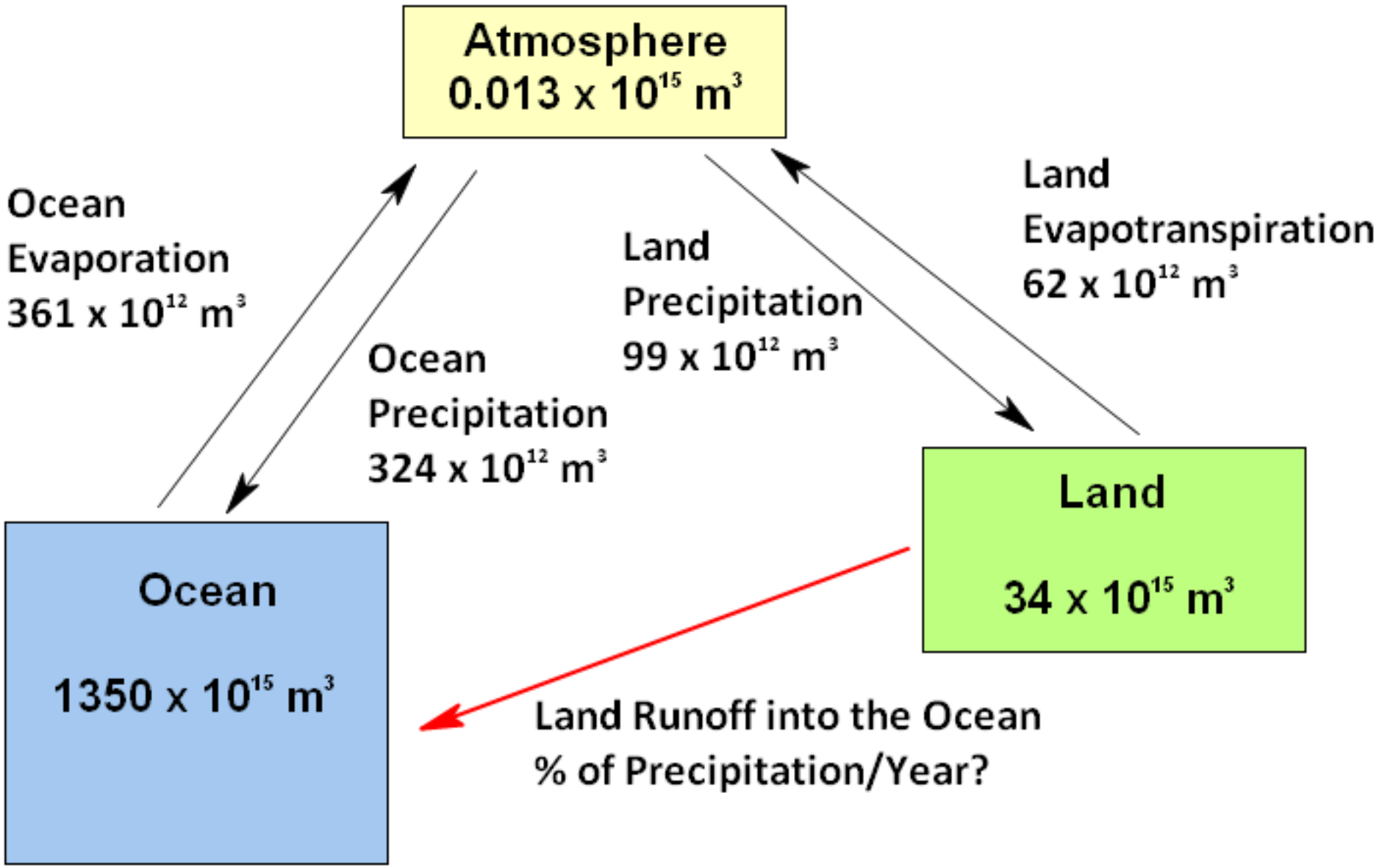
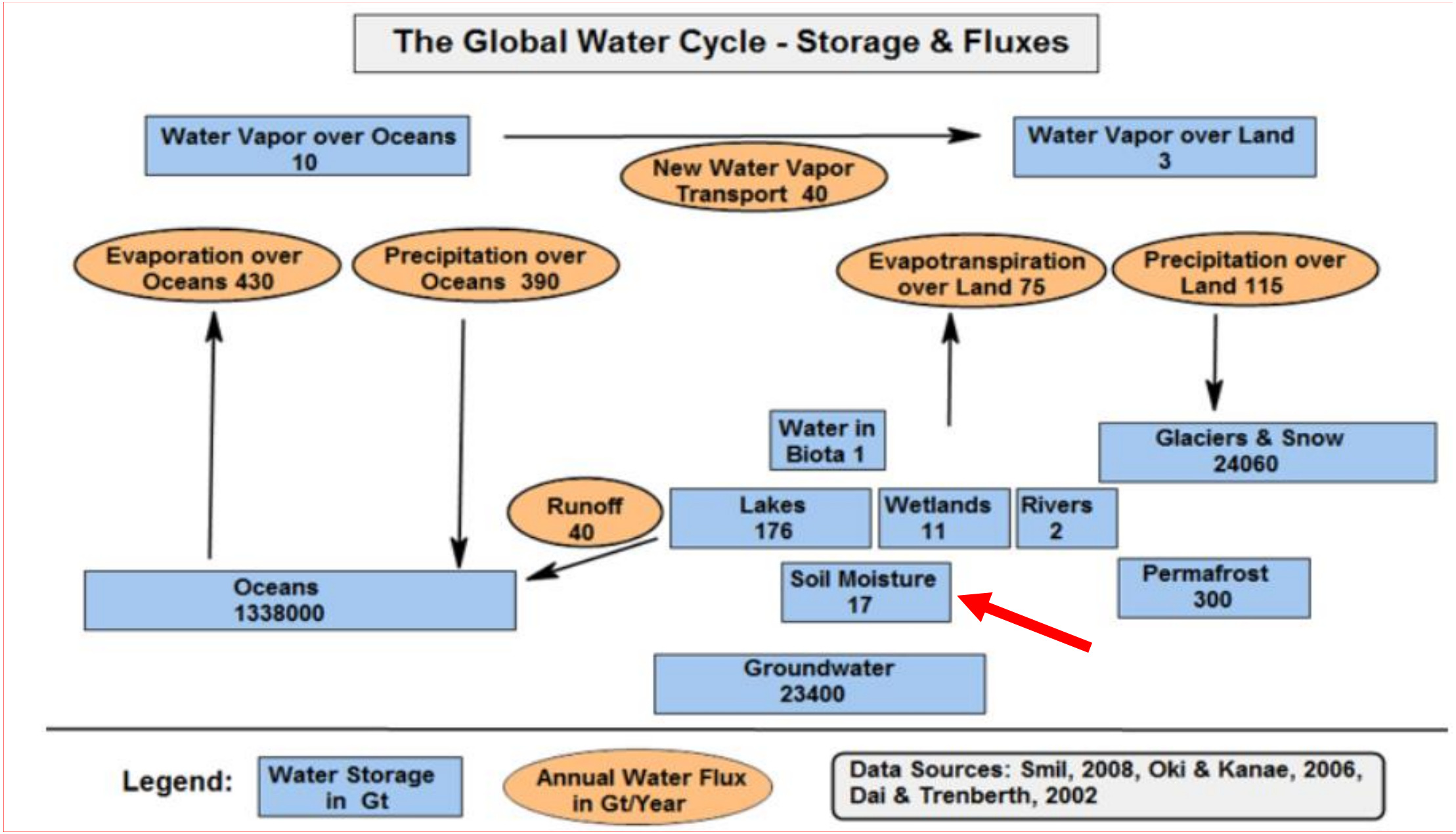
Introduction to Integrated Watershed Management

