

GLOBAL WATER ISSUES

A Challenge for Earth System Science and Technology

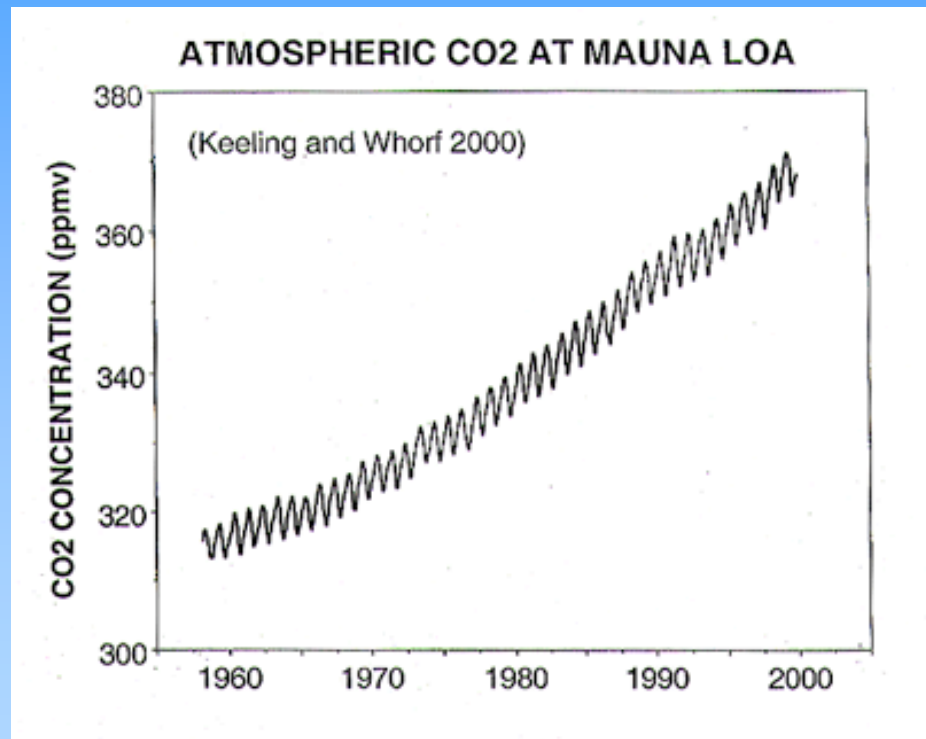


Charles J. Vörösmarty and many colleagues
from CCNY and UNH



*For the
Global
Climate
Challenge*

A Scientific
Data Set
That Has
Mobilized
the Politics
of a Planet



Sanitation and access to clean water



"Engineered" water



Water as Friend and Foe

Water for development



Food security



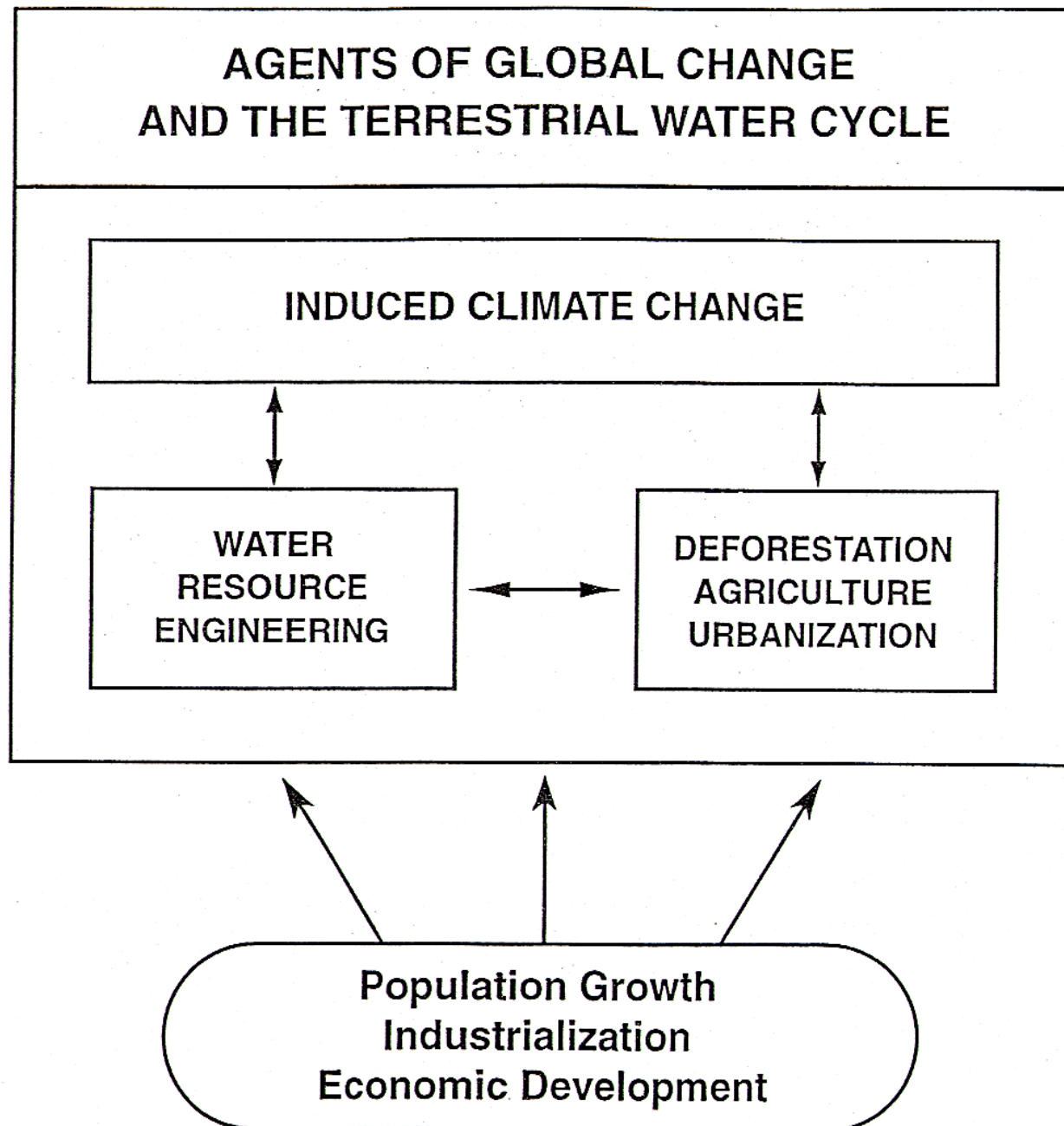
Weather extremes



Maintaining aquatic ecosystem services

Pollution





State-of-the-Global Water System

- In the broadest sense.....

“Global Climate Δ ”

\neq

“Global Change”

Roadmap for This Talk

- The Nature of the Beast
 - What Are the Key Challenges?
 - How the Challenges Are Organized?
 - What Perspectives Are Needed to Address the Challenges...*today and into the future* ?

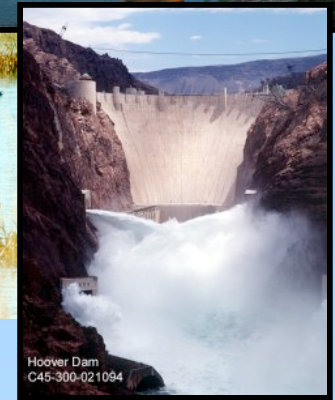
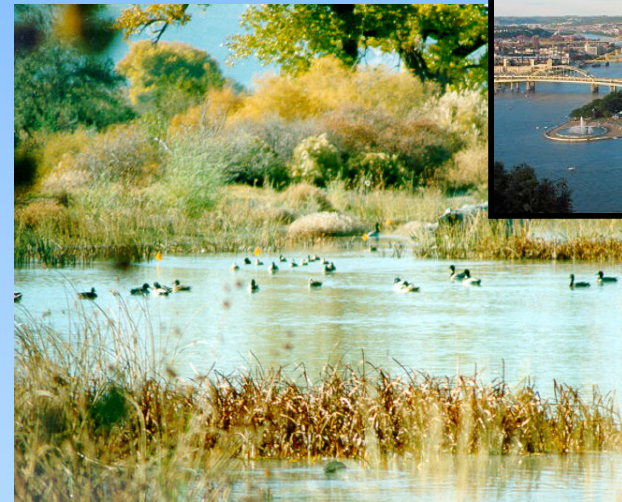
Major feature in the modern water system

Asymmetries between:

- Upstream/Downstream Users



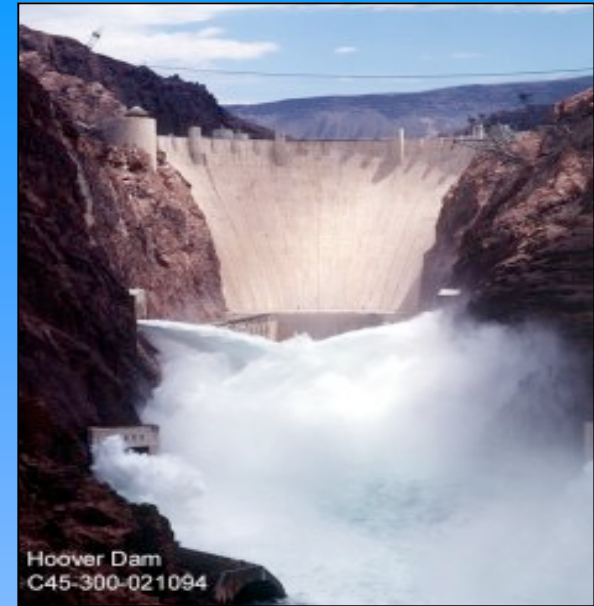
- Humans and Nature



...and both stressed by pollution, watershed mismanagement, poor engineering, biotic threats

