Urban Watershed Management
How to Deal With the Combination of Land Use Intensification and Increased Climatic Variability

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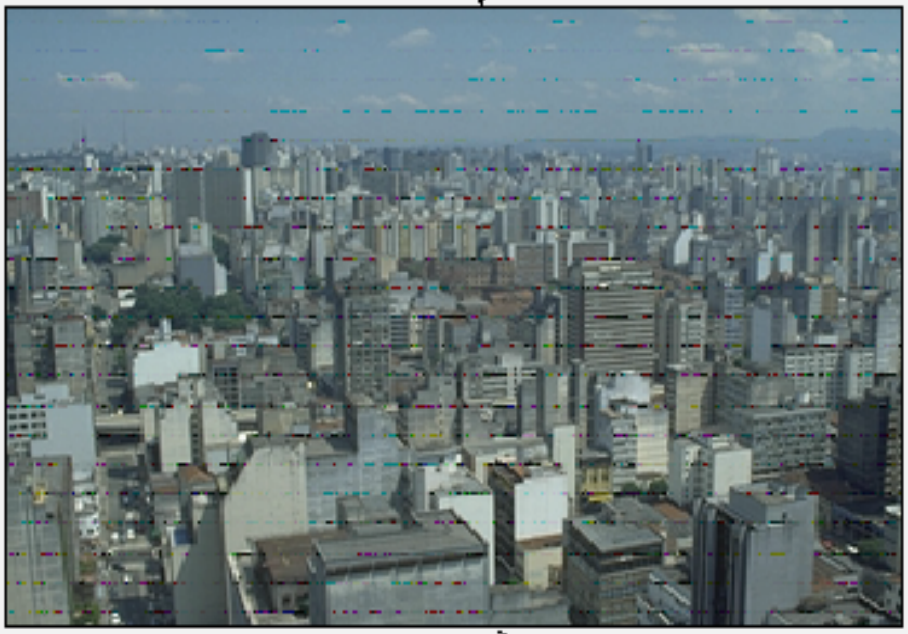
University of British Columbia, Vancouver, Canada

Introduction

Domestic Water Use

Urban Stormwater

Waste Water



Integration

Summary

We need a new approach for water management in Canada?

Key Water Issues

Urban Expansion

Increasing demand for safe drinking water
Increasing Waste Water
Increasing Non-point sources of pollution
Increase flooding during storms events

Agricultural Intensification

Greater water demand for irrigation
Non-point sources of pollution
Manure Management Problems
Virtual Water

Water & Environment

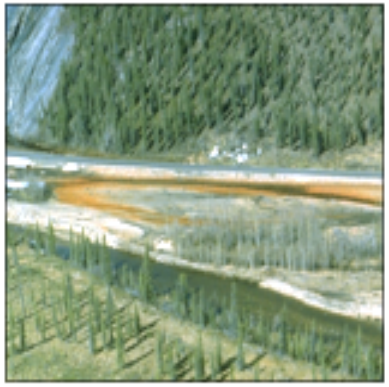
Increasing requirement to maintain sfficient flow during dry season to maintain biota and environmental services
Maintaining natural variability

Increased Climatic Variability

Higher and earlier peakflow
Lower baseflow
Warmer Temperatures
Glacier melt
Rain on snow events
More floods & droughts

Hydropower

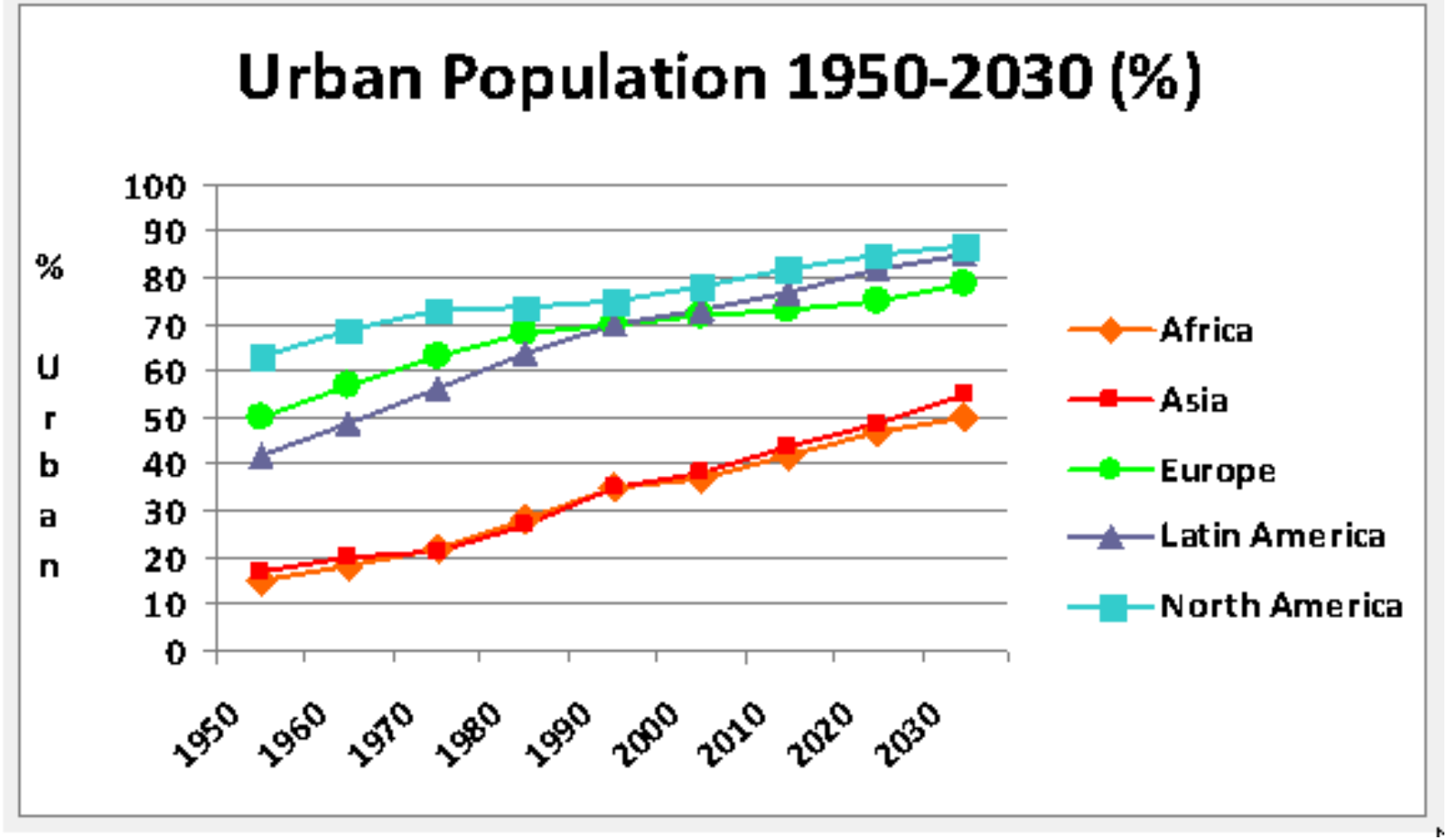
Increasing demand for Green Energy
More hydro dams
More Run-of River Systems

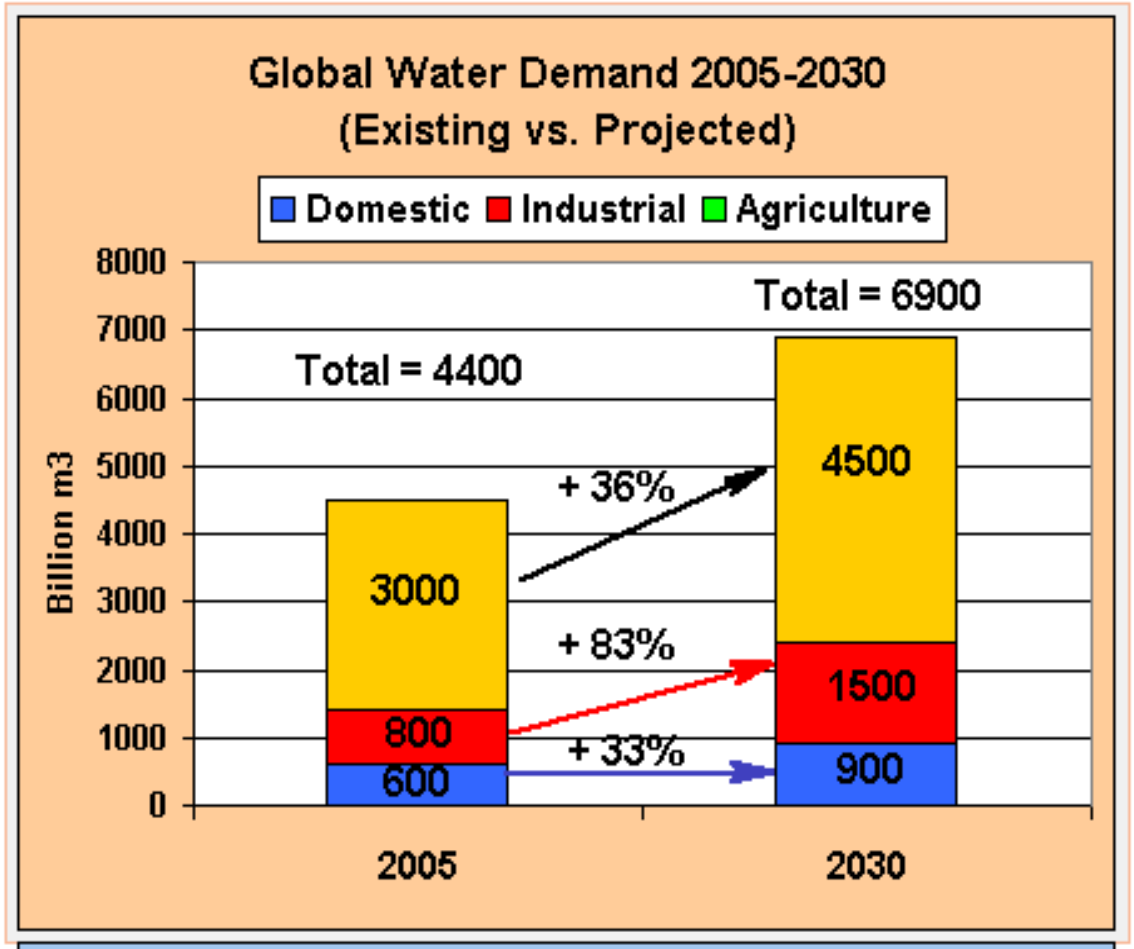


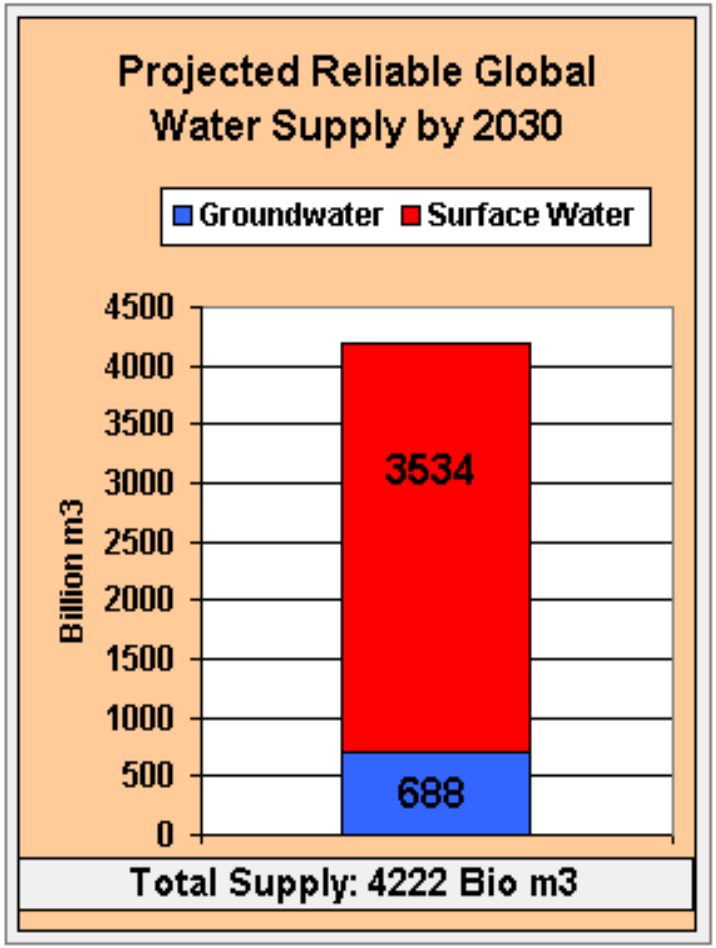
Water Quality Problems

NPS & cumulative effects
Pharmaceutical
Poor Wastewater Treatment
Eutrophication
Chemical interactions

In 2008 - 50% of the Global Population lived in Cities (3.3 Billion)
In 2030 - 80% of the Global Population will live in Cities (5.0 Billion)

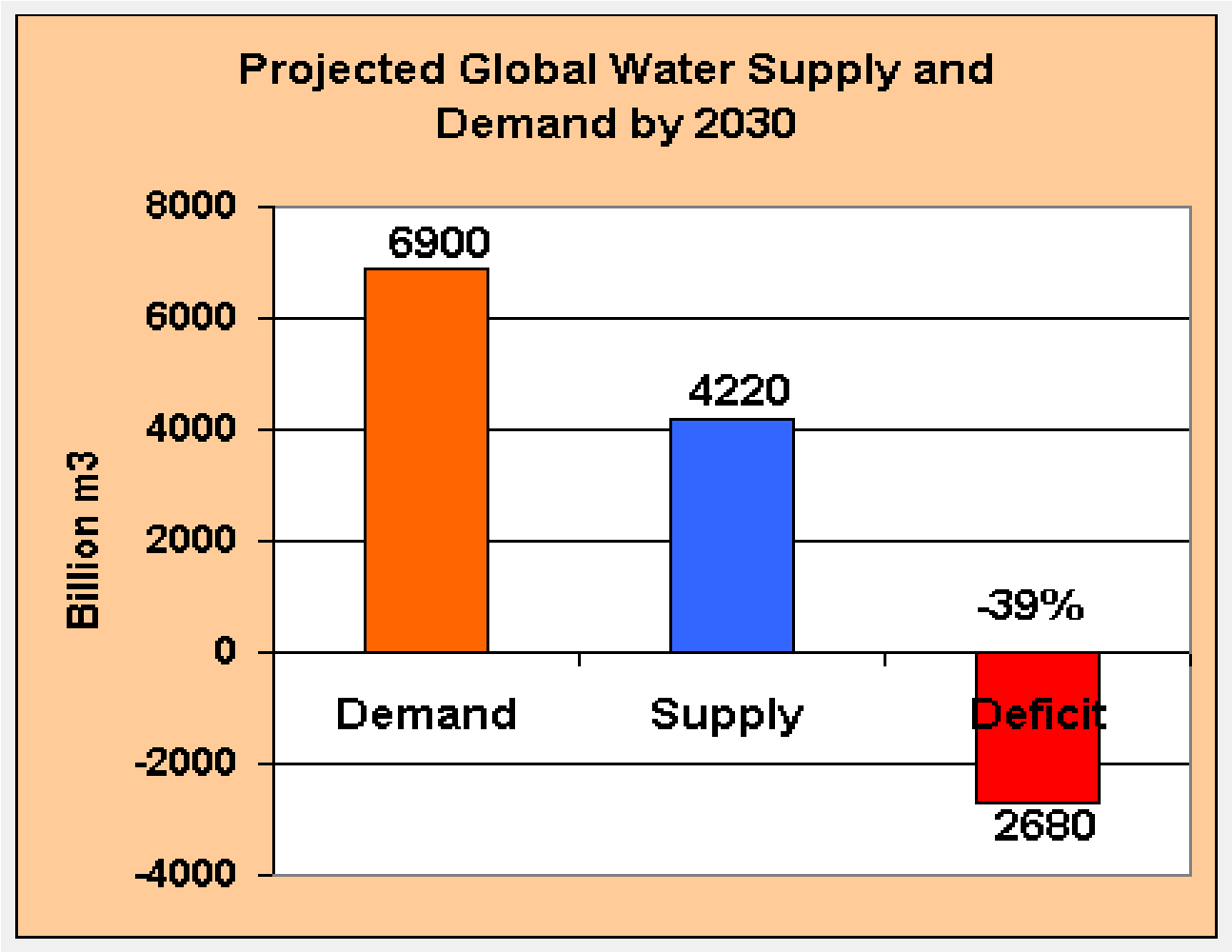






Without efficiency gains the water demand will increase by 64% between 2005-2030

Source:
Mckinsey Water Resource Group 2010.
Charting our Water Future.
Economic Frameworks to Inform Decision Makers
www.mckinsey.com/App_Media/Report/Water



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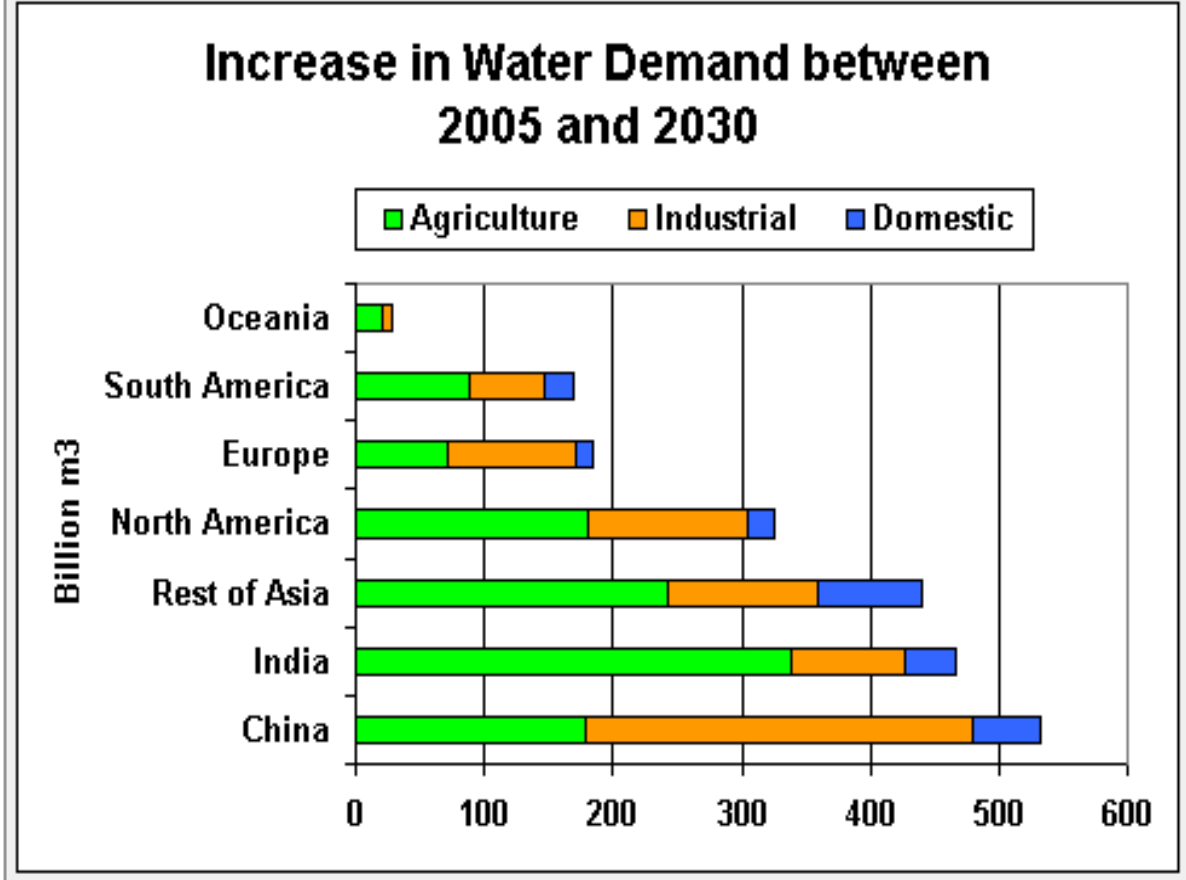
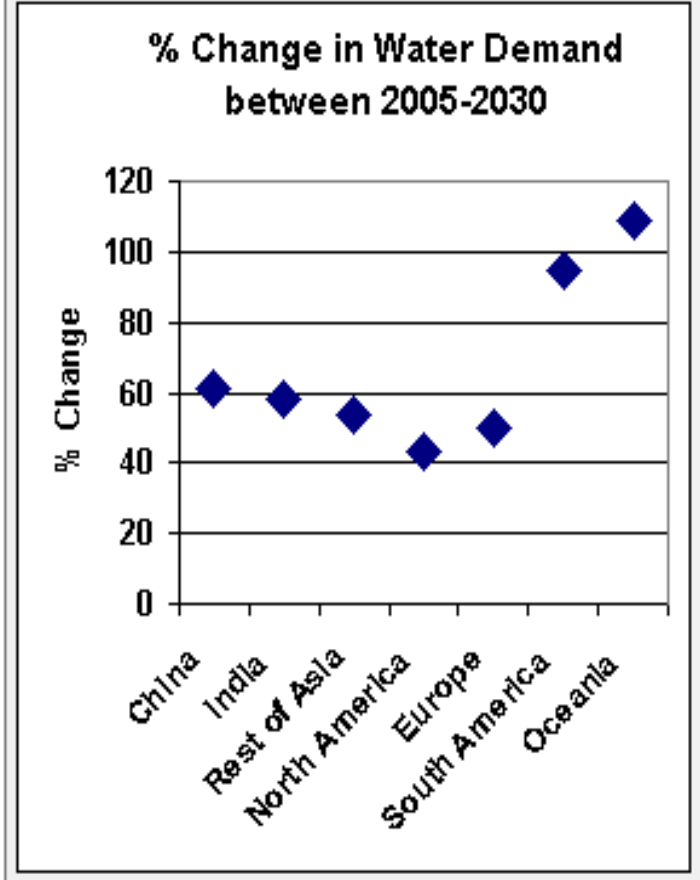
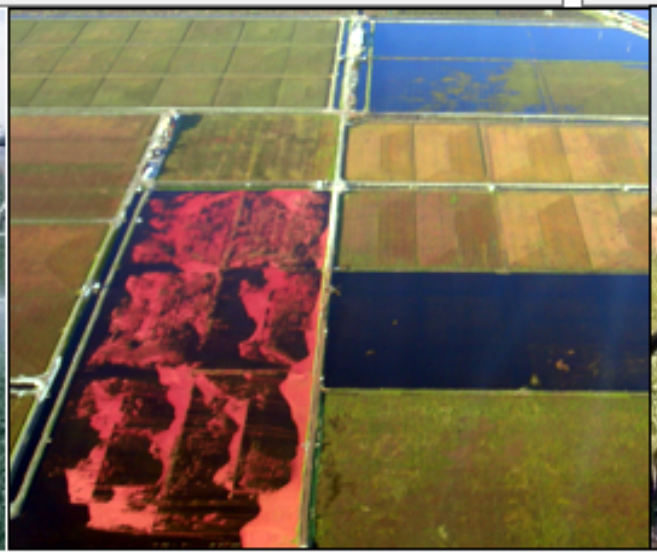
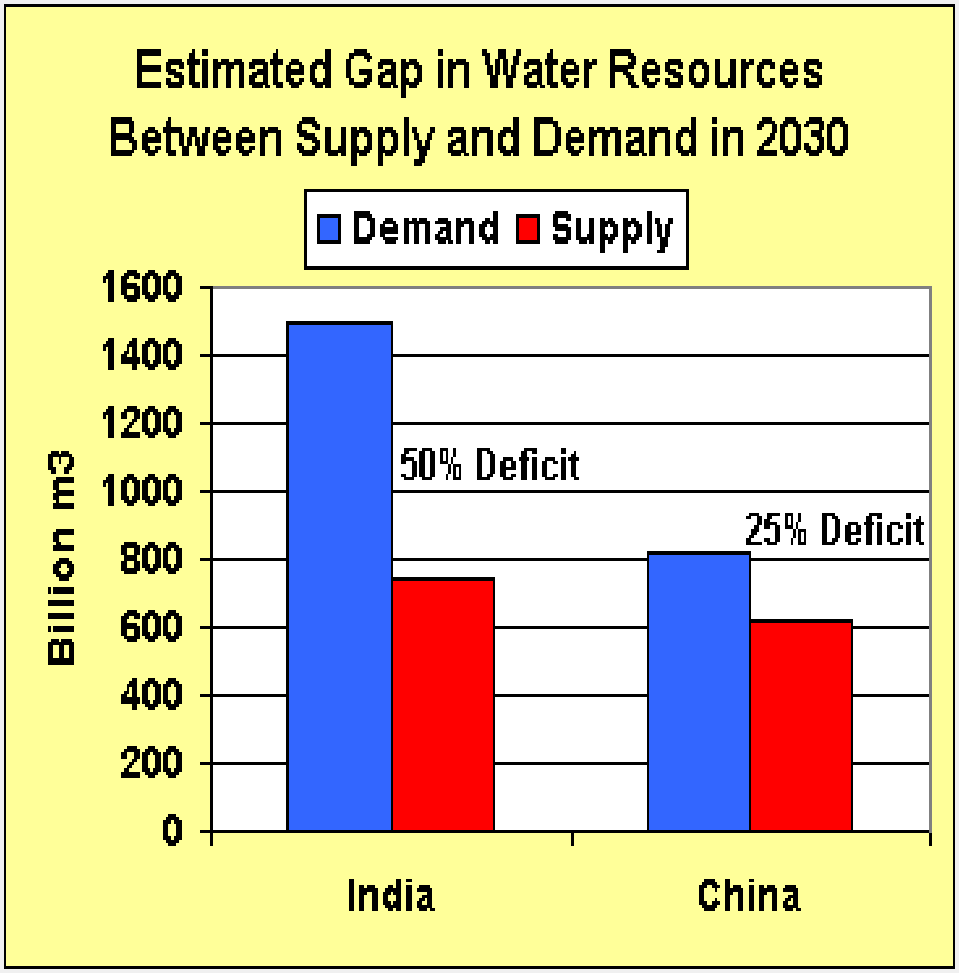

