Virginia Tech
The Charles E. Via Jr. Department of Civil and Environmental Engineering

CEE 5314: River Mechanics and Sediment Transport
(Fall 2017)

Description: This course focuses on physical processes related to the dynamic feedback between flowing water and movable sediment in rivers and estuaries. The course looks briefly at the watershed system as a whole and then narrows down to focus primarily on the coupling of the water and sediment phases within the channel. Both theory and engineering calculations will be covered. An emphasis is placed on quantification.

Prerequisites: CEE 3314 Water Resources Engineering (or consent of the instructor)

Instructor: Kyle Strom, Associate Professor
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Required Material:

1. *Sedimentation Engineering: Processes, Measurements, Modeling, and Practice* edited by M. García (2008), ASCE (Manual 110) [PDF access through VT library]
2. Additional required material will be distributed either in-class or through the class Canvas page.

Reference Material:

The topics of river mechanics and sediment transport are areas of current research that spans a range of disciplines from basic fluid mechanics to geology. For this reason, I encourage you to use a spectrum of reference textbooks and scientific literature when studying for this course. The following is a small list of useful textbooks pertaining to various aspects of the course. In addition, there is a reading list at the end of the syllabus with some key papers and links to video resources that should be helpful.

1. *1D Morphodynamics of Rivers and Turbidity Currents*, by Gary Parker (e-book)

2. *Sediment Transport: A Geophysical Phenomenon* by Albert Gyr and Klaus Hoyer (2006), Springer. [PDF access through VT library]
3. *Fluvial Processes in River Engineering* by Howard Change (1988), printed 2002, Krieger Publishing.
4. *Fluvial Hydrodynamics: Hydrodynamic and Sediment Transport Phenomena* by Subhasish Dey (2014), Springer. [PDF access through VT library]
5. *Sediment Transport: Theory and Practice* by C. Ted Yang (1996), McGraw-Hill.
6. *Cohesive Sediment in Open Channels* by E. Partheniades (2009), Elsevier.
7. *The Little Book Of Geomorphology: Exercising The Principle Of Conservation* by Robert S. Anderson (pdf)
8. *Fluvial Forms and Processes: A New Perspective* by David Knighton (1998), Arnold Publishers.
9. *Fluid Mechanics* by Kundu and Cohen (2004), Elsevier. [electronic access through VT library]

Course Topics:

1. Overview of the watershed and fluvial system
   (a) The fluvial system
   (b) The watershed
   (c) Basic downstream trends
   (d) Estimating overland erosion (lateral inputs)

2. Properties of the two primary phases in natural channel flow
   (a) Conservation principles applied to fluid and sediment phases
   (b) Properties and governing equations for turbulent channel flow
      i. Continuity and the Navier-Stokes equations
      ii. Introduction to turbulence and RANS formulations
      iii. 2D channel flow and vertical profiles for steady uniform flow
      iv. Resistance equations
   (c) Sediment properties
      i. Broad classifications
      ii. Grain size distributions and methods of measurement
      iii. Angle of repose, porosity, etc.
      iv. Settling velocity

3. Transport physics, modeling approaches, and flux equations (sands and gravels)
   (a) Modes of transport
   (b) Conservation equations for the coupled system
   (c) Incipient motion
   (d) Overview of sand and gravel bed rivers
   (e) Bed load transport: physics and flux equations
      i. Formulation approaches
      ii. Single grain size
      iii. Multiple grain sizes

(f) Bed forms: types, prediction, and impacts on flow resistance and sediment transport.
(g) Suspended load transport: physics, modeling, and vertical profiles
(h) Total load: approaches and integrated flux equations

4. Predicting reach and larger-scale equilibrium and change
    (a) Emergent patters and the idea of dynamic equilibrium
    (b) Reach-scale morphology and classifications
    (c) The concept of grade and Lane's sediment balance
    (d) Hydraulic geometry and regime theory
    (e) Morphodynamic 1D numerical solutions (vertical change)
    (f) Planform evolution and meandering (lateral change)
5. Introduction to the transport of cohesive sediments (if time allows)
    (a) Sediment properties
    (b) Flocculation and impacts on settling velocity
    (c) Erosion and deposition