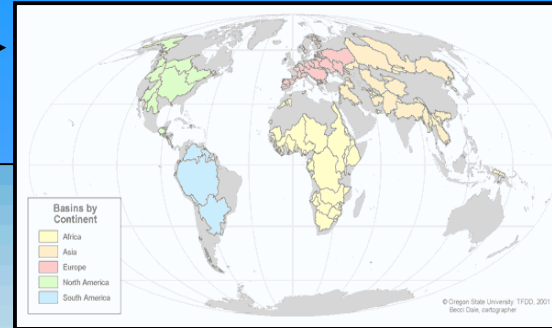
More People, More Development, Means More Water Engineering to Help Manage Asymmetries

- Widespread Hydrological Alterations
Arising from
 - *Irrigation*
 - *Dams and Reservoirs*
 - *Interbasin Transfer/Flow Diversion*
- Benefits & Concerns
- Often These are Costly Supply-side
Solutions



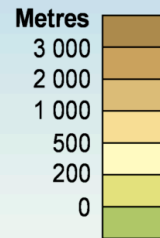
ASYMMETRIES IN WATER SUPPLY & USE DRIVE SOME OF THE CRISIS

261 Int'l Basins $\xrightarrow{\text{Source of conflict or *cooperation*?}}$



Water withdrawal and availability in the Aral Sea basin

- Flow generation:** water available in the country from rainfall and glacier melt
- Water abstraction:** withdrawal from surface water sources (rivers, canals and lakes)



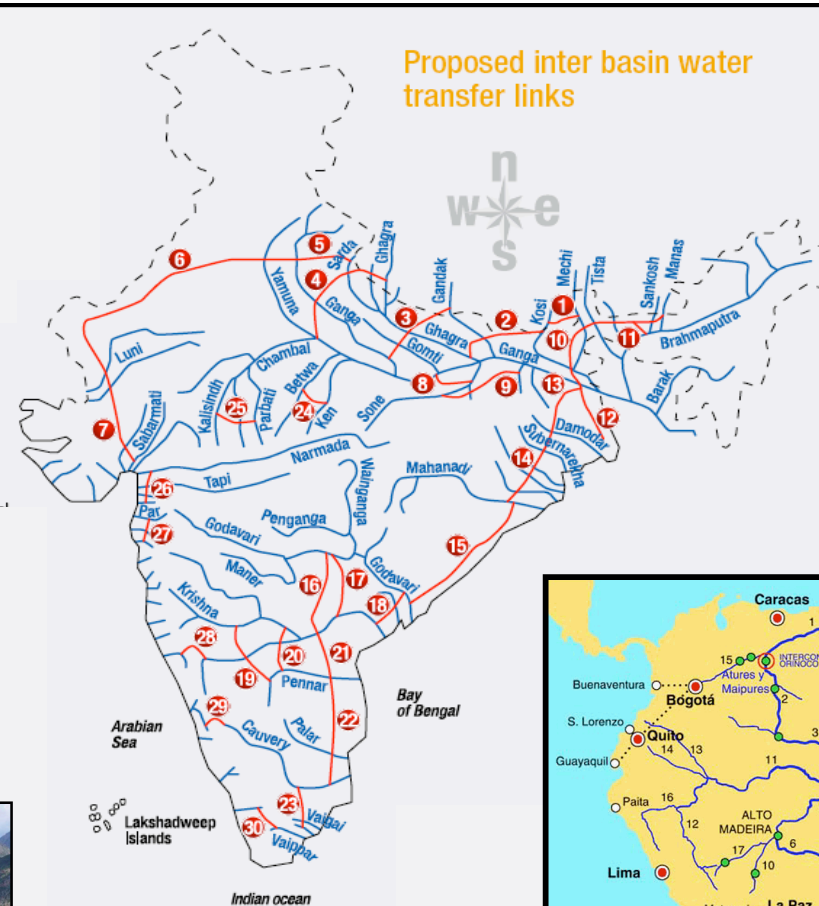
Source: Diagnostic Report on Water Resources in Central Asia, ICWC 2000.

THE MAP DOES NOT IMPLY THE EXPRESSION OF ANY OPINION ON THE PART OF THE AGENCIES CONCERNING THE LEGAL STATUS OF ANY COUNTRY, TERRITORY, CITY OR AREA OF ITS AUTHORITY, OR DELINEATION OF ITS FRONTIERS AND BOUNDARIES.

MAP BY VIKTOR NOVIKOV AND PHILIPPE REKACEWICZ - UNEP/GRID-ARENDAL - APRIL 2005

Physical Re-Connection: Inter-Basin Transfers & Flow Diversions

- Costly 'hard path'
- Engrain patterns of overuse
- Creates an asymmetry on both nature & human systems



← Forced by food security issues

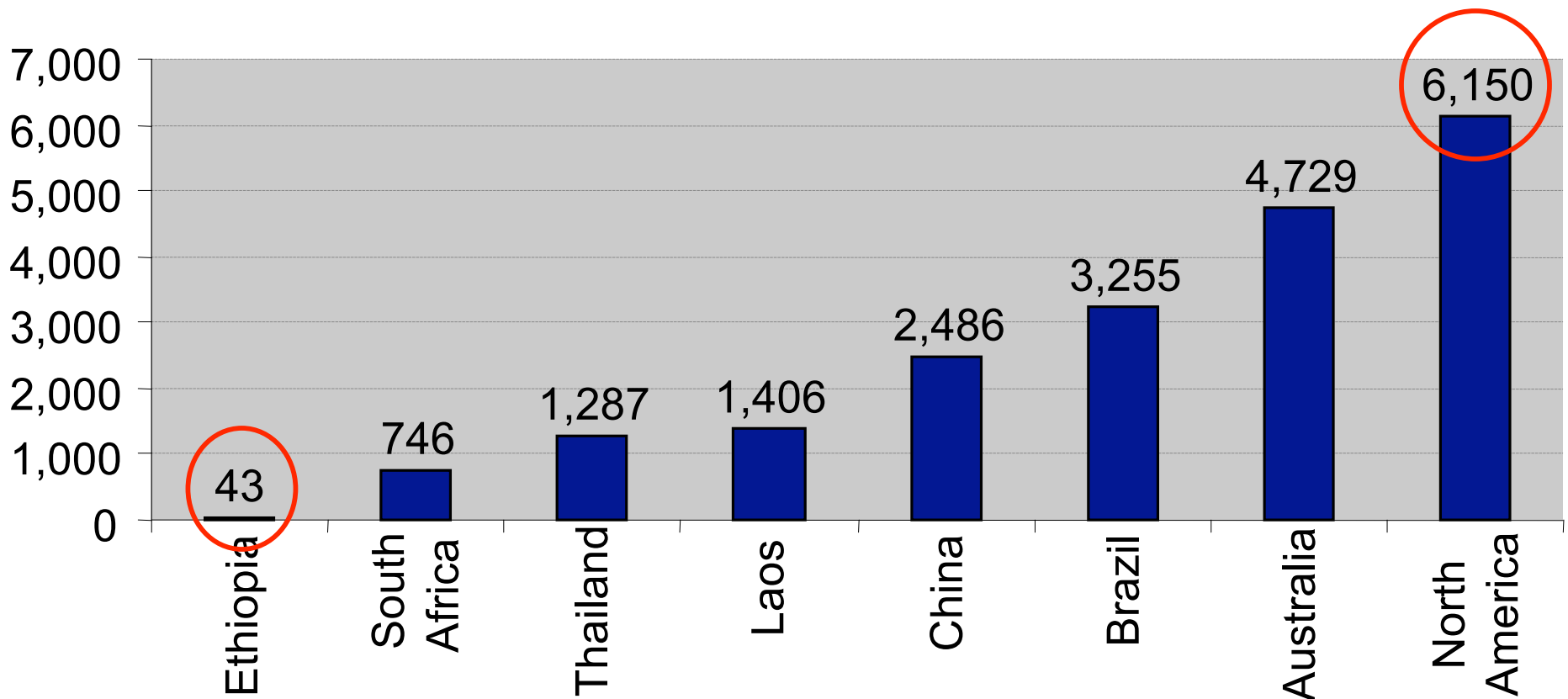
35,000 km of hydrovias....
direct links to globalization & food trade



Asymmetries in the Capacity to Control the Resource

Infrastructure gap: Reservoir water storage

Water storage per person (m³)



