ENVIRONMENTAL SYSTEMS ANALYSIS:

CENG 6652

Chapter 1

Environmental systems analysis an over view

Contents

1.1 What is system analysis?

- Water environment systems analysis – operations research (OR) of "water environment components" (e.g., reservoirs, rivers, watersheds, groundwater, distribution systems, Ecology etc.), as standalone or integrated, for single or multi-objective problems.
- OR seeks the determination of best (optimum) course of action of a **decision problem** under the limiting factor of limited resources,
- Tools:
  - "Traditional" OR (LP, NLP),
  - Data driven modeling (ANN),
  - Qualitative modeling (Fuzzy Logic)
  - Evolutionary computation (GA, ACO) – single/multi-objective

What is SA? …

- The scientific and practical challenge in dealing quantitatively with water environment management problems is in taking into consideration from a systems perspective
- The system perspective integrates social, economical, environmental, technical etc. dimensions, into a single framework for trading - off in time and in space competing objectives
- Inherently, such problems involve modeling of water quantity and quality for water environment systems components, such as: surface water, groundwater, water distribution systems, reservoirs, rivers, lakes, and others, as stand alone and/or linked elements

1.2 Why analysis (plan and manage)?

- Because there are problems to solve and/or opportunities to obtain increased benefits by changing the management and use of water and related environmental resources.
- Proposed solutions to problems may provoke conflict at the other end. Hence there is the need for careful study and research in the search for the best compromise plan or policy.
- The most common reasons for SA in water environment:
  - Too little water
  - Too much water
  - Too polluted
  - Too expensive
  - Ecosystem too degraded
  - Reservoir related issues

Too Little Water

- Can result from too little rain, patterns of land and water use, growing urbanization, the growing needs to meet instream flow requirements, and conflicts over public rights regarding water allocations.
- Other issues involve trans-basin water transfers and markets, objectives of economic efficiency versus the desire to keep nonefficient activities viable, and demand management measures, including incentives for water reuse and water reuse financing.

Analysis may help identify Measures to reduce the demand for water in times of supply scarcity should be identified and agreed upon before everyone must cope with an actual water scarcity.

Too Much Water

- Damage due to flooding is a direct result of floodplain development that is incompatible with floods.
- In many river basins of developed regions, annual expected flood damages are increasing over time, in spite of increased expenditures in flood damage reduction measures. This is in part due to increased economic development taking place on river flood plains, not only of increased frequencies and magnitudes of floods.

Analyses can help identify the appropriate level of development and flood damage protection works based on the beneficial as well as adverse economic, environmental, and ecological consequences of flood plain development.

Too Polluted

- Wastewater discharges by industry, agriculture and households are the main causes
- Issues include:
  - Upstream versus downstream conflicts on meeting quality standards,
  - Threats from aquatic nuisance species,
  - Quality standards for recycled water,
  - Nonpoint source pollution discharges including sediment from erosion,
  - Inadequate groundwater protection, compacts, and concerned institutions.

Analysis can help manage the harmful effects different pollutants in our water environments vs. water quality standards and management policies.

Too Expensive

- Too many of the world's population do not have adequate water to meet all of their needs. Much of this is not due to the lack of technical options, rather those options are deemed to be too expensive.
- Meaning: solving the water problem is beyond the ability of those living in poverty to pay and recover the costs of implementing, maintaining and operating the needed infrastructure.
- If financial aid is to be provided, to be effective it has to address all the root causes of such poverty, not only the need for clean water.

Analysis may be obtaining alternate investment scenario on the basis of the small available financial resource

Ecosystem Too Degraded

- Ecosystems may be subject to a number of threats including:
  - Habitat loss due to river training and reclamation of floodplains and wetlands for urban and industrial development,
  - Poor water quality due to discharges of pesticides, fertilizers and wastewater effluents, and
  - The infestation of aquatic nuisance species.

Analysis may be on importance of funds spent in prevention and early detection and eradication threats against the need to spend considerably more funds on management and control once such threats are well established.

Reservoir Related Issues

- Issues related to reservoir include:
  - Loss of land and evacuation of residents.
  - Ecological barriers for migrating fish species.
  - Sedimentation, active (useful) storage reduction and more erosion downstream.
  - Stratification, water-related diseases, algae growth, and abrasion of turbines.
  - Multi purpose use
  - Risk of a dam break.
  - Reduced oxygen content of the outflowing water.

Water environment systems??

- Water environment systems are complex due to :
  - The computational limitations
  - Insufficient understanding of the multiple interdependent physical, biochemical, ecological, social, legal, and political (human) processes that govern the behavior of the system.
- System performance is affected by
  - Uncertainties measurement and prediction.
  - The unpredictable actions of individuals and institutions take in response to a physical and social environment which may be water environment related or not .

1.3 System Planning Scales: Spatial

- Watersheds or basins are usually considered logical regions. This makes sense if the impacts of decisions regarding water environments are contained within the watershed or basin.
- How water environments managed in one part of a river basin can impact the water environment in other parts of the basin?
- For example,
  - How the discharge of pollutants or the clearing of forests in the upstream affect the downstream?
  - How dam or weir construction block fish migration?

Analysis may be to maximize the economic and social benefits obtained from different spatial scales of development, and to insure that these benefits and accompanying costs are equitably distributed.

System Planning Scales: Spatial

- NOTE:
  - While basin boundaries make sense from a hydrologic point of view, they may be inadequate for addressing particular water environment problems that are caused by events taking place outside the basin.
  - What is desired is the highest level of performance, however defined, of the entire physical, socio-economic, and administrative water environment system.
  - The physically based "river basin" focus of planning and management should be expanded to include the entire applicable "**problem-shed**."
  - Hence consider the term "**problem-shed**" while fixing the spatial scale.

System planning scales: Temporal

- Planning is a continuing iterative process.
- Water environment plans need to be periodically updated and adapt to new information, new objectives, and updated forecasts of future demands, costs and benefits.
- Current decisions should be responsive to current needs and opportunities, and have the ability to be adaptable in the future to possible changes in those needs and opportunities.
- Time shall be fixed on the basis of the variability of the supplies of and demands for water environments and on the purposes to be served by the water environments.

1.4 System modeling role in planning and management

- Planning, designing, and managing water environment systems inevitably involve impact prediction, commonly aided by the use of models.
- There is inherent limitation of models as representations of real system. Because model structure, input data, objectives and assumptions of how the real system functions or will behave under alternative management policies or practices are uncertain.
- Future events are always unknown and of course any assumptions about them may affect model predictions.
- The results of any quantitative analysis (modeling) are always only a part of the information that should be considered.

System modeling role in planning and management

- Models produce information. They do not make decisions or replace those individuals that do.
- If model results are not available when needed, they are likely to be ignored when they become available.
- If model results do not support the preferences of decision-makers, they may not also be considered.
- **We all feel greater responsibility for what we do than for what we do not do.** Thus, decision-makers may feel safer in inaction than action.
- Modeling efforts should be driven by the need for information and improved understanding.
- Improved understanding eventually lead to improved system design, management, and/or operation.

Exercise 1

1. Identify some of the major water environment management issues in the region where you live. What management alternatives might effectively reduce some of the problems or provide additional economic, environmental, or social benefits.
2. Describe some water environment systems consisting of various interdependent natural, physical and social components. What are the inputs to the systems and what are their outputs? How did you decide what to include in the system and what not to include?
3. Identify and discuss briefly some of the major issues and challenges facing water managers today.