Course Evaluation mechanisms:

Course grades will be based on 7 to 8 homework assignments and 1 in-class comprehensive final. The final is scheduled for **December 19th from 4:25 PM - 6:25 PM** in the lecture room. Cooperation between students on the homework is allowed (and encourage). However, each student must turn in their own original homework assignment. Direct copies of another students work will be counted as cheating and the student will be reported to the departmental academic dishonesty coordinator.

*Please note that *some of the homework will require you to make use of analytic tools* such as Excel and/or your programing language of choice (e.g., Python, R, Matlab, Fortran, etc.). I do not consider CEE 5314 to be a computing intensive course, but I do assume that students have some basic coding experience.

Grading

Contributions Towards Final Grade	
Homework	65%
Final Exam	35%
Total	100%

Letter Grade	Overall Avg.	Letter Grade	Overall Avg.
A	94-100%	C	73-76%
A-	90-93%	C-	70-72%
B+	87-89%	D+	67-69%
B	83-86%	D	63-66%
B-	80-82%	D-	60-62%
C+	77-79%	F	<60%

Video Resources:

Here is a list of helpful lectures and short videos highlighting various aspects of sediment transport.

Reading Resources (in addition to the primary text):

1. Overview of the watershed and fluvial system
   - chapters 1 and 2 of, Knighton, D. (1998). *Fluvial Forms and Processes: A New Perspective*. Arnold Publishers
   - Kirchner, J. W. (1993). Statistical inevitability of Horton's laws and the apparent randomness of stream channel networks. *Geology*, 21(7):591–594
   - Dodds, P. S. and Rothman, D. H. (2000). Scaling, universality, and geomorphology. *Annual Review of Earth and Planetary Sciences*, 28(1):571–610
   - Perron, J. T., Kirchner, J. W., and Dietrich, W. E. (2009). Formation of evenly spaced ridges and valleys. *Nature*, 460:502–505
   - AGU 2011 Sharp Lecture by T. Perron (video)
   - sections of chapter 8 dealing with RUSLE from Haan, C. T., Barfield, B. J., and Hayes, J. C. (1994). *Design Hydrology and Sedimentation for Small Catchments*. Academic Press
   - Shabani, F., Kumar, L., and Esmaeili, A. (2014). Improvement to the prediction of the USLE k factor. *Geomorphology*, 204(1):229–234

2. Properties of the two primary phases in natural channel flow
   - Conservation principles applied in natural channels flows
     - Paola, C. and Voller, V. R. (2005). A generalized Exner equation for sediment mass balance. *Journal of Geophysical Research*, 110(F04014)
   - Properties and governing equations for turbulent channel flow
     - Nezu, I. (2005). Open-channel flow turbulence and its research prospect in the 21st century. *Journal of Hydraulic Engineering*, 131(4):229–246
     - Ferguson, R. (2007). Flow resistance equations for gravel- and boulder-bed streams. *Water Resources Research*, 43(5):W05427
     - Kean, J. W. and Smith, J. D. (2010). Calculation of stage-discharge relations for gravel bedded channels. *Journal of Geophysical Research*, 115(F3):F03020
   - Sediment properties
     - chapter 3, "Sediment Textures" of, Boggs, S. (2001). *Principles of Sedimentology and Stratigraphy*. Prentice Hall
     - Strom, K. B., Kuhns, R. D., and Lucas, H. J. (2010). Comparison of automated image-based grain sizing to standard pebble-count methods. *Journal of Hydraulic Engineering*, 136(8):461–473
     - Kleinhans, M. G., Markies, H., de Vet, S. J., in 't Veld, A. C., and Postema, F. N. (2011). Static and dynamic angles of repose in loose granular materials under reduced gravity. *Journal of Geophysical Research*, 116:E11004
     - Ferguson, R. and Church, M. (2004). A simple universal equation for grain settling velocity. *Journal of Sedimentary Research*, 74(6):933–937

