ARIZONA STATE UNIVERSITY
GENERAL STUDIES PROGRAM COURSE PROPOSAL COVER FORM

Courses submitted to the GSC between 2/1 and 4/30 if approved, will be effective the following Spring.
Courses submitted between 5/1 and 1/31 if approved, will be effective the following Fall.
(SUBMISSION VIA ADOBE.PDF FILES IS PREFERRED)

DATE 9/14/2010

1. ACADEMIC UNIT: School of Earth and Space Exploration

2. COURSE PROPOSED: GLG 108 Water Planet 4

(prefix) (number) (title) (semester hours)

3. CONTACT PERSON: Name: Kelin X. Whipple Phone: 5-9508

Mail Code: 1404 E-Mail: kxw@asu.edu

4. ELIGIBILITY: New courses must be approved by the Tempe Campus Curriculum Subcommittee and must have a regular course number. For the rules governing approval of omnibus courses, contact the General Studies Program Office at 965–0739.

5. AREA(S) PROPOSED COURSE WILL SERVE. A single course may be proposed for more than one core or awareness area. A course may satisfy a core area requirement and more than one awareness area requirements concurrently, but may not satisfy requirements in two core areas simultaneously, even if approved for those areas. With departmental consent, an approved General Studies course may be counted toward both the General Studies requirement and the major program of study. (Please submit one designation per proposal)

<table>
<thead>
<tr>
<th>Core Areas</th>
<th>Awareness Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literacy and Critical Inquiry–L</td>
<td>Global Awareness–G</td>
</tr>
<tr>
<td>Mathematical Studies–MA CS</td>
<td>Historical Awareness–H</td>
</tr>
<tr>
<td>Humanities, Fine Arts and Design–HU</td>
<td>Cultural Diversity in the United States–C</td>
</tr>
<tr>
<td>Social and Behavioral Sciences–SB</td>
<td></td>
</tr>
<tr>
<td>Natural Sciences–SQ SG</td>
<td></td>
</tr>
</tbody>
</table>

6. DOCUMENTATION REQUIRED.
(1) Course Description
(2) Course Syllabus
(3) Criteria Checklist for the area
(4) Table of Contents from the textbook used, if available

7. In the space provided below (or on a separate sheet), please also provide a description of how the course meets the specific criteria in the area for which the course is being proposed.

The course description and all required and supplementary documentation are attached as separate files.

CROSS-LISTED COURSES: ☐ No ☐ Yes; Please identify courses: ________________________________

Is this a multisection course?: ☐ No ☐ Yes; Is it governed by a common syllabus? _______

Chair/Director (Print or Type) ____________________________ Chair/Director (Signature) ____________________________

Date: ____________________________

Rev. 1/94, 4/95, 7/98, 4/00, 1/02, 10/08
• Proposal Cover Page page 1
• Table of Contents page 2
• Course Description with Brief Schedule of Topics page 3-6
• Course Syllabus page 7-12
• Detailed Schedule of Topics page 13-20
• SQ/SG Criteria Checklist page 21-28
• Detailed Criteria Justification page 29-37
• Textbook Table of Contents page 38-46
GLG108 Water Planet: Course Description and Brief Schedule of Topics

Course Description – Catalog

This course offers an overview of the processes that control water supply to natural ecosystems and human civilizations. The course is broken into two parts: Part I is an introduction to the basic science that helps us understand the water planet: Including the hydrologic cycle, glaciers and ice; rivers, oceans, and natural hazards associated with water such as flooding and contaminant transport. Part II is an overview of how science provides an essential guide to water resource management and to resolving some of the challenges that face humanity today: Including droughts, groundwater contamination, impacts on fisheries, conflicts over water, patterns of water use, and effects of global climate change on future water supplies. Course includes weekly laboratory exercises. Throughout the course, water issues facing Arizona and California will be used as examples.

Course Description – Detailed

*Water Planet* is an introductory (100-level) science survey course that will be offered for the first time in Spring 2011. It aims to lead students to *want* to learn science. Our most precious resource – water – is used to motivate an appreciation of science and engineering and the complex challenges facing Arizona, the nation, and the world in regards to sustaining water resources for a growing population. A central theme is establishing the critical importance of science in developing sounds water resource policy in the face of growing needs and environmental pressures including climate change and the prospect for extended droughts. The course aims to illustrate how the integration and application of math, physics, chemistry, and biology is essential to sound water resource planning. The course opens with motivating examples of issues and challenges related to water resources, both global and local, and an introduction to the scientific method as an approach to the problem. Discussion forums are used to engage students in thinking about the problems we face and potential pathways to finding solutions *in advance* of lectures on the topic, a strategy employed throughout the course as we turn to new topics.

*Water Planet* offers an overview of the processes that control water supply to natural ecosystems and human civilizations. The course is broken into two parts:

**Part I** is an introduction to the basic science that helps us understand the water planet: Including the climate system, the hydrologic cycle, glaciers and ice; rivers, groundwater, and natural hazards associated with water such as flooding. The approach of this class is to emphasize how the science is done – how data is collected and how it is employed in guiding predictions of water supply, quality, and hazards, with attention to the uncertainties involved. Use of mathematics is restricted to algebraic manipulations in keeping with an introductory course without prerequisites, but the power of mathematics for formalizing, generalizing, and quantifying observed relationships and for formulating quantitative predictions, with known uncertainty, is emphasized throughout.

**Part II** is an overview of some of the management and resource allocation topics that face humanity today: Including droughts, groundwater contamination, impacts on fisheries, conflicts over water, patterns of water use, and effects of global climate change on future water supplies.
How the science of hydrology is used to make predictions and guide management is emphasized. Throughout the course, water issues facing Arizona and California will be used as examples.

The course includes weekly laboratory exercises that are closely tied to lecture materials and designed to enrich and augment the learning experience. Observations, data collection, and data analysis are emphasized in the laboratory exercises. Authentic local examples of serious water resource challenges are used in most laboratory exercises to make the problems “real and present” in the lives of the students, and to illustrate the utility of applying the science and math learned in class to practical everyday problems.

The course is intended for students who are motivated by this profound topic to understand what makes the Earth able to support life and human development. This target audience includes students studying for BA degrees, including prospective majors in the new BA in Earth & Environmental Sciences in ASU’s School of Earth & Space Exploration (SESE) and as an elective for Sustainability majors. However, Water Planet is primarily designed for students across the academic spectrum as an introduction to the scientific method and how natural science disciplines are applied and integrated in pursuit of questions that are both at the frontier of human knowledge and critical for human welfare and the sustainability of human society. As such, Water Planet is particularly well suited as an SQ subject within the new Sustainability Minor and will soon be added to their list of approved courses. Approval for SQ status will help this course reach a broad cross-section of ASU students and help in creating a science-literate citizenry.

Course Schedule: Lectures, Labs, and Readings


Part I: The Basic Science Of The Water Planet

Unit 1: Watersheds and the Water Cycle
Schedule: Jan. 19, 21, 24, 26, 28
Topics: The water planet; processes of water movement – evaporation, transpiration, dependence on water; defining fluxes and volumes for processes
Concepts: Scientific method; mathematical descriptions of process; thermodynamics; topographic analyses; why Earth is the water planet
Lab #1: Watersheds and the Water Cycle (due Fri, Jan. 28)
Reading: PWR, Chapters 2 (24-45), 3 (74-77), and 14 (455-477)
Discussion: What does science contribute to our understanding of water resources? What does society need to know from scientists about water resources?

Unit 2: Weather, Climate and Surface Water
Schedule: Jan. 31, Feb. 2, 4, 7, 9, 11
Topics: Solar energy as driver; latitudinal controls on climate; insolation; greenhouse gases and climate change; river networks; watershed definitions; mass balance and flow pathways
Concepts: Formulating and testing hypotheses; mathematical reasoning in modeling; radiative balance (conservation of energy); radiometric dating; quantifying controls on water discharge
Lab #2: Climate, Radiative Balance, Evaporation (due Fri, Feb. 11)
Reading: PWR, Chapters 2 (46-66), 3 (74-86), Reader – Radiative balance, evaporation, radioactivity and radiometris dating, overland flow
Discussion: Is climate change real? Dangerous? Caused by humans? Why do we have rivers?

Unit 3: Floods, Flood Prediction and Groundwater
Schedule: Feb. 14, 16, 18, 21, 23, 25
Topics: Open channel flow; river stage and discharge; flow hydraulics; quantifying sediment transport; groundwater; saturation and capillary tension
Concepts: Darcy’s Law; measuring flow; quantifying equipotential; topographic controls of flow; scientific uncertainty; quantifying prediction from geologic records;
Lab #3: Surface Water, Flow Records, and Predicting Floods (due Fri, Feb 25)
Reading: PWR, Chapters 3 (86-103), 4 (104-136), Reader – Flood frequency analysis, uncertainty
Discussion: What is the role of the insurance industry in assessing flood danger and influencing zoning? How certain are flood forecasts?

Part II: Science as a Guide to Water Resource Management

Unit 4: Water Use and Development
Schedule: Feb. 28, Mar. 2, 4, 7, 9, 11
Topics: Historical water use and development; water quality and pollution; organic chemicals in water resources; waterborne diseases; pollutant fate and transport
Concepts: pH, temperature, dissolved Oxygen, turbidity controls; redox state and water chemistry; periodic table of elements; Nitrogen and Phosphorous cycles
Lab #4: Groundwater and Overdraft Impacts (due Fri, Mar 11)
Reading: PWR Chapters 1 (1-23), 5 (137-174), Reader – AZ water resources
Discussion: What are tradeoffs between development and water quality? How does A Civil Action highlight importance of groundwater and downstream effects?

Spring Break

Unit 5: Municipal Water Development
Schedule: Mar. 21, 23, 25, 28, 30, Apr. 1
Topics: Quantifying municipal water use; case studies; comparison of water sources; wastewater treatment; irrigation history, techniques used in AZ
Concepts: Mass conservation and water use; per capita water use; chemistry of water treatment: fluoridation, chlorination, ultraviolet, reverse osmosis; biogeochemistry and the role of microorganisms

Lab #5: Your Water Use (due Fri, Apr 1)
Reading: PWR Chapters 6 (185-216), 11 (374-405)
Discussion: What are you drinking? Desalination – a solution for a thirsty world? Water use in Phoenix – irrigation vs. housing development

Unit 6: Dams, Landuse Impacts and Wildlife
Schedule: Apr. 4, 6, 8, 11, 13, 15
Topics: Dams – purpose, design, operation and impacts; case studies; impacts of deforestation on hillslope hydrology; salmon industry and watershed geomorphology; wetlands – ecology and hydrology
Concepts: River hydrology and ecology; upstream and downstream effects; hillslope hydrology; interactions between physical and biological processes
Lab #6: Deforestation and Water Resources (due Fri, Apr 15)
Reading: PWR Chapters 7 (217-248), 12 (406-440), Reader – Deforestation and water supplies
Discussion: Can rainfall be changed by deforestation? Salmon – wild or farmed?

