MILLENIUM DEVELOPMENT GOAL (MDG)
“UNIVERSAL ACCESS TO IMPROVED SOURCES OF DRINKING-WATER AND SANITATION BY 2025”

The ancient Romans had better water quality than half the people alive now.
Water: Source of Life, Food and Fiber
Water, At Times, Brings Miseries Too.

Hurricane Katrina (Sept. 2005)

Kenya Drought (Spring 2006)

China Drought (Spring 2010)

City of Multan (Aug. 2010)
Water and Health

• Water responsible for spreading
  – 80% of diseases in developing countries
• Pathogens transmitted through water
  – Kill 25 million people every year by amoeba linked diarrhea, cholera, and typhoid
  – ~3900 children die EVERY DAY (WHO, 2004)
• 90% of 2.2 million deaths of children under 5
• The most effective management intervention
  – Providing safe drinking water and proper disposal of human waste
Water Resources: Challenge

• Two Main challenges
  – Enough water of adequate quality to all, at all places, at all times and at an affordable cost
  – Sufficient resilience against floods and droughts

• Have we, as a global society, met the challenge?
  – The answer is: an emphatic “NO”

• Can the challenge be met?
  – The answer is: “Yes” but with certain constraints

• Are we on track to meet the challenge?
  – The answer is: partly “Yes” partly “No”
Factors Compounding the Challenge

Rapid Urbanization:
• Massive land use change
• Significant deforestation

Global Warming/Climate Change:
• Increasing temperatures
• Changing rainfall patterns
• Increasing hurricane activity
• Increasing tornado activity
• Increasing frequency of floods
• Increasing frequency of droughts
FACTORS COMPOUNDING THE CHALLENGE (CONTD.)

Global Warming/Climate Change:
• Migration of people for lack of water
• Human health
• Risk to ecosystem
• Threat to infrastructure
• Challenge to engineering design

River Systems at Risk:
• Misuse and gradual destruction of rivers

Current Life Style:
• Enormous thirst for energy

Is our civilization at risk?
• Probably
Questions

• Do we have enough water?
• Will we have enough water at an affordable cost
  – in the foreseeable future?
  – in the distant future?
• How does climate change impact water availability and how do we prepare for it?
  – Planning
  – Infrastructure development
  – Design
  – Management
Diverging Viewpoints: Availability of Freshwater

• Plenty of water to go around and people are not using all that much water.
  – Thousands of cubic kilometers of freshwater fall as rain, snow, or come from melting ice.
  – Outside of the Middle East, most nations use one fifth or less of water they receive.
  – Global average withdrawal of freshwater <9% of that flows through the hydrologic cycle.
  – Latin America and Africa use less than 6%.
• All problems are local.
• How much water can people safely use?
  – It cannot be 100% for sure. At places it may be less than 20%, the average for Asia as a whole.
A Different Viewpoint

- Depleting groundwater resources
- Pollution of surface streams and rivers at an alarming rate
- Decaying water infrastructure
- There will not be enough clean water to support our current lifestyles.
- Half of world’s population will suffer from severe water shortages by 2025, three fourth by 2050.
- Quickly headed towards water bankruptcy
Global Water Situation: What is happening?

- Local water shortages are multiplying.
- Current patterns of use and abuse—the amount being withdrawn dangerously close to the limit and even beyond.
- An alarming number of rivers no longer reach the sea: The Indus, the Rio Grande, the Colorado, the Murray-Darling, the Yellow River—the arteries of main grain growing areas.
- Severe and long droughts in Australia, India, Brazil and South America: Hydroelectric power have not enough had water to drive turbines and there have been repeated brownouts.
- Excess pumping of water from rivers feeding Aral Sea in Central Asia led to its collapse in 1980.
Global Water Situation: What is happening? (Contd.)

- Freshwater fish populations are in precipitous decline: Fish stocks fallen by 30% (WWF for Nature), larger than fall in populations of animals in any ecosystem.
- 50% of world’s wetlands have been drained, damaged or destroyed in the 20th century.
- Fall in volume of freshwater in rivers: Invasion of saltwater in delta, changing in balance between freshwater and salt water
- Global water crisis: Impact on supplies of food and other goods.
Meeting the Challenge: Equation

- Availability of water
- Supply of water
- Demand for water
- Need for water
- Use of water
- Strategy
WATER AVAILABILITY

Freshwater Storage
Rainwater Variability
Limited Fresh-Water!