3. Transport physics, modeling approaches, and flux equations (sands and gravels)
   - Incipient motion
     - Paintal, A. S. (1971). Concept of critical shear stress in loose boundary open channels. *Journal of Hydraulic Research*, 9(1):91–113
     - Buffington, J. M. and Montgomery, D. R. (1997). A systematic analysis of eight decades of incipient motion studies, with special reference to gravel-bedded rivers. *Water Resources Research*, 33(8):1993–2029
     - Diplas, P., Dancey, C. L., Celik, A. O., Valyrakis, M., Greer, K., and Akar, T. (2008). The role of impulse on the initiation of particle movement under turbulent flow conditions. *Science*, 322(5902):717–720
     - Lamb, M. P., Dietrich, W. E., and Venditti, J. G. (2008). Is the critical Shields stress for incipient sediment motion dependent on channel-bed slope. *Journal of Geophysical Research*, 113:F02008
     - Ferguson, R. I. (2012). River channel slope, flow resistance, and gravel entrainment thresholds. *Water Resources Research*, 48:W05517
   - Bed load transport: physics, modeling approaches, and flux equations (sands and gravels)
     - Ballio, F., Nikora, V., and Coleman, S. E. (2014). On the definition of solid discharge in hydro-environment research and applications. *Journal of Hydraulic Research*, 52(2):173–184
     - Lajeunesse, E., Malverti, L., and Charru, F. (2010). Bed load transport in turbulent flow at the grain scale: Experiments and modeling. *Journal of Geophysical Research*, 115(F4):F04001
     -
     - Wilcock, P. R. and Crowe, J. C. (2003). Surface-based transport model for mixed-size sediment. *Journal of Hydraulic Engineering*, 129(2):120–128
     - Recking, A. (2010). A comparison between flume and field bed load transport data and consequences for surface-based bed load transport prediction. *Water Resources Research*, 46(3):W03518
     - Recking, A. (2013). A simple method for calculating reach-averaged bed-load transport. *Journal of Hydraulic Engineering*, 139(1):70–75
   - Bed forms: types, prediction, and impacts on flow resistance and sediment transport
     - Charru, F., Andreotti, B., and Claudin, P. (2013). Sand ripples and dunes. *Annual Review of Fluid Mechanics*, 45(1):469–493
     - Cartigny, M. J., Ventra, D., Postma, G., and van Den Berg, J. H. (2014). Morphodynamics and sedimentary structures of bedforms under supercritical-flow conditions: New insights from flume experiments. *Sedimentology*, 61(3):712–748
     - Wright, S. and Parker, G. (2004). Flow resistance and suspended load in sand-bed rivers: Simplified stratification model. *Journal of Hydraulic Engineering*, 130(8):796–805
     - Strom, K., Papanicolaou, A. N., Evangelopoulos, N., and Odeh, M. (2004). Microforms in gravel bed rivers: Formation, disintegration, and effects on

bedload transport. *Journal of Hydraulic Engineering*, 130(6):554–567

- Suspended load transport: physics, modeling, and vertical profiles
  - Bolla Pittaluga, M. (2011). Stratification effects on flow and bed topography in straight and curved erodible streams. *Journal of Geophysical Research*, 116:F03026
  - Liu, X. and Nayamatullah, M. (2014). Semianalytical solutions for one-dimensional unsteady nonequilibrium suspended sediment transport in channels with arbitrary eddy viscosity distributions and realistic boundary conditions. *Journal of Hydraulic Engineering*, 140(5):04014011

