Is there a Global Water Crisis?

Peter Rogers
Harvard University
Tufts University Graduate Program in Water Issues
December 3, 2004
TO KEEP IN MIND

• Over 1 billion people without safe water
• 2.4 billion without access to adequate sanitation
• 10% of the world's food is grown with water from aquifers which are being depleted faster than the rate of recharge.

• What does this mean for ordinary people in the developing world?
  ➢ A farmer in Kenya: "Water is life and because we have no water, life is miserable."
  ➢ A young man in Russia: "How can we sow anything without water? What will my cow drink? Water is our life."
  ➢ An old woman in Ethiopia: "We live hour to hour, wondering whether it will rain."

• In many parts of the world, access to water and power distinguishes the poor from the non-poor.
AND

In the next 30 minutes about 180 children in developing countries - six children per minute - will have died from disease caused by unsafe water
SIX THINGS THAT COULD CAUSE A GLOBAL WATER CRISIS

• Global climate change
• Rapid population and economic growth
• Increased demands for irrigation water
• Increased demands for urban water
• Replacing environmental flows
• Trans-Boundary conflicts
  • Or
• Some combination of the above
huge needs

- over 1 billion people without safe water, 2 w/o sanitation, 4 w/o sewage treatment
- existing systems are run-down
- needs in developing and transition economies: up to $50bn/year or 1% of GDP

no money

- fiscal constraints
- official aid stagnant (< $3bn/yr, WB $1bn)
- public utilities unable to self-finance or to carry debt
- private investment: a relative trickle so far

An old story

what can we do?
• Water availability
• Climatic changes
• Growing pollution

Diminishing Resources

World population suffering from water shortage (millions)

Source: Masons Water Yearbook 2001
### Table b: Deaths by Age, Sex and Cause (2002)

<table>
<thead>
<tr>
<th></th>
<th>World Total</th>
<th>World Children (0-4)</th>
<th>Developed countries Total</th>
<th>Developed countries Children (0-4)</th>
<th>Developing countries (high mortality) Total</th>
<th>Developing countries (high mortality) Children (0-4)</th>
<th>Developing countries (low mortality) Total</th>
<th>Developing countries (low mortality) Children (0-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuberculosis</td>
<td>1,604,819</td>
<td>40,548</td>
<td>80,813</td>
<td>192</td>
<td>977,714</td>
<td>36,044</td>
<td>545,287</td>
<td>4,289</td>
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<tr>
<td>HIV/AIDS</td>
<td>2,821,472</td>
<td>370,841</td>
<td>56,860</td>
<td>543</td>
<td>2,610,716</td>
<td>363,149</td>
<td>151,651</td>
<td>7,041</td>
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<tr>
<td>Malaria</td>
<td>1,222,180</td>
<td>1,098,999</td>
<td>151</td>
<td>44</td>
<td>1,196,085</td>
<td>1,076,074</td>
<td>25,093</td>
<td>22,232</td>
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<tr>
<td>Diarrhoeal diseases</td>
<td>1,767,326</td>
<td>1,578,583</td>
<td>20,187</td>
<td>12,114</td>
<td>1,509,541</td>
<td>1,360,321</td>
<td>236,483</td>
<td>205,355</td>
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<tr>
<td>Respiratory infections</td>
<td>3,844,724</td>
<td>1,919,083</td>
<td>454,004</td>
<td>35,464</td>
<td>2,749,685</td>
<td>1,692,473</td>
<td>636,668</td>
<td>189,974</td>
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<tr>
<td>Lower respiratory infections</td>
<td>3,765,624</td>
<td>1,890,284</td>
<td>445,718</td>
<td>32,841</td>
<td>2,709,579</td>
<td>1,677,957</td>
<td>606,015</td>
<td>178,334</td>
</tr>
<tr>
<td>Upper respiratory infections</td>
<td>75,497</td>
<td>28,259</td>
<td>7,991</td>
<td>2,588</td>
<td>37,660</td>
<td>14,121</td>
<td>29,800</td>
<td>11,529</td>
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<tr>
<td>Otitis media</td>
<td>3,603</td>
<td>540</td>
<td>295</td>
<td>35</td>
<td>2,446</td>
<td>394</td>
<td>853</td>
<td>110</td>
</tr>
</tbody>
</table>


Reported in Evans, Hutton, and Haller, 2004
Don’t panic!

