Narrative

The Current Situation

Funds are requested for laboratory equipment to be used by undergraduates to perform chemical analyses of water, soil, and sediments as part of laboratory exercises in one new and several extant courses, and as part of their research projects. Appropriate equipment needed for these activities does not presently exist at Alfred University.

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

Alfred University is a private institution with an enrollment of approximately 2000 students. The University consists of five colleges and schools: Liberal Arts and Sciences, Business Administration, Professional Studies, Engineering, and Art and Design. The programs involved in this project are in the College of Liberal Arts and Sciences. The cornerstone of the university is a commitment to academic excellence. *U.S. News and World Report* recently recognized this commitment by ranking Alfred University *first* among institutions of a similar nature (regional universities) located in New York State, and third among regional universities located in the northern United States.

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). We suspect this increase reflects overall environmental awareness of incoming freshmen, 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. 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).

The Geology Program at AU is closely associated with the Environmental Studies Program. An average of 10-12 geology majors graduate each year, and approximately 60 percent of the current geology majors will receive a dual major with ENS. Many of these students go on to graduate school or to careers in the earth and environmental sciences (see App. C).

The Division of Chemistry consists of five faculty members. An American Chemical Society accredited major is offered. General chemistry courses with typical enrollments of 150 serve the university. Following the national trend toward fewer chemistry majors, the number of majors graduating has decreased to about three per year. Recent graduates are in medical, veterinary, or graduate school, or employed in industry (see App. C).

Relevant Extant Resources - Equipment

Major analytical equipment holdings of the Environmental Studies Program at AU are minimal. However, due to administrative support and a recent NSF-Undergraduate Course and Curriculum Development grant to two of the principal investigators (Hluchy and Godshalk), the program 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 (see App. A). Field and some laboratory equipment is also available for use in the Geology Department (see App. A). The Instrumentation Laboratory maintained by the Division of Chemistry is equipped with several spectrometers (e.g. NMR and infrared), chromatographs (e.g. GC-MS, HPLC), and other instruments (App. A). Schaefer is in charge of this laboratory which is used extensively in several chemistry courses. Undergraduates also use this laboratory to do ARGUS projects (see below) and other independent research.

Relevant Extant Resources - Administrative Support

University administration has expressed enthusiastic support for interdisciplinary efforts in general and in environmental studies in particular. Additional space, more faculty effort (new and existing), and nominal but useful budget additions have all been allocated to ENS in the last two years. Our dean highly supports the proposed project (see letter in App. E).

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 five years several students participating in this program have presented their research at national and regional professional meetings (see App. D). Three of the principal investigators have advised ten of the twenty ARGUS recipients since the inception of the program, (Schaefer: two, Hluchy: seven, and Godshalk: one), have served or are currently serving on the faculty coordinating committee for the ARGUS program, and Schaefer is presently program coordinator. In addition to those funded by the ARGUS program, the principal investigators have supervised numerous other students doing research projects (see App. D).

Current Curricular Deficiencies/Needs

Students graduating from our programs should be strong in field, analytical, and computational aspects of environmental and related sciences (cf. AAAS 1989:11). Because of recent grants from a variety of sources, we have been able to strengthen our field and computational activities, but have been unable to increase our analytical capabilities.

Students must 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). Hands-on experience in the use of state-of-the-art laboratory equipment used for the analysis of water, soil, and sediment samples is *essential* for modern environmental professionals specializing in biology, chemistry, or geoscience. Feedback from our graduates and their potential employers indicates that our students must strengthen their skills in the area of analytical chemistry. We want to expose more AU students to analytical methods. By having our students perform assays not solely in the realm of research scientists but used routinely in environmental management, we will convince them that science is both relevant and stimulating (LaSalle 1989, Brown and Lawson 1990). Finally, we want to prove that even though chemists may do such analyses, teams of scientists usually collaborate to plan experiments, implement sampling protocols, and interpret results; teamwork is as effective in the classroom as it is on the job (Moench 1986, Emiliani 1989, 1991, Mayer et al. 1992, Metzger 1992).