17th - 19th Centuries



20th Century



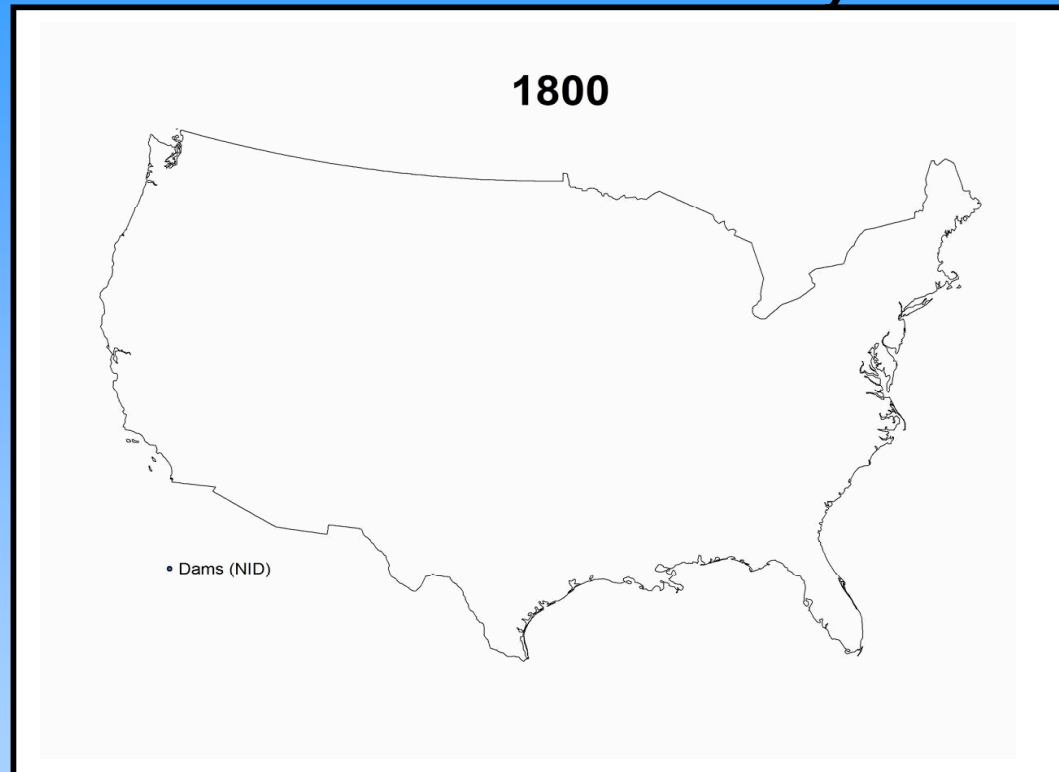
Hoover Dam
C45-300-021094

Changing Nature
Of Water Engineering

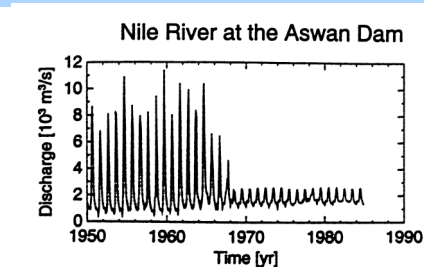
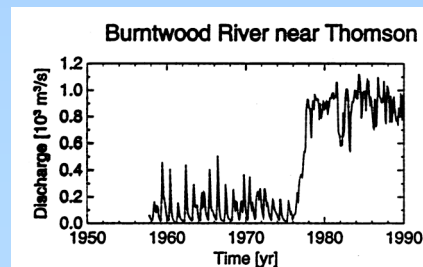
*“Instant” control thru
“instant” hydrograph distortion*

Trapping Water in Dams: A *hedge* against space and time asymmetries

Source : National Inventory of Dams

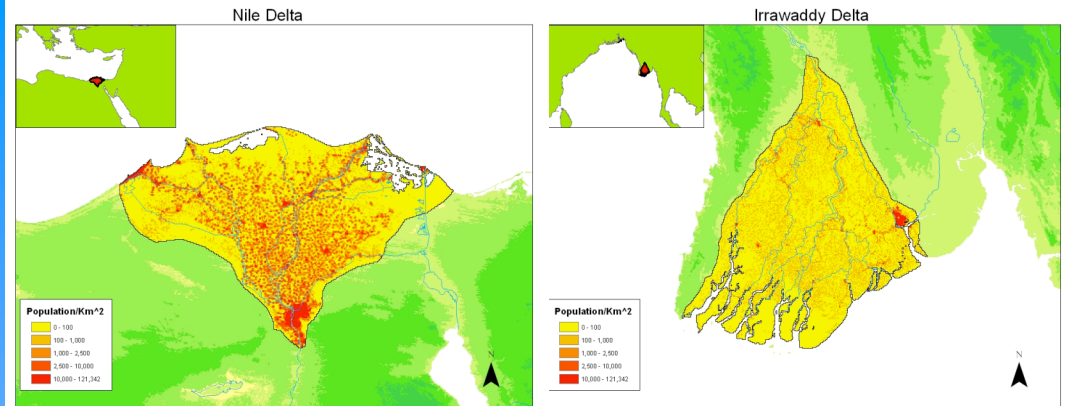


...emblematic of water development globally

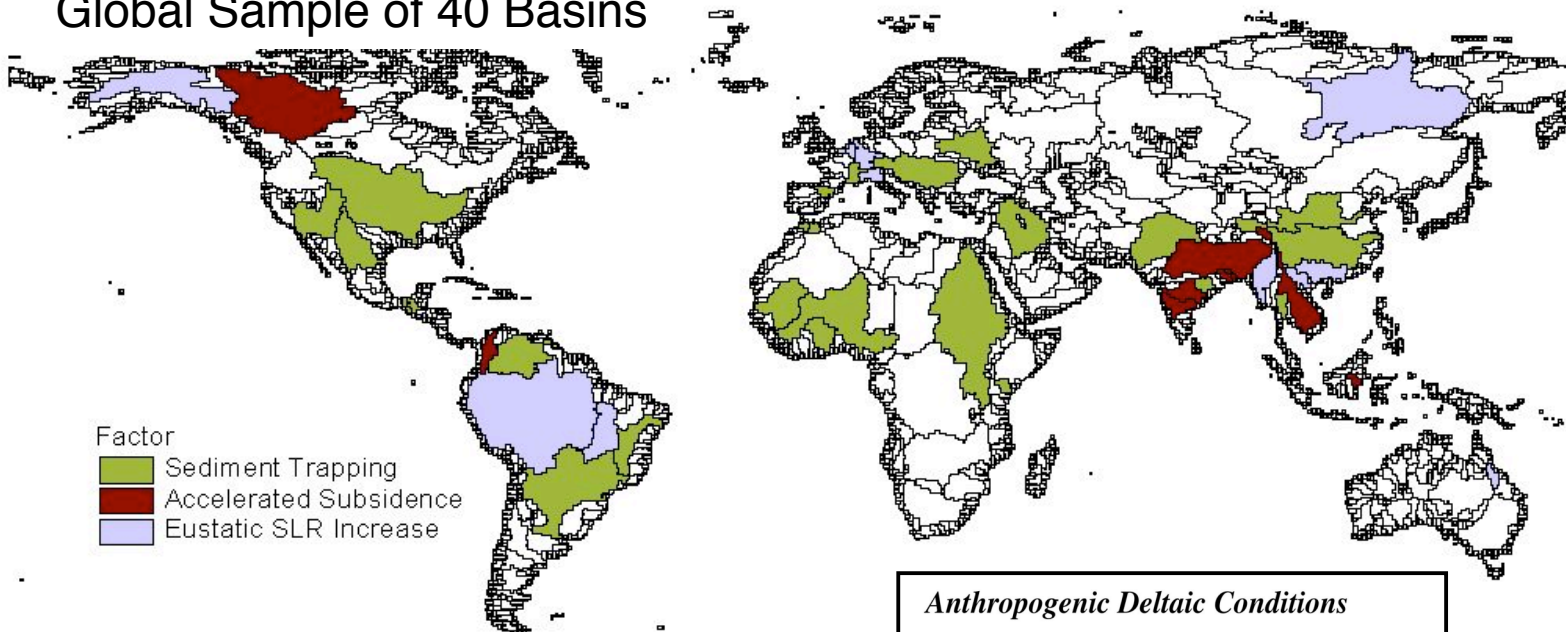


Deltas Under Threat

Basin Water Management Reverberates to Coastlines: *Eustatic/Steric Sea Level Rise Only Part of the Story*



Global Sample of 40 Basins

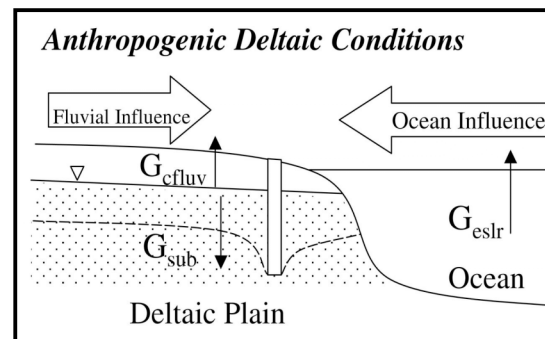


Factor

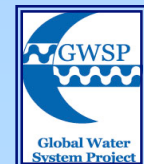
- Sediment Trapping
- Accelerated Subsidence
- Eustatic SLR Increase

Sources of Change:

- 5 Global Sea Level Rise
- 8 Groundwater/petroleum extraction
- 27 Upstream sediment trapping & diversion