Douglas Adams,
The Hitchhiker’s Guide to the Galaxy

Help is on the Way

John Kerry
November 2, 2004
BOX 1 The eight Millennium Development Goals

With starting points in 1990, each goal is to be reached by 2015:

1. **Eradicate extreme poverty and hunger**
   Halve the proportion of people living on less than one dollar a day.
   Halve the proportion of people who suffer from hunger.

2. **Achieve universal primary education**
   Ensure that boys and girls alike complete primary schooling.

3. **Promote gender equality and empower women**
   Eliminate gender disparity at all levels of education.

4. **Reduce child mortality**
   Reduce by two-thirds the under-five mortality rate.

5. **Improve maternal health**
   Reduce by three-quarters the maternal mortality ratio.

6. **Combat HIV/AIDS, malaria, and other diseases**
   Reverse the spread of HIV/AIDS.

7. **Ensure environmental sustainability**
   Integrate sustainable development into country policies and reverse loss of environmental resources.
   Halve the proportion of people without access to potable water.
   Significantly improve the lives of at least 100 million slum dwellers.

8. **Develop a global partnership for development**
   Raise official development assistance.
   Expand market access.

Three points about the Millennium Development Goals: First, to be enduring, success in reaching the goals must be based on systemwide reforms to support progress. Second, focusing on these outcomes does not imply focusing on education and health services alone. Health and education outcomes depend on too many other factors for that to work—everything from parents’ knowledge and behavior, to the ease and safety of reaching a health clinic or school, or the technology available for producing outcomes. Third, in countries that have already achieved universal primary completion or low infant and maternal mortality rates, the spirit of the Millennium Development Goals—time-bound, outcome-based targets to focus strategies—remains important.
WATER RESOURCE BASE
Atmospheric Moisture

Total terrestrial water

Total Ocean water

Boxes indicate stocks; arrows indicate annual fluxes. All units in ‘000 km³. Source Data: Shiklomanov and Sokolov (1983).
Allocation of Terrestrial Renewable Fresh Water

- **RFWS_{land}** (110,300 km³/year)

- **Total runoff** (40,700 km³/year)
  - Remote flow (7774 km³/year)
  - Uncaptured floodwater (20,426 km³/year)

- Geographically and Temporally accessible runoff (AR) (12,500 km³/year)

- **Total evapotranspiration on land** (69,600 km³/year)

- Human appropriation of ET [18,200 km³/year (26%)]

- Human appropriation of accessible RFWS_{land} [24,980 km³/year (30%)]

- Human appropriation of total RFWS_{land} [24,980 km³/year (23%)]

- **Withdrawals** [4430 km³/year (35%)]
  - Human appropriation of AR [6780 km³/year (54%)]

- Instream uses [2350 km³/year (19%)]

- Source. Postel, et al., 1996
WORLDWIDE FRESHWATER ALLOCATION

World Total Water
- 97% Seawater
- 3% Freshwater

World Total Freshwater
- 13% Accessible Freshwater
- 87% Not Accessible Freshwater

World Total Accessible Freshwater
IPCC (TAR) Temperature Change Projections

It is like Alice’s Restaurant!

This shows the wide range of temperature outcomes for the scenario models chosen by the IPCC. The details of the scenarios are given in IPCC/TAR Volume 1.
A2: Slow decline in fertility levels and regional patterns of economic growth
B2: More rapid fertility decline and local economic solutions

Source: IPCC/TAR
Shortage, Scarcity, and Stress

1. **water shortage**: a dearth, or absolute shortage; low levels of water supply relative to minimum levels necessary for basic needs. Can be measured by annual renewable flows (in cubic meters) per head of population, or its reciprocal, viz. the number of people dependent on each unit of water (e.g. millions of people per cubic kilometer).

