The Hydrosphere:

Lecture 12: Water Resources Management

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THE BLUE PLANET

Over two-third of the earth surface is covered by water...

http://www.eco-pros.com/blueplanet.htm

WATER AND LIFE

Water is essential for life:

- ✓ *cells are made of water*
- ✓ *living organisms contain a lot of water (humans 65%, plants 90%, microbes 85%)*
- ✓ *water is a universal solvent (carrier of nutrients)*
- ✓ *water allows for biochemical reactions*
- ✓ *thermal regulation (change of phase)*

Global Water Balance

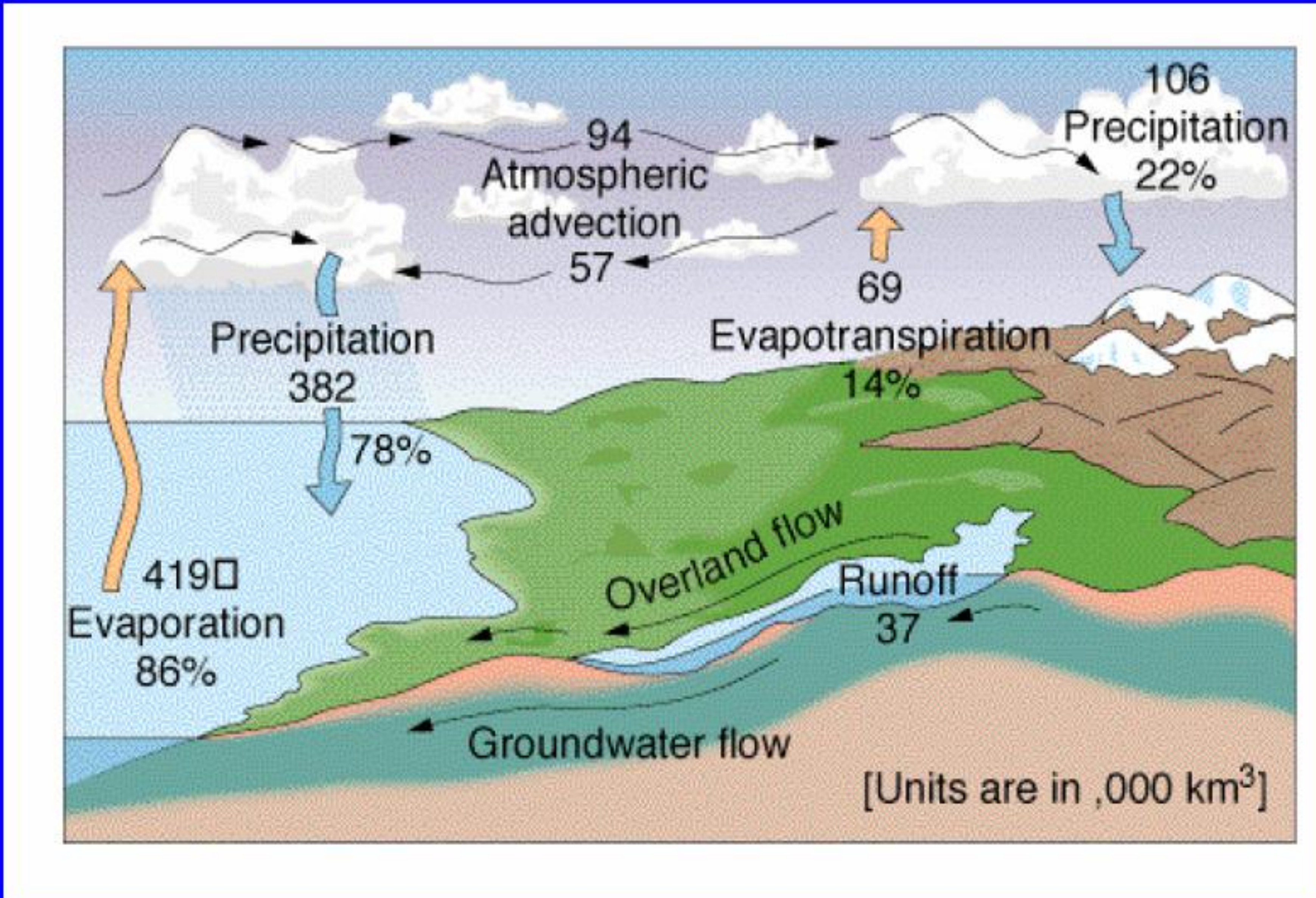
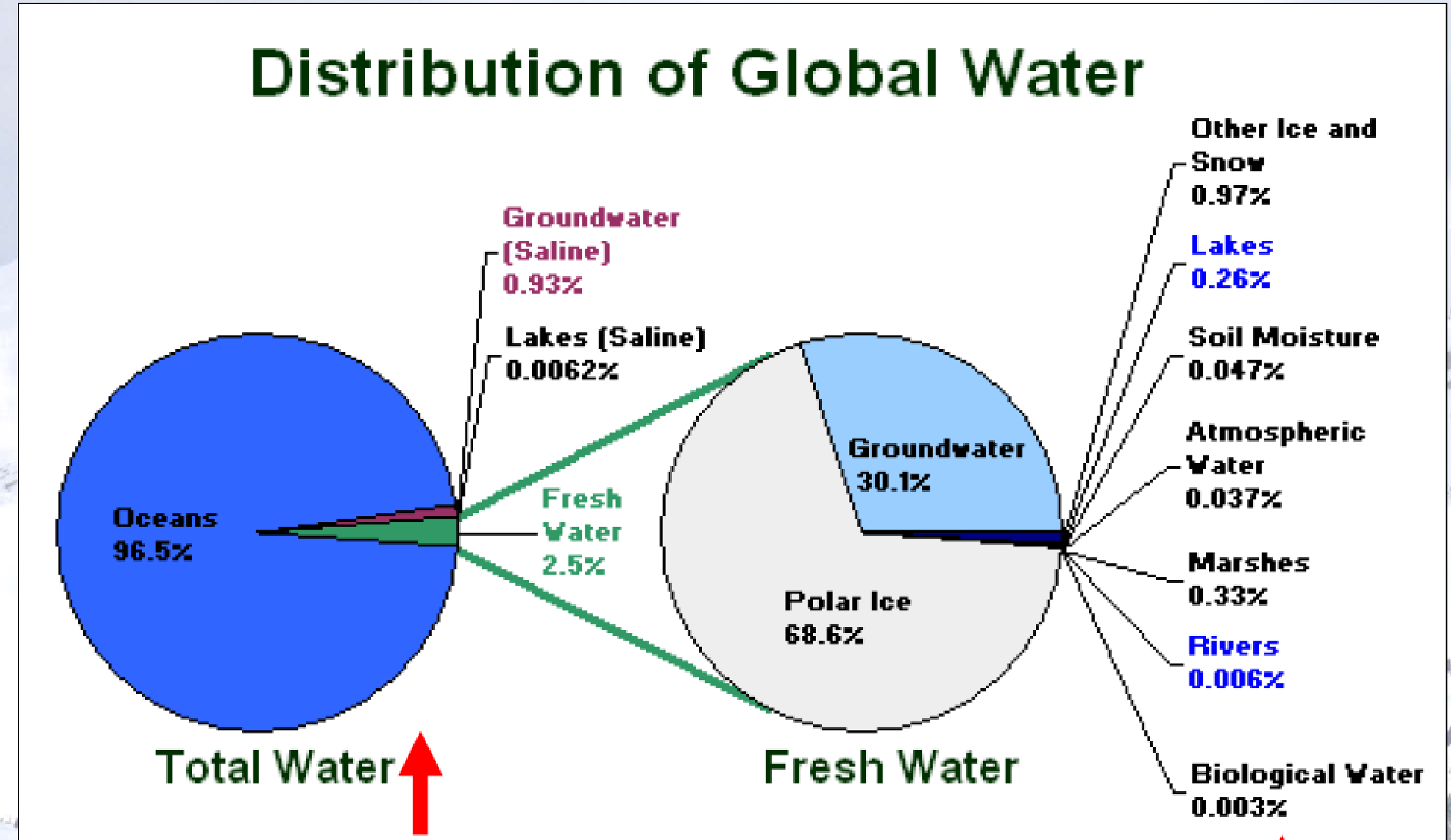


Fig. 9.2 Christopherson

WATER DISTRIBUTION



- ✓ *WATER is mainy stored in the oceans*
- ✓ *Surface fresh waters (accessible to humans) are less than 1% of the overall fresh water, and less than 0.025% of the total water*

Uses of the hydrologic cycle (HC)

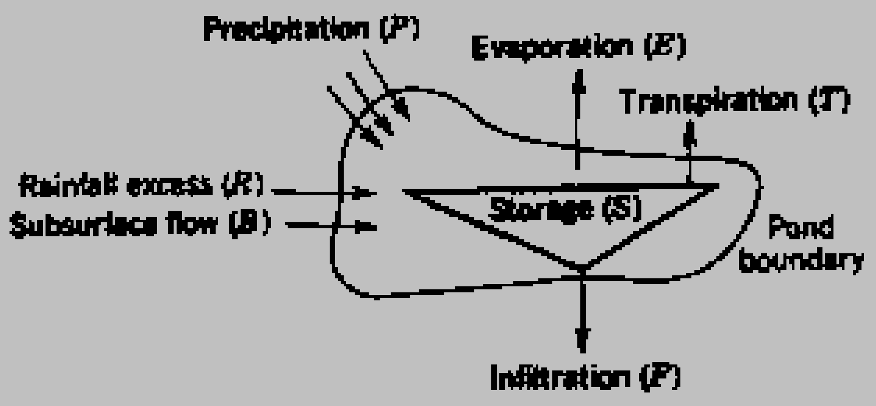


FIGURE 1.3 Schematic of hydrologic cycle.

- One of the uses of the HC is in the estimation of surface storage.
- Storing and transferring a sufficient quantity of water has been one of the major problems.
  - What volume of water is stored in a surface reservoir/soil and how does the volume change over time? What causes the water supply to be depleted or increased?
  - How are the storage and releases managed?

Watershed Water Cycle

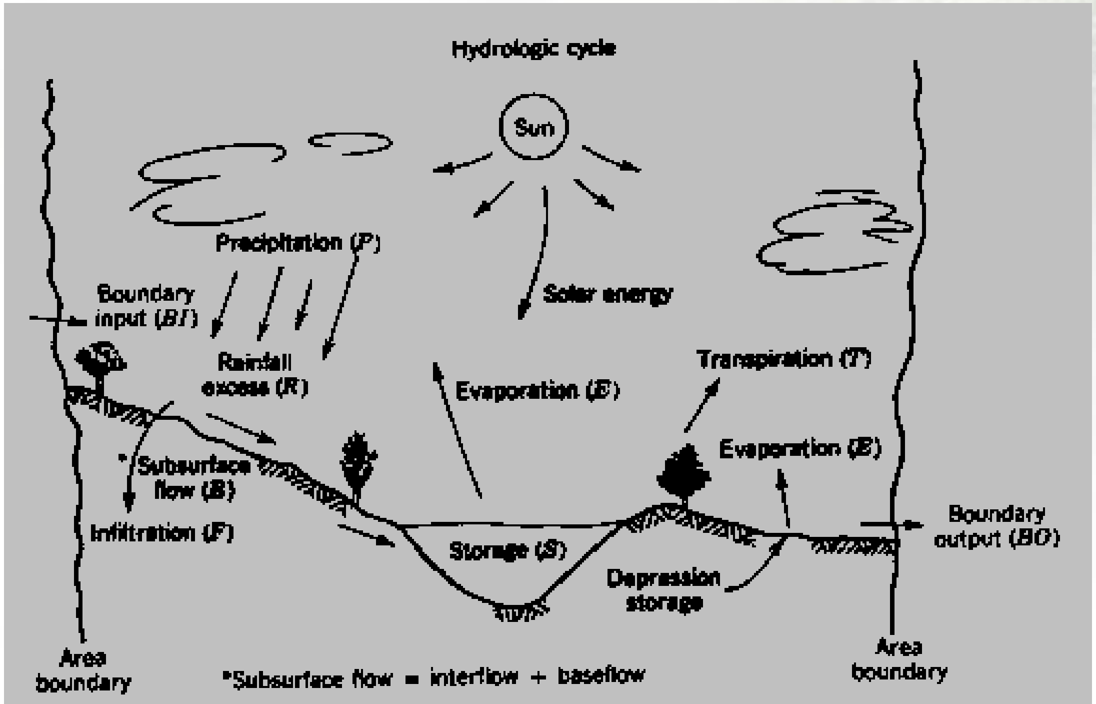


FIGURE 1.2 Hydrologic cycle.

- Based on the conservation of mass:
- Input – output = change in storage
- P + R + B - F - E - T = ΔS
- volumes are measured in units m^3, L, ac-ft, f^3, gal, or in & cm over the watershed area

WATER AND HUMAN NEEDS

Each of you needs:

- ✓ ***2 liters/day for drinking***

- ✓ ***50 liters/day for cooking and bathroom and sanitaries services***

- ✓ ***3600 liters/day for food production (e.g. meat and wheat)***

As you can see, food and water are strongly related...
fighting poverty and increasing the chances of developing countries are basically problems linked to the WATER AVAILABILITY

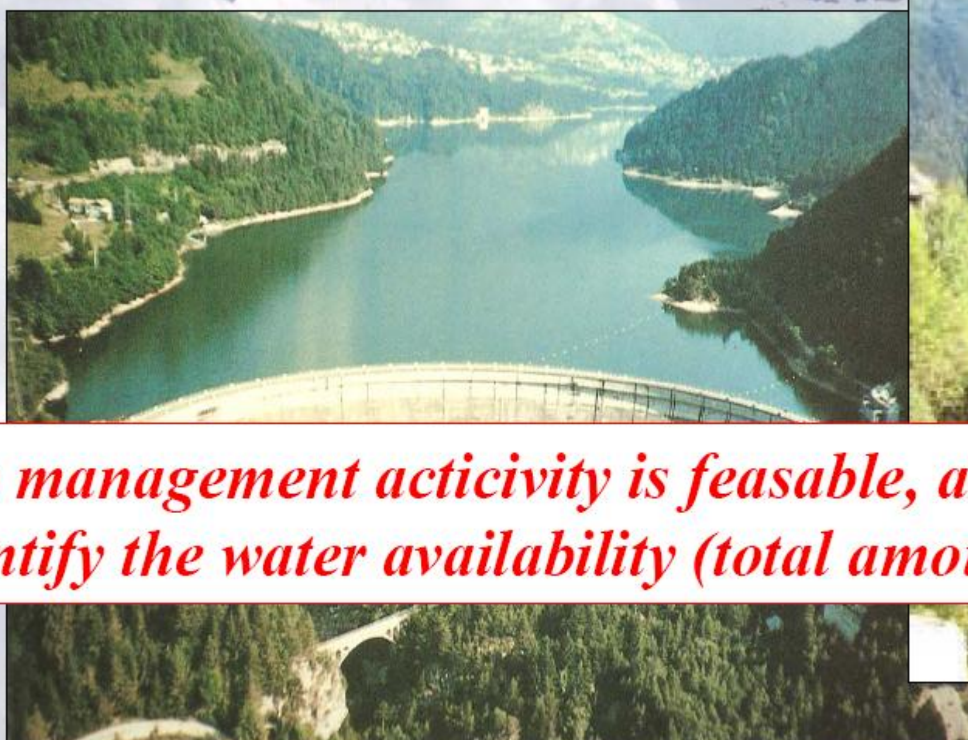
The Palestininian – Israeli conflict is chiefly based on water...

