EEES RESEARCH INFRASTRUCTURE
Office, Classrooms and Laboratories

The laboratories and facilities of the Department of Environmental Engineering and Earth Sciences (EEES) at Clemson University are located at two main locations: (1) approximately 8 miles off campus at the L. G. Rich Environmental Laboratory (342 Computer Court, Anderson, SC 29625) and (2) in Brackett Hall and the Biosystems Research Complex (BRC) on the main University campus. The Rich Lab is a state-of-the-art 42,000 square foot building housing the main departmental offices as well as classrooms and numerous environmental laboratories. The Brackett Hall location houses offices, classrooms and additional laboratories associated mainly with Earth sciences. The BRC is a research facility housing research groups from a variety of disciplines.

The Rich Lab houses laboratory space available for conducting sponsored research in a total of 24 laboratories ranging in size from 300 to over 900 square feet. There are also several dedicated purpose laboratories, including an instrument room equipped various state-of-art instruments listed below, a low-level counting laboratory, a radiochemical separations laboratory, an organic separations laboratory, aquifer characterization laboratory, a biotechnology laboratory, a nanoenclosure/microbalance room, and a two-story open-bay laboratory, in addition to numerous general purpose laboratories. Also included are research support areas, comprising an autoclave and media preparations room, and a gas cylinder storage area. A loading dock for receiving supplies and environmental samples is conveniently located adjacent to the various storage rooms. The Department also has a machine, fabrication and electronics shop with a full time staff member.

Adequate office space is available for administrative, faculty and clerical offices. 1000 square feet are dedicated to nine administrative offices and a clerical area, and 3200 square feet to 19 offices for faculty and postdoctoral researchers. The graduate student offices equipped with student carrels (72 total) occupy a total of 2565 square feet.

Additionally, in 1996 Clemson University received a gift from WMX, Inc., the Clemson Technical Center (next door to Rich Lab), which is a premier radioactive and mixed waste technology development and demonstration laboratory. This building was later renamed the Clemson Engineering Technologies Laboratory (CETL). Clemson University is licensed by the South Carolina Department of Health and Environmental Control to conduct research with a range of fission/activation products (for example, \(^3\)H, \(^{57}\)Co, \(^{96}\)Sr, \(^{99}\)Tc, \(^{137}\)Cs), uranium isotopes (\(^{232}\)U, \(^{233}\)U, \(^{234}\)U, \(^{235}\)U, and \(^{238}\)U), and transuranics (\(^{238}\)Pu, \(^{239}\)Pu, \(^{240}\)Pu, \(^{241}\)Pu, \(^{242}\)Pu, \(^{241}\)Am, \(^{237}\)Np, \(^{244}\)Cm, \(^{252}\)Cf). The EEES department maintains three radiochemistry laboratories within the Rich Lab and three radiochemistry laboratories in the CETL facility. EEES also has several non-radiochemistry laboratories in the CETL facility.
The Rich Lab is located next to the Clemson University building that houses the Advanced Materials Research Laboratory (AMRL). In addition to individual laboratories for materials-based research, the AMRL building houses the Center for Optical materials Science and Engineering Technologies (COMSET) and the University’s Electron Microscope (EM) Facility (http://www.clemson.edu/electronmicroscope/). The EM Facility is a state of the art, Multiuser facility with a wide range of equipment, including SEMs (Hitachi S3500N, Hitachi S-3400N, Hitachi S4800), Hitachi HD2000 STEM, Hitachi H7600T TEM, Hitachi FB200A Focused Ion Beam, KRATOS AXIS 165 XPS, and Scintag XDS 2000XRD). Other equipment available in the AMRL building includes an array of instruments for materials characterization (e.g., gas and liquid chromatography; UV, Vis, NIR and IR spectroscopes; NMR; particle size/zeta analyzer and PCS; and TGA, DSC and TMA).

Typically, graduate level courses (800 level) are taught at the Rich Laboratory where there are two classrooms (1065 square feet) and an auditorium (1270 square feet) that are used for student instruction. The lectures and laboratory exercises for the laboratory courses (e.g. EE&S 611 and EE&S 813) are taught in the Rich Laboratory. The auditorium and classrooms in the Rich Laboratory are equipped with computer projection systems. EE&S 610 is the only course in the EHP curriculum that is taught on campus, typically in Lowry Hall. Classrooms in Lowry Hall are controlled by the Department of Civil Engineering, which cooperates with EE&S in providing classroom space for EE&S 610.

