Narrative

The Current Situation

Funds are requested for the expansion of an undergraduate field laboratory for the study of surface and subsurface water. This facility is presently used in exercises in several undergraduate courses and research projects in both the Geology and Environmental Studies programs at Alfred University.

Alfred University and the programs involved (Geology, Environmental Studies)

Alfred University is a private institution with an enrollment of about 2000 undergraduate students. The University consists of five colleges and schools: Liberal Arts and Sciences, Business, Professional Studies, Engineering, and Art and Design. The cornerstone of the university is a commitment to academic excellence. *U.S. News and World Report* repeatedly recognizes this commitment and has ranked Alfred University at or near the top among institutions of a similar nature located in the northeastern United States in several recent annual surveys.

The Geology Department at Alfred University consists of three faculty members and offers 21 courses in the earth sciences. The curriculum includes a comprehensive core of major courses including Mineralogy, Petrology, Structural Geology, and Stratigraphy/Sedimentation. These are augmented by elective courses such as Hydrogeology, Research Methods in Geology, Geochemistry, and Tectonics, which reflect the expertise of the faculty and current trends in the geological sciences. Approximately 250-300 students annually enroll in courses taught by the Geology faculty. An average of 10-12 geology majors graduate each year, and approximately 50 percent of the geology majors in the past six years have received a dual major with Environmental Studies. Many of these graduates go on to graduate school or to careers in the earth and environmental sciences (see App.C).

The Environmental Studies Program (ENS) at AU has been in existence since 1971, offering a B.A. degree with an emphasis in either natural or social sciences. Courses comprising the major include several specifically designed for the program ("ENS" designation) as well as many others taught by faculty in various departments, such as Hydrogeology (GEO 464), Aquatic Ecology (BIO 396), Organic Chemistry (CH 352), and Environmental Economics (ECO 312). An independent research project is required of all ENS majors. Enrollment in the Environmental Studies Program has been increasing over the past several years (see App. C). Twenty-three seniors with ENS majors graduated in 1996, our biggest class to date. We suspect this increase reflects overall environmental awareness of incoming freshmen, our emphasis on project-oriented hands-on learning, and greater administrative support for the program in terms of faculty assignments, course development, and minor equipment needs. At the same time that we have had an increase in *quantity,* we have also maintained a rigorous program and seen the *quality* of our students rise. One fifth of the 1996 Alfred University Scholars (the university-wide honors program) were ENS majors and nearly one third of the 1996 ENS graduates were National Merit Scholars. Two-thirds of our majors have an emphasis in natural science, one-third in social science. We strongly encourage our students to get a second major in a "traditional" discipline to add specialty to their education; an increasing proportion of them do this (currently one-third), commonly in Geology, Biology, Chemistry, or Mathematics. About one-third of our seniors go immediately to graduate school, more within a few years; this proportion is also increasing (see App. C).

Relevant Extant Resources–Equipment

Funding from a 1994 NSF-ILI grant allowed us to purchase a Dionex DX-500 ion chromatograph and a Perkin Elmer 3110 atomic absorption spectrophotometer equipped with a graphite furnace. These instruments are used for water analyses and maintained jointly by the ENS and Chemistry programs. The ENS program also has a small but well-equipped computer facility for students and a number of small items for field and laboratory testing of soil and water samples, including bailers, water-level indicators, conductivity and pH meters (see App. A). Field and some laboratory equipment is also available for use in the Geology Department (see App. A).

Relevant Extant Resources- the "well field"

Four shallow wells were installed on the Alfred University campus in 1994 for teaching and research purposes. This modest field facility, referred to hereafter as the "well field", consists of three two-inch diameter "observation" wells surrounding a central four-inch diameter "pumping" well. These wells extend to a depth of 20 feet, have 10 feet of slotted screen at the bottoms, and penetrate a near-surface water-bearing unit composed of moderately sorted gravely loam characterized as stratified glacial drift. A plan view of the well configuration and the near surface stratigraphy are shown in Appendix E. The water-bearing unit is an unconfined aquifer lying atop a glacial lacustrine deposit of weakly laminated clayey-silt. The lake sediments extend from a depth of 20 feet below the surface to at least 28 feet below the surface at this location. (Because of financial constraints, drilling did not extend beyond 28 feet in 1994). Local well logs indicate that this glaciolacustrine unit is as much as 40-50 feet thick in some areas and that it is often underlain by a coarser, water-bearing unit. The field site is located approximately 600 feet from Canacadea Creek, a perennial stream that is presumed to be partially fed by subsurface water.