Student research projects also presently suffer from the lack of available analytical facilities at AU. The required senior research project is one of the strongest aspects of the Environmental Studies major. However, the accomplishment of several recent projects would have been greatly enhanced if appropriate analytical facilities had been available to our students. Students returning from environmentally-related summer jobs or internships often have great ideas for senior projects that are more sophisticated instrumentally than we can now accommodate. In 1993-1994, half of the seniors did projects that should have relied on instruments requested in this proposal. Students studying lead residues in soils, for example, had to send samples to commercial laboratories for analysis or rely on relatively crude and time-consuming wet-chemical methods instead of contemporary atomic absorption spectrophotometry. Those students who were able to get their samples commercially analyzed received reliable data, of course, but they did not benefit from the experience of doing the preparation and analyses themselves, and the number of analyses was severely limited because of their high cost. Involvement in scientific research is an extremely valuable activity for undergraduates in the sciences, but the frustration often felt by our students, stemming from inadequate analytical facilities, has unfortunately detracted from the positive aspects of the experience. We feel certain that the equipment requested in this proposal will not only solve this problem, but will also stimulate additional undergraduate research.

The Development Plan

The requested equipment will be used in a new course and several existing courses. ENS majors will gain experience with now unfamiliar instruments and applications typically to be encountered in their probable careers. The new course is ENS 2XX: Environmental Biogeochemistry. Laboratory and class exercises will be incorporated into several courses offered by the Environmental Studies, Chemistry, Geology, and Biology programs. They are:

<u>ENS 110: Methods in Environmental Science</u>

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 and sediments to a local reservoir. This project will be significantly improved with the availability of analytical equipment better than Hach hand-held colorimeters. Students will collect samples of reservoir water, of inputs (streamflow into the reservoir, precipitation onto the reservoir, and ground water flowing into the reservoir), and of outputs (streamflow out of the reservoir). Concentrations of dissolved constituents (nitrate, phosphate, calcium, etc.) in the samples will be measured using the ion chromatograph and atomic absorption spectrophotometer. These data will be combined with discharge and volume data (also collected by the students) to determine loadings to the reservoir. Data will be used to construct simple computer models of lake/reservoir chemical dynamics and to predict the effects of environmental perturbations, e.g. to predict the effect of a drastic increase in the nitrate concentration of the input stream (due to fertilizer runoff) on the reservoir quality.

ENS 2XX: Environmental Biogeochemistry

This will be a truly interdisciplinary course to familiarize students in environmental studies, geology, and biology with the earth as a biogeochemical system. Aspects of chemistry which are particularly relevant to environmental issues will be presented by three instructors (chemist Schaefer, geologist Hluchy, and ecologist Godshalk). The one-year general chemistry sequence will be a prerequisite for this course. Students in this class will learn a variety of sampling protocols, laboratory procedures, and analytical techniques that are commonly used by environmental researchers and monitors. We will teach quantification by potentiometric and spectroscopic methods, and separation techniques such as chromatography and extraction. Water, soil, and sediment samples will be collected by the students and analyzed for organic and inorganic constituents at the same time that principles of chemical kinetics, thermodynamics, and activity-concentration relationships are discussed in class. In one exercise, students will collect and analyze water samples to document chemical changes as the water moves from the atmosphere (precipitation) to interact with the biosphere (throughfall and stemflow) and the lithosphere (soil moisture and ground water). As changes in composition are detected, students will learn to understand the biochemical and geochemical processes which govern these changes. All students will be expected to complete a mini-research project of their own involving analytical work during the course of the semester. We intend to teach this course for the first time in the spring semester of 1996.

GEO 464: Hydrogeology

Laboratory activities in this course have traditionally dealt with physical aspects of surface and ground water flow and computer analysis of physical data. The addition of equipment capable of performing chemical analyses of water samples will support new exercises on evaluation and interpretation of water quality. Several ground water wells have recently been installed on the AU campus specifically for teaching purposes. Students will collect water samples from these wells, from precipitation collectors, and seasonally from a nearby stream. Chemical analyses will be performed by the students. They will use their data to evaluate the effect of weather on ground water and stream water chemistry. For example, we expect that during dry seasons students will see stream water of higher ionic strength due to dissolved constituents of the local aquifer material (e.g. calcium, magnesium, etc.), reflecting a greater contribution of ground water to stream flow. The "chemical signatures" of the ground water, surface flow, and precipitation will be determined, and the students will be able to evaluate the relative contribution of each to the stream.