Unit 7: Climate Change and Water Limits
Schedule: Apr. 18, 20, 22, 25, 27, 29
Topics: Greenhouse gases and climate; anthropogenic impacts on climate; Pleistocene ice ages; testing climate models, policy implications on climate change; AZ water resources, allocation, and potential impacts of climate change; the economics of water; population growth
Concepts: Data-model comparisons; atmospheric CO$_2$ and temperature; global atmospheric circulation models; predicting climate change; volcanoes and natural drivers of climate change; limitations of short-term records; groundwater storage
Lab #7: Phoenix Water Resource Sustainability (due Fri, Apr 29)
Reading: PWR Chapter 13 (441-454), 14 (455-477 refresh), Reader – AZ water allocation, sustainability, IPCC report on Climate Change, Summary for Policy Makers
Discussion: Causation vs. correlation for CO$_2$ and climate change? How will sea level change impact wetlands?

Unit 8: Wrap up and Future Implications
Schedule: May 3
Concepts: Science and prediction; the politics of water
Lab #8: N/A
Reading: PWR Chapter 15 (482-502)
Discussion: Will water wars replace oil wars?
GLG 108: Earth: Water Planet (4 credit hours)
Syllabus, Spring 2011
Time: MWF hour TBD
Location: TBD

Instructor
Arjun Heimsath
Office: PSF-548
Phone: 965-5585
Email: Arjun.Heimsath@asu.edu
Office Hours: TBA

TA Staff: TBD

Catalog Description
This course offers an overview of the processes that control water supply to natural ecosystems and human civilizations. The course is broken into two parts: Part I is an introduction to the basic science that helps us understand the water planet: Including the hydrologic cycle, glaciers and ice; rivers, oceans, and natural hazards associated with water such as flooding and contaminant transport. Part II is an overview of how science provides an essential guide to water resource management and to resolving some of the challenges that face humanity today: Including droughts, groundwater contamination, impacts on fisheries, conflicts over water, patterns of water use, and effects of global climate change on future water supplies. Course includes weekly laboratory exercises. Throughout the course, water issues facing Arizona and California will be used as examples.

Formal Description
Water Planet explores key concepts in the natural sciences that determine the processes that control water supply to natural ecosystems and human civilizations.

The course is intended for students who are motivated by this profound topic to understand what makes the Earth able to support life and human development. This target audience includes students studying for BA degrees, including prospective majors in the new BA in Earth & Environmental Sciences in ASU’s School of Earth & Space Exploration (SESE) and as an elective for Sustainability majors. However, Water Planet is primarily designed for students across the academic spectrum as an introduction to the scientific method and how natural science disciplines are applied and integrated in pursuit of questions that are both at the frontier of human knowledge and critical for human welfare and the sustainability of human society. As such, Water Planet is particularly well suited as an SQ subject within the new Sustainability Minor and will soon be added to their list of approved courses. Water Planet will contribute to the creation of a science-literate citizenry.
Water Planet is broken into two parts, each divided into individual modules developed to integrate the lab exercises with the course material:

**Part I** is an introduction to the basic science that helps us understand the water planet: Including the climate system, the hydrologic cycle, glaciers and ice; rivers, groundwater, and natural hazards associated with water such as flooding. The approach of this class is to emphasize how the science is done – how data is collected and how it is employed in guiding predictions of water supply, quality, and hazards, with attention to the uncertainties involved. Use of mathematics is restricted to algebraic manipulations in keeping with an introductory course without prerequisites, but the power of mathematics for formalizing, generalizing, and quantifying observed relationships and for formulating quantitative predictions, with known uncertainty, is emphasized throughout.

**Part II** is an overview of some of the management and resource allocation topics that face humanity today: Including droughts, groundwater contamination, impacts on fisheries, conflicts over water, patterns of water use, and effects of global climate change on future water supplies. How the science of hydrology is used to make predictions and guide management is emphasized. Throughout the course, water issues facing Arizona and California will be used as examples.

This course aims to lead students to want to learn science. Our most precious resource – water – is used to motivate an appreciation of science and engineering and the complex challenges facing Arizona, the nation, and the world in regards to sustaining water resources for a growing population. A central theme for this course is establishing the critical importance of science in developing sound water resource policy in the face of growing needs and environmental pressures including climate change and the prospect for extended droughts.

Water Planet aims to illustrate how the integration and application of math, physics, chemistry, and biology is essential to sustainable water resource planning. The course opens with motivating examples of issues and challenges related to water resources, both global and local, and an introduction to the scientific method as an approach to the problem. Discussion forums are used to engage students in thinking about the problems we face and potential pathways to finding solutions in advance of lectures on the topic, a strategy employed throughout the course as it turns to new topics.

Water Planet includes a weekly laboratory component that is being developed for SQ credit.

**Course Objectives**

1. To provide a broad audience of students with an introduction to the science and management topics surrounding the Earth’s most precious natural resource: water.
2. To engage students in the importance of science in formulating sound natural resource management policy.
3. To excite students about the applied aspects of Earth and Environmental Studies, utilizing basic concepts in geoscience, life science, chemistry, physics, and engineering, around the theme of water.
4. To educate students about some of the most pressing concerns over a scarce natural resource that is essential for sustaining life on Earth.
5. To motivate students to become engaged in local water resource topics and help them formulate practical and achievable practices to help sustain water resources.
6. To expose students to science-as-it-really-is: An ongoing process of exploration and discovery, guided by the scientific method.

**Student Learning Objectives**

After taking this course students will be able to:

1. Utilize basic concepts in geoscience, life science, chemistry, physics, and engineering to understand the Earth’s hydrological cycle and how all life depends upon it.
2. Understand why there are limits to the water supply, how these limits are divided between diverse users of water resources, and how they may change in the future.
3. Critically compare human impacts on the water cycle with natural changes to the cycle.
4. Critically assess how climate change, both natural and anthropogenically driven, impacts the supply and distribution of water on Earth.

**Curricular Articulation**

This is one of the introductory laboratory science courses that can be chosen by students to fulfill their required disciplinary core for the BA major in SESE. It will provide students with tools and material that will help prepare them for success in the upper division electives. However, *Water Planet* is primarily designed for students across the academic spectrum as an introduction to the scientific method and how natural science disciplines are applied and integrated in pursuit of questions that are both at the frontier of human knowledge and critical for human welfare and the sustainability of human society. As such, *Water Planet* is particularly well suited as an SQ subject within the new *Sustainability Minor* and will soon be added to their list of approved courses. *Water Planet* will contribute to the creation of a science-literate citizenry.

**Prerequisites**

None. Exposure to basic sciences and mathematics at the Arizona high school level is the only expectation.

**Textbook and Reader**

*Principles of Water Resources: History, Development, Management, and Policy, 3rd Edition*, by Thomas Cech, Wiley, 2010 (PWR), plus additional reading assignments and reference materials will also be provided throughout the course (course reader) to supplement this text in order to cover course content. Lecture materials will be provided and distributed on the class website. Weekly reading assignments will be posted online and in the class schedule.

**Website**
The class has a website on Blackboard that is a critical means of distributing and collecting course material. Lecture slides presented in class will be posted on Blackboard. Announcements, discussions, and supplementary reading will also be delivered through Blackboard.

Communication

Messages critical to student success in this class will be sent by email and posted as announcements on the website, so students must:

- Be sure the email address ASU has for you is valid.
- Be sure to check that account regularly.
- Make sure that this account is not clogged and able to receive messages.
- Check the course website regularly for important announcements.

Course philosophy and teaching method:

We believe that a science class should be a fun way to explore and visualize our natural world, not a static collection of facts. Accordingly, we will concentrate on understanding natural processes and how we explore and learn things about our planet, rather than terms and factual trivia. We will concentrate on active, inquiry-based learning and will learn how to observe, think about, and understand our place in the natural environment. This class will try to develop skills that you can use in any profession and give you an appreciation of how earth surface processes impact our environment and society through their impact on the water cycle. Class time will not simply consist of the instructor repeating via lecture everything that is in the reading.

It is the student’s responsibility and obligation to complete the required readings prior to lecture and laboratory assignments. Class time may be used for clarifying written materials, introducing new material, small-group activities, discussions, independent work projects, and/or identifying and applying principles and concepts. Lectures will be strongly tied to the weekly, hands-on laboratory exercises that are delivered as on-line homework. One hour of lecture per week will emphasize the specific problems addressed in these laboratory exercises, introducing the problems, reviewing required approaches and clarifying expectations. It is our experience that hands-on, project-based active learning is the most effective means for explaining scientific concepts. The online delivery of laboratory exercises makes this a hybrid lecture and online course.

Course expectations:

The instructor’s role in this class is to provide a framework that includes theory, best practices, activities, and assignments for you to utilize in your own development of knowledge, understanding, and skills. We care very much how and what the students learn in this class, but believe that they are responsible for participating in learning from the activities provided. This class requires much outside preparation and reading. It will be impossible to cover all issues in the readings during class time. This is partly why we incorporate a laboratory component in our approach to this course.

Assessments and Grading Policy:
**Laboratory Exercises:** There will be weekly laboratory exercises with summative laboratory reports due every two weeks. Laboratory exercises will track the content of the course outline, listed in the course schedule below. The laboratory exercise assignments have definite due dates (every 2nd Friday) posted on the course website and in the course schedule. Laboratory exercises are introduced and discussed (necessary background, approaches required, expectations) during class time, but are completed as online homework, delivered via Blackboard.

**Exams:** Two exams are issued for the class. The first exam is the mid-term, taken in-class during a 50-minute period. The second exam is the final, taken during the standard scheduled (100-minute) time.

**Weights:** Laboratory assignments and associated project work will account for 40% of the class grade (5% per assignment). The remaining 60% will be distributed between the two exams, 25% for the midterm, 30% for the class final, and 5% for class participation (including online discussion forums).

**Grade Posting**

All grades will be posted on Blackboard at myasucourses.asu.edu. *You have 7 days after a grade has been posted to dispute an entry.* After the 7-day period, the grade stands as entered. Do not wait until the end of the semester to check your grades – that will be too late! Grades are not assigned by a “curve”, where a certain percent is assigned “As”, “Bs”, etc. Instead, you are competing against my expectations, not your classmates, and there is no predetermined percentage of “As”, “Bs”, and “Cs”. The exact division between letter grades will not be determined until the final points are totaled, but the grade breaks will not be raised above typical values (e.g., the A-B grade break will be 90% or lower, etc.). No items are weighted—your grade is based solely on total points received.

**Incomplete grade:** A mark of “I” is given only when a student who is otherwise doing acceptable work is unable to complete a course because of an illness or other situation beyond the student’s control. The student is required to arrange for the completion of the course requirements with the instructor. The university does not allow instructors to assign a grade of “I” simply because a student has quit attending classes and/or completing assignments.

**Class Policies**

**Attendance:** Each student is expected to attend all classes. It is the student's responsibility to inform the instructor of an excused absence as soon as possible. The instructor may excuse absences for emergency situations unofficially. Instructor-excused absences must be obtained prior to or on the day of the student’s absence. Make-ups for such absences will be at the option of the instructor. *There will be absolutely no make-ups for unexcused absences.* Please contact the instructor if you have circumstances arise that conflict with attending class.