Several EEES labs for teaching and conducting research are also available in Brackett Hall and Biosystems Research Complex on campus. Brackett Hall houses the biosystems engineering, geology and hydrogeology programs and research. Labs pertaining to water and soil analysis, fermentation and other bioprocessing areas are also available in Brackett Hall. Also in Brackett Hall, the Thin Section Lab contains several rock saws, a trim saw, a thin-section cutoff saw, and a thin-section grinder. These instruments allow the complete preparation of standard thin sections for petrographic study, or polished sections for microprobe analysis. The lab also contains two sieve shakers and associated sieve pans for grain-size distribution analyses.

The Petrography Lab includes several petrographic microscopes. An automated Swift Model F point-counting stage is available for obtaining modal analyses. The Hydrogeophysics laboratory (B03 Brackett) has several equipment packages from National Instruments available for performing real-time imaging and complex conductivity experiments using assorted columns and tanks. The Undergraduate Field Research Lab has a suite of instruments and data loggers available for watershed monitoring including water level loggers, soil moisture probes, rain gauges, and a weather station.

A few labs in the Biosystems Research Complex (BRC) houses a few research labs in the areas of biosystems engineering and environmental engineering. The BRC (www.clemson.edu/public/brc/) is a
research facility occupied by research groups from various departments of the University, including groups from EEES.

The EEES facility contains 21 laboratories (~30,000 sq ft) for research in environmental engineering and science. Of these, 4 laboratories are dedicated to the NEES focus area. In addition, approximately 3,000 sq ft of laboratory space in the CETL building is dedicated to radiochemistry research. Both laboratory facilities are operated under a current South Carolina Department of Health and Environmental Control radioactive materials licenses. The licenses are for liquid and solid sources from 3H to 244Cm; the CETL laboratory license allows for significantly greater amounts of radioactive materials. Both laboratories are equipped with appropriate laboratory facilities and radioanalytical equipment. The organic separations laboratory contains specialized glassware, large chemical fume hoods, supercritical fluid extraction equipment, and other apparatus for the preparation of environmental samples for analysis. Several well-equipped laboratories are established for the study of the decomposition of industrial pollutants through the use of biological and physicochemical methods. The biological treatment labs include bench-scale continuous flow bioreactors of various sizes, as well as batch respirometric equipment for analyzing biodegradation kinetics. A biotechnology lab includes equipment for applying molecular techniques to the characterization of microbial community structure. The physicochemical treatment lab contains equipment for studying adsorption and chemical oxidation, as well as other unit operations.

The aquifer characterization lab is equipped to measure hydraulic properties of outcrop and subsurface samples from aquifers and oil reservoirs. The lab contains a suite of flexible wall permeameters and the small-drill-hole permeameter for measuring saturated permeability. In addition, the lab contains a Hassler cell for making permeability measurements under confining pressure and a Boyle’s Law helium porosimeter. A capillary pressure vessel is also available.

A well-equipped analytical instrumentation laboratory is available for student and faculty member use. The laboratory contains several gas chromatographs with mass spectrometers, flame ionization, nitrogen-phosphorus and electron capture detectors. All GCs are equipped with an autosampler and are computer controlled. There are also a Perkin Elmer inductively coupled plasma optical emission spectrometer, high pressure liquid chromatographs, UV-Visible spectrophotometers, organic carbon analyzers, and ion chromatographs.

Research support areas include: a darkroom, and autoclave and media preparations room, and a gas cylinder storage area. A loading dock for receiving supplies and environmental samples is conveniently located adjacent to the various storage rooms. The EEES machine shop is capable of manufacturing an array of
specialized research equipment. Other more precise needs can be met at the College of Engineering and Science machine research facility. A two story high bay is available for research requiring unusually tall equipment.

The Rich Laboratory and Brackett Hall contain departmental computer laboratories for student use. These facilities contain Windows 7 Enterprise computers that are maintained by the Clemson Computing and Information Technology (CCIT). Students have 24/7 access to the Rich Lab and the EEES facilities in the CETL building. This includes student offices, the computer lab, and research labs.

EEES laboratories are equipped with a variety of instrumentation for different types of environmental research. The following is a list of analytical equipment available in the EEES laboratories. These instruments are accessible to the EEES faculty, students and researchers on a need basis. The great majority of the analyzers are computer controlled and equipped with autosamplers. All of the equipment described below is available for research purposes as well as the two laboratory courses – EE&S 611: Ionizing Radiation Detection and Measurements and EE&S 813: Environmental Radiation Protection Laboratory.