2. **water scarcity**: an imbalance of supply and demand under prevailing institutional arrangements and/or prices; an excess of demand over available supply; a high rate of utilization compared to available supply, especially if the remaining supply potentials difficult or costly to tap. Because this is a relative concept, it is difficult to capture in single indices. However, current utilization as a percentage of total available resources can illustrate the scale of the problem and the latitude for policymakers.

3. **water stress**: the symptoms of water scarcity or shortage, e.g. growing conflict between users and competition for water, declining standards of reliability and service, harvest failures and food insecurity. Difficult to capture in numbers, though a checklist approach is possible (FAO 1995, Ch. 2).
Critical regions of water resources in 2025 according to a baseline scenario of socio-economic and climate changes. “Critical regions” are river basins that fulfil the following conditions: (1) they are river basins under “severe water stress” in 1995, (2) water availability decreases under a reference climate scenario up to 2025, and/or (3) water withdrawals increase up to 2025 because of economic or population growth. (Source: Alcamo and Henrichs, 2001).
ECONOMIC AND SOCIAL SUSTAINABILITY?
Annual Water Withdrawals
(1987 GNP/capita $22,300)
Change in Water Use: Egypt and Korea

• **Egypt 1950**
  - population 20.33 million
  - income per capita $203
  - water available 58.8 cubic km
  - cereal self-sufficiency 63%

• **Korea 1950**
  - population 20.36
  - income per capita $146
  - water available 62.9 cubic km
  - cereal self-sufficiency 67%

• **Egypt 1995**
  - population 62.93 millions
  - per capita income $790
  - water for agriculture 47.9 cubic km
  - cereal self-sufficiency 63%

• **Korea 1995**
  - population 44.90 millions
  - per capita income $9,700
  - water for agriculture 12.6 cubic km
  - cereal self sufficiency 34%
FIGURE 12
GNP and Water Resources

Water Availability (m³/cap/yr)

5000

4000

3000

2000

1000

0

IRA
MAU
LBN
SYR
SOM
MAR
EGY
YEM
JOR

FIGURE 13
GNP and Water Resources, Excluding Major Oil Producers

Water Availability (m³/cap/yr)

5000

4000

3000

2000

1000

0

SOM
EGY
MOR
YEM
JOR

### Table 1: Sanitation Technology Cost Estimates (US$ 2000)

<table>
<thead>
<tr>
<th>IMPROVEMENT</th>
<th>JMP estimates</th>
<th>Other estimates</th>
<th>Recurrent Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AFRICA$^{*1}$</td>
<td></td>
<td>Level</td>
</tr>
<tr>
<td>Sewer and WWT</td>
<td>120</td>
<td>450$^{*1}$</td>
<td>v. high</td>
</tr>
<tr>
<td>Sewer connection</td>
<td>154</td>
<td>150-260$^{*2}$</td>
<td>High</td>
</tr>
<tr>
<td>Small bore sewer</td>
<td>60</td>
<td>120$^{*3}$</td>
<td>Medium</td>
</tr>
<tr>
<td>Septic tank</td>
<td>115</td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Pour-flush</td>
<td>91</td>
<td></td>
<td>med/low (lumpy)</td>
</tr>
<tr>
<td>VIP</td>
<td>57</td>
<td></td>
<td>low (lumpy)</td>
</tr>
<tr>
<td>Simple pit latrine</td>
<td>39</td>
<td></td>
<td>low (lumpy)</td>
</tr>
<tr>
<td>Improved trad. Practice + Hygiene Promotion</td>
<td>10$^{*8}$</td>
<td>low (US$0.60 per annum)</td>
<td>Household</td>
</tr>
</tbody>
</table>

Source: adapted from UNEP/GPA *Financing Domestic Wastewater Collection and Treatment in Relation to the WSSD Target on water and sanitation*

Reported in Evans, Hutton, and Haller, 2004
Table 6. Costs and benefits of water-related opportunities (billion US$)

