

## Outline & notes for water lecture #2

“Earth, Air, Water, Fire” almost title of course – from Greeks ~500BC – all other materials from these 4 transmutable ones (changeable). Many properties of water (especially liquid water) are still incompletely understood. But we know that it’s a main constituent of life as we know it on Earth, and critical to the rise of humans as primary species on planet. (See first lecture for properties of water, distribution on planet, hydrologic cycle, and ocean circulation.)

“Water, water everywhere, nor any drop to drink.” – Coleridge, *Rime of the Ancient Mariner*  
Written on ocean, but also applies to not enough safe fresh to drink or raise crops with.

1) Hypothesis: Without irrigation for agriculture, humans would not be dominant on planet.

- A. Evidence: all great ancient civ’s did it and some died for lack of sustainability: Sumerians around Tigris/Euphrates, Egyptians, Chinese, Greeks, Romans (as good for Rome as is today), Mayans (demise still mystery, but leading theory is overstretched water supply system and intense drought), Tihuanaco (altoplano –Peru/Bolivia, likewise extensive drought)
- B. history and current situation stacked against us:
  - i. Sandra Postel, *Pillar of Sand: Can the Irrigation Miracle Last?*, “The overriding lesson from history is that most irrigation-based civilizations fail.”
  - ii. most world food from cropland, rangeland, fisheries; latter suffering badly from overfishing, rangeland down 20% due to overgrazing, cropland critical (J. Leslie, Harper’s mag, 7/2000)
  - iii. projections from Science articles – review at end.

2) Supply side effectively fixed by hydrologic cycle and climate state

- A. Lakes, rivers, glaciers, groundwater, ancient aquifers, (see lecture #1 data)
- B. Therefore people fight over it:
  - i. Aral sea(lake) rivers (Amu Drya, Syr Drya) – <1960 55km<sup>3</sup>/yr, now <5km<sup>3</sup> into lake, Afghanistan/Uzbekistan/Turkmenistan – to cotton growing in 60s – almost no sea left (1/3 size), 48000 tons/yr fishing gone, air-borne salt killing cotton, salinity up 3x, “will be salt pan size of Ireland”, changed regional climate, forest gone, ½ mammal species gone, ¾ bird species gone, all native fish species gone
  - ii. India v. Pakistan – Indus river agreement in 60’s
  - iii. Israel/Palestine v. Jordan - Jordan river: 40% to Israel/Palestine, of which 80% to 130k Israelis, 20% to ~2M Palestinians
  - iv. Turkey v. Iraq v. Syria – Tigris/Euphrates – headwaters all in Turkey, takes most; Iraq just drained most of wetlands at lower end, now native marsh populations (both flora, fauna and people) homeless
  - v. Maryland v. Virginia – US Supreme court- Mon NYTimes
  - vi. Colorado, New Mexico, Arizona, California, Mexico (7 states + Mexico)– split based on very wet 18 years, so most often not enough in river...feeding LasVegas, Phoenix, LA, all crops

- C. Deep groundwater supplies very threatened. Constitute ~60x what's in lakes, etc.
  - i. Ogallala Aquifer 225,000 sq mi, feeds 1/5 irrigated US, going down 3-10m/yr
  - ii. India, draining at 2x recharge rate,
  - iii. Land sinking under – Beijing ~10cm/yr, Mexico City ~30cm/yr,
  - iv. sea water invasion Florida, pollution invasion
- D. Dams – can't live without, but now some can't live with.
  - i. great decades of it in 1950-90 (see EOS article), Hoover dam 1935, Aswan 1971
  - ii. serves ~ 1/5 power, and high % of irrigation water
  - iii. 3 gorges in China will be largest, largely political willpower, typical sed fill rate ~2.3%/yr
  - iv. stop most of largest rivers from reaching sea: Nile, Colorado, Yellow, Mississippi,

### 3) Uses

- A. People use/consume ~26% of evapotranspiration and 54% of runoff accessible
- B. Split of use was ~90% agriculture irrigation, 10% industry and muni, now ~65/25/10 (McNeill tables as graphs, also Scientific American fig pg. 42)
- C. In last 200yrs, increased area irrigated 30x, population risen by 6x, however, still less than 1/5 agricultural area irrigated, but produces 2/5 of world food, (see McNeill Table 6.2 as graphic)
- D. Irrigation caused Green Revolution ~1960s, plus fertilizing and pesticides, see agri
- E. Translation of water to grain, ~1#:1000#, except in dry, eg. Saudia Arabia 1980s ~1:3000, grain imports are form of water import, grain-fed beef add factor of ~100
- F. Since 1996, land spoiled by salinization, etc. as fast as irrigated...no net gain.
- G. Many ways to save in municipal use – e.g. NYC toilets, replaced ~1.3 M, 29% reduction, saves 70-90 Mgal/day w/~\$300M investment (cheaper by 1/3 than new pumping system), saved another ~11Mgal/day by fixing leaks.

### 4) Health & ecology issues

- A) water borne diseases up: malaria, typhoid, cholera, schistosomiasis (Egypt –Nile dams) (see also <http://www.worldwater.org/table22.htm> and <http://www.worldwater.org/table13.htm>; cancer, hepatitis and typhoid fever very high around remnant of Aral sea,
- B) access to clean water down (see <http://www.worldwater.org/table7.htm>, <http://www.worldwater.org/table8.html>)
- C) Cutting of Suez between Red Sea and Med was ok when salinity very different, but with Nile dammed, now salinity of eastern Med much higher, Red Sea species can migrate successfully, changing east-Med marine eco-systems
- D) Dead zone in Gulf of Mexico due to Mississippi nutrient loading ->high plankton ->high bacteria -> use all oxygen at depth -> no fish or other animals survive: seasonal, but growing larger ~20,000 sq km.

### 5) Future not great

- A) population projected to rise by 50% (~ 9 billion by 2025), but can tap only another 10% runoff (Postel, Science), see

- B) most rain-fed areas already in agricultural production, will need  $10^9$  hectares converted to more agriculture (>size of US), will add  $\sim 2.5x$  nutrients & therefore eutrophication of water ecosystems (like GoM/Mississippi)
- C) drought situation not good, but human population will be bigger driver than climate change – see projections from Vorosmarty et al, Science 289, July 2000