University of Idaho
College of Engineering

Investing in the University of Idaho College of Engineering

For the consideration of

DeVlieg Foundation

October 26, 2009

Proposal

to

Develop the Taylor Wilderness Research Station

as a Sustainable Laboratory

College of Engineering at the University of Idaho

For over 100 years the College of Engineering at the University of Idaho has been providing exceptional learning and research opportunities for students from Idaho and around the world. The college is composed of six departments that offer eight accredited undergraduate degree programs, and twelve graduate degrees at the master's and Ph.D. levels. Undergraduate and graduate degrees are offered in Biological and Agricultural Engineering, Civil Engineering, Chemical Engineering, Computer Science, Electrical Engineering, Computer Engineering, Materials Science Engineering, and Mechanical Engineering. Additional graduate degrees are offered in Nuclear Engineering, Geological Engineering, Environmental Engineering, and Engineering Management. The college has over 100 dedicated faculty and staff that are located state-wide on campuses in Idaho Falls, Post Falls, Boise, and on the main campus in Moscow.

This fall's enrollment in the College of Engineering is up about 3% which marks the third consecutive year of increases and includes an accomplished group of seventeen National Merit Scholars who are in the top one percent of the nation's high school graduates. Enrollment success is the result of a wide range of factors but faculty and staff are one of the most critical and valuable factors. Our excellent faculty help the university deliver its mission and serve the greater community. Research funding for fiscal year 2009 for the College of Engineering was approximately $15 million and the College disburses approximately $561,860 annually in scholarships with a $13,979,955 Endowment Principal. UI engineering students routinely pass the Fundamentals of Engineering exam at a rate of 95 percent compared to a national average of 85 percent, ---10% more than the engineering students at Carnegie universities.

The College of Engineering directs an extensive K-12 Outreach Program in science, technology, engineering and mathematics (STEM) fields to provide a bridge for K-12 students to experience and learn more about the creativity, design, and critical thinking skills that engineers use every day to solve real world challenges. These valuable learning experiences lead students to understand the value of STEM, and ultimately help them become the future engineers, scientists, and innovators of the world.

Introduction

The Taylor Wilderness Research Station, a unique pristine environment within a large intact ecosystem, represents a treasure of the University of Idaho, the State of Idaho, the nation and the world. Several characteristics support this conclusion. First, the facility is situated on a historic site of rich archaeological and landscape value. At least four distinct landscape layers are visible on or near the property including the pre-European Takudeka (often called 'Sheep eater') cultural landscape, the outfitter ranch of David Lewis, the recreational ranch of Dorothy and Jesse Taylor, and the university research station that has evolved since the early 1980's. These landscape layers offer a myriad of research opportunities. Even greater opportunities exist to research the natural systems and ecology of the surrounding wilderness area. Few areas in the United States offer such potential to serve as a 'control' or 'baseline' for long term environmental/climate change and impacts in comparison to other areas with greater human impact. Finally, there is an intangible value simply by being in the center of the wilderness area. This could become a place to show off the core values of the university in terms of critical inquiry and environmental stewardship. When people think of Idaho, they often have a magical vision of rugged wilderness that is embodied in this facility.

University of Idaho President Nellis spoke last week at his inauguration about the need to put higher education in leadership roles to innovate and collaborate to stimulate success for the future of our state and the world. He noted that the resources of our planet are shrinking in the face of a projected population increase of two billion people in the next two decades, so the race is on for us to address the food, water and energy capacity issues that likely will impact our quality of life. He continued to say that public research universities like the University of Idaho are perfectly positioned to use their great minds and resources to lead the way in helping the world respond with science and technology education to the increasing complexities of the future. He said the transition to sustainable energy and water systems will require the ingenuity of Idaho researchers and the understanding and support of the general public. For these reasons, the university seeks to preserve, maintain, and enhance the Taylor Wilderness Research Station and its programs. The educational and research opportunities at this facility will be integrated into a vision connected with the university strategic plan and the research focus areas currently under development. This program will allow university researchers, some who may not yet be familiar with the facility's many educational and research opportunities, to take advantage of the opportunities available to them as well as researchers from other academic institutions and government agencies to collaborate and integrate their activities with the facility.

The goal of this proposal request to the DeVlieg Foundation is to further develop the station to be sustainable to support current and future research efforts that can uniquely take advantage of the station. The proposal has two main components. The first component combines research with sustainable infrastructure installation to enhance the physical function of the station. The second component is a program opportunity for high school, undergraduates, and graduate students in a learning environment that includes both installing infrastructure while learning about the science and application of technology.