**Analytical Laboratory Equipment:**

In addition to the radiochemistry equipment, below is a list of analytical instruments for use by both the nuclear and the non-nuclear students:

- Cary Spectrophotometers (300 Bio and Cary 50)
- Thermo FlashEA 1112 Series CHNS/O Analyzer
- Varian 4000 GC-MS/MS
- HPLC with diode array and florescence detectors

**Alpha Spectroscopy Systems:**

- Four Ortec Octete (32 alpha chambers total) alpha spectrometers coupled to a personal computer running Alpha Vision software
- Six Canberra 7401 alpha spectrometers with 450 mm2 PIPS detectors. Each of the four NIM based teaching workstations contains an alpha spectroscopy chamber.
- Each of the radiation detection laboratory workstations has a Hidex Triathler LSC which can be used for field measurements

**Data Acquisition and Analysis systems:**

- Ortec A-spec 927
- Canberra Inspector 1000
- Amptek MCA 8000
- Target NanoSpec MCA
- Target Dual Parameter MCA

**Digital data acquisition systems:**
- Canberra Inspector 2000
- XIA DGF-4c
- Gage CompuScope CS8012PCI
- ICP-MS: A Thermo X Series II ICP-MS is dedicated for the analysis of long-lived radionuclides, primarily actinides.

The ICP-MS has an inductively coupled argon plasma source and a quadrupole mass analyzer capable of measuring the concentration of most elements in liquid samples to less than 1ppb (ng/g). To train students in contemporary problems in nuclear science such as nuclear forensics applications, students are currently using this instrument for uranium isotope ratio measurements in the environmental laboratory

**Gamma Ray Spectroscopy Systems:**
Seven high-purity Germanium Gamma Ray Spectrometers with efficiencies ranging from 10% to 43%. Of these, one detector is portable and can be used for field measurements, and two have a thin window for low energy detection.

**Gas Chromatography Systems:**
- Varian Model 4000 gas chromatograph-mass spectrometer (GC-MS-MS) with CombiPAL liquid, headspace and SPME Autosampler
- HP 5890 Series II gas chromatograph with FID and NPD detectors
- Two HP 5890 gas chromatographs with FID and ECD detectors
- Two Agilent 6850 gas chromatographs with -ECD detectors
- Agilent 6890 gas chromatograph with FID and -ECD detectors
- Agilent 6890Plus gas chromatograph with -ECD detectors
- Two Shimadzu gas chromatographs with FID detectors

**Liquid Chromatography Systems:**
- Agilent 1100 HPLC with UV-VIS detector, autosampler (2 systems)
- Dionex UltiMate 3000 HPLC with fluorescence, UV-Vis and RI detectors; fraction collector, autosampler (3 systems)
- Dionex Model CD25A/GP50-2 ion chromatograph with EC detector, autosampler
- Dionex ICS2100 ion chromatography system, autosampler
- Waters HPLC with multiwavelength detector and autosampler

**Neutron Detection:**
Eberline NRD-1 Neutron REM Sphere, an N. Wood G15-6 BF3 Tube, and three LND BF3 detectors

**Labeled Compound / Radiochemical Analysis:**
- Eight high-purity germanium gamma-ray spectrometers (one portable and one low energy)
- One low-energy high-resolution X-ray spectrometer (HPGe, Be window)
- Three NaI(Tl) spectrometers (5” x 5”, 3” x 3”, and 2” x 2”)
- Four benchtop alpha/beta liquid scintillation counters alpha/beta discriminating liquid scintillation counters
  - Wallac 1220 Quantulus LSC
  - Hidex 300 SL
  - Packard 2550 TR/AB Tricarb LSC
  - Wallac 1415 LSC
- Three flow cell radiation detectors (one digital, one pulse shape discriminating)
- 38 alpha spectrometers
- 18 gas flow proportional counters
- Miscellaneous gas-filled and scintillation detectors
- Neutron dosimetry instruments
- Portable health physics instrumentation
- Geophex GEM2 EM induction sensor

**Organic Carbon and Nitrogen Analyzers:**
- Shimadzu Model TOC-V Total Organic Carbon/ Total Nitrogen analyzer
- Thermo Model EA1112 Combustion CHNS-O analyzer

**Other Analyzers:**
- Applied Biosystems StepOne Plus 96well RT PCR system
- Anton Parr SurPASS electrokinetic analyzer
- Analytik Jena multiX2500 adsorbable organic carbon (AOX) analyzer with APU2 adsorption module
- BioRad Gel DocXR
- Brookhaven Instruments 90Plus particle analyzer with ZetaPALS and ZetaPlus; autotitrator
- Dionex ASE200 accelerated solvent extraction system
- Harshaw Model 3500 thermo luminescence dosimetry system
- Jenapol U petrographic microscope
- Kruss contact angle measurement system (for drop shape analysis)
- Microbics M500 toxicity analyzer
- Micromeritics ASAP2010 and ASAP2020 physisorption (surface area and pore size distribution determinations) analyzers with chemisorption capabilities
- Metrohm 836 Titrando computer controlled titration system
- Misc. aquifer testing equipment
- Model MP401 electronic field gas permeameter
- Perkin Elmer Model C653 fluorescence spectrometer
- Perkin Elmer Optima 3100RL inductively coupled plasma-optical emission spectrometer (ICP-OES) with autosampler (radial view, UV only)
- Thales ProMark III differential GPS receivers
- Thermo ICP-Mass Spectrometer X Series II with autosampler
- Thermo Nicolet FTIR spectrometer
- Widco model 1500 well logger
- Virtis bench top 6K freeze dryer
- Zeiss Model AXIOSKOP 2 research fluorescence microscope

