHAIC LEGAL SYSTEM | LACK OF CAPACITY | Water PRICING & CONSERVATION |
| LACK OF MONITORING | LACK OF PRIORITY | COMMUNITY INVOLVEMENT |
| CRISIS MANAGEMENT | LITTLE WILLINGNESS TO INITIATE PROGRAM | STEWARDSHIP SUPPORT PROGRAMS |

## Conclusions

1. Governments need to change the management structure of water We need a much more collaborative approach.

2. Watershed wide management is critical and there is a need to integrate activities

3. The water focus needs to shift from expanding Supplies to reducing Demands (this means changing social behaviour)

4. We need to learn adaptive management to deal with increased variability and uncertainty

5. We will have limited response capabilities, hence no single option will work effectively

6. There is a lack of scientific data and research on key factors of climate change in catchments

7. We need a massive public education program to bring science into the mainstream of the public debate.

8. People's Involvement in the decision making process is critical