A Goulds Model 10GN05 submersible pump has been installed in the four-inch well at our site which allows us to perform standard pump-tests and collect ground water samples for chemical analysis. A Druck PDCR 940 pressure transducer within the well, a tipping-bucket rain gage, and two temperature probes are presently being installed and connected to a Campbell Scientific CR-10 data logger. This will allow us to collect continuous, long term hydrogeologic data at the site.

Relevant Extant Resources –Administrative Support

Two years ago, university officials allowed us to permanently install the four wells described above on university property. As is evident in the letter of support included in Appendix F, our dean is very supportive of projects, such as that proposed, which enhance student learning experiences by encouraging undergraduate research (see below) and hands-on exercises.

Alfred University has also made a firm commitment to promote undergraduate research in the sciences. Since the 1989-1990 academic year, financial support has been provided to qualified undergraduate students in the sciences who participate in faculty-supervised research projects. The program is called **A**lfred **R**esearch **G**rants for **U**ndergraduate **S**tudents (ARGUS), and in the past seven years several students participating in this program have presented their research at national and regional professional meetings (see App. D). Since the ARGUS program began in 1991, 32 projects have been awarded funding. I have advised eight of these projects in the areas of geology and environmental studies.

Current Curricular Deficiencies/Needs

Numerous recent studies have shown that we learn science by doing science (Penick and Crow 1989, Dunkhase and Penick 1990, Miller and Cheetham 1990, Uno 1990, Lewis 1991, see review by Bonwell and Eison 1991). Students have a heightened interest in analyzing data that they have collected themselves, either in the field or the laboratory (Fletcher, 1994). Students graduating from our particular programs should be strong in field, analytical, and computational aspects of environmental and geological sciences (cf. AAAS 1989:11, Weis 1990). We have made a good start at providing opportunities for students to increase their skills in these areas, but feel that we need to do more, especially in the area of hands-on field experiences. A recent survey of alumni who have graduated from our geology program confirms this. The majority of those responding to the survey, done as part of a curricular review, indicated that they wish they had had more practical field experience.

In that same alumni survey, respondents indicated by an overwhelming margin that Hydrogeology (GEO 464) was the most important course that they had taken at AU. This is not surprising given recent employment trends in the geosciences toward environmental applications and hydrogeology in particular (Claudy 1991a, 1991b; Stephenson et al. 1991; Fletcher 1994, Eaton, 1995a, 1995b). Average enrollments in AU's Hydrogeology course are higher than any other 400-level (junior and senior) science course in the college. It is taken by most geology majors and many environmental studies majors.

The installation of our well field in 1994 was the first step toward providing our students with more experience studying subsurface water in the field, but we need to go further. For example, we can presently collect the data necessary to determine horizontal flow in the aquifer, but because our wells are all screened at the same depth, we cannot evaluate vertical flow paths or hydraulic conductivity. Similarly, we can collect ground water samples which represent water taken from 10-20 feet below the surface (the screened interval of the wells), but we cannot sample from discrete depths to study how the chemistry of water changes as it moves through the subsurface. Finally, we can gage the discharge of the Canacadea Creek using a flow meter, but we cannot determine the amount of ground water input into the stream. We need to ensure that our students have a solid understanding of the physical and chemical behavior of subsurface water in the saturated and unsaturated zones, and of the interaction between subsurface flow and surface water bodies (Fletcher 1994, Siegel 1996). We can do this by adding a deeper well, nested piezometers, and a gaging station.

The Development Plan

The improved facility will be used in several geology and ENS courses and will expand the possibilities for undergraduate research projects. The planned improvements to the facilities are as follows (also see diagram Appendix E):

1. Addition of a deeper well (approximately 100 feet deep) at the well field to allow our students to study water-bearing units below the glaciolacustrine clay and to investigate hydrologic connections between upper and lower aquifers. A submersible pump and pressure transducer (connected to our extant data logger) will be installed at this well.
2. Installation of two piezometer nests – groups of piezometers, each open at a different depth – to measure differences in hydrologic head with depth. One nest of three piezometers (eight, twelve, and sixteen feet deep) will be installed very near the wells and another will be installed close to Canacadea Creek.
3. Installation of a pressure transducer (in a perforated pipe) in Canacadea Creek to serve as a low-cost gaging station when connected to a data logger.
4. Installation of an autosampler at Canacadea Creek to collect stream water samples during and between precipitation events.

Specific activities to be included in individual courses follow.

