The power of moving sediment: integrating experimental sedimentology into the undergraduate geoscience curriculum

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Project Summary:
We seek support to enable construction of two flow ducts to equip a new flume laboratory dedicated to hands-on undergraduate experimentation at Winona State University (WSU). The duct design is adapted from equipment in use at MIT and at numerous other institutions. Visualization of sediment transport via the use of flumes enhances student learning (King, 1980; Glumac, 1999; Hickson et al., 2003). Experimental sedimentology will be integrated throughout the WSU Geoscience curriculum at all levels, from general-education through senior majors courses and student-research projects. By enabling students to better visualize complex geologic phenomena we hope to increase the numbers of students pursuing degrees in geoscience (and STEM fields in general), and particularly to increase the number of female students choosing the geological sciences as a career path.

Broader Impact: This project seeks to recruit increased numbers of students to science careers, and specifically, to attract increased numbers of female students to geoscience. WSU enrolls approximately 70% female students, although fewer than one-third of current geoscience majors are female. We seek to incorporate inquiry-based, hands-on learning activities and to engage students in scientific experimentation and research throughout the geoscience curriculum. We anticipate that integrating experimentation throughout our undergraduate curriculum will increase positive student perceptions of science and student confidence in their ability to do science. When students can directly observe complex scientific processes, they are more likely to feel they understand the phenomena. When students have confidence in their ability, their investigative skills increase and there is a higher potential that they will remain in the discipline (Rosser, 1995). By focusing much of our curriculum around applications of experimental sedimentology, we anticipate that our graduates will take a more quantitative approach to solving real-world problems. By making our facility accessible to the local community and K-12 students, we hope to inspire more students to pursue STEM careers, and to increase public awareness of the importance of scientific exploration. Production and dissemination of videos of our experiments, targeted to specific learner levels, will enable K-16 educators to incorporate the use of visualization into the classroom.

Intellectual Merit: This project will integrate experimental sedimentology throughout the undergraduate geoscience curriculum at a non-Ph.D.-granting institution. Flume laboratories are typically housed at research institutions, allowing limited undergraduate use, particularly as a teaching/learning tool. We propose to build ducts that will serve as a comprehensive set of teaching/learning tools, and as a venue for undergraduate student research. The proposed ducts will allow students to model a variety of surficial processes, enabling them to explore a large array of field situations and problems. Thus, students can more clearly relate experimentation to field studies because they can develop and explore their own research questions. The PI has considerable experience with this approach, having worked in the MIT Center for Experimental Sedimentology as a graduate student. While at MIT, and as an instructor at Wellesley College, the PI involved undergraduate students in experimental sedimentology and saw first-hand how powerful a teaching/learning tool this approach is.

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*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Goals & Objectives: We seek NSF support to build two flow ducts in a new flume laboratory at Winona State University (WSU). These ducts will enable faculty to integrate experimental sedimentology and geomorphology throughout the Geoscience curriculum, enabling students from first-year through senior levels to better understand the mechanics of sediment transport, fluid motion, and the interactions between complex geological systems. By integrating more inquiry-based, hands-on experimentation, we seek to integrate fundamentals of STEM research throughout the curriculum, in the hopes of increasing the numbers of students, particularly women, pursuing careers in science. Our final goal is to provide a venue for the public to better understand the natural world, by making the laboratory accessible to the community via hands-on interaction with one of the ducts, via large viewing windows into the laboratory to enable passers-by to watch experiments, and by the production of videos of experimental runs. As the only geoscience department in the southeast MN region, we take very seriously our strong history of community education, and we expect to continue this with the new equipment. To this end, the laboratory is located in a prominent corner of our new science facility where it will be accessible to all visitors.

Detailed Project Plan: We propose construction of two flow ducts, to minimally equip a new flume laboratory and to provide the basis by which to fully integrate experimental sedimentology into the WSU Geoscience curriculum. Flume laboratories have traditionally been restricted to large research institutions, but undergraduate education has been expanding in this direction because of the benefit hands-on experimentation provides to student learning [1-3].

The first duct will be a small (12" x 18" x 16'), tilting, water-and-sediment-recirculating tank that will enable the development of unidirectional bedforms under various combinations of water depth, flow velocity, and sediment size. This duct will allow students to observe bedform development and to construct their own bedform-phase diagrams [4]. This approach will help students understand the relationships between velocity and bedphase, as well as between bedform and the stratification (and cross-stratification) resulting from aggradation of the passing bedform. These concepts have always been difficult for students to understand without adequate visualization. Similar ducts are present at universities across the country, including MIT, Univ. of Minnesota, Ohio State, and Univ. of Wisconsin, Eau Claire. Various removable components are also available, which enable users to model additional features such as flow over a weir, closed-channel flow, and simple breaking waves. By equipping the duct with these simple additional components, we are able to greatly expand the teaching/learning impact of this duct. Perhaps most significantly, a wave generator enables us to model simple oscillatory flow conditions, greatly enhancing its utility in undergraduate education. Activities, such as those developed by King [1], could thereby be readily be modeled in this duct.