Current Infrastructure Needs and Sustainable Research Opportunities

The College of Engineering, working collaboratively with the College of Natural Resources and others on campus, seeks to provide sustainable and economically viable solutions to the Taylor Wilderness Research Station's energy and water needs. This forward-thinking research will provide an opportunity to showcase the extraordinary and important sustainable efforts that Idaho researchers lead in this arena.

Dr. Herb Hess, Professor in the department of electrical and computer engineering, and a team of undergraduate and graduate students are currently designing an improved, integrated energy system for Taylor Wilderness Research Station. They are in the process of upgrading the existing hydroelectric generation system, more than doubling its capacity and greatly improving its reliability. In addition to this, they are designing nearly 20 kilowatts of solar photovoltaic generation. All generation, including the existing backup diesel generator, will be fully integrated and entirely transparent to the average Taylor Wilderness Research Station resident. This effort is funded by a $160,000 grant from the National Science Foundation (NSF), made possible by a seed grant from the DeVlieg Foundation. Completion date for the complete design and installation of this system is the fall of 2010. The NSF-funded integrated power system gives the College of Engineering researchers a foundation for renewable energy research and teaching on this marvelous site. However, this is just the beginning of a great opportunity. Taylor Wilderness Research Station provides an excellent place to create an ongoing program to investigate how other renewable energy sources and storage can be integrated into an energy mix. The location provides a clean, isolated platform where researchers can readily prove energy independence and emphasize responsible environmental practices.

Dr. Erik Coats, Professor in the department of civil engineering, and his research group have constructed a scale-model Advanced Water Reclamation Research Facility (AWRRF). The 4,800 gallon facility has been constructed at the Moscow treatment plant site and can be operated in multiple configurations. The AWRRF is operated and maintained by UI civil engineering students and provides undergraduates and graduates with unique opportunities to study and research biological wastewater treatment at a scale and level of complexity consistent with real-world systems. The AWRRF discharges reclaimed water into the city's treatment facility which eliminates any risk of violating discharge regulations and allows students to evaluate different operational scenarios. With this AWRRF, Dr. Coats has created an advanced teaching and learning environment for civil engineers. Taylor Wilderness Research Station provides an excellent place to create an ongoing investigation into water reclamation and waste water treatment.

We propose that current funding from NSF and future partnership with the DeVlieg Foundation would allow UI engineers and researchers to focus on the following activities:

Renewable energy systems: Renewable energy systems, particularly the isolated ones, fail for lack of maintenance. Expertise in this skill is sorely needed, particularly in developing nations. Taylor Wilderness Research Station provides a superb place to investigate such issues and to teach them to a wide range of students.

1. **Hydroelectric power and biofuel:** A water transport infrastructure for the upgraded hydroelectric facility is proposed to be designed and installed. A collaborative effort to study the incorporation of a biofuel-based micro turbine is proposed. These turbines are exceptionally quiet and run on just about any liquid or gaseous fuel. Currently, the College of Natural Resources has an ongoing biofuel effort, making liquid fuel from biomass. As this project proves to be feasible, we will seek funding to acquire and install the turbine as part of the energy generation mix, replacing the diesel generator.
2. **Energy storage**: Alternative energy systems generate only under certain conditions. These conditions give an intermittent character to the generation effort. As such, energy storage is necessary to fill in the gaps in generation and demand. *This is the most significant problem preventing large-scale adoption of alternative energy worldwide.* Lead acid batteries provide energy storage for the incumbent installation at Taylor Ranch. We propose improvements such as better batteries, adoption of other methods such as flywheel energy storage, and seamless integration of these into the Taylor Ranch energy system. Engineering faculty member and Professor Dean Edwards, Ph.D. and his engineering team recently entered into a Cooperative Research and Development Agreement with the U.S. Department of Energy's Savannah River National Laboratory (SRNL) and Exide Technologies, a global leader in stored electrical-energy solutions, to develop and commercialize improvements on lead-acid battery technology.
   This project is part of SRNL's diverse portfolio of research and development programs in support of the nation's energy security, which includes energy storage, nuclear energy , and renewable like wind and biofuels. Dr. Edwards and his team have more than 20 years of experience in academic research and development on enhancing lead-acid battery technology, particularly concerning additives to improve utilization of the active material in the battery.

