FINAL REPORT
FEASIBILITY STUDY OF A GEOTHERMAL HEAT PUMP SYSTEM
LAPWAI MIDDLE-HIGH SCHOOL, LAPWAI, ID
NEZ PERCE INDIAN RESERVATION

June 2006

FINAL REPORT
FEASIBILITY STUDY OF A GEOTHERMAL
HEAT PUMP SYSTEM
LAPWAI MIDDLE-HIGH SCHOOL, LAPWAI, ID
NEZ PERCE INDIAN RESERVATION

Andrew Chiasson
Geo-Heat Center
Oregon Institute of Technology

Geo-Heat Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601

Prepared for:

Midwest Research Institute, National Renewable Laboratory under contract Task Ordering Agreement No. KLDJ-5-55052-00, Task Order No. KLDJ-5-55052-01, "Feasibility Studies and Life-Cycle Cost Analysis", Task 1: Nez Perce Geothermal Heat Pump (GHP) Feasibility Study

June 2006

DISCLAIMER STATEMENT

This report was prepared with the support of the U.S. Department of Energy, Geothermal Technologies Program and Midwest Research Institute, National Renewable Energy Laboratory Division under contract Task Ordering Agreement No. KLDJ-5-55052-00, Task Order No. KLDJ-5-55052-01. Any opinions, findings, conclusions, or recommendations expressed herein are those of the author and do not necessarily reflect the view of DOE.

TABLE OF CONTENTS

GEO-HEAT CENTER

Oregon Institute of Technology, Klamath Falls, Oregon 97601 541/885-1750 FAX 541/885-1754

John W. Lund, Director
Andrew Chiasson
Tonya "Toni" Boyd

EXECUTIVE SUMMARY

The Geo-Heat Center conducted a feasibility study of a geothermal heat pump (GHP) system for the planned new Lapwai Middle-High School in Lapwai, ID, Nez Perce Reservation. This work has been funded and completed under Midwest Research Institute, National Renewable Energy Laboratory (NREL) Task Order No. KLDJ-5-55052-01, "*Feasibility Studies and Life-Cycle Cost Analysis*", Task 1: Nez Perce Geothermal Heat Pump (GHP) Feasibility Study.

A conventional heating, ventilating, and air-conditioning (HVAC) system for the new school building has already been designed by Elkhorn Engineers. The HVAC system consists of split units for classrooms, and rooftop units for common areas, each with propane heat and direct expansion (DX) cooling.

For this feasibility study, the heating and cooling loads were first verified with building energy simulation software. The peak heating load is estimated at 2.9 million Btu/hr and the peak cooling load for the building is estimated at 1.375 million Btu/hr (115 tons). The annual heating load is estimated at 1.04 billion Btu/yr and the annual cooling load is estimated at 483 million Btu/yr.

The conventional system as designed by Elkhorn Engineers lends itself quite well for GHP re-design, and a GHP system would be very cost-competitive. This is because the conventional design calls for a split system in each classroom, which is also the design approach in a GHP system. With the exception of the earth coupling, there are several cost tradeoffs between the "in the building" portion of the GHP and conventional systems. Split systems require two pieces of equipment: furnaces and rooftop condensing units. Gas piping needs to be installed to each furnace, and copper refrigerant lines need to be routed to rooftop condensers. With GHP systems, only water piping is required to each heat pump unit, but heat recovery units are typically installed with the GHP systems in schools to maximize heat pump capacity and minimize energy consumption.

The hydrogeology of the Lapwai area makes an open-loop GHP system the most logical choice. Groundwater in the area is extracted from the Grande Ronde Basalt, which is highly productive with some wells producing in excess of 500 gpm at relatively shallow depths. Groundwater temperatures are about 58^{o}F, with a total dissolved solids (TDS) concentration of 200-220 mg/L. Approximately 200 gpm of groundwater would be required for heating, and about 100 gpm would be required for cooling of the school building.

A summary of the economic comparison of alternatives is as follows:

HVAC System	Total Capital Cost	Annual Costs		Periodic Costs	Simple Payback (yrs)	Net Present Value of 50-yr Life-Cycle Cost
		Energy	Maint.			
1. Conventional system (split systems + rooftops with propane heat and DX cooling)	$519,332	$25,966	$3,541	$55,000 ,Year 17	-	**$1,001,776**
2. Geothermal heat pump (open-loop wells)	$633,992	$8,086	$4,721	$25,000 ,Year 20	**6.5**	**$750,659**

The total incremental cost of the open-loop GHP system is $114,660, but it can be operated with an annual energy savings of about $17,880 or about one third of the cost of the conventional system. This operating cost reduction is mostly attributable to the much higher heat pump efficiency over fossil fuel combustion, and the relatively high propane cost relative to electricity cost. The GHP system has a 50-year life-cycle cost that is 33% lower than the conventional alternative and a simple payback period of about 6.5 years.