**Tardiness:** Tardiness is discouraged, since it disrupts class. Tardy students will not be allowed extra time to make-up for the time lost on timed exams. In-class exams and in-class points
cannot be made up for non-emergency, unexcused absences, or absences that occur without prior notification to the instructor. **Points missed due to tardiness cannot be made up.**

**Academic misconduct and academic dishonesty** will not be tolerated. Students engaging in misconduct or dishonest practices on exams, quizzes, or other assignments will be dealt with according to the guidelines established by the university ([http://provost.asu.edu/academicintegrity](http://provost.asu.edu/academicintegrity)).

**Class disruptions** are defined as activities that distract the instructor or other students from the course content. Such activities include talking or whispering, cell phones ringing, tardiness or whispering about another tardy student, noisily preparing to leave the class prior to the end of the period, etc. Disruptive students will be asked to leave the class. Repeat offenders may be withdrawn.

**Audio/visual recording:** Neither audio nor video recording will be permitted except under special circumstances prescribed by the ASU Disability Resource Center (DRC). You are also not allowed to use the camera in your phone to record pictures or video, without expressed consent of the instructor.

**Cellular telephones/text messaging/pagers:** Please turn off all cellular telephones and pagers during class time – this includes text messaging. If your work situation requires that you be on call, please notify the instructor prior to class. Text messaging is not permitted in this class.

**Use of laptops in the classroom:** You are only permitted to use a laptop during class to take notes, as long as you do not disturb your neighbors. Many of the notes in this class, however, will involve sketches, so a laptop may not be the best way to take notes in this class. Laptops may not be used during class time to answer email, browse the web, listen to music, or any other activity not related to class. If you are using your laptop for one of these unauthorized activities, you will lose all in-class points for that day. If you are disrupting other students you will be asked to leave the lecture hall.

**Help along the way:** Students may enter this class with a bit of anxiety. Other students may have various disabilities, including test anxiety, which may make traditional classroom environments very difficult. If you are having difficulty understanding the course work, please contact one of the instructors or the teaching assistant immediately. ASU has learning centers ([http://www.asu.edu/duas/wcenter/](http://www.asu.edu/duas/wcenter/); [http://www.asu.edu/vpsa/lrc/](http://www.asu.edu/vpsa/lrc/)), disability resource centers (see below), and counseling centers ([http://www.asu.edu/counseling_center/](http://www.asu.edu/counseling_center/)) to address the various needs of students.

**Disabilities:** If you need disability accommodations, please contact me at the beginning of the term so I can direct you to the available resources. Information regarding disability is confidential ([http://www.asu.edu/drs/](http://www.asu.edu/drs/)).
**Water Planet**
GLG 108

**Part I: The Basic Science of the Water Planet**

**Unit 1**  Watersheds and the Water Cycle

**Question**  Got water?

**Objective**  Revealing the hydrological concepts underpinning the course and highlighting water use challenges

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Date</th>
<th>Title</th>
<th>Topics</th>
<th>Key Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Jan. 19</td>
<td>Welcome to Water World</td>
<td>Course syllabus and structure</td>
<td>Social context for science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Motivation for Water Planet</td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td>Jan. 21</td>
<td>Science, Water, &amp; YOU</td>
<td>Scientific method</td>
<td>Societal needs from science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Science and engineering approaches</td>
<td>Importance of mathematics</td>
</tr>
<tr>
<td>#3</td>
<td>Jan. 24</td>
<td>The Global Water Cycle</td>
<td>Elements of the water cycle</td>
<td>Mass balance concepts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Driving forces and processes</td>
<td>Energy balance - why the Water Planet?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Defining fluxes and reservoir volumes</td>
<td>Measurements and uncertainty</td>
</tr>
<tr>
<td>#4</td>
<td>Jan. 26</td>
<td>Rates of Key Fluxes</td>
<td>Evaporation/transpiration and rainfall</td>
<td>Water molecule properties</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Potential vs. actual rates</td>
<td>Scientific measurements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oxygent isotopes as tracers</td>
<td>Thermodynamics intro.</td>
</tr>
<tr>
<td>#5</td>
<td>Jan. 28</td>
<td>Watersheds</td>
<td>Fluid flow</td>
<td>Hydrology basics intro</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Defining watershed boundaries</td>
<td>Topographic analysis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Surface water vs. groundwater</td>
<td>Political boundaries</td>
</tr>
</tbody>
</table>

**Readings**  PWR Chapter 14 (455-477)
PWR Chapter 2 (24-45), chapter 3 (74-77)

**Lab #1**  Watersheds and the Water Cycle (due Fri, Jan. 28)
Conservation of mass in the water cycle - recycling and isotopic tracers (Amazon rainforest); Defining watersheds
**Unit 2**  Weather, Climate and Surface Water  
**Question**  How do humans disrupt the processes they depend on?  
**Objective**  Quantitatively understanding the controls on climate and how climate drives hydrological processes

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Date</th>
<th>Title</th>
<th>Topics</th>
<th>Key Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>#6</td>
<td>Jan. 31</td>
<td>Climate and Weather</td>
<td>Solar energy as driver, Latitudinal controls on climate, Axial tilt and circulation patterns</td>
<td>Net insolation; pressure and temperature, Thermodynamics of precipitation, Fluid flow, Coriolis effect</td>
</tr>
<tr>
<td>#7</td>
<td>Feb. 2</td>
<td>Conservation of Energy</td>
<td>Radiative balance and climate, Water vapor and carbon dioxide</td>
<td>Absorption and emissivity, Greenhouse gases</td>
</tr>
<tr>
<td>#8</td>
<td>Feb. 4</td>
<td>Global Warming</td>
<td>Observations of temperature, Oxygen isotopes and radiometric dating, Separating science from politics</td>
<td>Testing hypotheses, Mathematical analyses, Impact of politics on science</td>
</tr>
<tr>
<td>#9</td>
<td>Feb. 7</td>
<td>Climate and Watersheds</td>
<td>Definition of watersheds, Mass balance in watersheds, Influence of climate and climate change</td>
<td>Topographic definitions, Hydrologic cycle, Feedbacks in systems</td>
</tr>
<tr>
<td>#10</td>
<td>Feb. 9</td>
<td>Overland Flow</td>
<td>Fluid flow and water pathways, Predicting runoff rates, Flow hydrographs</td>
<td>Hydrology basics intro, Topographic analysis, Graphical analysis</td>
</tr>
<tr>
<td>#11</td>
<td>Feb. 11</td>
<td>Controls on Hydrograph</td>
<td>River networks and water routing, Types of lakes, Thermal cycles and lake overurning</td>
<td>Mathematical reasoning, Mass balance analyses, Residence time analysis</td>
</tr>
</tbody>
</table>

**Readings**  
PWR Chapter 2 (46-66), Reader - Radiative balance, evaporation, radioactivity and radiometric dating  
PWR Chapter 3 (74-86), Reader - Overland Flow

**Lab #2**  Climate, Radiative Balance, Evaporation (due Fri, Feb. 11): Why a Water planet? Evaporation rates and evaporative cool

**Unit 3**  Floods, Flood Prediction, and Groundwater
**Question** Would you build your house here?

**Objective** Quantifying hydrological analyses and the application to human development

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Date</th>
<th>Title</th>
<th>Topics</th>
<th>Key Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>#12</td>
<td>Feb. 14</td>
<td>Open Channel Flow</td>
<td>Measuring and predicting flow</td>
<td>Force balance - river hydraulics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gauging rivers</td>
<td>Hydrological rates, Web data resources</td>
</tr>
<tr>
<td>#13</td>
<td>Feb. 16</td>
<td>Flood Generation</td>
<td>Flood hazards - science and policy</td>
<td>Applying science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Estimating flood frequency</td>
<td>Uncertainty in analyses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Geologic records of paleofloods</td>
<td>Radiometric dating</td>
</tr>
<tr>
<td>#14</td>
<td>Feb. 18</td>
<td>Sediment Transport</td>
<td>Modes of transport</td>
<td>Newton's Laws</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Controls on sediment transport rates</td>
<td>Force balance analyses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Implications for water resource planning</td>
<td>Science and policy</td>
</tr>
<tr>
<td>#15</td>
<td>Feb. 21</td>
<td>Groundwater</td>
<td>Aquifer types and basic geology</td>
<td>Radiometric dating</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Recharge and flow</td>
<td>Mass balance analyses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Groundwater resources in Arizona</td>
<td>Politics of water resources</td>
</tr>
<tr>
<td>#16</td>
<td>Feb. 23</td>
<td>Groundwater Flow</td>
<td>Saturation and capillary tension</td>
<td>Forces in soil water</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Darcy's Law</td>
<td>Empiricism in science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Flow and equipotential line analyses</td>
<td>Mathematical analyses</td>
</tr>
<tr>
<td>#17</td>
<td>Feb. 25</td>
<td>Quantifying Flow</td>
<td>Techniques for studying groundwater</td>
<td>Engineering methods</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pumping tests</td>
<td>Data analyses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fate of contaminant plumes</td>
<td>Applying science</td>
</tr>
</tbody>
</table>

**Readings**

- PWR Chapter 3 (86-103), Reader - flood frequency analysis, uncertainty
- PWR Chapter 4 (104-136)

**Lab #3**

- Surface Water, Flow Records, and Predicting Floods *(due Fri, Feb. 25)*
  Stage-discharge relationships, analysis of gauge data, uncertainty in flood hazard assessment
**Part II: Science as a Guide to Water Resource Management**

**Unit 4 Water Use and Development**

**Question** Do you really want to water your lawn?

**Objective** Establish the importance of science in managing water resources

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Date</th>
<th>Title</th>
<th>Topics</th>
<th>Key Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>#18</td>
<td>Feb. 28</td>
<td>Historical Water Use</td>
<td>Historical drinking water Historical irrigation and flood control</td>
<td>Scientific context Historical scientific uses</td>
</tr>
<tr>
<td>#19</td>
<td>Mar. 2</td>
<td>Water Use in Arizona</td>
<td>AZ water resource development AZ water use law</td>
<td>Resource limitations Science and Law</td>
</tr>
<tr>
<td>#20</td>
<td>Mar. 4</td>
<td>Water Pollution</td>
<td>Major pollutants and sources Point vs. non-point sources Pollution in water resources</td>
<td>Pollutant properties Management implications Chemistry of water quality</td>
</tr>
<tr>
<td>#21</td>
<td>Mar. 7</td>
<td>Surface Water Chemistry</td>
<td>Periodic table of elements Isotopes Inorganic chemicals</td>
<td>Atoms and elements Atomic structure Redox chemistry</td>
</tr>
<tr>
<td>#22</td>
<td>Mar. 9</td>
<td>Organic Chemicals</td>
<td>Pesticides and nutrients The nitrogen cycle The phosphorous cycle</td>
<td>Equilibrium conditions Eutrophication Feedback cycles</td>
</tr>
<tr>
<td>#23</td>
<td>Mar. 11</td>
<td>Waterborne Diseases</td>
<td>Pollutant fate and transport Monitoring water quality Water quality management</td>
<td>Flow path analyses Uncertainty analyses Applying science</td>
</tr>
</tbody>
</table>