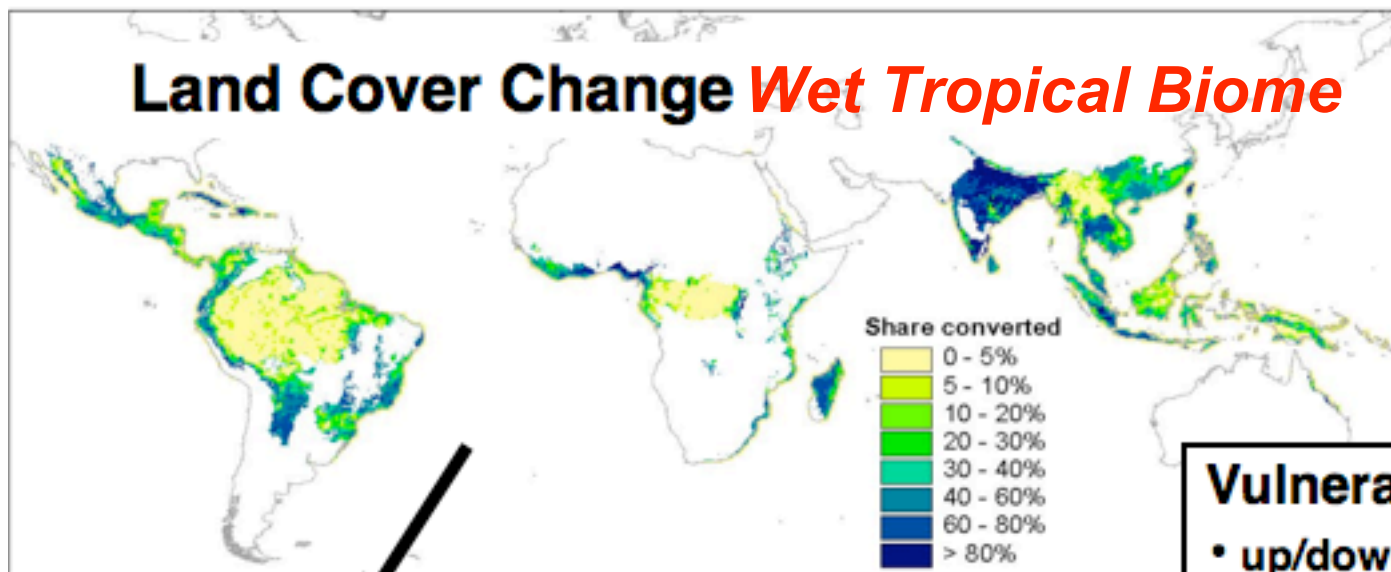


*~0.5 Billion
People
Live on
Deltas
Worldwide*

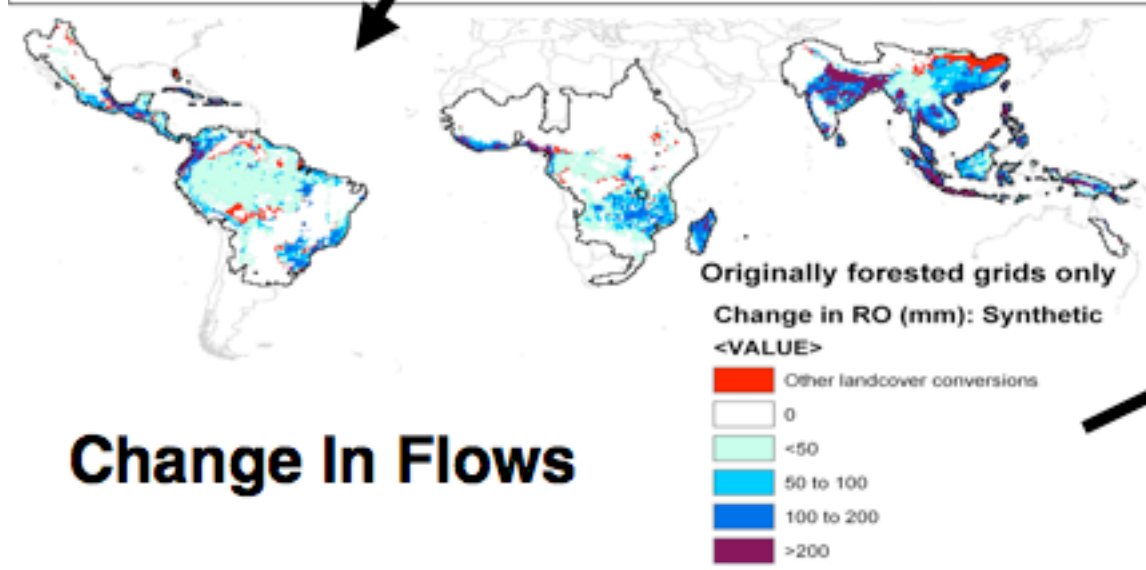


LANDSCAPE MANAGEMENT MATTERS

Upstream-Downstream Asymmetries



**NEW CLASSES
OF
“teleconnections”**



Vulnerability Translated

- up/downstream stakeholders
- humans & nature

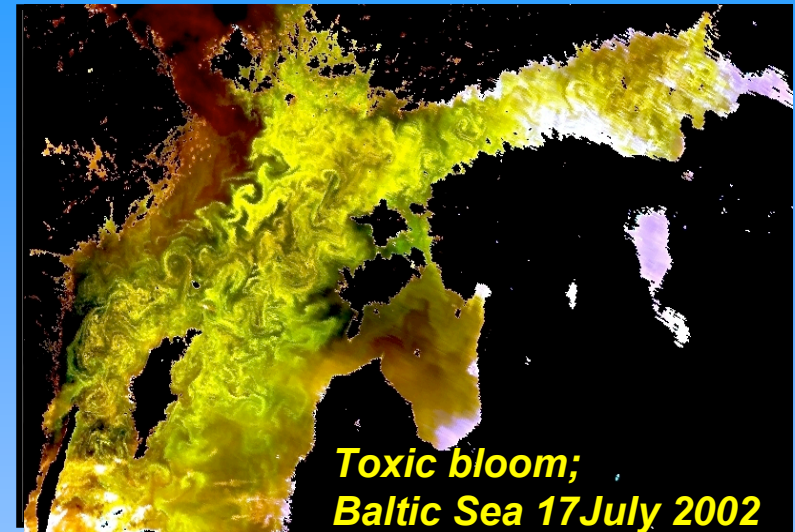
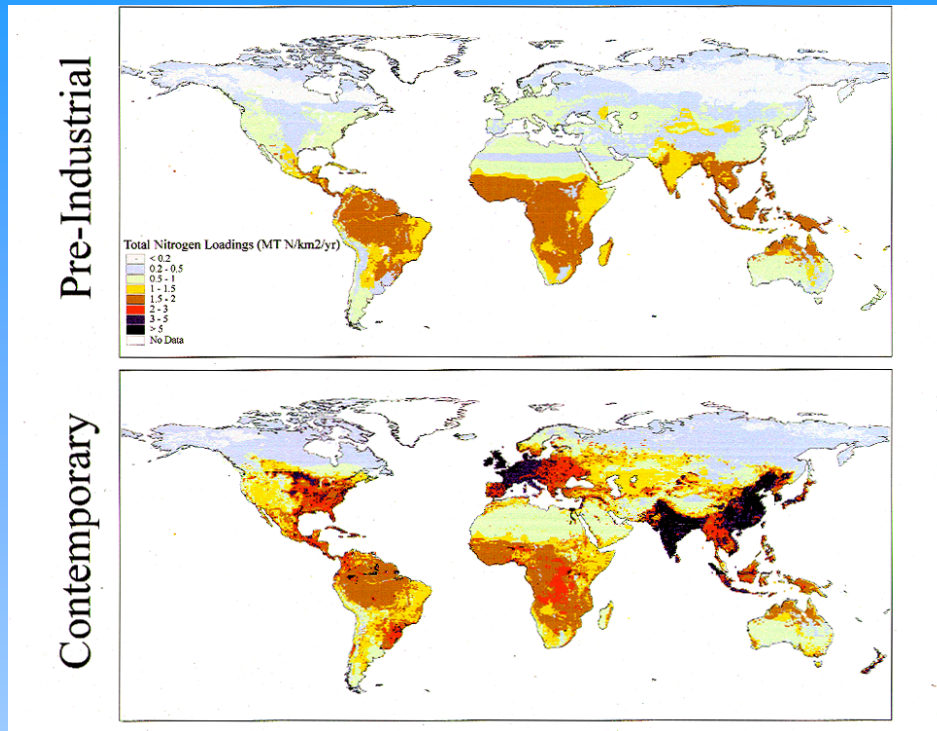
600M at risk

