Challenges of Water Availability

Can we Eat, Drink AND Turn on the Lights?

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Kappe Lecture
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The Kappe Lecture Series was inaugurated by the Academy in 1989 to share the knowledge of today's practitioners with tomorrow's environmental engineers and scientists.
The “Golden Girls” say “Simply Fabulous”
But others say "Do I have to stick around for this?"
A global water crisis doesn’t mean the extent of the crisis or its solutions are uniform.

We don’t really value water.

Irrigated agriculture is largest user, lowest value user and largest exporter of water from arid areas.

Municipal and industrial water users are much more resilient than agriculture – they can afford technological solutions.

There are substantial opportunities for conservation and reuse as well “new” water sources.

Despite this, there will be disruptions in supply due to climate variability, market instability and lack of long-term planning.
Challenges

• Water is not valued
  ✓ Value added by 1 acre-ft of water in agriculture <$100 (<$0.10/m³)
  ✓ Municipal value of water $1000-2000/acre-ft ($1-2 /m³)
  ✓ Hydraulic fracturing for oil and gas >$100,000/acre-ft ($100/m³)
  ✓ Compare to oil at $40/bbl = $314,000 acre-ft ($330/m³)

• Disposal of water is cheaper than treating/recycling
  ✓ Social/economic resistance to “toilet to tap”
  ✓ Produced water disposal wells $0.10/bbl to $2-3/bbl ($0.01-0.24 /m³)

• All water problems and solutions are local
  ✓ Economics deter any trans-watershed solutions
  ✓ Legal- social impediments pose challenges to trans-watershed solution
  ✓ Ideally water should be fit for use but does the local use fit your water?
Our Focus

• Technologies and practices to produce more resilient water systems

• Large urban areas have financial, technical and human resources to manage water problems
  ✓ Deficiencies from poor planning not lack of capacity?

• Small western rural and agricultural communities do not have resilient water supplies and do not have the human, technical and financial resources to resolve these problems
  ✓ Energy resource development often further stresses water supplies
Water Challenges

• Too little water
  ✓ Population shifts, particularly to the arid southwest, have increased conflicts among urban, agricultural, industrial and environmental needs for water.
  ✓ Water requires energy, energy requires water and food requires both
  ✓ Conflicts between human and ecological needs for water increasing

• Too much water
  ✓ Flooding is responsible for 2/3 of all federally declared disasters in the US and their economic and environmental impacts are likely to worsen as climate changes

• Poor water quality
  ✓ Groundwaters of marginal quality throughout much of west
  ✓ Legacy of contamination from point and distributed sources
  ✓ Potential new and replacement sources of water generally of poorer quality

• Inadequate water and wastewater infrastructure
  ✓ Aging infrastructure contributing to water loss and quality challenges
  ✓ Infrastructure inadequately protected from human and natural hazards
Texas Water Demand and Value

Sources:
- Texas Water Development Board
- Office of State Comptroller

Irrigated agriculture 56% of consumptive water demand but 0.6-0.8% of economy.
Figure 4. Existing (as of 2010) and future (2060) water demands for each water use category in each water planning region (TWDB 2012).

Legend:
- Mining
- County-other
- Steam Electric
- Manufacturing
- Livestock
- Municipal
- Irrigation

Scale: acre-feet (million)

Acre feet

Water Allocation and Demand

TAMU, 2012
Texas Rainfall/Evaporation Map

Odessa ..... 14.48”
Big Spring .. 19.63”
Snyder ...... 22.68”
Watershed ...21.00”

Evaporation- Watershed ..... 61.00”

Precipitation

Evaporation
Ogallala groundwater level declines

EXPLANATION
WATER-LEVEL CHANGE, IN FEET

Declines:
- More than 150
- 100 to 150
- 50 to 100
- 10 to 50

Rises:
- More than 10

LESS THAN 10-FOOT CHANGE

BOUNDARY OF THE HIGH PLAINS AQUIFER

Groundwater level declines beneath the High Plains portion of the Ogallala Aquifer, as of 1997
Challenges to Water Quality In Addition to Availability
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Water Needs for Energy

Hydraulic Fracturing?
Water Preferred Power Sources

Wind and Concentrated Photovoltaics best for water minimization

Natural gas uses far less water overall than coal, nuclear, geothermal or concentrated solar power (CSP)

Meldrum et al. 2014
Water Needs and Availability
Hydraulic Fracturing

• **Typical hydraulic fracturing water needs**
  - 1000 gal/ft (1128 L/m) of horizontal extent
  - Total Water needs 4-10 M gallons (15-40,000 m³)

• **Overall small part of water needs**
  - Texas ~125,000 acre-ft/yr (~ 0.5% of state total use)
  - Hydraulic fracturing for gas one of most water-efficient technologies for energy

• **But local challenges- Eagle Ford Play in South Texas**
  - Water demand- 5-6.7% of total (Jester, 2011)
  - But local use can be much higher
  - Projected water needs as % of total water use by county in Eagle Ford
    - Webb – 5.2%
    - De Witt – 35%
    - Karnes – 39%
    - Live Oak – 12%
    - Dimmit – 55%
    - La Salle – 89%

Increasingly rural and lower overall water use
(Nicot & Scanlon, 2012)
Alpine High Oil and Gas Play

- Limited water resources
  - 10 in rain/yr
  - Ephemeral rivers

- Sensitive areas

- Development Controlled by Water Availability!

Apache’s new play

The Houston-based oil exploration company announced a new discovery on Wednesday, with an estimated 75 trillion cubic feet of natural gas and more than 3 billion barrels of oil.