The second duct will be a tilting, non-recirculating geomorphology channel. This is designed to enable students to model the development and evolution of surficial processes, and is modeled after a similar duct in use while the PI was a graduate student at MIT. This duct will be 15' long, 6' wide, and 2' deep. Moveable interior walls will enable a wide variety of internal channel configurations. Combined with the tilting capability and the construction of a removable head-box, this duct will enable students to model the development of slope-dependent landforms, such as braided and meandering streams, alluvial fans, and deltas, as well as provide an opportunity to model landslides and other mass-wasting phenomena. The proposed geomorphology duct is similar to a large, high-tech, stream table, but enables more sophisticated modeling of geomorphic phenomena. Finally, this duct will enable students to model changes in natural features arising from human modification, such as dam construction along a river. Given WSU's location along the Mississippi River, this duct will play an important role in our community outreach-education plan because it will enable the public to see a scale model of the river.

Engineering Laboratory Design (ELD), a firm specializing in flume design and construction, will build each duct. WSU does not have appropriate on-campus facilities (machine shop, etc.), so building these ducts in-house is not a viable option. The ducts we propose are shorter than those typically installed at research institutions, but are still sufficiently long to accomplish our teaching/learning goals. Decreasing duct length decreases the construction costs, by several tens of thousands of dollars. ELD is located only a 40-minute drive from WSU, making shipping and other construction costs minimal. ELD has a long history of flume construction; they have built ducts similar to the ones proposed here at institutions nationwide. ELD costs for this project are less than half those quoted by the other major company (Armfield) that manufactures laboratory flumes. Both ducts will be built with abrasion-resistant plexiglass walls.

Need for this project: This project addresses a critical need in STEM education by enabling students to engage in hands-on–minds-on learning in ways that build critical-thinking skills and stimulate participation in research. AAAS [5] suggests that critical-thinking skills are best learned in the context of the discipline. Repetition and active participation helps *all* students learn [6]. Integrating use of two different ducts throughout our curriculum will force students to make connections from one class to another. Although the details will differ between courses, the repetition of experimental techniques will help students build increasingly greater sophistication with the equipment and with a research approach to problem solving; by providing different foci in the range of activities taking place in the flume lab in different courses, students will develop a deep sense of how experimentation can help solve real-world geologic problems. By linking laboratory experiments with field activities, students will learn to connect laboratory solutions with both the modern and ancient record.

WSU has a large female student population (nearing 70%); however, fewer than 33% of current Geoscience majors are female. One of our project goals is to increase the percentage of female students choosing a geoscience major. This will be critical to meeting the increasing demand for trained STEM professionals. US Department of Labor occupation statistics indicate that by 2008, MN will see a 27% increase in the numbers of geologists employed; WI will see a 55% increase. WSU students come primarily from MN and WI, and most students seek employment in their home state after graduation. As the only geology program in the SE MN region, WSU plays an important role in preparing students to fill the professional needs of our regional economy. Research suggests that women often drop out of the science-career "pipeline" because they have fewer opportunities to participate in science via detailed observation, and because the way science is taught fails to make connections to real-world problems [7-8]. Our project will provide ample opportunity for **all** students to engage in scientific observation, and specifically in observations related to environmental and other real-world problems. Note that we do not seek to *decrease* the numbers of males participating in science; rather we seek to increase female participation above current figures. Because girls in K-12 levels typically have fewer science experiences than boys, to increase female participation in STEM fields we must provide female students hands-on opportunities that enable them to increase the numbers of observational opportunities and the amount of time dedicated to observation and data collection [8]. By dramatically increasing experimentation in our curriculum via the flume laboratory, we anticipate that we will appeal to female students who may have had fewer hands-on experiences in high school science curricula. Use of the various ducts will enable students to gain both a qualitative and a quantitative perspective on geologic phenomena. Such a technique may appeal to female students who have had less experience with mathematics, and can provide a strong experiential basis for quantitative analysis [8-9].

In this regard, the geomorphology duct is critical to the success of this project. It allows us to connect the mechanics of sediment transport and wave motion (modeled in the sediment-transport duct) with real-world phenomena that our largely first-generation-college population can more readily relate to. WSU is situated just five blocks from the Mississippi River, which plays an integral role in the lives of our student body. The geomorphology duct will enable faculty and students to model important fluvial phenomena in the laboratory in ways that would be difficult to delineate in the field. Students will more readily connect processes active in the geomorphology duct to their everyday lives. Once this connect becomes clear to them, they will be better prepared and able to appreciate and recognize the complex systems modeled in the other duct.