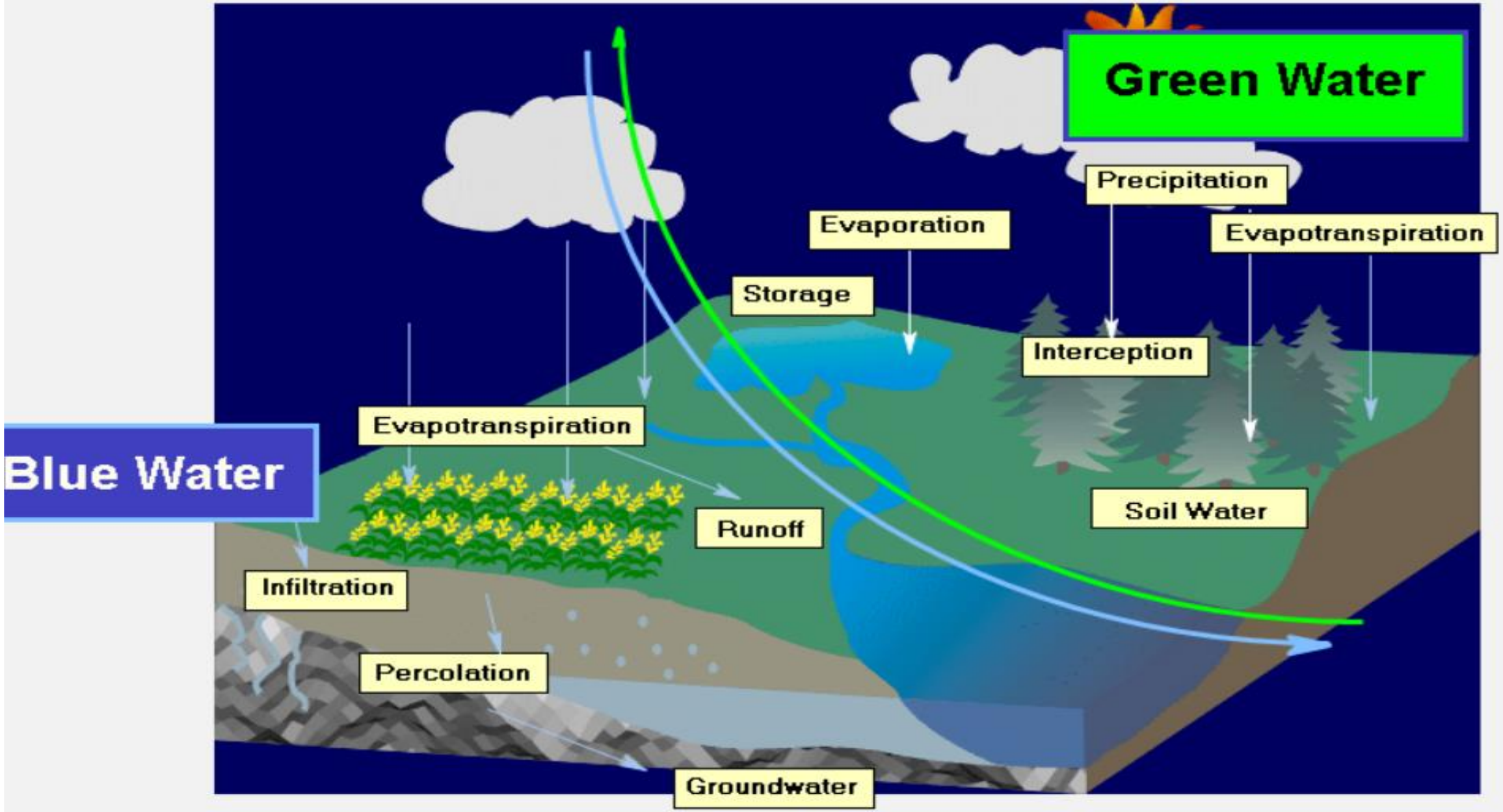
Hans Schreier, Land & Food Systems, Univ. of British Columbia, Canada

Global Water Cycle

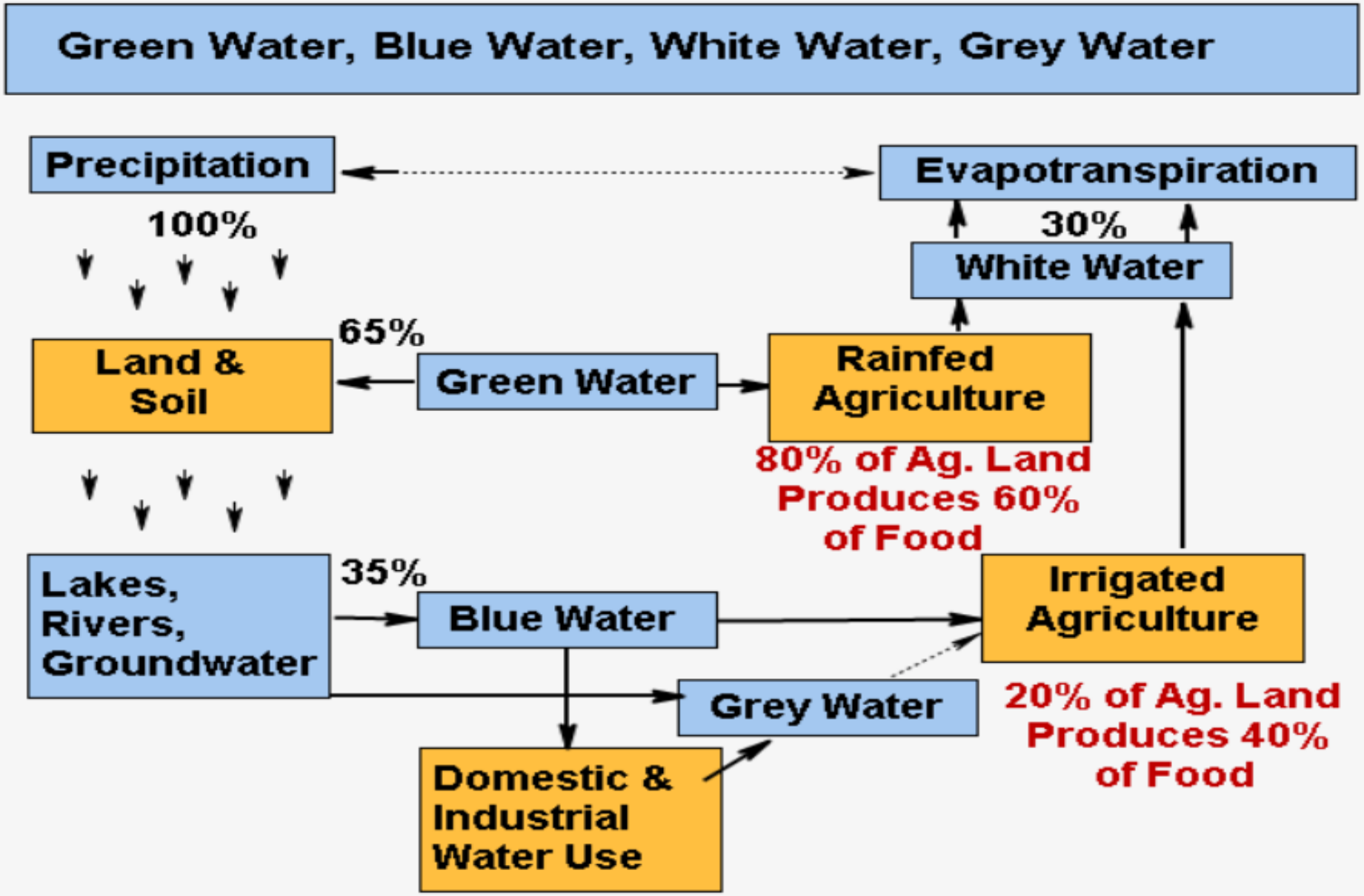



The Global Water Cycle - Storage & Fluxes
Water Vapor over Oceans 10
New Water Vapor Transport 40
Water Vapor over Land 3
Evaporation over Oceans 430
Precipitation over Oceans 390
Evapotranspiration over Land 75
Precipitation over Land 115
Water in Biota 1
Glaciers & Snow 24060
Runoff 40
Lakes 176
Wetlands 11
Rivers 2
Oceans 1338000
Soil Moisture 17
Permafrost 300
Groundwater 23400
Legend:
Water Storage in Gt
Annual Water Flux in Gt/Year
Data Sources: Smil, 2008, Oki & Kanae, 2006, Dai & Trenberth, 2002

The Blue and Green Hydrological Cycle



The Proportion of Water Moving Through Different Cycles



Projected Global Populations in Each Category by 2050

Blue Water	Green Water	
	Green Water Limited < 1300 m3/capita/yr	Green Water Sufficient > 1300 m3/capita/yr
Blue Water Limited < 1000 m3/capita/yr	46 %	14 %
Blue Water Sufficient > 1000 m3/capita/yr	21 %	19 %

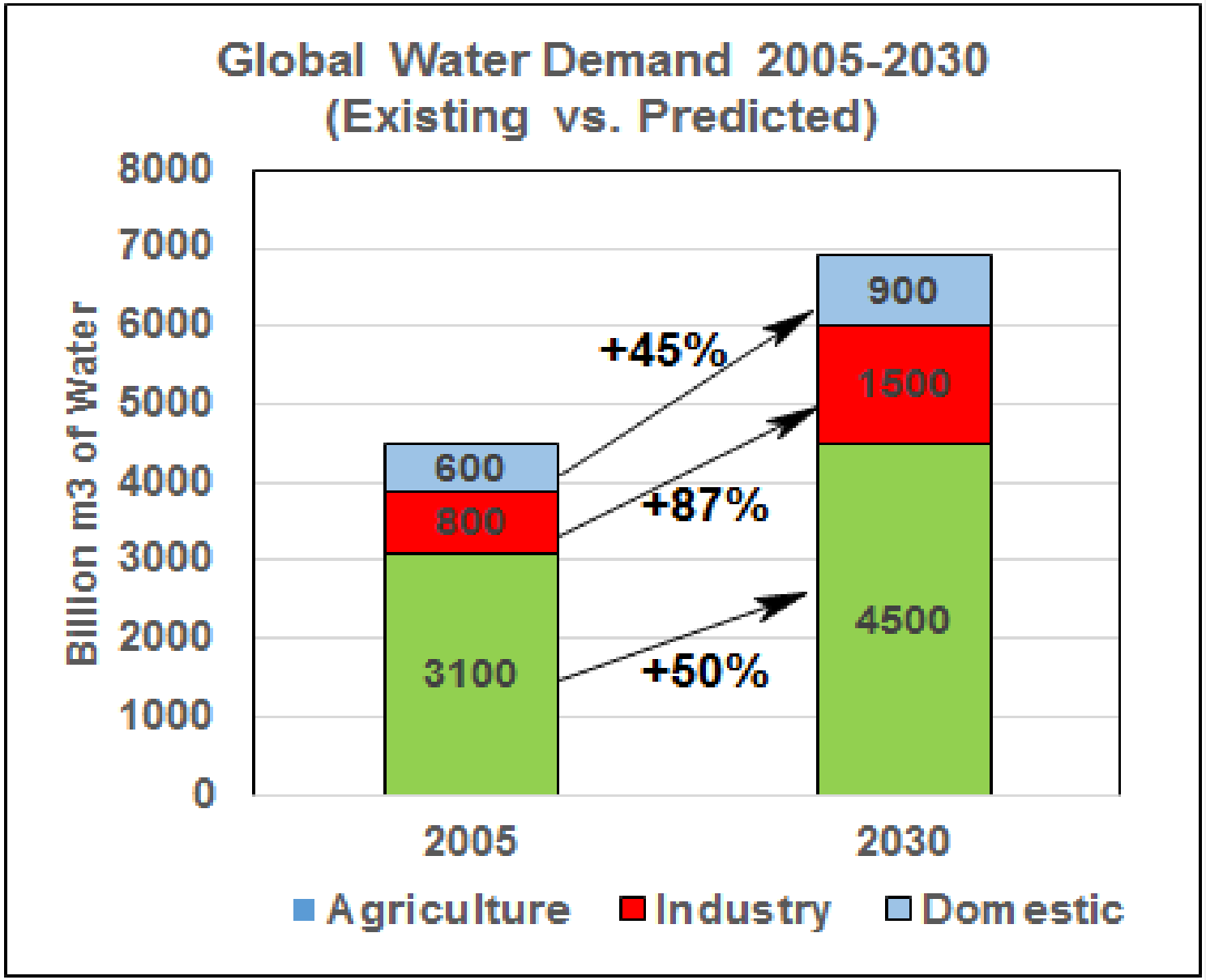
Data Source: Rockstrom et al. 2007, Falkenmark & Rockstrom, 2011