<u>GEO 464: Hydrogeology</u>

Laboratory activities in this course have traditionally dealt with physical aspects of surface and ground water flow and computer analysis of physical data. Our recent acquisition of an ion chromatograph and an atomic absorption spectrophotometer allow us to incorporate quantitative chemical analyses of surface and subsurface waters and interpretation of those data into the laboratory activities. Students currently perform aquifer tests (pump tests and slug tests) and calculate hydraulic conductivities of the near-surface water-bearing unit. Horizontal ground water flow directions are also calculated from static head measurements in the four extant wells (their elevations have been surveyed, so water level measurements are reasonably accurate). With the improved facility, we will be able to determine vertical (and, therefore, three-dimensional) flow paths using data from the piezometer nests (Freeze and Cherry 1979, Dalton et al. 1991, Fetter 1994). We will also outline flow patterns into (or out of) Canacadea Creek using measurements of hydraulic head from the piezometer nest close to the stream. We will pump the shallow and deep wells separately and monitor the response of the unpumped wells to determine if a hydrologic connection exists between the upper and lower water-bearing units. Long-term, continuous monitoring of hydraulic head in the 20-foot well and the new deep well using pressure transducers and data loggers will allow our students to compare the relative responses of the deep and shallow water-bearing units to short-term and seasonal changes in the hydrologic cycle and to develop annual ground water hydrographs. Data from the gaging station will be used to develop annual and storm hydrographs for Canacadea Creek.

Shallow ground water (from piezometers and shallow well) and deep ground water (from deep well) will be collected for chemical analysis. The stream will also be sampled during and between precipitation events. An autosampler will be used to take samples at frequent intervals during and immediately after these precipitation events. The "chemical signatures" (concentrations of common cations and anions) of the samples will be determined by ion chromatography and atomic absorption spectrophotometry in order to illustrate the chemical evolution of the subsurface water and to evaluate the relative contribution of different water sources to the stream using simple bivariate mixing equations (Siegel 1996). Ground water chemistry will be plotted on ion concentration diagrams, such as Stiff and Piper diagrams, to aid in interpretation – e.g. to determine chemical relationships or trends between samples and to characterize hydrochemical facies (Freeze and Cherry 1979, Hem 1985, Fetter 1994).

As an added benefit, the wells and piezometers will be installed during the academic year and students in the Hydrogeology class (and other classes) will observe the drilling and installation process. (We did this in 1994 when the first wells were installed.) The entire process will be videotaped so that students in subsequent years can also observe the drilling and installation. These tapes will be available for use by faculty at other institutions (see section on Dissemination).

ENS 351: Environmental Biogeochemistry

This interdisciplinary course, team-taught by an aquatic ecologist and me, is designed to familiarize students in geology, environmental studies, and biology with the earth as a biogeochemical system. Since biogeochemical cycles often rely on water as a transport medium, we emphasize hydrogeochemistry in the course. Students taking the course will collect and analyze water samples (for common cations, anions, dissolved oxygen, pH, alkalinity, and conductivity) to document chemical changes as the water moves from the atmosphere (precipitation) to interact with the biosphere (throughfall and stem flow) and the lithosphere (soil moisture and ground water from various depths, and stream water). As changes in composition are detected, students will learn about the biochemical and geochemical processes which govern these changes. In another exercise, students will compare the fluid chemistries of water filtered immediately upon collection versus unfiltered water (filtered just before analysis) from all sampled depths to determine the effect of particulates on the concentration of dissolved constituents. Both of these exercises will also help students to recognize the uncertainties associated with common water sampling procedures. All students in this course are expected to complete a mini-research project involving field and analytical work, and we anticipate that the expanded well field will be the site of many of these projects.

ENS 110: Methods in Environmental Science

This class allows freshmen and sophomores to experience the way science is done. It is a course which integrates field, laboratory, and non-laboratory activities. Students work in groups on projects designed (by them) to answer questions about the environment. One of the projects deals with loading of nutrients to a local reservoir. Students collect samples of reservoir water, of input sources (including the Canacadea Creek) and of output sources for chemical analysis using the ion chromatograph and the atomic absorption spectrophotometer. The expansion of our subsurface sampling facilities will enable students to collect ground water inputs to Canacadea Creek as well, and thereby gain an understanding, even at the introductory level, of the interaction between surface and subsurface water.