Population density
within floodplains



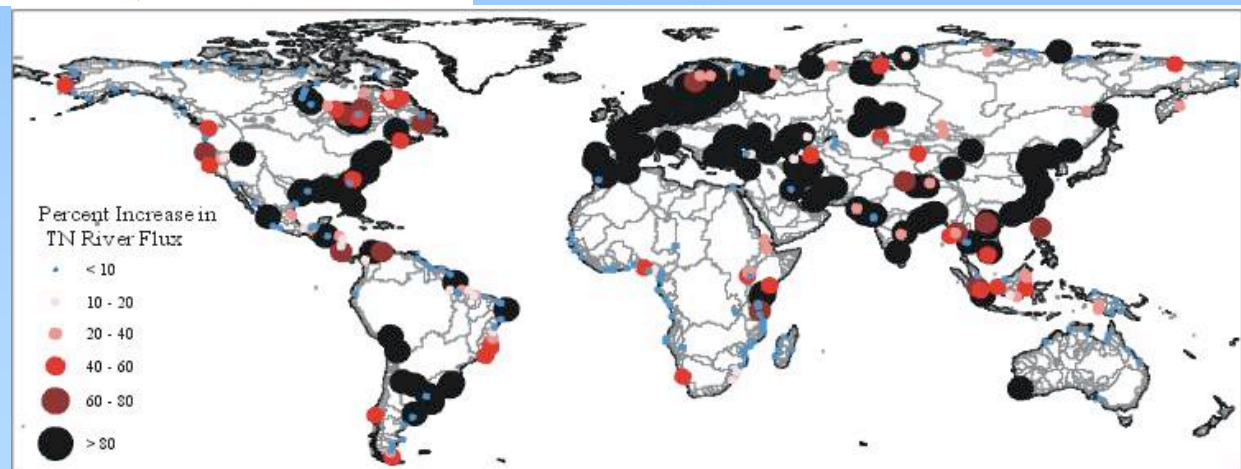
100M under
largest hydro
change

Chemical Asymmetry: Doubling of Global Nitrogen Pollution



Terrestrial
Loading

% Change in
River Fluxes

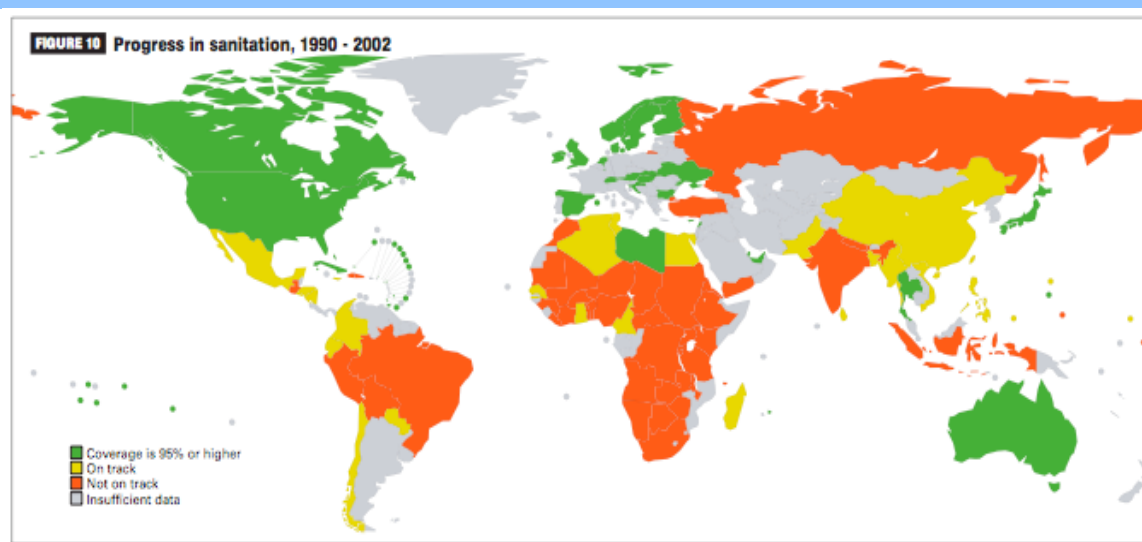
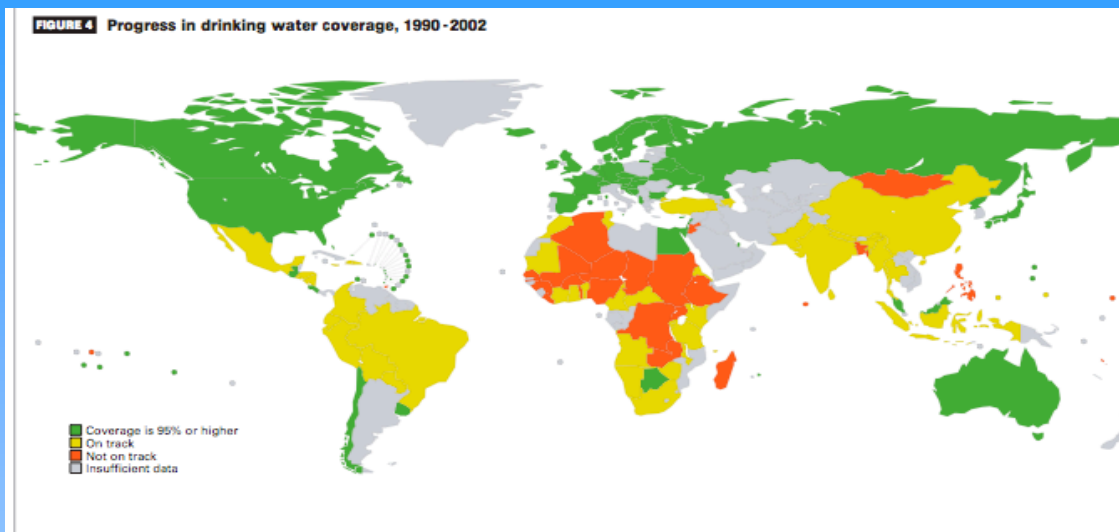


Green et al. 2004; Biogeochemistry

Asymmetry in Basic Provision of Clean Water & Sanitation: *A Millennium Development Imperative & Destabilizing Force*

**1.1 billion people lack
clean drinking water**

**2.6 billion people
lack basic
sanitation**



- 1.7M deaths from water-related diarrheal disease
- \$100B? globally from health costs and decreased productivity
- Political not technical failure..no esoteric technology needed

DIAGNOSING WATER RESOURCES IN THE 21st CENTURY

The Future is Not What It Used to Be Technology



Charles J. Vörösmarty, the Water Systems Analysis Group & many others

Managing 21st Century Water

*The Future is Not What
It Used to Be*

Charles J. Vörösmarty¹ for András Szöllösi-Nagy²

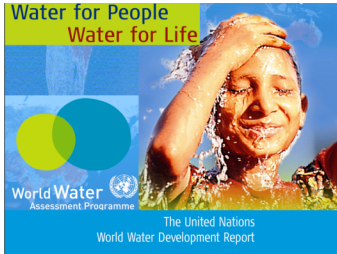
Environmental Cross-Roads Initiative



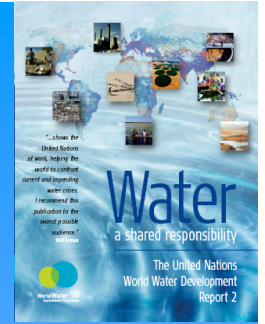
¹ City College of New York
City University of New York



² UNESCO International Hydrological Programme
and World Water Assessment Programme

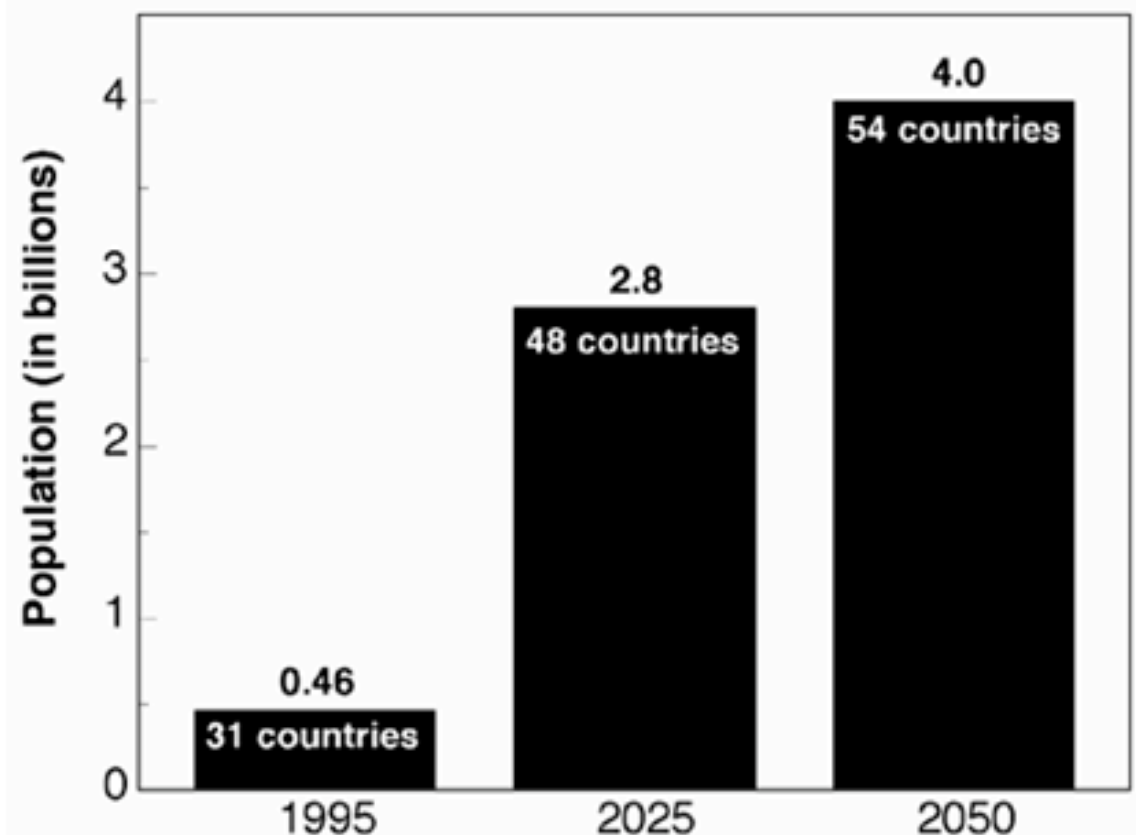


Water Crisis



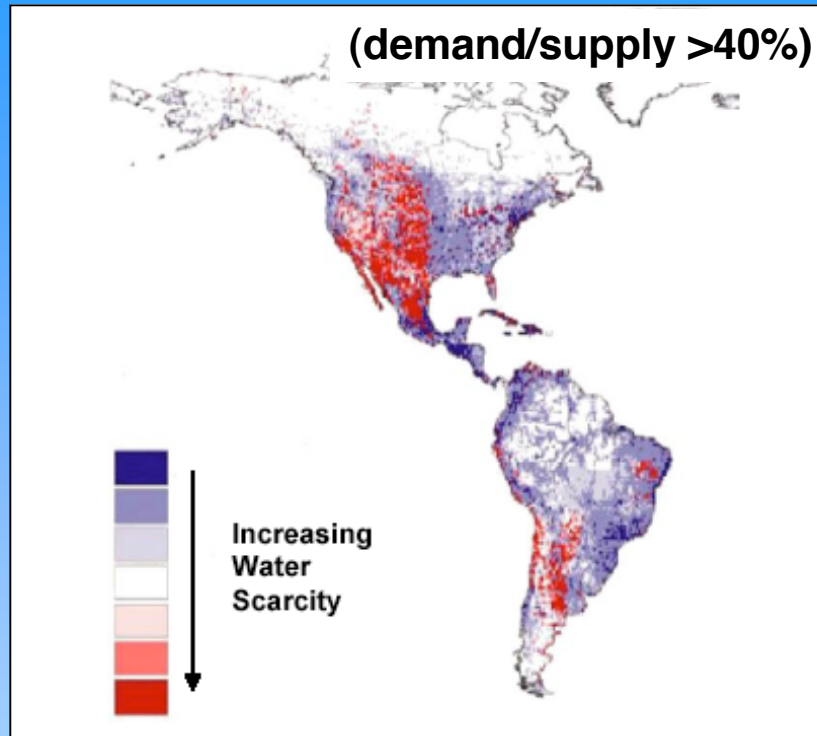
- WWDR1 and WWDR2 highlighted the fact that **we are in the midst of a water crisis, that will continue**