**Readings** PWR Chapter 1 (1-23), Chapter 5 (137-174), Reader - Arizona water resources

**Lab #4** Groundwater and overdraft impacts (due Fri, Mar 11)
Darcy's law and groundwater flow, response of the groundwater table to pumping

Detailed Schedule
Unit 5  Municipal Water Development  
**Question** What, me live in a desert?  
**Objective** Applying water development concepts to human population centers

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Date</th>
<th>Title</th>
<th>Topics</th>
<th>Key Concepts</th>
</tr>
</thead>
</table>
| #24      | Mar. 21| Municipal Water System | History and requirements  
Case studies: LA, NYC, Phoenix | Science and politics  
Hydrologic cycle and climate |
| #25      | Mar. 23| Water Uses in Phoenix  | Quantifying water use in Phoenix  
Evaporative losses | Conservation of mass  
Per-capita analyses |
| #26      | Mar. 25| Irrigation          | History and techniques  
History in Arizona  
Agricultural use vs. housing development | Mass balance analyses  
Conservation of mass |
| #27      | Mar. 28| Drinking Water      | What are you drinking?  
Comparison of water sources  
Chemistry of modern water treatment | Purity measures  
Geochemistry |
| #28      | Mar. 30| Desalinization      | A solution for a thirsty world?  
Process, problems and potential | Engineering solutions  
Chemistry and economics |
| #29      | Apr. 1 | Wastewater Treatment | Historical perspective  
Modern treatment processes  
Septic tanks and leach fields | Biogeochemistry  
Fluid flow mechanics |

**Readings**  
PWR Chapter 6 (185-216),  
PWR Chapter 11 (374-405)

**Lab #5**  
Your Water Use (**due Fri, Apr 1**)  
Personal water budget -- tracked throughout the term, analyzed and extrapolated; Evaporative losses in pools
### Water Planet

#### GLG 108

**Unit 6**  
Dams, Landuse Impacts and Wildlife

**Question**  
Do you know what you’re water skiing on?

**Objective**  
Using hydrologic principals to understand competing demands on limited resources

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Date</th>
<th>Title</th>
<th>Topics</th>
<th>Key Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>#30</td>
<td>Apr. 4</td>
<td>Dams</td>
<td>Purpose, design and operation</td>
<td>Engineering principals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Case studies: desert cities of the SW</td>
<td>Water resource sustainability</td>
</tr>
<tr>
<td>#31</td>
<td>Apr. 6</td>
<td>Impact of Dams</td>
<td>River hydrology, morphology, ecology</td>
<td>Conservation of momentum</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>River incision and aggradation</td>
<td>Erosion equation</td>
</tr>
<tr>
<td>#32</td>
<td>Apr. 8</td>
<td>Impacts of Deforestation</td>
<td>Tree removal and hillslope hydrology</td>
<td>Biological controls</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Changes in the hydrological cycle</td>
<td>Biophysical feedbacks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Importance of scale</td>
<td>Climate cycle connections</td>
</tr>
<tr>
<td>#33</td>
<td>Apr. 11</td>
<td>The Ecology of Rivers</td>
<td>Riparian vegetation</td>
<td>Biological needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>History of environmental legislation</td>
<td>Evolution and species loss</td>
</tr>
<tr>
<td>#34</td>
<td>Apr. 13</td>
<td>Salmon in Rivers</td>
<td>Impact of dams</td>
<td>Salmon spawning cycle</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Removal of woody debris</td>
<td>Sediment transport</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Physical processes in salmon evolution</td>
<td>Evolutionary controls</td>
</tr>
<tr>
<td>#35</td>
<td>Apr. 15</td>
<td>Wetlands</td>
<td>Hydrology, ecology and geomorphology</td>
<td>Hydrological principals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Physical and biological processes</td>
<td>Coupled systems, emergent behavior</td>
</tr>
</tbody>
</table>

**Readings**  
PWR Chapter 7 (217-248), chapter 12 (421-427)
PWR Chapter 12 (406-440)
Reader - Deforestation and Water Supplies

**Lab #6**  
Deforestation and Water Resources (due Fri, Apr 15)
Analysis of the impact on water availability, quality, and ecosystem health associated with deforestation

Detailed Schedule  
6
Unit 7  Climate Change and Water Limits
Question Water world, ice world, desert world?
Objective Understanding human impacts on climate and how they impact water resources

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Date</th>
<th>Title</th>
<th>Topics</th>
<th>Key Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>#36</td>
<td>Apr. 18</td>
<td>Greenhouse Gases</td>
<td>Comparisons between models and data</td>
<td>Insolation control, natural vs. man-made Policy implications</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Uncertainty in climate models</td>
<td></td>
</tr>
<tr>
<td>#37</td>
<td>Apr. 20</td>
<td>What About the Ice Ages</td>
<td>Extent and timing of the ice ages</td>
<td>Radiometric dating Milankovitch cycles Data analyses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carbon dioxide and temperature</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Causation vs. correlation</td>
<td></td>
</tr>
<tr>
<td>#38</td>
<td>Apr. 22</td>
<td>Testing Climate Models</td>
<td>Climate change predictions</td>
<td>Global circulation models Mathematical analyses Error analyses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Controls on climate models</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Uncertainties in predicting change</td>
<td></td>
</tr>
<tr>
<td>#39</td>
<td>Apr. 25</td>
<td>AZ Water and Climate</td>
<td>Water as limit to growth</td>
<td>Human water needs Limitations of short-term records Science and politics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The Colorado River Pact</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>History of water use in AZ</td>
<td></td>
</tr>
<tr>
<td>#40</td>
<td>Apr. 27</td>
<td>Economics of Water</td>
<td>Central Arizona Project</td>
<td>Physical flow models Groundwater models Conservation of mass</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Groundwater banking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>AZ water management</td>
<td></td>
</tr>
<tr>
<td>#41</td>
<td>Apr. 29</td>
<td>Estimating Future Needs</td>
<td>Phoenix and Tucson water needs</td>
<td>Predicting water availability Non-local effects of water use Political vs. hydrologic boundaries</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Native American water rights</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Global water conflicts</td>
<td></td>
</tr>
</tbody>
</table>

Readings PWR Chapter 13 (441-454), Chapter 14 (455-477 refresh)
IPCC report on Climate Change, Summary for Policy Makers
Reader - AZ water allocation, sustainability

Lab #7 Phoenix Water Resource Sustainability (due Fri, Apr 29)
Analysis of uncertainty in forecasting Phoenix water availability under different scenarios (Water Sim - DCDC model)
**Unit 8**  Wrap Up and Future Implications  
**Question**  Will water wars replace oil wars?  
**Objective**  Motivating the need for water conservation

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Date</th>
<th>Title</th>
<th>Topics</th>
<th>Key Concepts</th>
</tr>
</thead>
</table>
| #42     | May 3| Uncertainty?| Uncertainty in water resource prediction  
AZ and global implications | Science and prediction  
Politics of water                      |

**Reading**  PWR Chapter 15 (482-502)
Rationale and Objectives

In a relatively short time in the history of civilized societies, humankind moved from what was essentially an agrarian population into an industrial age, which in recent years has been profoundly shaped by such scientific and technological advances as genetic engineering, the computer, and space exploration. Our history of irrepressible ingenuity makes a compelling case for a future that will be even more profoundly influenced by science and technology. It is imperative that we react expeditiously and effectively to the problems and the promise that these advances create. We must ensure that technological change is directed to the benefit of society and that it will promote human dignity and values. Success in achieving this goal will depend upon the insight and knowledge of political and public opinion leaders, and the scientific enlightenment of educated citizens. To a significant degree, the ability of these individuals to understand the nature of the issues and the alternative courses of action will be determined by the quality of science presented at the nation's institutions of higher learning.

The recommendation of at least one laboratory course that includes a substantial introduction to the fundamental behavior of matter and energy in physical or biological systems derives from a number of considerations. First, all physical and biological phenomena have at their roots the fundamental principles governing the behavior of matter and energy. These principles have been shown over a period of time to be a value in reliably predicting and rationalizing a broad range of phenomena. Unless the lines to these roots are established, our understanding of the broader range of the sciences, and other fields upon which these sciences impinge, will be impaired. Second, because these fundamental principles have been experimentally established beyond reasonable doubt, the essentials of the scientific method can be clearly and coherently revealed by their study. Third, the study of the behavior of matter and energy illustrates the usefulness of mathematics in precisely describing and rationalizing certain physical phenomena, and the expressiveness of mathematical equation.
Proposer: Please complete the following sections and attach appropriate documentation.

### ASU--[SQ] CRITERIA

#### I. - FOR ALL QUANTITATIVE [SQ] NATURAL SCIENCES CORE AREA COURSES, THE FOLLOWING ARE CRITICAL CRITERIA AND MUST BE MET:

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>Identify Documentation Submitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>A. Course emphasizes the mastery of basic scientific principles and concepts. SQ criteria justification (1); Detailed course schedule (2)</td>
</tr>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>B. Addresses knowledge of scientific method. Supporting docs 1,2</td>
</tr>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>C. Includes coverage of the methods of scientific inquiry that characterize the particular discipline. Supporting docs 1,2</td>
</tr>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>D. Addresses potential for uncertainty in scientific inquiry. Supporting docs 1,2</td>
</tr>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>E. Illustrates the usefulness of mathematics in scientific description and reasoning. Supporting docs 1,2</td>
</tr>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>F. Includes weekly laboratory and/or field sessions that provide hands-on exposure to scientific phenomena and methodology in the discipline, and enhance the learning of course material. Supporting docs 1,2</td>
</tr>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>G. Students submit written reports of laboratory experiments for constructive evaluation by the instructor. Supporting docs 1,2</td>
</tr>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>H. Course is general or introductory in nature, ordinarily at lower-division level; not a course with great depth or specificity. Supporting docs 1,2</td>
</tr>
</tbody>
</table>

#### II. - AT LEAST ONE OF THE FOLLOWING ADDITIONAL CRITERIA MUST BE MET WITHIN THE CONTEXT OF THE COURSE:

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>Identify Documentation Submitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>A. Stresses understanding of the nature of basic scientific issues. Supporting docs 1,2</td>
</tr>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>B. Develops appreciation of the scope and reality of limitations in scientific capabilities. Supporting docs 1,2</td>
</tr>
<tr>
<td>![ ]</td>
<td>![ ]</td>
<td>C. Discusses costs (time, human, financial) and risks of scientific inquiry. Supporting docs 1,2</td>
</tr>
</tbody>
</table>
### III. - [SQ] COURSES MUST ALSO MEET THESE ADDITIONAL CRITERIA:

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>Identify Documentation Submitted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>☑️</td>
<td>☐</td>
<td>A. Provides a substantial, quantitative introduction to fundamental principles governing behavior of matter and energy, in physical or biological systems.</td>
</tr>
<tr>
<td>☑️</td>
<td>☐</td>
<td>B. Includes a college-level treatment of some of the following topics (check all that apply below):</td>
</tr>
<tr>
<td>☑️</td>
<td>☐</td>
<td>a. Atomic and molecular structure</td>
</tr>
<tr>
<td>☐</td>
<td>☑️</td>
<td>b. Electrical processes</td>
</tr>
<tr>
<td>☑️</td>
<td>☐</td>
<td>c. Chemical processes</td>
</tr>
<tr>
<td>☑️</td>
<td>☐</td>
<td>d. Elementary thermodynamics</td>
</tr>
<tr>
<td>☑️</td>
<td>☐</td>
<td>e. Electromagnetics</td>
</tr>
<tr>
<td>☑️</td>
<td>☐</td>
<td>f. Dynamics and mechanics</td>
</tr>
</tbody>
</table>

### [SQ] REQUIREMENTS CANNOT BE MET BY COURSES:

- Presenting a qualitative survey of a discipline.
- Focusing on the impact of science on social, economic, or environmental issues.
- Focusing on a specific or limiting but in-depth theme suitable for upper-division majors.
Proposer: Please complete the following section and attach appropriate documentation.