Example Countries by 2050

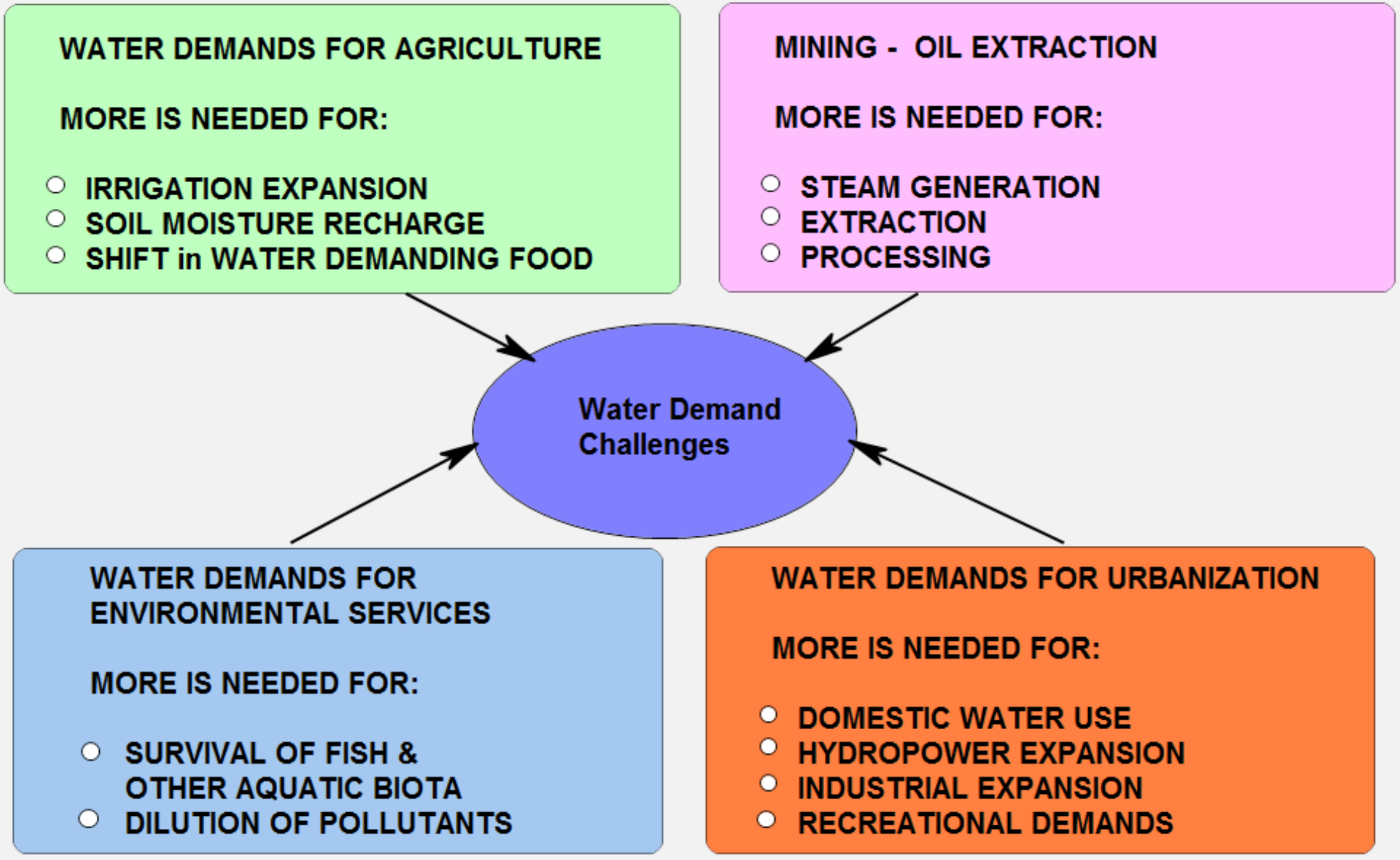
Blue Water	Green Water	
	Green Water Limited < 1300 m3/capita/yr	Green Water Sufficient > 1300 m3/capita/yr
Blue Water Limited < 1000 m3/capita/yr	Jordan, Egypt India, China	South Africa
Blue Water Sufficient > 1000 m3/capita/yr	Korea, Japan	Brazil, Canada

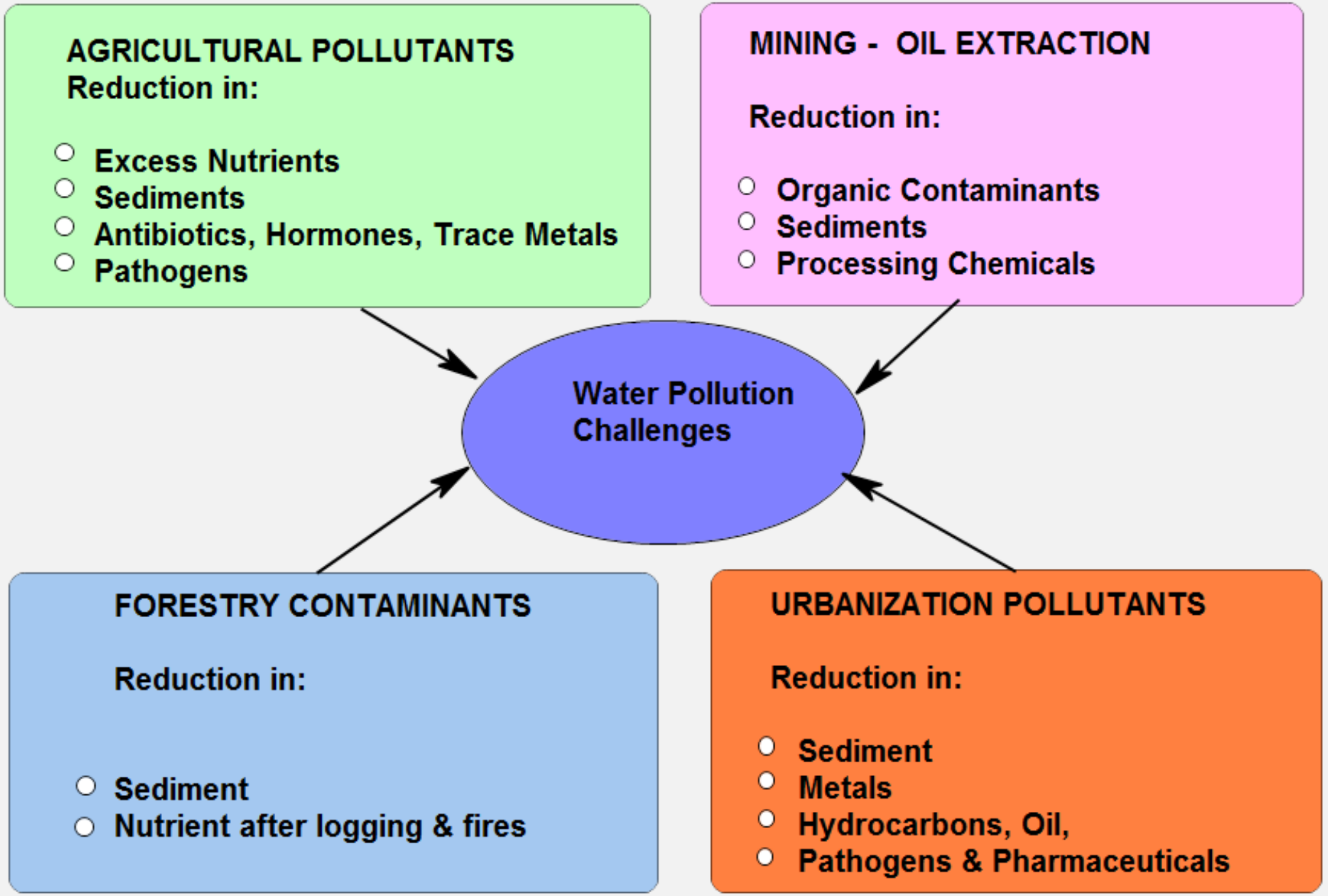
Data Source: Rockstrom et al. 2007, Falkenmark & Rockstrom, 2011