3. **Stream hydroelectric**: Big Creek flows through the property, providing a significant water flow. Hydroelectric generation in the stream adds to the reliable, consistent energy source. Methods of capturing such energy without damming or diverting the stream are sorely needed in the Northwest. We propose to research and provide an in-depth investigation and feasibility study to demonstrate that this power generation is a viable and sustainable option.
4. **Wind power generation:** We just started a study of the possibility of adding wind generation. The wind resources at Taylor Wilderness Research Station do not appear promising yet, but a careful study may show otherwise. We propose that a feasibility study will be completed regarding this power generation option.
5. **Geothermal:** Taylor Wilderness Research Station is in an active geothermal region, as is a significant part of the state of Idaho. It bears investigation to determine if adding this to the energy mix makes sense. Taylor Wilderness Research Station has a unique position to carefully integrate this energy source. We propose that s feasibility study will be completed to investigate this power generation option.
6. **Solar Thermal or Solar Photovoltaic generation**: We propose to research the economic feasibility to install solar thermal and/or photovoltaic energy generation to potentially provide space heating, water heating and electricity at the Taylor Wilderness Research Station.

Sustaining River Environments

1. **Sediment and the Hydropower Water Supply System**: Integral to the hydropower system is the need to reduce the sediment load into the system at the water intake. As Idaho engineering geomorphologists have found in the field, these systems often fail for maintenance reasons; in the case of Taylor Wilderness Research Station, sediment will only contribute to the long term wear on the system. Not only is this an issue at the ranch, but would be even more of an issue for facilities in developing nations that do not have ready access to spare parts and equipment. Perhaps more importantly, sediment/suspended matter are also a concern in regard to drinking water safety. Research has clearly linked suspended matter with the presence of microbes, which could be potentially pathogenic. Again, not only is this a concern at the Station, but in developing countries. Integrating power supply with the provision of safe drinking water could greatly enhance the lives of many in developing countries, as well as operations at the Station. We propose that sustainable potable water supply infrastructure will be planned, designed and installed.

Dr. Elowyn Yager, assistant professor in civil engineering at the Center for Ecohydraulics Research in Boise, has received a CAREER Award from the National Science Foundation. Dr. Yager is one of the rising stars in water research at the national and international level. The early career development award is the most prestigious award offered by the National Science Foundation in support of junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education and the integration of education and research. Dr. Yager studies fluvial geomorphology, the science of rivers in the landscape. Her research focuses on the measurement and prediction of turbulence and sediment transport of river systems in the field and laboratory. Applications of her research include sustaining and restoring spawning habitats of salmon and maintaining the quality of river environments. Dr. Yager's current project includes research to better predict and understand sediment transport rates in mountain streams, which are typical of many Idaho rivers. Sediment fluxes are typically over-predicted in these streams by several orders of magnitude.

Water Reclamation and Reuse

The increasing scarcity of water in the world along with rapid population increase in urban areas gives reason for concern and the need for appropriate water management practices. In an effort to help meet growing demands being placed on available water supplies and water treatment facilities, many communities throughout the United States and the world are turning to water reclamation and reuse. Water reclamation and reuse offer an effective means of conserving the Earth's limited high-quality freshwater supplies while helping to meet the ever growing demands for water in residential, commercial, and institutional development.

1. **Gray Water Re-use:** One approach to reduce water demands – for developed countries, for the Taylor Wilderness Research Station and in developing countries would be to re-use gray water (that is derived from laundry, showers, baths, and bathroom sinks, etc.). In the United States gray water represents up to 75% of the water used inside a home. Depending on the level of treatment (could be no treatment, or perhaps as simple as filtration), this water could be re-used multiple times before being discharged as wastewater. Potential uses include, but are not limited to, toilet flushing and laundry. A gray water management and use plan and infrastructure will be implemented.
2. **Wastewater and Biosolids**: Managing and treating these two interrelated waste streams is an issue at the Station, and is certainly an issue in developing countries. Alternatives include re-use to fertilize

non-food crops, use to fertilize non-tuber crops (i.e., plants wherein food is above-ground growth), and possibly to generate electricity via a microbial fuel cell. At a minimum we propose to develop and implement a sustainable waste treatment strategy.

