MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Civil and Environmental Engineering

1.731 Water Resource Systems

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Lecture 1, Introduction, Sept. 7, 2006

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Logistics:

Student survey: Fill in survey (Problem Set 1)

Web site: http://web.mit.edu/1.731/www/

Text: On-line text suggested background but not essential. You can download a legal free copy from http://www.wldelft.nl/rnd/intro/fields/water-management/book.html

Class format, grading, etc.: See syllabus on web site for details

Software used: MATLAB, GAMS, see links on web site

Introduction to Water Resource Systems:

Key concepts based on words: "water", "resource", and "system":
* Water is viewed as a valued resource, to be beneficially managed.
* Management frequently must deal with a complex "system" composed of many interconnected parts -- It is often difficult to subdivide the original problem into independent subproblems. How do we define the "system"? How large? Over what time scale? How much detail? Should it include social and political institutions?

We often try to find the "best" solution – but how do we define "best"?

Traditional examples of water resource systems problems:

* River basin management – select facilities (reservoirs, aqueducts, irrigation infrastructure, etc.) to maximize benefit from resource
* Aquifer management – focus on installation and operation of wells and recharge areas, longer time scales make water quality issues especially important
* Capacity expansion – how much should facilities be expanded, when?
* Real-time operations – decisions re. what to do today, considering impaqcts on the future (e.g. reservoir operations)
* Remediation – select best mix of remedies for cleaning up contamination, especially in subsurface

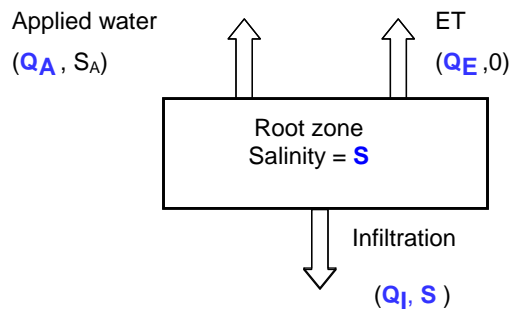New examples that go beyond water resources but deal with environment:

- Hazard prevention/mitigation – how should we respond to hazards such as hurricanes and associated flooding, rebuilding, prevention, etc.
- Energy-related topics – petroleum reservoir development, carbon sequestration, investment in alternative energy sources, etc.
- Merging of diverse types of data for environmental characterization – data fusion, data assimilation

What do these problems have in common?

1. **Tradeoffs** – optimal decision trades off opposing effects (often benefits vs. costs).
2. **Constraints** – limited resources
3. **Uncertainty** – many uncertainties about future events, physical processes, etc.
4. **Policy/economics** – inevitable when we seek "best" solutions where people are involved.

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Irrigation Example (irrigation.m)

How does irrigation efficiency affect net crop revenue? Decision variables in boldface.

Applied water
($\mathbf{Q_A}$, S_A)

ET
($\mathbf{Q_E}$, 0)

Root zone
Salinity = $\mathbf{S}$

Infiltration

($\mathbf{Q_I}$, $\mathbf{S}$)

Assume steady-state.

$\mathbf{Q_A}$, $\mathbf{Q_E}$, $\mathbf{Q_I}$ m/yr
S_A, $\mathbf{S}$ gm/m^3

Water mass balance:

$$A(\mathbf{Q_A} - Q_E - \mathbf{Q_I}) = 0$$

Salt mass balance:

$$A(\mathbf{Q_A} S_A - \mathbf{Q_I} \mathbf{S}) = 0$$

Efficiency:

$$e = 1 - \frac{\mathbf{Q_I}}{\mathbf{Q_A}} = \frac{Q_E}{\mathbf{Q_A}}$$
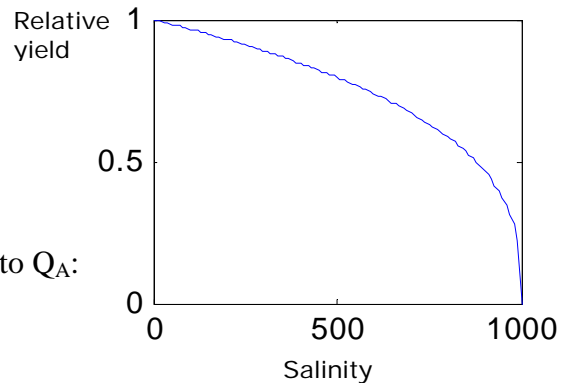
Salinity as a function of efficiency:

$$\mathbf{S} = \frac{S_A}{1-e}$$

Postulate yield as a function of salinity (and efficiency):

$$Y(\mathbf{S}) = Y_0 \left[1 - \frac{\mathbf{S}}{S_{max}} \right]^{1/3} = Y_0 \left[1 - \frac{S_A}{(1-e)S_{max}} \right]^{1/3}$$

Assume revenue is linearly proportional to Y:
$$R(\mathbf{Y}) = pAY(\mathbf{S})$$

Assume applied water cost is linearly proportional to Q_A:

$$C(\mathbf{Q_A}) = c\mathbf{Q_A} = c\frac{Q_E A}{e}$$

Maximize net revenue (profit) with respect to e:

$$\underset{e}{Max} \; P(e) = pAY_0 \left[1 - \frac{S_A}{(1-e)S_{max}} \right]^{1/3} - c\frac{Q_E A}{e}$$

Optimum efficiency = 0.31

Tradeoff: Crop revenue vs. applied water cost
Constraints: Mass balances
Uncertainty: All functions & parameters are uncertain
Policy: What are implicit policy assumptions/implications?

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