Sharp increase of population in water scarce and water stressed countries



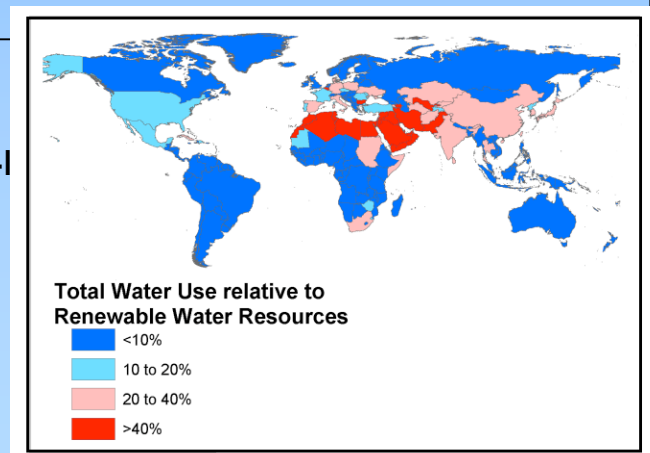
New Geospatial Approaches Raise Estimates of Scarcity

Contemporary and Future Population under High Water Stress



- Number highly sensitive to accounting unit
- Grid-based (30' lat/long) estimates ($n > 60,000$) capture spatial variability & show much higher numbers than country-level statistics ($n \approx 200$)

Water Stress	DIA/Q (unitless)	Total Population (billions)		
		U.N.	Grid Sum	Grid-based Full Resolution
Low	<0.1	1.72	1.95	3.16
Moderate	0.1 to 0.2	2.08	1.73	0.38
Med-high	0.2 to 0.4	1.44	1.54	0.37
High	>0.4	0.46	0.45	1.76



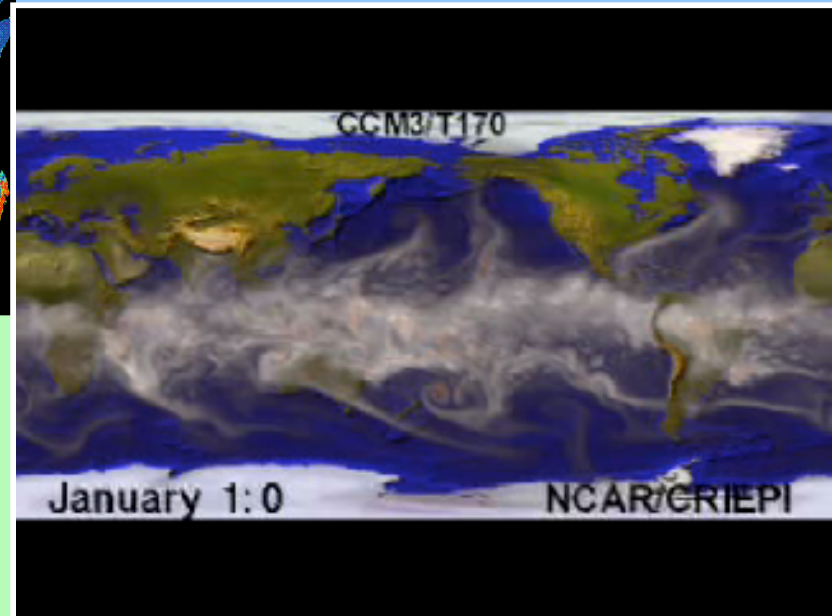
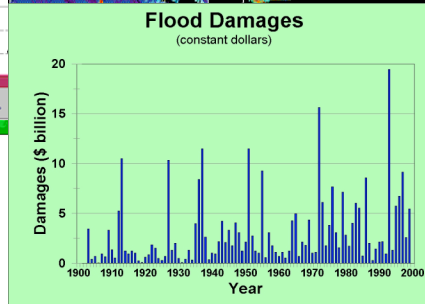
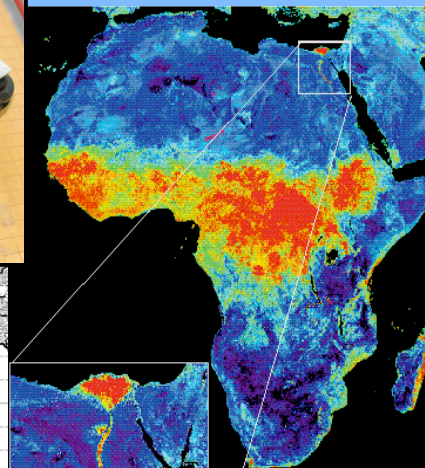
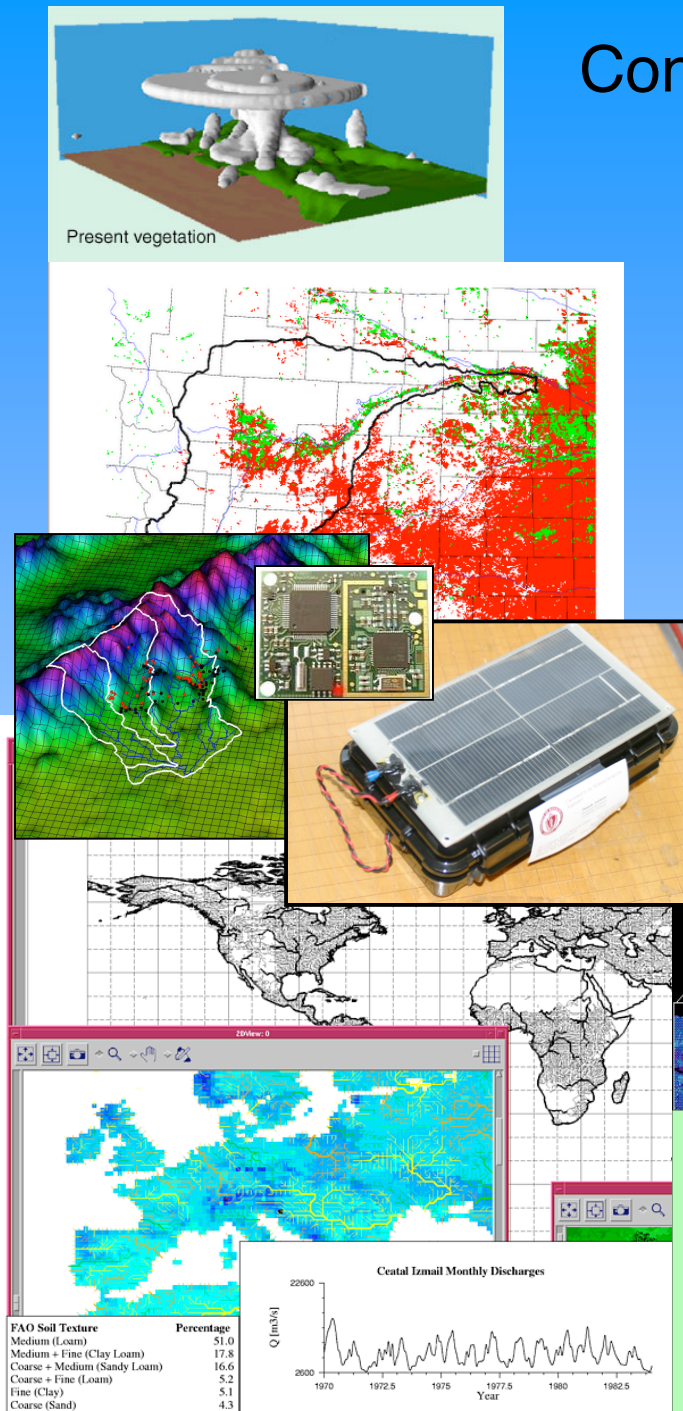
Vorosmarty et al. 2000

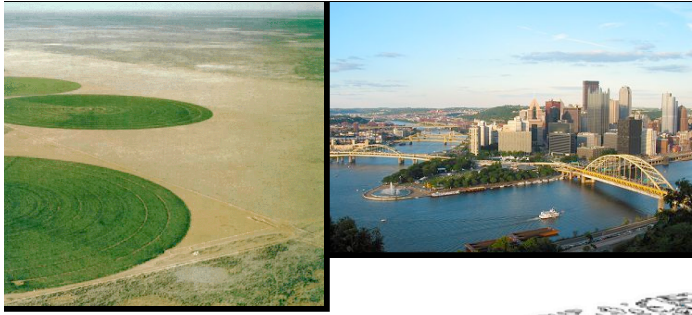
Contributions from Earth System Science

- Augmenting *in situ* networks in severe decline
- Operational satellite-based monitoring of the hydrosphere
- Simulation models and data analysis tools (NWP-4DDA, GCMs, RCMs, ESMs)
- Geo-referenced social science data

...are creating new ways to view the
“global water crisis”