What we plan to do: The use of the new flow ducts will be incorporated throughout the existing Geoscience curriculum. Implementation of experimentation begins in introductory courses, growing more and more sophisticated as students' progress through the curriculum. Students will use this equipment in all aspects of geologic study, from visualization, to project design, data collection, data analysis and interpretation, to independent research and formal presentations.

At the introductory level (for majors and non-majors) students will conduct experiments during laboratory sessions and collect appropriate data, or will see videos of experiments in classes without a laboratory component. At the sophomore and junior levels, students will collect data in long-term experiments, and will synthesize those data in reports that relate laboratory experiments to real-world situations. By the senior level, students will design and complete experiments related to real-world problems, both as part of particular courses and as a part of independent research projects.

Specifically, the following courses will be modified to include use of the flume laboratory:

GEOS 120-Dynamic Earth: This course serves as our introduction to the major and is a popular general-education option for non-science majors. The course meets in a large lecture section with smaller weekly laboratory meetings. We will modify the laboratory component to include sessions on landform development (using the geomorphology duct) in which students will explore how slope impacts stream-channel morphology and how braided and meandering systems evolve through time.

GEOS 130-Earth & Life Through Time: is a required course for Geoscience majors, environmental science majors (in biology, chemistry, and geoscience), and for all science-teaching majors seeking licensure at the middle level (grades 5-8 in MN). A section of this course is devoted to sedimentary structures: how they form and how they are used to interpret ancient environments and flow parameters. This course will be redesigned to include experiments in which students produce a variety of bedforms and stratification under varying flow parameters using the sediment-transport duct. Students will also use the geomorphology duct to explore lateral variability of depositional systems to help them understand how disconformities in vertical stratigraphic successions develop.

GEOS 110-Oceanography: This course is a popular general-education course, and is required for all earth-science teaching majors (students seeking MN licensure in earth and space science, grades 5-12). This course will be modified to include new laboratory sessions that focus on use of the wave-generating mechanism in the sediment-transport duct. Students will first learn about wave motion, and progress into more complex topics such as the variation of wave amplitude up a slope, the movement of water under a wave and the nature of oscillatory sediment transport, the development of breaking waves, and the mechanics of density currents. Similar experiments have been built into an undergraduate curriculum [1]; some of these experiments could be appropriate for GEOS 340.

GEOS 103-Natural Disasters: This course is a non-laboratory general-education course. It typically enrolls 150+ students/semester. This course will include interaction with the sediment-transport tank via the remote capability giving students the opportunity to view wave motion, and will bring experiments into the classroom via the production of movies that illustrate experiments. Experiments include showing fluvial-system development and flooding, and landslide activity.

GEOS 201-Investigative Science I: Earth, the Water Planet: This is an introductory course developed specifically for elementary education majors. It is an integrated inquiry-based course designed to develop pedagogical content knowledge by modeling how to teach science as students learn content appropriate for their future elementary classrooms. Students will use both ducts to understand fluid motion and landscape evolution. A secondary goal in this course is to introduce pre-service teachers to resources available for their future classrooms. We hope that students in this class will bring their future students to visit the flume laboratory.

GEOS 240-Watershed Science: This sophomore-level class is required of all Geoscience majors and all Environmental Science majors. Intensive work with the geomorphology duct to explore controls on watershed evolution will help students learn the basics of research by trying to create in the laboratory a scale-model of phenomena they study in the field. Stream tables have been used to teach similar concepts in hydrogeology [10]; the geomorphology duct is an adaptation of the stream-table concept that permits longer term, more realistic scale models and can also be used for research.

GEOS 315-Surficial Processes & Soils: This upper-level class is required of all Geoscience majors, and an elective for earth-science teaching majors and Environmental Science majors. Students will use the geomorphology duct to model landscape evolution over geological timescales and to investigate the controls on fluvial and alluvial architecture (cf. [10]). Combining direct observation using the duct with computer simulation of landform evolution (via WILSIM-Web-based Interactive Landform Simulation Model; http://www.niu.edu/landform/home.html; an NSF-CCLI project) will provide our students with powerful visualization tools to aid their learning. Students in this class currently use the WILSIM site to complete model the development of local geomorphic features; combining use of the duct would enable students to verify their computer models.

GEOS 340-Sedimentology and Stratigraphy: This upper-level class is required of all Geoscience majors, and is an elective for earth-science teaching majors and Environmental Science majors. Students complete a semester-long field study of the local Cambrian Jordan Sandstone. They begin studying sedimentary structures in the field, and currently turn to the literature to help them make interpretations. With the addition of the flume laboratory, students will instead be able to study structures in the field and then interpret them with the help of the sediment-transport duct (cf. [2-3]). Students will make intensive use of the sediment-transport duct to model bedload sediment transport, bedform development and to create their own bedform phase diagrams (after [4]). Similar exercises have been shown to be effective methods to teach undergraduate sedimentology [1-3].