Increase in Water Demand between 2005 and 2030
Agriculture
Industrial
Domestic
Billion m3
Oceania
South America
Europe
North America
Rest of Asia
India
China
0
100
200
300
400
500
600


% Change in Water Demand between 2005-2030
% Change
120
100
80
60
40
20
0
China
India
Rest of Asia
North America
Europe
South America
Oceania





India and China are projected to have large water deficits between water supplies and demands by 2030 without massive increases in water use efficiency and conservation

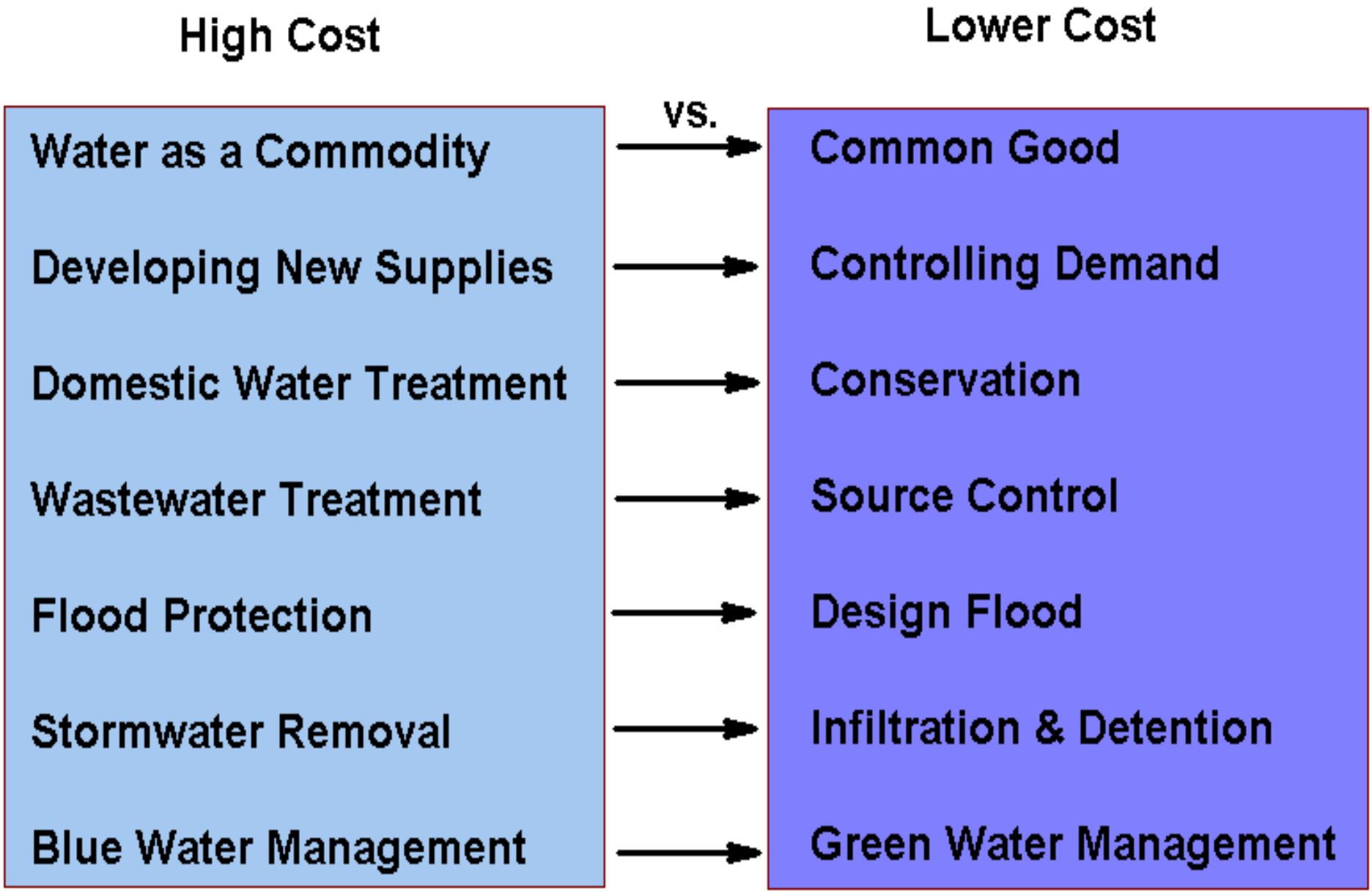
China's Solutions:

Finding New Supplies:
Massive River Diversion
Desalinization

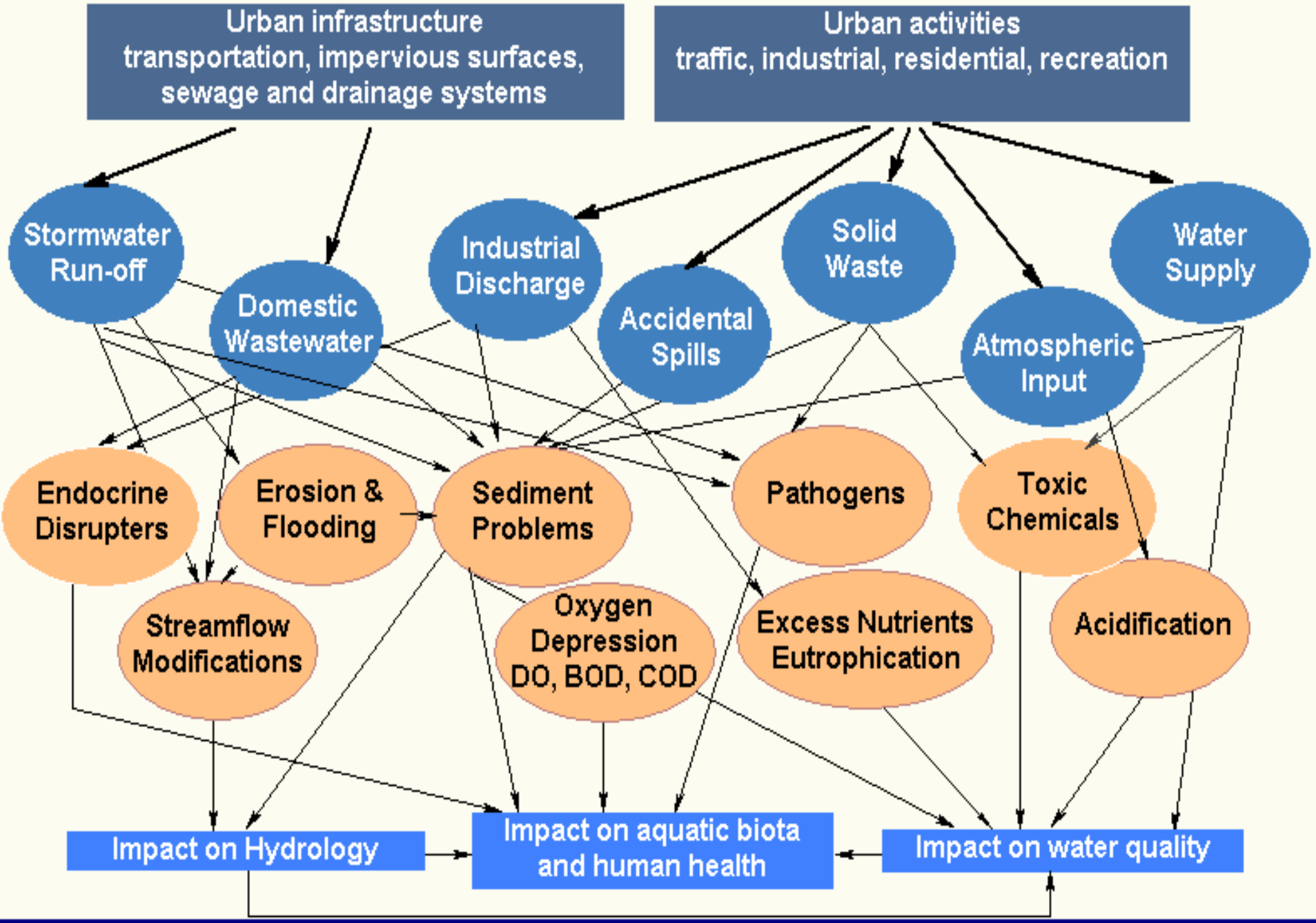
Other Solutions:

Water Use Efficiency
Improved Irrigation
Water Reuse
Conservation to Reduce Demand
Import Water Intensive Products:
Water Intensive Food
Water Intensive Materials

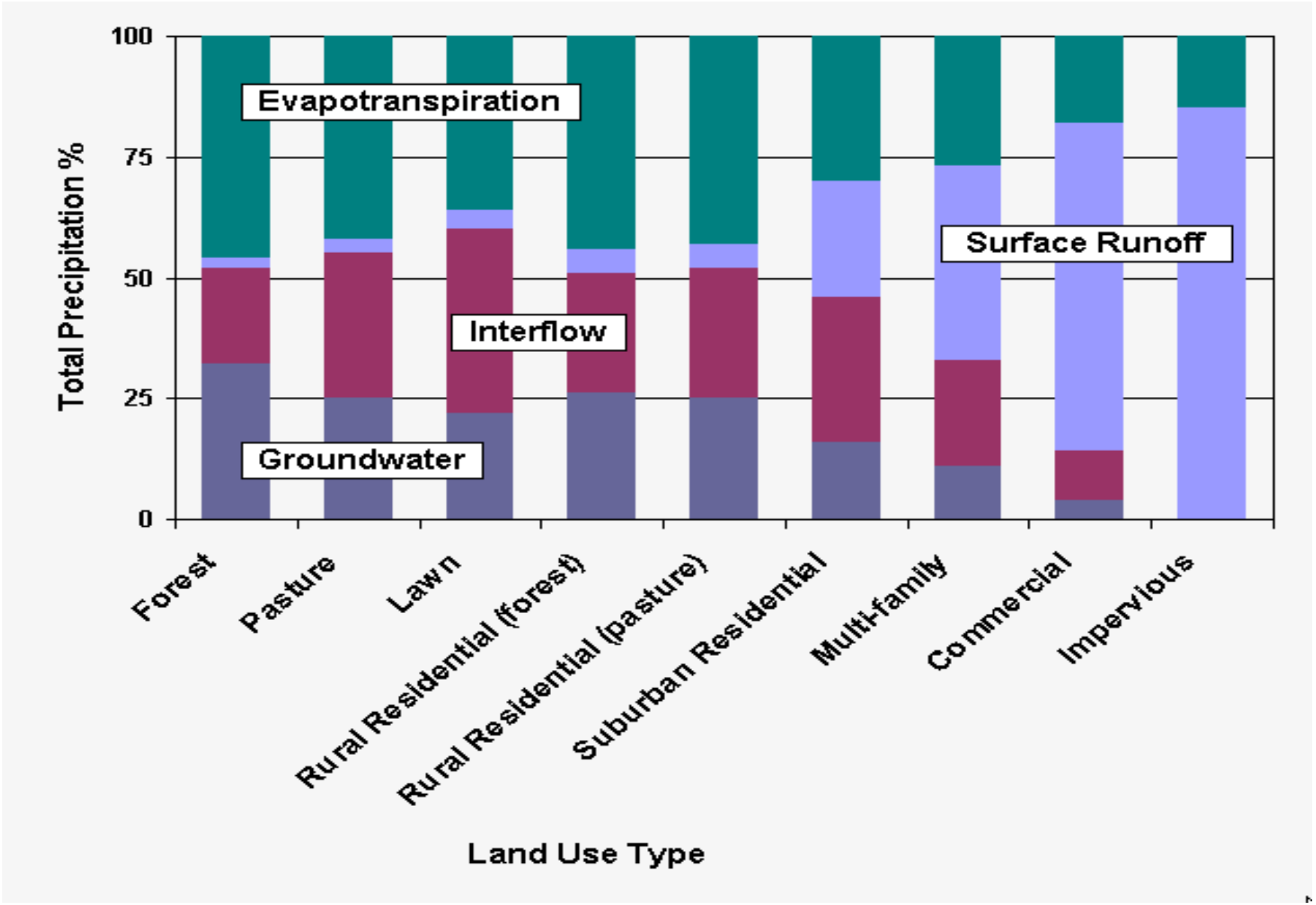
Cost Considerations



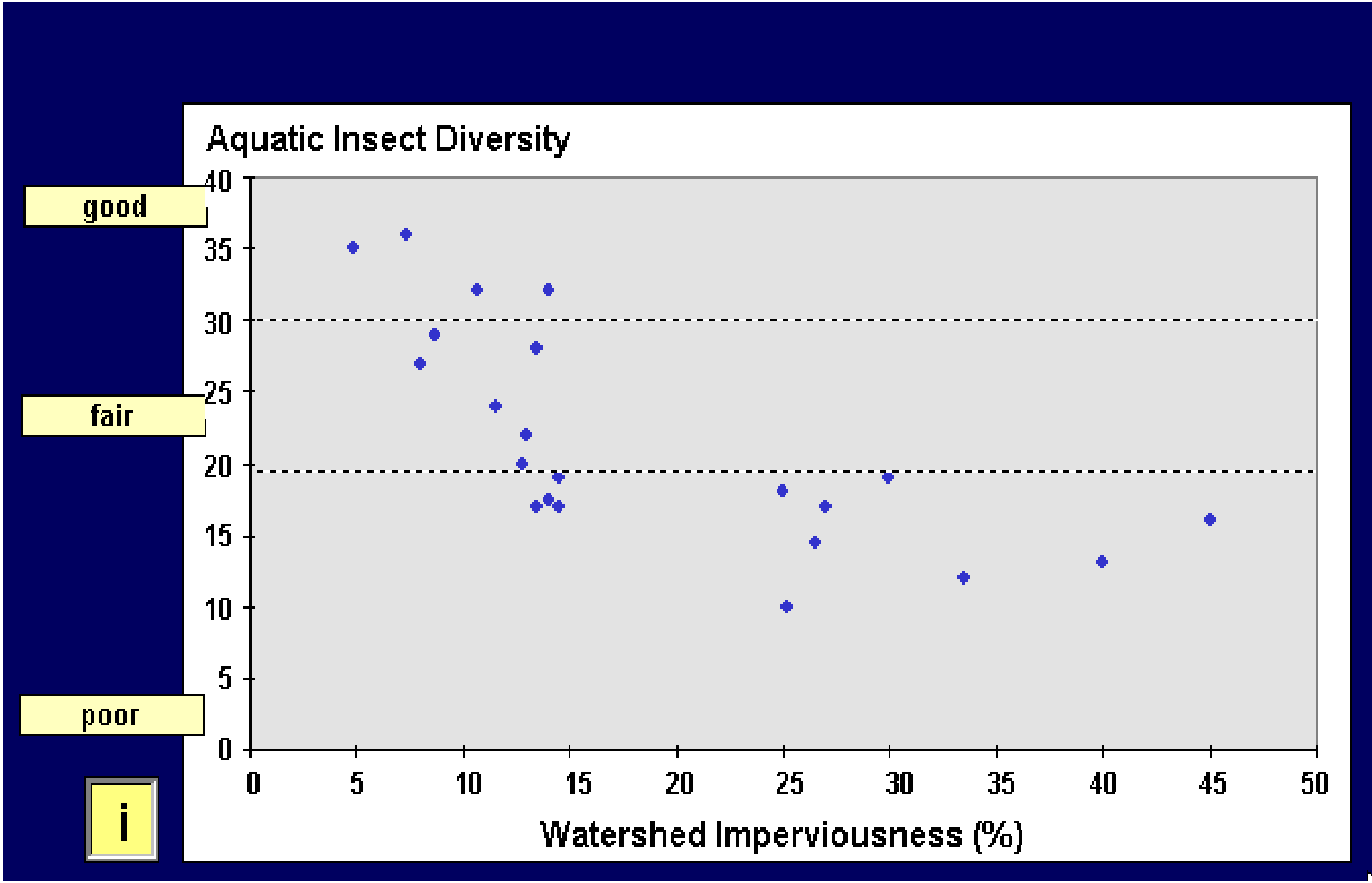
Urban Impact on Water Resources



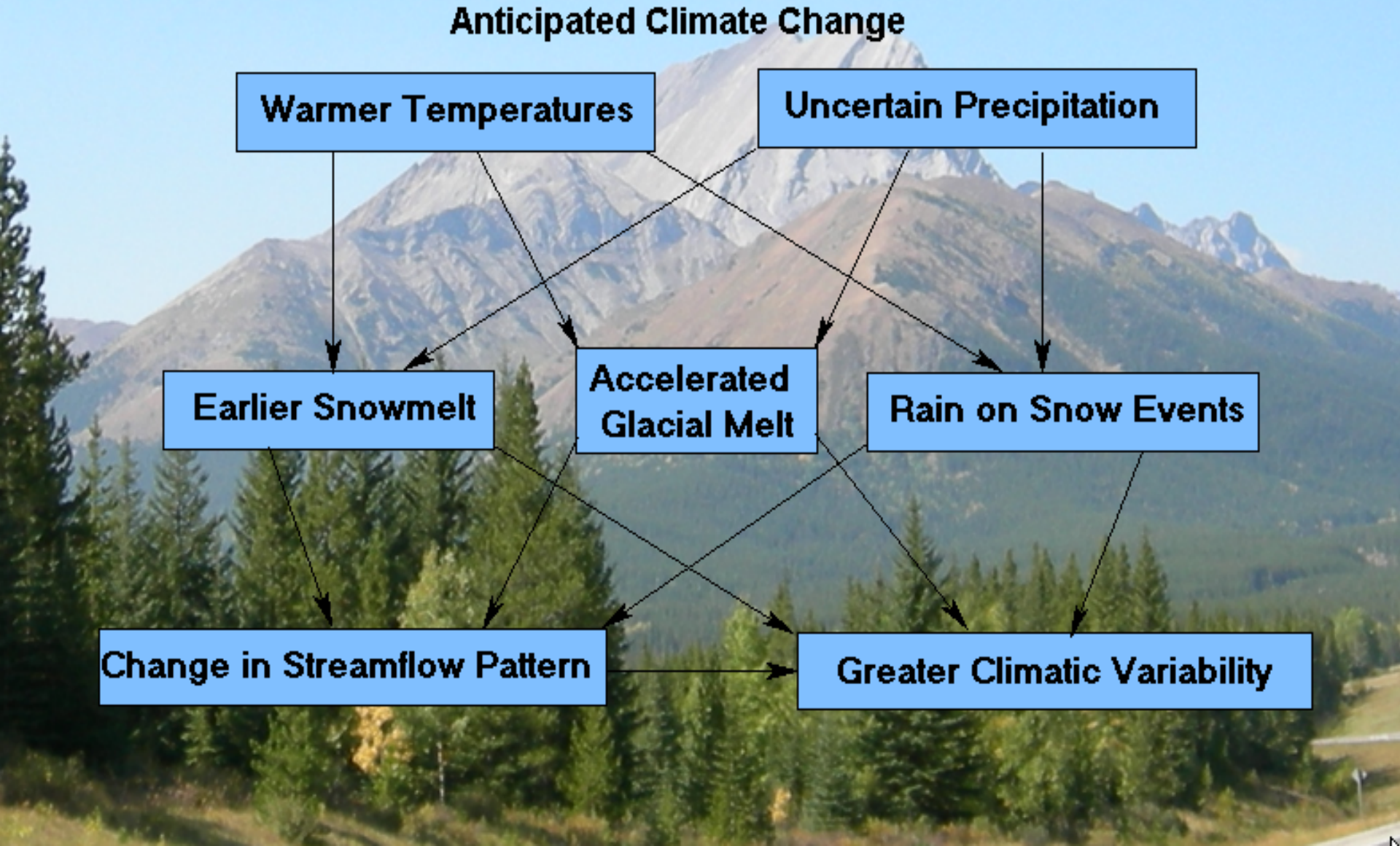
Land use Impact on the hydrological cycle