<table>
<thead>
<tr>
<th>Water Opportunities</th>
<th>Total Benefits</th>
<th>Total Costs</th>
<th>Annualized B/C</th>
<th>Discount rate / remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community managed low-cost water supply and sanitation(^1)</td>
<td>392</td>
<td>80</td>
<td>4.9</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>502</td>
<td>102</td>
<td>4.9</td>
<td>5%</td>
</tr>
<tr>
<td>Small-scale water technology for livelihoods(^2)</td>
<td>350</td>
<td>50</td>
<td>7</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>100</td>
<td>7</td>
<td>5%</td>
</tr>
<tr>
<td>Re-use of waste-water for peri-urban agriculture</td>
<td>Very high</td>
<td>Medium</td>
<td>Very high</td>
<td></td>
</tr>
<tr>
<td>Sustainable agriculture in wetlands</td>
<td>Medium</td>
<td>Small</td>
<td>High</td>
<td>Focus on Africa</td>
</tr>
<tr>
<td>Research to increase water productivity in food production</td>
<td>Very high</td>
<td>Very small</td>
<td>Very high (15-20)</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Annualized costs, for the period 2004-2015. \(^2\) Multiplier for indirect benefits assumed as 3.

Rijsberman, 2004
AGRICULTURAL WATER
Food Security

- Irrigation produces 1/3 of food from 1/6 of cropland
- Losing irrigated land by 30% in 2025 and 50% by 2050
- In LDCs, 2% of irrigated land is mechanized (32% in US)
- 50% of people will depend on world markets for food
WATER?
200,000 kg of water

100 kilograms of grain

10 kilograms of people eating steak

WATER?
200,000 kg of water

100 kilograms of grain

10 kilograms of people eating grain
Irrigation effects on poverty

Net effect: districts with:

- < 10% of cropped area irrigated --- 69% below poverty line
- > 50% of cropped area irrigated --- 26% below poverty line
VIRTUAL WATER FLOWS AND TRADE LIBERALIZATION

Jorge Ramirez-Vellejo and Peter Rogers
Harvard University
Presented at the Stockholm Water Symposium,
August 12, 2003
ISSUES

• Agricultural Protection and Trade Liberalization
• Food Production and Security
• Trade in Embodied Water
Comparison of Estimates Under Current Trade Regime

- Hoekstra and Hung, 2002
  - 840 km$^3$ per annum
- Oki, 2002
  - 683 km$^3$ per annum
- WWC-FAO, 2002
  - 1,148 km$^3$ per annum
- Ramirez-Vallejo and Rogers, 2003
  - 684 km$^3$ per annum
Estimates Under Future Liberalized Trade Regimes

• Ramirez-Vallejo and Rogers, 2002
  – 984 km\(^3\) per annum for animal products liberalization
  – 749 km\(^3\) per annum for cereal products liberalization
The Virtual Waterfall of NAFTA

Before NAFTA
1993-1994

Canada
United States
Mexico

23.2 km³
8.4 km³
20.4 km³
1.14 km³

After NAFTA
2001-2002

Canada
United States
Mexico

36.6 km³
43.5 km³
16.0 km³
1.67 km³

Canada
United States
Mexico
URBAN WATER SUPPLY AND SANITATION

Typically huge poor population, villages within cities!
15 of top 20 mega cities globally will be in the poor countries by 2015
1975-2015 cities > 5 million go from 11 to 45 in the poor countries
Problems with the definitions: Adequate versus Improved?

- For water supply, “improved” provision is “reasonable access to water supply from a household connection, public standpipe, borehole, protected well, protected spring, and rainwater connection—with at least 20 litres per person per day available from a source within one kilometre of the user’s dwelling; piped systems are considered acceptable if they operate at 50 percent of capacity; hand pumps if they operate 70 percent of the time.

- For sanitation, “improved” provision is access to a private or shared toilet with connection to a public sewer or septic tank, or access to a private or shared pour-flush latrine, simple pit latrine or ventilated improved pit latrine. WHO staff that “improved” sanitation provision does not greatly reduce the risk of fecal-oral diseases.

Water: Growing Demand

- Growing population
- Exploding urban population

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

Source: Masons Water Yearbook 2001
This will cost a lot?

Need to add coverage of water to 280,000 and sanitation to 567,000 persons per day from now until 2015.