GEOS 400-Directed Research in Geoscience: This is our undergraduate research course. Students work closely with faculty on a project of mutual interest. Approximately 75% of our students complete an independent research project (either as a requirement or as an elective). The new flume laboratory will provide additional possibilities for student research options; it will be particularly useful for projects completed in the spring semester, when field work is limited by poor weather.

GEOS 420-Applied Hydrogeology: This is a senior-level course, required of all Environmental Geoscience majors, and an elective for other science majors. Students will use the geomorphology and the sediment-transport ducts to explore porosity-permeability relationships and more advanced concepts such as flow over a weir or the impact of creating dams within a fluvial system, etc.

GEOS 440-Basin Analysis & Tectonics: This senior-level course is required of all geology majors, and is an elective for environmental geoscience majors. Students will model effects of varying rates of subsidence, alluvial architecture, basin evolution, and principals of sequence stratigraphy (cf. [3]).

In addition to the redesign of the above courses, the flume laboratory will be available for public viewing whenever the new science facility is open. We have designed the lab to maximize views of the ducts (Appendix A, B). We anticipate running experiments throughout the day, so that systems can reach equilibrium. People passing by the lab will be able to see into the working ducts and watch the systems evolve over time. The sediment-transport duct will have the capacity to be controlled remotely from the atrium. When not in use for experiments, we will set up this duct as a wave tank. Visitors will be able to adjust the wave frequency and amplitude of incoming waves, as well as the slope angle of the beach. Thus, visitors will be able to experiment informally with the relationship between wave regime and beach profile. [A more elaborate system is on display at the MN Science Museum; however, reproducing a system exactly like this one is prohibitively expensive for a public undergraduate institution.] Signage in the atrium will provide instructions and exploration questions for public use. Remote access will be switched off during times the duct is used for class-related experiments and instruction. We have chosen to make this configuration (the wave generator) available for public interaction because it is mechanically simple. Our personal experience with the tank at the Science Museum suggests that this configuration can be a powerful learning tool. Because WSU is ~2.5 hours (drive) from either Minneapolis or Madison (WI), the University serves as a community resource. We take this role seriously, and have maintained museum-quality displays in our existing space. This tradition will be carried forward in this project.

As experimentation progresses, we will develop a series of videos that we will make available to the geologic and education community. We will create "enhanced moving pictures"[11] by digitally captioning each clip so that viewers can more readily follow the experiment. Videos will be targeted to specific grade levels, from middle school, through high school, to introductory through senior-level undergraduate, so that they may be used selectively for each audience. Videos produced for K-12 learners will tie content to the National Science Education Standards [12] and to the AAAS Benchmarks for Science Literacy [13] so that inservice teachers can readily tie this content to their existing curriculum. Videos produced for undergraduate use will have both "enhanced" and non-text versions, so that individual instructors can choose the option that best suits their needs.

Facilities & Resources available: WSU is in the final stage of construction of a new science laboratory facility. The new building will be available for classes during the Fall 2004 semester. This facility provides a significant increase in space for Geoscience laboratories (department space increases from three teaching labs to five, and includes dedicated rock preparation and student-faculty research spaces, which were previously unavailable). Notable to this project, the facility includes a new 1600 sq. ft. space dedicated to a flume laboratory that was designed specifically to accommodate these ducts and to facilitate community education (see Appendix A). The department maximized windows looking into the lab by removing windows in an adjacent laboratory, based on MN building code requirements (see Appendix B). The acquisition of the new flume laboratory reflects a major commitment by University administration, recognizing the importance of experimentation in the geoscience curriculum. This lab serves as both a teaching laboratory and provides additional student-faculty research space.

Engineering Laboratory Design (ELD) will design and construct the ducts (see Appendix C). Because ELD is nearby, we will have minimal costs during the construction phase. ELD has a long history of flume design and with university installations. The sediment-transport duct proposed in this project has been previously installed by ELD at other sites. ELD engineers assure us that construction of the geomorphology duct is a straightforward task; mechanically, it is far less complicated than the sediment-transport duct.

WSU has a dedicated E-learning center, staffed by 4 full-time employees and several student workers. The E-learning center maintains a streaming video server and digital-transfer media. E-learning staff will train Geoscience department faculty to create video clips of experiments, and will provide streaming video for experiments broadcast to the public. The E-learning center will also train faculty to produce "enhanced moving pictures" (*sensu* [11]) that provides captioning within the video to explain what the viewer is watching.

Experience & Capability of the PI(s): This proposal is a good fit with faculty expertise at WSU. Three of four faculty members in the department are trained in sedimentology or geomorphology. Our curriculum is fairly traditional, with an option focusing on classic geology and a second option focusing on environmental geoscience. A third tract in the major prepares students for MN licensure in Earth & Space Science teaching, grades 5-12. Students are about evenly divided between the options. All faculty contribute to teaching general-education geoscience courses and recruiting majors. Thus, the entire department will play a role in this project.