4. Predicting reach and larger scale equilibrium and change

- Church, M. (2006). Bed material transport and the morphology of alluvial river channels. *Annual Review of Earth and Planetary Science*, 34:32554
- Montgomery, D. R. and Buffington, J. M. (1997). Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin*, 109(5):596–611
- Tal, M. and Paola, C. (2007). Dynamic single-thread channels maintained by the interaction of flow and vegetation. *Geology*, 35(4):347–350
- Gary Parker's e-book
- AGU 2008 Langbein Lecture by W. Dietrich (video)
- Dade, W. B. and Friend, P. F. (1998). Grain-size, sediment-transport regime, and channel slope in alluvial rivers. *The Journal of Geology*, 106:661–675
- Eaton, B. C. and Church, M. (2011). A rational sediment transport scaling relation based on dimensionless stream power. *Earth Surface Processes and Landforms*, 36(7):901–910
- Dust, D. and Wohl, E. (2012). Conceptual model for complex river responses using an expanded Lane's relation. *Geomorphology*, 139-140:109 – 121
- Parker, G., Wilcock, P. R., Paola, C., Dietrich, W. E., and Pitlick, J. (2007). Quasi-universal relationships for bankfull hydraulic geometry of single-thread gravel-bed rivers. *Journal of Geophysical Research*, 112(F04005)
- Bolla Pittaluga, M., Luchi, R., and Seminara, G. (2014). On the equilibrium profile of river beds. *Journal of Geophysical Research: Earth Surface*, 119(2):317–332
- Camporeale, C., Perona, P., Porporato, A., and Ridolfi, L. (2005). On the long-term behavior of meandering rivers. *Water Resources Research*, 41:W12403
- Ferguson, R. and Church, M. (2009). A critical perspective on 1-d modeling of river processes: Gravel load and aggradation in lower Fraser River. *Water Resources Research*, 45:W11424
- Nittrouer, J. A. and Viparelli, E. (2014). Sand as a stable and sustainable resource for nourishing the mississippi river delta. *Nature Geoscience*, 7(5):350–354
- Lague, D. (2013). The stream power river incision model: evidence, theory and beyond. *Earth Surface Processes and Landforms*, 39(1):38–61

5. Transport of cohesive sediments (clay and marine mud)

- chapter 4 of, García, M. H., editor (2008). *Sedimentation Engineering: Processes, Measurements, Modeling, and Practice*. ASCE Manuals and Reports on Engineering Practice No. 110. ASCE
- Strom, K. and Keyvani, A. (2011). An explicit full-range settling velocity equation for mud flocs. *Journal of Sedimentary Research*, 81(12):921–934
- Sanford, L. P. and Maa, J. P. Y. (2001). A unified erosion formulation for fine sediments. *Marine Geology*, 179(1-2):9 – 23
- Winterwerp, J. C. (1998). A simple model for turbulence induced flocculation of cohesive sediment. *Journal of Hydraulic Research*, 36(3):309–326

Honor Code

Students enrolled in this course are responsible for abiding by the Graduate and Undergraduate Honor Codes. A student who has doubts about how the Honor Code(s) applies to any assignment is responsible for obtaining specific guidance from the course instructor before submitting the assignment for evaluation. Ignorance of the rules does not exclude any member of the University community from the requirements and expectations of the honor codes. For additional information about the Honor Code, please visit:

Graduate Honor Code
Undergraduate Honor Code

The Virginia Tech Honor Code applies to all work in this class, including homework and examinations. When written work is submitted for grading, it is implied that the work is the sole effort of the person, or persons, whose name(s) appears on the paper. You may seek help on the principles and applications involved in the major assignments, and you may talk to each other about these principles and applications, but you are not to simply copy the work of another person or allow another person to work a problem for you.

Undergraduate students should be reminded that the normal sanction recommended by the Office of Undergraduate Academic Integrity for academic misconduct is F*, which is quite severe.

Special Accommodations Statement

If you need adaptations or accommodations because of a disability, if you have emergency medical information to share with me, or if you need special arrangements in case the building must be evacuated, please make an appointment with me within the first two weeks of classes.