Annual Additional Funding Needed 2000-15 in billion US$

- World Bank $75
- Water Aid $25
- Vision 21 $19-34
- GWP $30
- IUCN $20
- Price Waterhouse $180

(Source, WSSCC, 2000)
<table>
<thead>
<tr>
<th>World Region</th>
<th>Population (m.)</th>
<th>Annual cost</th>
<th>People receiving improvement (millions)</th>
<th>Water MDG Annual cost</th>
<th>World population receiving improved water and sanitation Annual cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Saharan Africa</td>
<td>968</td>
<td>1,821</td>
<td>220</td>
<td>581</td>
<td>4,805</td>
</tr>
<tr>
<td>Latin America</td>
<td>624</td>
<td>731</td>
<td>75</td>
<td>224</td>
<td>1,911</td>
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<tr>
<td>East Mediterranean &amp; North Africa</td>
<td>373</td>
<td>250</td>
<td>32</td>
<td>67</td>
<td>635</td>
</tr>
<tr>
<td>Central &amp; Eastern Europe</td>
<td>460</td>
<td>237</td>
<td>27</td>
<td>74</td>
<td>622</td>
</tr>
<tr>
<td>South and SE Asia</td>
<td>2,162</td>
<td>4,513</td>
<td>592</td>
<td>475</td>
<td>9,977</td>
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<tr>
<td>West Pacific developing countries</td>
<td>1,673</td>
<td>3,736</td>
<td>490</td>
<td>667</td>
<td>8,806</td>
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<tr>
<td>Developed regions</td>
<td>923</td>
<td>269</td>
<td>32</td>
<td>44</td>
<td>625</td>
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<tr>
<td><strong>All regions</strong></td>
<td><strong>7,183</strong></td>
<td><strong>11,557</strong></td>
<td><strong>1,468</strong></td>
<td><strong>2,134</strong></td>
<td><strong>27,380</strong></td>
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</tbody>
</table>

Reported in Evans, Hutton, and Haller, 2004
Reasons NOT to Invest in the Water Business…

Degree of cost recovery

Financial autonomy
Reasons to Invest in Water and sanitation

Look at the Economic and Social Benefits—Do not focus on the Costs!
Table j: Total annual benefits of meeting sanitation MDG in natural units

<table>
<thead>
<tr>
<th>World Region</th>
<th>Pop’n (m.)</th>
<th>Current annual diarrhoea cases (million)</th>
<th>Diarrhoea cases averted</th>
<th>Hours gained per year due to closer access</th>
<th>Productive days gained (15+ age group) due to less illness</th>
<th>Nr of school days gained (5-14 age group)</th>
<th>Baby days gained due to less illness (0-4 age group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Saharan Africa</td>
<td>968</td>
<td>1,239</td>
<td>115</td>
<td>38,616</td>
<td>304</td>
<td>66</td>
<td>257</td>
</tr>
<tr>
<td>Latin America</td>
<td>624</td>
<td>552</td>
<td>25</td>
<td>9,306</td>
<td>114</td>
<td>21</td>
<td>41</td>
</tr>
<tr>
<td>East Mediterranean &amp; North Africa Central &amp; Eastern Europe</td>
<td>373</td>
<td>286</td>
<td>9</td>
<td>4,156</td>
<td>30</td>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>Europe</td>
<td>460</td>
<td>130</td>
<td>3</td>
<td>3,818</td>
<td>17</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>South and SE Asia</td>
<td>2,162</td>
<td>1,795</td>
<td>135</td>
<td>28,445</td>
<td>587</td>
<td>61</td>
<td>287</td>
</tr>
<tr>
<td>West Pacific developing countries</td>
<td>1,673</td>
<td>1,317</td>
<td>102</td>
<td>39,929</td>
<td>1,239</td>
<td>39</td>
<td>90</td>
</tr>
<tr>
<td>Developed regions</td>
<td>923</td>
<td>69</td>
<td>2</td>
<td>2,253</td>
<td>15</td>
<td>0</td>
<td>3</td>
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<tr>
<td><strong>All regions</strong></td>
<td><strong>7,183</strong></td>
<td><strong>5,388</strong></td>
<td><strong>391</strong></td>
<td><strong>126,523</strong></td>
<td><strong>2,306</strong></td>
<td><strong>194</strong></td>
<td><strong>707</strong></td>
</tr>
</tbody>
</table>