Cathy Summa, the lead PI, completed her Ph.D. at MIT, under the direction of Dr. John Southard. While there, she worked in Southard's Center for Experimental Sedimentology, and assisted with the construction of an oscillatory flow duct and multiple experimental runs in ducts similar to those proposed here. While at MIT, and as a geology instructor at Wellesley College, Summa taught undergraduate sedimentology classes. She brought students to the MIT lab and developed exercises that took students from novice to advanced by integrating experimentation with field analysis of sedimentary structures. She supervised several undergraduate research projects that made use of experimental sedimentology. Her expertise in experimental sedimentology and science education drives this project. Summa will be responsible for overseeing construction of the ducts and for ensuring that the co-PI's are trained to run each duct. She teaches GEOS 130, in which geoscience majors are first introduced to sediment transport. She will thus be responsible for introducing most of the WSU geoscience majors to the use of these ducts via this course. Summa has written an in-house laboratory manual for the WSU GEOS 120 course, and will be responsible for developing introductory-level experiments for general-education majors. Summa completed a MS in science education since joining the WSU faculty, and works extensively with local K-12 programs and on-campus science teaching majors. She will be responsible for coordinating outreach activities, including development of the duct-operating instructions and activities described above.

Jim Meyers is a sedimentologist. He teaches GEOS 110 and 340. He will be developing activities, making use of the sediment-transport duct, for these classes. Toby Dogwiler teaches geomorphology, hydrogeology and environmental science. He will be responsible for developing student-learning activities utilizing the geomorphology duct, enabling students to model the evolution of landscapes. His primary role is developing activities related to environmental connections. Steve Allard teaches GEOS 103. He will be utilizing these ducts to introduce non-majors to experimentation by modeling landslides and other disasters in an effort to make this class come alive and to try to interest non-science majors in science, potentially drawing some to STEM majors. Although trained as a structural geologist, he completed his Ph.D. at the University of Wyoming, where he became familiar with experimental sedimentology via the work of Paul Heller.

Evaluation Plan: WSU's Office of Assessment coordinates campus-wide assessment activities. The implementation of the Seven Principles of Good Practice in Undergraduate Education [14] has been central to the teaching mission of WSU since 1990. WSU hosts an annual "Assessment Day" every February; individual departments are encouraged to use this opportunity to collect data related to their progress in meeting self-identified student learning outcomes. Assessment Office staff work directly with faculty to develop instruments that enable faculty (departments) to collect information appropriate to their targeted goals.

To assess the success of this project, we will work closely with our Assessment staff to develop a new instrument targeted to this project. We will develop questions geared specifically toward introductory students that will help us understand how to best integrate the use of experimentation into lecture-only and lecture-laboratory classes for non-majors, as well as whether the integration of experimentation increased students interest in science or caused any statistically-significant number of students to change their majors or attitudes toward science. These data will be relatively easy to collect because WSU has created a culture of assessment in which all students participate as part of both their general-education program and their major programs. Questionnaires are administered on-line via a secure server, and all students log-on during a particular assessment window. High student participation is motivated by providing a number if incentives, such as the opportunity for early registration for classes during the next semester. Department faculty are committed to a continuous assessment cycle, and frequently modify courses based on student feedback.

We will evaluate the impact of the curriculum modifications on student learning at all levels by adapting existing science assessment strategies (i.e., conceptual diagnostic tests, and performance assessment) for our revised courses (these strategies are available at the NSF-sponsored Field-Tested Learning Assessment Guide website: http://www.flagguide.org). The chosen evaluation method will vary based on the level of the class and the course goals, but will become increasing skills-based as students' progress through the curriculum. Based on our results, we will further refine the exercises incorporated into different classes (but it's impossible to predict in advance).

Assessment data collected over the past 7 years in our existing GEOS 130 and 340 courses indicate that students have considerable difficulty visualizing and conceptualizing how sedimentary structures form. Using the flumes will enable us to compare pre- and post-flume assessment data to better quantify the impact of the new equipment on student learning.