BIO 396: Aquatic Ecology

In this comparative limnology course, students perform field and laboratory analyses of lakes, streams, and wetlands. Most of their activities address some realistic situation (e.g. potential eutrophication), and students must develop a question, design a sampling protocol, and collect data to evaluate their hypothesis. We use contemporary field instruments and standard procedures for routine limnological parameters such as temperature, conductivity, pH, alkalinity, and oxygen. But for nutrient analyses, we now resort to Hach reagents because our old Spec 20s do not justify more sophisticated colorimetric assays. Students will use the ion chromatograph routinely for these analyses. Likewise, determination of heavy metals is presently beyond our capability. With the proposed instrumentation in place, students will be asked to assess current and past impacts of nearby refinery and foundry sites on the Genesee River which is a major water supply for several downstream municipalities. Water and sediment samples will be extracted and analyzed with the new instruments.

CH 321: Introduction to Analytical Chemistry

Equilibria in aqueous solution is the main subject of this course. We discuss acid-base and complex ion equilibria as well as reduction-oxidation reactions and electrochemistry. Laboratory work is a significant component of the course; two 3-hour laboratory periods per week are required. Although traditional wet chemical methods are emphasized, instrumental methods are included and increasingly considered. Experiments such as the determination of phosphate by spectrophotometry and the examination of keto-enol tautomerism by NMR spectroscopy are part of the laboratory sequence. Enhanced instrumental capabilities, particularly those for the analysis of aqueous solutions, will improve the laboratory component of the course.

CH 423: Instrumental Analysis and CH 461: Advanced Laboratory

These courses are normally taken concurrently. Although CH 461 is an integrated laboratory course in which the laboratory exercises are designed to draw on all of the traditional areas of chemistry, additional emphasis is placed on instrumental analysis. Extensive use of the chemical instrumentation laboratory is designed into the laboratory exercises for CH 461. The atomic absorption instrument will serve as the students laboratory experience with atomic spectroscopy. Matrix, ionization and flame temperature effects in atomic absorption spectroscopy will be investigated to support the discussion of the technique in CH 423. The analysis of calcium with an examination of the effects of potassium and phosphate on the analysis using both acetylene-air and acetylene-nitrous oxide flames will provide a suitable examination of some important factors in the technique.

Equipment

Equipment Request:

The analyses described in the preceding section will be done on aqueous solutions — natural water samples, fluids that are filtered from sediment slurries, or fluids extracted from sediments or soils using methods such as the Toxicity Characteristic Leaching Procedure ("TCLP" - a standard method recommended by the Environmental Protection Agency for determining the toxicity of contaminated material). Two instruments which will analyze aqueous solutions with the accuracy and sensitivity necessary for the samples that our students will be encountering are an atomic absorption spectrophotometer and an ion chromatograph. With these instruments, solutions containing a wide variety of cations and anions can be analyzed.

Atomic Absorption Spectrophotometer: An instrument with both flame and graphite furnace atomization capability is important for thorough instruction in this technique and demonstration of typical environmental analyses. Atomic absorption spectrophotometry is, in fact, the EPA-recommended method for the analysis of many inorganic cations. Use of a graphite furnace is necessary to obtain accurate results from solutions containing low concentrations. We have selected Perkin Elmer equipment based on the availability of service, price, and prior experience with equipment from this company.

Ion Chromatograph: Environmental Studies students, especially, will make extensive use of the ion chromatograph for the analysis of water samples. Our current capabilities for water analyses are inadequate. This instrument will provide new and much needed analytical capabilities for the determination of organic and inorganic ions. The EPA has recently approved the use of ion chromatography for the analysis of certain ions in aqueous solution. We will purchase an instrument manufactured by Dionex based on that company's strong presence in the area of ion chromatography and recommendations from colleagues at other institutions.