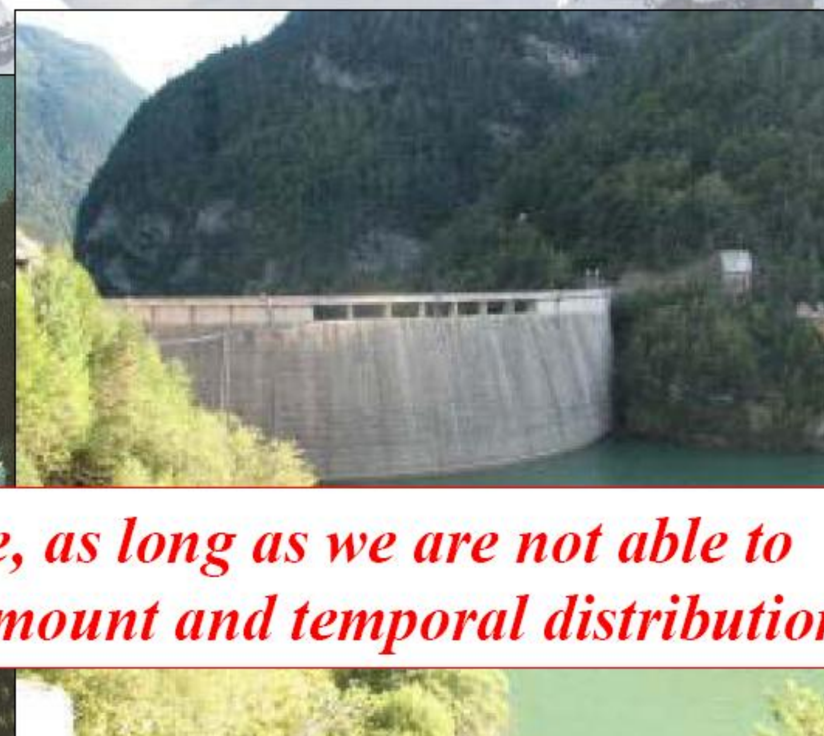
[F. Scaglia, il custode dell'acqua, Piemme 2002]

WATER RESOURCES MANAGEMENT

MANAGEMENT ... *(managing the "small" without knowing the whole thing?)*

- ✓ *WHAT IS TO BE MANAGED?*
- ✓ *WHO MANAGES?*
- ✓ *according to which RULES/CRITERIA?*





...no management acticivity is feasable, as long as we are not able to quantify the water availability (total amount and temporal distribution)

Basic Definition

- WATERSHED MANAGEMENT is the **process** of **guiding** and **organizing** land and other resource use on a watershed to provide desired goods and services without affecting **adversely** soil and water resources.

Introduction: What is Water Resources Management?

<u>1950-1970' Policy</u>

WRM is a primary engineering task to build dams, lay pipelines, install pumps, and operate systems

<u>Today's Policy</u>

WRM must pursue sustainable development with measures that manage water for human system, but at the same time protect and nuture natural systems for the benefit of future generations

Today WRM‘ policy is a very complex problem

This is often source of deep conflicts

WR manager requires skills well beyond technical training (e.g., pure engineering, science, management, or law)

WR manager must be able to communicate, cooperate in teams, speak other languages, work with other cultures, understand environmental problems and resolve conflicts via cooperation

„Anyone who solves the problem of water deserves not one Nobel Prize but two – one for science and the other for peace“ [John F. Kennedy]

The idea of sustainable development was born

Sustainable development and integrated WRM

World Commission on Environment and Development (1986):

„Sustainable development is a process that meets the needs of the present without compromising our ability to meet those of the future“

Water Quality 2000 team:

„Sustainability mirrors a society living in harmony with healthy natural systems“

Integrated Water Resources Management

- Water use efficiency and conservation
- Ecological integrity and restoration
- Clean water
- Equity and partecipation in decision making
- Institutional reformes,

In general it maintains and preserves (i.e., integrates) the water resource for future generations, and does not degrade the natural environment

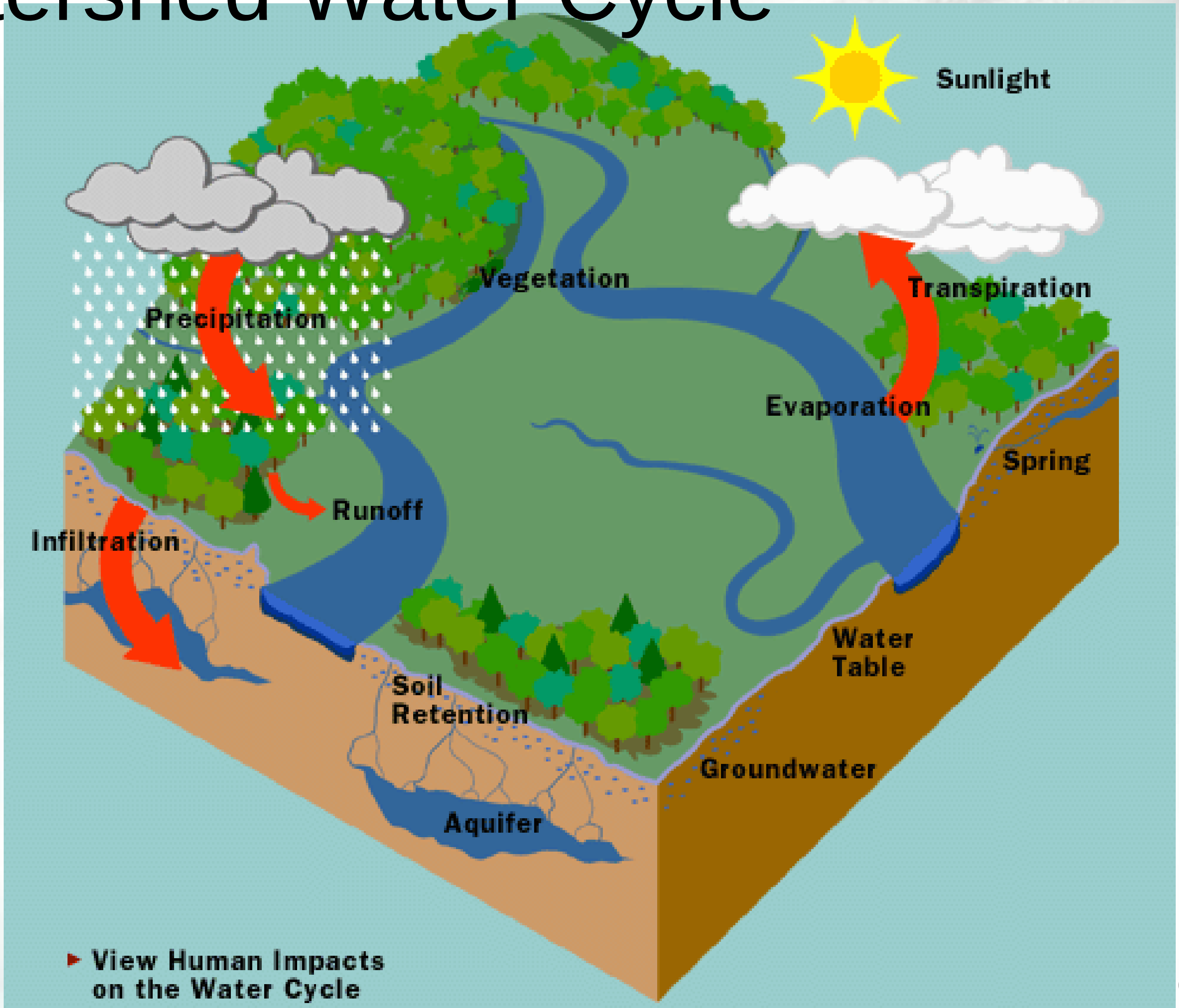
Water Resources Managers: required knowledge

- Hydroecology
- Infrastructures of water management: structures and systems, water uses and users
- Planning and decision making
- Organizational theories
- System analysis and decision support systems
- Water and environmental law
- Financial Management
- Principle of water resources managements

WS Management Strategies & Responses to Problems

- Watershed management involves:
  - Nonstructural (vegetation management) practices
  - Structural (engineering) practices
- Tools of WS management
  - Soil conservation practices
  - Land use planning
  - Building dams
  - Agroforestry practices
  - Protected reserves
  - Timber harvesting
  - Construction regulation
- The common denominator or integrating factor is water

Watershed Water Cycle



Impacts of Management

Period of renewal for the water in the hydrosphere

Water of Hydrosphere	Period of renewal
World Ocean	2500 years
Ground water	1400 years
Polar ice	9700 years
Mountain glaciers	1600 years
Ground ice of the permafrost zone	10000 years
Lakes	17 years
Bogs	5 years
Soil moisture	1 years
Channel network	16 days
Atmospheric moisture	8 days
Biological water	several hours

In the process of turnover the river runoff is not only recharged quantitatively, but its quality is also restored. If it were so that man could suddenly stop to contaminate rivers, then with time water could return its natural purity. So the river runoff, actually representing the renewable water resources, is the most important component of hydrological cycle. SOURCE: http://webworld.unesco.org/water/

The state of water use in the world

Table 1.1: Sectoral water withdrawals by region, rounded numbers (%).

Region	Residential	Industry	Agriculture
Africa	7	5	88
Europe	14	55	31
North America	13	47	49
Central America	6	8	86
South America	18	23	59
Asia	6	9	85
Oceania	64	2	34

Source: World Resources Institute (1998).

Water consumption per person per year has dramatically changed

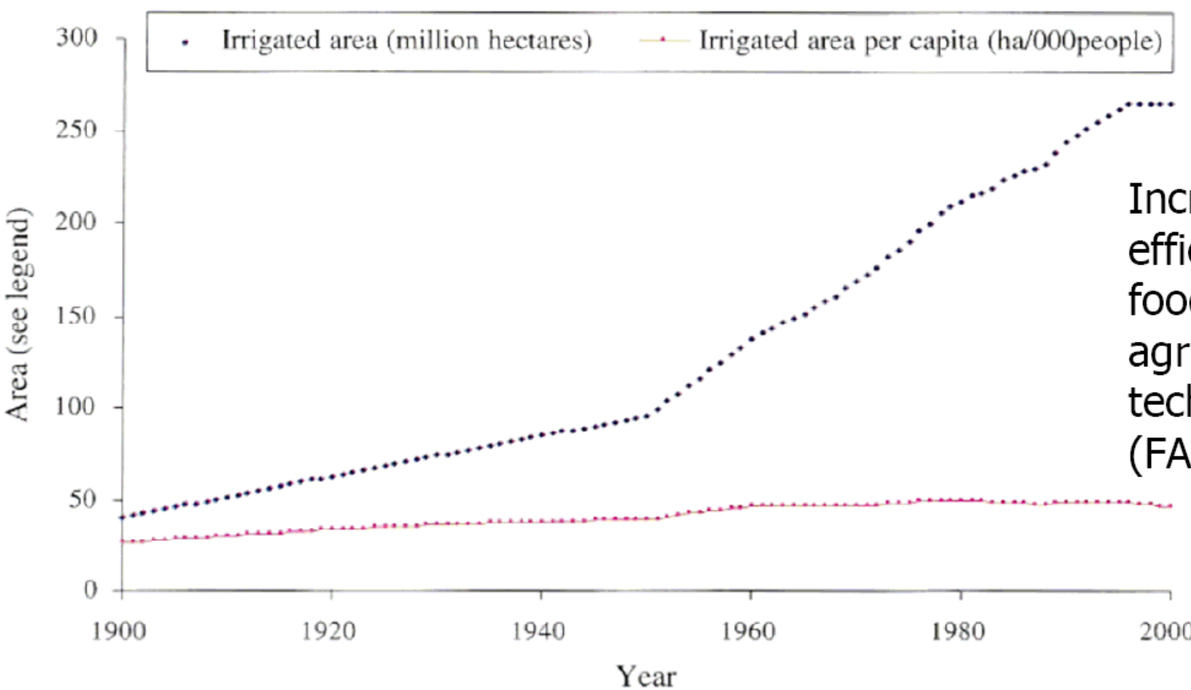
350 cm → 1900

642 cm → 2000

However, the amount of available water today is more or less the same as when Mesopotamian civilization prospered

Increased consumption led to increased water withdrawal!

Irrigation is by far the largest source of water use which has expanded by more than fivefolds in a century, albeit the increase per capita is constant



Irrigated area of the world and irrigated area per capita 1900–2000.

Increased efficiency in the food production agriculture technology (FAO, 2005)

Example: how much water do we need to produce our food, cloth and computers?

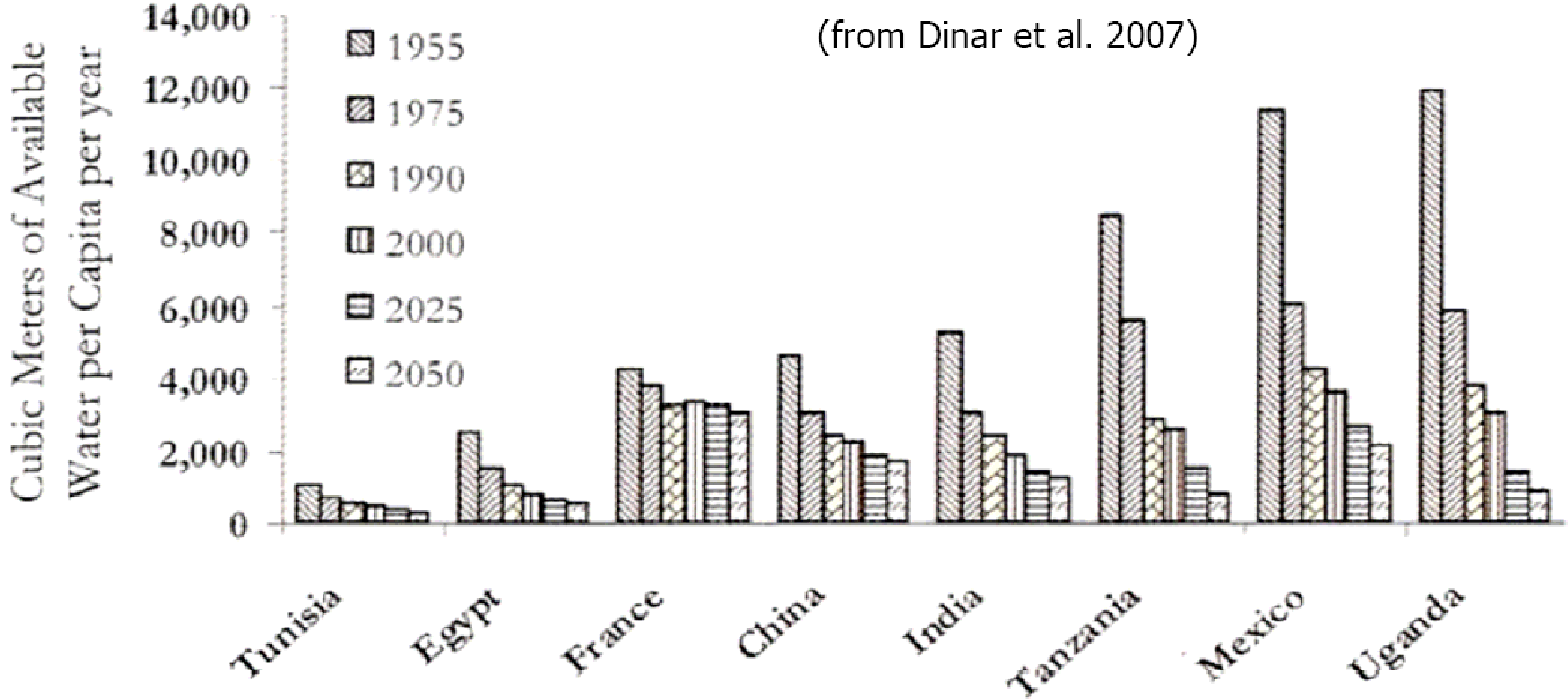
Water (m^3) needed to produce 1 kg of various foods: Potatoes 0.5; wheat 0.9, rice 1.9, poultry 3.5, and beef 15 (Clarke and King, 2004).