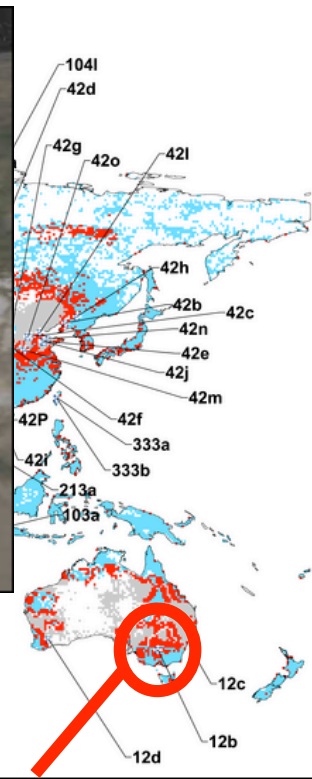
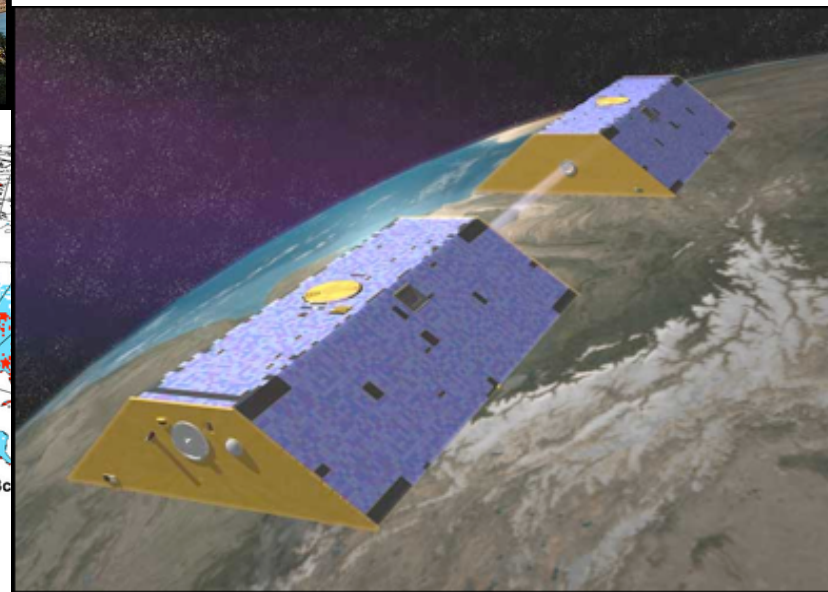
...to inform policy and
improve management



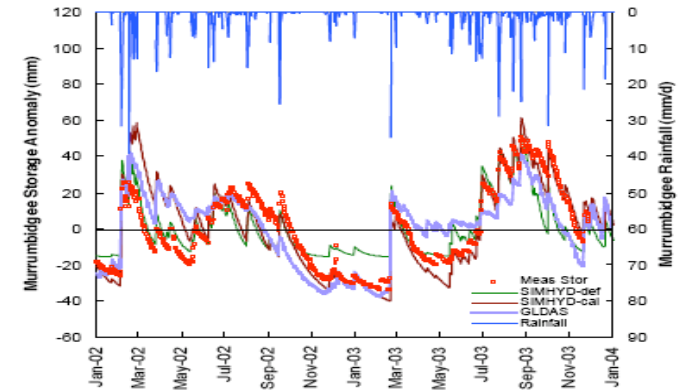
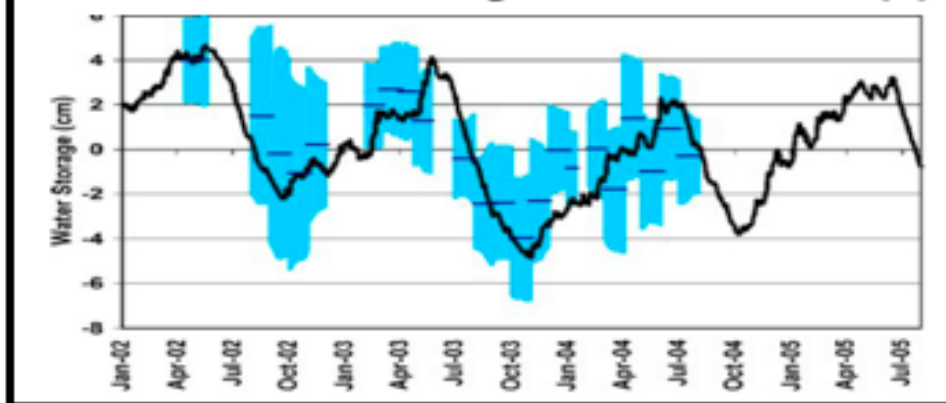


Irrigation & Urban Water Use in Excess of Sustainable Supplies

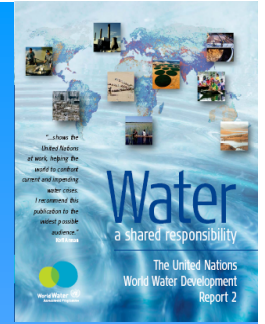
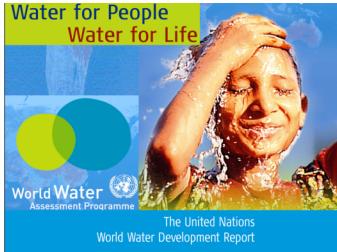
Documentary evidence and simulations now converging



GRACE Δ storage for Mississippi



Tributary of Murray River: Ellett et al. 2005 MODSIM



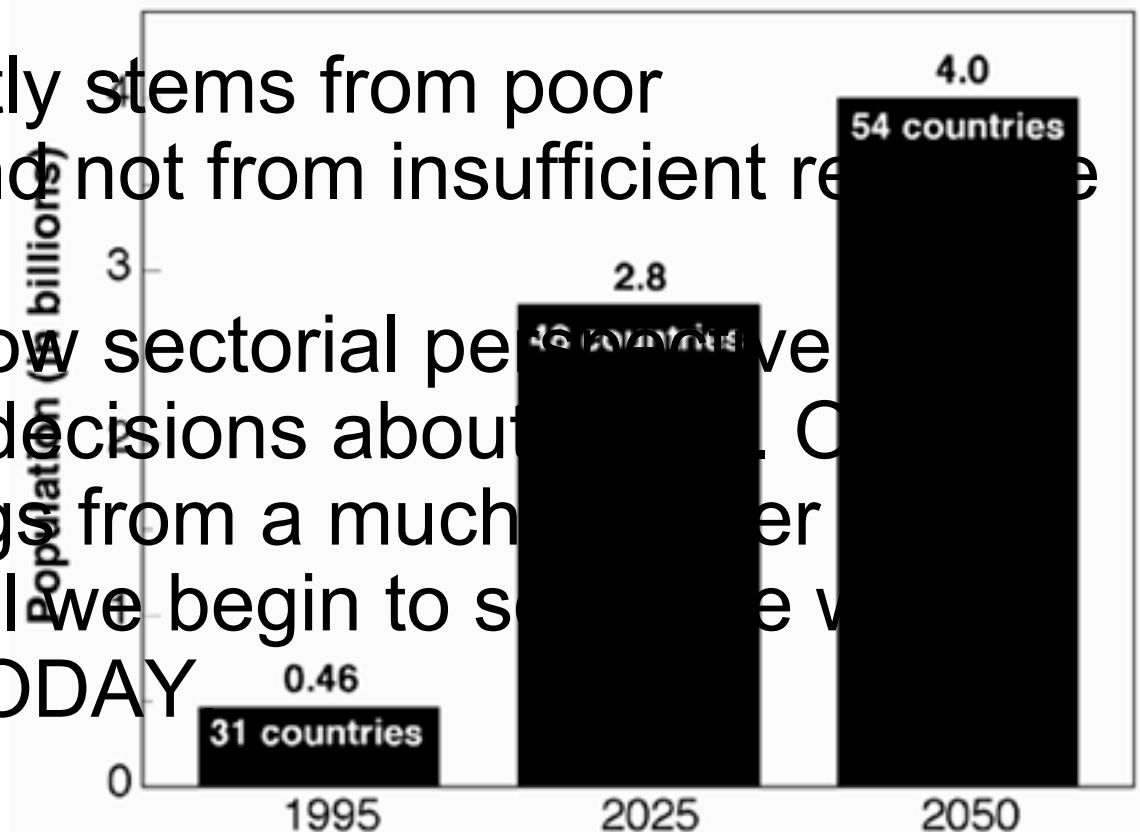
Water Crisis

- WWDR1 and WWDR2 highlighted the fact that **we are in the midst of a water crisis, that will continue**

• The crisis mostly stems from poor governance and not from insufficient resources

• WWDR3: Narrow sectorial perspective blinded many decisions about water. Looking at things from a much broader perspective will we begin to solve the water crisis, TODAY

• The increase of population in water stressed countries



In Conclusion

- Nature of the Beast:

Broad spectrum of global water challenges, linked over space, time, and theme

- Asymmetries abound:

Upstream/downstream, nature/humans, rich/poor

- Multiple perspectives necessary to understand & formulate sound solutions: *Joint role for biogeosciences, human dimensions, and new technologies & engineering*

Some References

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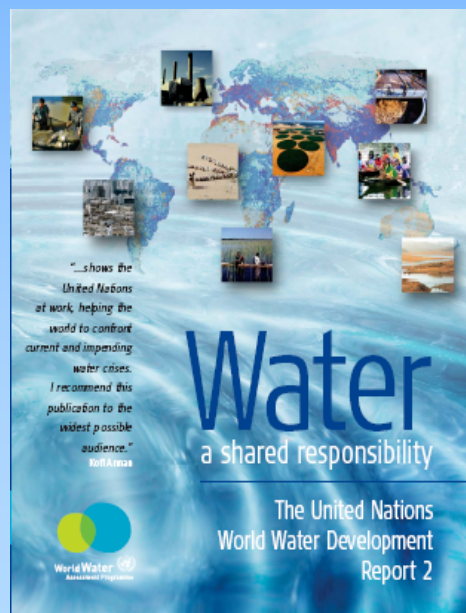
.....and now

.....a few *advertisements*

Water for People Water for Life



The United Nations
World Water Development Report



Release in March



www.unesco.org/water/wwap/

GWSP Home page - Netscape

http://www.gwsp.org/

New Tab GWSP Home page

ESSP DIVERSITAS IGBP IHDP WCRP

GLOBAL WATER SYSTEM PROJECT

Home
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ABOUT GWSP

The Global Water System Challenge

Water is essential to life on earth, plays a key role in the development and functioning of society and is recognised as a high priority resource for sustainable development. Over the past few decades, environmental science has produced insights into the linkages, interconnections and interdependencies in the global water cycle. The various human and physical, biochemical, and biological facets of the cycle make up the global water system.