In 2010
69% of all
Water was
used for
Agriculture

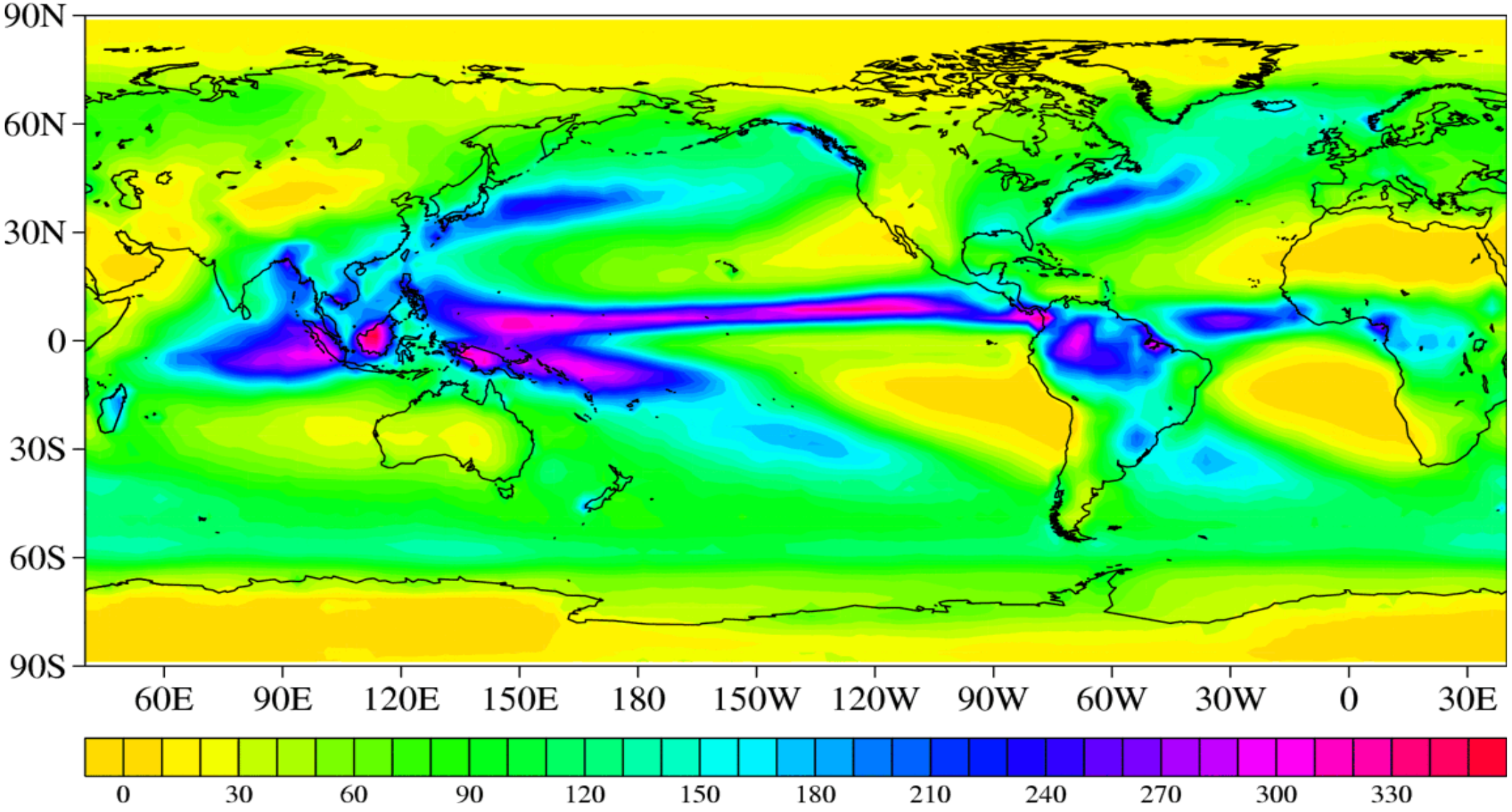


Data Source: McKinsey Corp. 2012

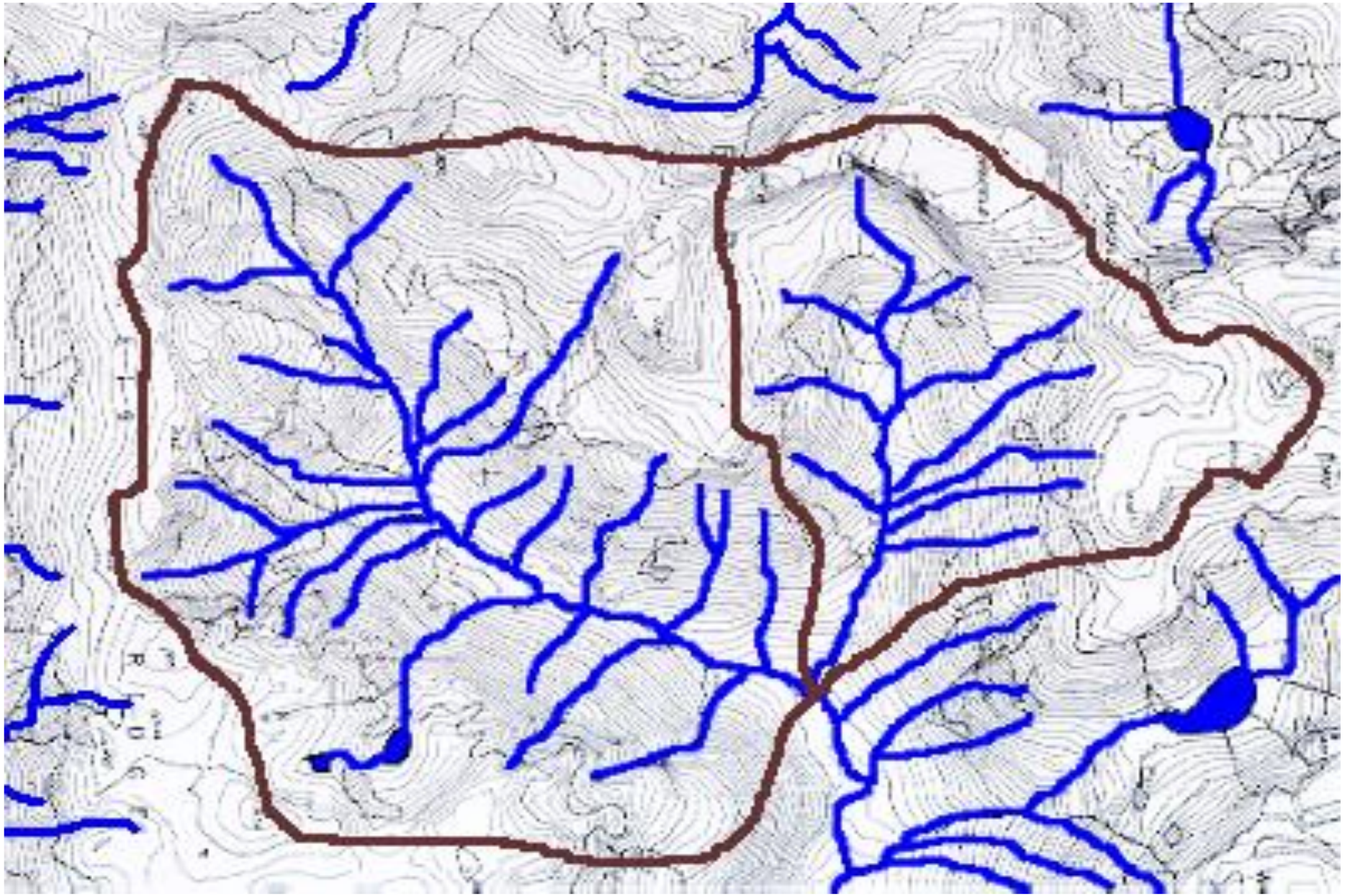

WATER DEMANDS FOR AGRICULTURE
MORE IS NEEDED FOR:
IRRIGATION EXPANSION
SOIL MOISTURE RECHARGE
SHIFT in WATER DEMANDING FOOD
MINING - OIL EXTRACTION
MORE IS NEEDED FOR:
STEAM GENERATION
EXTRACTION
PROCESSING
Water Demand Challenges
WATER DEMANDS FOR ENVIRONMENTAL SERVICES
MORE IS NEEDED FOR:
SURVIVAL 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