Water (m^3) needed to produce 1 cup of various beverages: milk 0.25, coffee 0.14 (Waterfootprints, 2006), tea 0.034 (Chapagain and Hoekstra, 2003).

Water (m^3) needed to produce 1 medium size cotton T-shirt 4.1, one computer microchip 0.032 (WWF, 2006).

(from Dinar et al. 2007)

Water scarcity: a first look



Water availability per capita (cm/yr) considering just one parameter (population growth rate) has been decreasing (60 ÷ 80%) nearly worldwide (Italy is an exception) between 1955 and 2050 (based on UN mean population growth prediction rates in the same years).

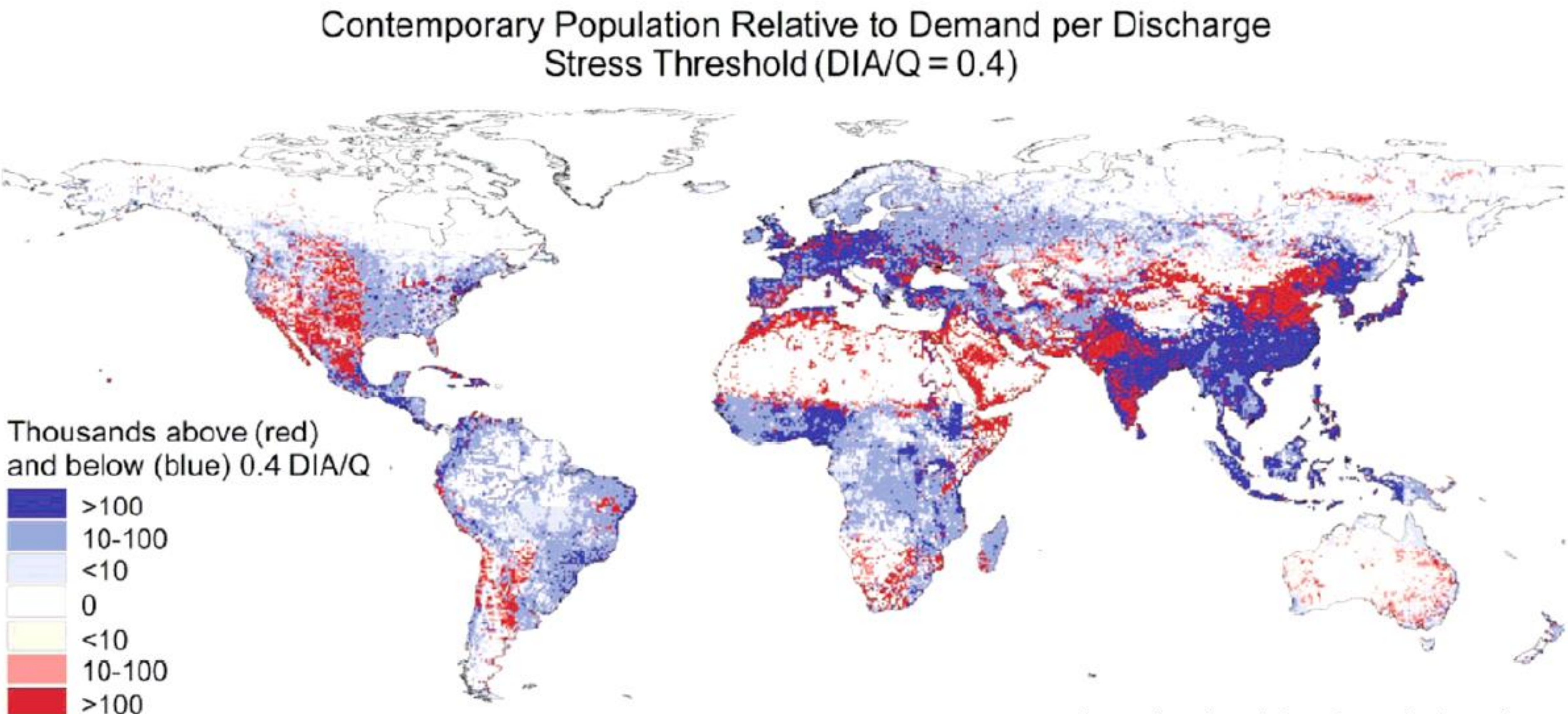
Factors affecting water scarcity

Anthropic origin

Hydrologic origin
(See WHH about how to define WS)

- Water quality maintainance due to water uses (e.g., pollution increases WS)
- High living standards (e.g, washing mashines, swimming pools) increase WS
- Technology level of a Country (decreases WS via water recycling technology, eg. California, Israel)

Water scarcity worldwide



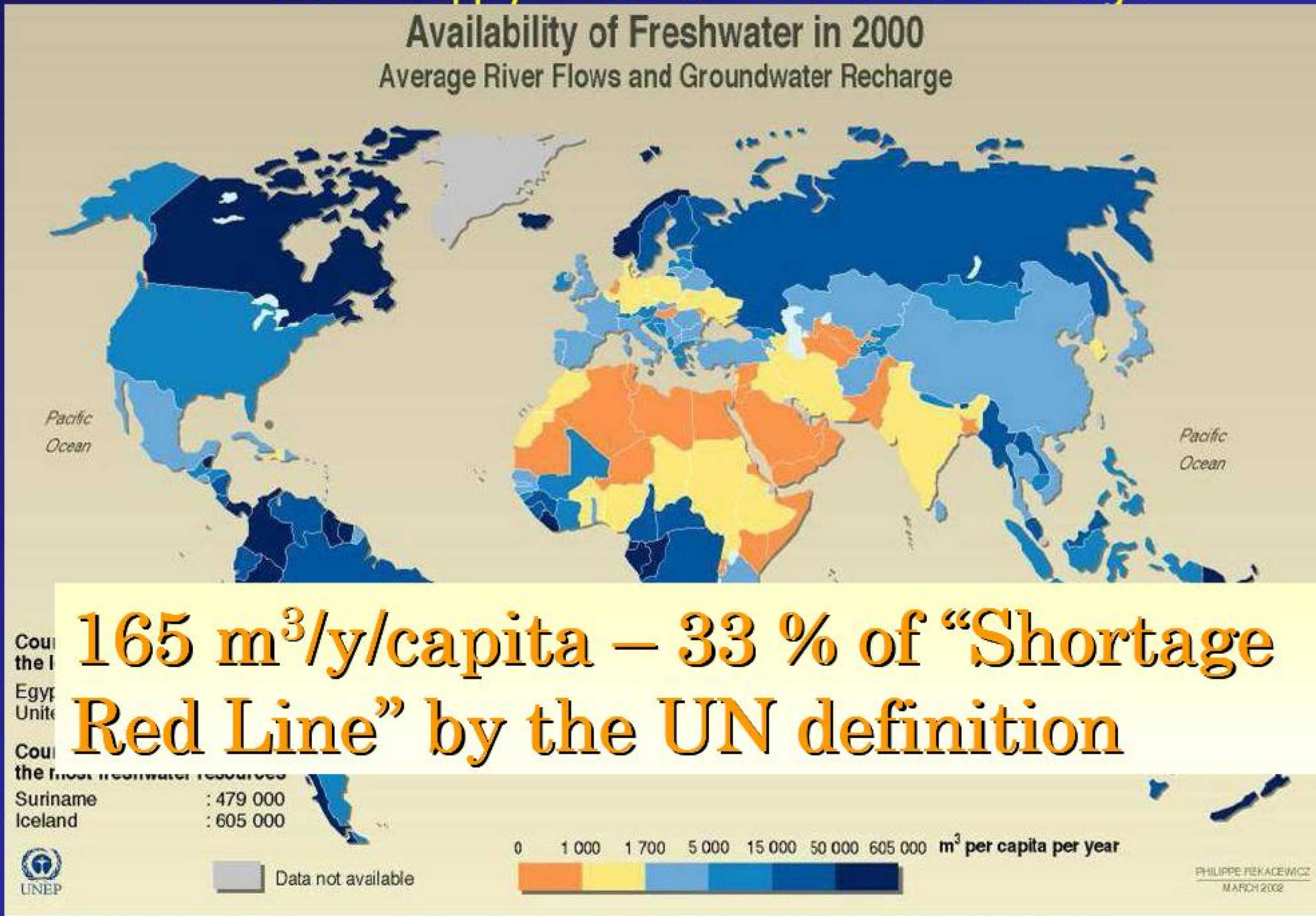
DIA=Domestic and Industrial and Agricultural uses

Q = River discharge for a given basin

SOURCE: Vörösmarty et al. (2000) *Science* 289:284-288

Main water management challenges

Water supply - the extent of water shortage



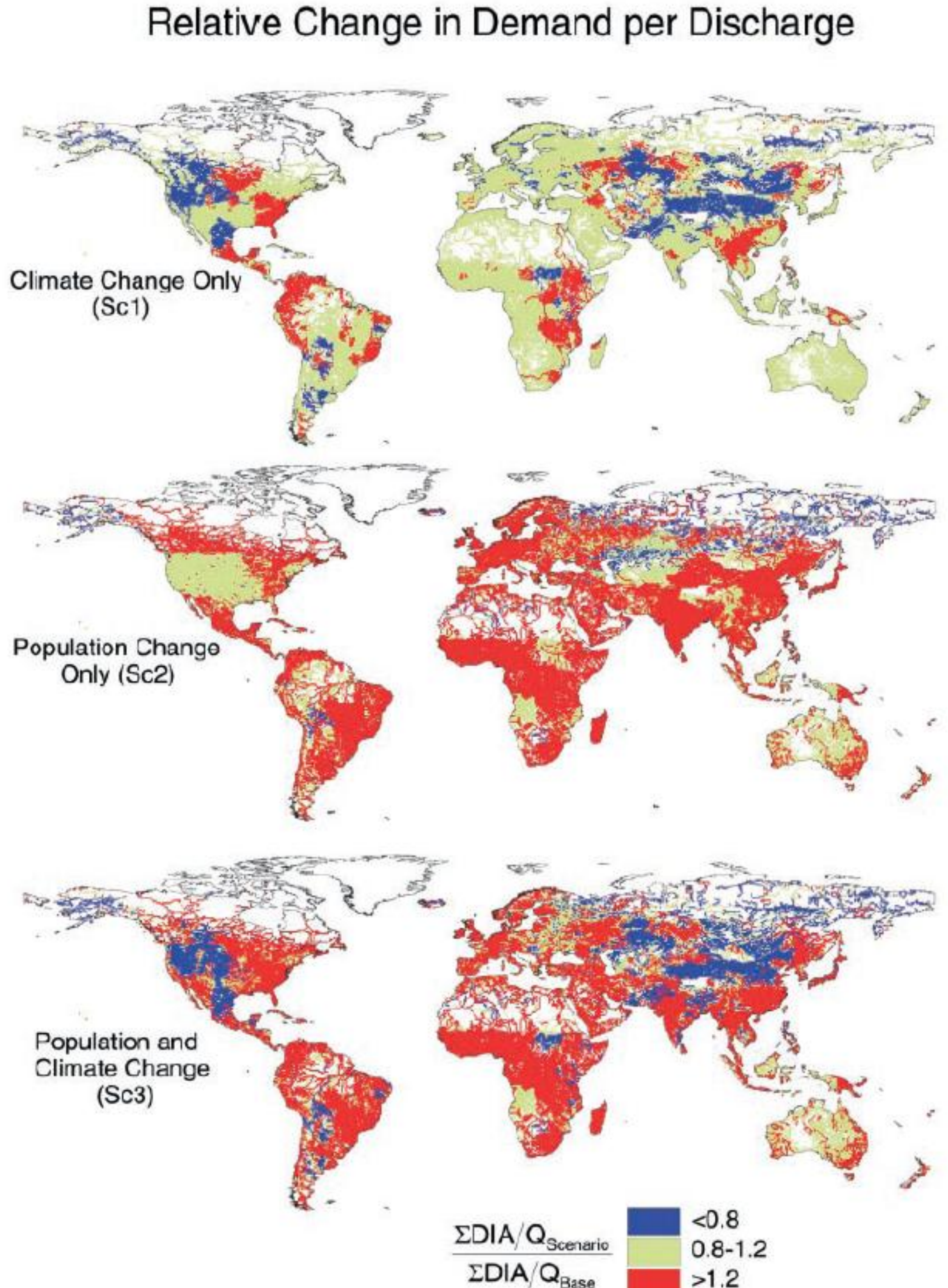
Source: *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000.

165 m^3/y/capita – 33 % of "Shortage Red Line" by the UN definition

Perspective under CC

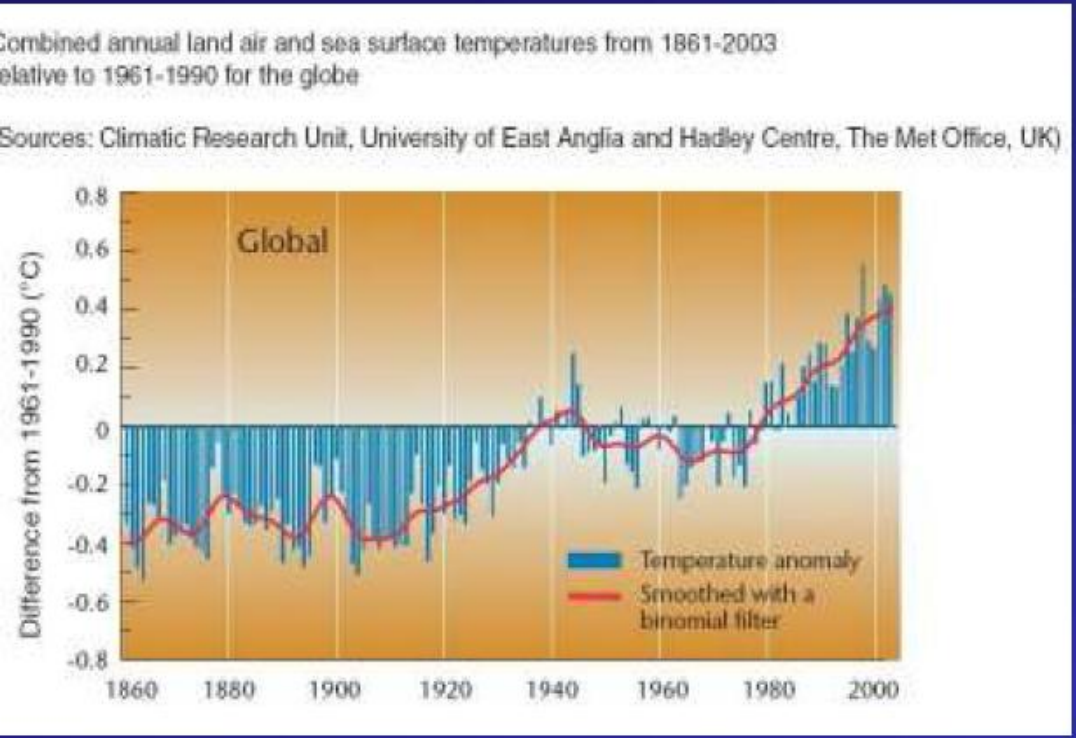
Crucial for International (and National) Water bodies, e.g. Conflicts and Cooperations dynamics

