Revised syllabus added 3/23/2015

**Washington State University**
**MAJOR CURRICULAR CHANGE FORM - - NEW/RESTORE COURSE**

- ☐ **Please attach rationale for your request, a complete syllabus**, and explain how this impacts other units in Pullman and other campuses (if applicable).
- ☐ **Obtain all required signatures with dates.**
- ☐ **Provide original stapled packet of signed form/rationale statement/syllabus** PLUS **10 stapled copies** of complete packet to the **Registrar's Office**, campus mail code 1035.
- ☐ **Submit one electronic copy of complete packet** to wsu.curriculum@wsu.edu.

Requested **Future** Effective Date: 01/01/2016 (term/year) Course Typically Offered: Spring

**DEADLINES:** For fall term effective date: **October 1st**; for spring or summer term effective date: **February 1st**. See instructions.

**NOTE: Items received after deadlines may be put to the back of the line or forwarded to the following year. Please submit on time.**

☒ **New Course** ☐ Temporary Course ☐ **Restore Course**

| CE | 562 | Advanced Subsurface Flow and Transport |
|---|---|---|
| course subject/crosslist | course no. | title |

| 3 | ( - ) | | |
|---|---|---|---|
| Credit hrs | lecture hrs per week | lab or studio hrs per week | prerequisite |

Description for catalog: see attached

**Additional Attributes: Check all that apply.**

☐ Crosslisting (between WSU departments)* ☐ Conjoint listing (400/500): _____

☐ Variable credit: _____ ☐ Repeat credit (cum. max. hrs): _____

Special Grading: ☐ S, F; ☐ A, S, F (PEACT only); ☐ S, M, F (VET MED only); ☐ H, S, F (PHARMACY, PHARDSCI only)

☐ Cooperative with UI ☐ Other (please list request ): _____

**The following items require prior submission to other committees/depts. (SEE INSTRUCTIONS.)**

☐ Request to meet Writing in the Major [M] requirement **(Must have All-University Writing Committee Approval.)**

☐ Request to meet UCORE in _____ **(Must have UCORE Committee Approval › › See instructions.)**

☐ Special Course Fee _____ **(Must submit request to University Receivables.)**

**Contact:** Brooke Whiting Phone number: 335-1219 Campus mail code: 2910

Email: bwhiting@wsu.edu Instructor, if different: nick.engdahl@wsu.edu

| | | |
|---|---|---|
| 1/28/15 | 1/28/15 | |
| **Chair/date** | **Dean/date** | **All-University Writing Com / date** |
| | | |
| **Chair (if crosslisted/interdisciplinary)*** | **Dean (if crosslisted/interdisciplinary)*** | **UCORE Committee Approval Date** |
| | | |
| **Catalog Subcommittee Approval Date** | **GSC or AAC Approval Date** | **Faculty Senate Approval Date** |

***If the proposed change impacts or involves collaboration with other units, use the additional signature lines provided for each impacted unit and college.**

Catalog Course Description:

CE 562 Advanced Subsurface Flow and Transport

Analysis of the dynamics of subsurface fluid flow in porous media that give rise to contaminant transport behaviors at multiple scales. Emphasis is placed on developing a qualitative knowledge of the features that cause deviations from idealized transport behaviors and the mathematical tools required to model transport in natural, heterogeneous aquifers for both passive and reactive solutes.

**Course Proposal: CE 562 Advanced subsurface flow and transport**

## Course Description

CE562 is a graduate-level class designed for students with an interest in understanding the mechanics and processes that drive the migration of solutes and other contaminants in groundwater flow systems. The goal of the class is to develop the mathematical skills and geological intuition needed to describe transport phenomena in porous media with a strong emphasis on the limitations of the classically applied approaches. The class covers the fundamental mechanics of groundwater flow through porous media starting at small scales to understand how those behaviors propagate to larger scales. Significant information about the distribution of groundwater velocities is lost when modeling at normal scales (greater than individual pores) and this lost information is crucial to accurate prediction of contaminant migration in natural systems. The class focuses on understanding the governing equations and developing familiarity with the mathematical tools used to solve the complex differential equations of solute transport, with a strong emphasis on the connections to physical processes in the real world. Additional topics include uncertainty analysis, stochastic hydrology, volume averaging, and some geochemistry. Overviews of emerging techniques for modeling solute transport, with and without reactions, are also provided, giving students direct exposure to the latest theoretical advances.