Source: Hutton – calculations updated for this paper

Table k: Some economic benefits of meeting sanitation MDG, and cost-benefit ratios

<table>
<thead>
<tr>
<th>World Region</th>
<th>Population (m.)</th>
<th>Health sector treatment costs avoided</th>
<th>Patient health seeking costs avoided</th>
<th>Annual value of time gain</th>
<th>Total benefits*</th>
<th>Benefit/Cost ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Saharan Africa</td>
<td>968</td>
<td>1,130</td>
<td>72</td>
<td>12,873</td>
<td>16,183</td>
<td>8.9</td>
</tr>
<tr>
<td>Latin America</td>
<td>624</td>
<td>514</td>
<td>16</td>
<td>5,695</td>
<td>7,325</td>
<td>10.0</td>
</tr>
<tr>
<td>East Mediterranean &amp; North Africa Central &amp; Eastern Europe</td>
<td>373</td>
<td>148</td>
<td>6</td>
<td>5,157</td>
<td>5,865</td>
<td>23.5</td>
</tr>
<tr>
<td>Europe</td>
<td>460</td>
<td>60</td>
<td>2</td>
<td>2,381</td>
<td>2,508</td>
<td>10.6</td>
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<tr>
<td>South and SE Asia</td>
<td>2,162</td>
<td>1,378</td>
<td>84</td>
<td>8,112</td>
<td>11,104</td>
<td>2.5</td>
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<tr>
<td>West Pacific developing countries</td>
<td>1,673</td>
<td>1,645</td>
<td>64</td>
<td>8,905</td>
<td>11,619</td>
<td>3.1</td>
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<tr>
<td><strong>All regions</strong></td>
<td><strong>7,183</strong></td>
<td><strong>4,955</strong></td>
<td><strong>244</strong></td>
<td><strong>51,525</strong></td>
<td><strong>63,269</strong></td>
<td><strong>5.5</strong></td>
</tr>
</tbody>
</table>

Source: Hutton – calculations updated for this paper.

Reported in Evans, Hutton, and Haller, 2004
Figure a shows a breakdown in the distribution of benefits.

**Figure a**

Share of each benefit compared to total economic benefits from meeting sanitation MDG, at global level

- School days, 8%
- Baby days, 1%
- Health sector savings, 8%
- Productive days, 1%
- Patient savings, 0%
- Time gain, 82%

Source: Hutton – estimates updated for this paper

Reported in Evans, Hutton, and Haller, 2004
<table>
<thead>
<tr>
<th>Region</th>
<th>Population (million)</th>
<th>Cost-benefit ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Saharan Africa</td>
<td>968</td>
<td>8.7</td>
</tr>
<tr>
<td>America</td>
<td>624</td>
<td>9.9</td>
</tr>
<tr>
<td>Mediterranean &amp; North Africa</td>
<td>373</td>
<td>23.7</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>460</td>
<td>10.6</td>
</tr>
<tr>
<td>And SE Asia</td>
<td>2,162</td>
<td>2.9</td>
</tr>
<tr>
<td>Pacific developing countries</td>
<td>1,673</td>
<td>3.4</td>
</tr>
<tr>
<td>Total</td>
<td>7,183</td>
<td>5.9</td>
</tr>
</tbody>
</table>

*– calculations updated for this paper*

Reported in Evans, Hutton, and Haller, 2004

Column should read Benefit/Cost Ratio
ENVIRONMENTAL FLOWS

IUCN defines environmental flows as a water regime provided within a river, or in a wetland or coastal zone (which may be groundwater), to maintain ecosystems and their benefits in a negotiated state, where there are competing water uses and flows are regulated.
Water Going to Waste?

