Course Overview

This class provides a structured introduction to the integrated analysis of physical and institutional systems for water management and development. Multiple scales and settings, from developing country villages to a US city water supply to regional watershed restoration to national planning are considered. The emerging global water crisis driven by rapid population growth and its relation to agricultural water use will be a recurrent theme through the class. Novel topics include the consideration of climate variability and change in developing system operation rules and infrastructure planning. There will be one guest lecture from an engineer/scientist/professor working in the water sector. The class is quantitative and case-study oriented. Grading is based on homework, in class participation, opinion articles, a term project, and a final examination.

Reading

Readings are assigned before each lecture. Textbooks that are available online for free will be suggested whenever appropriate for specific modules. Recommended readings will sometimes be listed, which may be read for that week, or referenced for homework or the group project.

Assignments

Homework:

Four homework assignments are assigned covering the concepts introduced in the class lectures. They are based on hypothetical or real world case studies and will include quantitative data analysis. Excel will be used for the analysis. Students should form groups (≤5) that they maintain for the semester – consider combining backgrounds to ensure appropriate contributions and learning from each other. One submission per group is sufficient for each homework assignment.

Articles - Water Matters:

Four short opinion articles on assigned topics have to be submitted individually. The article should not exceed 500 words. Topics will be general water discussion topics and students are encouraged to gather information from various sources to write the article. Evaluation is based on students’ understanding and articulation of the water issues assigned.

Class Project:

At the end of the semester, a class project on a selected topic has to be submitted as a group. (The groups may differ from the homework groups.) Sample projects from past years include “developing water storage for Ethiopia”, “Urban Water systems in NYC”, “Assessing drought risk for USA”, and “designing rainwater harvest catchment systems” among many others.
Scope of the Project: Clear articulation of the problem, detailed quantitative analysis followed by your solutions or recommendations. Each group will present their proposed project methodology and plan to solve/find answers during class on March 11.

1) Each team will prepare and present their proposed project ideas as a brief 7 minutes presentation. Allow for 2 minutes of questions and discussion.

2) Include the following aspects in your presentation:
   a. Problem definition.
   b. Important questions that need to be addressed for the problem.
   c. Data sources.
   d. Evaluation procedure or methods.
   e. Road map over the semester or plan of work.

Final submission includes a brief report (maximum 7 pages excluding figures, images and tables etc.) and a final class presentation. Report and Presentation (15-20 minutes) will carry equal points for the project. Evaluation of the project will be based on the group's ability to understand, analyze and present solutions. Groups will work closely with the instructor throughout the project.

Final Exam:
The exam will include both simple numerical questions and illustrative questions to test the concepts learned in the class.

**Evaluation**

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<tr>
<th></th>
<th>No.</th>
<th>Points</th>
<th>Total % of Final Grade</th>
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<tbody>
<tr>
<td>Homework</td>
<td>4</td>
<td>7.5 each</td>
<td>30</td>
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<tr>
<td>Water Matters: 300 – 500 words opinion article on assigned topics</td>
<td>4</td>
<td>5 each</td>
<td>20</td>
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<tr>
<td>Class Project</td>
<td>1</td>
<td>20</td>
<td>20</td>
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<tr>
<td>Class Participation</td>
<td>1</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Final Exam</td>
<td>1</td>
<td>20</td>
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Homework assignments must be posted before the start of class on the day they are due. The following Absolute Grading System will be followed. This system will remain final and no changes will be made.

- A+ ≥ 97
- 93 ≤ A < 97
- 90 ≤ A- < 93
- B+ < 90
- 87 ≤ B < 87
- 80 ≤ B- < 83
- C+ < 80
- 77 ≤ C < 77
- 70 ≤ C- < 73
- D+ < 70
- 67 ≤ D < 70
- 63 ≤ D- < 67
- F < 60

**School Policies and Expectations:**

**Academic Integrity**
The School of Continuing Education does not tolerate cheating and/or plagiarism in any form. Those students who violate the Code of Academic and Professional Conduct will be subject to the Dean's Disciplinary Procedures. The Code of Academic and Professional Conduct can be viewed online:
http://ce.columbia.edu/node/217

Please familiarize yourself with the proper methods of citation and attribution. The School provides some useful resources online; we strongly encourage you to familiarize yourself with these various styles before conducting your research:
http://library.columbia.edu/help/howto/endnote.html

Violations of the Code of Academic and Professional Conduct will be reported to the Associate Dean for Student Affairs.