Student Summer Experience at Taylor Wilderness Research Station

The goal of the student summer experience effort is to engage the future stewards of our environment by hosting a two-week on-site research experience where students hike the thirty miles to Taylor Wilderness Research Station from the Cascade trailhead, learn how to build and maintain sustainable renewable energy systems, water purification/reuse systems, waste water treatment systems and sediment and water supply, and then hike back. There would clearly be no shortage of volunteers for this camp!

The program will require an application process and include 3-5 high school students, 3-5 undergraduate students, and 2-3 graduate students from a variety of majors including engineering, environmental science, and natural resources. Beyond the two-week experience students will be included in year-round efforts on assigned research projects. While student efforts will include the manual labor required for infrastructure installation, it will also involve a "classroom" setting in which students are educated on all aspects of the project. Over the first year, the program will be designed with the help of a few middle school teachers. They will select students for the initial cohort. Students will contribute to the feasibility studies on research areas such as a biofueled micro turbine, or installing wind and geothermal elements to the energy mix. We will conduct careful assessment to improve the experience for the second year's group of students. Based on performance of the program, we will seek continuation of funding and appropriate endowment.

Science, technology, engineering, and mathematics (STEM) fields are becoming increasingly more important in a global, technical society. Often, employers indicate that they need individuals who have a solid technical background and can apply their knowledge to real-world situations. However, STEM classes, as well as some college level courses, are often taught as separate subjects without the integration that demonstrates the relevance of STEM. Faculty in the Colleges of Engineering and Natural Science will collaborate to develop a program that will provide leadership in STEM education and sustainability that will integrate the disciplines in a way that will excite students about STEM in renewable energy and water sustainability and keep them interested not only throughout their educational experience but throughout their lives and careers.

The objectives of the student outreach program are to:

- Increase the workforce pipeline in STEM fields in energy and water sustainability by engaging and inspiring the next generations of engineers
- Raise awareness of STEM disciplines
- Create a global citizenry that can apply an integrated understanding of mathematics, engineering, literacy, technology, and science to solve complex issues that challenge a global society

Taylor Wilderness Research Station Sustainable Laboratory

Objectives and Deliverables: Year 1

Renewable energy system:

- Design and install water transport infrastructure. Coordinate and enact maintenance plan.
- Design micro turbine / biofuels system for electric power and domestic hot water. With satisfactory design, seek funding for purchase and installation.
- Engage CNR personnel to begin design for biofuel conversion.

Energy Storage:

- Complete a feasibility study for energy storage. Investigate the range of possibilities, including appropriate battery storage, flywheel energy storage, hot water storage, etc.
- Determine appropriate mix of energy storage options and seek funding for purchase and installation.

Stream hydroelectric

- Complete a feasibility study for stream hydroelectric.

Sediment and the Water Supply

- Design and install sustainable potable water supply infrastructure.

Gray Water Reuse:

- Develop a gray water management and re-use plan including the selection of candidate cabin(s) for installation of such a system. Obtain appropriate materials and equipment for installation.

Wastewater and Biosolids

- Develop a sustainable wastewater management/ treatment strategy.

Summer research experience

- Recruit teachers from selected middle schools to work with planning.

- Plan the experience, including installation of water systems and microturbines, input to next round of feasibility studies, and input to maintenance plans and methods.
- Recruit and train personnel for teaching and supervision of the experience.
- Select students for the experience.

Objectives and Deliverables: Year 2

Renewable energy system:

- Add micro turbine, if funded, initially with fossil fuels.
- Design conversion to biofuels.

Energy Storage:

- Prepare funding request and seek funding as feasibility study warrants.
- Seek product from Boeing flywheel energy group. Purchase batteries for testing.
- Set up and test in Moscow to determine performance with battery integration.
- Revise maintenance plan for integrated energy storage system.

Stream hydroelectric

- Prepare funding request and seek funding as feasibility study warrants.

Wind power generation

- Complete a feasibility study for wind power generation.

Geothermal

- Complete feasibility study for geothermal energy. Investigate use for domestic hot water and building heat.

Sediment and the Water Supply

- Assess system performance and revise maintenance schedule and methods appropriately.

Gray Water Reuse:

- Install gray water re-use infrastructure according to approved strategy. Seek additional funding for construction, as necessary. Coordinate and enact maintenance plan.

Wastewater and Biosolids

- Install wastewater and biosolids infrastructure according to approved strategy. Coordinate and enact maintenance plan.

Summer research experience

- First group of students go through the summer research experience.
- Students assist installation of water systems and micro turbine; assist with feasibility study of wind and geothermal systems.
- Assess performance of learning objectives. Plan for second group of students the following year.
- Plan for expanded program to include schools not initially involved.