There is no single molecule of water on the planet that is not actively employed in doing something. The concept of “going to waste” does not apply. What is involved is a choice of allocation among users and potential users. The choice is between homo sapiens and nature, and within the anthropogenic quota there are several competing users, industry, agriculture, and domestic. What’s left becomes “environmental flows.”
The Operation of the Cap on Murray-Darling Basin Diversions

Average flow to sea

Growth in Diversion up to 1993/94

Cap on Diversions

Annual Basin Diversion (GL)
Figure 2: Destination of run-off in the Murray-Darling Basin under ‘natural’ and ‘current’ conditions (based on modelled data).
International River Basin Conflicts: One Small War can Ruin Your Day

261 International Basins
45.3% of global land area covered
261 International River Basins

Vilfredo Pareto (1848-1923) was an Italian railway engineer turned economist who formulated a theorem that underpins much of modern welfare economics—that there exists a set of solutions involving multiple persons, or groups, which can not be improved upon (make some one person better-off) without making some one worse off.

A change that can make at least one individual better off, without making any other individual worse off is called a **Pareto improvement**, and when no further Pareto improvements can be made, **Pareto efficient**.

COASE’s THEOREM


Given well-defined property rights, low bargaining cost, perfect competition, and the absence of wealth and income effects, resources will be used efficiently and identically regardless of who owns them.
February 25 2003

- WRM&D essential for growth & poverty reduction
- Better management & more development
- Main challenge NOT vision but principled pragmatism
- Assist with stock of well-functioning infrastructure
- New business model for “high risk, high-reward” engagement
- Tailor to country conditions, consistent with CAS
Of course, it can never be sustainable unless....

• Given the large and growing size and wide spread of the species Homo Sapiens, it is not possible to maintain the *status quo ex ante*!

• Sustainability must contain some measure of compromise between human and nature’s use of water.
Dublin Principle IV

Water as an economic good

• Water has value as an economic good
• Values and charges are two different things
• Useful water value concepts
  – economic value
  – full value
• Useful water cost concepts
  – full supply cost
  – full economic cost
  – full cost
• The goal of full cost recovery
• Managing demand through economic instruments
• Financial self-sufficiency versus water as a social good
How to use Prices to Promote Equity, Efficiency, and Sustainability

Well Known Effects

1) Increased price reduces demand
   (i) Substitutes become cheaper
   (ii) Conservation becomes affordable
   (iii) Change consumption preference

2) Increased price increases supply
   (i) Marginal projects become affordable
   (ii) Provides economic incentives to reduce water losses

3) Increased price facilitates re-allocation between sectors
   (i) From irrigation to domestic and industrial
   (ii) From off-stream to in-stream uses
Less Well Known Effects

1) Increased prices improve managerial efficiency due to increased revenues
   (i) Improving maintenance
   (ii) Improving staff training and education
   (iii) Making modern monitoring techniques affordable
   (iv) Making modern management techniques affordable

2) Increased prices reduce the per unit cost of water to poor people
   (i) Increases coverage of poor urban and peri-urban populations because additional water is available for extending the system
   (ii) Reduces reliance by the poor on water vendors
   (iii) Makes water available to “tail-enders” in irrigation systems

3) Increased prices leads to sustainability
   (i) Reduces demands on resource base
   (ii) Reduces pollution loads due to recycling of industrial water
   (iii) Make more water available for ecosystems
Three important concepts

COST: O&M costs, capital costs, opportunity costs, costs of economic and environmental externalities.

VALUE: Benefits to users, benefits from returned flows, indirect benefits, and intrinsic values.

PRICE: Amount set by the political and social system to ensure cost recovery, equity and sustainability. The price may or may not include subsidies. Prices for water are not to be determined solely by costs or value.
General Principles for Value and Cost of Water

Cost:
- Full Cost
  - Full Supply Cost
    - Capital Charges
    - O&M Cost
    - Environmental Externalities
  - Full Economic Cost
    - Economic Externalities
  - Opportunity Cost

Value:
- Full Value
  - Economic Value
    - Net Benefits from Return Flows
    - Net Benefits from Indirect Uses
    - Adjustment for Societal Objectives
  - Intrinsic Value
    - Value to Users of Water
Comparison of Value-in-Use, Costs, and Prices Charged for Three Sectors in the Subernarehka River Basin, India