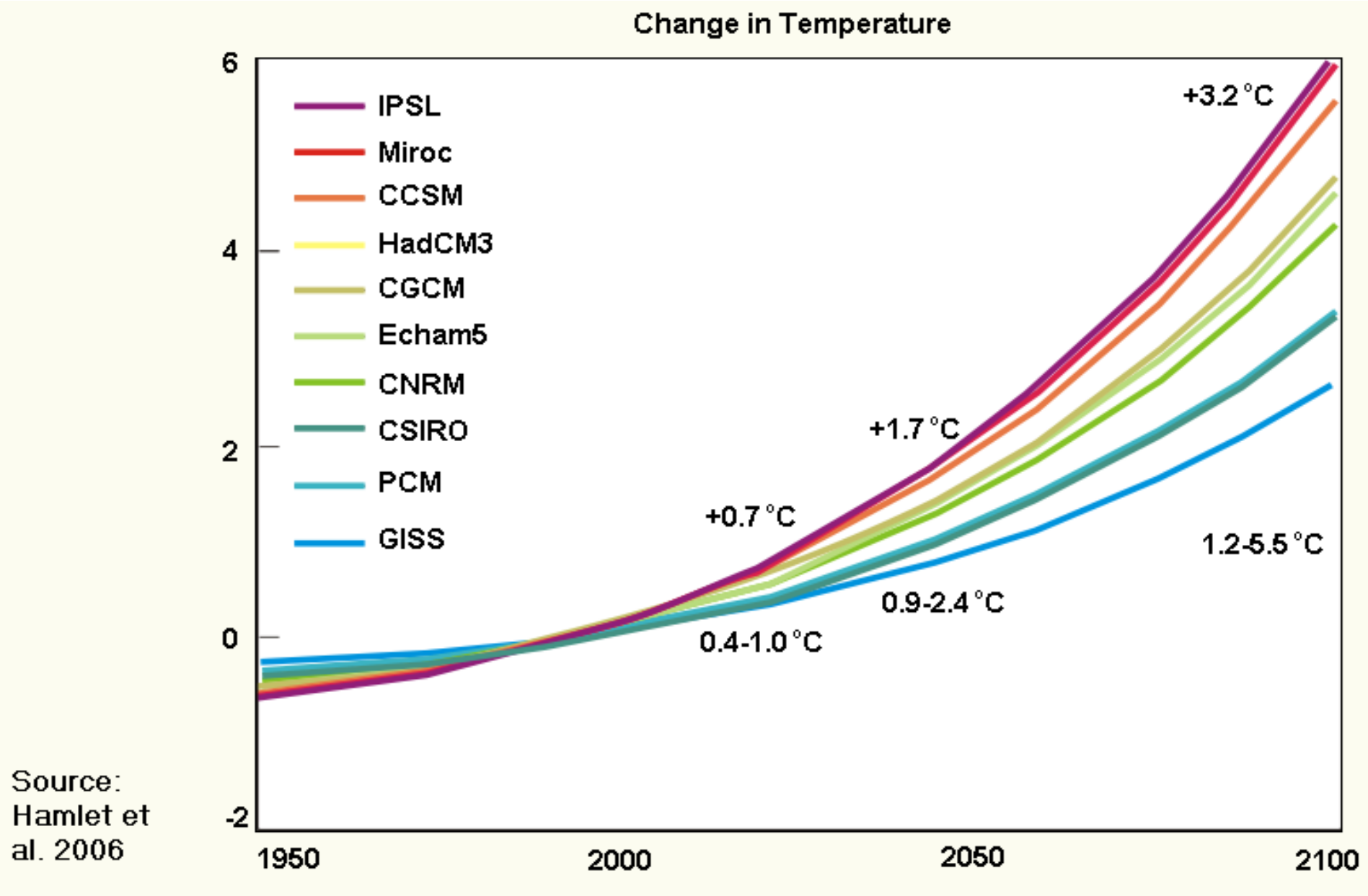
Aquatic Biodiversity vs. Imperviousness



Land Use Activities and Increased Climatic Variability Have a Profound Impact on the Hydrological Cycle Separating the two factors is almost impossible !

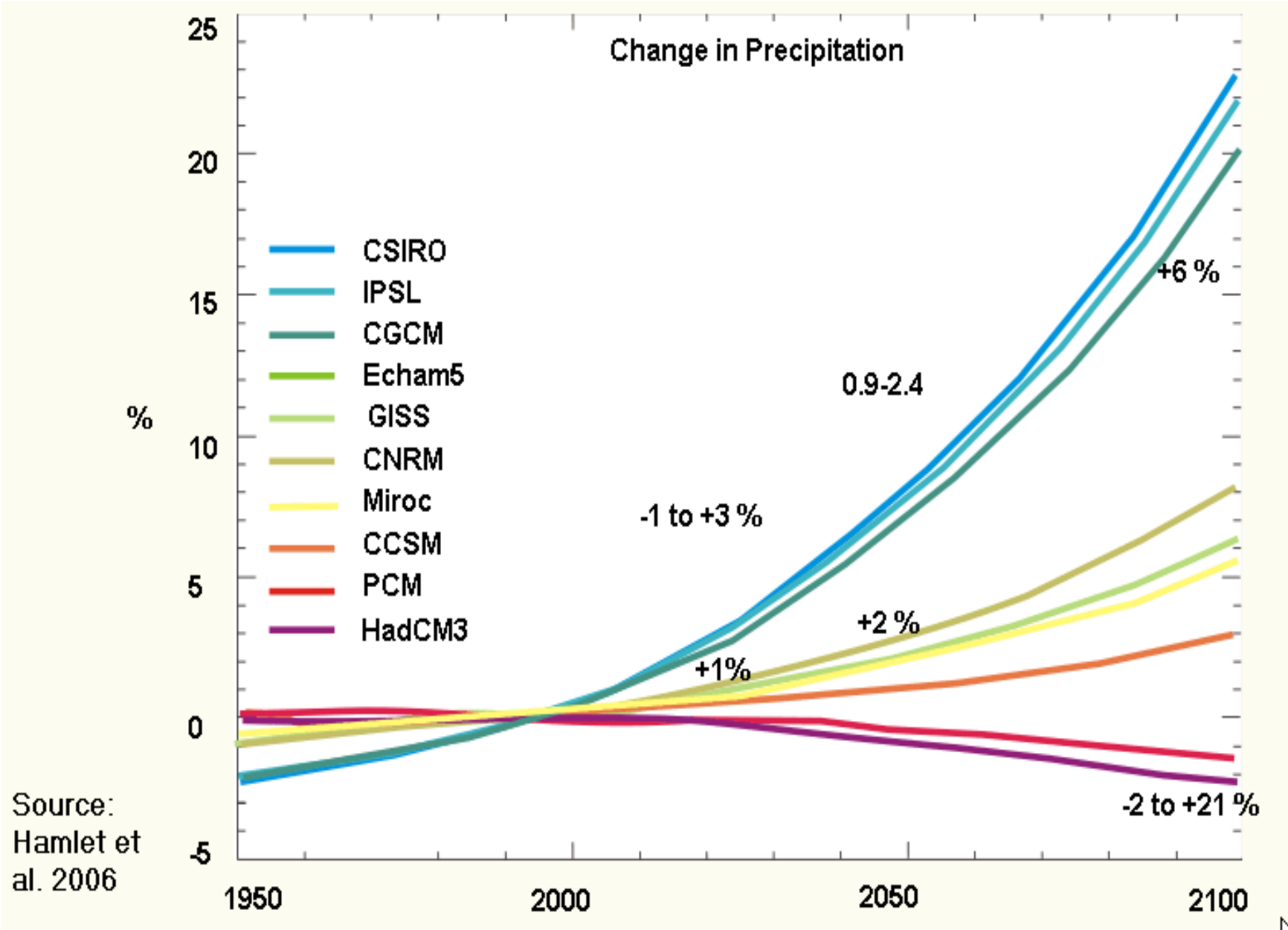


Temperature Scenarios based on Global Climate Models

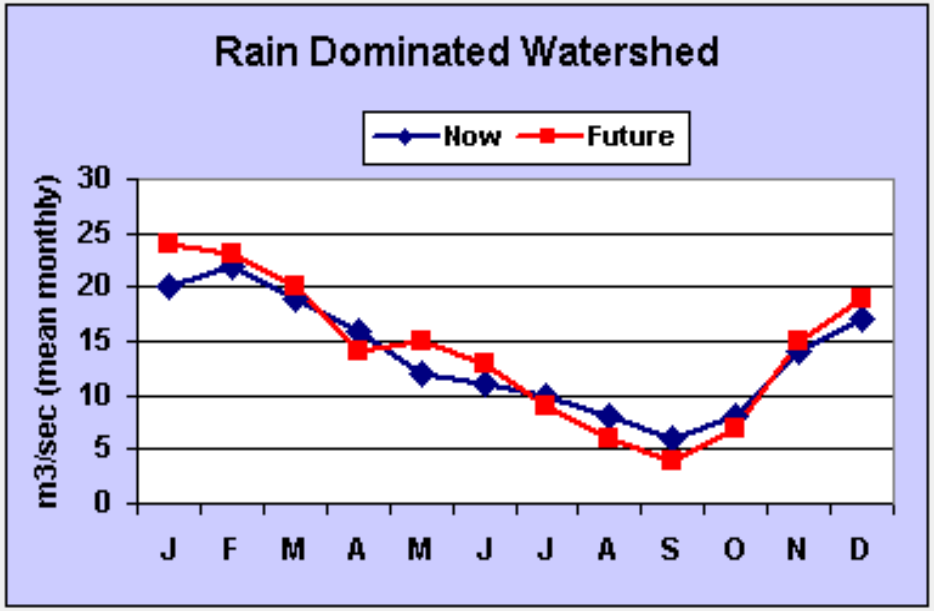


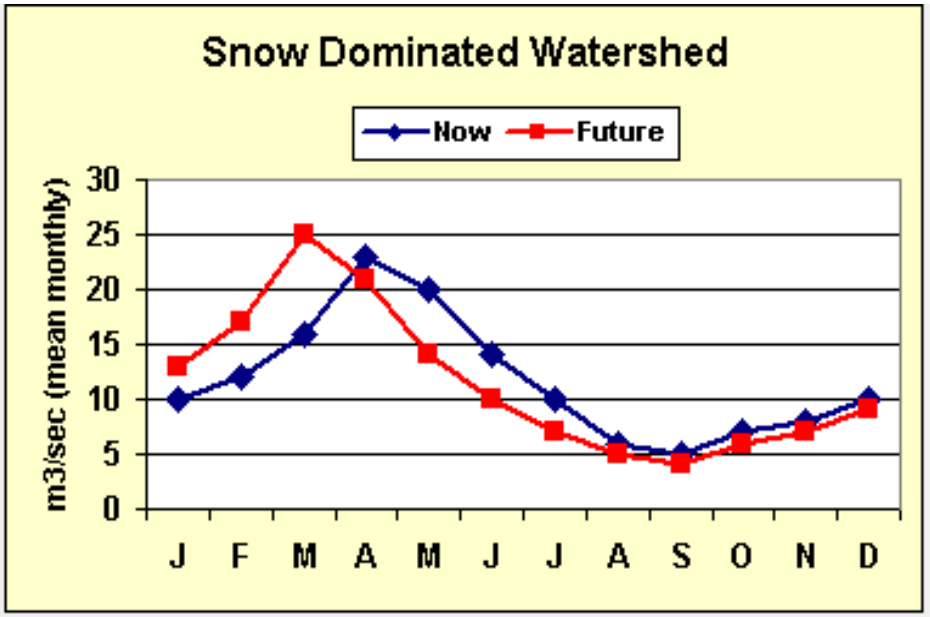
Source: Hamlet et al. 2006

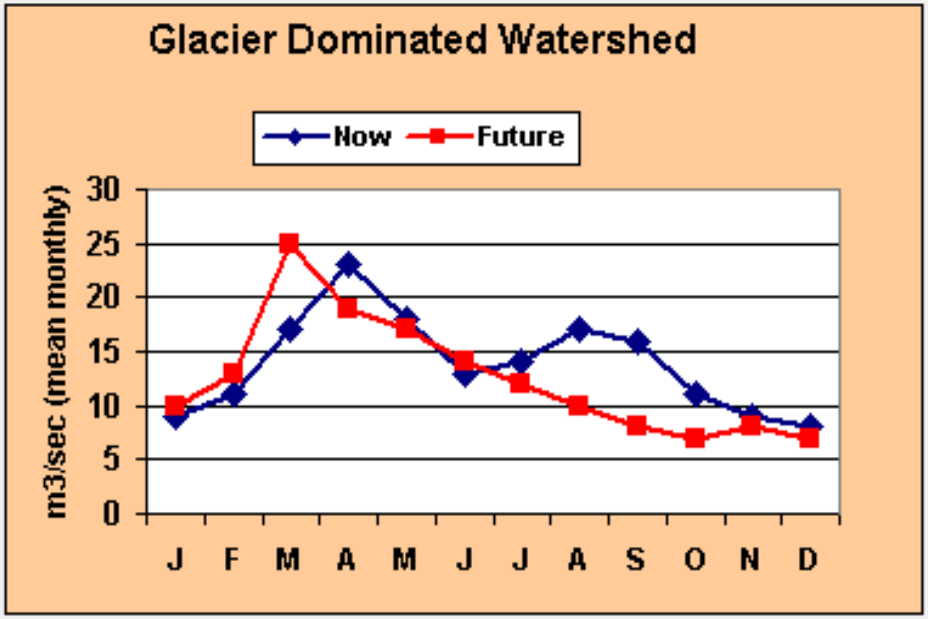
Precipitation Scenarios based on Global Climate Models



Changes in Stream Discharge Due to Climate Warming







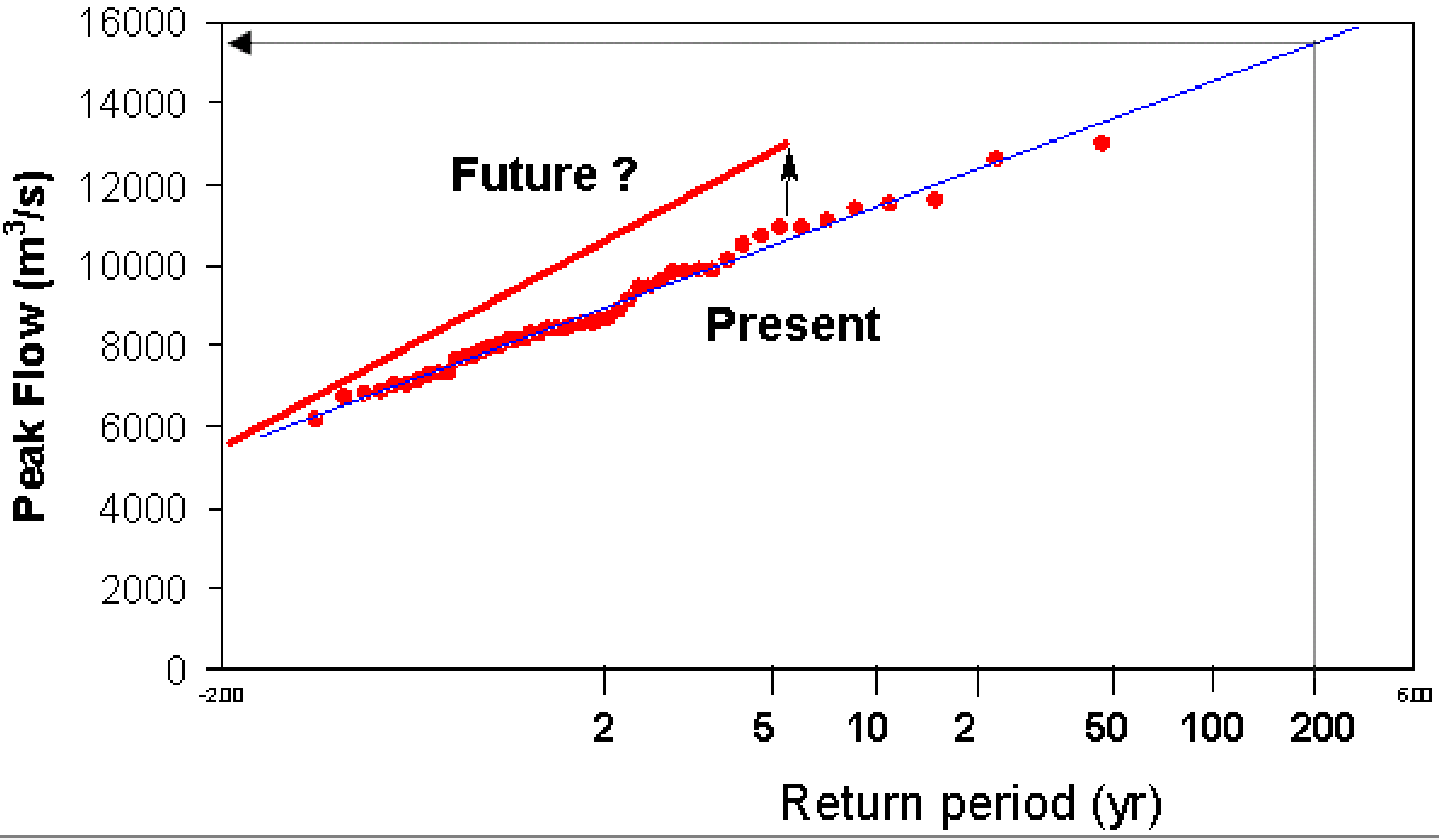
Anticipated Hydrological Changes:

Greatest changes in glacier dominated watersheds

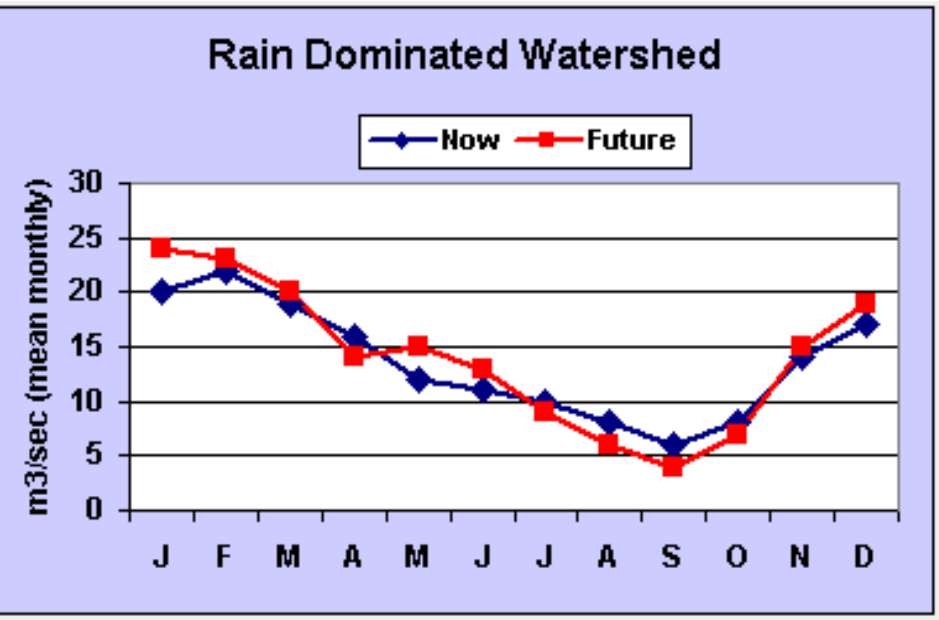
Major shift in peak and low flow in snow dominated watershed

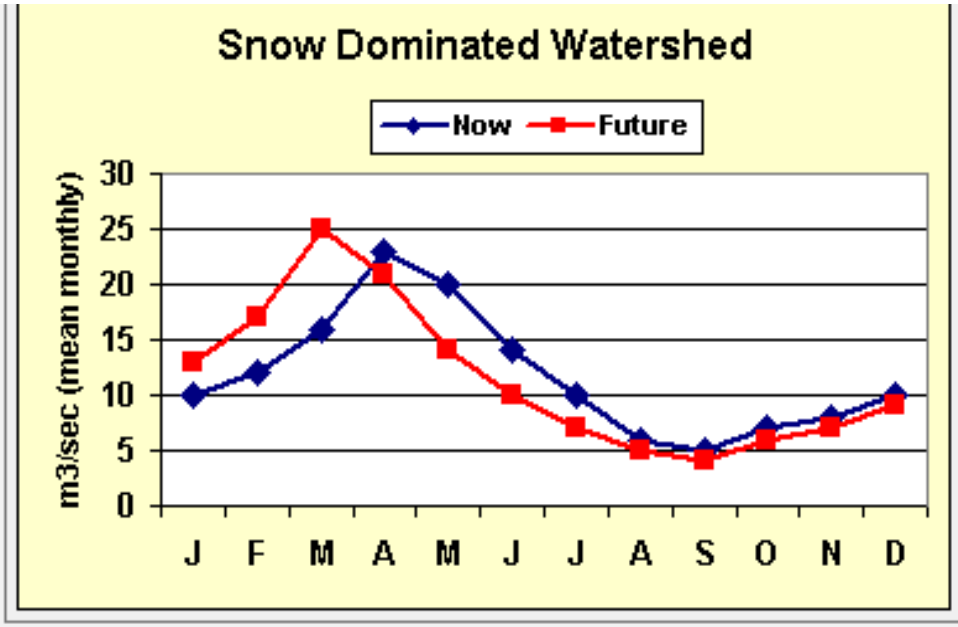
More variability in rain dominated watershed