Equipment on Hand for the Project:

Enhanced instrumental capabilities will provide a strong laboratory component to help increase the exposure to analytical chemistry for environmental studies majors. We will rely on existing equipment for sample acquisition and preparation and for some analyses. The Division of Chemistry's GC/MS system will be an important part of this project. Instruction on the analysis of volatiles and semivolatiles will be done using this instrument. Software for several EPA methods is already installed on the instrument. An HPLC system is also available. Scanning and fixed wavelength UV-visible spectrophotometers are available and will be used. The FTIR will be used to provide an introduction to infrared spectroscopy.

Implementation and Equipment Maintenance:

The requested equipment will be placed in the Chemical Instrumentation Laboratory (room 112 Myers Hall) with other major instruments. Responsibility for maintenance of the equipment and instruction of students in its use will be in the Division of Chemistry. Routine maintenance of existing equipment in the Chemical Instrumentation Laboratory has been performed by division personnel, and a special fund has been maintained for several years to pay for major repairs. Only minor site preparation will be necessary to place the new equipment in the laboratory. Sufficient bench space is available for both requested instruments and supporting equipment. A properly positioned vent is already available for the AA, and compressed air lines and gas cylinders are nearby.

Faculty Expertise

Fred Schaefer is a chemist trained in analytical and polymer chemistry. He teaches courses in introductory and analytical chemistry and has developed the advanced chemistry laboratory course (a laboratory course for senior majors integrating experiments from the various areas of chemistry). He has interests in chemistry courses for non-science majors and the use of instrumental techniques in the general chemistry laboratory. He is a member of the American Chemical Society (Polymer and Polymeric Materials: Science and Engineering Divisions), the Society for Applied Spectroscopy and Sigma Xi. Schaefer has participated in three NSF faculty workshops: Advanced NMR techniques at Rensselaer Polytechnic Institute (1992), Solid State Chemistry at SUNY Binghamton (1993), and Macromolecular Science at Virginia Polytechnic Institute (1994).

Michele Hluchy is a geologist whose research expertise is in the fields of clay mineralogy and low-temperature geochemistry. Hluchy's teaching duties are divided between the Environmental Studies Program and the Geology Department and include courses in hydrogeology, x-ray techniques, sedimentology, and environmental geology, as well as two interdisciplinary courses in environmental science. Hluchy has attended workshops on teaching critical thinking, has presented papers dealing with the teaching of laboratory techniques to undergraduates, is a member of several professional societies, including the National Association of Geology Teachers and the Council on Undergraduate Research, and serves as chair of the Continuing Education Committee of the Clay Minerals Society. In 1991, she received a grant (now concluded) from the ILI Program for the purchase of laboratory equipment for use by undergraduates (see Results of Prior Support), and is co-recipient of a current Undergraduate Course and Curriculum Development grant for an interdisciplinary course in environmental science. Hluchy has participated in two NSF-sponsored Undergraduate Faculty Enhancement programs, one on Water Resources (1992) at the U.S. Geological Survey's National Training Center in Denver, CO, and another on Applied Environmental Problem Solving (1994) at the Great Lakes Research Consortium in Oswego, NY. She has had experience using pieces of equipment similar to those in this request.

Gordon Godshalk is a limnologist concerned primarily with effective science teaching. He directs the growing Environmental Studies Program (see App. C) and teaches general ecology, aquatic ecology, introductory environmental science (with Hluchy), environmental data analysis, environmental problem solving, environmental issues, environmental studies seminar, preparation for environmental research, and supervises several independent studies projects each year. He serves on ad hoc committees proposing curricular changes in the College of Liberal Arts and Sciences and creating an Institute for Math and Science Education. He has participated in several workshops on teaching critical thinking and national conferences exploring ways to improve undergraduate curricula. He participated in an NSF-sponsored Undergraduate Faculty Enhancement Program on Water Resources during the summer of 1992 at the U.S. Geological Survey Training Center in Denver. He has presented papers on specific techniques used in his classes and has been the chair of the Education Section of the Ecological Society of America. His research interests center on aquatic decomposition and the fate of organic matter in lakes, streams, and wetlands. His published articles come from both basic and applied research, and he is writing a textbook.