Objectives and Deliverables: Year 3

Renewable energy system:

- Convert the micro turbine to biofuels.
- Assess and improve maintenance plan for the integrated renewable energy system.

Energy Storage:

- Install energy storage system on site. Integrate with incumbent energy storage methods.
- Assess and improve maintenance plan and methods.
- Prepare funding request and seek funding as feasibility study warrants.

Stream hydroelectric

- Install stream hydroelectric generator. Integrate into energy system.
- Assess performance and revise maintenance plan and methods.

Wind power generation

- If feasibility study warrants, request funding to add wind turbine.

Geothermal

- If feasibility study warrants, request funding to add geothermal system for domestic hot water and building heat.

Sediment and the Water Supply

- Assess performance and revise maintenance schedule and methods appropriately.

Gray Water Reuse:

- Assess performance and revise maintenance schedule and methods appropriately.

Wastewater and Biosolids

- Assess performance and revise maintenance schedule and methods appropriately.

Summer research experience

- Second group of students go through the summer research experience.
- Students assist installation of energy storage.
- Students assist with maintenance plans and determine appropriate equipment replacement and upgrade guidelines.
- Assess performance of learning objectives. Plan for next group of students the following year.
- Seek funding / endowment based on performance of summer program.

Budget

	Year 1	Year 2	Year 3
Research and Infrastructure Installation			
Hydro and solar beyond NSF funding	$10,000	$5,000	0
Water purification and reclamation	$10,000	$10,000	0
Waste water treatment	0	$10,000	$10,000
Transportation			
Air travel (10 trips @ $800)	$8,000	$8,000	$8,000
Graduate student support			
Two graduate students	$45,600	$47,880	$50,274
Graduate student Tuition and Fees	$11,200	$11,984	$12,823
Four undergraduate students	$30,000	$31,500	$33,075
Summer intern program(12 students each summer)			
Student travel support ($2K per student)	$24,000	$24,000	$24,000
Faculty mentors for intern program (2 at $10K)	$20,000	$20,000	$20,000
Administration and Gift Tax	$4,914	$5,201	$4,895
Total per year	**$168,714**	**$178,565**	**$168,067**
Total for three years			**$515,346**

Budget Justification

Research and Infrastructure Installation

Items as detailed in research objectives for solar, hydro, completion of hydro transport, water purification, and waste water treatment.

Transportation

Ten trips per year for students and faculty to design and install equipment; coordinate with Taylor staff.

Graduate student support

Research assistantships at $20 per hour for the university's 39-week academic year and thirteen weeks in the summer. Inflation assumed at 5%.

Tuition and fees at current rates. Inflation assumed at 7%.

Summer intern program

Undergraduate students at $10 per hour for one-quarter time during the university's 39-week academic year and full time for thirteen weeks in the summer. Inflation assumed at 5%.

Faculty mentors support

Two faculty at $10K. This is approximately four to five weeks of summer salary. Academic year salary assumed part of state research experiment station allotment.

University Gifts Administration is 3% of total gift.

To make this research productive takes talented people. The University of Idaho needs incentives to recruit such good people. Funding three graduate students would provide the necessary talent to make the Taylor Wilderness Research Station facility a superb research place without overwhelming the infrastructure or the environment. Four undergraduate students would engage with the graduate students. Instead of simple scholarships, these undergraduates should be paid for their work/study at appropriate rates for their research. We have had great success with this model, providing an ongoing research program supported by such organizations as the US Navy, Boeing, and Micron. The student teams provide great results because they are working for an employer with real deliverables; the ongoing natural resources work at Taylor Wilderness

Research Station provides an obvious reality to create the motivation that our work/study method requires. When combined with a summer research experience for students including high school, undergraduate, and graduate students, in a two-week camp would be a one-of-a-kind experience for educating the stewards of the future.

Summary

In summary, the Taylor Wilderness Research Station provides the opportunity for an isolated, environmentally safe, renewable energy and sustainable water laboratory. Additional unique opportunities exist to develop sustainable potable water systems integrated within effective gray water and wastewater management systems. Real energy needs combined with a wide range of energy generation and storage issues as well as water reclamation and water reuse provide a wonderful place to educate the next generation of students who will make Idaho and the nation energy independent and environmentally responsible.