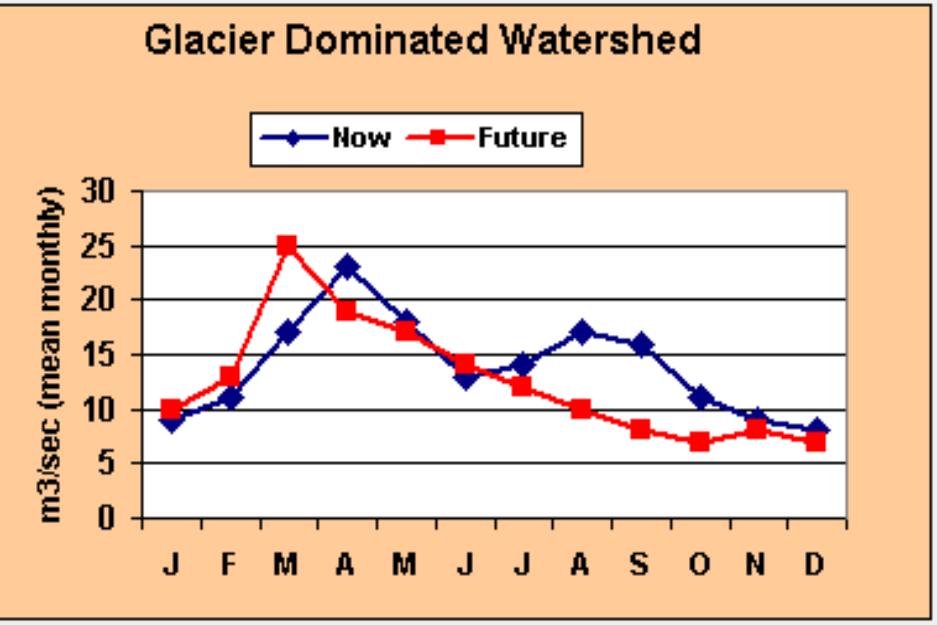
CHANGES IN FLOOD FREQUENCY ANALYSIS



Expected Changes in Stremflow regimes







Anticipated Hydrological Changes:

Greatest changes in glacier dominated watersheds

Major shift in peak and low flow in snow dominated watershed

More variability in rain dominated watershed

625 mm Rain (20 days)
Capilano Watershed
Entire Vancouver on
Boil Water Alert

35 cm Snow
High Wind
200'000 people
without power
for up to 5 days

Windstorm 140 km/hr
3000 trees decapitated
in Stanley Park

Second Highest
Snowfall 66 cm
Airport closed for
2 days

Rainfall 26 out of 30 days
in November 2009

Warmest
January on
Record 7.1 °C

Highest Temp.
Historic Record)
33.8 °C

Driest July
in 25 years

Jan
Nov
Dec
Jan
Dec
Jul 26
Nov
Jan
July

2006 | 2007 | 2008 | 2009 | 2010

Anticipated Water Issues Due to Climate Change

More Intensive Storms
Greater Stromwater Runoff & Floods
Rain on Snow Events
More Freeze and Thaw Events
Greater Variability in Streamflow
Extensive Summer Dry Periods
Increasing Water Demands

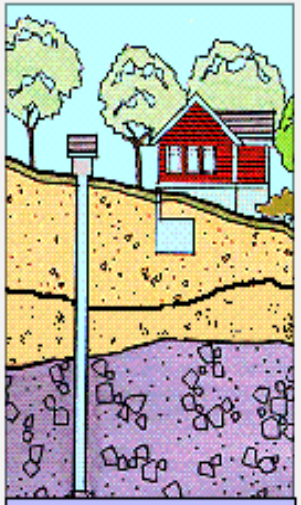
Anticipated Water Issues Due to Land Use Intensification

Imperviousness & Surface Compaction
Increased Nutrient and Chemical Loadings
Water Shortages due to Increasing Demands
Increased Erosion and Sediment Transport
Lower Base Flow and Higher Peakflow

Water Supplies & Conservation

Domestic Water Sources

Reservoir

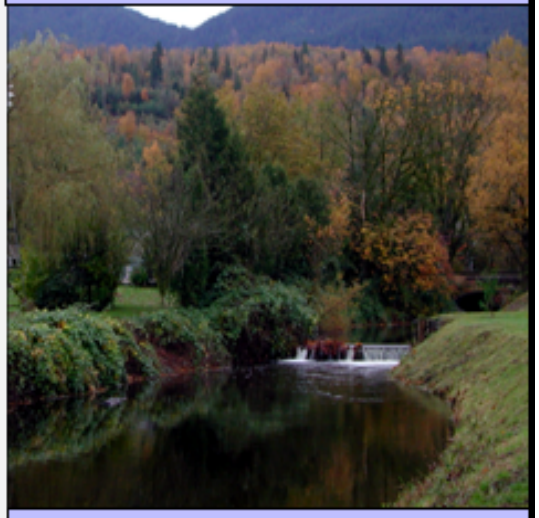


Groundwater

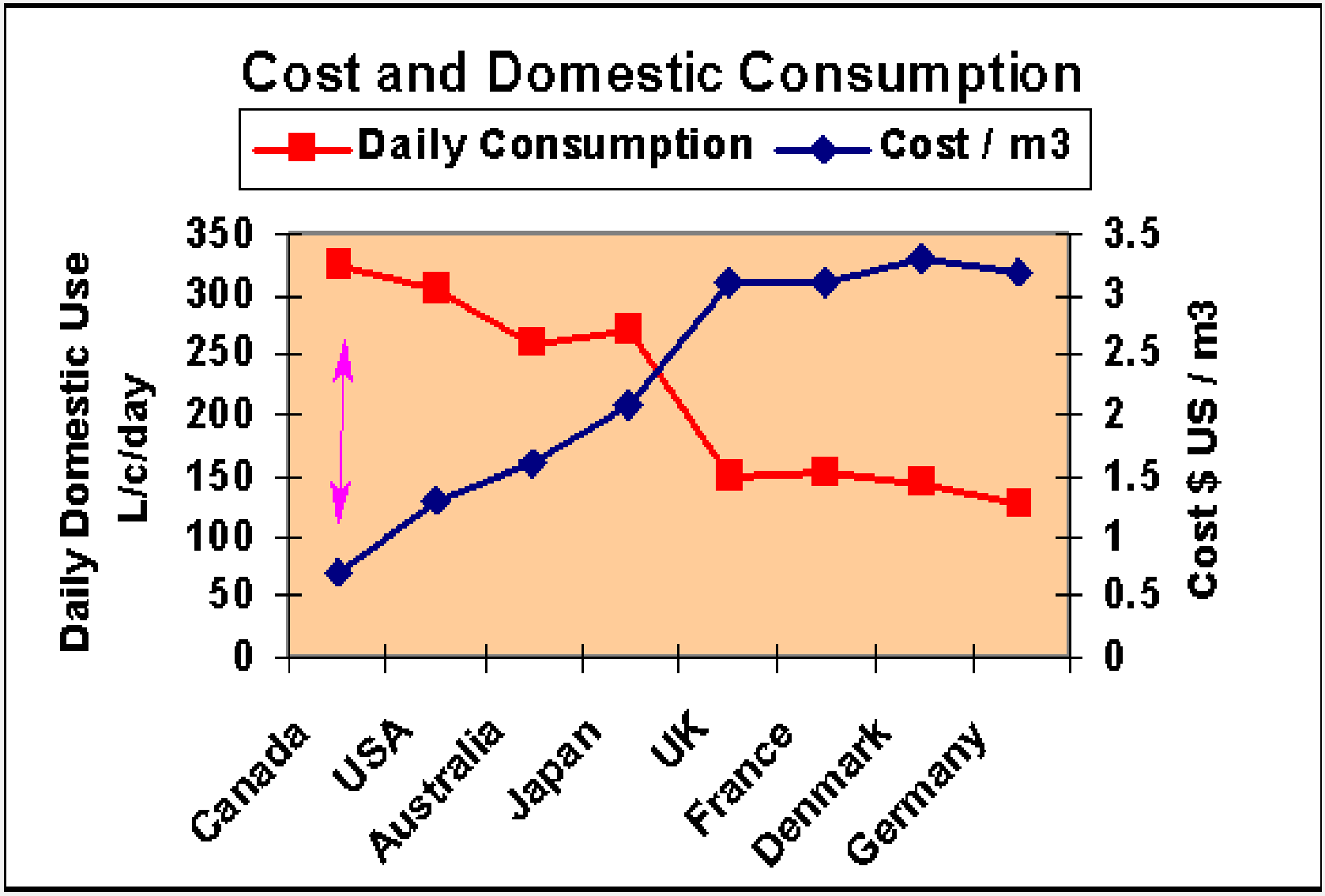
Rainwater Harvesting

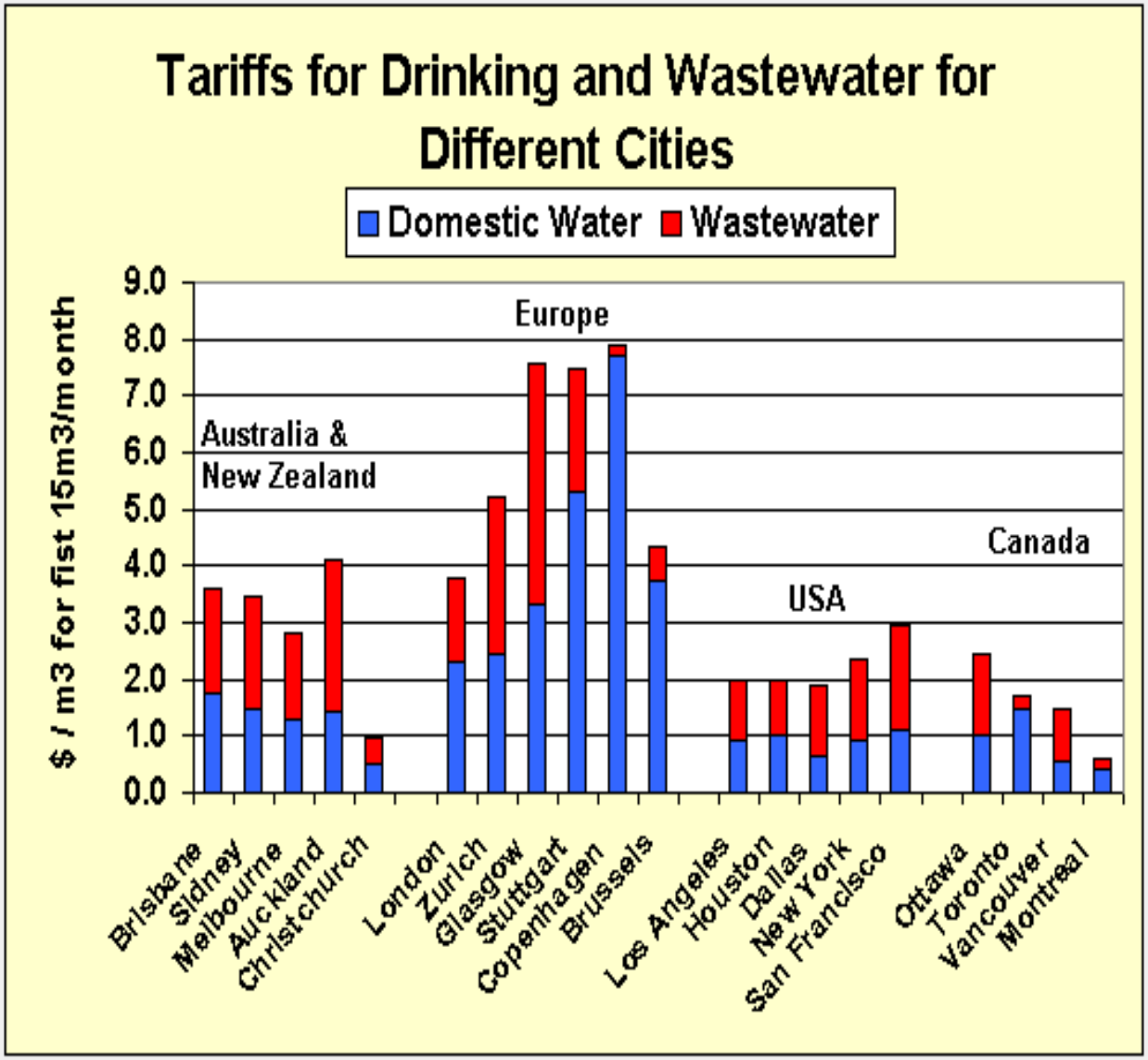
Lake Water

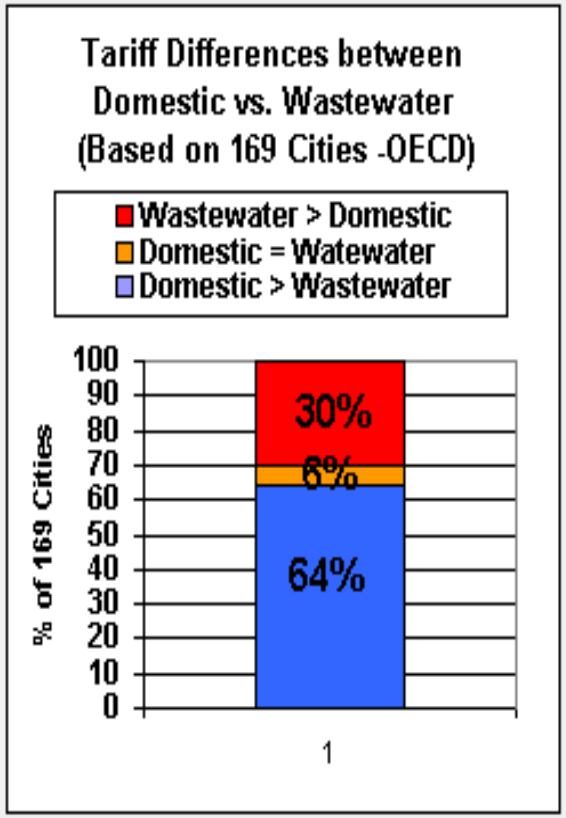
Spring Water



Streamwater

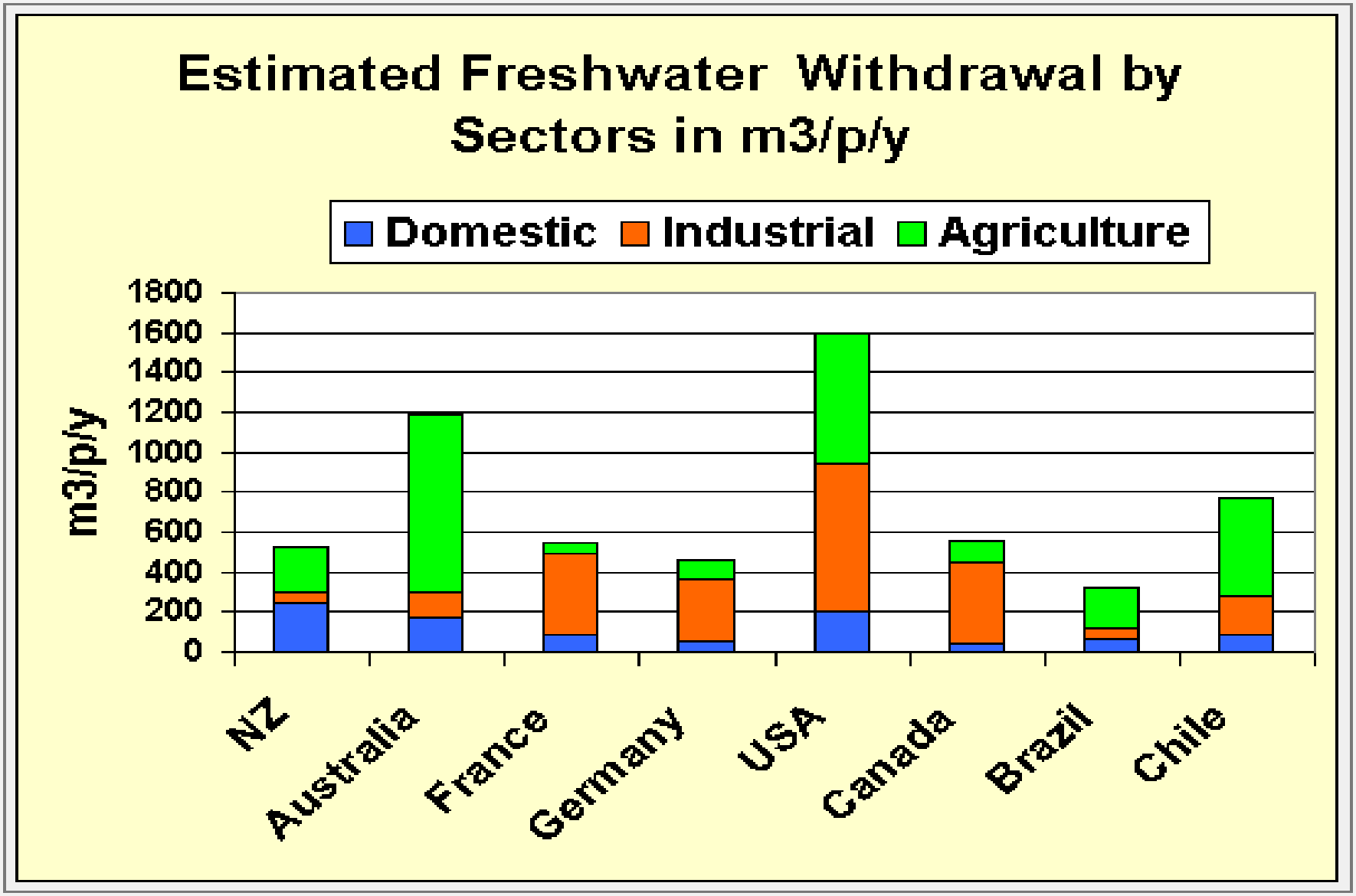

Cost and Domestic Consumption
Daily Consumption
Cost / m3
Daily Domestic Use
L/c/day
350
300
250
200
150
100
50
0
3.5
3
2.5
2
1.5
1
0.5
0
Cost $ US / m3
Canada
USA
Australia
Japan
UK
France
Denmark
Germany





Source: GWI / OECD 2007 Water Tariff Survey. www.globalwaterintel.com/survey2007.xls
Gleick, 2009. The World's Water 2008-2009 The Biennial Report on Freshwater Resources

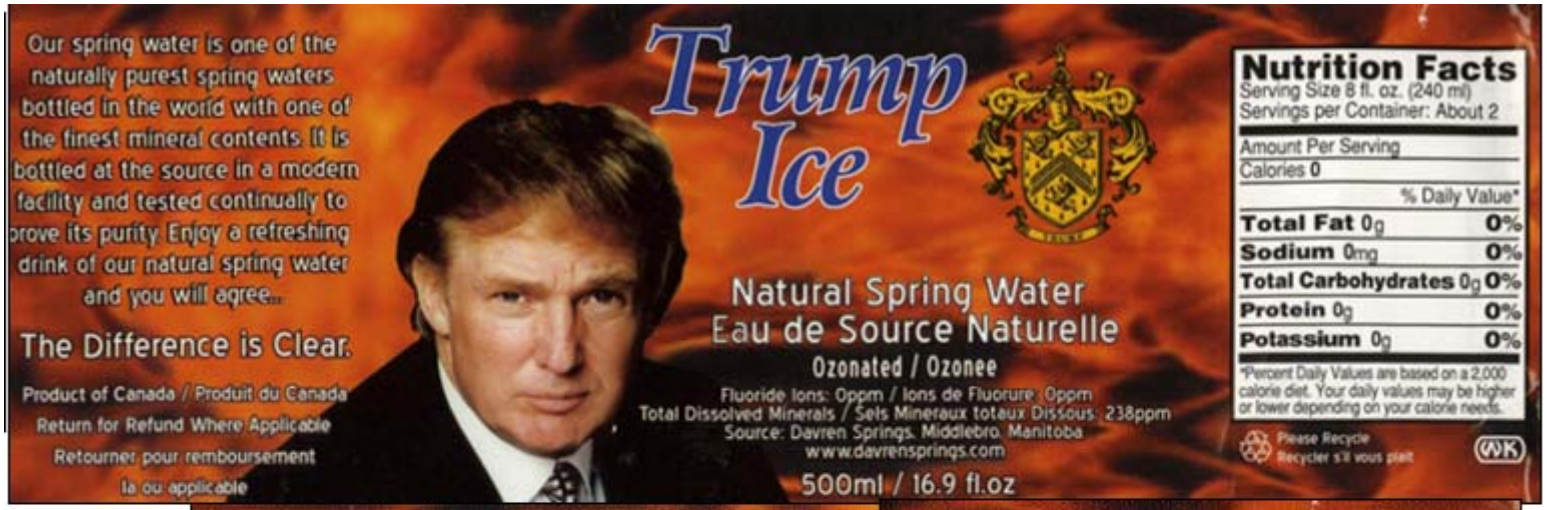
Freshwater Use



Source: GWI / OECD 2007 Water Tariff Survey. www.globalwaterintel.com/survey2007.xls
Gleick, 2009. The World's Water 2008-2009 The Biennial Report on Freshwater Resources