The course is currently being taught (Spring 2015) for the first time with a temporary course number. Enrollment is 7 individuals, all from civil and environmental engineering. It is anticipated that enrollments will increase once the course is given a permanent number and more students are aware of the class. The class will appeal to students in civil and environmental engineering as well as the geology and soil science programs.

Table 1. Past semesters during which the proposed class has been offered with a temporary course number.

| Course Number | Course Title | Semester | Enrollment |
|---|---|---|---|
| CE 552(1) | Advanced subsurface flow and transport | Spring 2015 | 7 |

## Course Rationale

Contamination and remediation of limited water resources is one of the single most important issues facing society. Understanding and accurately predicting the migration of solutes is crucial for assessing human health risks, agricultural sustainability, ecosystem management, along with many other areas of profound relevance to society. Some of the most common examples of problems directly involving the transport of contaminants into drinking water include concerns about fracking fluid, chlorinated solvents, arsenic, dissolved gasses, non-aqueous phase liquids, salt-water, and nitrate. Current course offerings at WSU provide an introduction to groundwater flow and some aspects of reactions in subsurface flow systems, in separate classes, but no advanced courses on groundwater are currently offered and no courses exist addressing the migration of contaminants in natural systems. As our reliance on groundwater as a society increases it is important to understand the details of the challenges we face in order to design effective solutions for the future preservation of our water resources. This class will provide students with a unique balance of theory, concepts, and exposure to modern research on solute transport equipping them to develop solutions for the complicated problems faced by civil, environmental, and geological scientists and engineers.

updated syllabus 3/23/2015

**CE 562 – Advanced subsurface flow and transport**

**Spring 2015**
**Tu/Th 10:35 am -11:50am**
**Room: Sloan 233**

**Prerequisites**: Fluid mechanics, introduction to groundwater recommended, or instructor permission.

**Course material**: Mechanics of groundwater flow and solute transport in natural and engineered porous media systems.

**Textbook:** Charbeneau, R.J, Groundwater hydraulics and pollutant transport, 2006.

**Instructor:** Nicholas Engdahl, Albrook 25, 509-335-9140, nick.engdahl@wsu.edu
Office Hours: Tuesdays 1:00pm-2:00pm, or by appointment, or any time the door is open.

**Course Objectives:** To develop an understanding of the fundamental processes driving groundwater flow in natural systems that give rise to solute transport behaviors in natural (non-ideal) systems.

| Student Learning Outcomes for this course:<br><br>At the end of this course, students should be able to: | Course Topics/Dates<br><br>The following topic(s)/dates(s) will address this outcome: | Evaluation of Outcome:<br><br>This outcome will be evaluated primarily by: |
|---|---|---|
| Understand the complexities of flows through natural porous media. | Weeks 1-4 (see expanded outline below) | In class exercises, homework assignments |
| Develop the fundamental equations describing solute transport in different, idealized systems. | Weeks 5-9, (see expanded outline below) | In class exercises, homework assignments, exam 1 |
| Explore how the idealized models can be adapted for more complex, and real-world applications of mass transport problems. | Weeks 10-15, (see expanded outline below) | In class exercises, homework assignments, final exam |

**Lectures**: Content for lectures will follow the outline given on the syllabus and updates to the material, as well as relevant material for the following class period, will be announced each day. Participation in the lectures and/or discussion of the material is essential to developing an intuitive understanding of the material, so active engagement in the class is expected.

