Global Management of Water Resources

- Earth’s water resource
- Sustainability
- Water supply
- Extreme events: floods and droughts
- Aquatic eco-system and health
- Integrated management
- Case study
The Earth’s Water Resource

Water is essential for life

Global water management concerns

- water availability
- influence of climate, risk
- sustainability
- decision-making
- legislation, insurance, conflict resolution
- gender, education
The Earth’s Water Resource

Total amount = 1360 M km³

Freshwater = 4 M km³

UN .... access to water is a basic human right, which entitles everyone to ‘sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses’

ECOSOC (2002)

UN Millennium Development Goal – to halve the number of people without sustainable access to adequate and affordable safe drinking water by 2015

UN (2005)
## Water Needs by Use

<table>
<thead>
<tr>
<th>Type of Use</th>
<th>Water Use (km$^3$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1900</td>
</tr>
<tr>
<td>Agriculture</td>
<td>525</td>
</tr>
<tr>
<td>Industry</td>
<td>38</td>
</tr>
<tr>
<td>Municipal</td>
<td>16</td>
</tr>
<tr>
<td>Reservoir loss</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>579</td>
</tr>
</tbody>
</table>

Shiklomanov (1991)
## Water Needs by Continent

<table>
<thead>
<tr>
<th>Continent</th>
<th>Water Use (km$^3$/year)</th>
<th>1980</th>
<th>2000</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>168</td>
<td>230</td>
<td></td>
<td>37 %</td>
</tr>
<tr>
<td>Asia</td>
<td>1784</td>
<td>2245</td>
<td></td>
<td>26 %</td>
</tr>
<tr>
<td>Australia/Oceania</td>
<td>29</td>
<td>33</td>
<td></td>
<td>14 %</td>
</tr>
<tr>
<td>Europe</td>
<td>445</td>
<td>534</td>
<td></td>
<td>20 %</td>
</tr>
<tr>
<td>North America</td>
<td>663</td>
<td>718</td>
<td></td>
<td>8 %</td>
</tr>
<tr>
<td>South America</td>
<td>111</td>
<td>180</td>
<td></td>
<td>62 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3200</strong></td>
<td><strong>3940</strong></td>
<td></td>
<td><strong>23 %</strong></td>
</tr>
</tbody>
</table>

Shiklomanov (1991)
## Variation in Water Availability

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Jordan</td>
<td>5</td>
<td>120</td>
<td>EL</td>
</tr>
<tr>
<td>Pakistan</td>
<td>137</td>
<td>490</td>
<td>EL</td>
</tr>
<tr>
<td>Poland</td>
<td>38</td>
<td>1200</td>
<td>VL</td>
</tr>
<tr>
<td>India</td>
<td>919</td>
<td>1380</td>
<td>VL</td>
</tr>
<tr>
<td>China</td>
<td>1209</td>
<td>1860</td>
<td>VL</td>
</tr>
<tr>
<td>Russia</td>
<td>148</td>
<td>29000</td>
<td>H</td>
</tr>
<tr>
<td>Brazil</td>
<td>159</td>
<td>40100</td>
<td>H</td>
</tr>
<tr>
<td>Canada</td>
<td>29</td>
<td>117000</td>
<td>VH</td>
</tr>
<tr>
<td>World</td>
<td>5629</td>
<td>6800</td>
<td></td>
</tr>
</tbody>
</table>

Shiklomanov (1991)
Sea Level Rise


U.S. EPA Climate Change Website
Sustainable Development

‘… meets the needs of the present without compromising the ability of future generations to meet their own needs’

WCED (1987)

Sustainability of a River System

River system unsustainable if rate of change to ecosystem > rate at which system can adequately respond

Sustainability used to examine ecological health

healthy river retains pristine aquatic conditions without human interference

sustainability (health) indicators are primarily biological
Water Supply

3 litres of water per day → bare existence

300 litres per day → full health

In Africa, daily consumption: 2 to 300 litres

“Water has an economic value in all its competing uses and should be recognized as an economic good. Within this principle, it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price.”