The Claims and Quality of Bottled Water

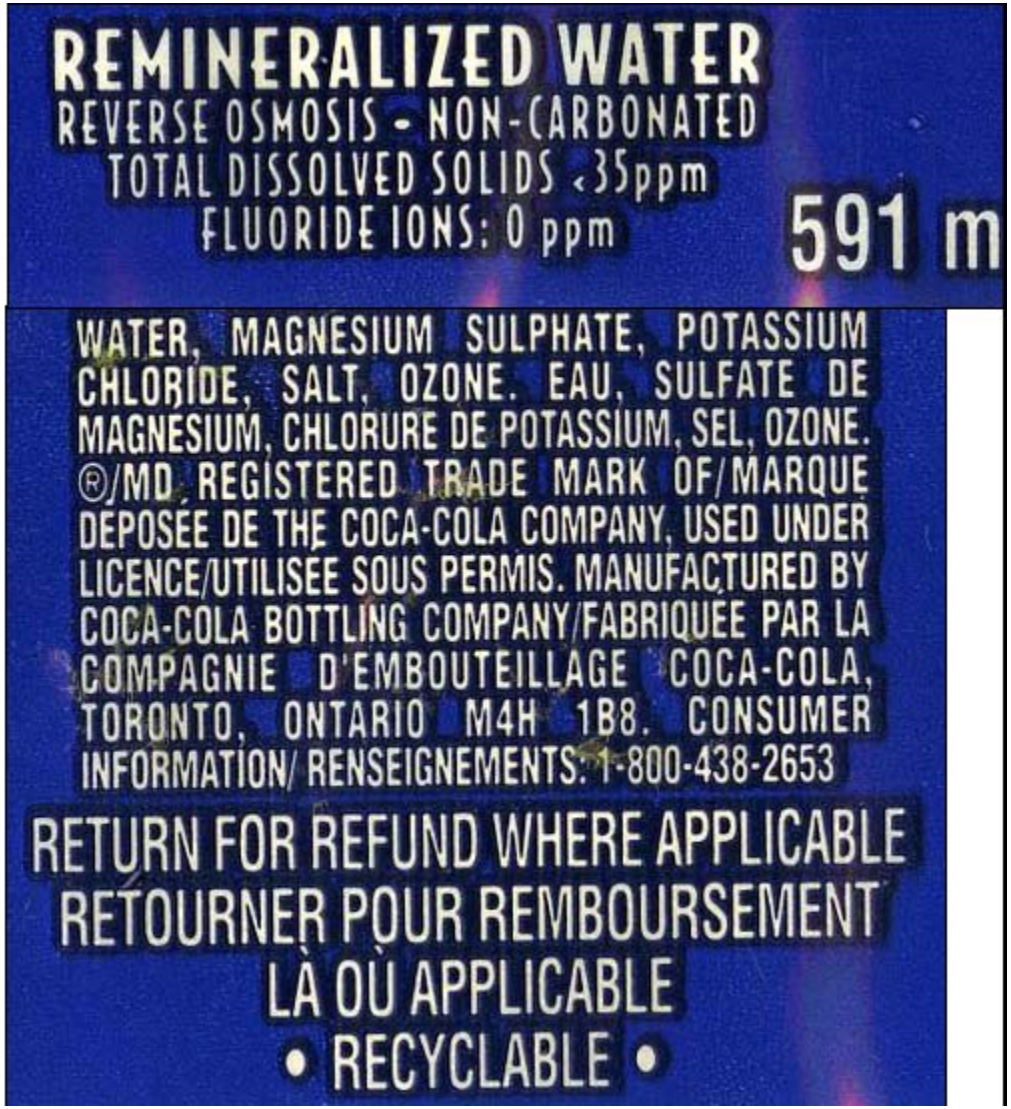
Examples:
Everest Water from Texas
Yosemity Water from LA Municipal Sources
Glacial & Arctic Water from Florida

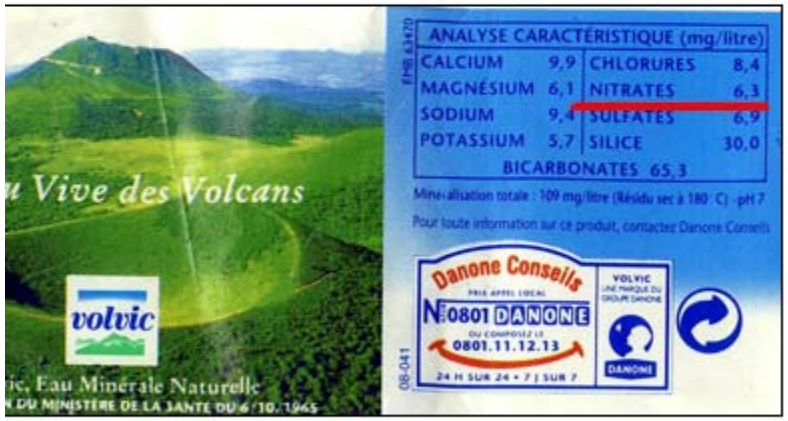


Our spring water is one of the naturally purest spring waters bottled in the world with one of the finest mineral contents. It is bottled at the source in a modern facility and tested continually to prove its purity. Enjoy a refreshing drink of our natural spring water and you will agree...

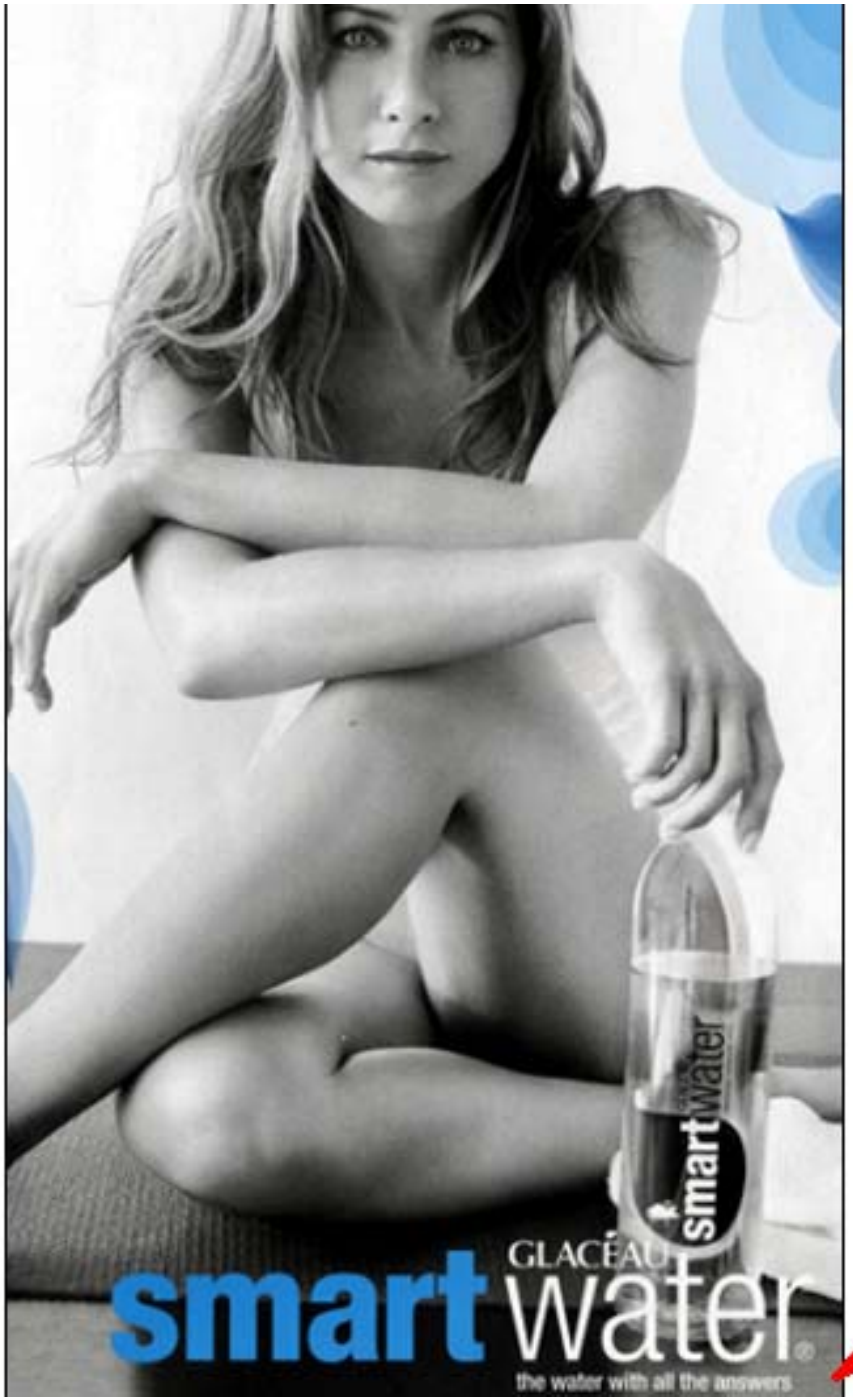
Nutrition Facts
Serving Size 8 fl. oz. (240 ml)
Servings per Container: About 2
Amount Per Serving
Calories **0**
% Daily Value*
Total Fat 0g **0%**
Sodium 0mg **0%**
Total Carbohydrates 0g **0%**
Protein 0g **0%**

Pure Refreshment
DASANI
REMINERALIZED WATER
REVERSE OSMOSIS - NON-CARBONATED
TOTAL DISSOLVED SOLIDS <35ppm
FLUORIDE IONS: 0 ppm
591 mL


REMINERALIZED WATER
REVERSE OSMOSIS - NON-CARBONATED
TOTAL DISSOLVED SOLIDS <35ppm
FLUORIDE IONS: 0 ppm
591 m
WATER, MAGNESIUM SULPHATE, POTASSIUM CHLORIDE, SALT, OZONE. EAU, SULFATE DE MAGNESIUM, CHLORURE DE POTASSIUM, SEL, OZONE.
®/MD REGISTERED TRADE MARK OF/MARQUE DEPOSEE DE THE COCA-COLA COMPANY, USED UNDER LICENCE/UTILISEE SOUS PERMIS. MANUFACTURED BY COCA-COLA BOTTLING COMPANY/FABRIQUEE PAR LA COMPAGNIE D'EMBOUTEILLAGE COCA-COLA, TORONTO, ONTARIO M4H 1B8. CONSUMER INFORMATION/ RENSEIGNEMENTS: 1-800-438-2653
RETURN FOR REFUND WHERE APPLICABLE
RETOURNER POUR REMBOURSEMENT
LÀ OÙ APPLICABLE
• RECYCLABLE •



Nitrate Content:
Pierval: 11mg/L (Hongkong- France)
Volvic: 6.9 mg/L (France)
Vittel: 4.6 mg/L (France)

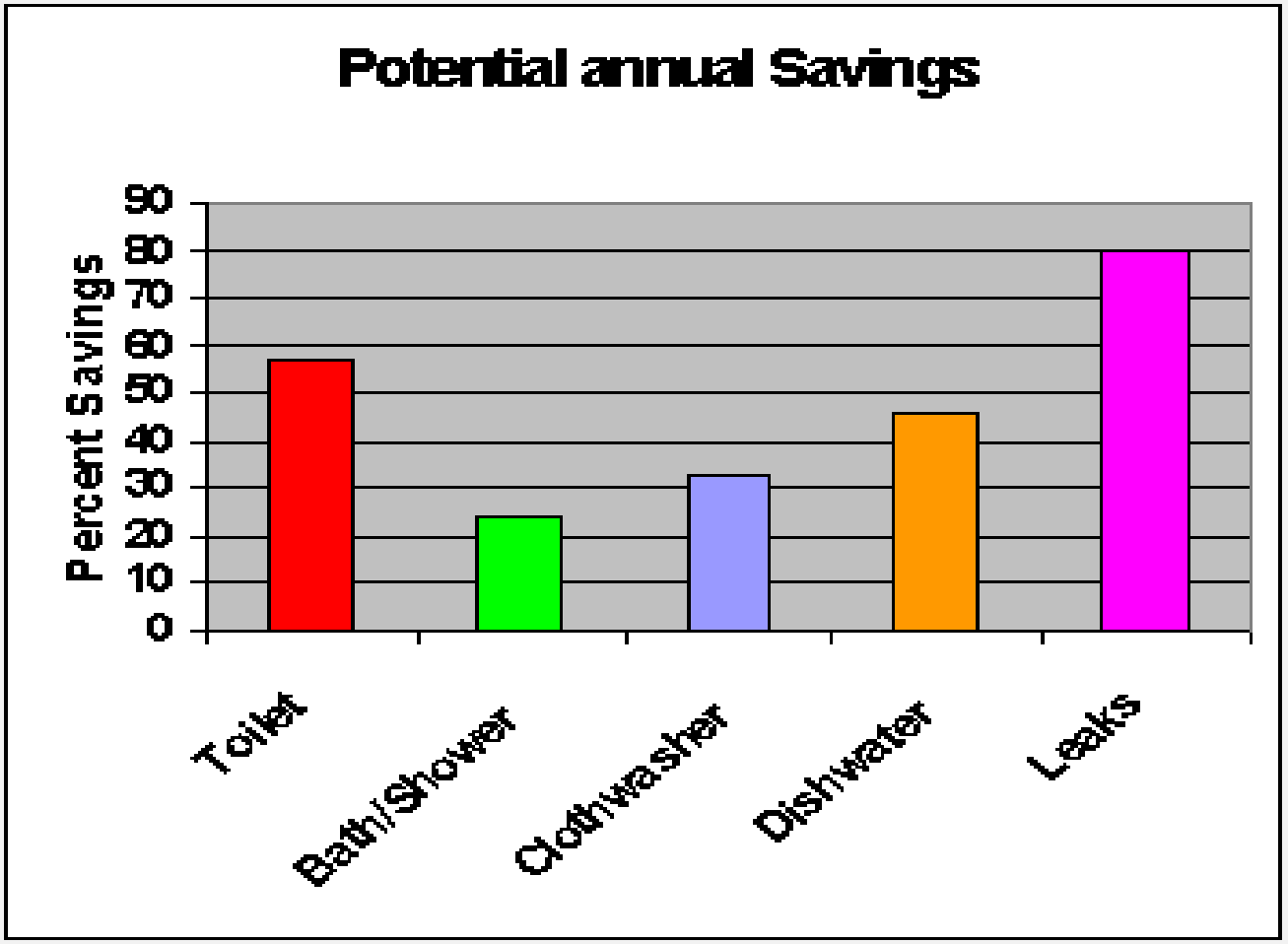


Smart Water

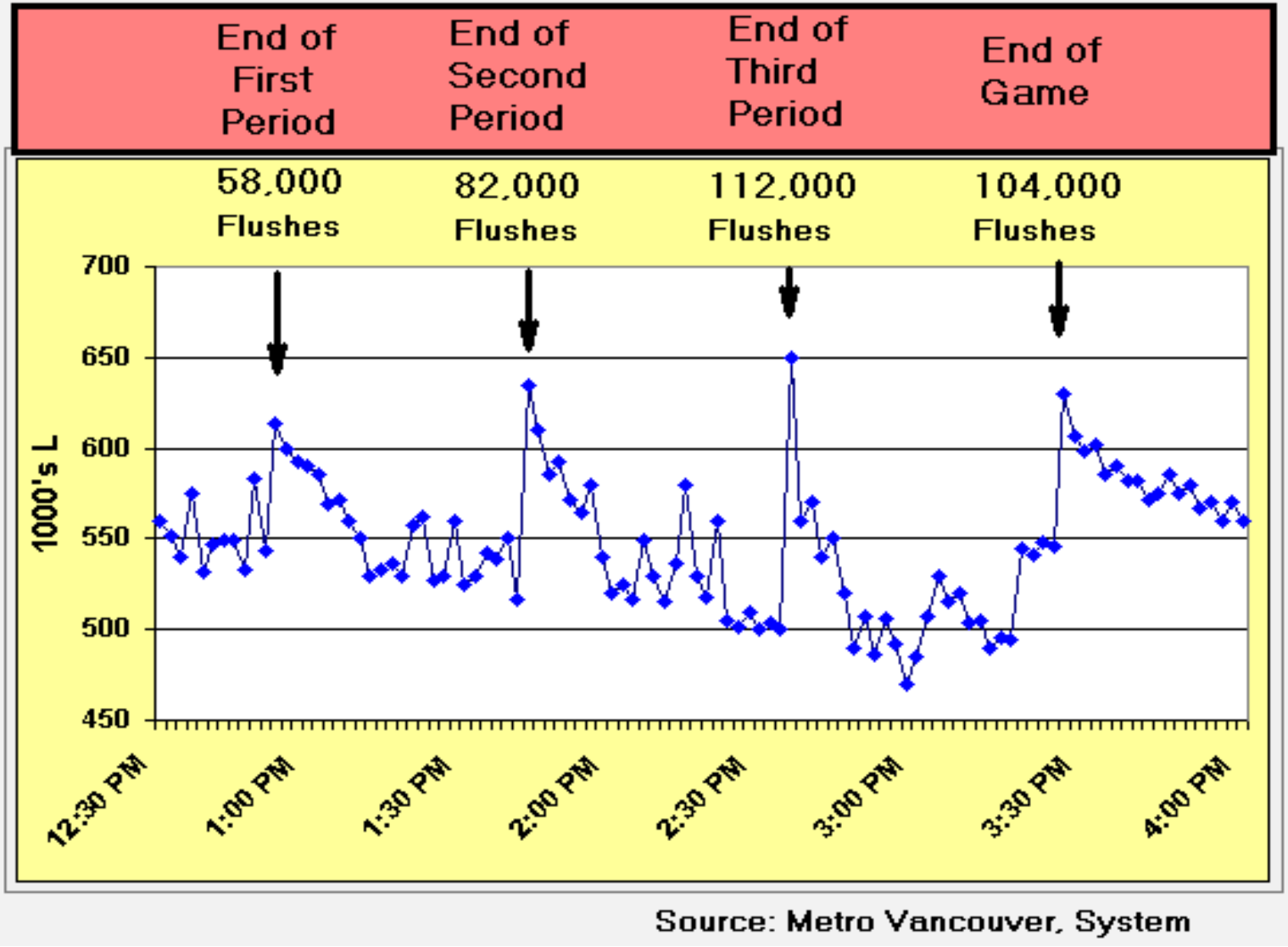
The Water With all the Answers

Domestic Water Use Reduction

Savings in Indoor Water Use



Water Use In Vancouver During the Olympic Gold Metal Ice Hockey Game February 26, 2010