Total water: 1,400 mn cu km
- 97% saline
- 2.5% fresh (35 million cubic kilometers)
- Only 0.8% usable (12 mn cu km)
- 1/3 of this is too polluted (8 mn cu km)

Freshwater: 42 mn cu km
- 68.7% Ice, glaciers etc.
- 30.1% fresh groundwater
- 0.26% Lakes (105 K cu km)
- 0.006% Rivers (2500 cu km)
Per-Capita Freshwater Availability (2000)

Countries with the least freshwater resources
Egypt: 26
United Arab Emirates: 61

Countries with the most freshwater resources
Suriname: 479,000
Iceland: 605,000

Data not available

m³ per capita per year
Per Capita Water Storage
(Dams and Other Storages in cum/capita)

Asia = 400; India = 130; US = 5000 cum/capita
Precipitation Variability

Map 2 - Mean annual precipitation [mm]
climate normal 1961-1990

(c) Center for Environmental Systems Research,
University of Kassel,
May 2002 - Water GAP 2.1D
Runoff Variability

Map 4. Long-term average runoff on a global grid [mm/annum]

(© Center for Environmental Systems Research, University of Kassel, April 2002 - Water GAP 2.1D)
Flow Variability at Kotri Barrage

March 14, 2009

June 29, 2009

August 24, 2010

August 25, 2010
WATER DEMAND AND USE
Individual Water Use

• A person needs 4 to 5 gallons of water per day to survive.
• The average American *individual* uses 100 to 176 gallons of water at home each day.
• The average African *family* uses about 5 gallons of water each day.
• Poor people living in the slums often pay 5-10 times more per liter of water than do wealthy people living in the same city.
Virtual Water Use

- **Meaty American and European diets**
  - 5,000 l of water/day
- **Vegetarian African and Asian diets**
  - 2,000 l of water/day
- **Meat consumption in China**
- **Dietary habits difficult to be reversed!!**
Water and Energy

- Energy production needs a lot of water
  - ~ 25 gallons per kWh
  - ~ 39% of freshwater withdrawals in USA (excluding hydropower demand) are for thermoelectric plants (136 bgd)
Water and Energy (Contd.)

- Huge amounts of energy are needed for making water available to various users
  - Withdrawal, conveyance, treatment, and supply
  - In USA: 116 billion pounds of CO$_2$ while producing such energy
    - Equal to pollution from 10 million cars
Water Use for Energy Production

- Electricity production is one of the largest users of water. [Example: For a 60-watt incandescent light bulb burning for 12 hours a day for a year in 111 million houses, a powerplant would consume about 655 billion gallons of water.]

- Water use efficiency (Virginia Tech Study, 2008)
  - Natural gas  3 gallons/million BTU
  - Hydroelectric  20 gallons/million BTU
  - Coal  41 to 464 gallons/million BTU
  - Liquid natural gas  145 gallons/million BTU
  - Nuclear  2,400 to 5,600 gallons/million BTU
  - Fossil fuel thermoelectric  230 to 270 gallon/million BTU
  - Ethanol  2,500 to 29,100 gallons/million BTU
  - Biodiesel  14,000 to 75,000 gallons/million BTU

- Biofuels – an irony when it comes to water
  - Currently 2% irrigated water used for energy crops
  - If all plans were implemented, 180 km³ of water will be needed.
POPULATION RISE AND DEMOGRAPHIC CHANGES
World Population Evolution

Three hypothesis for the world population evolution:
According to the population bureau of the United Nations, the medium hypothesis is the most likely one: for 1995-2000 and 2045-2050, it takes into consideration the decrease of number of children per woman (2.82 to 2.15) as well as an improvement of life expectancy (65 to 76 years). The natural growth would fall from 1.35% in 1995-2000 to 0.47% in 2045-2050.

Constant progression:
The blue line represents what would be the demographic evolution if the current birth rate (2.82 children per woman).

Global Urban Population: Trend

Urban population: status and trends

- **Ratio of Urban to Rural population**
  - World population 2005: 6.4 billions
  - Urban: 49%
  - Rural: 51%

- **Urban Population (billions)**
  - Low and middle income countries
  - High income countries

Sources: Food and Agriculture Organization statistical databases (FAOSTAT); Country income according to World Bank 2005.
WATER WITHDRAWAL
Sector-wise Global Withdrawals (1900-2000)

Source: Abramovitz 1996 (1)
Urban Water Supply Coverage
(Continent-wise)
CRISES: WATER, FOOD, ENVIRONMENT, AND ENERGY
### Global Water Stress

<table>
<thead>
<tr>
<th>State</th>
<th>Parameter</th>
<th>1995</th>
<th>2025</th>
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<tbody>
<tr>
<td><strong>Stressed</strong></td>
<td>Population</td>
<td>270 mn</td>
<td>2.3 bn</td>
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<td></td>
<td># of Countries</td>
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<td>15</td>
</tr>
<tr>
<td><strong>Scarce</strong></td>
<td>Population</td>
<td>166 mn</td>
<td>1.7 bn</td>
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<tr>
<td></td>
<td># of Countries</td>
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<td>39</td>
</tr>
</tbody>
</table>

- **Water Scarce** (<1000 m³ per capita/year)
- **Water Stressed** (<1700 m³ per capita/year)
Water Stressed River Basins
Depleting Lake Waters
(e.g., Lake Chad)