**ASU--[SG] CRITERIA**

I. - FOR ALL GENERAL [SG] NATURAL SCIENCES CORE AREA COURSES, THE FOLLOWING ARE CRITICAL CRITERIA AND MUST BE MET:

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>Identify Documentation Submitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>✗</td>
<td>✓</td>
<td>1. Course emphasizes the mastery of basic scientific principles and concepts.</td>
</tr>
<tr>
<td>✗</td>
<td>✓</td>
<td>2. Addresses knowledge of scientific method.</td>
</tr>
<tr>
<td>✗</td>
<td>✓</td>
<td>3. Includes coverage of the methods of scientific inquiry that characterize the particular discipline.</td>
</tr>
<tr>
<td>✗</td>
<td>✓</td>
<td>4. Addresses potential for uncertainty in scientific inquiry.</td>
</tr>
<tr>
<td>✗</td>
<td>✓</td>
<td>5. Illustrates the usefulness of mathematics in scientific description and reasoning.</td>
</tr>
<tr>
<td>✗</td>
<td>✓</td>
<td>6. Includes weekly laboratory and/or field sessions that provide hands-on exposure to scientific phenomena and methodology in the discipline, and enhance the learning of course material.</td>
</tr>
<tr>
<td>✗</td>
<td>✓</td>
<td>7. Students submit written reports of laboratory experiments for constructive evaluation by the instructor.</td>
</tr>
<tr>
<td>✗</td>
<td>✓</td>
<td>8. Course is general or introductory in nature, ordinarily at lower-division level; not a course with great depth or specificity.</td>
</tr>
</tbody>
</table>

II. - AT LEAST ONE OF THE ADDITIONAL CRITERIA THAT MUST BE MET WITHIN THE CONTEXT OF THE COURSE:

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
<th>Identify Documentation Submitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>✗</td>
<td>✓</td>
<td>A. Stresses understanding of the nature of basic scientific issues.</td>
</tr>
<tr>
<td>✗</td>
<td>✓</td>
<td>B. Develops appreciation of the scope and reality of limitations in scientific capabilities.</td>
</tr>
<tr>
<td>✗</td>
<td>✓</td>
<td>C. Discusses costs (time, human, financial) and risks of scientific inquiry.</td>
</tr>
<tr>
<td>Criteria</td>
<td>How course meets spirit</td>
<td>Detailed evidence of how course meets criteria</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>I. A. Course emphasizes mastery of basic scientific principles and concepts</td>
<td><em>Water Planet</em> explores a broad range of basic scientific principles and concepts with the driving motivation of understanding the natural and anthropogenic controls on our water resources.</td>
<td>Throughout, examples: Lec 1-5 Water cycle, mass balance Lec 6-11 Climate system, energy balance, fluid flow Lec 12-17 Force balance, uncertainty, radioactivity All Labs</td>
</tr>
<tr>
<td>B. Addresses knowledge of scientific method</td>
<td>The scientific method is addressed explicitly the first week and is employed in lectures and labs throughout</td>
<td>Lec 2  Scientific Method Lec 38 Testing Climate models And throughout All Labs are built around students engaging in the scientific method</td>
</tr>
<tr>
<td>C. Includes coverage of the methods of scientific inquiry that characterize the particular discipline</td>
<td>Each Laboratory is an exercise in employing methods of scientific inquiry using real or simulated data. Methods of scientific inquiry are discussed in lecture for each unit.</td>
<td>All Labs Best examples are: Labs 2, 3, 4, 6, 7</td>
</tr>
<tr>
<td>D. Addresses potential for uncertainty in scientific inquiry</td>
<td>Lectures and lab exercises emphasize appreciation for the sources and magnitudes of uncertainty and how these impact predictive capability</td>
<td>Lec 4 Measurement uncertainty Lec 8 Global warming evidence Lec 13 Flood hazards Lec 23 Water quality assessment Lec 25 Water use assessment Lec 36-38 Climate models Lec 41-42 Water availability Labs 2, 3, 5, 7 especially</td>
</tr>
<tr>
<td>E. Illustrates the usefulness of mathematics in scientific description and reasoning</td>
<td>Mathematical representation of processes is essential to understanding controlling variables, making predictions and assessing uncertainty. Such relations will be explained in lecture and utilized in labs.</td>
<td>Lec 3, 4, 6-10, 12-14, 16, 25, 31-32, 36-39, 41 All Labs</td>
</tr>
<tr>
<td>F. Includes weekly laboratory and/or field sessions that provide hands-on exposure to</td>
<td>Weekly laboratory exercises are integrated into each unit of the course. Each lab is subdivided</td>
<td>All Labs</td>
</tr>
<tr>
<td><strong>Scientific phenomena and methodology in the discipline, and enhance the learning of course material</strong></td>
<td>into initial hypothesis formulation and data analysis (week 1) followed by synopsis and interpretation of results (week 2)</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>G. Students submit written reports of laboratory experiments for constructive evaluation by the instructor.</strong></td>
<td>The first week of each unit, students will submit their initial hypotheses and initial data analysis for feedback. Armed with a fuller understanding of the underpinning data, concepts and analysis, students will submit summative written lab reports at the end of the second week of each unit. Feedback on reasoning, logic, and presentation will be provided</td>
<td>All Labs</td>
</tr>
<tr>
<td><strong>H. Course is general or introductory in nature, ordinarily at lower-division level; not a course with great depth or specificity</strong></td>
<td><em>Water Planet</em> emphasizes a broad appreciation of the scientific method, water resources, climate change, future pressures (climate, landuse, population) in ways that will be exciting for a non-science student as well as the budding scientist.</td>
<td>All Lectures and Labs</td>
</tr>
</tbody>
</table>
| **II. A. Stresses understanding of the nature of basic scientific issues** | *Water Planet* is an interdisciplinary course that encompasses the physical, chemical, and biological process that influence water resources and the operation of the Earth’s climate system | Unit 1: Lec  3-5  
Unit 2: Lec 6-11  
Unit 3: Lec 12-16  
Unit 4: Lec 20-22  
Unit 6: Lec 31-35  
Unit 7: Lec 36-38, 41  
All Labs, esp.: Labs 2-4, 6-7 |
| **II. B. Develops appreciation of the scope and reality of limitations in scientific capabilities** | Throughout the term students are challenged to confront issues of scientific uncertainties and limitations to our predictive capability through discussions and lab exercises. Limitations of predictive capacity are a central theme in lecture as well. | Unit 1: Lec 1-2  
Unit 2: Lec 8  
Unit 3: Lec 13, 17  
Unit 4: Lec 22-23  
Unit 6: Lec 32-35  
Unit 7: Lec 36-38  
Unit 8: Lec 42  
All Labs, esp.: Labs 2, 3, 7 |
| **II. C. Discusses costs (time, human, financial) and risks of scientific inquiry** | *Water Planet* explores the costs and risks of scientific inquiry through its exploration of several topics that bridge science and policy topics. | Lec 1, 5, 8, 14, 19, 23, 24, 28, 30-34, 36-42  
Labs 2, 3, 6, 7 |
<table>
<thead>
<tr>
<th>III. A. Provides a substantial, quantitative introduction to fundamental principles governing behavior of matter and energy, in physical or biological systems.</th>
<th><em>Water Planet</em> emphasizes the conservation of mass and energy in the operation of the climate system and hydrologic cycle, including interaction between chemical, physical, and biological processes.</th>
<th>Unit 1: Lec 3-5  Unit 2: Lec 6-11  Unit 3: Lec 12-16  Unit 4: Lec 20-22  Unit 5: Lec 25, 28  Unit 6: Lec 31-35  Unit 7: Lec 36-38  Labs 1, 2, 3, 4, 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>III. B. a. Atomic and molecular structure</td>
<td>Treatment includes: properties of the water molecule; phase transitions; surface/capillary tension; isotopes, radioactive decay; chemical pollutants; atomic and crystalline structure and absorption/emissivity.</td>
<td>Lec 3, 4, 7-8, 16, 21, 36-37  Labs 1, 2, 3</td>
</tr>
<tr>
<td>III. B. b. Electrical processes</td>
<td>Not covered</td>
<td></td>
</tr>
<tr>
<td>III. B. d. Elementary thermodynamics</td>
<td>Instruction includes topics in conservation of energy (1st Law Thermodynamics), convection, evaporation and precipitation, and the physical nature of temperature and pressure.</td>
<td>Lec 3-4, 6-8, 16, 36  Lab 2</td>
</tr>
<tr>
<td>III. B. e. Electromagnetics</td>
<td>In discussing the Earth’s climate system we start from solar radiant energy, the temperature dependence of black body radiation, absorption and emissivity of earth materials, and thus the role of greenhouse gasses.</td>
<td>Lec 3, 6-8, 36-37  Lab 2</td>
</tr>
<tr>
<td>III. B. f. Dynamics and mechanics</td>
<td>Basic dynamics and mechanics are distributed throughout the lectures and lab exercises: conservation of mass, energy, momentum and the mechanics of fluid flow in the climate system and hydrological cycle.</td>
<td>Lec 3, 5, 6-11, 12-17, 31-32, 34-35, 36, 38  Labs 2, 3, 4, 6</td>
</tr>
</tbody>
</table>
Criteria Justification

ASU – [SQ] Criteria for GLG108 Water Planet

Specific Criteria Details

I. CRITICAL CRITERA

A. Course emphasizes mastery of basic scientific principles and concepts

Human allocation and utilization of our Earth’s water resources is fundamentally interdisciplinary. *Water Planet* explores a broad range of basic scientific principles and concepts with the driving motivation of understanding the natural and anthropogenic controls on our water resources. For examples: Conservation of mass principles are used to guide understanding of several topics from the hydrological cycle to climate change and water resource allocation; Thermodynamic principles enable clearer understanding of both climate change impacts on water resources and watershed processes; Engineering concepts are coupled with scientific principles in understanding how dams work, how pollutants might be detected, and how water balances are determined; Chemistry of surface waters and how water quality is measured; Politics and policy play important roles in water allocation and *Water Planet* exposes students to the critical ways that science and policy are intertwined.

Other basic scientific principles include conservation of energy (e.g., radiative balance, greenhouse gases and climate); physics of fluid flow; conservation of momentum, sediment transport and erosion; the Coriolis effect and planetary-scale circulation; environmental chemistry applied to the water, carbon, nitrogen, and phosphorous and cycles; understanding the Scientific Method (see section below); appreciating the role of uncertainty, especially in mathematical modeling; the hydrological cycle, and quantifying the controls of climate.