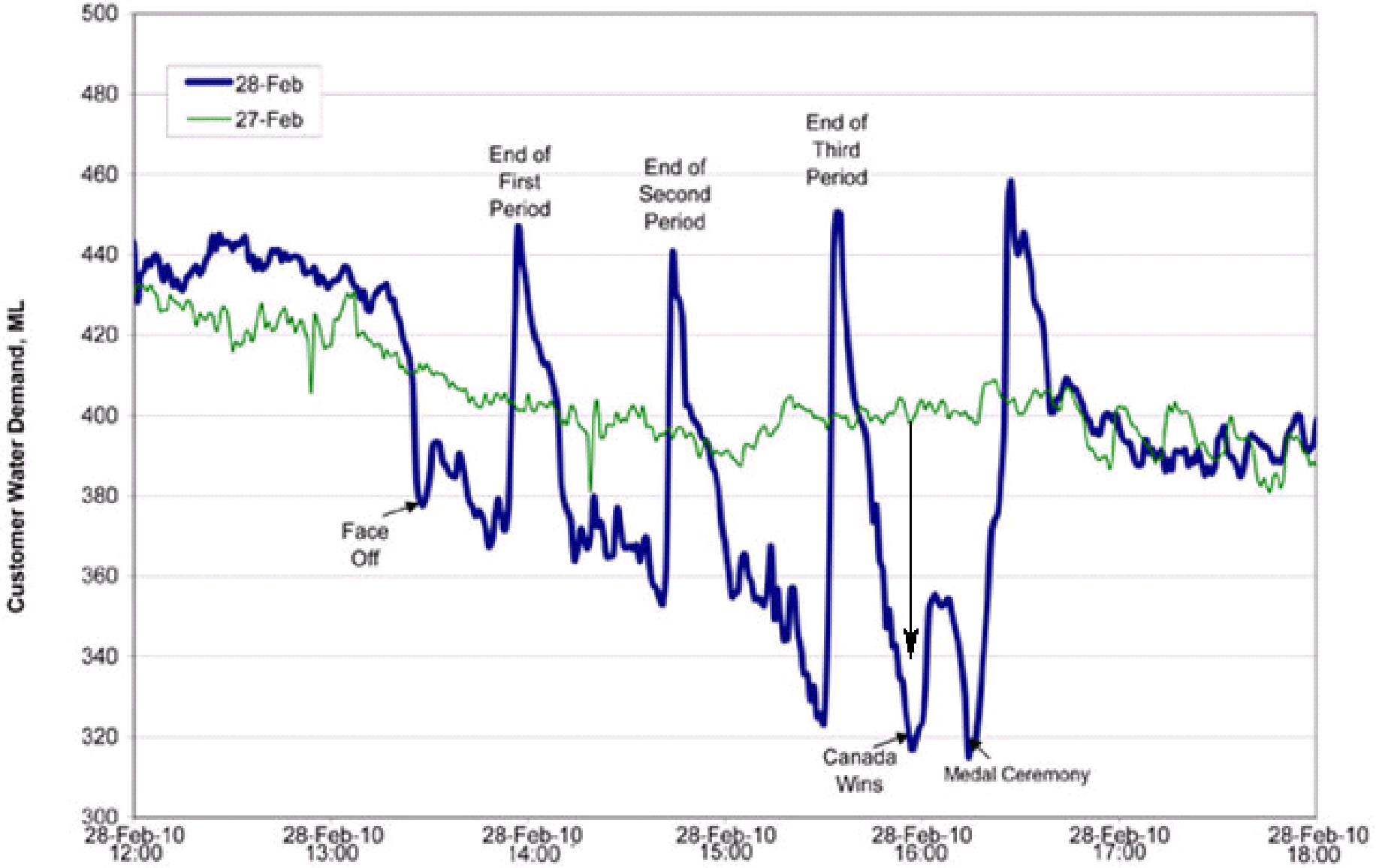


Source: Metro Vancouver, System

Domestic Water Use Reduction

EPCOR

Water Consumption in Edmonton During Olympic Gold Medal Hockey Game



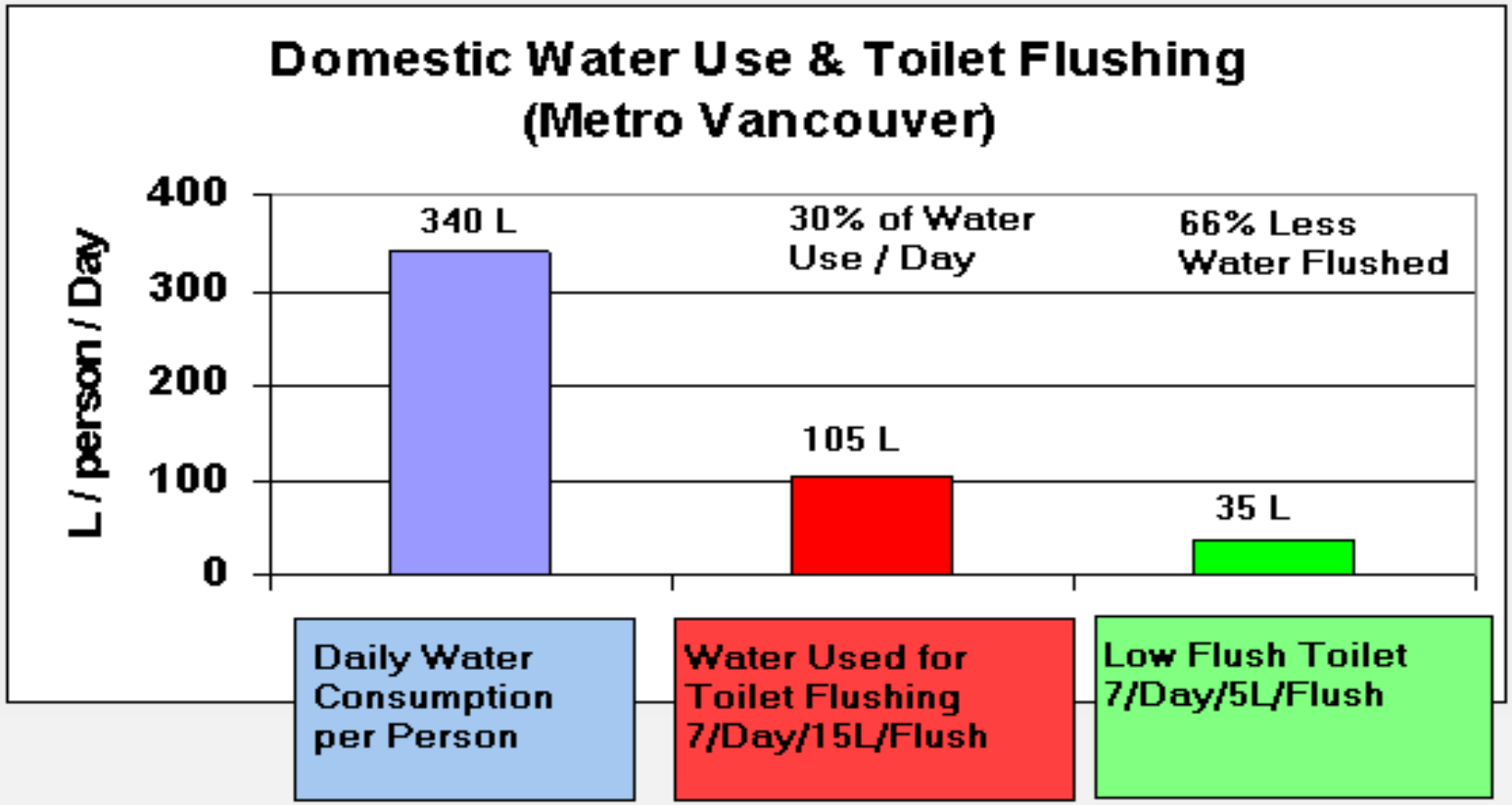
Savings using Low Flush Toilets

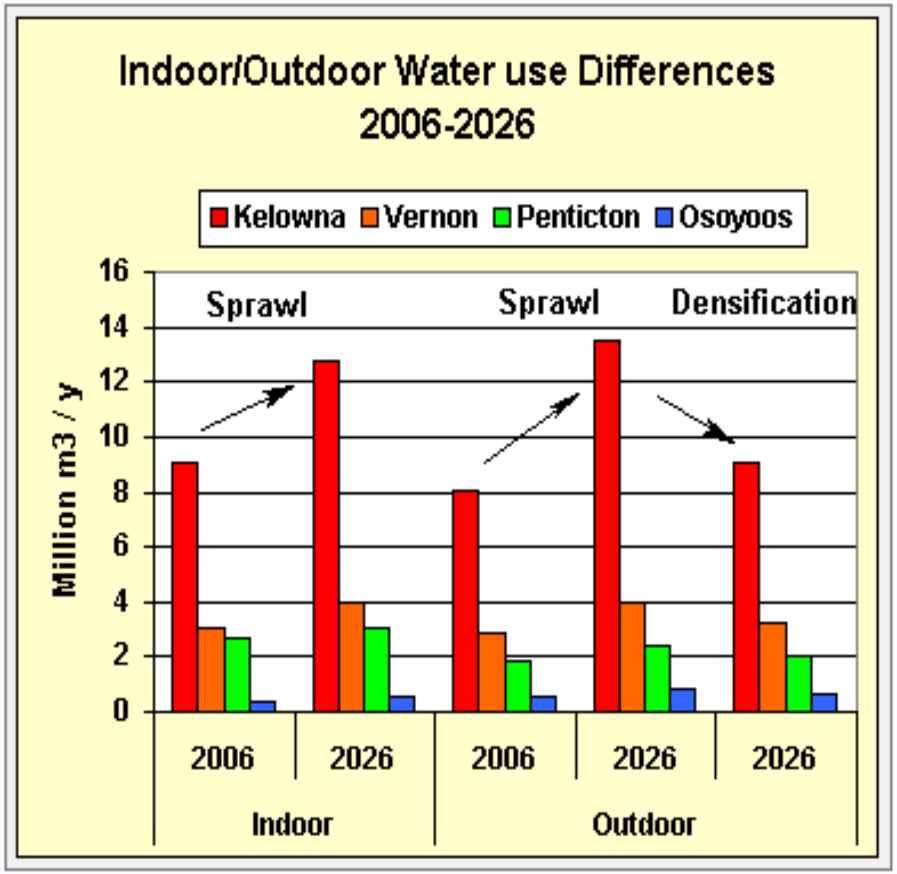
Domestic Water Use Reduction

2.1 Million People in Metro Vancouver

340 L / Day / Person = 714 000 000 L/Day = 714 000 m3 of Water /Day
15 L/Flush, 7 Times/Day = 210 000 m3 of Water /Day

30% OF BACTERIAL FREE DOMESTIC WATER IS USED FOR FLUSHING TOILETS





48% of all Domestic Water Use in the Okanagan is Used for Watering Lawns

Demand Changes If Increased Drought due to Climate Change
Based on Current Wet vs. Dry Years

Towns	Difference between Wet & Dry Years (1973 vs.2003)	
Kelowna	1.36 Million m3/y	19%
Vernon	0.72 Million m3/y	31%
Penticton	0.46 Million m3/y	30%
Osoyoos	0.09 Million m3/y	18%
Total	3.35 Million m3/y	23%

Problems of Soil Management for Lawns in Urban Development

1. First Step: Remove the Topsoil
2. Second Step: Compact the Soils
3. Last Step: Role out the Turf

Minimum soil depth
Poor Infiltration and percolation
Low soil storage capacity

Solution 1:

30 cm Topsoil Requirements can reduce the irrigation requirements by at least 30%

Solution 2:

Xeriscaping can reduce outdoor water consumption by 90%

Outdoor Water Use

Between 30% - 50% of Domestic Water is Used for Watering Lawns

Roofwater Harvesting can reduce this demand by at least 50%

Water Smart Living Target: 33% by 2020

Metering reduces consumption by > 30%
Low Flush Toilets reduces consumption by > 30%
Outdoor Water use reduction > 30%

Projections of Global Water Demand for Industries and Domestic Use

Domestic Water Demand		Industrial Water Demand	
2010	2030	2010	2030
600 Billion m3 →	900 Billion m3	800 Billion m3 →	1500 Billion m3

Municipal Risks

Physical Risks:
Problems with water scarcity
Problems with water quality

Pricing & Conservation Issues:
Pricing, Efficiency, Accounting
Cost

Reputational Risks:
Increased Competition
Social Responsibility
Performance , Efficiency

Business Risks

Physical Risks:
Problems with water scarcity
Problems with water quality

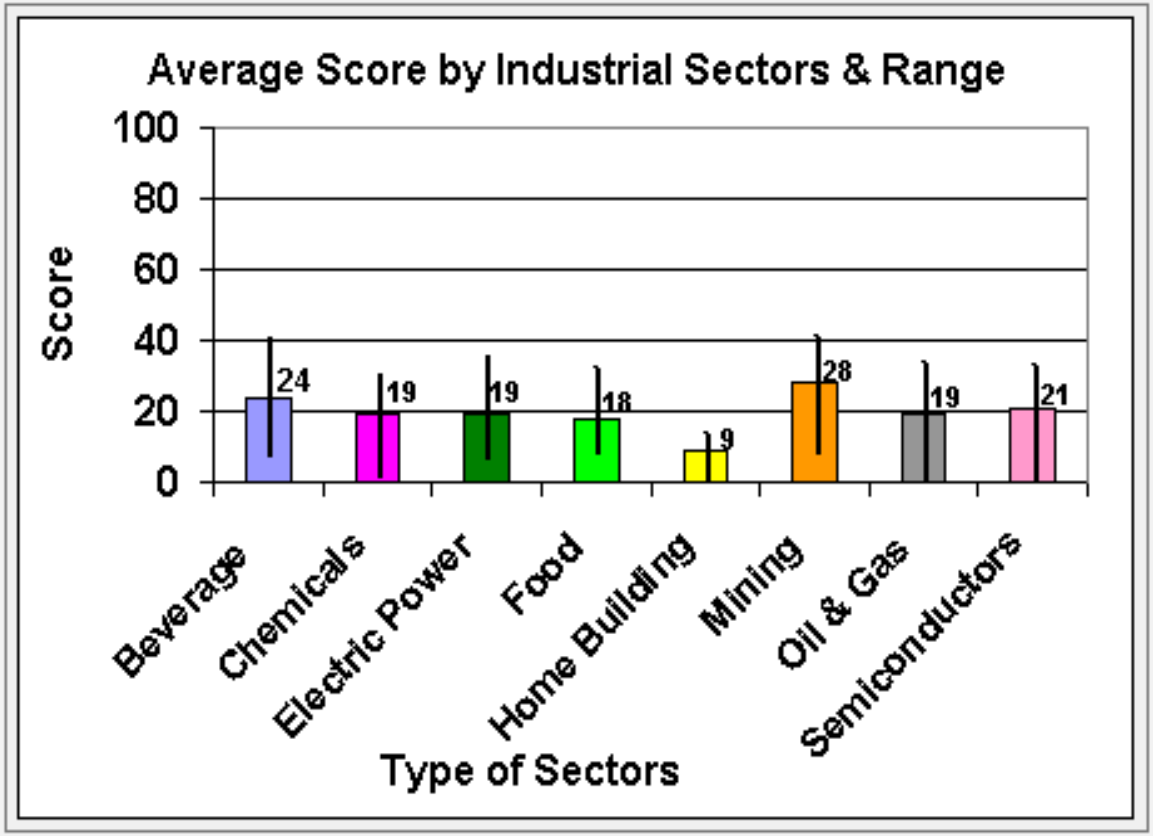
Regulatory Risks:
Changes in National & Global Regulations
Pricing, Efficiency, Pollution
Changes in Standards and Licences

Reputational Risks:
Increased Competition
Social Responsibility
Performance and Public Opinions

Sensitive to Local Supplies

Sensitive to Local & Global Supplies

Water Accounting & Risk Assessment for Different Industries



Source:
Barton, B. 2009 Corporate Reporting on Water Risk. CERES, Feb. 98pp.

Assessment Method for Corporate Water Disclosure

Water Accounting	**36 Points**
Withdrawals/Consumption	
Wastewater Discharge	
Water Footprint of Supply	
Risk Assessment	**24 Points**
Physical & Reputational Risk	
Regulatory & Litigation Risk	
Direct Operations	**27 Points**
Water Policies & Management	
Non-Compliance Info. Waste	
Efforts to Reduce Waste Water	
Targets to Reduce Consumption	
Targets to Reduce Wastewater	
Supply Chain	**7 Points**
Water Risk for Supply	
Track Data on Water for Supplies	
Targets to Reduce Water for Supplies	
Stakeholder Engagement	**6 Points**
Collaboration for Drinking & Waster	
Watershed Management & Restoration	
Impacts on Water for Expansion	
Total Score	**100 Points**

Urban Stormwater Management

Traditional Approach

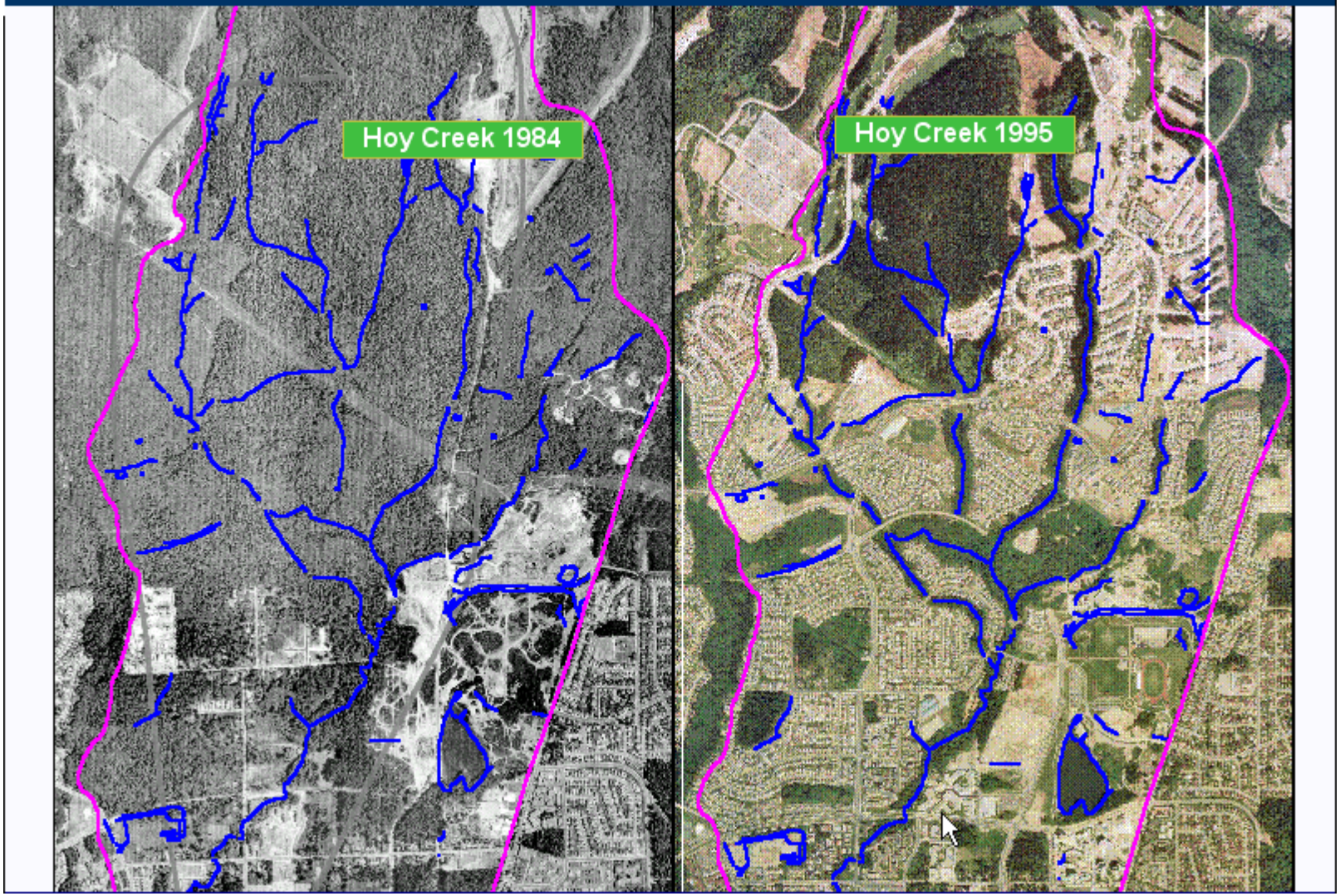
Drain and Remove

Using an Extensive Network of Pipes to Drain Stormwater into Streams

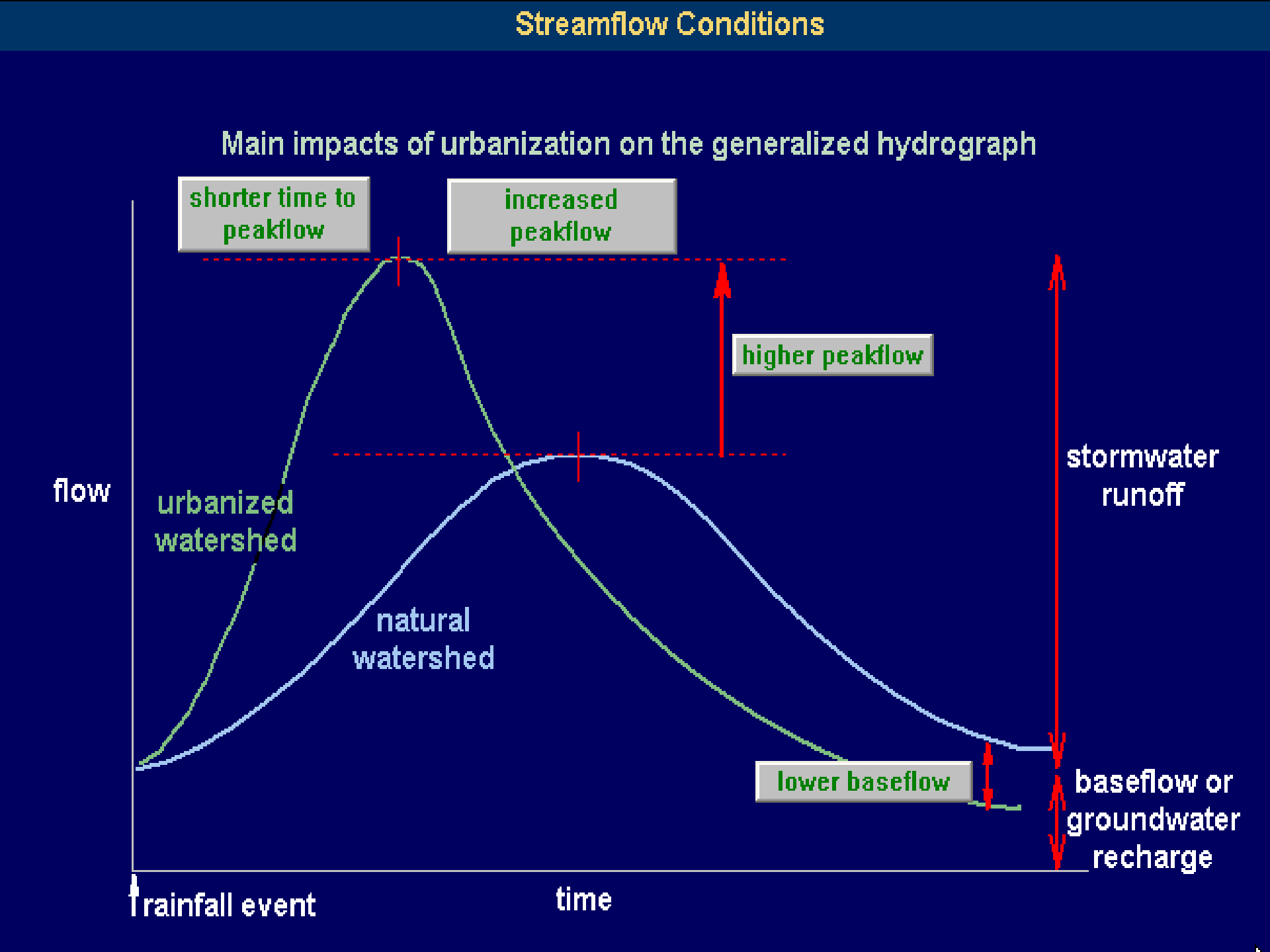
Definition

lawns / open space
roofs
driveways / parking
sidewalks
streets

Imperviousness & Soil Compaction



Streamflow Conditions



Urban Stormwater Management

SCALE	TRADITIONAL APPROACH	INNOVATIVE APPROACH
Site (Property)	Drain & Remove (Piping)	Retain Rain on Site
Neighbourhood (Subdivision)	Drain & Remove (Piping)	Store & Delay Runoff
Watershed	Store Runoff (dams) Channalize Flow Protective Structures	Delay & Reduce Floods, Large Buffer Zones & BMP's

Site or Property	Innovations
Keep Rain on Site Detention & Infiltration Focus on Light Rain	Green Roof Roofwater Harvesting and Re-Use Minimize Impervious Surfaces Pervious Pavement 30 cm Topsoil Requirements Encourage Urban Tree Planting
Neighborhood Scale	**Innovations**
Delay Runoff Detention & Filtration Focus on Heavy Rain	Smaller Roads (no Curbs & Gutters) Swales for Road Runoff Detention Ponds (Wetlands) Pervious Pavement Innovatice Parking Lots
Watershed Scale	**Innovations**
Minimize Floods Detain, Devert and Temporate Storage	Lange Buffer Zones Diversify Stream Channel Pervious Pavement Land Use Zoning Floodplain Management