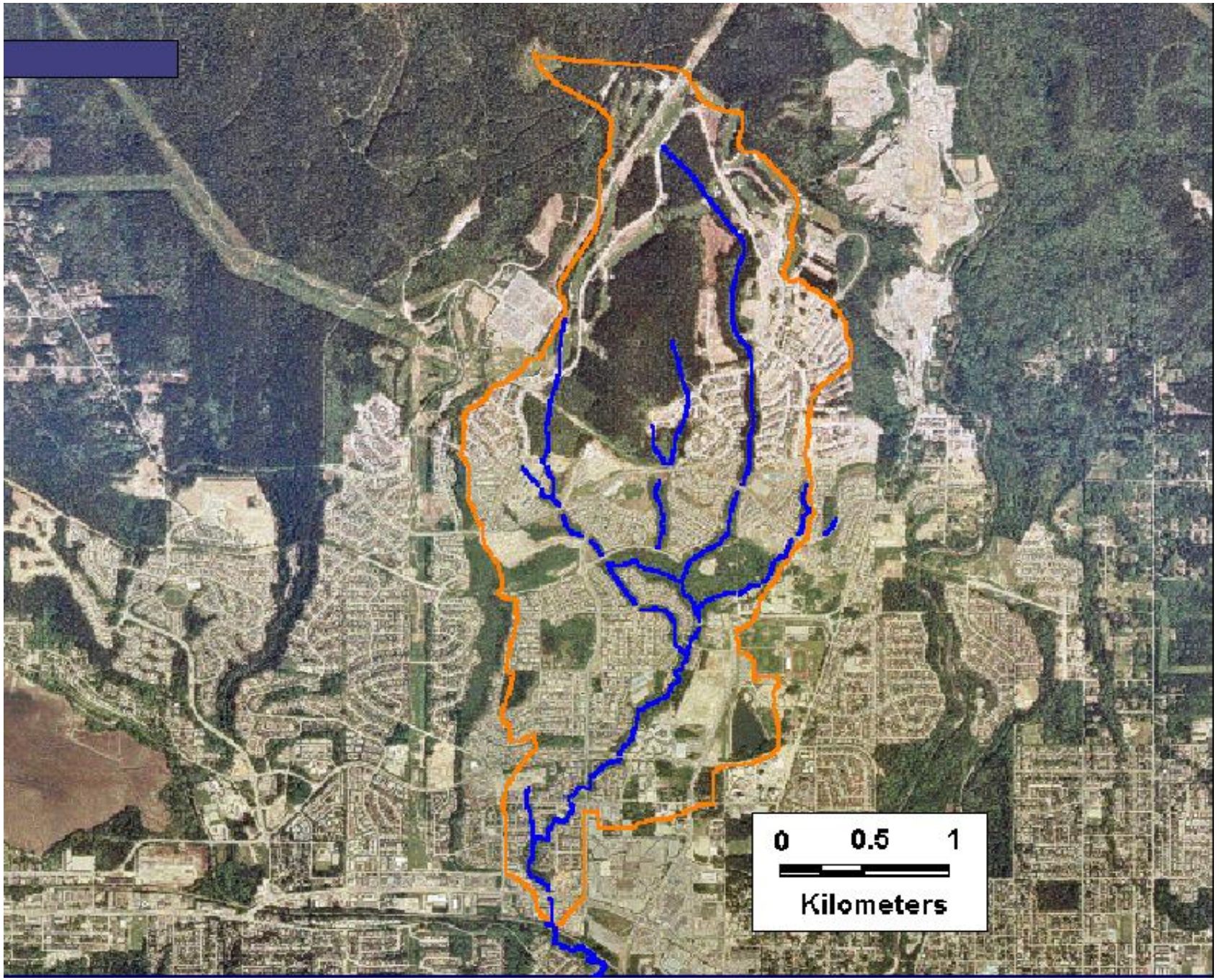

AGRICULTURAL POLLUTANTS
Reduction in:
Excess Nutrients
Sediments
Antibiotics, Hormones, Trace Metals
Pathogens
MINING - OIL EXTRACTION
Reduction in:
Organic Contaminants
Sediments
Processing Chemicals
Water Pollution Challenges
FORESTRY CONTAMINANTS
Reduction in:
Sediment
Nutrient after logging & fires
URBANIZATION POLLUTANTS
Reduction in:
Sediment
Metals
Hydrocarbons, Oil,
Pathogens & Pharmaceuticals

Annual total precipitation (cm, GPCP)



Why Integrated Watershed Management?




0
0.5
1
Kilometers

Advantages of Using a Watershed Approach

Natural System	Process Studies	Integration	Complexity	Decision Making
Natural Unit Ideal for Monitoring Scaling Options Landscape Hierarchy	Mass Balance Input-Output Modelling Enables Cause & Effect Assessment	Integrates Land Use Effects Links Land Use and Water Facilitates System Analysis	Allows Cumulative Effects Analysis Air-Soil-Water Interactions Can Assess Diffuse Sources	Science Based Decision Making Effective for Management Enables Adaptive Management

Difficulties of Using a Watershed Approach

Long Term Data

Long Term Monitoring Needed and is Expensive

Needs for an Undistrubed Control Site

Boundary Issues

Political, Census Boundaries do not Match

Data is Collected over Different Areas

Extrapolation

Every Watershed is Different-Makes Extrapolation Challenging

Processes Change over Time & Space

Scale Issues

Non-Linear Processes make Up-Scaling & Down-Scaling Difficult

Accuracy Changes Between Scales

External Factors

Air-Pollution Climate Change Transportation do not Recognise Watershed Boundaries

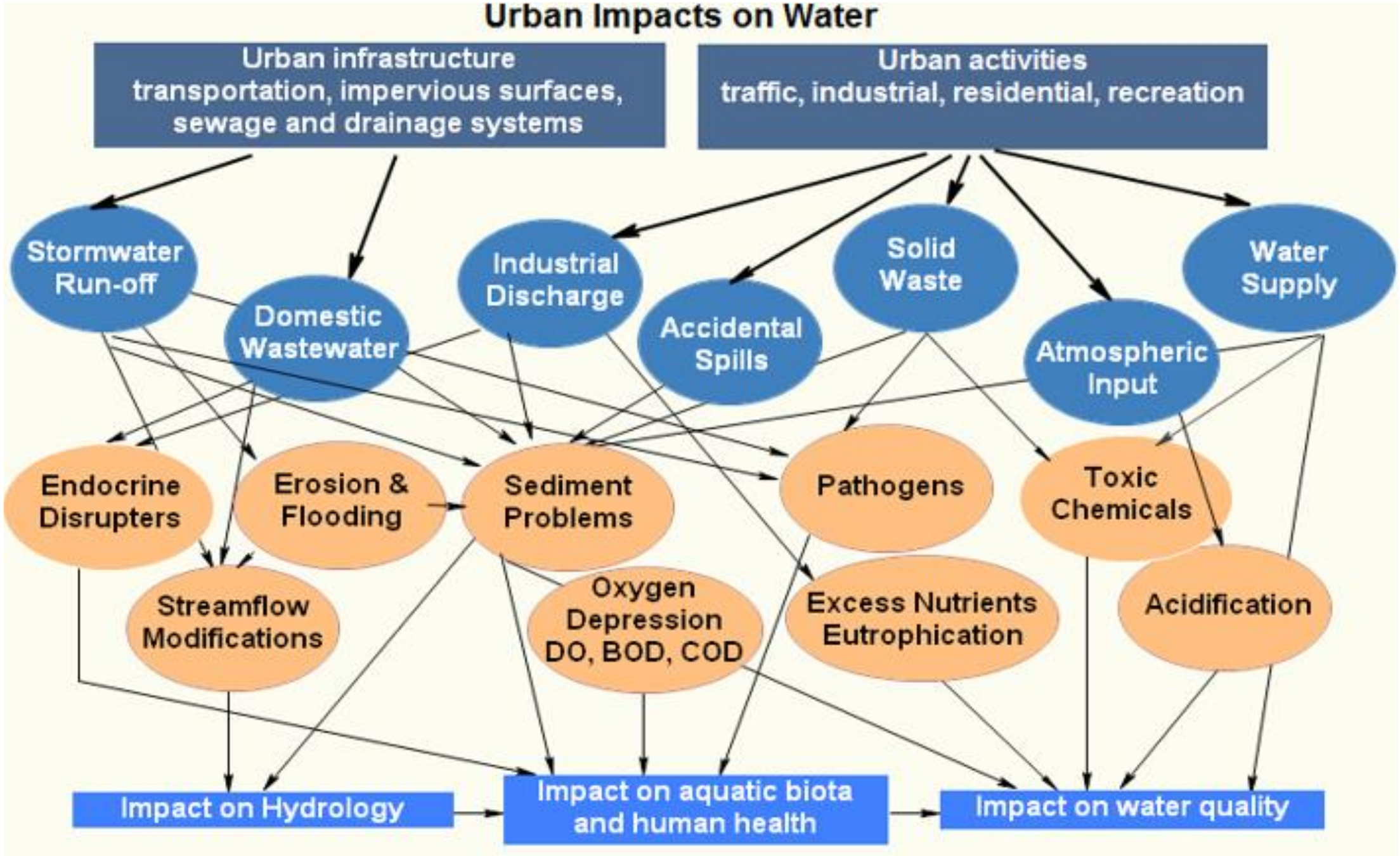
How to Cope with Climate Extremes and Land Use Intensification and its Impact on Water