Source: Apache

Houston Chronicle
Building Resilience...Strategies

New Technologies and Treatment Infrastructure

- Conservation: 24.9%
- New Reservoirs: 18.7%
- Surface Water: 33.8%
- Water Reuse: 10.2%
- Groundwater: 8.9%
- Seawater Desalination: 1.4%
- Conjunctive Use: 1.4%
- ASR: 1.4%
- Other: 1.4%

Developed by Regional Water Management Districts: Cost- $53 Billion

Texas Water Development Board, 2012
Agricultural Irrigation

Approaches

- Appropriate crop selection
- Efficient hybrids
- Efficient Irrigation Systems
  - Drip irrigation
  - Efficient scheduling
  - Canopy Temperature Control
  - Satellite Soil Moisture Sensing
- Target ~80% of crop ET needs evapotranspiration needs

West, 2014
Municipal Conservation

San Antonio 1984-2009

Customers ↑ 67%

Water ↑ 0%

Puente, 2012
Alternative Water Sources

Location, Location, Location......

• Employ Municipal Wastewaters
  ✓ Available in sufficient volume near point of use?
  ✓ Limited by any requirements for effluent return to surface waters
  ✓ Can quality be guaranteed for direct reuse?

• Use of Produced Water
  ✓ Typically very poor quality limits its use to industrial (hydraulic fracturing)
  ✓ Sufficient production wells near point of use?
  ✓ Discouraged by water owners, regulatory issues
  ✓ Cost of any necessary treatment competitive with disposal

• Employ Brackish Waters
  ✓ Infrastructure, cost and energy requirements for treatment?
  ✓ Available in sufficient volume near point of use?
  ✓ Who owns access rights?
  ✓ Limited by variable chemistry and aquifer characteristics
  ✓ Connections to surface water and other aquifers?
Magnitude of de facto reuse

Reuse Municipal Effluents

Use of wastewater effluent for HF

Direct Reuse Use of RO Reject Water for HF
Reuse Produced Water?

Too Saline for anything except industrial uses such as for hydraulic fracturing.
• Poor water quality limits options for beneficial use
  ✓ Brackish waters far easier to divert to other beneficial uses than produced water
  ✓ Cheaper to desalinate seawater and pump to west Texas than desalinate produced water?

• Primary option for produced water is use as hydraulic fracturing fluid but barriers remain
  ✓ Low disposal costs
  ✓ Imbalance between produced water and fracturing needs
    • Volume
    • proximity
  ✓ Availability of fresh or brackish waters
    • Landowner benefits from fresh or brackish water sales
  ✓ Regulatory impediments
    • Inability to redirect produced water to non-O&G uses
Recycling Example in Region of High Well Density

Dense well field owned by operator
Approximate balance of produced water and fracturing needs
Minimal treatment requirements ($\text{ClO}_2$)
Saline Groundwater (Brackish Water)?

Mauter et al, 2014
Low Salinity Brackish Water Uses

• Substantial water reserves
  ✓ 10 times Great Lakes in Southwestern US

• Requires better assessment
  ✓ Chemistry and implications
  ✓ Productivity of aquifers, aquifer characteristics

• Requires efficient use of technologies for utilization
  ✓ FIT FOR USE! Change the use not the water
  ✓ Variability a significant challenge to conventional technologies
  ✓ Opportunities such as electrosorptive (capactive deionization) technology for flexible scalable minimal treatment options

• There is not “one” solution nor “one” water source
Variability makes use technologically challenging
Brackish Aquifer - Dockum

Extreme Spatial Variability
General increase with depth

Uddameri, 2016
Energy Requirements for Desalination

• Direct use of Dockum aquifer under Ogallala limited by Water quality
  ✓ TDS > EC > SAR > B

• Energy needs are highest were water is more scarce

Uddameri and Reible, 2017
Other uses for brackish water?

Energy cost of desalinating vs blending for Ag

Uddameri and Reible, 2017
An Alternative Vision for Water Delivery

• Current practice
  ✓ Deliver high quality water for all uses
    • ~2% is used for drinking and cook
  ✓ Attempt to move toward segregation of grey water and expand reuse

• A model more consistent with “fit for use”
  ✓ Deliver marginal quality water
    • Blend with freshwater for non-potable uses?
    • To allow for inadvertent consumption likely must be treated for pathogens
  ✓ Employ simple scalable technologies to treat water for human consumption
    • Need simple, low maintenance technologies
    • Energy requirements not a significant concern due to low volumes required
  ✓ Implementation
    • New community/development structured as demonstration
    • With infrastructure for delivery of non-potable waters
Conclusions

- Energy development and agriculture place significant demands on water and often in water scarce areas
  - Freshwater use can be minimized and sources extended by alternatives
  - Alternatives for avoiding freshwater use for oil and gas development and hydraulic fracturing
    - Flowback and Produced Water
    - Brackish Water
  - Alternatives for increasing high quality water availability
    - Use of brackish waters with innovative treatment and appropriate blending with freshwater
  - Challenges are often logistical rather than technical due to low value of water and cost of transportation and treatment
  - Should we rethink our paradigm of high quality water for all uses?
Can we Eat, Drink AND Turn on the Lights?

Turn on the Lights? ✓

Water consumption is low in hydraulic fracturing and conventional power plants (although some energy sources consume much more water, e.g. biofuels.)

Drink? ✓

But we could use high quality waters more efficiently!

Eat? ?

Agricultural cannot easily support investments necessary to achieve maximum efficiency and there are other high value needs for the water.
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