A sensitivity analysis of the GHP cost items on the simple payback period has shown that the most sensitive items are the heating energy savings and the incremental GHP system capital cost. Sensitivity of the simple payback period to well drilling cost is less significant, while almost insensitive to the cooling energy savings, due to the low number of cooling hours. A 20% change in the heating energy savings or the GHP system capital cost alters the simple payback period by about 1.5 years.

A greenhouse gas analysis has shown that use of a GHP system can reduce annual greenhouse gas emissions by 60 tons of equivalent CO_2 per year in using a GHP system over split systems and rooftop units with propane heat and DX cooling.

INTRODUCTION AND BACKGROUND

This work has been funded and completed under Midwest Research Institute, National Renewable Energy Laboratory (NREL) Task Order No. KLDJ-5-55052-01, "*Feasibility Studies and Life-Cycle Cost Analysis*", Task 1: Nez Perce Geothermal Heat Pump (GHP) Feasibility Study.

The motivation for conducting this project originated from interest by persons of the Nez Perce Tribe in reducing energy consumption (and costs) in the Lapwai Middle-High School. When this Task Order was submitted, a retrofit of the heating, ventilating, and air-conditioning (HVAC) system to a GHP system in the existing school building was being considered. Since that time, it was deemed that constructing a new school building would be more beneficial and cost-effective than renovating the existing one.

A full set of design drawings and specifications for demolition and new school construction had been prepared in late 2004 by Design West Architects (Pullman, WA). The HVAC system for the new school was designed by Elkhorn Engineers (Meridian, ID). A copy of these drawings and specifications was forwarded to the Geo-Heat Center by Jon Paisano, Hydrologist, Nez Perce Tribe Water Resources Division. A comprehensive hydrogeologic report of the Lapwai Valley has been furnished by Kevin Brackney, P.G., C.G.W.P., Hydrogeologist, Nez Perce Tribe Water Resources Division. Much of the GHP feasibility study described in this report is based on information from these sources.

OBJECTIVE AND SCOPE

The objective of this project is to estimate the feasibility of a geothermal heat pump (GHP) system for the new Lapwai Middle-High School building. Since a new HVAC system has already been designed, our approach is to estimate incremental first costs of a GHP system, and compare energy savings to the conventional system. The feasibility of the two alternatives are evaluated using a present value and a simple payback approach.

METHOD OF STUDY

The methods and approach conducted by the Geo-Heat Center to accomplish the project objectives are summarized as follows:

.

- Obtained construction drawings of the new school building and hydrogeologic information of the area,
- Developed a computer model of the building using eQuest (J.J. Hirsch, 2005) graphical user interface,

- Computed peak hourly and annual heating and cooling loads of the building using the DOE-2 simulation engine (York and Cappiello, 1981),
- Simulated annual energy consumption of the conventional HVAC system using the DOE-2 building simulation software. The conventional HVAC system has been designed by Elkhorn Engineers, and consists of split systems and rooftop units, all with propane heat and direct expansion (DX) cooling,
- Conducted an economic analysis of the alternative GHP system, along with an associated sensitivity analysis of cost assumptions,
- Conducted a greenhouse gas analysis to estimate the possible reduction in greenhouse gas emissions by using geothermal heat pumps. This analysis was done using RetScreen software (NRC, 2005).

HEATING AND COOLING LOADS ANALYSIS

A computer model of the building was developed in order to verify design loads, but more importantly to estimate annual energy consumption of the HVAC system. The system equipment as designed by Elkorn Engineers has a total heating capacity of 2.9 million Btu/hr and a total cooling capacity of 1.6 million Btu/hr (136 tons). Much of the excess heating load with respect to the cooling load may be attributed to outdoor air loads.

A single-story school building with a total floor area of 47,212 ft^2 was modeled with the eQuest/DOE-2 software using weather data for Lewiston, Idaho. Occupancy schedules for people, lighting, and equipment usage for a typical school building were assumed. An occupancy of 50% was assumed during summer months.

The peak cooling load for the building is estimated from the DOE-2 software at 1.375 million Btu/hr (115 tons) and the peak heating load is estimated at 2.9 million Btu/hr. These values are in excellent agreement with the designed equipment capacity. The annual heating load is estimated at 1.04 billion Btu/yr and the annual cooling load is estimated at 483 million Btu/yr.

DESIGN CONSIDERATIONS FOR THE GEOTHERMAL HEAT PUMP SYSTEM

The Conventional System

The conventional HVAC system designed by Elkhorn Engineers (as mentioned above) consists of a mix of split systems and rooftop units. Split systems are designed for each classroom, and consist of propane furnaces with DX cooling. Condensers are to be installed on the school roof. The split systems account for 64% of the total heating capacity and 66% of the total cooling capacity of all equipment planned for the school. Rooftop units are planned for hallways, offices, and common areas. The rooftop units are also propane heat with DX cooling. All equipment is specified as Carrier brand, with a heating efficiency of 80%, and a SEER of 11.

The overall conventional HVAC system design should be very energy efficient, relatively easy to maintain, and have a high level of comfort. This is due to the fact that a split system is planned for each classroom. Thus, each system only responds to the needs of each individual room, which allows for excellent control and efficient operation. Further, outdoor air, controlled by CO_2 sensors, is ducted to each unit, which helps to optimize energy efficiency and comfort.