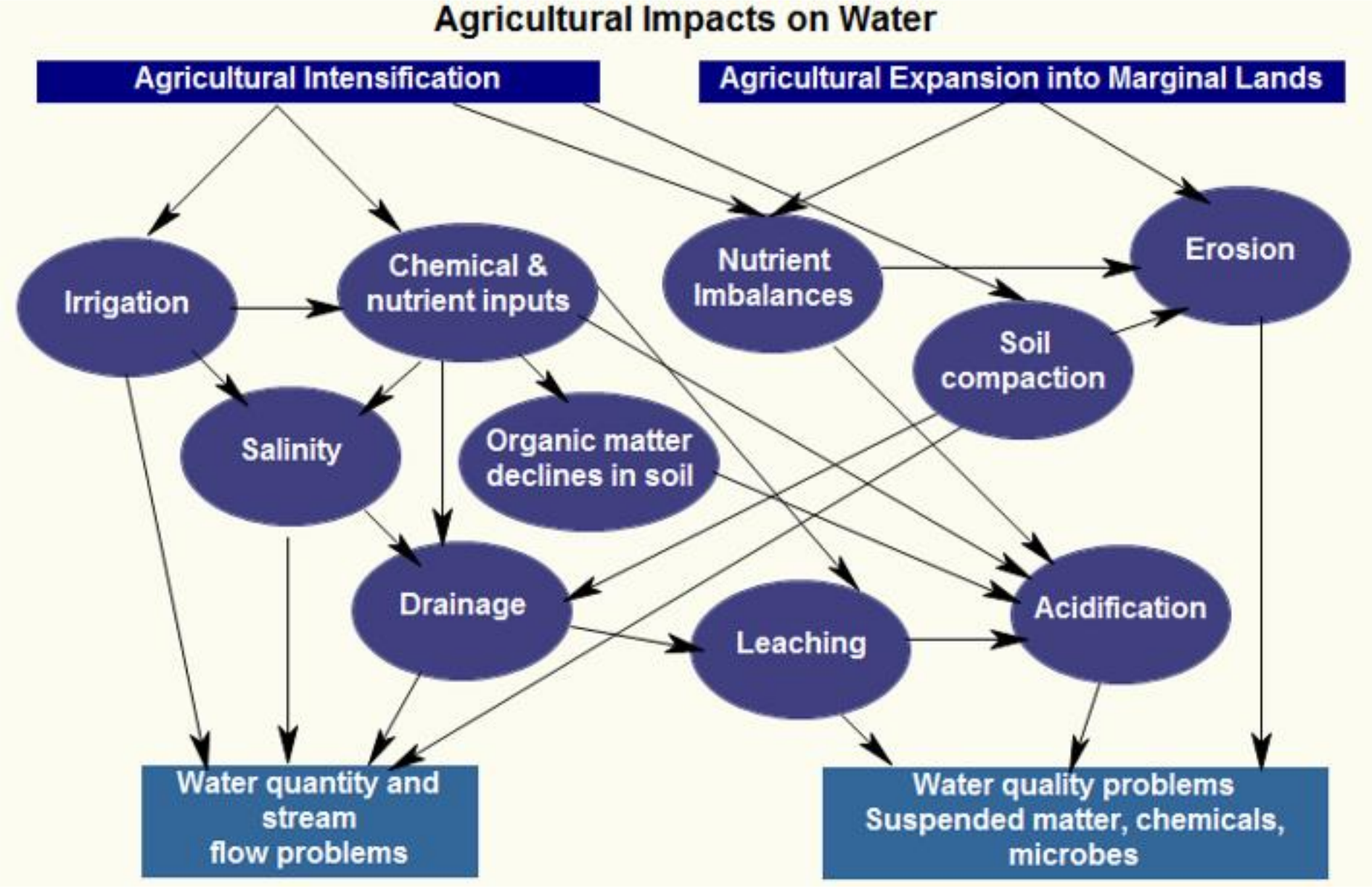
Densification = More Imperviousness

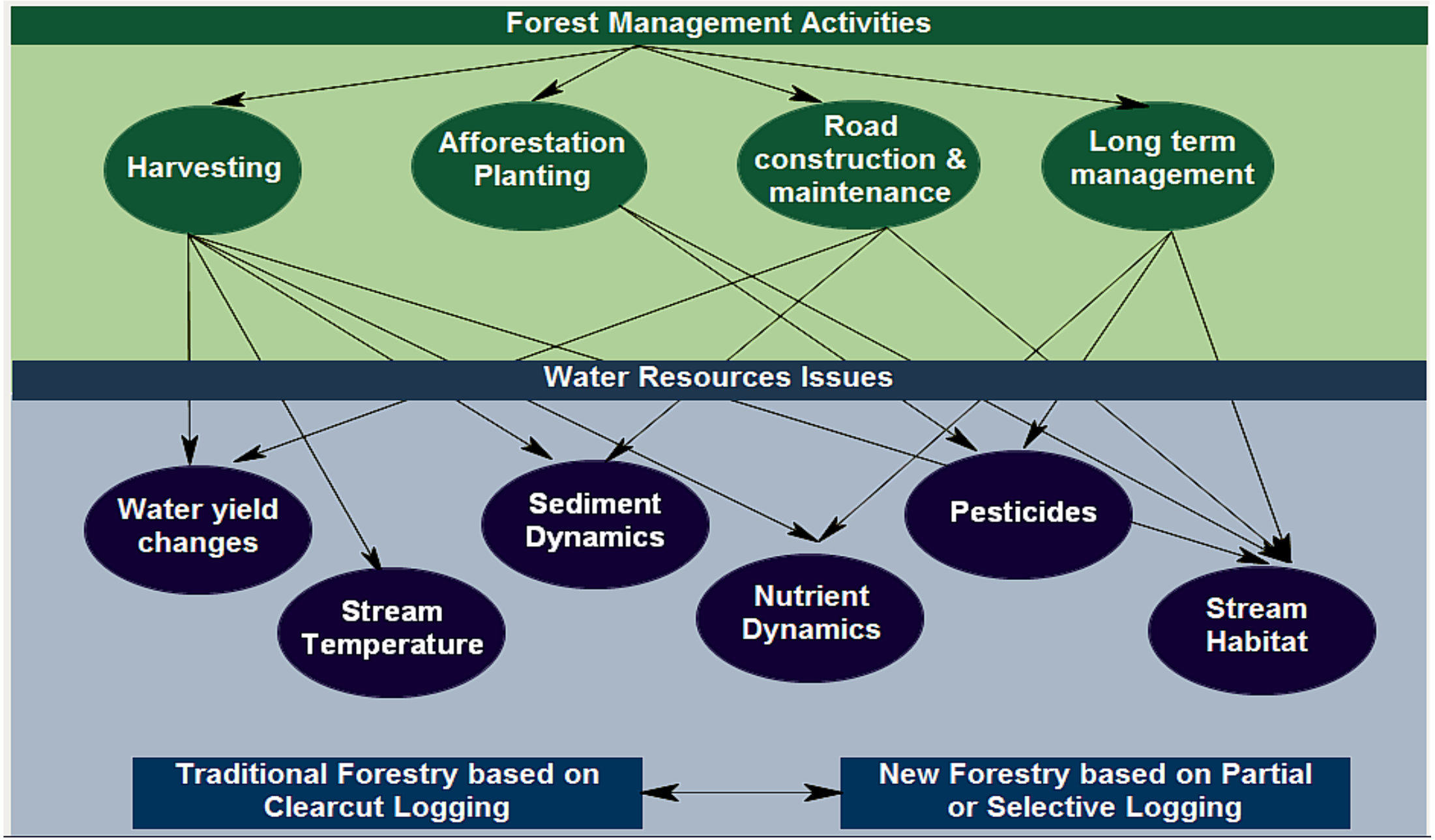
Climate Change = Increased Variability

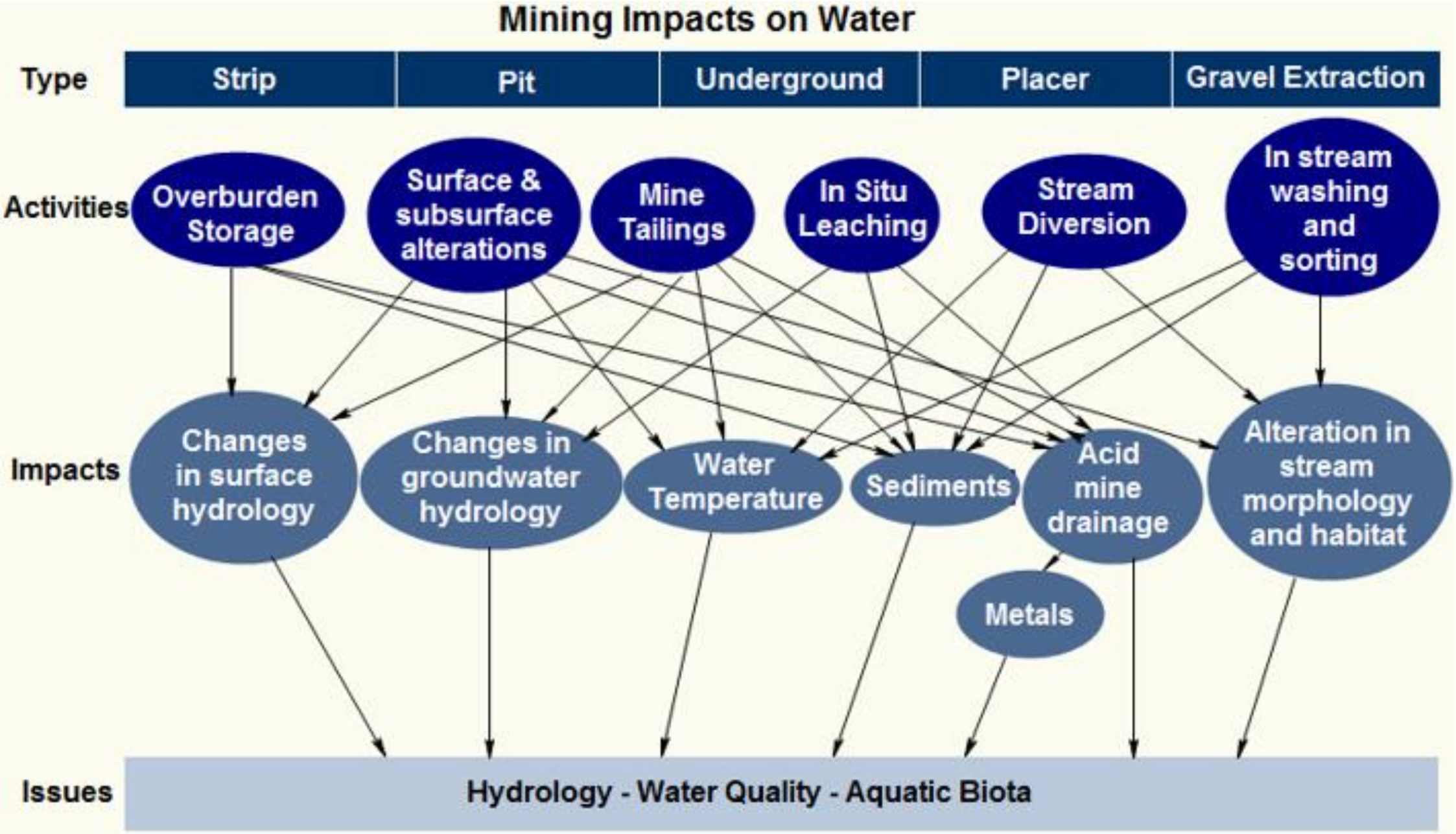
Impact Differences

Flood Impacts	Droughts Impacts
Flood impacts occur in individual watersheds Floodplains are the main impacted areas	Droughts cover very large areas The impact can be over large watersheds
The source of the flood water usually is long distance away from the flood impact	The impact is regional and not specific to floodplains
The impact is over relatively short time periods (Days-Weeks)	The impact is over longer periods (Months- Years)


Urban Impacts on Water
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

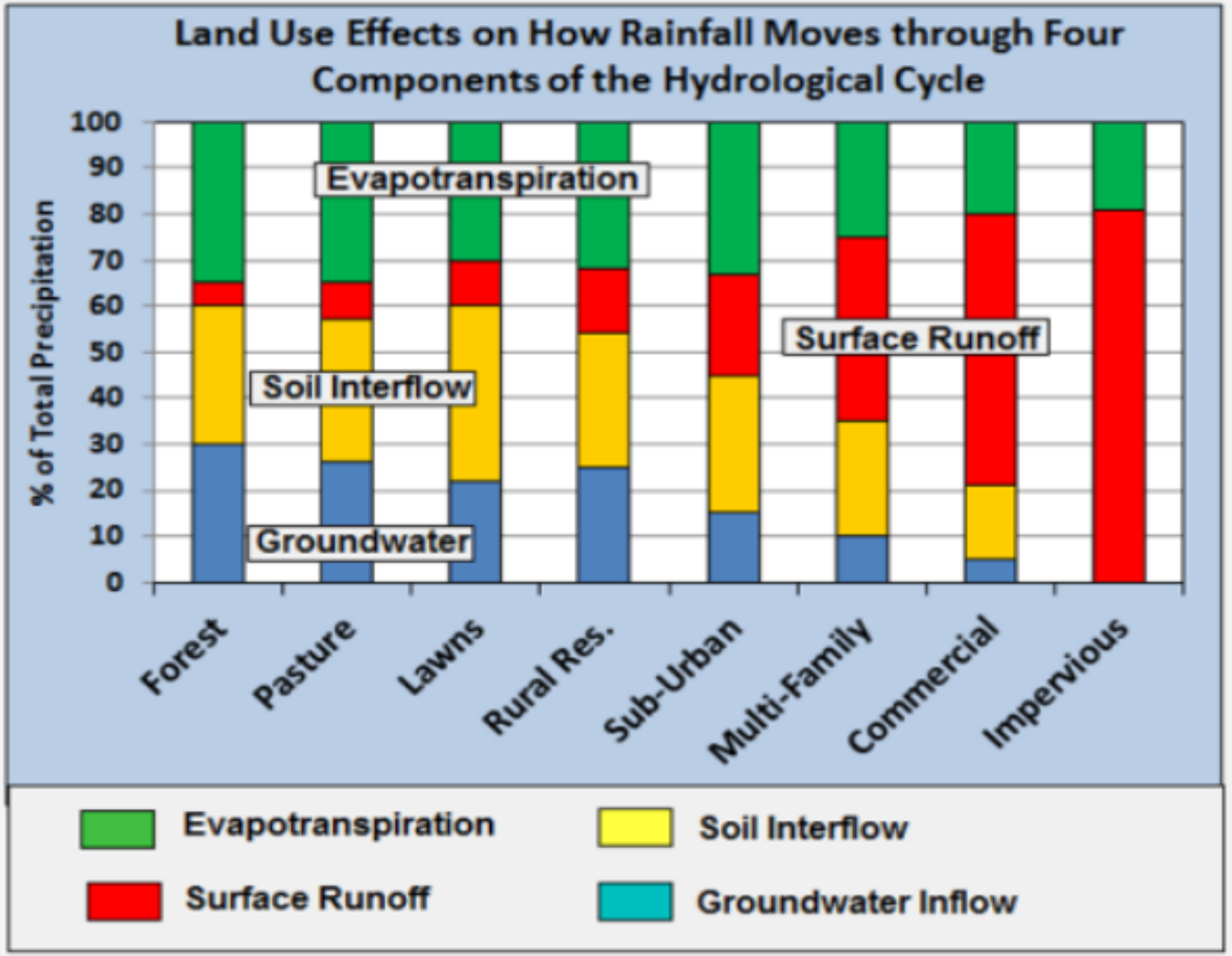

Agricultural Impacts on Water