Site (Property) Scale : Green Roofs

- Green Roofs
- Rain Harvesting
- Imperviousness

Site: Roofwater Harvesting

Tradition

Roofwater into Stormwater Drain

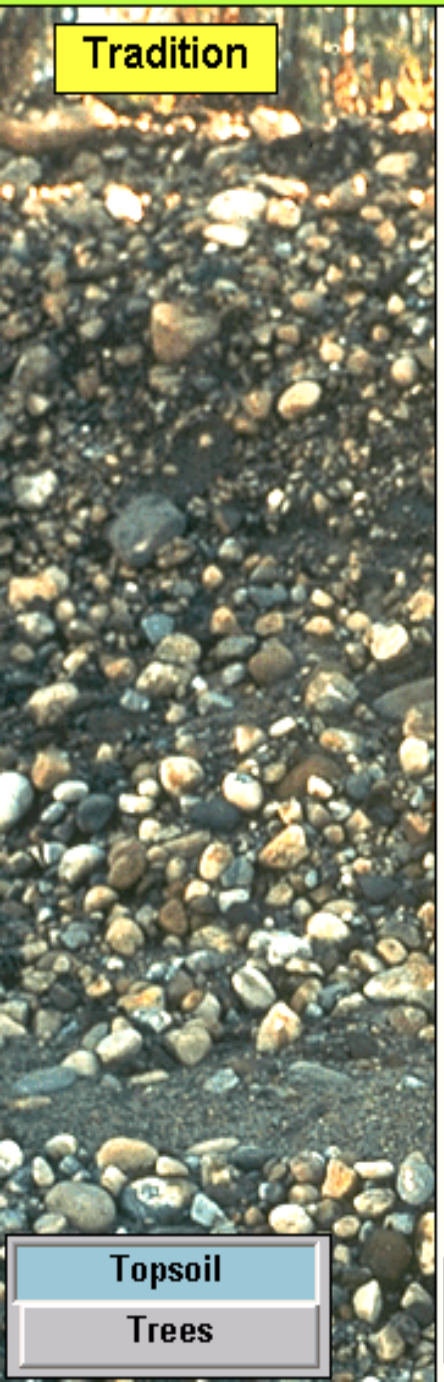
Innovation

- Green Roofs
- Rain Harvesting
- Imperviousness

Site (Property) Scale : Minimizing Imperviousness

Site: Topsoil and Xeriscaping

Tradition



Topsoil

Trees

Add at least 30-50 cm of top soil before adding turf

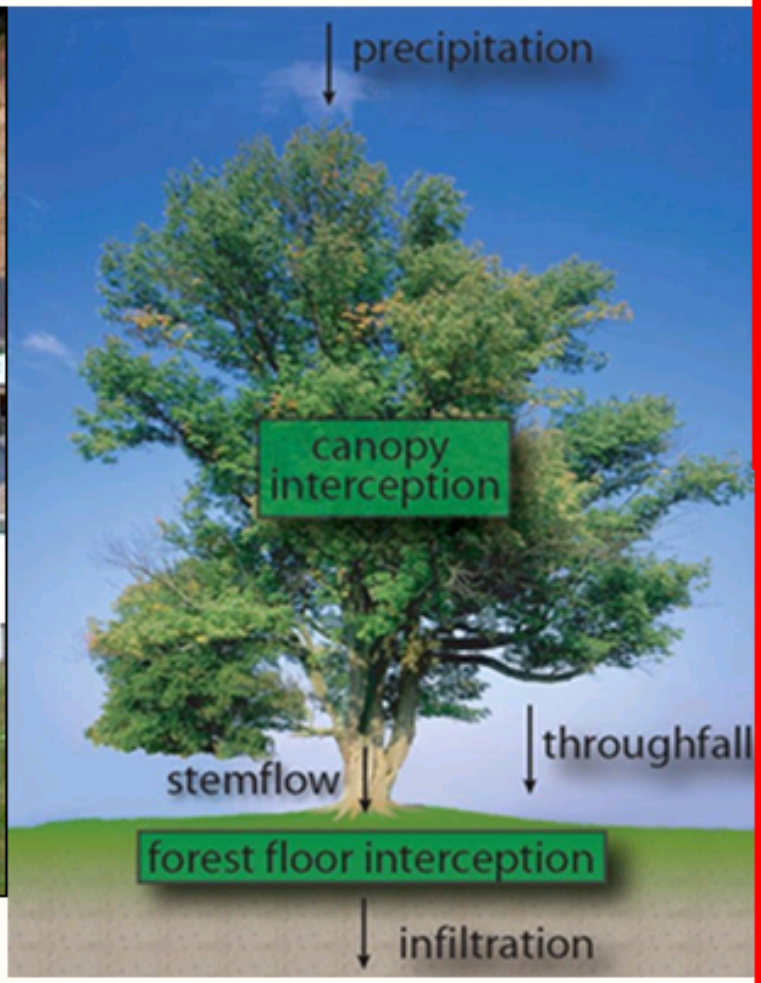
It reduces irrigation needs by 30-40%

Innovation

Xeriscaping

The use of Urban Trees for Stormwater Management

Tradition



Topsoil

Trees

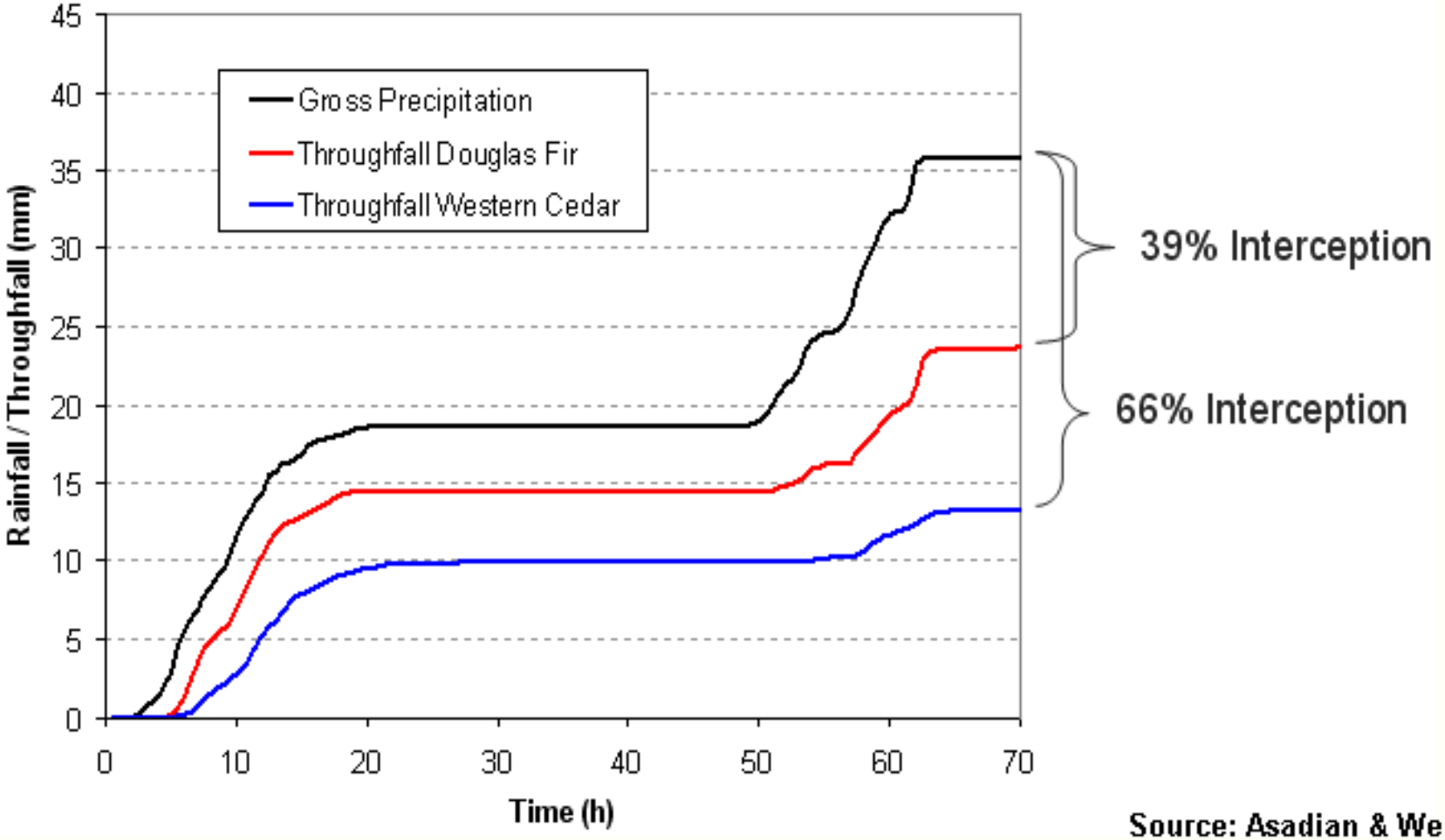
Innovation

Traditions
Innovations

Results from Urban Tree Interception Study

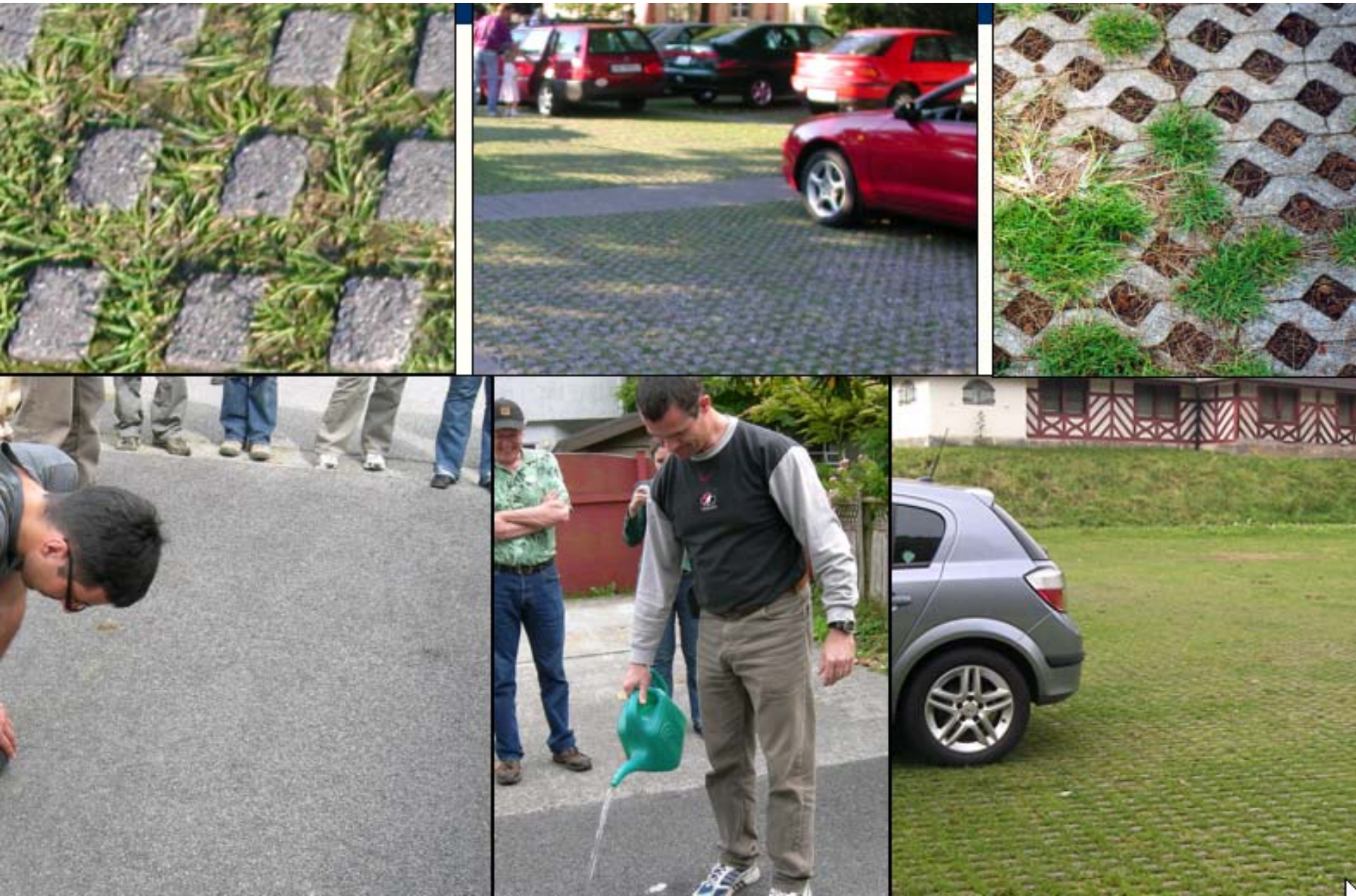
Data Analysis - Total interception

Example: 4 March 2007



Source: Asadian & Weiler 2009

Pervious Pavement



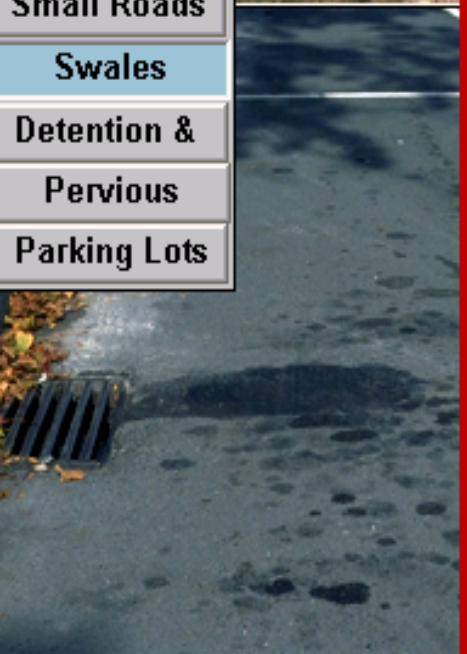
Neighborhood: Small Roads (no Curbs or Gutters)

- Small Roads
- Swales
- Detention &
- Pervious
- Parking Lots

Neighborhood Scale : Swales

Tradition

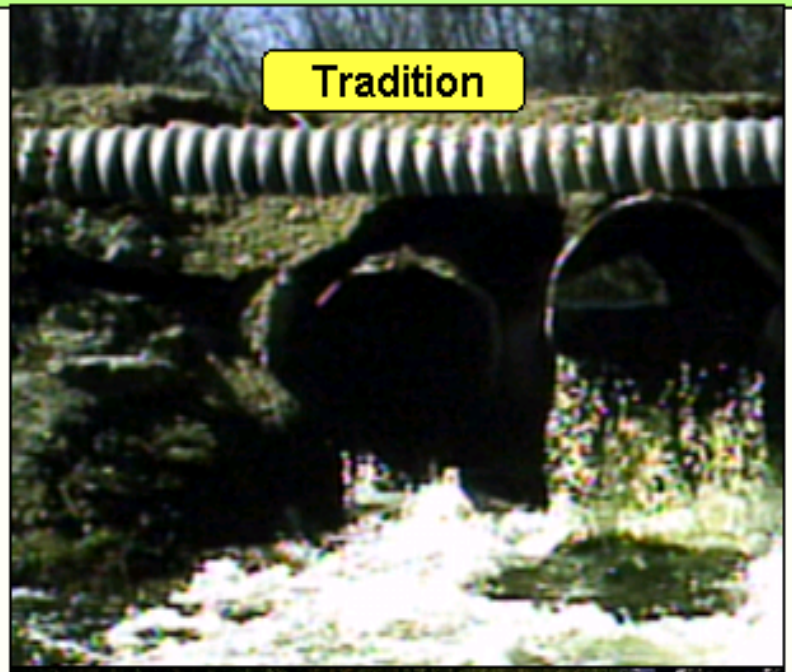
Innovation

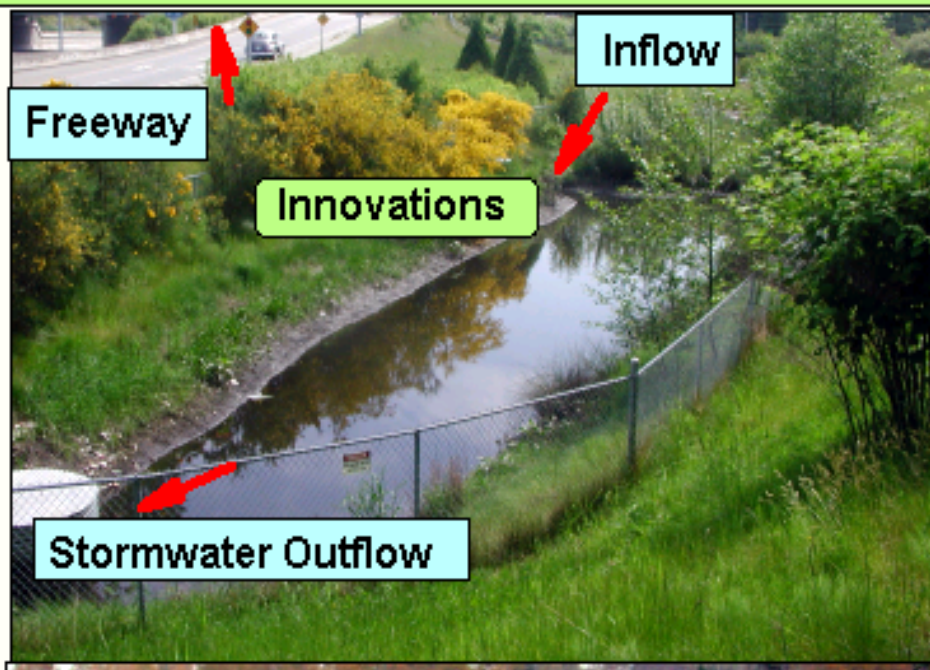


- Small Roads
- Swales
- Detention &
- Pervious
- Parking Lots

Source: Kerr Wood Lidal 2007

Neighborhoods : Detention Ponds and Wetlands





- Small Roads
- Swales
- Detention &
- Pervious
- Parking Lots

Neighbourhoods: Pervious Parking Lots

Tradition

Innovation

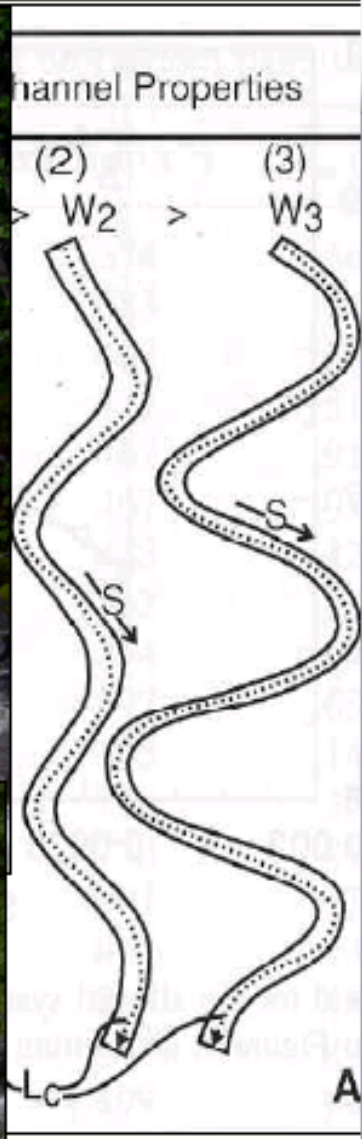
- Small Roads
- Swales
- Detention &
- Pervious
- Parking Lots

Neighborhoods: Innovative Parking Lots

Watersheds: Artificial Channels vs Diversified Channels

Tradition

Innovations



- Buffers
- Channels
- Pervious
- Zoning
- Floodplain

Watersheds: Riparian Buffer Zone

Watersheds: Floodplain

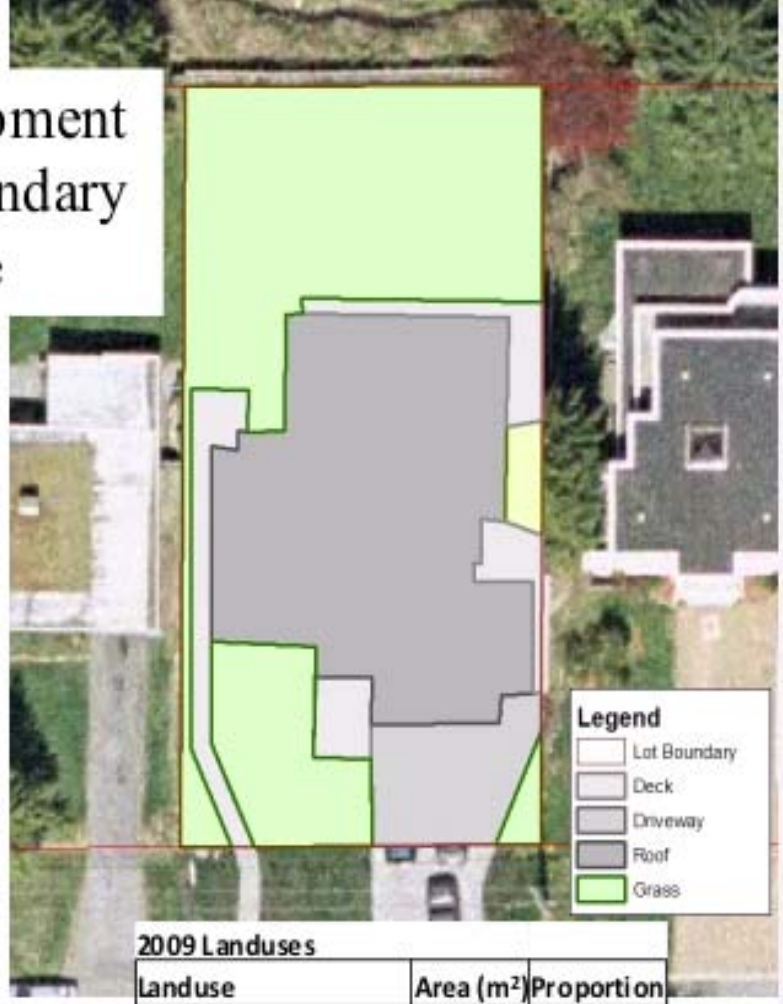
Change

EIA

Hydrology

Redevelopment : Addition of Suite

Redevelopment with Secondary Suite



2007 Landuses

Landuse	Area (m^2)	Proportion
Driveway	47	6%
Roof	270	35%
Grass	420	54%
Tree Canopy	44	6%
Impervious	317	41%
Pervious	464	59%

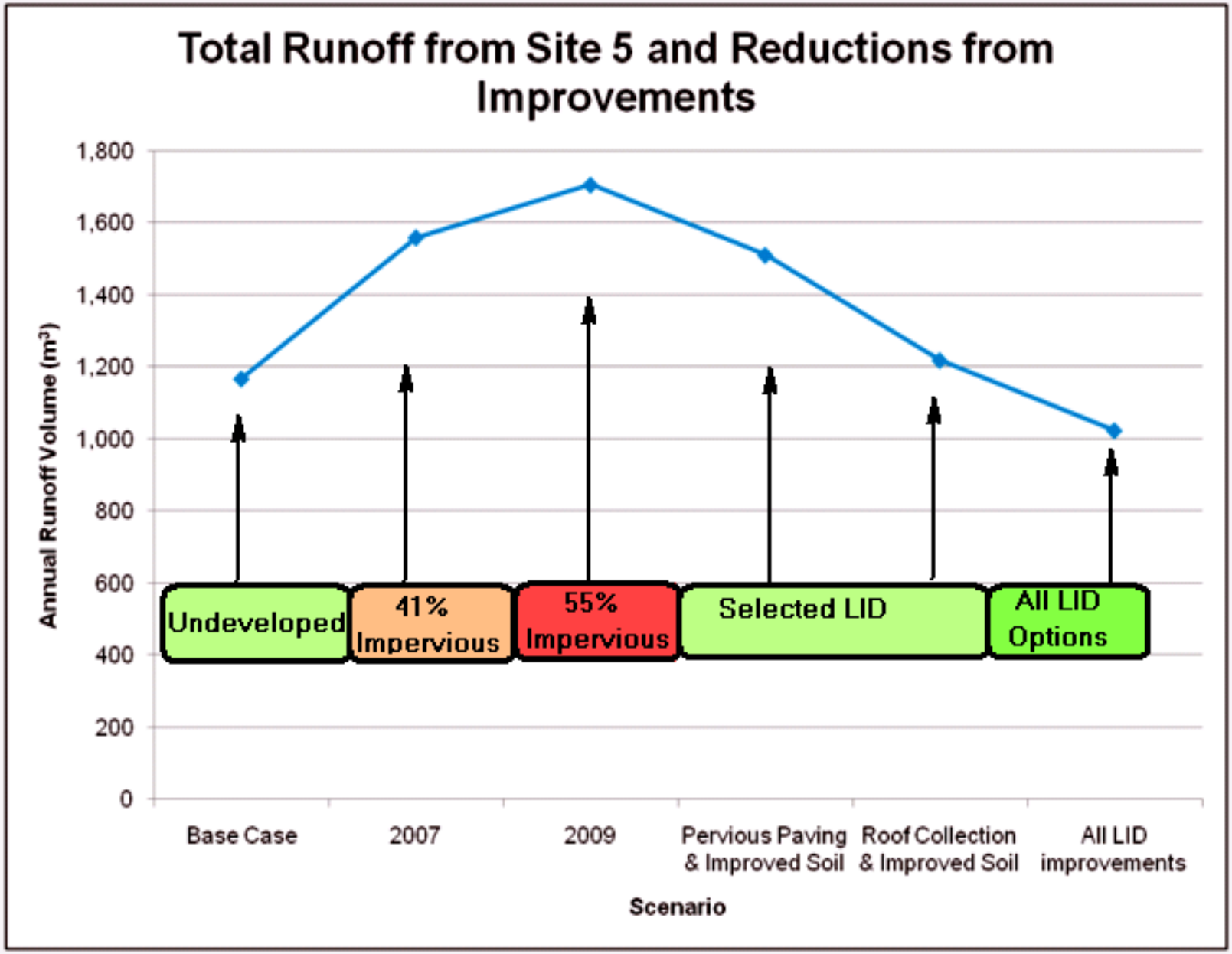
2009 Landuses

Landuse	Area (m^2)	Proportion
Driveway	55	7%
Roof	291	37%
Deck	80	10%
Grass	344	44%
Tree Canopy	11	1%
Impervious	426	55%
Pervious	355	45%