**Radon Detection:**
- A Niton RAD 7 Portable radon detector, as well as Electret Radon Monitors/Ionization Chambers

**Scintillation Detectors/Photomultiplier Tube Assemblies:**
- Numerous NaI(Tl) detectors including Bicron 2” x 2” and 5”x5” NaI(Tl); Scionix 3” x 3” NaI(Tl); Bicron CP-792 3” NaI well. 1.5” x 1.5” LaBr3(Ce).

**UV-Vis Spectrometers:**
- Varian Cary 300 UV-Vis Spectrophotometer
- Varian Cary 50 UV-Vis Spectrophotometer
- Thermo Nanodrop 2000 Spectrophotometer
- Beckman DTX880 Multimode detector/plate reader

The EEES Rich Lab laboratory has a Type I distilled deionized water production system (Super-Q Plus, MilliPore). In addition to the research infrastructure, EEES has two teaching laboratories equipped (e.g., balances, centrifuges, turbidity meters, spectrophotometers, respirometers, dissolved oxygen probes, pH meters, muffle furnaces, drying ovens, and various miscellaneous lab equipment) to conduct Unit Operation Laboratories (i.e., Dispersion Number and Residence Time Distribution, Microbial Growth on Alternative
Substrates, Coagulation and Flocculation, Energy Balance in Microbial Systems, Precipitation, Sedimentation, Activated Sludge, Aerobic Digestion, Filtration, Anaerobic Processes, Activated Carbon Adsorption, and Gas Transfer) and various other wet chemistry laboratory courses.

EEES has a variety of field equipment that can be used for geophysical and hydrogeological studies. The equipment is stored at various locations in the department and elsewhere on campus.

**Geophysical instruments**
- Ground penetrating radar: Pulse Ekko 100 and 1000 (50,100, 225, 450, 900MHz surface and 100MHz borehole antennas)
- Electrical resistivity: IRIS Syscal R1+ Switch 48 imaging system
- EM induction: Geophex GEM-2
- EM induction: Geonics EM-34
- Magnetics: fluxgate magnetometer
- Gamma: GR-110 Exploranium portable gamma ray scintillometer
- GPS: Thales ProMark III differential GPS (rover + base station)
- Sensors & Software PE Pro GPR (8 channels with full complement of 500MHz antennas)
- Leica TPS1200+ robotic total station
- Geonics EM38-MK2 EM induction sensor

**Drilling Rig**
- CME 45 drill rig
- Augers (4” solid stem; 8” hollow stem)
- Diamond bit core barrel
- Hydraulic hammer
- Geoprobe sampling equipment

**Well Pumping Test Equipment**
- 5 Parascientific precision transducers
- Druck portable transducer
- 5 In situ Troll water level data recorders
- 15 kW Kubota generator, Honda generator
- 25, 7.5, 5, 3, and 1/3 Hp submersible pumps
- 2 Campbell Scientific CR10X data acquisition systems
- 2 Grunfos variable rate sampling pumps

**Vadose Zone Equipment**
- Portable mini-permeameter
- 2 Guelph permeameters
- 7502B time domain reflectometry soil moisture device
- Small-Drill-Hole Mini-Permeameter

**Water Chemistry**
- Water quality portable field meters (pH, DO, conductivity, turbidity, temperature, ORP)

**Stream Gauging**
- Swoffer current meter
- Ohio current meters
- Pygmy meter

**Borehole Geophysics**
- Logging instrument with caliper tool and capabilities for measuring Single point resistance
  - Gamma ray Temperature

**Hydraulic Fracturing Equipment**
A specially designed system for creating and monitoring shallow hydraulic fractures is available. This system consists of a slurry mixer and pump with related equipment for controlling the fracturing process and monitoring associated ground deformation.

**Departmental Library**
The departmental library is available for use by all students, staff and faculty of the Department of EEES. The library contains the journal collections of many of the department’s professors. The collection includes references that are important to environmental engineering and science, and radiological engineering and science. Also housed in the EEES library are select conference proceedings, reference materials, and textbooks that are used as references in courses.