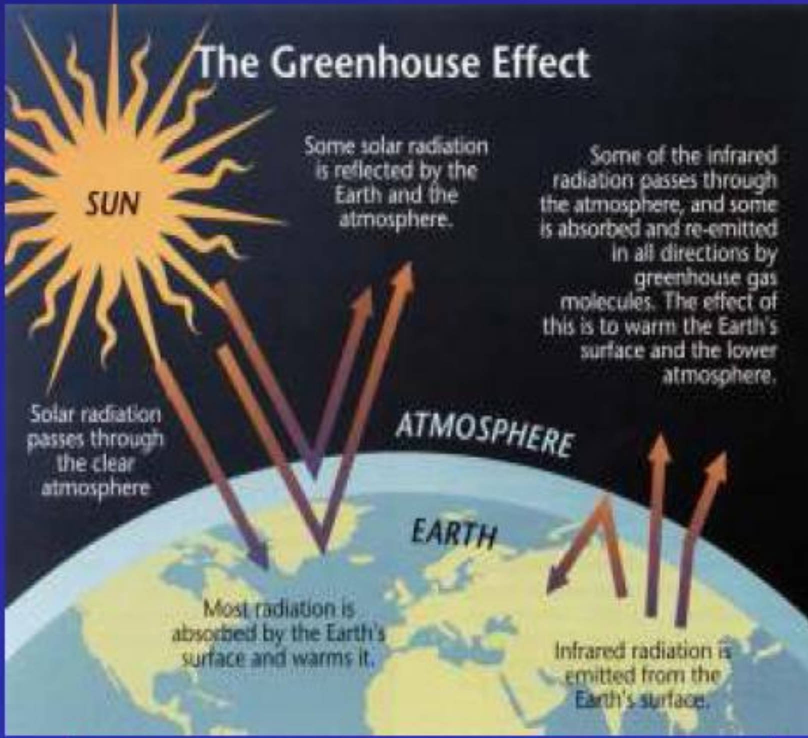
SOURCE: Vörösmarty et al. (2000) *Science* 289:284-28



Main water management challenges

Climate Change



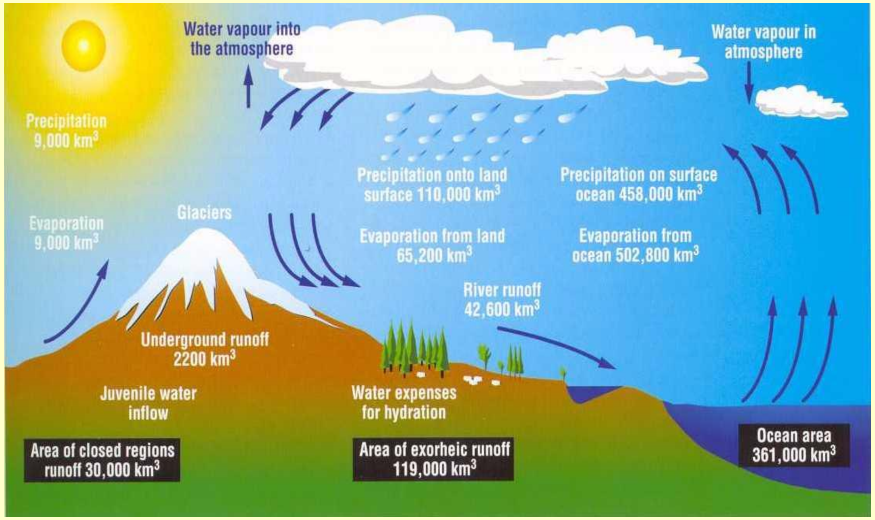


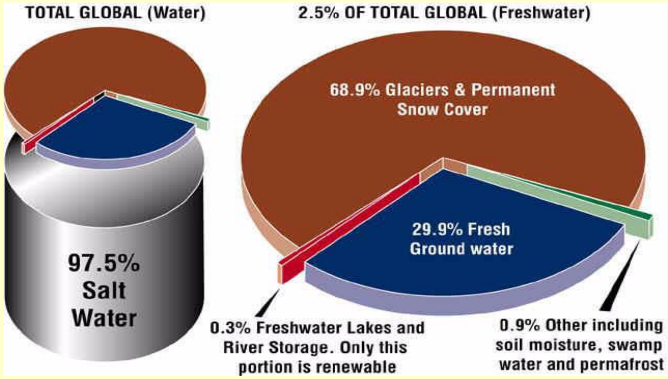
Source: Roger Braithwaite, University of Manchester (UK)

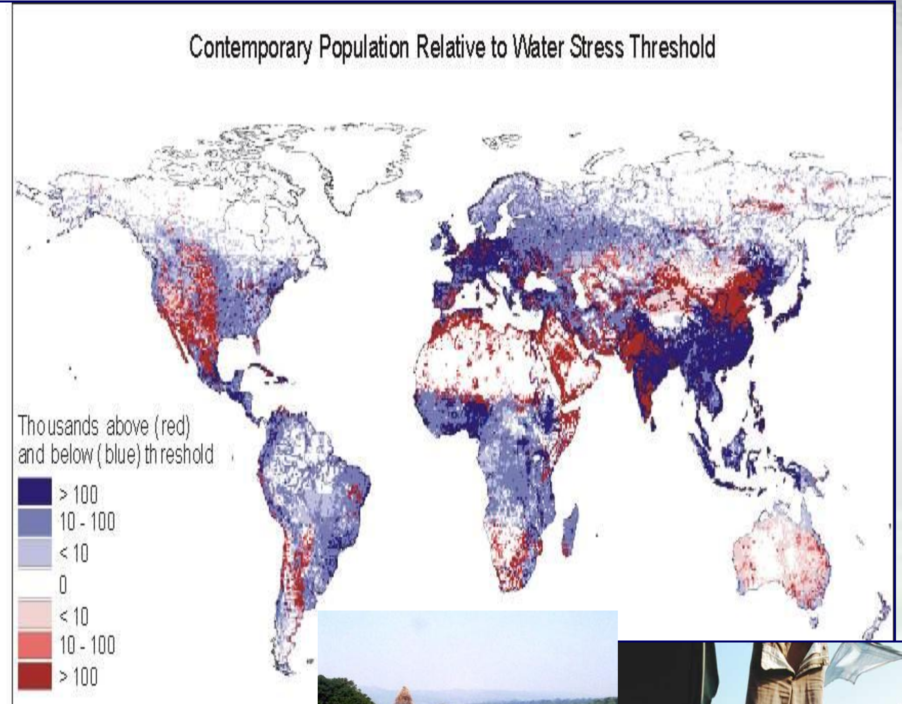
The importance of Water




"The Grim Arithmetic of Water"---Official Discussing Emerging Freshwater Crisis---Source: September 2002 National Geographic









Population is dramatically increasing

Ultimately, a limited water supply will meet limited needs

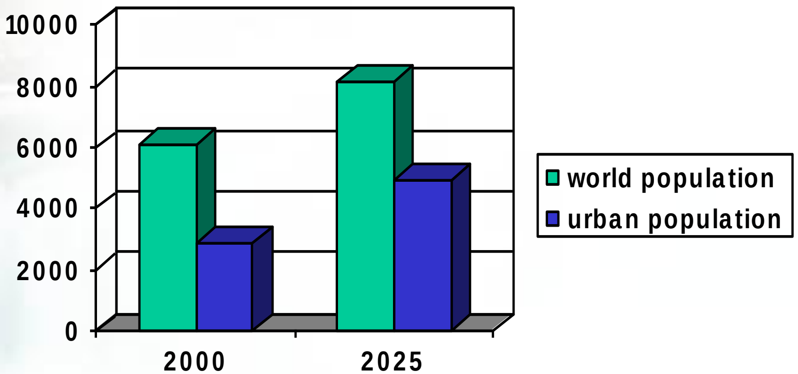
Importance of Water

Water is a fundamental basis of life on Earth, affecting: climate, pollution, food, human habitation, human conflict, and more

Understanding the Earth's hydrologic cycle provides:

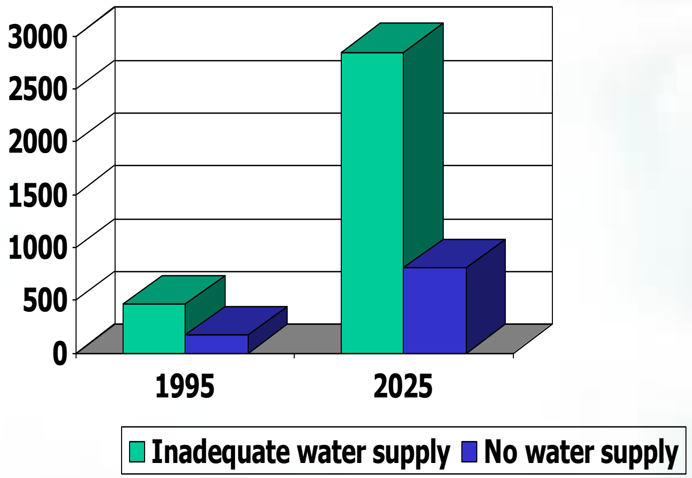
- **improved forecasts:** precipitation, drought, floods, food and water availability, agricultural & fisheries productivity, disease vectors
- **improved management:** agriculture, transportation, planning, social assistance requirements, other human activities

A Growing Need: Growing demand, Diminishing resources, Failing public services *(Inadequate institutional structures, Insufficient investment, Lack of maintenance, Poor management, Political interference),* Enormous investment requirements



- Deaths from water scarcity (12 M / year)
- Increased poverty in developing countries

World population suffering from water shortage (millions)

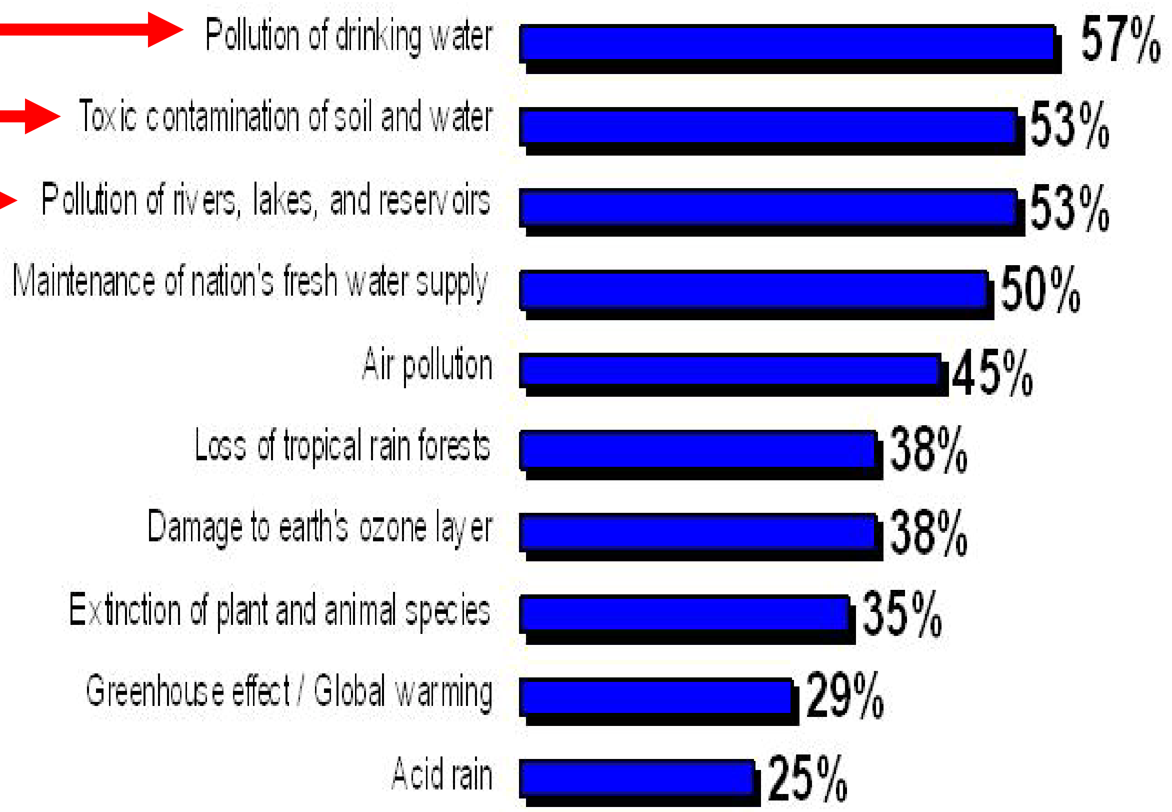


Importance of Water Applications

MOTIVATION

TOP 4 CONCERNS

Poll percentage that worried "a great deal" about:



Ranking of environmental concerns (taken from Gallup News Service: *Americans Sharply Divided on Seriousness of Global Warming*, March 25, 2002)

WSM: a global perspective

- Practices of resource use & management do not depend solely on the physical & biological characteristics of WS
- Economical, social, cultural & political factors need to be fully integrated into viable solutions.
- How these factors are inter-related can best be illustrated ?

WSM: a global perspective

- Land & water scarcity: is the major environmental issue facing the 21st century
- Demands > supplies (17%)
- Next 25yrs → 2/3 pop. water shortage
- Land scarcity → forest cut
- Desertification
- Hydrometeorological extremes, role of WSM

WHO Water/Health Facts

- Every 8 seconds a child dies of water-related disease
- 5 million per year die of illnesses linked to
  - unsafe drinking water,
  - unclean domestic environments, and
  - improper excreta disposal.
- Nearly ¼ of humanity remains without proper access to water and sanitation
- http://www.who.int/inf-fs/en/fact112.html

- **The *over-extraction* of water for agriculture and manufacturing, which causes the water table to decline in many parts of the world, is another *bad practice* which is producing severe consequences to the sustainability of these resources.**

Water supply data at global level

- The percentage of people worldwide who have access to an improved water supply has risen from 78% in 1990 to 82% in 2000. Some 902 million more people have been served during the decade (537 million in urban and 365 million in rural areas).

- **Data representing 94% of the Asian population suggest that only 48% of the population has *sanitation coverage*, by far the lowest of any region of the world. The situation is even worse in rural areas, where only 31% of the population has improved sanitation, compared with 78% coverage in urban areas.**

- **Total *water coverage* in Asia is also the second lowest, after Africa, at 81%. But again, water supply coverage is lower in rural areas (75%) compared with that in urban areas (93%).**

- **Because of the population sizes of China and India, along with other large nations in the region, Asia accounts for the vast majority of people in the world without access to improved services.**

- Eighty percent of the global population without access to improved sanitation, and almost two-thirds without access to improved water supply, live in Asia.
- At present, approximately one-third of the Asian population is urban and two-thirds live in rural areas. But this balance is predicted to shift over the coming decades. By the year 2015, the urban population is projected to be 45% of the region's total, and grow to just over one-half of the total Asian population by 2025.

- **To meet the international development target of halving the proportion of people without access to improved services by 2015, an additional 1.5 billion people in Asia will need to access to sanitation facilities, while an additional 980 million will need access to water supply.**

Water-related Diseases

- Potential water borne pathogens
- Bacteria
  Vibrio cholerae
  Shigella
  Campylobacter
  Francisella tularensis
  Aeromonas
  Legionella pneumophila
  Salmonella
  Toxigenic *Escherichia coli*
  Leptospira
  Yersinia enterocolitica
  Helicobacter pylori

- **Protozoa**

  Giardia lamblia
  Naegleria fowleri
  Entamoeba histolytica
  Isospora belli
  Toxoplasma gondii
  Cryptosporidium parvum
  Acanthamoeba
  Cyclospora cayetanensis
  Ballantidium coli
  Microsporidia

Viruses

Norwalk and Norwalk-like
Rotavirus
Hepatitis A and E

The “Water Sector”

Water is vital for life and livelihood: It is precious but scarce

Water cannot be manufactured, unlike other commodities

- Water supplies are fixed

Available water resources need to be

- Developed in a sustainable way
- Managed to derive optimal benefits
- Conserved and preserved as scarce resource

The need and therefore the potential market and business opportunities are enormous,

but is it a good and attractive business?