Change
EIA
Hydrology

2007
Imperviousness 41%

2009
Imperviousness 55%



Change

EIA

Hydrology

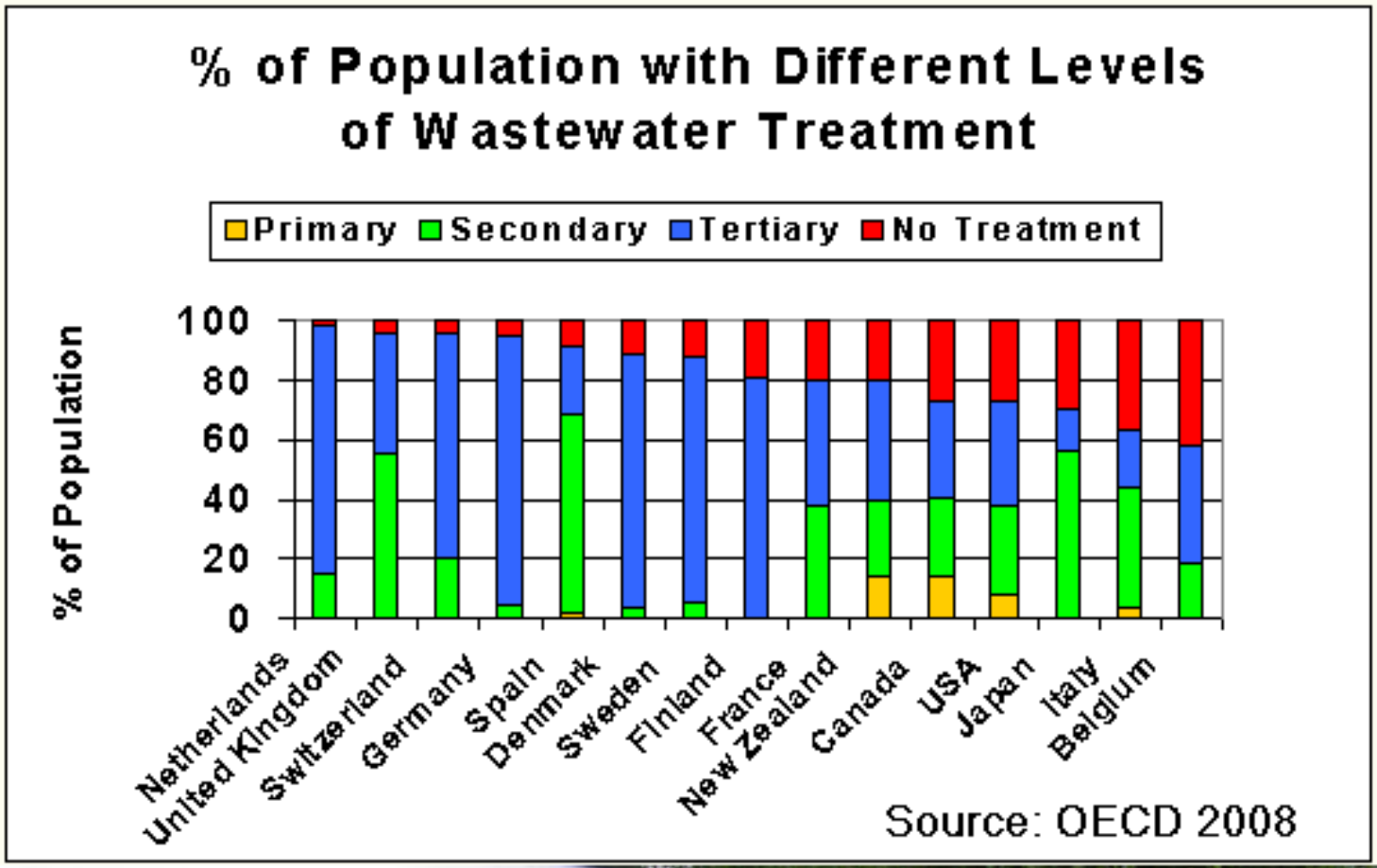
If the same redevelopment trend continues than 10% of exisiting Lots will be redeveloped in 20 Years

Average EIA / Lot has increased by 25% in 10 Years
300 Redevelopments (averaging 700 m2 in Area = 52500 m2 of EIA)
Results: A 10% increase of rainfall that ends up as Runoff

Result: 105,000 m3 of Additional Runoff

Wastewater

BLUE WATER	Rainfall that ends up into lakes, rivers & groundwater
GREEN WATER	Rain interception in soils & plants and evapotransired
WHITE WATER	Water evaporated leaving the watershed (non-productive)
GREY WATER	Wastewater, polluted but usuable for certain purposes
BLACK WATER	Wastewater, heaily polluted, not economically unusable


% of Population with Different Levels of Wastewater Treatment
Primary
Secondary
Tertiary
No Treatment
% of Population
100
80
60
40
20
0
Netherlands
United Kingdom
Switzerland
Germany
Spain
Denmark
Sweden
Finland
France
New Zealand
Canada
USA
Japan
Italy
Belgium
Source: OECD 2008

#1 in the #2 Business
ACE

What does this traffic sign indicate ???

If the water rises, run away !!

You are warned not to stay on the river bed ! The hydroelectric plants may cause a sudden flooding anytime, even in good weather !

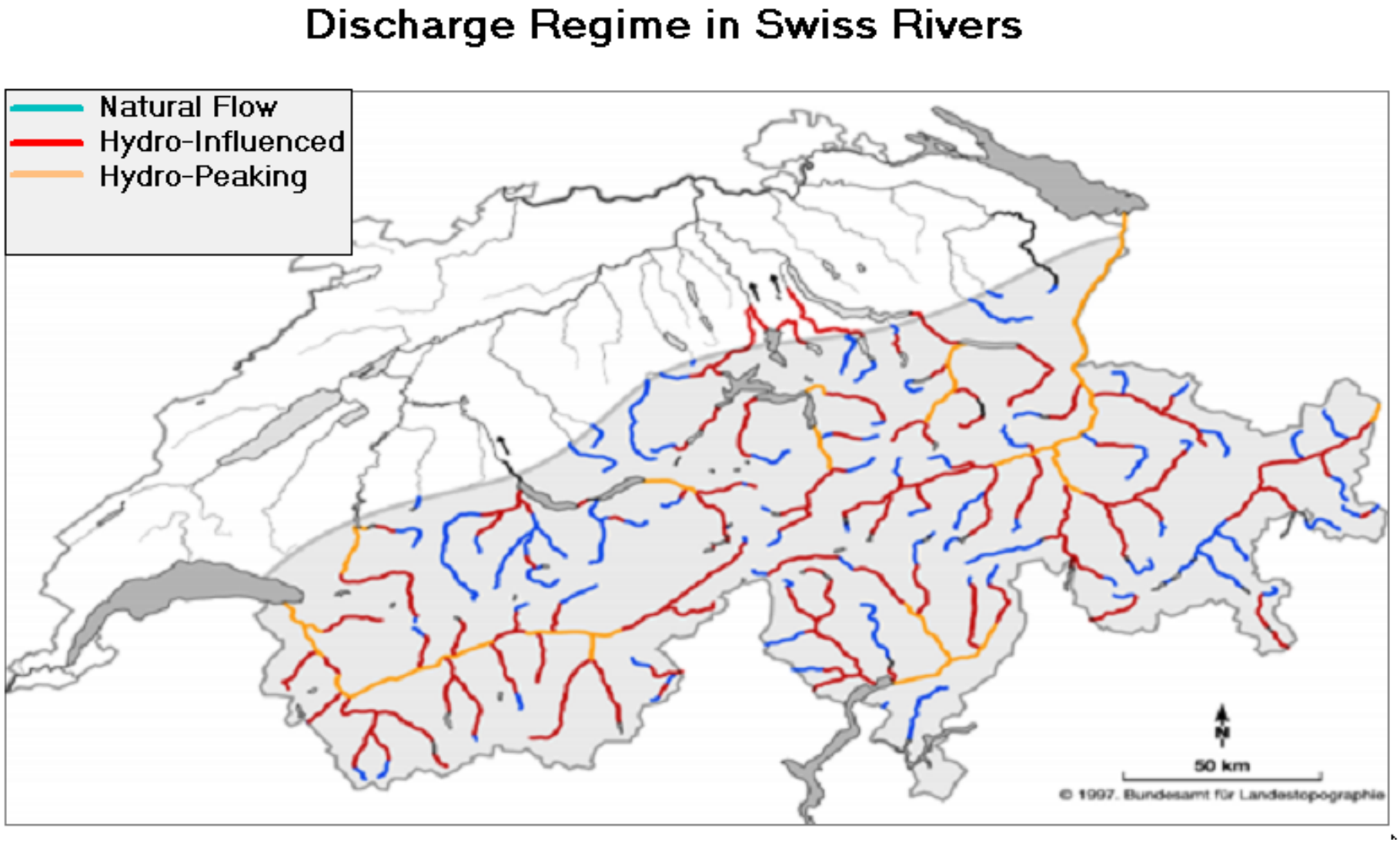
exz. officine idroelettriche della Bregaglia

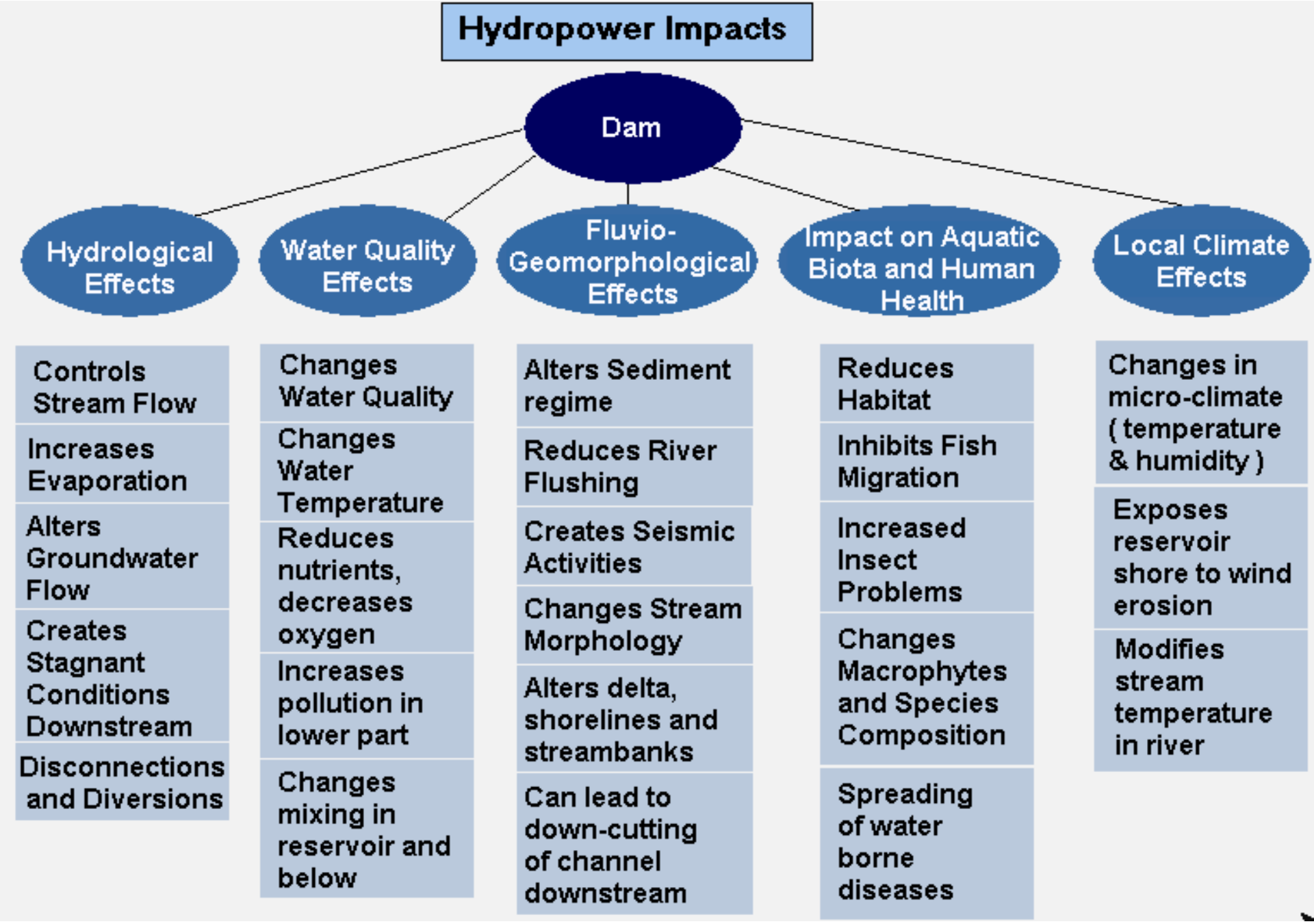
This reservoir and hydropower station only operates to produce peak power for Europe

An ON-Demand Power Station
6:00 -10:00 and
17:00 - 21:00 or whenever the demand for power increases

During 1 - 4 am they buy power from Nuclear plants to pump used water back into the reservoir.

Changes in River discharge because of different hydropower operations




Hydropower Impacts
Dam
Hydrological Effects
Water Quality Effects
Fluvio-Geomorphological Effects
Impact on Aquatic Biota and Human Health
Local Climate Effects
Controls Stream Flow
Increases Evaporation
Alters Groundwater Flow
Creates Stagnant Conditions Downstream
Disconnections and Diversions
Changes Water Quality
Changes Water Temperature
Reduces nutrients, decreases oxygen
Increases pollution in lower part
Changes mixing in reservoir and below
Alters Sediment regime
Reduces River Flushing
Creates Seismic Activities
Changes Stream Morphology
Alters delta, shorelines and streambanks
Can lead to down-cutting of channel downstream
Reduces Habitat
Inhibits Fish Migration
Increased Insect Problems
Changes Macrophytes and Species Composition
Spreading of water borne diseases
Changes in micro-climate (temperature & humidity)
Exposes reservoir shore to wind erosion
Modifies stream temperature in river

EXAMPLES OF INTERACTIONS BETWEEN CLIMATE CHANGE AND LAND USE (CUMULATIVE EFFECTS)

CLIMATE CHANGE		LAND USE CHANGE		CUMULATIVE EFFECTS
INCREASING HIGH STORM AND RAINFALL EVENTS	+	SOIL COMPACTION & IMPERVIOUSNESS	=	INCREASED PEAKFLOW INCREASED FLOODING
INCREASED TEMP. EARLIER SNOWMELT	+	CONVERSION OF FOREST INTO GRASSLAND	=	EARLIER SNOWMELT HIGHER PEAKS, LOWER BASEFLOW
HIGHER TEMPERATURES	+	INCREASED DEMAND FOR WATER (AGRICULTURE & URBAN)	=	DROUGHTS & WATER SHORTAGES LESS WATER FOR ENVIRONMENTAL SERVICES (ES)
HIGHER TEMPERATURES	+	MONO-CULTURE FOREST	=	MORE DISEASE & FIRES
HIGHER TEMPERATURES & GLACIAL MELT	+	INCREASED WATER DEMAND FOR TOURISM	=	MORE DROUGHTS & ES.
INCREASED MELTING OF PERMAFROST	+	MORE LAND DISTURBANCE BY TOURISM	=	MORE SEDIMENTS HAZARDS, ACCIDENTS

Summary: Managing Water at the Municipal Level

WATER CONSERVATION

1. WATER METERS
2. VOLUME BASED PRICING
3. LOW FLUSH TOILETS
4. LEBELLING WATER USE ON APPLIANCES
5. OUTDOOR WATER USE REDUCTION
6. RAINWATER HARVESTING
7. 30 CM OF TOPSOIL BEFORE PLANTING GRASS
8. XERISCAPING (REDUCING SIZE OF LAWN)

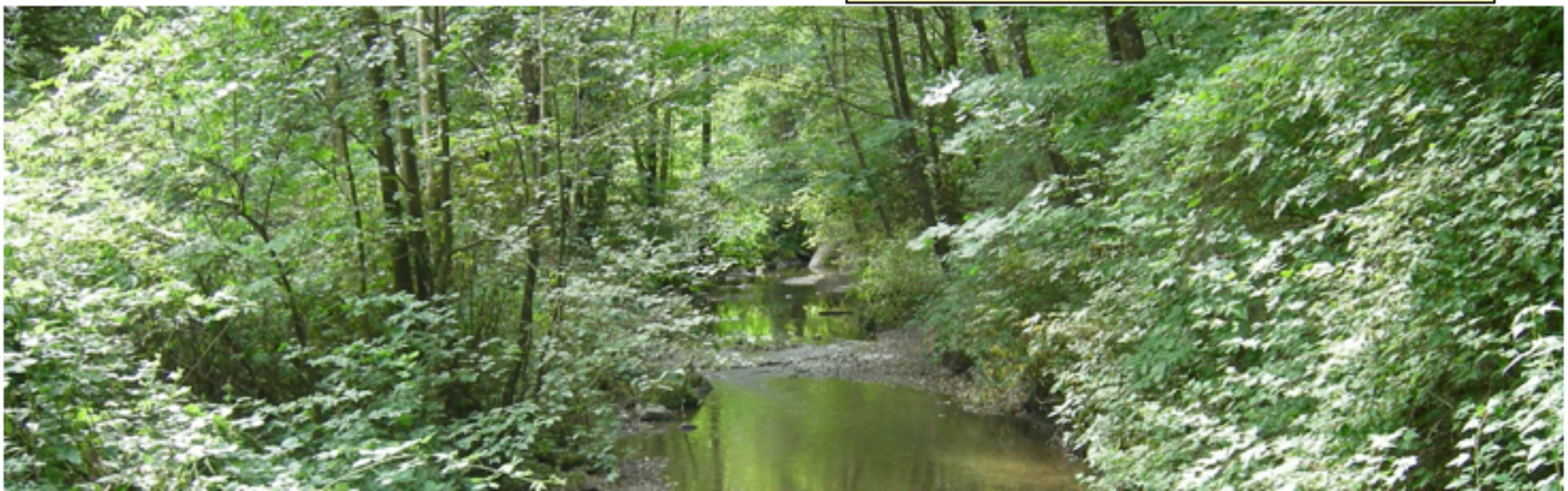
SOURCE WATER PROTECTION

SURFACE WATER

1. SOURCE CONTROL
2. LAND USE CONTROL (ZONING)
3. BUFFER ZONES
4. WETLANDS
5. BENEFICIAL MANAGEMENT PRACTICES

GROUNDWATER

1. CONFINED vs. UNCONFINED
2. VULNERABILITY ASSESSMENT
3. LAND USE CONTROL OVER CAPTURE ZONE
5. SOURCE CONTROL



Summary: Managing Water at the Corperate Level

ACCOUNTING FOR WATER USE

1. LOCAL WATER ACCOUNTING
2. BLUE & GREEN WATER ACCOUNTING
3. WATER ACCOUNTING IN SUPPLY CHAIN
4. LEBELLING WATER USE ON APPLIANCES
5. INITIATING CONSERVATION METHODS
6. CONSIDERING GLOBAL WATER
7. USING LOCAL AND SUPPLY CHAIN WATER SUPPLIES IN A SUSTAINABLE MANNER

ACCOUNTING FOR WASTEWATER

1. DETERMINING THE WASTEWATER LOAD
2. IDENTIFYING APPROPRIATE TREATMENT
3. SOURCE CONTROL (LIMIT WASTE INPUT)
4. GREY WATER REUSE
5. ACCOUNTING FOR WASTE IN SUPPLY AND DISTRIBUTION CHAIN
6. CONTINGENCY MEASURES FOR SPILLS AND ACCIDENTS RELATED TO WASTEWATER

DEVELOP A CLIMATE CHANGE ADAPTATION STRATEGY TO REDUCE RISKS

Summary: Managing Urban Stormwater

Detention, Infiltation, Temporary Storage

Property Scale

1. RAIN INTERCEPTION BY TREES
2. GREEN ROOFS
3. ROOFWATER COLLECTION
4. SOIL IMPROVEMENT (Infiltration)
5. RAIN-GARDENS
6. REDUCING IMPERVIOUS SURFACES
7. PERVIOUS PAVEMENT

Neigbourhood Scale

1. NO CURBS & GUTTERS
2. SMALLER ROADS WITH SWALES
3. DETENTION PONDS
4. WETLANDS
5. PERVIOUS PARKING LOTS
6. SWALES IN PARKING LOTS
7. INFILTRATION SYSTEMS

Watershed Scale

1. LARGE BUFFER-ZAONES
2. NATURAL CHANNELS
3. FLOOD ZONING
4. DESIGNATE AREAS FOR FLOOD STORAGE
5. WETLANDS FOR STORAGE AND TREATMENT
6. REDUCE IMPERVIOUS