Taylor Ranch Remote Electric Power Generation Feasibility Study and Design

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Abstract- **The article outlines the research and design of a small scale stand-alone electrical power generation system for a remote teaching and research facility. The document describes the process of forming feasible alternatives for the system and the criteria used in selecting and designing the most economical and functional system.**

I. INTRODUCTION

The University of Idaho, College of Forestry currently utilizes Taylor Ranch as a facility for teaching and research. Taylor Ranch is remotely located in the Frank Church Wilderness in Central Idaho. The only modes of transportation into the site are by small airplane or via a 37 mile foot trail.

Current energy requirements at the site are met by using propane, wood and two small solar generation systems. Propane is used for lighting, hot water, refrigeration and cooking, while heating is accomplished using woodstoves. Two buildings utilize solar power for radios and laptop computers, and a few DC lights.

II. PROJECT OBJECTIVES

The purpose of the project was to examine the feasibility of different sources of small-scale power generation to provide electricity for Taylor Ranch. Different system alternatives were to be evaluated to determine if they would meet the generation demands of the site, and determine if they were reliable and cost effective. The final objective was to design a system based on the lowest cost viable alternative.

III. SITE STUDY

The project team traveled to Taylor Ranch to gather information necessary for formulating a system plan. Activities performed during the site study included an inventory of existing and proposed building lighting and equipment, stream measurements, building and site measurements, and interviews with the College of Forestry personnel regarding site operations and the resulting impact on the proposed power system.

The inventory process involved inspecting every building on site and determining what lighting and equipment existed, along with the anticipated lighting and equipment that would be added with the addition of a power generation system. Each building was then measured for dimensions, to use later in determining lighting placement and wiring needs.

Stream measurements were performed on Pioneer creek, a stream in close proximity to the site. Measurements were taken using a sight level to determine the head drop of the creek from different possible source locations to different possible generation locations. Flow measurements were then performed to obtain an idea of the amount of water available at that time of the year. Details of measurement methods are outlined in Appendix F. Since these measurements were performed on the 1st of October, it was not considered a minimum flow, but more of an average representation of the flow for the year. The design team informed the College of Forestry that a stream measurement program should be implemented during the 1996-97 winter to ascertain a minimum flow condition for the creek. A typical procedure that could be used for this program is found in Appendix K.

Site layout measurements were performed by using a 100 ft. steel tape measure. Since an accurate site map was not obtainable at the time of the measurements, it was decided that this would be the best way to determine the distances between buildings and notable reference points. Surveyed drawings were later obtained from Hodge & Associates, Inc. in Moscow, Idaho, and the site measurements were checked for accuracy. The final site layout is Appendix A.

College of Forestry employees were interviewed regarding usage and maintenance of the site, and each individual building. Environmental impact and possible fire system and domestic water system improvements of a possible hydro system were discussed with the Forestry personnel. Environment impacts were also informally discussed with State of Idaho Fish and Game personnel, who were on site for the day. This discussion revealed that Pioneer creek was ndeed the only viable hydro stream in the area, as Big creek ind Rush creek are anadromous fisheries, each supporting hree possibly endangered fish species: steelhead trout, :hinook salmon and bull trout. Pioneer creek does not support iny fish species.

IV. LOAD DETERMINATION

The individual building and total system loads were :alculated using the information gathered during the :quipment and lighting inventory and interviews with Forestry personnel. These calculations defined the maximum wattage and current draw for each building, as well as for the total system. These calculations were used in sizing the various components of the generation systems researched. For methods and load calculations, see Appendix B.

Most of the loads identified by the inventory and interviews required 120 VAC power. It was therefore decided that the system designed would need to provide 120 VAC power in order to be considered as meeting the system's requirements. Using 120 VAC power would also provide the most flexible voltage source for future equipment connections.

V. PRELIMINARY RESEARCH AND DESIGN

Preliminary research and design was performed on four system alternatives utilizing the information obtained in the site evaluation and the load calculations. Central solar generation, distributed solar generation, alternating current (AC) hydro generation and direct current (DC) hydro generation were all investigated. Appendix D has summaries of all four alternatives used for comparison.

A. *Centralized Solar Generation*

Centralized solar generation was considered to be a viable alternative, as the site has plenty of open building roof space that would allow for mounting a central array of photovoltaic (PV) panels. From the load analysis, the number of PV panels required was calculated for panels of various watt output at peak sun hours. The actual load that had to be supplied daily was greater than the load that would have to be supplied by a hydro source of generation, as five days of power autonomy would need to be stored by the system in the case of bad weather for several days, when little or no power production could take place. The need for this autonomy greatly increased the amount of batteries that would be needed to store the excess back-up power (see Appendix J for battery calculations).