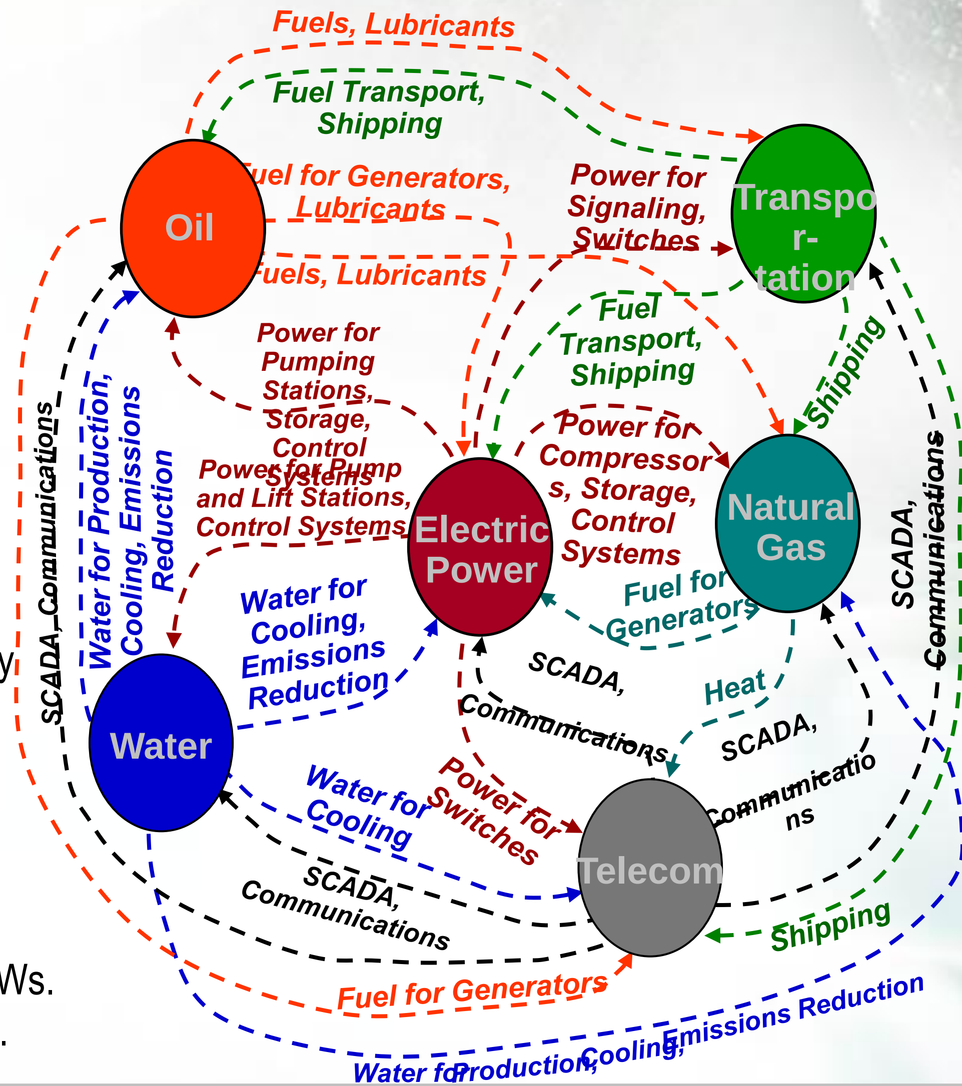
U.S. Drinking Water Statistics

- 160,000 public water systems (PWSs).
- 84% of U.S. population served by PWSs.
- PWSs produce 51 billion gallons drinking water/day
- 2.3 million miles of distribution system pipes.

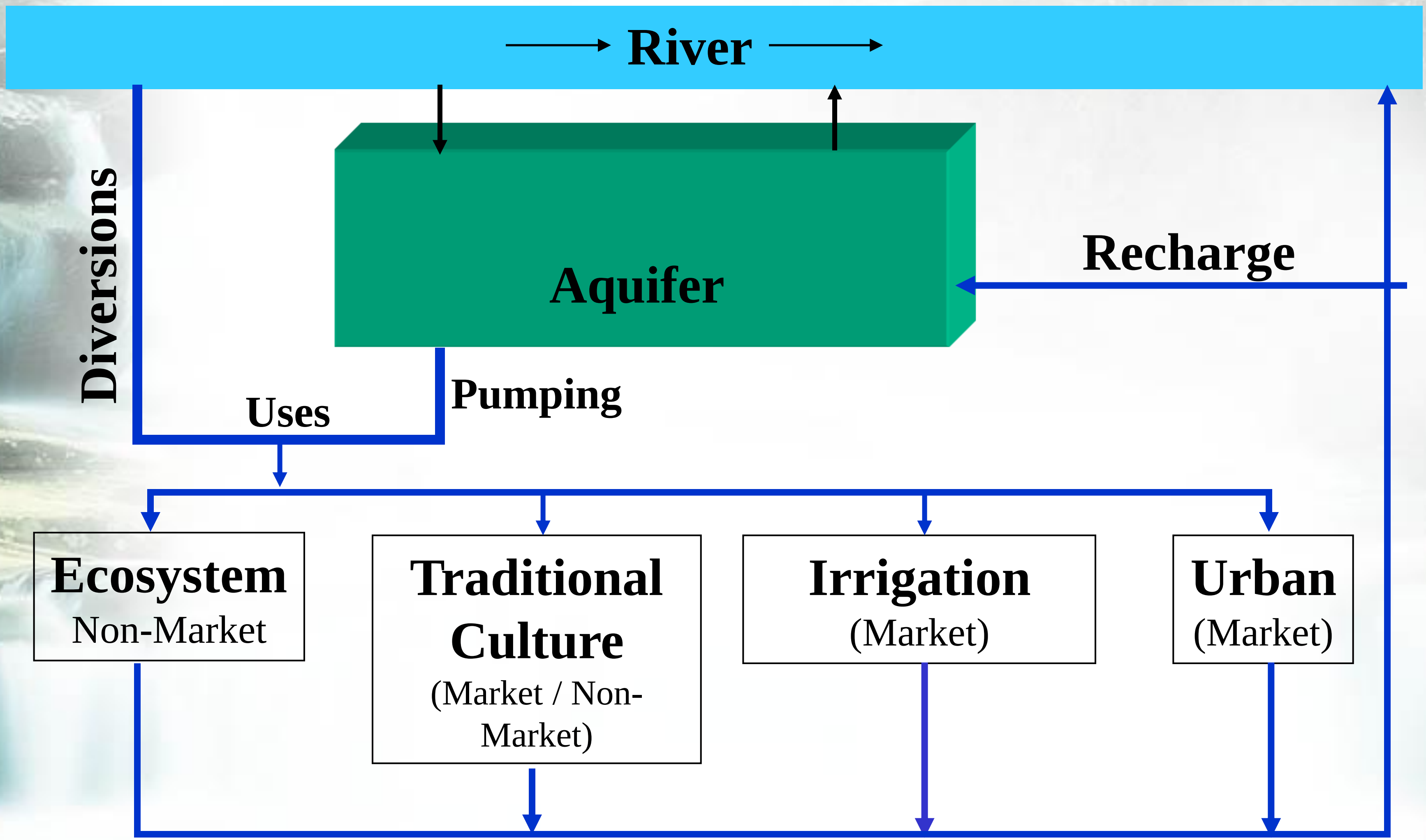
U.S. Wastewater Statistics

- 16,255 publicly owned treatment works (POTWs).
- 75% of U.S. population served by POTWs.
- 27,000 commercial/industrial facilities rely on POTWs.
- 32 billion gallons of wastewater treated every daily.

Water sector is part of a system of systems

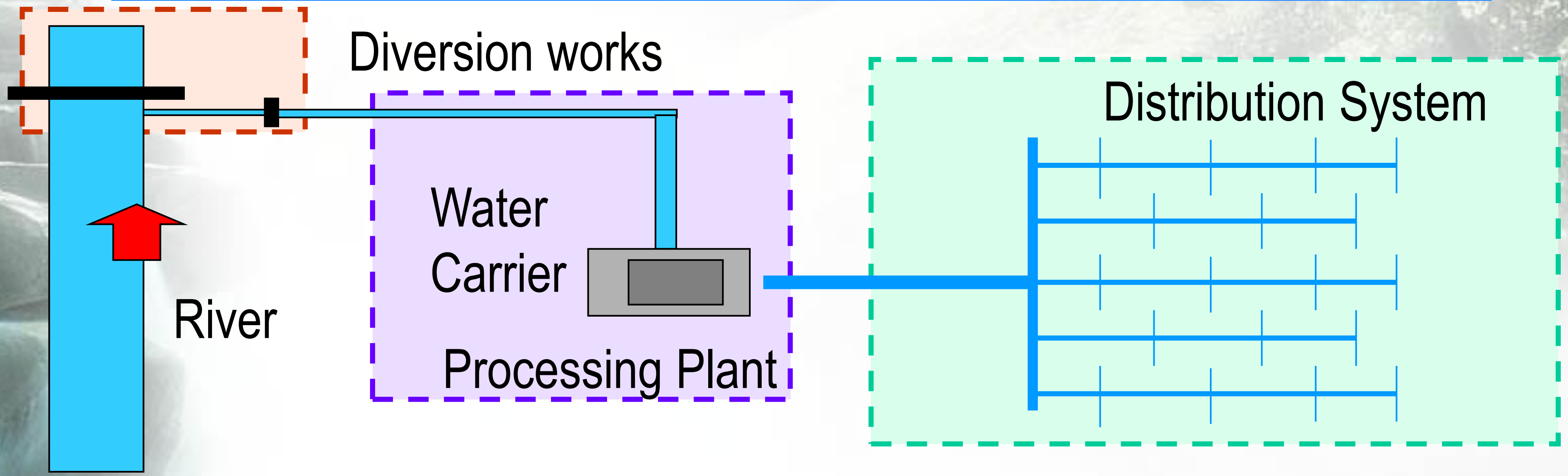


Water Sector: Integrated Systems



J.Chermak WR 572, University of New Mexico Spring 2005

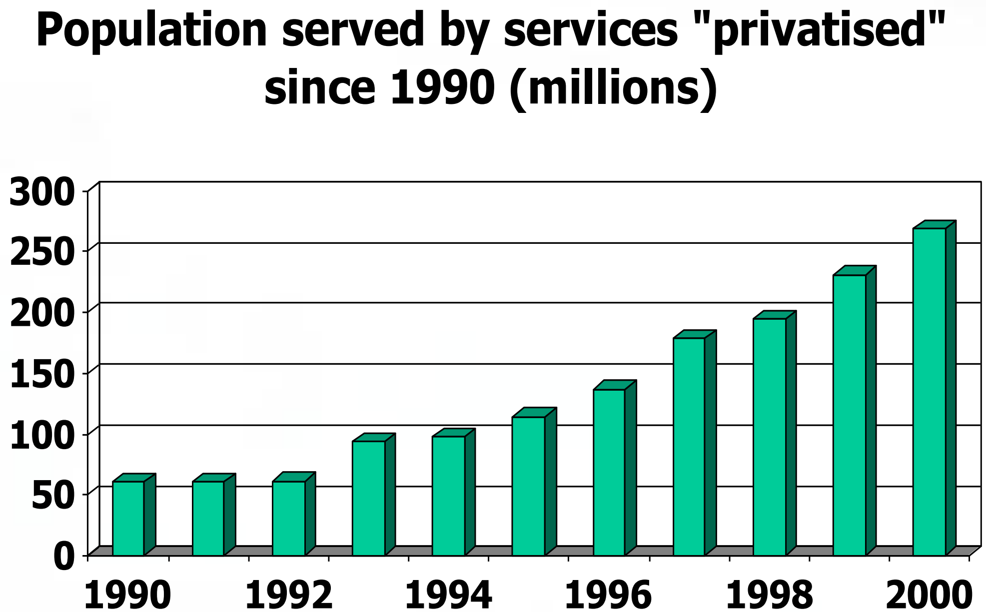
Water Sector: System Components



- Water resource development & management
- Supply, treatment, transport & storage
- Environmental management & conservation
- Research, administration & policy development
- River management, navigation & flood control & waste assimilation
- Hydropower & Agricultural irrigation
- Industrial, commercial & touristic water use
- Municipal & household water use & sanitation
- Wastewater collection & treatment, and sludge disposal

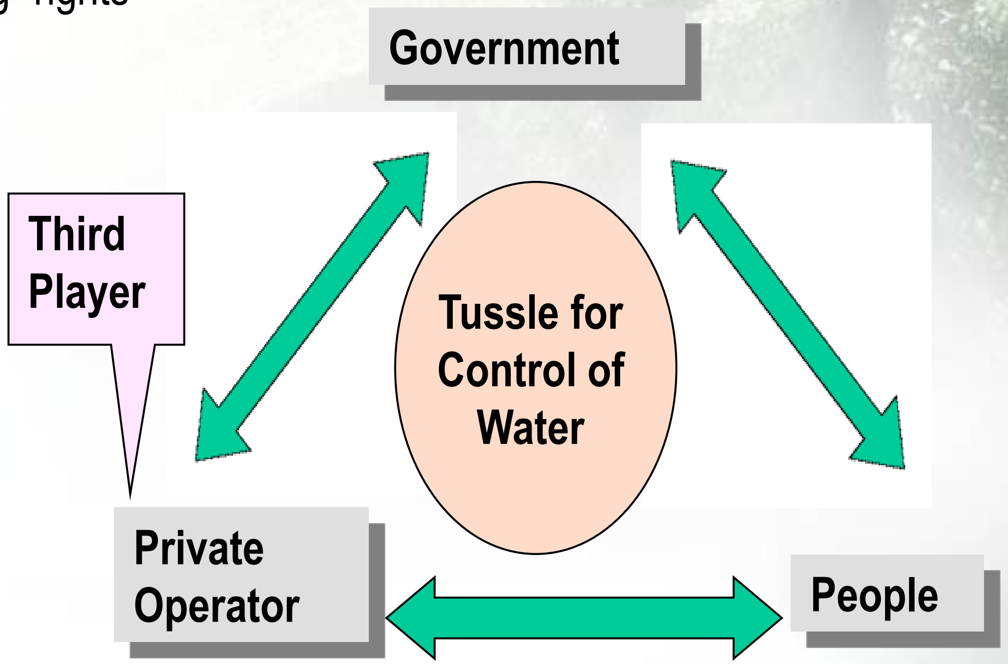
Water sector trends

- A shift from public to private management under contract
- A shift in emphasis from public (subsidized) funding to private investment
- A marked increase in risk in developing countries
- An emphasis on unrealistic service levels
- A positive awareness of the needs of the urban poor



Value of Water Rights

Markets give best evidence of value of underlying rights
Markets also lead to efficiency in water allocation



Problems:

- Ag. and Urban not same water
- Decreasing per-capita availability
- Degrading water quality
- Increasing competition/conflict
- Haves versus have nots
- Upstream versus downstream
- Competition/conflict with the environment
- Downstream users object
- Multiple agencies all end up with veto

suppose every time you tried to buy a candy bar you had to notify your dentist?