GEO 450: Independent Study & ENS 470: Senior Project

As mentioned previously, the expanded field site will greatly increase the opportunities for undergraduate research. Students typically choose their own research topics and they often look for locally relevant projects. It has become clear in recent years that very little is known about the local aquifer system, and since ground water is the sole source of municipal water for the village of Alfred, understanding the local ground water flow paths is of utmost importance. I anticipate that I will have several students in the next few years using the wells and piezometers to develop a detailed model for subsurface flow in the Alfred area. The data collected will be used in conjunction with computer models for ground water flow such as MODFLOW (McDonald and Harbaugh 1988) to simulate flow trajectories, to calculate water budgets and to predict the fate of hypothetical contaminants that may enter the subsurface.

The composition of water taken from various depths will also be the subject of student research. We have the facilities to chemically analyze dissolved constituents and to determine the mineralogy of colloidal particles and of the aquifer material itself (x-ray diffraction, scanning electron microscopy with energy dispersive spectrometry). These data will allow students to do detailed studies of the geochemical interactions between the solids and fluids in the subsurface.

Many students are curious about the dynamics of Canacadea Creek, which flows across the Alfred University campus. One student is currently developing a stage-discharge rating curve for a site on the creek that is just upstream from the local wastewater treatment plant (which discharges into the Canacadea). Continuous, long-term flow rates have not yet been determined for this stream, and this is another area for independent student research. This information is also of immediate interest to local officials who will need to upgrade the wastewater treatment plant in the next few years and have no discharge data available. Students studying the stream will be able to see how their data is used in municipal planning. Students will also be able to study seasonal changes in baseflow and quickflow (both quantity and quality) using the new equipment, and develop a detailed annual hydrograph for the stream.

Related studies will involve biology students. Gordon Godshalk, an aquatic ecologist at AU, has had students studying the biota of Canacadea Creek. With more information about the volume and composition of baseflow and quickflow contributing to the discharge, his students can embark on more detailed studies of the seasonal effects of water quality on stream biota.

Science and Engineering Summer Institute

Each summer, Alfred University hosts 80-100 high school students for a “Science and Engineering Institute.” During their time at Alfred, the students participate in four different hands-on activities supervised by science and engineering faculty. The well field is featured prominently in one of those activities – the study of subsurface water. In years past, these students have performed pump tests at the site. They will do so again, but with the proposed expanded facilities, they will be able to get a clearer picture of subsurface flow (both vertical and horizontal) and of connections between subsurface water-bearing units and surface water bodies by doing modified versions of some of the same exercises planned for the college Hydrogeology class.

Equipment Request

The deep ground water well will be identical (except for depth) to the “pumping” well now at the site. It will be a four-inch diameter well with PVC screens and risers installed with a hollow stem auger. Piezometer nests will consist of two-inch PVC pipes, open or screened only at the very bottom. These will also be installed using a hollow stem auger.

A Masterflex Model 7570-10 portable peristaltic sampling pump has been chosen for sampling from shallow monitoring wells and/or piezometers. This model was selected based on price and recommendations from professionals in the field. The submersible pump (Goulds 10GN05), pressure transducers (Druck PDCR 940), and data logger (Campbell Scientific CR-10X) that are requested are all identical to those that are already installed at the well field. They were originally chosen because of their reliability, ease of operation, and common use by environmental professionals. Choosing these models for this request allows us to save money by 1) using the same pump controller (already in hand) for both pumps, and 2) using the same software for the both data loggers (again, already in hand). Consistent use of the same equipment throughout the well field will also be less confusing for students.

An American Sigma 800SL autosampler has been chosen to collect stream water samples at specified intervals (it will be controlled by the Campbell CR-10X data logger). The Allegany County

Soil and Water Conservation District office has agreed to donate one of these autosamplers for our facility if the proposal is funded.

Faculty Expertise: Michele Hluchy

I am a geologist whose teaching duties are divided between the Geology Department and the Environmental Studies Program. I have attended workshops on teaching critical thinking, have presented papers dealing with the teaching of laboratory and research techniques to undergraduates, am a member of several professional societies, including the National Association of Geoscience Teachers and the Council on Undergraduate Research (recently nominated to be a CUR councilor). I have received, either solely or with other investigators, three grants from the NSF's Division of Undergraduate Education (see Results of Prior Support) and have participated in three NSF-sponsored Undergraduate Faculty Enhancement programs addressing strategies for teaching students about problem-solving and water resources. I have taken several post-graduate hydrogeology short courses (including, recently, one entitled "Effective teaching of Hydrogeology" at the Geological Society of America's 1996 annual meeting) and I have taught courses on hydrogeology at three institutions - Dartmouth College, Colgate University, and Alfred University. In addition to hydrogeology, I teach sedimentology, geomorphology, and research methods in geology, and co-teach several interdisciplinary, team-taught courses, including Methods in Environmental Science, Environmental Biogeochemistry, and Environmental Impact Analysis. I have also taught workshops for Alfred University's Institute for Math and Science Education for pre-and in-service K-12 teachers. I planned and implemented the installation of AU's well field in 1994 and I have experience using the equipment in this request.