B. *Distributed Solar Generation*

A distributed solar generation scheme was considered to see if providing generation at each individual building would improve the cost outlay of the system. It was found that for a system supplying the complete site load, there was actually a cost increase, due to multiple inverters and fusing packages that needed to be provided at each building. Cutting back on the system by eliminating some of the buildings that would be served was not considered a viable alternative, as the objective of the project was to provide power for the full system load.

C. *AC Hydro Generation*

Generation of direct 120 VAC power using a synchronous generator was considered. This configuration requires that the generator be sized to provide the entire maximum load of the system at any given time. This requires a large, expensive generation package, with load and frequency management controls to assure that as load is shed from the system, the generator is not harmed, or the system in general is not harmed by excessive current supply. Flow calculations (see Appendix G) revealed that in order to provide the maximum load power, a large percentage of the stream would have to be used by the generator, possibly impacting the stream ecosystem in an adverse way. Since the site is environmentally sensitive, this form of generation was a less than desirable alternative.

D. *DC Hydro Generation*

Research into DC hydro generation as an alternative revealed it as a source that would provide some of the best qualities of solar generation and AC hydro generation. This alternative uses a 24 VDC generator to charge a bank of storage batteries, just as an array of PV panels would do. The generator charges the batteries continuously, unlike PV panels, which will only charge when the sun is shining. This greatly reduced the number of storage batteries required by the system. Because the generator charges storage batteries, the generator does not need to be sized to supply the full system load at one time (see Appendix H for generator sizing calculations). As long as the generator provides enough continuous electrical output to meet the charging needs of the system loads, the batteries should be able to be sized to supply the peak load demanded by the system. This system also uses less than 25 percent of the stream flow, which is recommended for minimal impact to the stream environment.

VI. SELECTION OF SYSTEM FOR FINAL DESIGN

The preliminary research and design of the four generation alternatives yielded cost summaries for the basic systems (see Appendix D). These cost summaries did not take into account the common expected costs of supplier freight charges, cabin lighting and wiring and air transportation of system parts to the site. However, since these costs are essentially the same, and would only be estimates of the actual costs, each alternative was judged as an equal viable alternative to supply the needed system power.

The cost for each alternative was summarized and presented to Ed Krumpe and Alton Campbell from the College of Forestry, along with a discussion of each system's features. It was decided at this point to consider the DC hydro system as the system of choice, and pursue this system's design in greater detail. There were several factors that influenced this decision.

A. *Cost*

The DC hydro system was the most cost effective system for several reasons. The system's generator was much less expensive than the AC system's, and required less load control. The generator was also less expensive than the equivalent amount of PV panels, and required much less batteries than the solar alternatives, due to the system's ability to provide continuous charge.

B. *Environmental Impact*

The DC hydro system used less of the stream flow than the AC hydro system. The AC hydro system's usage was over 25 percent of the flow, which is an environmentally unfavorable situation. The DC hydro system can be contained completely in one power house building, resulting in minimal "line of sight" impact for the system. Since there are hiking trails running right by the site, and the location lies in wilderness area, it is important that the system not be highly visible. A large solar array in the wide open field would attract attention, and provide an adverse impact for persons utilizing the recreational area.

C. *System Utility*

The DC hydro system excelled in reliable power production, ease of maintenance and ease of installation. The DC hydro system excelled in reliability where the others didn't. At low stream flow conditions, the DC hydro system was capable of power production, whereas the AC hydro system would be ineffective. If the flow could not produce the synchronous speed required by the AC generator, there would be no power production at all. Solar generation would always be variable, when periods of high cloud cover would halt power production.

The DC hydro system's maintenance requires that the water source remain free and clean, along with periodic maintenance of the storage batteries (see Appendix L for battery maintenance procedures). The water supply is already a maintenance issue for the site, as the proposed new supply would be taken out of the existing domestic water supply's headbox. The water supply maintenance could possibly be less, however, because the new supply to the generator would maintain a constant flow through the pipe, therefore possibly avoiding winter freeze up of the headbox.. Solar panels add additional maintenance routines, as panels must be tilted for optimal winter and summer production, and during heavy snow conditions, the panels must be kept clean to produce power. There was also a concern about high winds possibly causing damage to a large solar array. The AC hydro system includes more mechanical parts than the DC hydro system, invariably making maintenance more difficult.