Solutions:

- Underlying rights need to be dependent upon water availability
- Rights must be freely tradable
- Water markets would reallocate water to high value uses
- End to water industry subsidies
- Peace is necessary for Water markets
- Regulator should: Set Rules; monitor performance; Enforce rules

- **"Many of the wars in this century were about oil, but wars of the next century will be about water.**"(Ismail Serageldin, Vice President, World Bank)

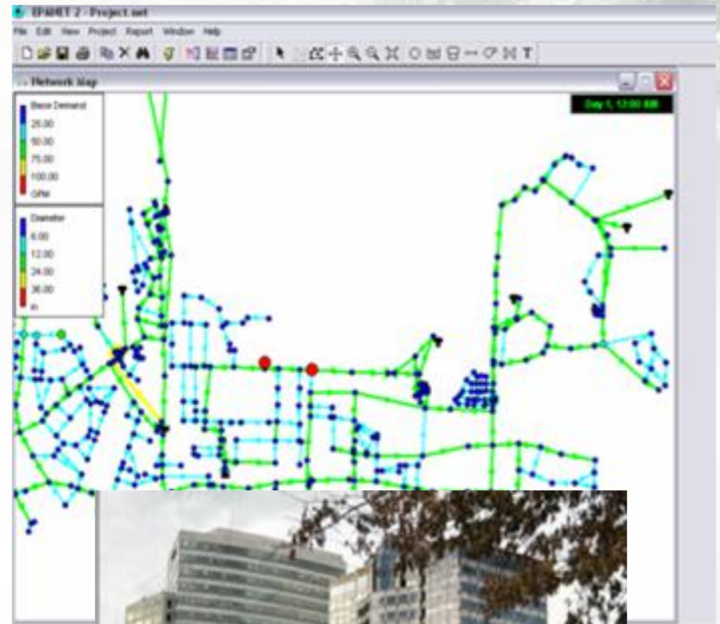
Future Opportunities: Water Security

Initial Focus

- **Two cases**
  - ***Point introduction urban area***
  - ***Back flush of targeted building***
- **Toxin, VX**

Ongoing Activities

- **Investigation of Impact**
  - **- Number of Causalities**
  - **- Economics**
- **Study of Multi-tiered Defense**



Water security is the ability to access sufficient quantities of clean water to maintain minimal standards of food and goods production, sanitation and health

Desalination

- ***Rainfall patterns and population growth is extremely diverse***, which leads to different levels of water demand, thus desalination needs are highly geographically variable.
- Desalination of brackish water / sea water is a ***drought-proof, mature technology***
- Currently, more than ***1,200 desalting plants operate in the U.S.***, producing over 300 million gallons of water per day. Worldwide capacity is over 6.0 billion gallons per day.
- The first large-scale seawater desalting plant in the U.S. (25 million gallons per day (mgd)) began operating, albeit sporadically, near Tampa Bay in Florida in 2003.
- The ***Southern U.S. has the greatest desalination demand*** in the U.S., focused on Florida, South and North Carolina. The trend in California is to move toward water recycling instead of desalination.
- The desalination industry depends on increasing ***demand for water***, as well as ***research and development*** (R&D), ***environmental***, ***regulatory and legal, technology,*** etc.
- Challenges to this market include regulatory programs, competitive strategies, new technologies, economic trends, market measurement trends, customer issues, sales and marketing strategies, new market opportunities, and market threats.
- ***Fate of concentrate is the biggest issue*** facing desalination (options include return to sea, evaporative basins, injection wells, disposal into surface waters or waste water stream)

Conclusion

Water is a fundamental basis of life on Earth, affecting: climate, pollution, food, human habitation, human conflict, and more

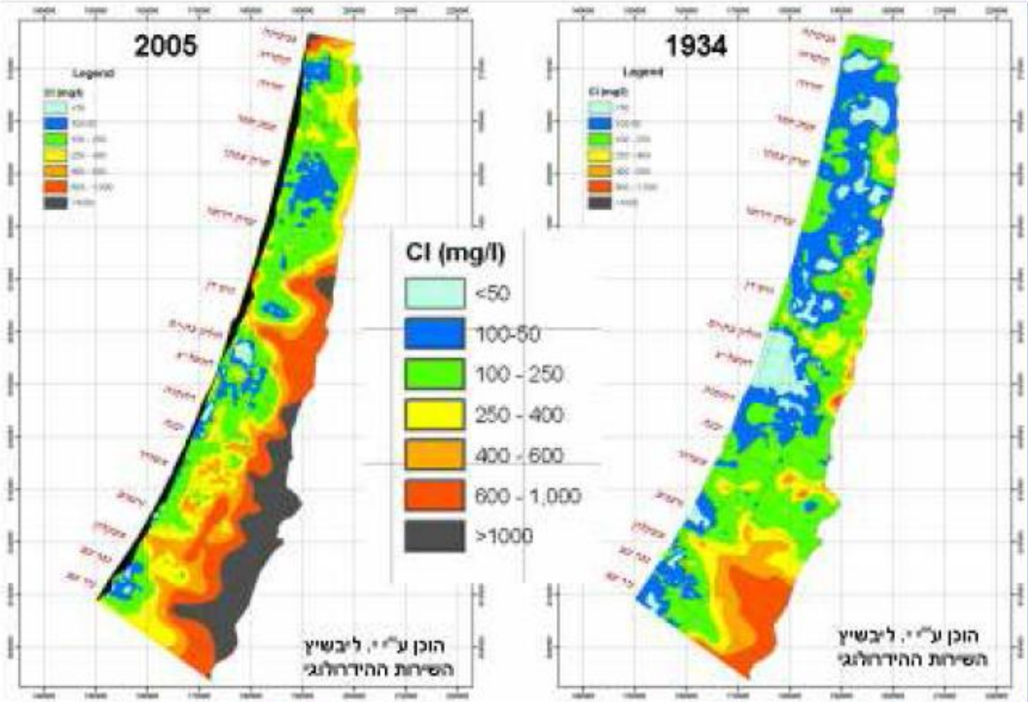
A Growing Need: Growing demand, Diminishing resources, Failing public services (Inadequate institutional structures, Insufficient investment, Lack of maintenance, Poor management, Political interference), Enormous investment requirements

The need and therefore the potential market and business opportunities are enormous, but is it a good and attractive business?

Care must be taken to avoid potential pitfalls: political, conflict, regulation, etc.

Main water management challenges in the Israeli water sector

1. Governance (How do we manage the water sector?)
2. Water supply in all types (both quantity and quality)
3. Natural water resources (preservation & rehabilitation?)
4. Transboundary water issues.
5. Preserving the nature's ecological systems
6. External threats (e.g., climate change)
7. Water sector efficiency (e.g. regulation, water tariffs)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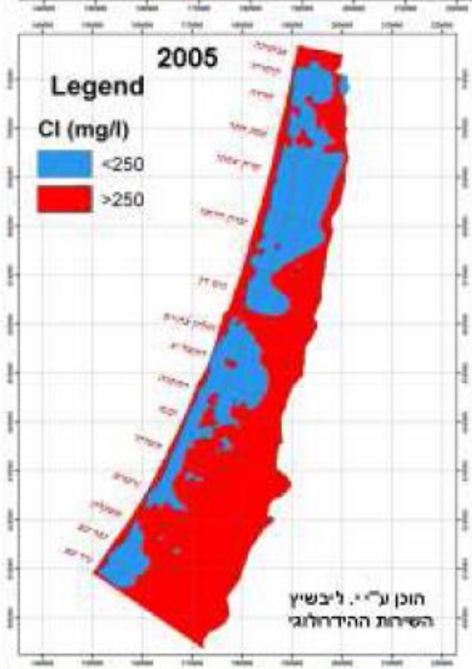
השירות ההידרולוגי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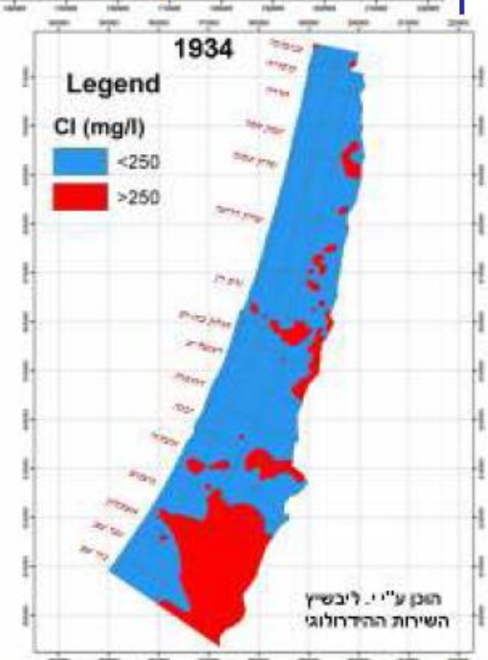
השירות ההידרולוגי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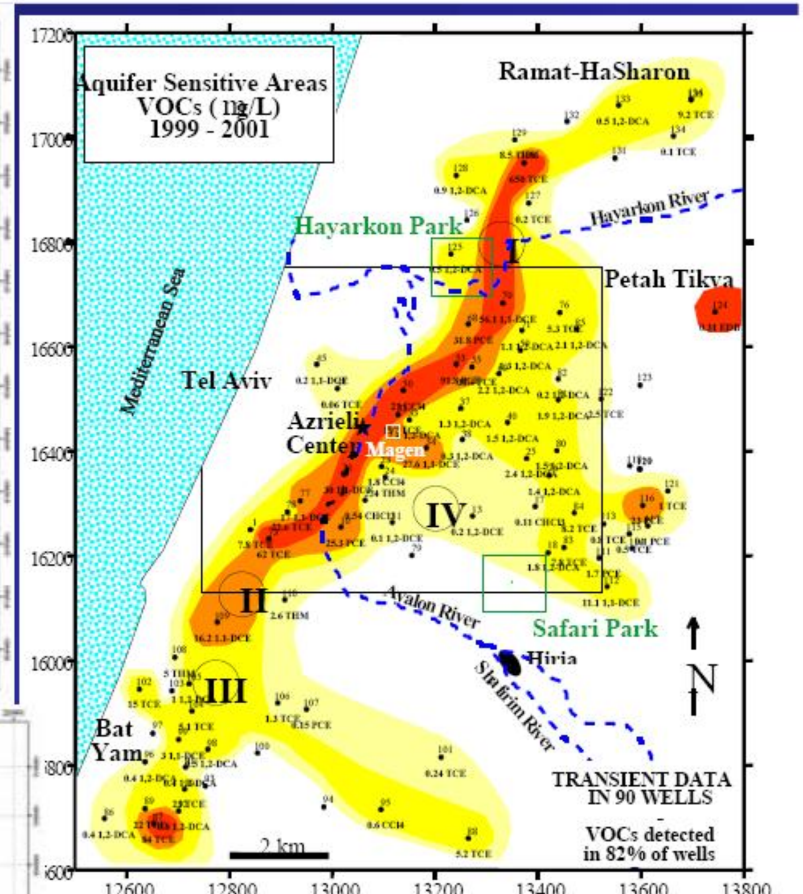
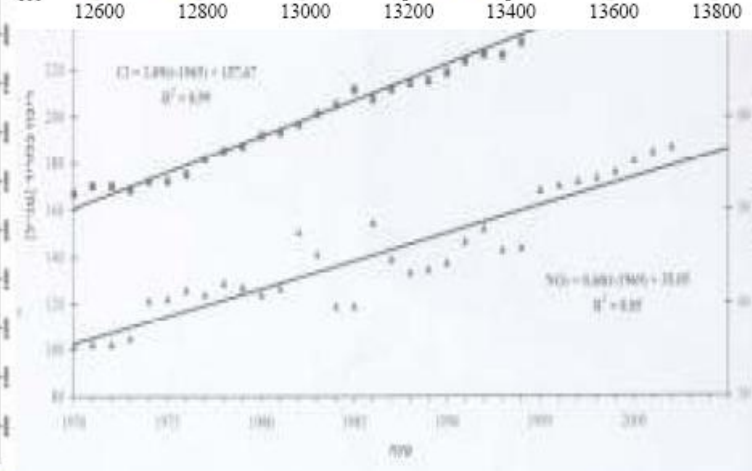
השירות ההידרולוגי


Aquifer Sensitive Areas
VOCs (ug/L)
1999 - 2001
Ramat-HaSharon
Hayarkon Park
Hayarkon River
Petah Tikva
Mediterranean Sea
Tel Aviv
Azrieli Center
Magen
I
II
III
IV
Ayalon River
Safari Park
Hiria
Shafirim River
Bat Yam
N
2 km
TRANSIENT DATA
IN 90 WELLS
VOCs detected
in 82% of wells
12600
12800
13000
13200
13400
13600
13800



Potential Solutions

Governance & Management

✓ IWA - A new institution was established (2007) for managing the water sector with most authorities ruling the "whole water cycle".

✓ Long term planning

✓ Regulation reforms

Potential Solutions

Water Management

- ✓ Incorporating risk management strategies
- ✓ Demand management
- ✓ Reallocation of water – targeting the quality of water available (potable, natural, manufactured, brackish, effluents) to the specific needs and consumption components.
- ✓ Rehabilitation and preservation of the natural resources.
- ✓ Increase water supply

Potential Solutions
Demand management

✓ Education (e.g Promoting a day of "water awareness" at elementary schools).

✓ Involving private sector in water conservation initiatives.

✓ Distributing water conservation devices.

Drought measures

✓ Restricted Allocations for urban gardening.

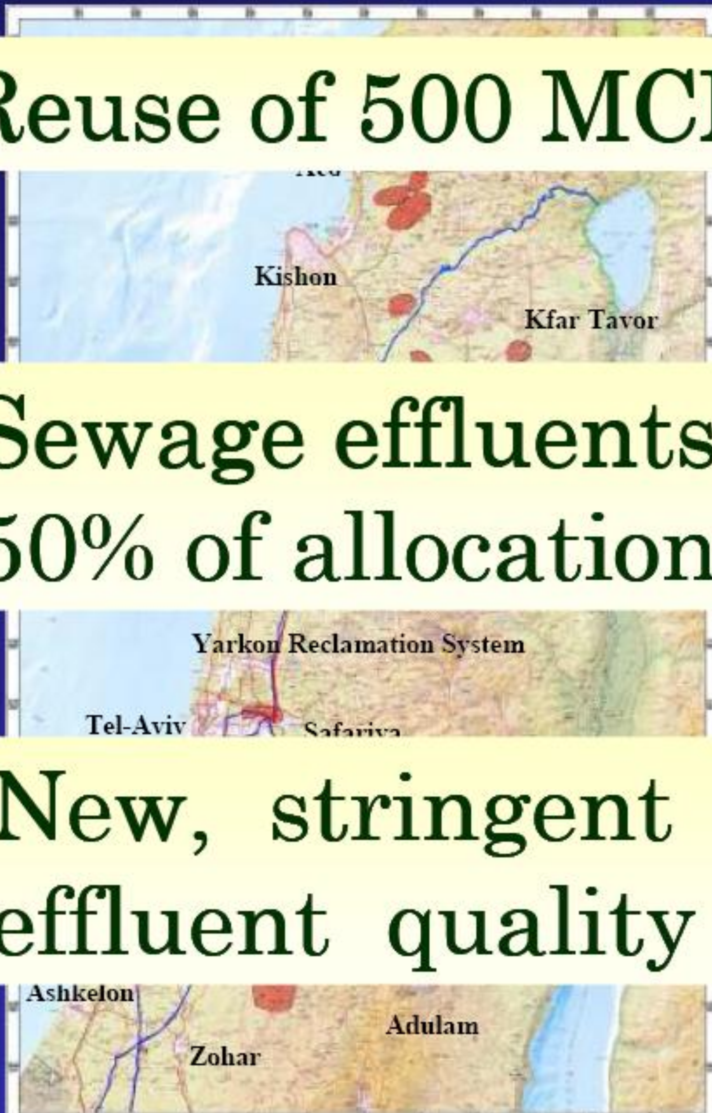
✓ Drought levies.