The global water system is being transformed by major syndromes including climate change, erosion, pollution and salinisation. We know more about the physical aspects of the global water system and much less about the nutrient flows, biodiversity loss and human dimensions.

The Project

The Global Water System Project (GWSP) is a newly established joint project of DIVERSITAS, an international programme of biodiversity science, the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP) and the World Climate Research Programme (WCRP). These four global change programmes form the Earth System Science Partnership (ESSP).

For further information:

- Download **GWSP Science Framework Document** (approx. 2MB)
- Download **Powerpoint Presentation** (approx. 3MB)
- Download **GWSP brochure** (700KB)
- Download **GWSP Factsheet** (130KB)

Transferring data from www.gwsp.org...

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www.gwsp.org



Eos, Vol. 85, No. 48, 30 November 2004

EOS
EARTH OBSERVATION
EARTH AND SPACE SCIENCE

Humans Transforming the Global Water System

PAGES 509, 513-514

Increasing human pressure in the water cycle of the Earth system and a key to understanding the full scope of global change. Greenhouse warming with a potentially accelerated hydrologic cycle is already a well-established science issue with strong policy implications. A broad array of other anthropogenic factors—widespread land cover change, engineering of river channels, irrigation and other consumptive uses, aquatic habitat degradation, and pollution—also influence the water cycle.

Agriculture, urbanization, hydropower, and recreational water use is crucial to a large and growing population that expects long-term improvements in well-being. Providing basic sanitation and clean drinking water services remains a major public health challenge. More than 1 billion people are without access to clean drinking water, 2.5 billion live without sanitation, and over 5000 people, mostly children, die each day from water-related diarrheal diseases (World Water Assessment Programme, 2003).

See [www.gwsp.org](#) for details and links to the

and World Climate Research Programme (WCRP) has been launched to study these complex issues. The primary aim of the Global Water System Project (GWSP) is to promote improved understanding of fresh water in the Earth system through integrated study of its interactions, feedbacks, and thresholds. The GWSP science agenda emerged from a broad consensus of the water science and assessment community with more than 200 contributors to interdisciplinary planning meetings starting in 2002, science planning documents, and a recent Open Science Conference (October 2003, Potsdam, New Hampshire). A peer-reviewed framework and implementation plan coordinate these deliberations (Planning Committee of the GWSP, 2004). This article presents the scientific rationale for the GWSP, the project's key research questions, and an emerging agenda.



Mapping the Links between Water, Poverty and Food Security

Summary Report on the Water Indicators workshop held at the Center for Ecology and Hydrology, Wallingford, 16th to 19th May, 2005



Report authors¹:

Caroline Sullivan, Charles Vörösmarty, Eric Craswell, Stuart Bunn, Sarah Cline, Claudia Heidecke, Adam Storygard, Alex Prousevitich, Ellen Douglas, Deborah Bossio, Dirk Günther, Anna Maria Giacomello, Dermot O'Regan and Jeremy Meigh

December 2005

greenhouse warming to extreme weather and reduced availability of water resources.

But several other factors, until recently largely ignored, are proving to be globally significant as well (Table 1). These involve a great variety of direct anthropogenic activities, many operating at highly local scales. Disturbances made possible by improvements in remote sensing, GIS data assimilation, and systems science that many impacts are now detectable over continental-to-global domains are well illustrated by the GWSP (2004).

A recent synthesis (Mebis and Voronov, 2004) goes further, suggesting that the global impact of direct human interventions in the terrestrial water cycle through land cover change, urbanization, industrialization, and water

is likely to regulate and climate change at scales. It provides a good example of rapid transformation (many rivers have been dammed), with the aim of storing water for irrigation and hydropower (70% of global use in 2000), improvement in drinking water quality, and

in dramatically transforming a world's largest river nearly complete loss in the ocean (e.g., the Amazon), global warming, and the resulting melting of the ice sheets in other parts of the world.

are now global in extent, yet we lack an adequate understanding of how the overall system works, how it responds to change, and how society can best adapt to rapidly evolving and potentially new system states. The GWSP is organized to address this question in a systematic and unified manner. A special issue of *Aquatic Sciences* (Pohl et al., 2002) highlights our collective capacity for pursuing this broad objective, which must

Eos, Vol. 85, No. 48, 30 November 2004

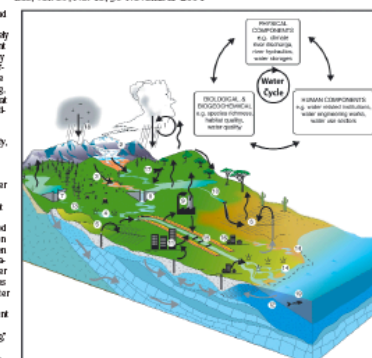


Fig. 1. The Global Water System under natural conditions is a complex amalgam of pools and processes, linked through complex interactions defined by the physics, biogeochemistry and biology of the planet. Its population regimes of the world's largest rivers have been radically altered through direct and indirect human interventions in the water cycle. Understanding these complex interactions requires an integrated, interdisciplinary perspective that considers humans as an important and increasingly part of the Global Water System. See Table 1 for description of numerical entities.

and surprises, such as a potential shutdown of North Atlantic deep water formation and ocean circulation arising from changes in Greenland ice discharge, or the emergence of anoxic dead zones near the mouths of rivers heavily polluted by upstream agriculture and urbanization (Planning Committee of the GWSP, 2004). The GWSP is supported by three framing questions, which form its thematic structure. Question 1: What are the magnitudes of

are now global in extent, yet we lack an adequate understanding of how the overall system works, how it responds to change, and how society can best adapt to rapidly evolving and potentially new system states. The GWSP is organized to address this question in a systematic and unified manner. A special issue of *Aquatic Sciences* (Pohl et al., 2002) highlights our collective capacity for pursuing this broad objective, which must

ESSP Report No. 3
GWSP Report No. 1

The Global Water System Project

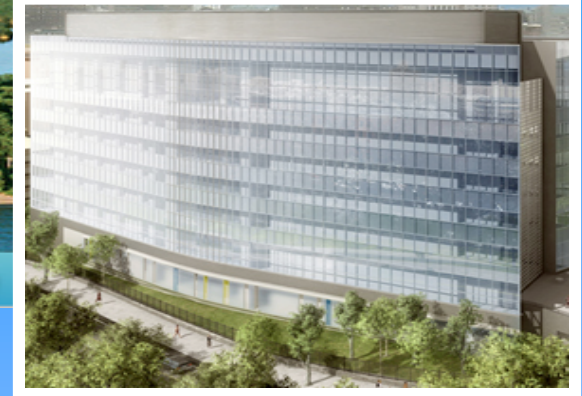
Science Framework and Implementation Activities

www.gwsp.org

CUNY Environmental Cross-Roads Initiative

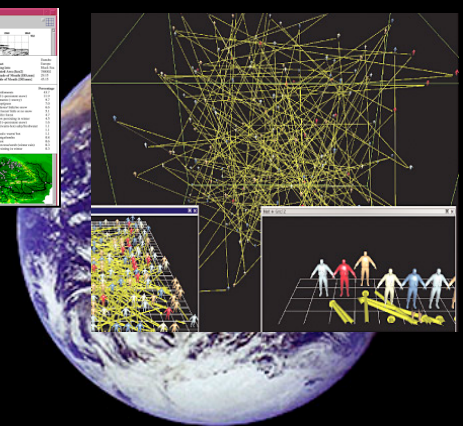
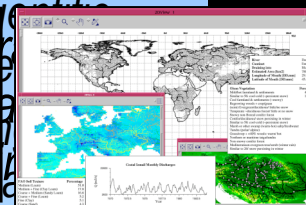
Our Mission

- The CUNY Environmental Cross-Roads Initiative creates a major focal point for experts to join forces, dialogue, and jointly solve the major 21st century strategic environmental challenges facing the region, the Nation, the world.



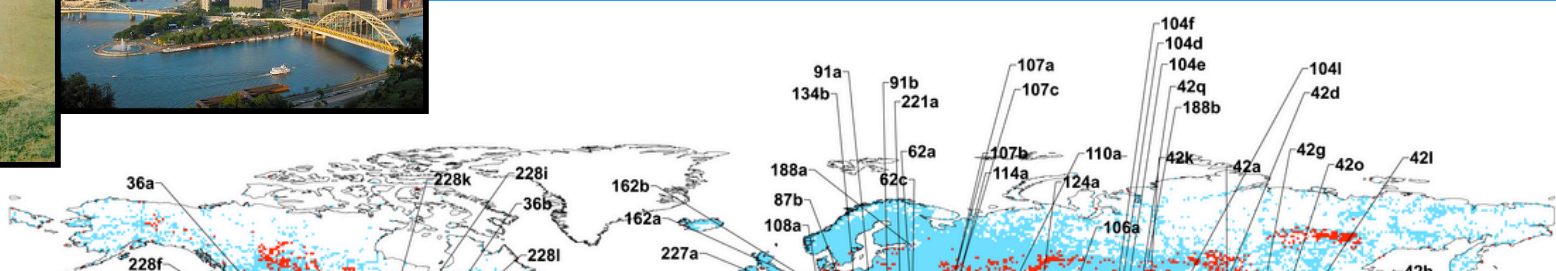
humans and nature over a

Technology is not merely a tool but a transformative force for environmental stewardship





Irrigation & Urban Water Use in Excess of Sustainable Supplies



Help us in documenting these patterns: If you are aware of any overuse in your region, please contact me charles.vorosmarty@unh.edu

- Name of location/region
- Latitude/Longitude
- The Nature of the “Overuse”:
 - groundwater over-abstraction?
 - interbasin transfers required to meet demand
 - depletion of river flows (navigation problems, lack of water to dilute pollution, ecosystem stress, etc.)