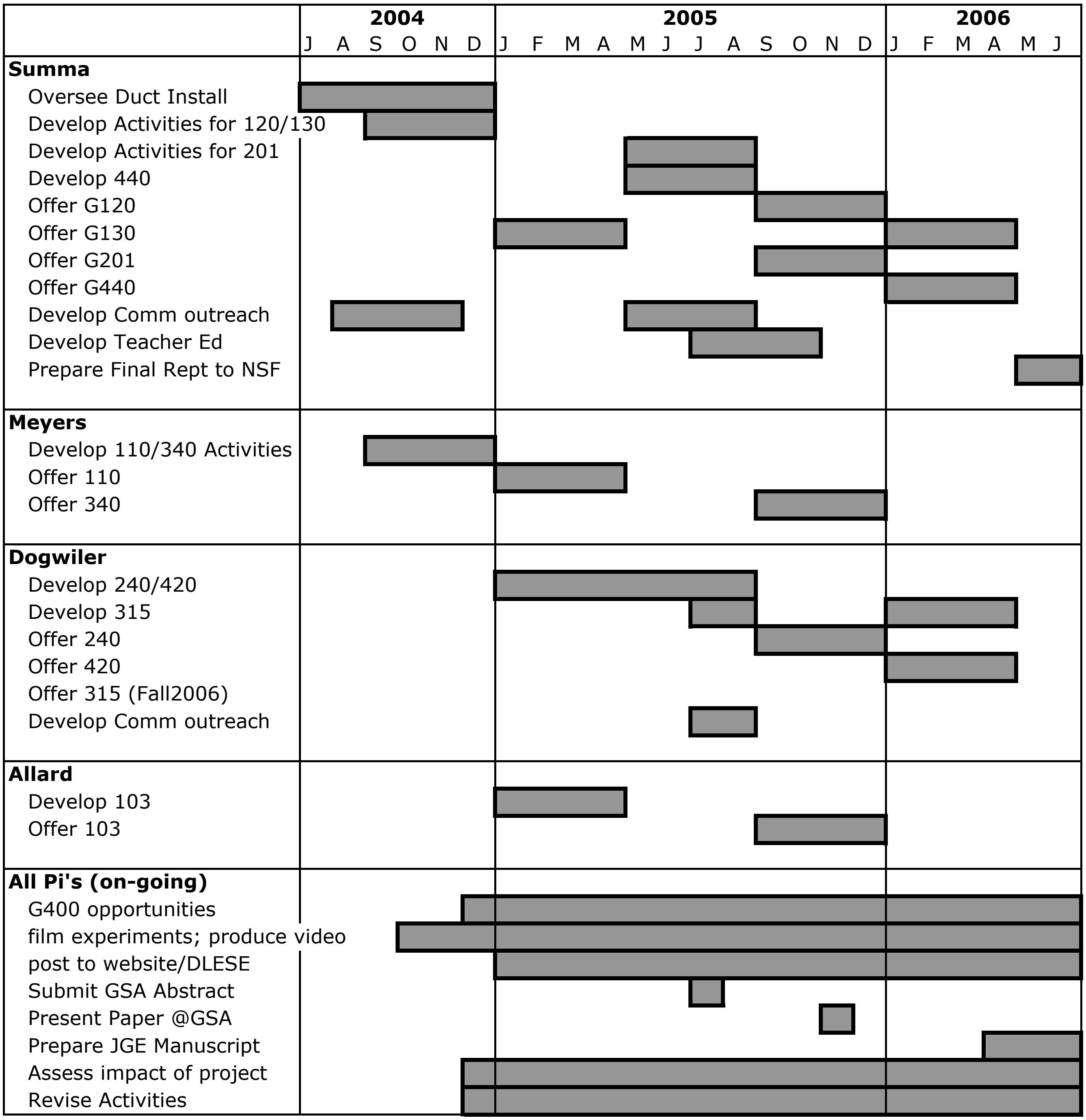
Timeline for assessment: For each course modified in this project, we will administer an attitude survey to collect data at the start of the semester that accesses student confidence and level of understanding. The same survey will be administered mid-term and end-of-term. Other assessment techniques will be administered throughout the semester (appropriate to the level of the course, see above). We will collect additional data about the impact of the integration of the flume laboratory across the curriculum by surveying our majors and the general-education population each February during the campus Assessment Day event. We will further track the impact students perceive this new approach has on their preparation by surveying our alumni following graduation (after the end of this project). Finally, external assessment of the project will come as part of our recurring departmental review process, which takes place every five years. The next departmental review is scheduled for the 2005-2006 academic year (second project year).

Dissemination of Results: Results of this project will be widely disseminated. The local community will be made aware of the ducts and experiments via our outreach programs with local

K-12 educators; through the WSU streaming video website; and through press releases published in local papers and other media. The WSU Communications Office will assist us in promoting our project by preparing relevant press releases and getting that material out to the community at large, including sending an announcement to undergraduate geoscience departments across the country. The geologic (and geoscience education) community will be made aware of project results via presentations at local and regional meetings (particularly at GSA and National Science Teachers Association meetings); via our departmental website (http://www.winona.edu/geology), where we will make a series of new pages related to activities in the flume lab; and via media clips posted to our departmental website — these materials will also be contributed to DLESE (Digital Library for Earth System Education — http://www.dlese.org) so that they may be accessed by the broader geological community. Server space to house the growing collection will be provided by our campus Technology Office; because of the campus commitment to the use of technology in learning, we have no limits placed on either the amount of space or how individual departments use server space. Thus, we foresee no difficultly managing a growing set of experimental resources. Finally, we will prepare and submit manuscripts focusing on specific laboratory exercises developed as part of this project to the Journal of Geoscience Education. Likewise, short announcements could be published in GSA Today, EOS, and GeoTimes, and posted to community list-servers to direct community members to resources available at the DLESE site or on our departmental site. If demand warrants, we will work with our campus Technology Office to duplicate disks in bulk (equipment that allows for mass duplication exists on campus), which could be made available on request. If this turns out to be necessary, we would prepare the disks and make them available at cost. The WSU Business Office would handle the distribution task so that it would not fall to departmental faculty.

