Theme 1: River and Flood Plain Science and Engineering

*(must choose one from this theme)*

**CE 5226 - Water Resources Engineering**
(3.0 cr; Prereq-3225, grad student; A-F or Aud, spring, every year)
Application of engineering economics, risk analysis, and operations research to the planning and management of water systems; major topics include flood control, hydroelectric power, water supply, multiobjective planning, sustainability and climate change.

**GEOL 5260 - Fluvial Geomorphology**
(4.0 cr; Prereq-3210 or 3420, Math 1296, (Phys 2011 or 2013 and 2014) or Grad student status or instructor consent; A-F or Aud, fall, even academic years)
Focuses on the physical processes operating in stream channels and watersheds including watershed-scale hydrology and topography in GIS; reach-scale fluid mechanics and sediment transport; and channel patterns, forms, and classification systems. Other topics included will be river history, human alterations to rivers, and river restoration efforts.

**LIM 5004 - Field Limnology**
(2.0 cr; Prereq-Graduate student or instructor consent; A-F or Aud, summer, every year)
Field measurements on local lakes, streams; research cruise aboard R/V Blue Heron on Lake Superior; laboratory exercises in biological, chemical, geological and physical limnology.

**LIM 5101 - Physical Limnology**
(3.0 cr; =LIM 5001; Prereq-Math 1297, Phys 2012 or 2015 and 2016, or grad student; A-F or Aud, fall, odd academic years)
Physical description of lake dynamics including: lake morphometry, water budget, light distribution, circulation, fronts, waves and mixing. Descriptive, mathematical, numerical and data-analysis techniques are used to investigate the various topics.

*One of the following only:*

**GEOL 4240 - Physical Hydrogeology**
(4.0 cr; Prereq-2110, Phys 2011 or 2013 and 2014, Math 1296 or Math 1290 or grad student or instructor consent; credit will not be granted if already received for 5240; A-F or Aud, spring, odd academic years)
Introduction to concepts of fluid movement in Earth's crust and the interaction of rocks and water. Introduction to the hydrologic cycle, theory of flow through porous media, crustal-scale flow systems, role of fluids in the plate tectonic cycle.

**GEOL 4250 - Environmental Hydrogeology**
(4.0 cr; Prereq-Math 1296 or Math 1290 and (Phys 2011 or 2013 and 2014) or grad student or instructor consent; credit will not be granted if already received for 5250; A-F or Aud, fall, odd academic years)
A quantitative introduction to hydrogeology and aquifer mechanics with emphasis on environmental applications, including, unsaturated flow, interaction between surface water and groundwater, wellhead protection, well hydraulics, inverse methods, and solute transport. Offered alternate years.

**GEOL 5251 - Well Hydraulics**
(3.0 cr; Prereq-2312, (Phys 2011 of 2013 and 2014), (Math 1296 or Math 1290), or grad student or
instructor consent; A-F or Aud, spring, even academic years) Hydraulics of groundwater flow to wells: equations of flow; analysis of steady and non-steady radial flow; aquifer response to stress; analysis of monitoring well networks, pumping tests, and single-point aquifer performance tests.

**Theme 2: River & Floodplain Ecology:**

**BIOL 5805 - Fisheries Ecology**
(3.0 cr; Prereq-2801, 2802, college-level course in statistics or WRS or IBS Grad student; A-F or Aud, fall, spring, offered periodically)
Lectures, readings and computer exercises relating to current issues in fisheries ecology. Computer exercises will emphasize techniques used by scientists working in the field and prepare the student for the use of quantitative research tools for independent research. Includes 2 one-hour lectures and 1 three-hour lab weekly.

**BIOL 5833 - Stream Ecology**
(3.0 cr; Prereq-2801 or WRS or IBS Grad student; A-F or Aud, fall, even academic years)
Studies of stream communities and ecosystems as influenced by biological interactions and physical factors. Emphasis on North Shore streams. (2 hrs lect, 6 hrs lab and field)

**BIOL 5870 - Wetland Ecology**
(3.0 cr; Prereq-2801, 2802 or WRS or IBS Grad student; A-F or Aud, fall, odd academic years)
Hydrology, nutrient cycling, and productivity of wetland ecosystems and the adaptations and interactions of resident biota; assessment, management, conservation, restoration, and creation of wetlands. Two daylong weekend field trips required.