Importantly, *Water Planet* exposes students to an interdisciplinary examination of how such principles and concepts interact to enable all life to survive upon the Earth.

The class does not assume prior university experience in any of the subject fields covered.

B. Addresses knowledge of scientific method

*Water Planet* is organized around the ongoing challenge of managing and quantitatively understanding our water resources. This challenge is especially important under the increasing pressures of a rapidly growing human population, land-use change, and a dynamically changing climate. To provide students with the building blocks of knowledge required to understand this challenge, *Water Planet* teaches how the scientific principles and concepts inherent to the course are used to develop and test hypotheses in a quantitative way. This, by definition, is the scientific method and the course is designed to expose students to science as a process of investigation.
Following immediate exposure to the interdisciplinary motivation for the course, students are taught the scientific method and how it will be used throughout the course to explore every topic covered. The method is presented as a rational and objective approach to understanding any problem, and is then used as an integral part of both the laboratory exercises and in the presentation of topical material in lecture. Each unit of the course is motivated by a provocative question intended to guide hypotheses generation. For example, the first unit on watersheds and the water cycle will present material that will help test hypotheses around the question: “What are the controls and limitations on the water YOU use?” The hypotheses generated through student brainstorming (e.g. “Hypothesis: the water I use is limited by the amount of water stored in a reservoir) will be used in comparison with actual hypotheses that have been tested and explored to provide the basic framework for lectures and lab material.

This approach of leading students through hypotheses generation followed by an exposure to how hypotheses can be tested encourages and even requires continued use of the scientific method. On-line discussion forums will help students interact with one-another, as well as the Teaching Assistants and faculty of Water Planet, to continually work on developing and refining hypotheses and tests of those hypotheses. To further this process, for example, students will be asked to brainstorm and discuss in online forums “What is science?” and “What is needed from scientists concerning water resources given challenges facing AZ and the world today?” Guiding questions such as these, and the questions motivating each unit, will help expose students continually to the process of exploration through the scientific method.

The concept of “Falsifiability” is developed as the first in the set of characteristics (Falsifiable, Logical, Comprehensive, Honest, Repeatable, and Sufficient – “FiLCheRS”) that scientific claims to knowledge must embody. The uncertainty of scientific knowledge (see section below) – the fact that scientific knowledge is never held above our ability to test that knowledge through observation and experiment – is presented as the cornerstone of the strength of science as a way of learning about the world.

A distinction is made between the creative, intuitive, aesthetic side of science – where theories “come from” – and the formal “scientific method” (i.e., hypothesis, prediction, test), that provides the means by which scientific theories are put to the test. This discussion is made very practical through a discussion of the “Method of Multiple Working Hypotheses,” citing early discussions of this method in Geology by T. C. Chamberlain.

C. Includes coverage of the methods of scientific inquiry that characterize the particular discipline

Both the lectures and labs for each of the units of Water Planet delve into the interdisciplinary scientific methods used to understand and quantify various aspects of water. The first part of the course, “The Basic Science of the Water Planet” focuses on the natural science methods used to establish the foundation of what we know about water. Unit 1 explores Watersheds and the
*Water Cycle* through the lens of various topics rooted in basic scientific inquiry. For example, measurement and understanding of the global water cycle requires that key hydrologic fluxes be measured, recorded, and compiled in ways that test fundamental hypotheses governing water flow, storage, and responses to changes in environmental conditions and land-use. The forces that drive the water cycle are taught using material that draws upon fundamental physics, chemistry, hydrology, and engineering. To understand the key fluxes that make up the water cycle means that students are exposed to measurement techniques for determining evaporation, transpiration, and rainfall amounts. Each of these measurements, seemingly simple, is presented with the framework that makes up the basic scientific inquiry that built our fundamental understanding of how our most important natural resource works. We emphasize throughout how different modes of inquiry (field observation, laboratory experimentation, theory, and simulation) must be combined to advance fundamental understanding.

Unit 2 of *Water Planet* focuses on climatic forces that drive the water cycle and respond to changes in the water cycle. Similar to Unit 1, this unit is fundamentally about the natural science of the forces that move water around our planet. Beginning with the presentation of how solar energy helps drive global climate, through an exploration of the radiative balance of insolation across the planet, and culminating with how river networks and thermal cycles in lakes impacts downstream flow of water, this unit exposes students to the essence of scientific inquiry. Floods and flood prediction, Unit 3, follows naturally from this basic understanding of water flow and storage, and introduces students to several more advanced aspects of fundamental science: Newton’s Laws, Force Balance Analyses, Radiometric Dating, Mass Balance Analyses, and how mathematics (see below) is applied to understanding and modeling our water resources.

Part II of *Water Planet* is built on four basic units of *Science as a Guide to Water Resource Management*: 1) Water Use and Development; 2) Municipal Water Development; 3) Dams, Landuse Impacts and Wildlife; 4) Climate Change and Water Limits. This part of the class integrates the natural science aspects of Part I with some of the social science aspects that make the study of water a truly interdisciplinary endeavor. In these units, as well as in the basic science units of Part I, students will combine laboratory exercises with lecture material. These lab exercises are designed to mimic real scientific investigations such that students gain a hands-on understanding of specific methods of scientific inquiry currently in use.

All laboratory exercises for the course provide this hands-on experience with current methods. Examples include: (1) Lab 1 -- Watersheds and the Water Cycle, which includes evaluation of mass fluxes within the water cycle with emphasis on water recycling by evapotranspiration and also includes topographic analysis to define watersheds; (2) Lab 2 -- Climate, Radiative Balance, Evaporation, which includes analysis of basic radiative balance to ask why Earth is the water planet and also explores methods of estimating evaporation rates and evaporative cooling; (3) Lab 3 -- Surface Water, Flow Records, and Predicting Floods, which includes working with basic hydraulic data and evaluation of stage-discharge relationships, analysis of gauge data, assessment of flood hazards and evaluation of uncertainties; (4) Lab 4 -- Groundwater and
overdraft impacts, which includes analysis of groundwater flow rates and patterns using Darcy's law, and evaluation of the response of the groundwater table to pumping; and (5) Lab 7 -- Phoenix Water Resource Sustainability, which includes analysis of uncertainty in forecasting Phoenix water availability under different scenarios using the Water Sim web-based model developed by DCDC program in GIOS.

D. Addresses potential for uncertainty in scientific inquiry

*Water Planet* integrates scientific methodology with prediction based on models in every unit covered by the course. This framework of establishing what we know through scientific measurements as a way to build models for prediction is intrinsically connected to uncertainty assessment. As a result, *Water Planet* exposes students to the concept of uncertainty in science, the sources of uncertainty, principles of error propagation, and an appreciation of uncertainty in prediction throughout the course.

Students gain more complete understanding of the role that uncertainty plays in scientific inquiry through the laboratory exercises, most of which utilize actual data or the compilation of publically available data. Here again uncertainty in the science of prediction is treated in several laboratory exercises. The most exemplary in this regard include: (1) Lab 2 -- Climate, Radiative Balance, Evaporation, which includes analysis of the difficulty and uncertainty in measuring evaporation rates over the short-term at specific locations and extrapolation of these measurements over large spatial domains and to annual timescales; (2) Lab 3 -- Surface Water, Flow Records, and Predicting Floods, emphasizes uncertainty in the historical flow record, and uncertainty in the assessment of flood hazards given limitations to our scientific knowledge and the short duration of historical records; and (3) Lab 7 -- Phoenix Water Resource Sustainability, which emphasizes analysis of uncertainty in forecasting Phoenix water availability under different scenarios using the Water Sim web-based model developed by DCDC program in GIOS.

E. Illustrates the usefulness of mathematics in scientific description and reasoning

Although the course does not delve deeply into mathematical analyses, math is integral to how scientific measurements are used to build the models and predictions covered by *Water Planet*. Each of the course units integrates topics that emphasize field based measurements used to collect scientific data – e.g. topographic measurements to define watersheds; measurements of rainfall, evaporation, and infiltration to determine water flux through the watershed; flow measurements in the rivers that drain the watersheds and feed the reservoirs or agricultural fields; flood frequency measurements; climatic observations that build our global circulation models of how the atmosphere is coupled with the hydrosphere; etc. Students are exposed to how these data are utilized to evaluate the relationship between environmental conditions and variables of
interest (e.g., water availability, water quality, etc), and how they inform development of theory and models.

These field-based observations are also used in models that are based on mathematical representation of systems with complex feedbacks that impact that predictions generated by the model. To truly comprehend the integrated nature of these models, students work with real data used in real mathematical models. Basic mathematical concepts and reasoning will therefore be inherent in how Water Planet connects theory with empirical observations to arrive at predictions that are critical for human survival and development.

**F. Includes weekly laboratory and/or field sessions that provide hands-on exposure to scientific phenomena and methodology in the discipline, and enhance the learning of course material**

Each unit of Water Planet is developed around a weekly laboratory exercise that builds on material presented in class to provide students with hands-on experiences in working with scientific data, methodologies, and the formulation and testing of hypotheses. As some of the examples used above helped to show, these laboratories are designed to enable students to investigate key science concepts using real data in an iterative, inquiry-driven way. Laboratory exercises will be delivered online, and feedback given to students on a weekly basis. To assist online delivery, lab expectations will be reviewed in lecture, and detailed lab instructions will be posted in both written and video TA-lecture format. In addition, TA and instructor will be available via on-line chat rooms for discussions and clarifications. We believe that if done well, online exercises can offer an advantage over traditional physical laboratory exercises. Rather than emphasizing use of laboratory equipment, we can emphasize the logic, reasoning, hypothesis formulation, data analysis, and hypothesis testing aspects that are so critical to the process of scientific inquiry. Thus the laboratory exercises can greatly enrich the learning experience by making students active participants in the process of scientific discovery. In addition, the laboratory exercises will often use data from real-world problems in Arizona water resources, and thus help make the topic “real and present” for the students. Labs 1, 3, 4, 5, and 7 are particularly strong in this regard.

The laboratory exercises are weekly, but integrated into the 2-week unit organization of the course. Laboratory exercises the first week of each unit will emphasize hypothesis formulation, data compilation, and preliminary data analysis. Feedback on these short answer reports due that week will be provide before students engage on the second half of the exercise to ensure they have understood the fundamentals. The second week of each unit, the laboratory exercise will emphasize data analysis, hypothesis testing, and interpretation due in the form of a written report (see below).

**G. Students submit written reports of laboratory experiments for constructive evaluation by the instructor.**

Each lab requires the submission of written reports by students. The style of these reports will vary. Each lab is integrated with a 2-week course unit and will therefore involve an iterative
process for the students. Week 1 of the lab will involve hypothesis formulation, short answers and basic data analyses as a strategy to rapidly immerse students in the process of data collection and analysis. Feedback on this initial analysis will help guide students in development of their final lab report (and ensure deeper learning of the material). Final lab reports will include short written summaries of the results of analyses, as well as a fuller written consideration of the implications of the analyses that will be due at the close of Week 2 of the lab exercise. This generic style that is applied to each of the lab exercises requires students to make scientific observations (or collect such observations from on-line sources of data), record the quantitative information about those observations, as well as draw conclusions from them and write a coherent paragraph discussing the properties of each. Importantly, the later labs in Water Planet also require a third style of write-up in which students are asked to reason with concepts developed in class and in earlier labs.