Dissemination and Evaluation

I will distribute information about this project in a variety of ways. I will report the results to my colleagues using traditional methods at professional meetings and by writing an article for one or more periodicals such as the *Journal of Geoscience Education* or the *Journal of College Science Teaching*. At its yearly meeting, the Geological Society of America invariably has several theme sessions dedicated to geoscience and/or environmental education. I have presented the results of my past NSF-DUE grants at these forums (see Results of Prior Support) and have found this to be an excellent way to discuss these projects with my colleagues from other institutions. I was inspired to write this proposal after reading a paper on hydrogeological field experiences for undergraduates in the *Journal of Geoscience Education* (Fletcher 1994), so I can personally attest that articles in that and similar publications are an effective means of conveying the results of ILI projects. Video tapes of the drilling and installation of the wells will also be made available to anyone who is interested (I've already had one request!).

I will continue to encourage my students to present their research at regional meetings of professional societies and special conferences for undergraduate researchers – in fact, Alfred University will host the first annual Western New York Undergraduate Science Research Symposium in April of 1997. I will also develop a site on the World Wide Web to make all data and results available to anyone interested in the project. I plan to include complete descriptions, diagrams, and/or photographs of the geology, equipment, installation, and costs incurred in setting up the field laboratory. A video clip of the well drilling and installation will also be included. Physical and chemical data collected at the well field will be posted on this web site for faculty and students at other universities to use. I will also solicit "requests" via this web site – that is, if someone at another institution would like to propose certain tests or sampling be done using our wells and piezometers, s/he can relay that request via the web site and my students and I will try to perform the procedure and send the samples or results. In this way, our site can become a "remote laboratory" for other institutions.

The well field is also available for use by local secondary schools and other local colleges. Alfred State College, literally across the street from Alfred University, is an agricultural and technical school with a two-year program in Environmental Technology. I have extended an open invitation to faculty at Alfred State College to use our field facilities. I have extended this same invitation to local secondary school teachers for their use in Earth Science and General Science classes. Finally, I have been contacted by colleagues at other institutions to work on a proposal for a possible consortium arrangement among a number of undergraduate institutions to involve students in field-oriented undergraduate research projects that would address problems in environmental science/geology. The well field will certainly be a part of that proposal as a field site for the study of ground and surface water.

I anticipate that we will be able to assess the impact of this project on our students and programs by maintaining a dialogue with the students, alumni, and their employers with regard to their opinions of our students' preparation for future study or employment in their chosen fields. We make a concerted effort to solicit and respond to the concerns of our students and alumni. There are student representatives on the ENS Program Coordinating Committee, and we periodically survey alumni (p. 4) to adjust our major programs so that our students are better prepared for graduate school and the work force. I will continue to gather this information and use it, in conjunction with our evaluation of student numbers and student "success" (at graduate schools and in the job market), to fully assess the impact of this project on the academic programs involved and the students associated with those programs.

I also plan to "track" future activities of AU and non-AU students who make use of the well field, including any secondary school students involved in AU's Summer Institute (p.9) or from local high schools. I will be particularly interested in whether or not they pursue related fields (geology, environmental science) when they enter college.

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ILI-IP DETAILED BUDGET (EQUIPMENT LIST)

Item (Descriptive name, probable brand and model)	How Many	Component/ Unit Price (List)	Unit Price (Discounted)	Total Cost (Discounted)
Campbell Scientific CR10X data logger	1	$1090	$1046	$1046
Druck PDCR940 pressure transducer w/cable	2	668	668	1336
Goulds 10GN05 submersible pump w/motor, motor lead, & cable	1	1976	1265	1265
100 foot well (4-inch diameter)	1	4600	4600	4600
Nest of 3 piezometers (2-inch diameter)	2	1200	1200	2400
MasterFlex 7570-10 portable sampling pump w/ pump head & charger	1	1025	1025	1025
American Sigma 800SL water autosampler with software	1	6621	6621	6621

Total Project Cost	$18,293
Non-NSF Contribution	$9147
NSF Request	$9146