**Assessments**: Student understanding of the material will be evaluated with a combination of homework and exams/projects:

| | |
|---|---|
| HW Assignments | 50% |
| Midterm exam/project | 25% |
| Final exam/project | 25% |

**Homework**: Homework assignments will be given in class and will have a specified due date at the time of assignment. These assignments are designed to require significant effort to complete and ample time will be provided to complete the tasks and all work must be clearly shown. It is highly recommended that students work together on the assignments but each is responsible for turning in their own individual work. Late work will not be accepted.

**Grading:** Final grades will be given based on normal letter grades. Thresholds for grades are: A > 93.5%, A- >89.5%, B+ > 86.5%, B > 83.5%, B- > 79.5%, C+ > 76.5%, C > 73.0%, C- > 69.5%, D+ > 66.5%, D>60%, F<60%.

**Exams/projects:** The details of the two mid-term exams will be announced at least two weeks prior to their dates; the first is currently scheduled for the 9$^{th}$ week of instruction and the second will be during finals week. Depending on class interests, one, or both, midterms may be replaced by a class project. Any changes to the midterm/project schedule will be announced in class at least two weeks before the exam or project due date. No makeup exams will be given; however, students that will miss an exam for an approved university function can make arrangements to take the exam prior to the exam date.

**Attendance/participation:** Attendance will not be taken during class but students will benefit most from class when they attend regularly. Similarly, credit will not be deducted for students that do not participate in class, but participation is expected to facilitate the mastery of content.

**Academic Honesty:** Academic integrity is the cornerstone of the university. Any student who attempts to gain an unfair advantage over other students by cheating, will fail the assignment and be reported to the Office Student Standards and Accountability. Cheating is defined in the Standards for Student Conduct WAC 504-26-010 (3).

**Expectations**: The goal of Washington State University is to provide students with the knowledge, skill and wisdom they need to contribute to society. Our rules are formulated to guarantee each student's freedom to learn and to protect the fundamental rights of others. People must treat each other with dignity and respect in order for scholarship to thrive. Behaviors that are disruptive to teaching and learning and that create a hostile, offensive or intimidating environment based on gender, race, ethnicity, color, religion, age, disability, marital status or sexual orientation will not be tolerated.

**Special Needs:** Reasonable accommodations are available for students with a documented disability. If you have a disability and may need accommodations to fully participate in this class, please visit the Disability Resource Center (DRC). All accommodations MUST be approved through the DRC (Washington Building, Room 217). Please stop by or call 509-335-3417 to make an appointment with a disability specialist.

**WSU Safety Statement:** Washington State University is committed to enhancing the safety of the students, faculty, staff, and visitors. It is highly recommended that you review the Campus Safety Plan (http://safetyplan.wsu.edu/) and visit the Office of Emergency Management web site (http://oem.wsu.edu/) for a comprehensive listing of university policies, procedures, statistics, and information related to campus safety, emergency management, and the health and welfare of the campus community.

**Tentative schedule:**
The exact schedule will vary from the outline given here based on student questions/input, level of detail, and other such factors, but the topics will generally follow the order given here as closely as possible.

*(The corresponding sections of the textbook are listed here and additional material from other sources on these topics will be provided to the class as necessary)*

Week 1: Review of classical groundwater flow concepts and equations (Ch. 1-2)

Week 2: Pore-scale flows and volume averaging

Week 3: Continuum scale flow modeling (Ch. 2)

Week 4: Dealing with spatial heterogeneity

Week 5: Fundamentals of mass transport (Ch. 5)

Week 6: Advective transport (Ch. 6)

Week 7: Diffusive transport (Ch. 7)

Week 8: The advection-dispersion equation (ADE) (Ch. 8) ***(Exam 1 - tentative)***

Week 9: Applications of the ADE (Ch. 8)

Week 10: Eulerian vs. Lagrangian models

Week 11: Travel time and residence time distributions (Ch. 6.5)

Week 12: Mass transfer models (Ch. 8.10)

Week 13: Breakdown of the ADE and alternate models

Week 14: Influence of reactions

Week 15: Catch up week or additional material

Week 16: **(Final)**