Accessibility Statement
Columbia is committed to providing equal access to qualified students with documented disabilities. A student's disability status and reasonable accommodations are individually determined based upon disability documentation and related information gathered through the intake process. For more information regarding this service, please visit the University’s Health Services website:
http://health.columbia.edu/services/ods/support

Attendance, Late Papers, Missed Tests, Class Behaviors and Civility
Students are expected to arrive on time, attend all classes, and to stay until the end of class unless they have notified the instructor at the beginning of the session that they will be leaving early. Students are responsible for all reading and homework assignments, and must post assignments on time. Assignments will be marked down a full letter grade for each day late.

Course Schedule

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<tr>
<th>Week</th>
<th>Readings (*Recommended)</th>
<th>Topics</th>
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| Jan 21 | Water and economic development (Brown and Lall, 2006)  
Global Hydrological Cycles (Oki, 2006)  
*Water in the 21st century (Lall et al 2008) | **Introduction**  
• Introduction to water issues, water sources and options, population dynamics, role of climate and storage  
• Course Overview  
• Evaluation Procedure  
• HWs, Project, Writing Articles, Exam |
| Jan 28 | Benefit Cost Analysis for Water Systems Planning (Charles Howe, Chapter 1 and p. 35-43 | **Benefit – Cost Analysis**  
• Evaluation of Water Projects  
• Water as Economic Good  
• Types of Benefits and Costs in Planning  
• Comparison of Benefits and Costs over Time  
• Project Cost Allocation  
• Case Studies: Tampa Bay Water or Delaware River Basin Commission  
**Article-1 assigned** |
| Feb 4  | Decision Tree Primer (Kirkwood): selected topics | **Decision Analysis**  
• Basic Structure of Formal Decision Making  
• Selection Criteria |
<table>
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<tr>
<th>Date</th>
<th>Assignment or Reading</th>
<th>Notes</th>
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</table>
| Feb 11   | Rippl, 1883 paper (Section 4) | Development of Water Systems  
- Design of Water Storage  
- Demand Estimation (current and projected)  
- Mass Balance and Reservoir Simulation and Optimization  
- Reliability and Risk  
- Probability and Statistics  
- HW-1 Due |
| Feb 11   | Section 1, Chapter 11 Loucks |  
*Klemes, 1979|
| Feb 18   | Section 2.2, Chapter 11 Loucks book | Development of Water Systems  
- Critical Periods  
- Rule Curves  
- Case Studies: India Water Stress, Drought Measures, Rainwater Harvesting  
- Brief introduction to Optimization Problem Formulation – Objective functions and Constraints  
- Article-2 assigned |
- Characteristics of Groundwater  
- Basic Definitions and Aquifer Types  
- Mass Balance of Groundwater  
- Optimizing common pool resource  
- Class Exercise using simple GW model  
- Case Studies: Punjab  
- Article-2 Due  
- HW-2 Assigned |
| Feb 25   | ACWA Groundwater Report, pp. 7-18 |  
*Klemes, 1979|
| Mar 4    | TBD | Guest Lecture: Kathleen Callahan  
- EPA Water Topics  
*Finish Groundwater Management if needed  
- HW-2 Due  
- Article-3 Assigned |
| Mar 11   | | Mid Term Project Presentation |
| Mar 25   | *ENSO papers  
*IRI data library/KNMI Climate Explorer  
*Atmospheric Water chapter | Climate Tele-connections and Prediction  
- Global Circulations and Precipitation driving mechanisms  
- Natural Models of Variability  
- State of the Art in Climate Prediction  
- Floods and Droughts  
- Statistical Forecasting Techniques and Validation  
- Article-3 Due  
- HW-3 Assigned |
<p>| Apr 1    | The Role of Monthly Updated | Water Systems Management |</p>
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<tr>
<th>Date</th>
<th>Activity</th>
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<tr>
<td>Apr 8</td>
<td>Guest Lecture: Dan Bena, Global Sustainable Development, Pepsico</td>
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<td>• HW-4 Assigned</td>
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<td>Apr 15</td>
<td>AWWA water rates study</td>
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<td>Water Utilities and Markets</td>
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<td>• Utility Risk, Debts</td>
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<td>• Cost Structures</td>
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<td>• Market Valuations</td>
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<td>• Water and Related Commodity Trading</td>
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<td>• Trends in markets and Climate related shocks</td>
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<td>• HW-4 Due</td>
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<td>• Article-4 Assigned</td>
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<td>Apr 22</td>
<td>Summary and Review</td>
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<td>• Course Summary</td>
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<td>• HW solutions</td>
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<td>• Exam Review</td>
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<td>• Project Questions</td>
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<td>• Article-4 Due</td>
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<td>Apr 29</td>
<td>Final Project discussions</td>
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ClimateForecasts in Improving Intraseasonal Water Allocation (Arumugam et al.)

*Introduction to Optimization, Ch4

- Optimization Problem Formulation – Objectives and Constraints
- Solution Methods
- Optimal solution interpretation
- Case Studies: National Crop Procurement (India)
- HW-3 Due