Agricultural Intensification
Agricultural Expansion into Marginal Lands
Irrigation
Chemical & nutrient inputs
Nutrient Imbalances
Erosion
Soil compaction
Salinity
Organic matter declines in soil
Drainage
Leaching
Acidification
Water quantity and stream flow problems
Water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


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

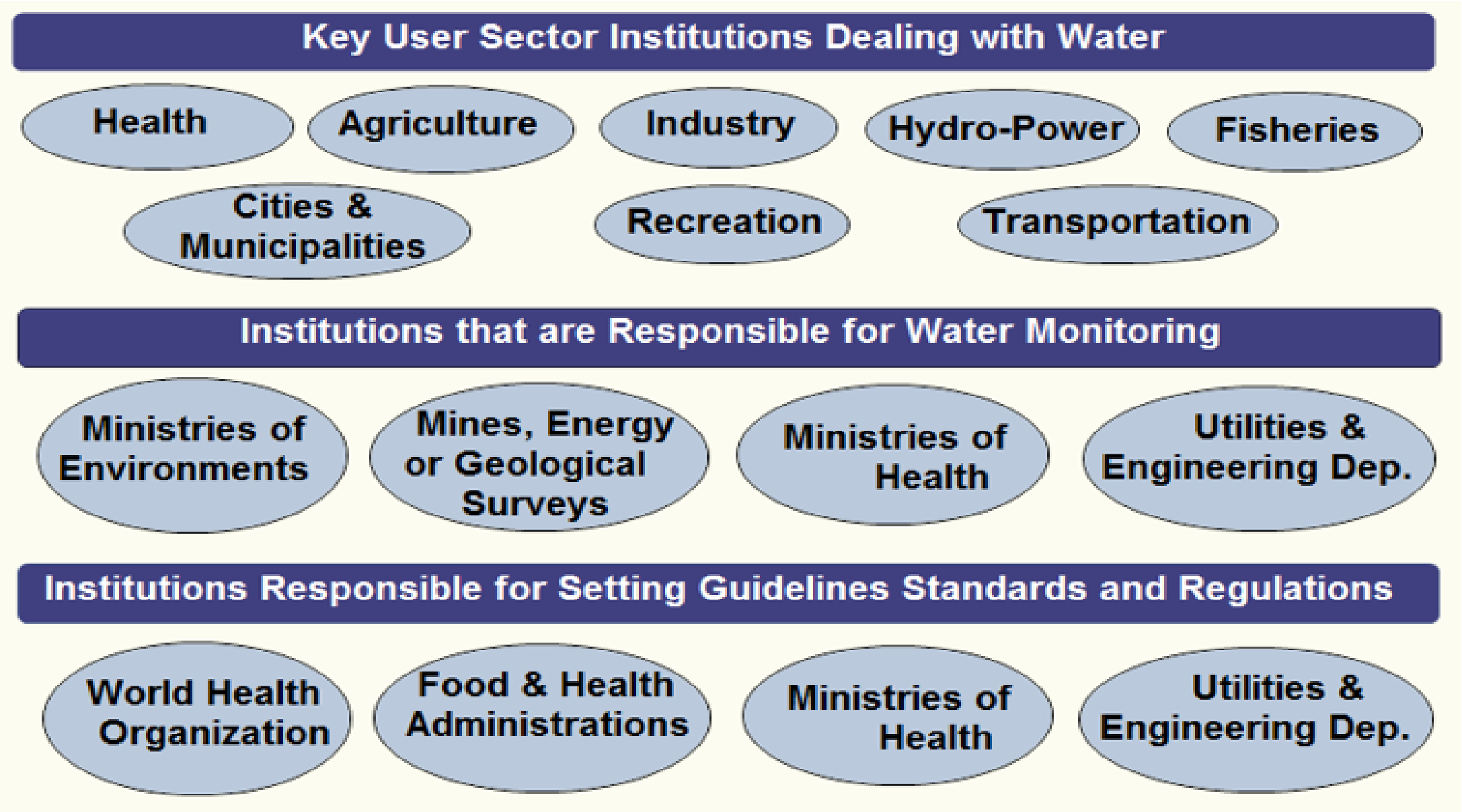

Mining Impacts on Water
Type
Strip
Pit
Underground
Placer
Gravel Extraction
Activities
Overburden Storage
Surface & subsurface alterations
Mine Tailings
In Situ Leaching
Stream Diversion
In stream washing and sorting
Impacts
Changes in surface hydrology
Changes in groundwater hydrology
Water Temperature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