J. Robert Pipal is a physical-inorganic chemist with research experience and publications in electrochemistry, single crystal x-ray diffraction, and powder x-ray diffraction. He chairs the Division of Chemistry and teaches general chemistry and physical chemistry, including their labs. He has taught inorganic chemistry and an advanced instrument-oriented lab course. His present research interests focus on the electrochemical study of metallocarborane compounds using cyclic voltammetry, polarography, and controlled potential electrolysis. He also is very interested in chemical education and presented a paper last summer on placing students in general chemistry classes. He is a member of the American Chemical Society and its Divisions of Inorganic Chemistry and Chemical Education.

Dissemination and Evaluation

We will report the results of this project to a variety of audiences, both in oral and written form. We will present our results at national meetings of the National Association of Geology Teachers, the Geological Society of America, the Council on Undergraduate Research, the Ecological Society of America, and the American Chemical Society. We will also publish a description of the project and its outcome in one or more periodicals such as the *Journal of College Science Teaching*, the *Journal of Geological Education* , or the *Journal of Chemical Education.*

We will continue to encourage our students to present their research at regional meetings of professional societies and special conferences for undergraduate researchers. We also hope to share our ideas with other small colleges with similar interests or programs. Godshalk has recently conducted an informal survey for sharing information among Environmental Studies Programs throughout the United States; a “letter report” about our activities will be sent to all participants of that survey. There are also Internet interest groups of directors and teachers in environmental science and chemistry programs with whom we will share our results and suggestions.

We anticipate that we will be able to assess the impact of this project on our students and programs by maintaining a dialogue with our students, alumni, and employers of our current students with regard to their opinions of our students' preparation for future study or employment in their chosen fields. For instance, we are in the process of formalizing the ENS internship program and will be able to monitor the number of students seeking opportunities in chemically-related positions and get specific feedback on their preparation from their sponsors.

We have also made a concerted effort to solicit and respond to the concerns and requests of our students. There are student representatives on the Environmental Studies Program Coordinating Committee. In the past, they have not been reticent about voicing their concerns over any inadequacies that they perceive in their academic preparation, and we have no reason to believe that they will stop giving us this valuable feedback. We maintain contact with and solicit opinions from our alumni and use this information to help adjust the major program so that our students are better prepared for graduate school and the work force. We will continue to collect this information and use it, in conjunction with our own 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.

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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)
Atomic Absorption Spectrometer, such as Perkin Elmer 3110				
3110 with gas controls and background corrector	1	17,300	15,570	15,570
Graphite furnace, HGA-600	1	18,500	16,650	16,650
Furnace autosampler, AS-60/70	1	9,150	8,235	8,235
Nitrous oxide burner head	1	605	545	545
Pressure regulator for acetylene	1	146	131	131
Pressure regulator for argon	1	148	133	133
Pressure regulator for nitrous oxide	1	580	522	522
Software, 3100 DS-NT	1	2400	2160	2160
IEEE 488 Interface	1	315	284	284
Air dryer/filter	1	375	338	338
Furnace accessory PNY2-HGA	1	265	238	238
Unit Cost		49,784	44,806	44,806
Ion Chromatograph, such as Dionex DX-500				
GP 40 gradient pump and LC 20 module	1	20,800	19,552	19,552
CD 20 conductivity cell with DS3 Stabilizer	1	1,250	1,175	1,175
EO1 Elutent Organizer	2	250	235	235
EO1 Regulator Accessory	1	75	71	71
Bottle, 2L, Plastic	3	100	94	94
ASRS-1 Anion Supressor	1	795	748	748
Installation Kit AMS or CMS	1	160	150	150
Ion Pac AS12A Analytical Column	1	725	682	682
Ion Pac AG12A Guard Column	1	220	207	207
CSRS-1 Anion Supressor	1	795	747	747
Ion Pac CS12 Analytical Column	1	695	653	653
Ion Pac ACG12 Guard Column	1	190	179	179
PeakNet Control 1 Software	1	5000	4,700	4,700
DX LAN Pump Interface Card	1	700	658	658
DX LAN Detector Interface Card	1	800	752	752
Unit Cost		32,555	30,603	30,603
Computer for instrument control, such as Gateway Pentium Tower	2	3999	7998	7998

Shipping Costs for Atomic Absorption Spectrometer	150	150	150
Shipping Costs for Ion Chromatograph	200	200	200

Total project cost:	$ 83,757
Non-NSF contribution (including any overmatch):	$ 41,879
NSF Request:	$ 41,878