**BIOL 4803 - Ecology Field Methods: Identification and Natural History of Terrestrial and Aquatic Organisms**
(4.0 cr; Prereq-1011, 1012, if you have taken Biol 3990 T:ID and Field Methods for ecological study of terrestrial and aquatic animals and plants, credit will not be granted for Biol 4803, no grad credit; A-F or Aud, summer, offered periodically)
Provides undergraduates with an introduction to field ecology, including field identification of northern Minnesota terrestrial and aquatic flora and fauna and basic field methods to quantify distribution and abundance of plants and animals. Sampling methods taught include releves, variable radius plots, point-counts, random plots, line transects, calling surveys, dip nets and tow nets. Fieldwork will include exploration of issues related to project design and data collection, summarization and evaluation. Additional hours in the field may be required beyond regular course hours

**BIOL 5808 - Landscape Ecology: Theory and Application**
(3.0 cr; Prereq-2801, 2802 or WRS or IBS Grad student; A-F or Aud, fall, offered periodically)
Key issues in landscape ecology including scale, measuring landscape patterns, mechanisms shaping landscapes, implications of landscape patterns on plant and animal populations, communities, and ecosystems, and implementing landscape principles for natural resource management.

**BIOL 5861 - Lake Ecology**
(3.0 cr; Prereq-2801 or WRS or IBS Grad student; A-F or Aud, spring, every year)
Ecology of lakes and reservoirs.
BIOL 5862 - Advanced Lake Ecology
(3.0 cr; Prereq-5861 (concurrent registration allowed) or WRS or IBS grad student; A-F or Aud, fall, offered periodically)
Lake and laboratory approaches to evaluation of ecosystem health and experimental aquatic ecology.

BIOL 5863 - Ecosystems Ecology
(3.0 cr; Prereq-2801, or WRS or IBS Grad student; A-F or Aud, fall, even academic years)
Survey of terrestrial and aquatic ecosystems, emphasizing current literature on ecosystem processes.

Theme 3: Water Quality

BIOL 5868 - Ecotoxicology
(3.0 cr; Prereq-2101, 2801, college-level statistics course or WRS or IBS Grad student; A-F or Aud, fall, spring, offered periodically)
Examines the effects of toxicants on constituents of the biosphere at levels of biological organization from cells to ecosystems. Toxicant identification, toxicity testing, exposure routes, bioaccumulation, toxicant effects, regulations, and current issues.

CE 5237 - Water Quality Engineering
(3.0 cr; Prereq-3025 or CHE 2001 or grad student or instructor consent; A-F or Aud, fall, odd academic years)
Applied analysis of water quality in natural systems. Review of mass-transport processes and approaches for solving water quality problems in lakes, estuaries, rivers, groundwater, and soil-sediment with TMDL (Total Maximum Daily Load) and remediation design applications. Applications in water and wastewater treatment.

GEOL 4710 - Aqueous Geochemistry/Chemical Hydrogeology
(4.0 cr; Prereq-Math 1290 or Math 1297 and Chem 1152 or grad student or instructor consent; credit will not be granted if already received for 5710; A-F or Aud, fall, even academic years)
Principles of solution chemistry, with application to chemical weathering, acid deposition, rivers, lakes, and oceans. Use of chemical equilibrium software to examine complex real world problems.

LIM 5102 - Chemical Limnology
(3.0 cr; Prereq-Math 1296, Phys 1002 or 1202, Chem 1152 or 1162, or grad student; Credit will not be granted if already received for 5001; A-F or Aud, fall, odd academic years)
Organic and inorganic chemistry of natural waters, major and minor ions, pH-Eh relationships, carbon and nutrient cycles, pore water chemistry, sediment chemistry, microbial geochemistry. Offered alternate years.

Theme 4: Water Policy & Management:

WRS 5101 - Water Policy
(3.0 cr; =CE 5201; Prereq-Grad student or instructor consent; credit will not be granted if already received for CE 5201; A-F or Aud, fall, every year)
Socio-cultural, legal, and economic factors that affect water resources management. Historical trends in
water policy, resulting water laws in the United States. Federal state and local institutional structures for water management.

**GEOG 5446 - Water Processes and Management**
(3.0 cr; Prereq-1414 or grad student; A-F only, spring, odd academic years)
Introduction to the components of surface water processes and water resources management, including precipitation, runoff generation, channel processes, spatial and temporal variations in water distribution, aspects of water quantity and quality, and basin management problems.

**BIOL 5865 - Conservation Biology**
(2.0 cr; Prereq-2801 or IBS Grad student; A-F or Aud, spring, offered periodically)
Introduction to science of species, habitat, and ecosystem conservation and management.