The TA and instructor will assess these lab reports. Feedback on analyses, reasoning, logic and presentation style will be provided.

H. Course is general or introductory in nature, ordinarily at lower-division level; not a course with great depth or specificity

Water Planet is by design a course for non-majors and entry to SESE’s new BA degree in Earth and Environmental Science. The course emphasizes a broad appreciation of the scientific method, water resources, climate change, future pressures (climate, landuse, population) in ways that will be exciting for a non-science student as well as the budding scientist. A fundamental message of the class is to impart the importance of having a rational scientific basis for resource allocation, planning, and policy.

The course makes no assumptions about scientific background beyond introductory high school material, and uses no mathematics beyond proportions and simple algebra. The textbook (Principles of Water Resources) is in its 3rd edition and has been used successfully in many introductory-level science courses. The course reader augments the text to enhance treatment of some fundamental science topics not covered in any detail in typical water resources courses: blackbody radiation, radiative balance, emissivity/absorption of earth materials, radioactivity and radiometric dating (unit 2); and flood frequency analysis, quantifying uncertainty, error propagation (unit 3). In addition the course reader includes supplementary information on Arizona water resources issues (units 4 and 7), and the impacts of land-use change on water resources. Course content covers a broad range of fundamental concepts from many fields of scientific inquiry that intersect in the study of the hydrological cycle, climate system, and water resource quality and availability. While this course is (and is intended to be) more challenging than most General Studies science courses (SG courses), it retains the broad survey format of a General Studies SQ course.
II. AT LEAST ONE OF THE FOLLOWING CRITERIA

A. Stresses understanding of the nature of basic scientific issues

*Water Planet* exposes students to the fundamental underlying basic scientific issues across each of its subject units. The interdisciplinary nature of the subject matter requires material to be presented by connecting scientific material traditionally taught in a disciplinary way. For example, to fully understand water supply to a domestic source requires an integration of basic concepts drawn from the fields of geomorphology, geology, hydrology, engineering, atmospheric science, chemistry and physics. These disciplines span the fundamental scientific concepts that are used to underpin the subject matter of this class: concepts such as conservation of mass, conservation of energy, carbon, phosphorous and nitrogen cycles, fluid flow, isotope fractionation, radioactive decay, isotopic dating, groundwater flow, atmospheric and oceanic circulation, and the operation of the Earth’s climate system and hydrological cycle.

B. Develops appreciation of the scope and reality of limitations in scientific capabilities

Students are presented with an interesting paradox at the beginning of *Water Planet* and the theme of the paradox continues throughout the course. This paradox is quite simply the fact that although our knowledge of basic scientific principles governing the movement of water across the Earth is quite well developed, our capability to predict future water availability is quite limited. This paradox underlies the nature of flood forecasting, determining the impacts of climate change, predicting the hazards of contaminant transport, as well as the impacts of deforestation. All these examples are exploited as vehicles for the discussion of uncertainty – determining sources and magnitudes of uncertainty, propagation of error, and ultimately uncertainty in predictions. Throughout the course, appreciating the scope and reality of the limitations of scientific capabilities is placed in the critical context of the complex connection between science and policy. A key question students are asked to reflect on is: how best can science be used to guide policy, resource allocation, and planning for future use and development, while fully accounting for the uncertainty inherent in the science of prediction.

C. Discusses costs (time, human, financial) and risks of scientific inquiry

*Water Planet* explores the costs and risks of scientific inquiry through its exploration of several topics that bridge science and policy topics. The first two units of the course provide the basic science that goes into quantifying climate and the amount of water flowing through any Earth system. These scientific building blocks are then used in subsequent units that focus on flood prediction, water use and development, municipal water development, dams and deforestation, and climate change. In each of these subsequent units the lab exercises as well as some of the lecture material will highlight the decision making process that goes into human water
III. ADDITIONAL SQ CRITERIA

A. Provides a substantial, quantitative introduction to fundamental principles governing behavior of matter and energy, in physical or biological systems.

*Water Planet* emphasizes the conservation of mass and energy in the operation of the climate system and hydrologic cycle, including interactions between chemical, physical, and biological processes. Thus, as described above in response to various specific criteria, and further elaborated in the detailed course schedule, the course includes substantial, quantitative but introductory-level treatment of: the conservation mass and energy in many guises within the climate system and hydrological cycle; radiative balance and Earth’s climate including blackbody radiation as a function of temperature and the emissivity and absorption properties of earth materials at different wavelengths; force balances in the surface water and groundwater flows; convection, the Coriolis effect, and planetary circulation; conservation of momentum, sediment transport, erosion and water quality; radioactivity, isotopes and isotope fractionation; surface water chemistry and biogeochemical cycles (nitrogen, phosphorous and carbon); and measurement error, error propagation, and scientific uncertainty,

See Criteria checklist and Detailed Schedule of Topics for itemization of specific topics covered in both lectures and labs.

B. Includes a college-level treatment of aspects of the following topics:

Treatments of each of these fundamental science topics is briefly summarized below. Lectures and Labs cited below are described in the Detailed Schedule of Topics on pages 13-20.

a. Atomic and molecular structure

Treatment includes: properties of the water molecule -- phase transitions, surface/capillary tension, universal solvent; isotopes, isotopic fractionation and radioactive decay; chemical pollutants and the importance of their molecular structure in the environment; and how atomic and crystalline structure control absorption/emissivity as a function of electromagnetic wavelength. These concepts are developed particularly in Lectures 3, 4, 7-8, 16, 21, 36-37, and employed in Labs 1, 2, 3 (see Detailed Schedule of Topics).

b. Electrical processes

Nothing significant.

c. Chemical processes
Treatment includes: Water quality (pH, salinity, toxicity); behavior of chemical species in soils, waterways and ecosystems; critical biogeochemical cycles (carbon, nitrogen and phosphorous); and the use of isotopic fractionation in physical and biotic processes as a tracer of water and elemental pathways, fluxes, and residence times within the hydrologic cycle and climate system. These concepts are developed particularly in Lectures 4, 7, 17, 20-22, 27-29, 36, and employed in Labs 1, 4, 6 (see Detailed Schedule of Topics).

d. Elementary thermodynamics

Instruction includes topics in conservation of energy (1st Law Thermodynamics) – particularly the radiative balance, greenhouse gases, and the operation of the climate system and hydrological cycle, convection and the thermodynamics of evaporation and precipitation, and the physical nature of temperature and pressure. These concepts are developed particularly in Lectures 3-4, 6-8, 16, 36, and employed in Lab 2 (see Detailed Schedule of Topics).

e. Electromagnetics

In discussing the Earth’s climate system we start from solar radiant energy, the temperature dependence of black body radiation (Wien’s Law, Planck’s Law), absorption and emissivity of earth materials a different electromagnetic wavelengths (a function of atomic and molecular structure control absorption/emissivity), and thus the role of greenhouse gases in controlling Earth’s climate. These concepts are developed particularly in Lectures 3, 6-8, 36-37, and employed in Lab 2 (see Detailed Schedule of Topics).

f. Dynamics and mechanics

Instruction in basic dynamics and mechanics is distributed throughout the lectures and lab exercises. Topics discussed in some detail emphasize the conservation of mass, energy, and momentum and their interplay with the mechanics of fluid flow to dictate much of the physical behavior of the climate system and hydrological cycle. Specific topics covered include: Newton’s Laws of motion, force balances, the Coriolis effect, planetary circulation patterns, atmospheric convection, distribution of precipitation, flood flow velocities, stage-discharge relationships, sediment transport, erosion, water quality, groundwater response to pumping, and residence times of various water resources. These concepts are developed particularly in Lectures 3, 5, 6-11, 12-17, 31-32, 34-35, 36, 38, and employed in Labs 2, 3, 4, 6 (see Detailed Schedule of Topics).
by Cech, Thomas V., Univ. of Colorado

Table of Contents

Chapter 1. Historical Perspective of Water Use and Development, 1
   Drinking Water for Early Civilizations, 1
   Early Irrigation and Flood-Control Projects, 6
      Egypt, 6
      China, 6
      The Middle East, 8
      India, Spain, Portugal, and South America, 9
      North America, 9
   Early Water Transportation Development, 13
      Egypt and Greece, 13
      China, 13
      Europe, 14
      United States, 15
   Early Hydropower Development, 18

Chapter 2. The Hydrologic Cycle, Climate, and Weather, 24
   The Properties of Water, 25
   The Hydrologic Cycle, 27
      Precipitation, 27
      Measuring Precipitation, 29
      Runoff, 32
   Surface and Groundwater Storage, 33
      Lakes and Reservoirs, 33
      CASE STUDY Great Salt Lake of Utah, 35
      CASE STUDY The Aral Sea of Uzbekistan, 35
      Wetlands, 36
      Groundwater, 37
   Evaporation, 38
   Condensation, 41
      GUEST ESSAY Fog Harvesting by Dr. Robert S. Schemenauer, 41
   Climate and Weather, 46
      Overview, 46
      Climate, 46
      Air Currents, 46
      Ocean Currents, 48
      Tilt of the Earth’s Axis, 49
      Monitoring Climate Change, 50
      Urban Microclimates, 51
      GUEST ESSAY Urbanization and Its Effects on Key Atmospheric and Surface Water Cycles by Dr. J. Marshall Shepherd, 51
Chapter 3. Surface Water Hydrology, 74
What Is Surface Water Hydrology?, 75
Watersheds, 75
   Delineating a Watershed, 75
Overland Flow, 78
Rivers, 79
   Components of a River, 79
   River Morphology, 79
   Types of Rivers, 82
   Gradient, 83
Lakes, 83
   Types of Lakes, 84
   Ecological Zones, 84
   Thermal Cycles, 85
   Seiches, 86
Water Measurement, 86
   Overland Flow, 87
   River Discharge, 87
   Water Storage in Lakes and Reservoirs, 90
Flood Events, 91
   Flood Frequency, 92
   Probable Maximum Precipitation, 93
   Probable Maximum Flood, 93
      GUEST ESSAY GIS and Flooding by Jake Freier, 94
Transport and Deposition, 97
   Velocity, 98
   Sediment Load, 98

Chapter 4. Groundwater Hydrology, 104
What Is Groundwater?, 105
What Is Groundwater Hydrology?, 106
The Geology of Groundwater, 107
   Sedimentary Rocks, 107
      GUEST ESSAY Sinkholes by Carlos Herd, 108
   Glaciated Terrain, 111
Alluvial Valleys, 113
Tectonic Activity, 113
Groundwater Recharge, 114
Aquifers, 115
  Aquifer Types, 116
  Properties of Aquifers, 119
Groundwater Movement, 121
Age of Groundwater, 126
Locating and Mapping Groundwater, 127
Drilling a Groundwater Well, 129