Results from Prior NSF support: The PI has no prior NSF support.

Project Timeline: Major project events listed according to primary person responsible for each activity.



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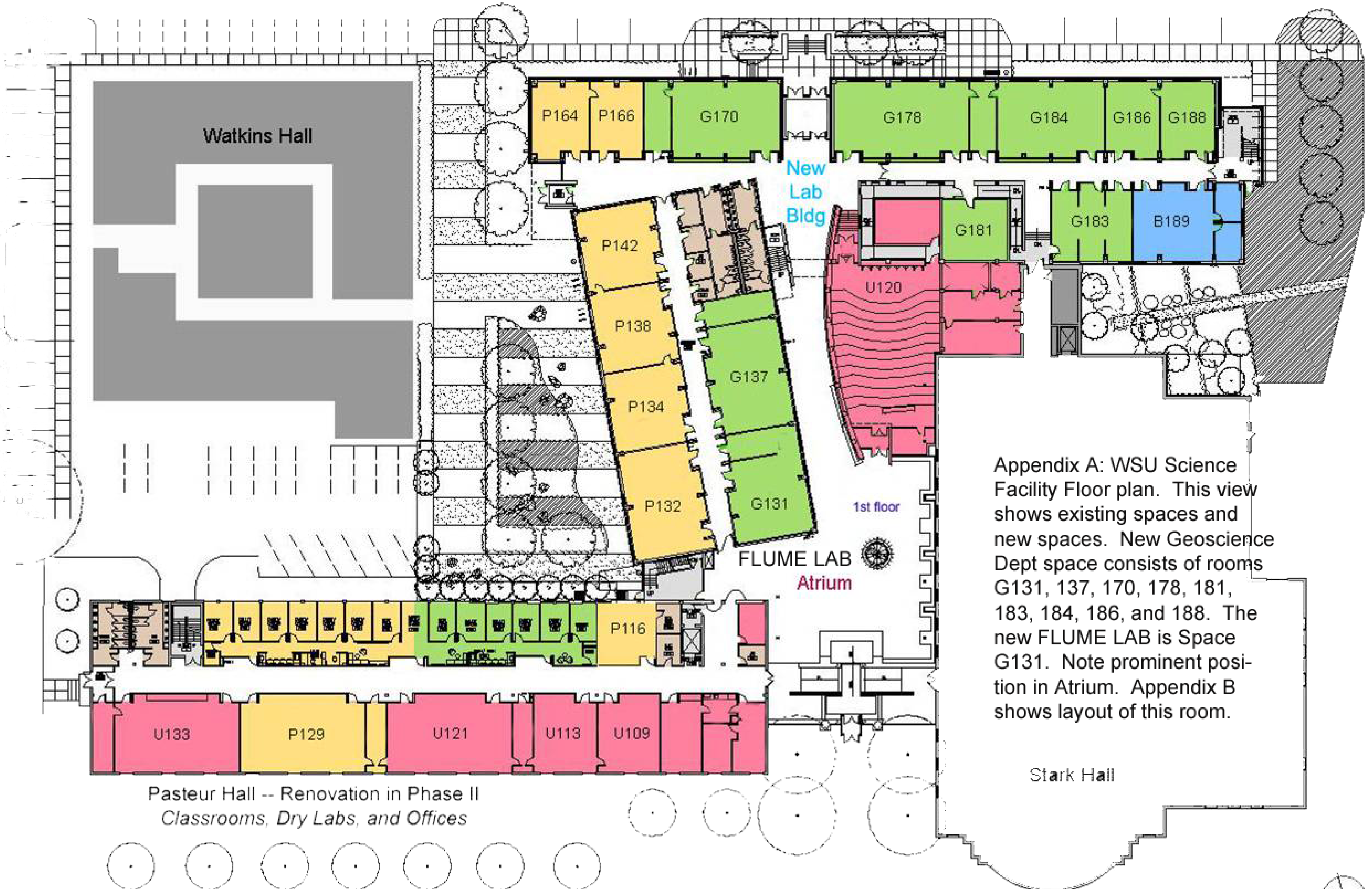
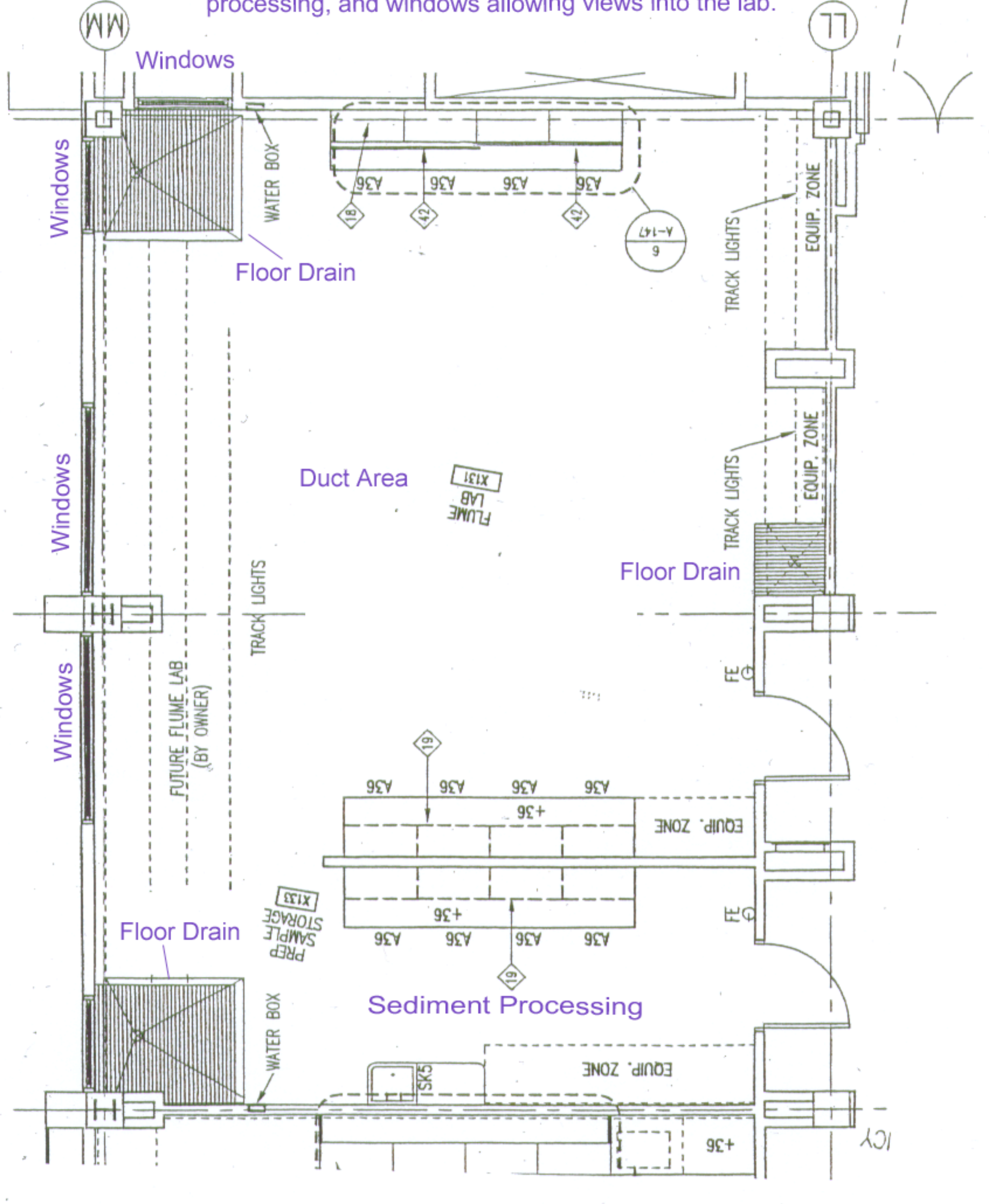


Appendix A: WSU Science Facility Floor plan. This view shows existing spaces and new spaces. New Geoscience Dept space consists of rooms G131, 137, 170, 178, 181, 183, 184, 186, and 188. The new FLUME LAB is Space G131. Note prominent position in Atrium. Appendix B shows layout of this room.

WSU Science Facility

Appendix B: WSU Flume Lab Floor Plan
This view shows space available for ducts, sediment processing, and windows allowing views into the lab.



Appendix C:
Engineering Laboratory Design
Sediment-Transport Channel and Geomorphology Duct design and costs

Sediment-transport channel: ELD Model S-16; this is a standard ELD product. We include complete design sketches and pricing.
Geomorphology Duct: Since this will be a new/custom design for ELD, only a sketch is provided. Complete drawings will be produced at time of order (if funding is secured).

Note: the materials sent by ELD include a quote for a 32' wave channel. We explored this option as a way to introduce concepts related to oscillatory flow mechanics into the curriculum. However, the duct is far too expensive for this project (or to justify its use in an undergraduate curriculum). Thus, we propose construction of the two ducts listed above. The addition of the "MODEL Set B" to the Sediment-transport duct enables us to produce simple waves, and thereby, to teach students the fundamental concepts of oscillatory motion.