✓ National campaign in the media

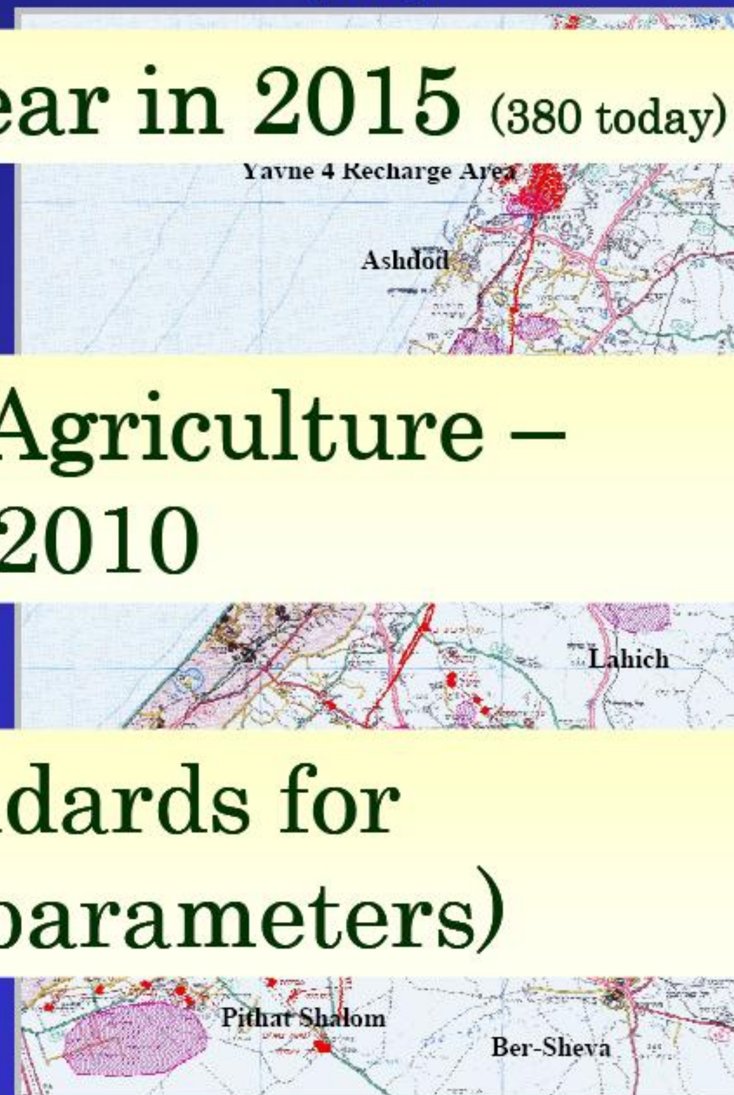
Potential Solutions

Reallocation of water

Effluents Supply systems



Shafdan Water Project (SAT)



Reuse of 500 MCM/Year in 2015 (380 today)

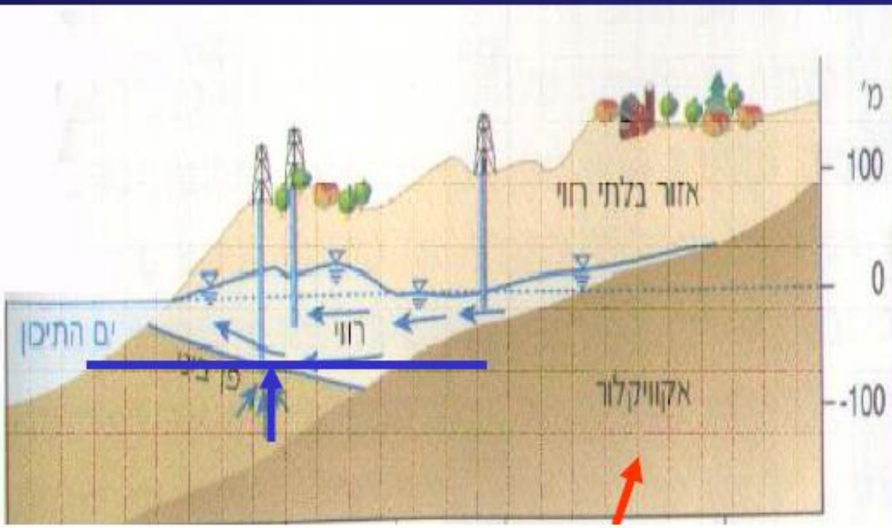
Sewage effluents for Agriculture – 50% of allocations in 2010

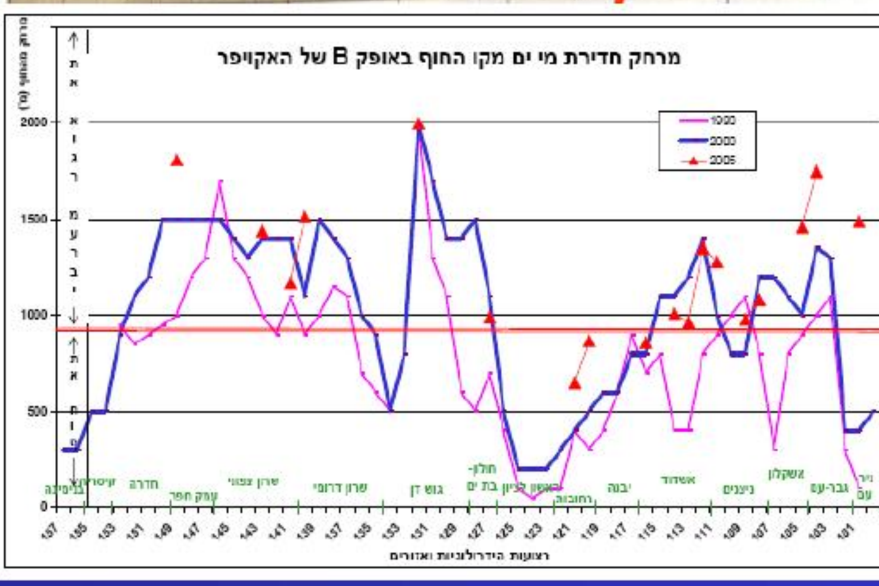
New, stringent standards for effluent quality (37 parameters)

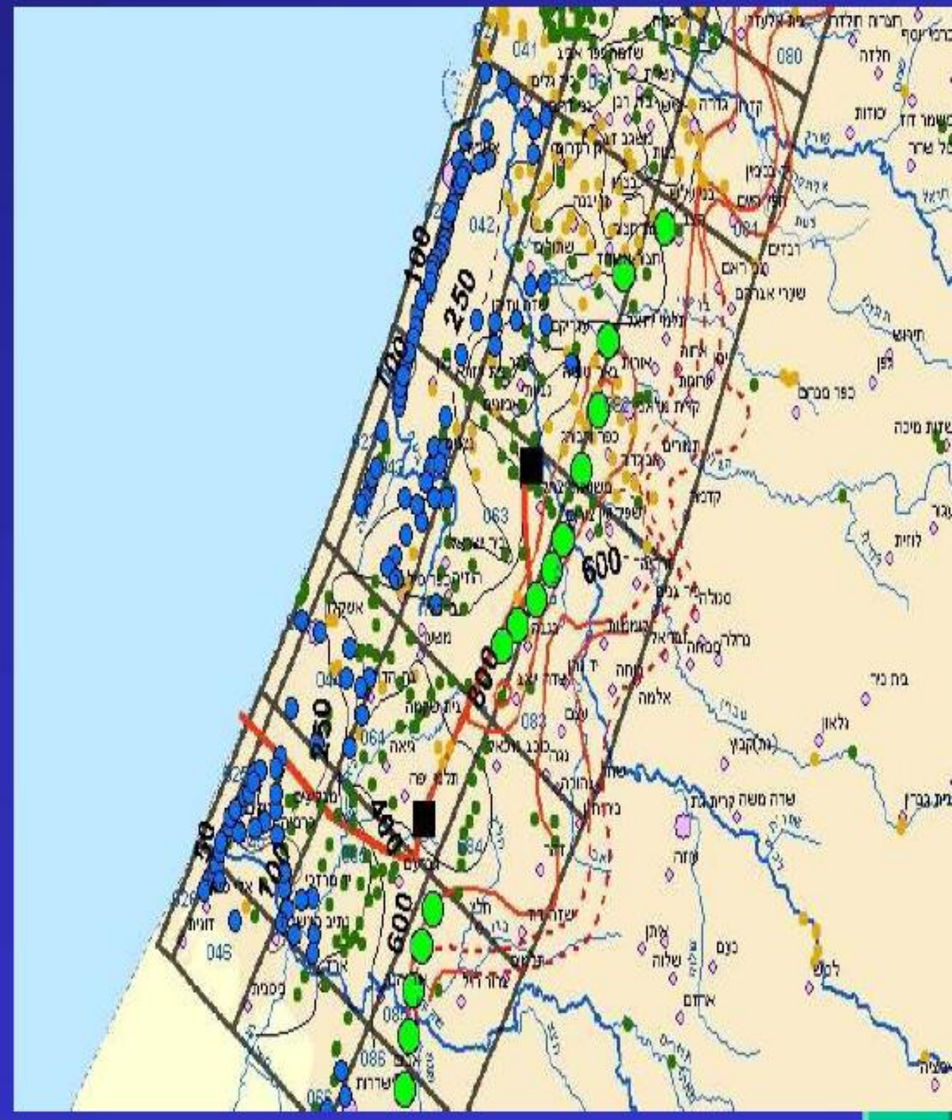
Potential Solutions

Rehabilitate and preserve natural sources

Rehabilitation of the Coastal Aquifer



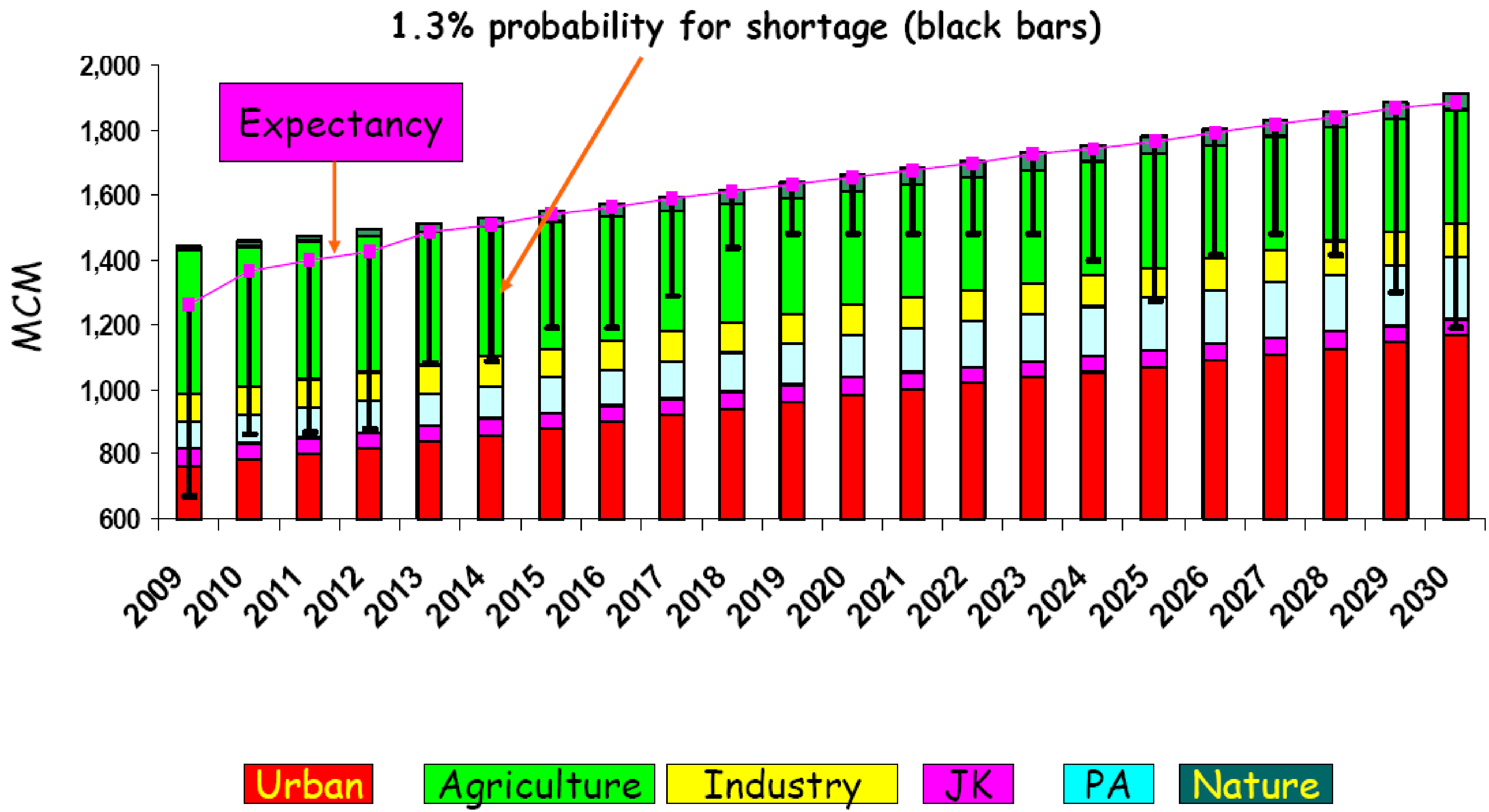




Potential Solutions

Planning & Risk Assessment

Scenario 3: 600 MCM Desalination in 2015, - 10% reduction in natural replenishment



Potential Solutions

Planning & Risk Assessment

Summery of results

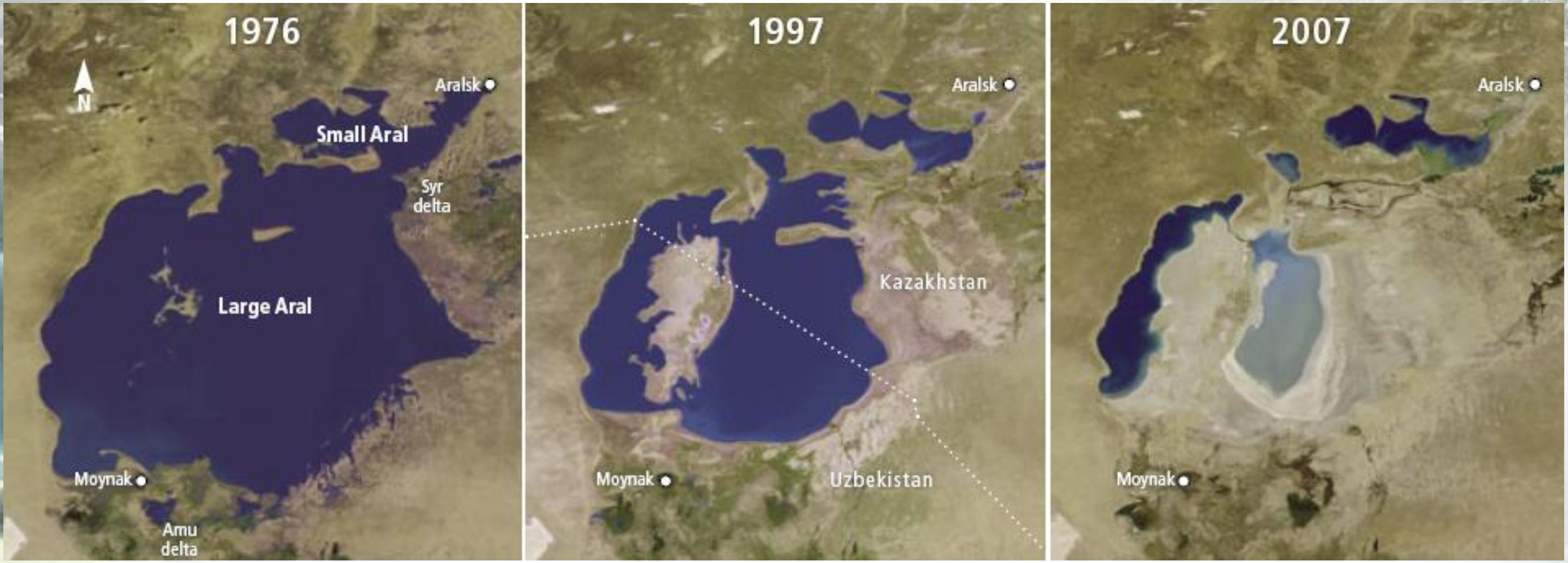
No	Scenario	Desalination 2015 capacity	Marginal cost	Addition al cost	Total NPV Incremental – 2008) cost (2020
		MCM/Year	NIS/CM	NIS/CM	Million NIS/Year
1	Base run	400	0	0.78	0
2	Supply -5%	500	14.3	1.11	1,433
3	Supply -10%	600	14.1	1.01	2,820
4	Supply -15%	650	16.8	1.13	4,196

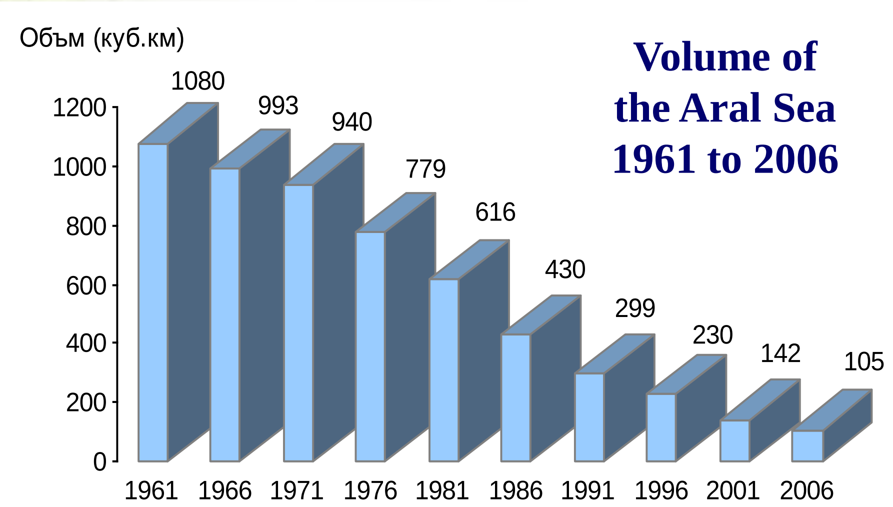
הערה: 1. חלופת בסיס כ - 10 מיליארד שקל בערך נוכחי.