Dublin Water Conference 1992
Management of Water Supply

Engineering measures … reservoirs, dams …

Alternatively … **water pricing strategy**

domestic consumers → essential needs met

economic incentive → efficient water usage

optimization problem – solved using game theory

And … Government imposition of economic rules to stimulate or inhibit water supply measures
Limited data on extreme hydrological events

Hydrological processes are

- time-varying
- theoretically without an upper bound
- stochastic or random

Statistical approaches → probability of exceedence
Flood Insurance

Death toll ↓ due to better early warning systems

But economic losses ↑↑

Flood maps inform insurers

**Risk** = probability of occurrence of event × impact

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Average annual flood damage in 2080s

OST (2002)
Aquatic Eco-system

Inputs: energy, nutrients, water → living system
Affected by seasons, daily cycle, and pollution

Water Quality

1.8 million children die each year due to unclean water and poor sanitation (UN, 2006)
Drinking water → colourless, odourless, tasteless
Water quality assessed according to water constituents
‘Polluter pays’ principle
<table>
<thead>
<tr>
<th>Water-Related Disease</th>
<th>Cases/year (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trachoma</td>
<td>500</td>
</tr>
<tr>
<td>Elephantiasis</td>
<td>250</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>200</td>
</tr>
<tr>
<td>Malaria</td>
<td>160</td>
</tr>
<tr>
<td>Gastro-enteritis</td>
<td>100</td>
</tr>
<tr>
<td>Onchocerciasis</td>
<td>30</td>
</tr>
</tbody>
</table>

Classification … water borne (e.g. typhoid)

Bradley (1974) water-washed (e.g. trachoma)
water-based (e.g. schistosomiasis)
insect vector (e.g. yellow fever)
Integrated Management

Participatory approach

Conflict resolution

Ownership ....

International agreements problematic to negotiate
Enforcement difficult even through international courts
Approaches .....

Free market
Customary law
Free market approach

Countries with surplus water trade with those in need

Disputes settled through legal compensation

Difficult to resolve ownership of water

Example: Nile ownership – Egypt or Ethiopia

What are the rights of a downstream country if an upstream country decides to sell its water to a third party?

Example: sale of Euphrates’ water to Israel by Turkey
Riparian nations have sole legal right, unless otherwise agreed, to use water of a river.

Claims and counterclaims made by competing countries to establish rights:
- upstream countries claim sovereignty
- downstream countries claim river integrity should be preserved

Claims and counterclaims resolved by equitable utilisation

Dellapenna (1999)
Case Study of Water Shortage: The Aral Sea

‘WATER is the prerequisite for life, especially valuable in the tropics, in the desert, because there is so little of it. If I have sufficient water for only one field, I cannot cultivate two fields; if I have water for one tree, I cannot plant two trees. Every cup of water is drunk at the expense of a plant – the plant will dry out because I drank the water it needed to live. An unceasing battle for survival takes place here between people, plants, and animals, a battle for a drop of water, without there is no existence.’

Kapuściński (1994)
Case Study of Water Shortage: The Aral Sea

NASA Terra MODIS true-color image April 3, 2003
Case Study of Water Shortage: The Aral Sea

Case Study of Water Shortage: The Aral Sea

http://www.columbia.edu/~tmt2120/introduction.htm
Conclusions

Access to water resources is increasingly restricted due to population growth and socio-economic development.

Customary law useful for resolving water-use disputes.

Use of water is an economic good; access to water is a basic human right.

Management should be integrated, participatory, and sustainable.

Climate change and human impacts make hydrological forecasting very difficult.

Scenario-based risk analysis useful in assessing extreme events.
Acknowledgements

James Dooge (Ireland, 1922-2010)

Sergey Ivanenko (Russia, 1954-2003)

Boris Azarenok (Russia, 2011)
Ballad of Ecological Awareness

The cost of building dams is always underestimated -
There’s erosion of the delta that the river has created
There’s fertile soil below the dam that’s likely to be looted
And the tangled mat of forest that has got to be uprooted.

There’s the breaking up of cultures with old haunts and habits lost,
There’s the education program that just doesn’t come across,
And the wasted fruits of progress that are seldom much enjoyed
By expelled subsistence farmers who are urban unemployed.
There’s a disappointing yield of fish beyond the first explosion;
There’s silting up and drawing down and watershed erosion.
Above the dam the water’s lost by sheer evaporation;
Below, the river scours and suffers dangerous alteration.

For engineers, however good, are likely to be guilty
Of quietly forgetting that a river can be silty
While the irrigation people too are frequently forgetting
that water poured upon the land is likely to be wetting.
Then the water in the lake and what the lake releases
Is crawling with infected snails and water-borne diseases
There’s a hideous locust breeding ground when water level’s low
And a million ecological facts we really do not know.

There’s benefits, of course, which may be countable, but which
Have a tendency to fall into the pockets of the rich.
While the costs are apt to fall upon the shoulders of the poor.
So cost-benefit analysis is nearly always sure
To justify the building of a solid concrete fact
While the ecological truth is left behind in the abstract.

Kenneth Boulding (1973)