This collection of maps has been sourced from a series of satellite images provided by NASA Goddard Space Flight Center:
Typical Ground Water Depletion Rates
Absolute Scarcity for 1 billion People by 2025
(Many countries will import >10% of cereals)
Water Scarcity: Causes

• 80% is attributable (Vörösmarty et al. 2000)
  – Population rise
    – Higher food and energy requirements leading to higher water requirements
  – Economic development (changing habits/diets)

• In last 50 years
  – Population: from 3 billion to 6.5 billion
  – Water use: Tripled

• Projections: 2025 & 2050
  – Population: Increase by another 2 billion and 3 billion
  – > 50% people will be water stressed or scarce
IMPACTS OF CLIMATE CHANGE
Climate Change Impacts on Hydrology

- Intensification of the hydrological cycle
  - More floods and droughts
  - More variability in rainfall
  - Shorter snowfall season
  - Early spring snowmelt earlier
  - Accelerated glacial melting

- May affect water availability, water quality, ecosystems, etc.

IPCC (2007) Freshwater Resources and Their Management
DROUGHTS: SOME RECENT OCCURRENCES
Dark red shows severest drought. Most parts of Yunnan and Guizhou provinces suffered from the severest droughts. The drought was classified into five grades: severest, severer, moderate, mild, and normal.
Land, Rivers and Water Transportation During China 2010 Drought

Affected:
- 60 mn people
- 12 mn livestock
- 5 mn hect. crops

Cost = $3.5 billion
Severe Drought Fires in Russia

(2010)
Deaths Due to Droughts

[Graph showing the average annual deaths and the average population exposed to droughts from 1980 to 2000 for various countries, with a color gradient indicating relative vulnerability.]
FLOODS: SOME RECENT OCCURRENCES
2010 Flood in China

15-21 June

6-12 July

Severity:
3000 Deaths; 1100 Missing
305 mn people; 1.36 mn Houses
28 Provinces
100,000 sqkm. Land
$ 41 bn in Damages

13 Aug. 2010
Pakistan 2010 Floods
(Worst Natural Disaster Ever: U.N.)

Severity:
2000+ Deaths
20 mn People Affected
1 mn Houses Damaged
160,000 sqkm. Land
$ 6 bn in Damages
$45 bn Total Economic Impact

Total Rainfall During
1 July to 23 Aug.
Impacts on Water Resources

1. Thickness of small island freshwater lens declines from 25 to 10 m due to 0.1 m sea level rise by 2040-2080.

2. Streamflow decreases such that present water demand could not be satisfied after 2020, and loss of salmon habitat.

3. Groundwater recharge decreases by more than 70% by the 2050s.

4. Flooded area for annual peak discharge in Bangladesh increases by at least 25% with a global temperature increase of 2°C.

5. Electricity production potential at existing hydropower stations decreases by more than 25% by the 2070s.

6. Increase of pathogen load due to more heavy precipitation events in areas without good water supply and sanitation infrastructure.
DIRECTIONS IN HYDROLOGY AND WATER RESOURCES
Water: Basis of Human Prosperity

Water is a God’s Gift. We must use it wisely. We owe it to our future generations that we leave it to them in a better shape than the shape we got it in.

- Adequate and high quality water leads to development and growth of
  - Social
  - Economic
  - Cultural
  - Political systems

- If not attended, water problems can, at times, even lead to geo-politically destabilization
New Directions

- Data
- Uncertainty analysis and risk estimation
- Interaction between hydrology and climate
- Integrated modelling
- Integrated water resources management
- Integration of multiple sectors, stakeholders, and decision makers
- Emerging tools
IWRM

Integrated vision

Social Equity

Environmental Sustainability

Economic Efficiency

Integrated tools for planning and decision-making

Management instruments
- Assessment
- Information
- Allocation instruments

Enabling environment
- Policies
- Legislations
- Governance

Institutional framework
- Central-local
- River basin
- Public-private

Integrated management of water as a resource and integrated framework for provision of water service
Strategies for Sustainable Water Use

- Conservation
- Efficient Use
- Water Supply
- Treat-Ment
- Reuse
- Recycle
- Develop Additional Sources
  - Desalination
Emerging Tools

- Uncertainty analysis (entropy theory)
- Risk analysis
- Multivariate stochastic analysis (copula theory)
- Intelligent systems (ANN, Fuzzy, etc.)
- Optimization
- Decision support systems
- GIS
- Data collection and mining
The Way Forward!

• Innovative, revolutionary, and self-sustaining programs
• Diverse and multi-institutional partnerships
• Pricing and valuing water for enhancing water-use efficiency
• Strongly integrated planning for water, energy and agriculture
• Robust regional-capacity building
• Development paradigm: Distributed and controlled urban growth
Thanks