2. לא מדובר בתוספת עלות למחיר בפועל.

Case study: Aral Sea

The degradation of the Aral Sea





Salinity increase from ca 14 to 100 g/l

ARAL SEA — 2008

… the environmental costs are so high that they go beyond the economic capacity of the newly independent republics in Central Asia.

- The World Bank

Ecological and socio-economic impacts

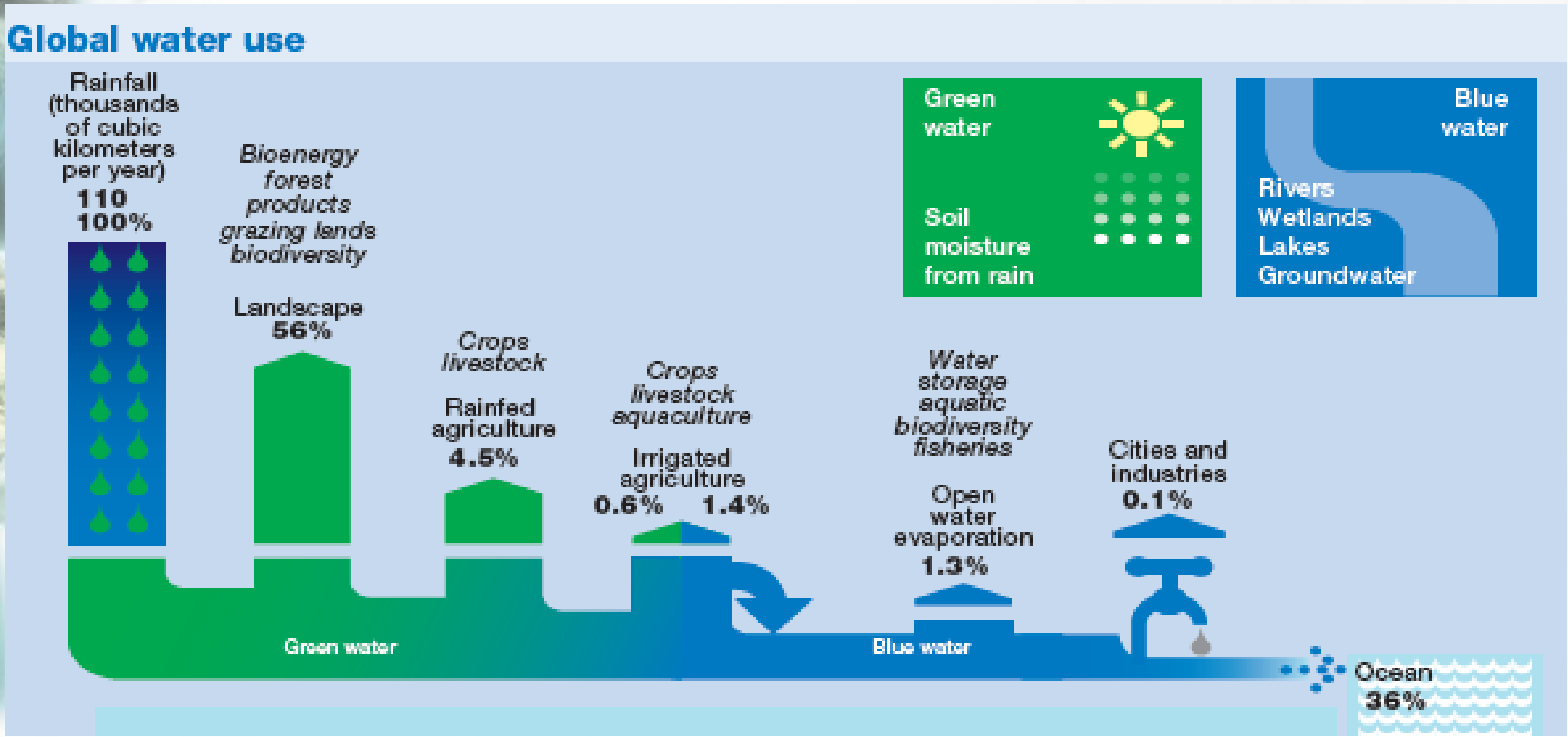
- Loss of biodiversity
- Disruption of ecosystem services
  - Fisheries
  - Climate regulation
  - Drinking water
  - Desertification
- Unemployment
- Impacts on human health
  - 75% of people in basin suffer from illnesses
  - 70% of fisherman are pre-cancerous

Case studies: Hydrological benefits of land-use and ecosystems

Land-use changes may result in lower run-off and more storage of water in soils

- Reduction of peak heights during floodings
- Release of water during droughts

Comprehensive assessment IWMI: change the way we think about water



Water Shortage in Cities

Drying up Water Resources

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Pumping of water at household level

Extraction of Fossil Water

Finally, Such a precious water dumped into the river without any treatment

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Centralized Wastewater Treatment Plants not in Operation !!!

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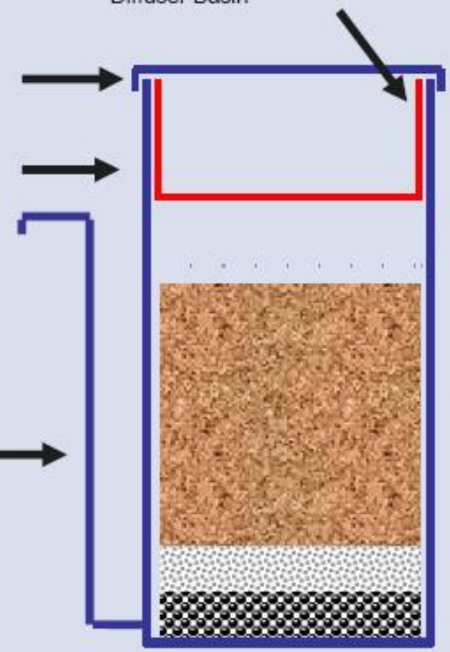
Eco-House

House Without City Water Supply
Reuse & Recycle of Waste

Built in 2002 occupies 135 m² Area

Dug well for groundwater collection and recharge

Treatment of Water



Greywater Treatment & Reuse

UN-HABITAT

WATER SUPPLY & DEMAND

Type of water use and requirement	Liters/month	%
Drinking & cooking	900	7
Dishwashing, bathing, showering, & laundry	7500	55
Toilet flushing, cleaning vehicle & gardening	5250	38
Total Water Demand	13650	100
Reuse of Treated Greywater	5250	38
Clean Water Requirement	8400	62

Perception from Visitors

Water existed long before the coming of humankind, and water will exist long after the going of humankind.

However, how we treat water during our brief passage on Earth will determine whether we and our children pass time in a dying world or a living heaven.

Simply – the choice is YOURS

The Holy Order of Water – William E Marks

NTNU

1st UNESCO IHP-VI workshop on
Integrated Urban water management in cold climate
3-4 November 2005, NTNU Trondheim Norway

Invited paper

Urban Water Management in Cold Climate

Technical issues

By

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NTNU

Cold climate conditions

According to Smith (1996) cold climate (CC) regions are, where the mean temperatures for one month of the year are below + 1°C and snow may stay on the ground for a period.

The temperature may range from as low as -50°C to as high as +40°C, a range on 90°C.

The climate is harsh, i.e. cold, snowy and windy, resulting in difficulties in water management and runoff conditions.

More than 1. billion people live in the CC regions.
Not all of them are "rich".

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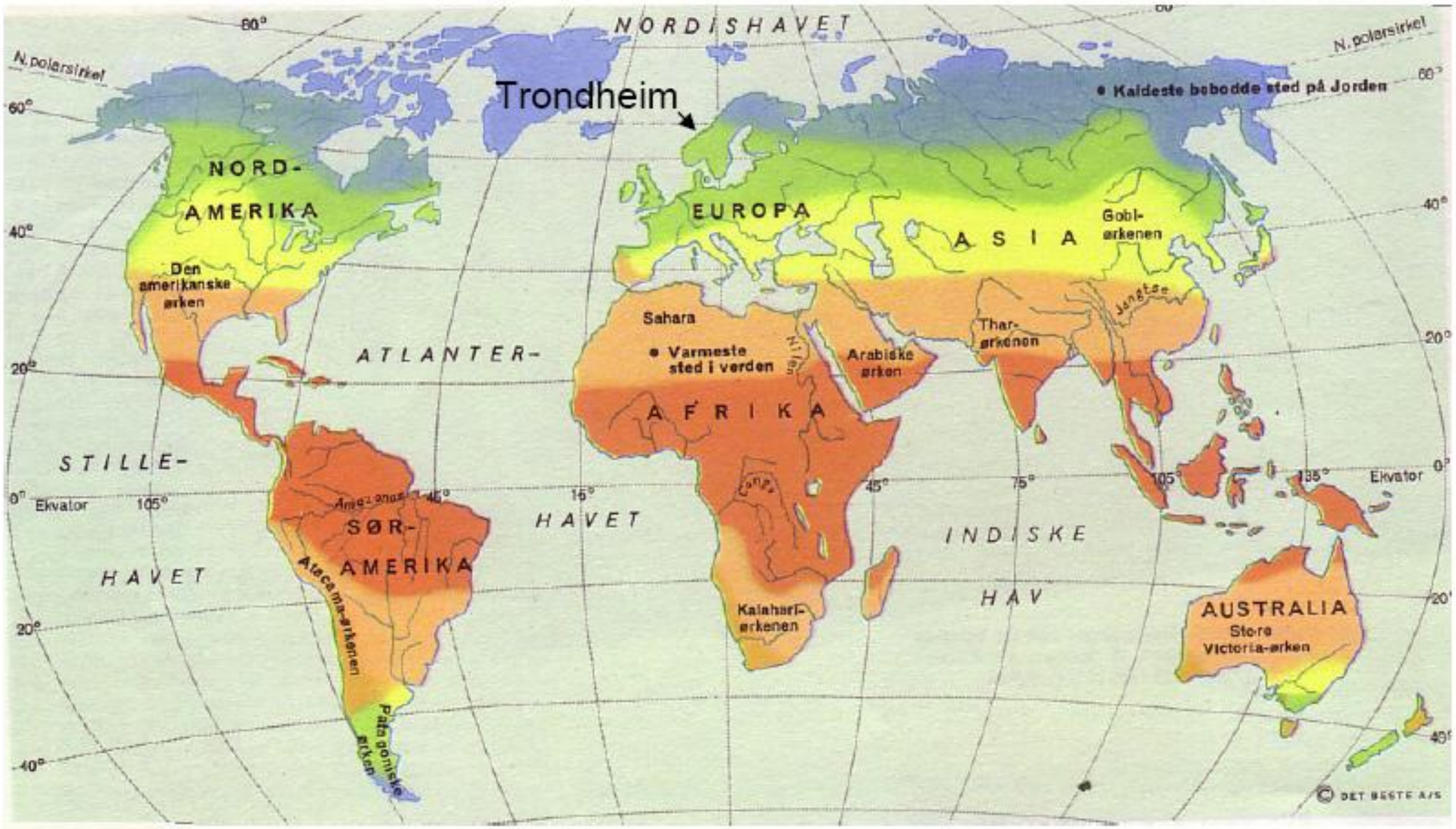
Where are the Cold Climate - regions?

The blue and green areas



- Always cold
- Warm summer – cold winters
- Very warm summer – cold winters
- Always warm
- Warm summer – Warm winters
- Always warm

Examples on unproper UWM in Trondheim, Norway

Polluting the drinking water

Jonsvannet (The Jons Lake)
The drinking water source
in Trondheim, Norway,
summer 2003.

Urban flood

Flooding in the Klæbustreet
in Trondheim, Norway
5th February 1999.

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Problems in CC-regions

Problems are due to:

- **Frozen ground**
- **Snow and ice cover**
- **Snow redistribution, most often man – made!**
- **Rain - on – snow**
- **Snow melting**

Problems in CC-regions (continue)

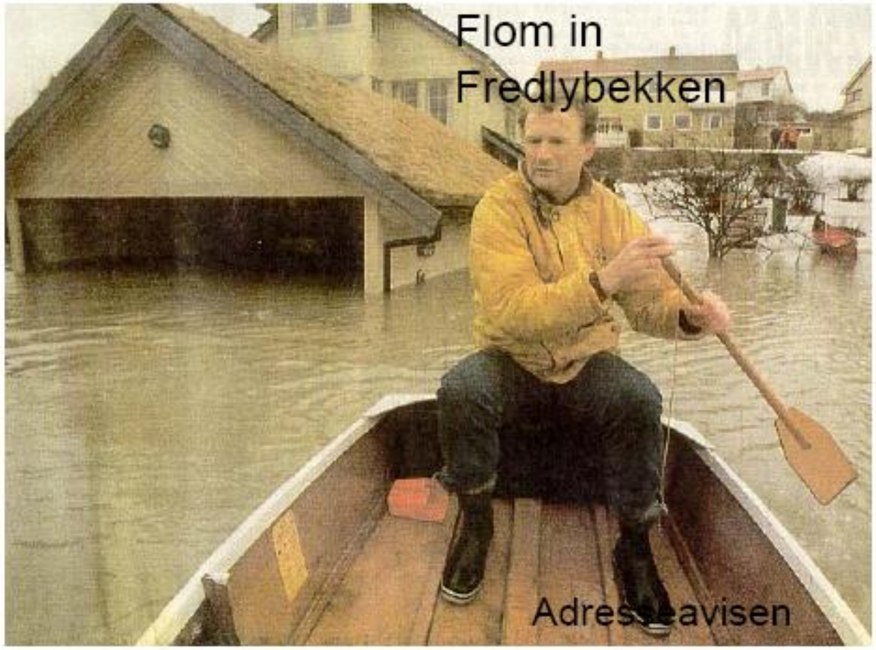
Problems are also due to:

- **Frost heave and freezing in pipes**
- **Ice on ground**
- **Clogged gutter and inlets**
- **Icing in manholes and storm sewers**
- **Ice in water courses and recipients**

Concurrence in flooding

Bergen vs Trondheim

Bergen, Norway 15th February 1996



Snowmelt and rain in Trondheim
31st March 1997

Pollution in snow

What pollution is in the snow?

1) Heavy meatls; Cu, Zn, Hg, Cd etc.

2) Organic micro pollutions:

PAH, PCB, etc.

3) Sediments such as: sand, gravel, crushed stone, clay etc.

4) Organic matters as leaves etc.

5) Salt (NaCl)

6) De-icing components

Where are the pollutions going?

Above ground pipelines in Alaska

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Measuring problems in cold climate

Trondheim, Norway. February 1997

Photo Thorolfsson