<table>
<thead>
<tr>
<th>Sector</th>
<th>Value</th>
<th>Cost</th>
<th>Tariff</th>
<th>Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>65</td>
<td>9.7</td>
<td>0.1</td>
<td>Cost/Value = 6.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tariff/Cost = .002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tariff/Value = .010</td>
</tr>
<tr>
<td>Urban Use</td>
<td>46.7</td>
<td>25</td>
<td>1.2</td>
<td>Cost/Value = 1.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tariff/Cost = .026</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tariff/Value = .048</td>
</tr>
<tr>
<td>Industrial Use</td>
<td>46.7</td>
<td>2.5</td>
<td>2.5</td>
<td>Cost/Value = .180</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tariff/Cost = .054</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tariff/Value = .001</td>
</tr>
</tbody>
</table>
Figure 3.1: Comparison between shadow prices of water and water fees in various irrigation districts in México

FULL-COST PRICING
The reliance on “full-cost pricing” as one major policy recommendation of the Water Commission’s Report leaves open the question of the exact definition of these words. There can be at least three definitions of full cost.

FULL SUPPLY COST
The first, full supply cost, is defined as the sum of the operation and maintenance costs plus the capital charges associated with the water supplied. Although there is little argument about the components of this cost, there are still arguments about which discount rate to use to compute the capital charges. Some would argue for the market rate, others for the opportunity cost of capital, and yet others for a social rate of discount. Depending upon the circumstances the choice may make a very large difference between the estimates of full supply cost.
Figure 11.6 Annual Investments and Revenue Collection (2001)
SUSTAINABLE MARKETS: Non-Market Systems are as Sustainable as Market Systems.
Valencia's Water Court. engraved by Tomas Rocafor, 1831.
...and Some Things are not!
Steamer on the Lower Colorado
Above is an early example of sport fishing for totoaba in the upper Gulf of California. These fish grew to well over 200 pounds in weight, and there are records of some that approached 300 pounds. The totoaba migrate from the upper Gulf of California to spawn in the brackish waters of the estuaries of the Colorado River delta.
REPRISE

SIX THINGS THAT COULD CAUSE
A GLOBAL WATER CRISIS

• Global climate change
• Rapid population and economic growth
• Increased demands for irrigation water
• Increased demands for urban water
• Replacing environmental flows
• Trans-Boundary conflicts
  • Or
• Some combination of the above
Nine Facts that may mitigate the Global Water Crisis

• Blue/Green/Brown water
  – Water moves from one to another state
• Asymmetries in water uses
  – Irrigation flywheel
• Virtual water escape hatch
  – Already resolving many water scarce situations
• Low cost desalination breakthrough
  – Coastal cities have almost unlimited supply of potable water
• Eco-sanitation revolution
  – Decoupling of water and sanitation
• Transboundary conflicts
  – Potential for good or evil
• Uncertainty of supply
  – Intrinsic variability and climate change
• Water is universally underpriced
  – Large potential for demand side management
• Idiosyncrasy of water institutions
  – Every country in the world suffers from overlapping controls on water
Most Important Focus of World Leaders

2004

- **Fresh water**: 93 high importance, 42 low importance
- **Renewable energy**: 85 high importance, 11 average importance, 4 low importance
- **Poverty**: 81 high importance, 16 average importance, 4 low importance
- **Public health**: 75 high importance, 20 average importance, 5 low importance
- **Biological diversity**: 70 high importance, 21 average importance, 8 low importance
- **Food security**: 69 high importance, 23 average importance, 8 low importance
- **Personal consumption in industrialized countries**: 54 high importance, 25 average importance, 21 low importance
- **Urban planning and infrastructure**: 50 high importance, 34 average importance, 15 low importance

The white space in this chart represents “DK/NA.”
Never say “Never”

- Technical fixes always help, but we already have all of the technology that we need to “survive” the next twenty to fifty years.

  **BUT**

- What always appears to be the limiting factor is the political will and effective institutions to take advantage of these technologies
Rachel Carson

• We stand now where *two roads diverge*. But unlike the roads in Robert Frost’s familiar poem, they are not equally fair. The road we have long been following is deceptively easy, a smooth highway on which we progress with great speed, but at its end lies disaster. The other fork in the road—*the one less traveled by*—offers our last, our only chance to reach a destination that assures the preservation of our earth. The choice, after all, is ours to make.