The DC hydro system affords a clean, simple installation. Each alternative was probably almost equal in this respect, but this did not detract from the advantages of the DC hydro system. Installation of the new water source would be an improvement to the existing water system, and therefore would serve a dual purpose.

VII. FINAL SYSTEM DESIGN

Once the appropriate alternative was selected, finalization began to ensure a complete and accurate system, along with the associated costs. System protection was finalized at this point, battery storage figures were re-checked, along with the generator and water supply sizing. The stream flow potential was found to be slightly less than was originally anticipated, but still provided a more than ample supply for the turbine. Shipping and transportation estimates were obtained to round out the system cost. A finalized cost summary is provided in Appendix I, with a breakdown of the function of each system component provided in Appendix J. The finalized system components are as follows:

A. *Harris Hydro 4 Nozzle Turbine with 24V Alternator*

This generator unit was selected based on it's reputation as a standard for this type of application. The output of the generator falls within the required output power range. Details of generator selection can be found in Appendix H.

B. *Ananda TDR-624A Diversion Controller*

This diversion controller was selected based on several items. The rated wattage of the controller is above the highest expected output from the generator. The controller is UL listed, and enclosed neatly in a NEMA 1 enclosure, ensuring an easy and neat installation.

C. *Ananda Powercenter 5-404*

The Powercenter provides the backbone for the system protection. The dual 400 Amp type-T fuses provide short circuit protection for the charging system as well as the system's load. The DC section breakers provide disconnects for the generator and diversion controller, while the AC section breakers provide individual disconnects for the AC building loads. This panel was selected for several reasons. The main reason was the ease of installation. Since all protection equipment is contained in this one central location, the panel can be mounted, wired and forgotten. This panel is also UL listed, and whereas installing separate fuse boxes and breaker panels would probably not be considered as code compliant, this panel is.

D. *Trace DR3624 3600 Watt Inverter*

The DR3624 provides 3600 watts of continuous power, which is well over the system maximum calculated load of 2600 watts. This allows for additional load to be connected in the event that excess power is available from the generation package. It is also better to run the inverter at somewhat less than it's full rated output, as the efficiency of the unit is greater for lower load output.

E. *Trojan TJ-105 6V Deep Cycle Batteries*

The batteries were selected based on cost, local availability, and total weight. The TJ-105's are simply the least expensive, lightest, and they can be purchased at almost any car parts store.

F. *Schedule 40 PVC Pipe*

This type of pipe was selected for it's smoothness, and subsequent low head loss. The pipe was sized to 3" per flow calculations, and can be obtained from any plumbing supplier.

G. *#8 Solid Copper Direct Bury 3 Conductor Cable*

This conductor was selected based on ease of installation, and function. The power loss calculated for the conductor was insignificant (see Appendix C), allowing for future connected amps without have to upgrade conductors.

H. *Building Lighting and Power Systems*

Each building was analyzed to determine the number of fixtures, switches, outlets, utility boxes, circuit breakers and length of wire required to provide power and lighting. An estimate was constructed with a cost breakdown for each building. Prices were obtained directly from the University Shop Stores for an accurate idea of the cost to the College. It should be noted that this portion of the system could be done on a pay-as-you go basis, for example, connect and wire one cabin at a time and allocate the cost over a period of time. This way, not all of the cost would have to be absorbed in one year. Another way to reduce this cost is to limit the use of compact fluorescent lights to high-use lights, while using inexpensive incandescent lighting for low-use lighting.

VIII. SUMMARY AND CONCLUSIONS

The DC hydro system designed should provide adequate power for the existing load at Taylor Ranch and allow for future equipment expansion. All devices were sized to allow room for additional growth of the system. The amount of this growth will inevitably depend on the power output from the generator. Varying stream flow and freeze-up in the winter months could limit production during those months. This is a variable that will inevitably be determined as the system is operated. As long as flow is maintained through the generator, power will be produced.

Electrical power supplied to the site will eleviate the site's propane use for lighting and refrigeration. At the same time, electrical power will make the site more useful by providing adequate power for lighting and equipment used for teaching and research. This design will allow for the power needs of the site and maintain a low environmental impact in line with the standards the College of Forestry wishes to maintain.

IX. ACKNOWLEDGMENT

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X. REFERENCES

For references, see Appendix M.