Rainfall Redistribution by Land Use

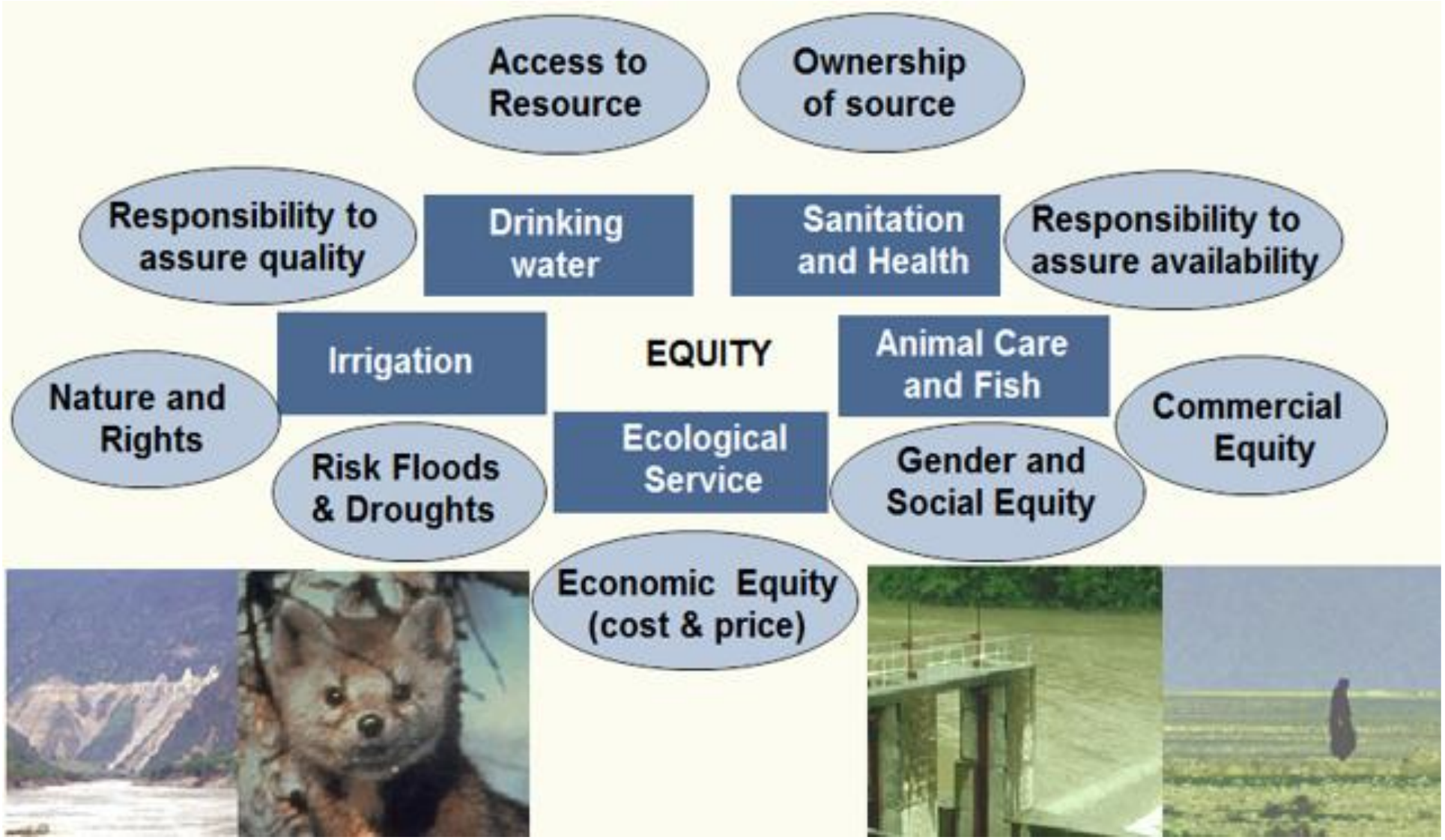
Note: Change in Surface Runoff as a result of land use changes (in Red)



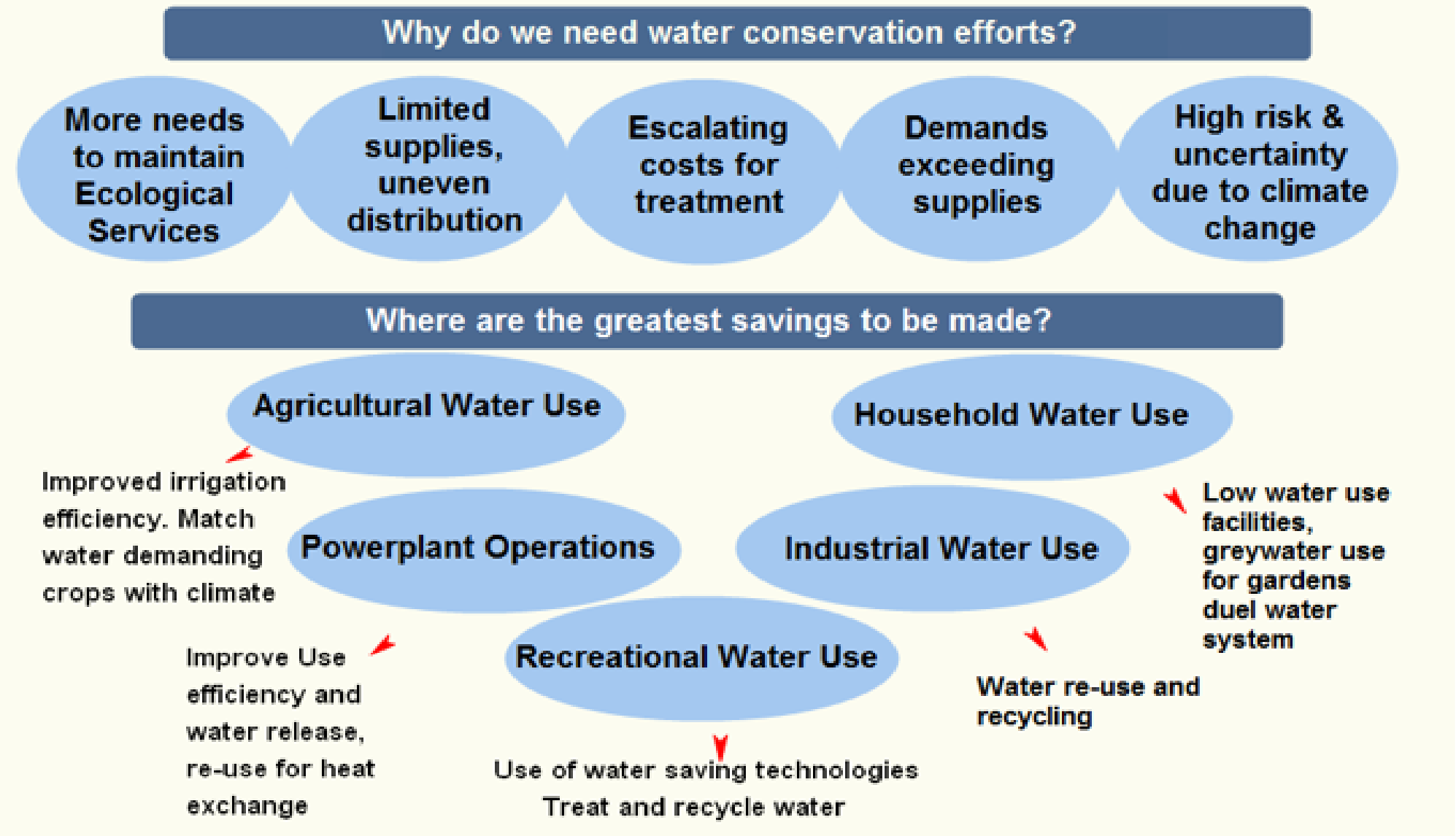
Water Governance Issues



Water Access & Equity Issues



Why We Need for Water Conservation



In Need of a Multi-Barrier Approach

Protective Measures:

1. Source Control - Reduce Input
2. Budget Accounting (N & P)
3. Large Riparian Buffer Zones
4. Wetland Preservation & Use
5. Beneficial Management Practices
6. Water Absorption & Infiltration
7. Limit Stocking Densities
8. Septic System Density
9. Tertiary Waste Water Treatment
10. Soil Erosion Control
11. Detention Ponds
12. Improved Manure Management

What have we been doing?

Changing Course

What should we be doing?

Traditional Approach	Innovative Approach
Green Revolution (low Carbon Input)	Increase Soil Carbon
Intensive Land Use (Soil Compaction)	Minimize Soil Compaction
Minimizing Buffer Zones	Maximizing Buffer Zones
Draining Wetlands	Creating Wetlands
Excessive Drainage	Detaining Drainage Water
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