Chapter 5. Water Quality, 137
Water Pollution, 137
  Point Source and Nonpoint Source Pollution, 139
    Point Source Pollution, 139
    Nonpoint Source Pollution, 142
Basic Parameters of Water, 143
  Temperature, 143
  Dissolved Oxygen, 144
    pH, 144
    Turbidity, 146
    Hardness, 147
Inorganic Chemicals, 147
  Metals, 148
    Lead, 148
  Arsenic, 149
  Minerals, 150
Salt, 150
  POLICY ISSUE, 150
  Fluoride, 152
  Selenium, 152
Organic Chemicals, 153
  Natural Organic Chemicals, 153
  Synthetic Organic Compounds, 153
Pesticides, 155
Nutrients, 157
  Nitrogen, 157
    Phosphorus, 158
The Nitrogen Cycle, 159
  Nitrogen Fixation, 160
  Mineralization/Ammonification, 160
  Nitrification, 160
  Denitrification, 161
The Phosphorus Cycle, 161
Eutrophication, 162
Waterborne Diseases, 162
Historical Problems, 162
Microorganisms, 164
  Indicator Organisms, 164
  Other Waterborne Organisms, 165
Water Quality Management, 167
Fate and Transport, 167
  Fate and Transport in Surface Water, 167
  Fate and Transport in Groundwater, 167
  GUEST ESSAY Managing Data for a Groundwater Restoration Project by Dr. Curt Elmore, 169
Wellhead Protection Programs, 171
  Organization, 171
  Delineation, 171
  Contamination Source Inventory, 173
  Source Management, 173
  Contingency Planning, 173
Watershed Protection Programs, 173
  Total Maximum Daily Loads, 174
  GUEST ESSAY Lake Okeechobee TMDLs by Dr. David Radcliffe and Dr. Todd Rasmussen, 175
Water Sampling, 177

Chapter 6. Municipal and Irrigation Water Development, 185
Municipal Water Systems, 186
  CASE STUDY Los Angeles Department of Water and Power, 187
  CASE STUDY Lincoln Water System, 191
  CASE STUDY New York City Department of Environmental Protection, 193
  GUEST ESSAY Construction of City Tunnel #3 by Eileen M. Schnock, 196
Irrigation, 202
  Historical Perspective, 202
  The Need for Irrigation, 202
  Irrigation Techniques, 205
    Gravity Irrigation, 206
    Sprinkler Irrigation, 210
    Drip Irrigation, 213

Chapter 7. Dams, 217
Dam Basics, 217
  Purposes of Dams, 217
  Components of Dams, 218
  Types of Dams, 219
  Dam Operations, 221
  CASE STUDY Hoover Dam and Lake Mead, Nevada/AZrizona, 223
  CASE STUDY Kingsley Dam and Lake McConaughy, Nebraska, 227
  CASE STUDY Grand Coulee Dam and Franklin D. Roosevelt Lake, Washington State, 231
Chapter 8. Water Allocation Law, 249
Ancient Water Allocation Law, 250
Code of Hammurabi, 250
Justinian Code, 251
Ancient Riparian Doctrine, 251
Water Allocation Law: 1200–1799, 252
Spanish Water Law, 252
First Possession, 254
English Common Law: 1200–1799, 255
Mill Acts of the Eastern United States, 255
Water Allocation Law: 1800–1847, 258
Code Napoléon, 258
Riparian Doctrine: 1800–1847, 258
Tyler v. Wilkinson, 259
Water Allocation Law in the Western United States: 1800–1847, 260
Water Allocation Law: 1848–1899, 262
Riparian Doctrine, 262
Doctrne of Prior Appropriation: 1848–1899, 262
The California Gold Rush, 264
The Colorado Gold Rush, 267
Water Allocation Law: 1900–Present, 272
Riparian Doctrine, 272
Doctrine of Prior Appropriation: 1900–Present, 274
Interstate River Compacts, 277
Selected River Compacts, 277
Colorado River Compact of 1922, 277
Niagara River Water Diversion Treaty of 1950, 281
Delaware River Compact of 1961, 281
Groundwater Allocation Law, 282
Historical Perspective, 282
Role of the Federal Government, 283
Legal Properties of Groundwater, 284
Federal Reserved Water Rights, 286
GUEST ESSAY Stream Subflow and Water Rights by John Regan, 287

Chapter 9. Federal Water Agencies, 294
U.S. Army Corps of Engineers (USACE), 295
Overview, 295
Brief History and Duties, 295
Navigation Duties, 296
Flood-Control Duties, 300
Wetlands Protection Duties, 303
U.S. Bureau of Reclamation (USBR), 306
  Overview, 306
  Brief History, 307
  National Irrigation Congresses, 308
  The Reclamation Act of 1902, 309
  The Anti-Dam Construction Era, 310
U.S. Environmental Protection Agency (USEPA), 312
  Overview, 312
  Brief History, 313
U.S. Geological Survey (USGS), 316
  Overview, 316
  Brief History, 316
U.S. Fish and Wildlife Service (USFWS), 320
  Overview, 320
  Brief History, 320
National Park Service (NPS), 322
  Overview, 322
  Brief History, 322
Bureau of Land Management (BLM), 324
  Overview, 324
  Brief History, 324
Natural Resources Conservation Service (NRCS), 325
  Overview, 325
  Brief History, 326
U.S. Forest Service (USFS), 326
  Overview, 326
  Brief History, 326
Federal Energy Regulatory Commission (FERC), 327
  Overview and Brief History, 327
National Marine Fisheries Service (NMFS), 329
  Overview and Brief History, 329
Federal Emergency Management Agency (FEMA), 329
  Overview and Brief History, 329

Chapter 10. Local, Regional, State, and Multistate Water Management Agencies, 338
Local Water Agencies, 338
  Municipal Water Departments, 338
    Historical Overview, 339
  Water and Sewer Districts, 341
    Overview, 341
      EXAMPLE: Highline Water District, Kent, Washington, 341
Levee and Flood-Control Districts, 342
    Historical Overview, 342
Levee Districts, 342
Flood-Control Districts, 345
EXAMPLE: Pima County Regional Flood Control District, Tucson, Arizona, 345
Mutual Ditch and Irrigation Companies, 346
Historical Overview, 346
Regional Water Agencies, 348
Overview, 348
Irrigation Districts, 348
EXAMPLE: Farwell Irrigation District, Farwell, Nebraska, 348
Conservancy/Conservation Districts, 349
EXAMPLE: Miami Conservancy District, Dayton, Ohio, 350
Natural Resources Districts—Nebraska, 350
EXAMPLE: Papio-Missouri River Natural Resources District, Omaha, Nebraska, 351
Groundwater Management Districts—Kansas, 352
EXAMPLE: Northwest Kansas Groundwater Management District No. 4, Colby, Kansas, 353
Water Management Districts—Florida, 353
State Water Agencies, 355
State of Arizona Water Agencies, 355
State of Rhode Island Water Agencies, 356
Multistate Water Agencies, 357
Chesapeake Bay Commission, 357
Missouri River Basin Association, 357
Water Management in Mexico and Canada, 359
Overview, 359
GUEST ESSAY Water Management in Mexico by Dr. Alvaro A. Aldama, 360
GUEST ESSAY Water Management in Canada: The Inter-Jurisdictional Context by Ralph L. Pentland, 366
Careers, 371

Chapter 11. Drinking-Water and Wastewater Treatment, 374
Historical Perspective on Drinking-Water Treatment, 374
GUEST ESSAY Water Desalination in the Middle East: One of the Realistic Options by Dr. Fares M. Howari, 380
Federal Protection of Drinking Water in the United States, 383
Drinking-Water Treatment Process, 384
Protection of Water Quality, 384
Intakes for Raw Water, 385
CASE STUDY Department of Water Management, City of Chicago, Illinois, 386
Pretreatment of Drinking Water, 388
Flocculation/Coagulation, 388
Filtration, 388
CASE STUDY Sewerage and Water Board, City of New Orleans, Louisiana, 389
Final Drinking-Water Treatment, 390
Distribution System, 390
Historical Perspective on Wastewater Treatment, 393
Wastewater Treatment Process, 396
Primary Treatment, 396
Secondary Treatment, 397
Tertiary Treatment, 398
Nutrient Removal, 398
Septic Tanks and Leach Fields, 399
Wetlands and Water Treatment, 400

Chapter 12. Water, Fish, and Wildlife, 406
Early Fish and Wildlife Protection, 406
Fish and Wildlife Protection in the 20th Century, 407
Wild and Scenic Rivers Act, 408
National Environmental Policy Act, 410
Endangered Species Act, 413
Wetlands and Wildlife, 415
CASE STUDY Snail Darters and the Little Tennessee River, 421
CASE STUDY Whooping Cranes and the Platte River, 424
CASE STUDY Salmon and the Columbia River, 428
Human–Environment Relationship, 434
GUEST ESSAY Careers in Fish and Wildlife Management by Larry Rogstad, 434

Chapter 13. The Economics of Water, 441
Introduction, 441
The Value of Water, 442
Water as a Public versus a Private Good, 443
Privatization, 444
Water Affordability, 445
Water Marketing, 446
Surface Water Marketing, 446
Groundwater Marketing, 449
Water Banking, 450
Pollution Fees and Credits, 451
Environmental Values, 452

Chapter 14. Water Use Conflicts, 455
Reasons for Water Use Conflicts, 455
Texas, 457
GUEST ESSAY Water Planning in Texas by Connie Townsend, 458
Alabama and Florida versus Georgia, 463
Northern and Southern California, 468
Canada, 469
The Middle East, 470
Religious/Political Background, 471
Water Resources in the Middle East, 473
West Bank Mountain Aquifer, 473
Jordan River, 473
Chapter 15. Emerging Water Issues, 482

Future Global Water Management Issues, 483
  Population, 483
  Lack of Wastewater Treatment, 483
  Environmental Degradation, 484
  SCENARIO 1: “Business as Usual”, 485

Future Global Water Management Solutions, 486
  Privatization of Water Treatment and Delivery, 486
  SCENARIO 2: “Technology Saves the Day”, 487
  Groundwater Recharge, 487
  Water Conservation, 488
  Dam Construction, 489
  SCENARIO 3: “Global Warming Floods the World”, 490
  Water Education, 490
    The Watercourse and Project WET, 490
    Water Education Foundation, 491
    Groundwater Foundation, 491
    American Ground Water Trust, 491
    Stockholm International Water Institute, 492
  The Need for Cooperation, 492
    The Human Factor, 492
    Ethics, 493
    The Power of the Individual, 494
  SCENARIO 4: “Space Is the Answer”, 495
  GUEST ESSAY Where Do We Go from Here? by Susan S. Seacrest, 496

Conclusions, 499

Appendix: Reading Topographic Maps, 503

Selected Environmental and Conservation Organizations, 504
  Ducks Unlimited, 504
  Environmental Defense Fund, 504
  National Audubon Society, 505
  National Wildlife Federation, 506
  Nature Conservancy, 506
  Natural Resources Defense Council, 506
  Sierra Club, 506
  Trout Unlimited, 507
  Wilderness Society, 507

Photo and Illustration Credits, 509

Glossary, 513

Index, 527

End Paper, 547