Re-Design of the Conventional System to a GHP System

The conventional HVAC system as designed by Elkhorn Engineers lends itself very well for a geothermal heat pump re-design. This is because schools with GHP systems typically have a geothermal heat pump installed in each classroom. In new construction, there are cost tradeoffs between a GHP system and a conventional system of the type designed for the Lapwai School, which makes the two systems similar in cost, with respect to both labor and materials. With the conventional split systems, gas piping needs to be installed to each unit, and copper refrigerant lines need to be routed to rooftop condensers. With GHP systems, only water piping is required to each heat pump unit.

A couple of options are available for re-design of the conventional rooftop units: (i) they could be swapped directly with rooftop geothermal heat pumps, or (ii) they could be replaced by ceiling-mounted geothermal heat pumps in the school, eliminating rooftop penetrations.

Aside from the earth loop installation (discussed below), there are some additional costs inside the building for GHP systems. Outdoor air heat recovery units are typically installed in GHP systems so that heat pump capacities are not compromised on extreme weather days. Also, GHP systems generally require a small mechanical room to house pumping and associated equipment.

Site Geological Conditions

Brackney (2006) gives a detailed discussion of the geology and groundwater resources of the Lapwai Valley of the Lewiston Basin. Groundwater occurs in aquifers contained within stratified basalts of the Columbia River Basalt Group that have been subsequently folded and faulted. The aquifers occur between the basalt flows and are localized primarily along permeable zones at the basalt flowtops. The interiors of the flows consist of massive basalt with relatively little water passing vertically between the basalt flows. This results in a stratification of aquifers that typically function independently of each other.

On March 5, 1992, the Idaho Department of Water Resources (IDWR) designated the Lindsey Creek aquifer as a Ground Water Management Area, which exists in the region between the cities of Lapwai and Lewiston. The Lindsey Creek Aquifer produces its water from the Saddle Mountain and Wanapum Basalts formation. The Management Area designation was based on evidence that the aquifer had limited recharge, and the potential for increased use of a portion of the shallow aquifer existed. New wells are prevented by the designation from tapping into the upper aquifer and must be completed down into the underlying Grande Ronde Basalt Aquifer. There is an estimated several hundred feet difference in hydraulic head between the Lindsey Creek and Grande Ronde aquifers. The Grande Ronde Basalt hosts the Lewiston Sole Source

Aquifer and produces up to 3 billion gallons of water per year (1994 data) with most wells maintaining a constant static water level.

Groundwater in the Lapwai area is extracted for domestic and municipal uses from the Grande Ronde Basalt. This aquifer is highly productive with some wells producing in excess of 500 gpm. Groundwater temperatures are about 58^{o}F, with a total dissolved solids (TDS) concentration of 200-220 mg/L. Geochemical sampling of surface and groundwaters by Brackney (2006) reveal that the groundwater is characterized as calcium-magnesium bicarbonate water.

Figure 1 shows the location of wells in the vicinity of the existing Lapwai Middle-High School. The future building will be built on the same property. The Geo-Heat Center obtained a well log for the Lapwai City Well #1 from the IDWR website. The well, completed in 1988, is 215 ft deep, and two production zones are indicated on the lithologic log: 100 gpm at a depth interval of 59-113 ft; and 348 gpm at a depth interval of 185-210 ft. Two abandoned Lapwai City water wells exist behind the current Lapwai high school building. These wells have been referred to as *baseball field north* and *south* wells by Brackney (2006). One well still has a pump in it and is still plumbed into the Lapwai Water System. In addition, a third well exists to the southwest of the school at the school district track (Lapwai SD track well) and is used for seasonal irrigation. Chemical analyses of samples from these wells show that constituents of concern are within EPA Drinking Water Quality Standards.

"Static" water levels in these wells are approximately 40 feet below grade. However, hydrographs reported by Brackney (2006) demonstrate that these wells respond to pumping from the active Lapwai City wells, showing variations in hydraulic head of 1-3 ft. As seen in Figure 1, the distance to the nearest pumping wells are 1,016 ft to Lapwai No. 5 and 3,012 ft to the Lapwai JD Well.

Design of the Geothermal Loop

In choosing the optimal geothermal loop configuration in a GHP system, a number of geologic, thermal, and hydraulic properties of the subsurface materials are considered. Given the excellent groundwater resources in the area, an open-loop GHP system was the focus of this study.

A conceptual diagram of an open-loop system is shown in Figure 2. The system consists of two "loops" separated by a stainless steel plate heat exchanger, which isolates groundwater from the heat pump equipment. This configuration reduces potential scale or corrosion to one piece of equipment. Routine maintenance and cleaning of the stainless steel plates usually results in a trouble-free system. The building piping loop would be filled with an antifreeze solution, typically a mixture of water and about 15% propylene glycol. As a backup, a second submersible pump could be installed in the injection well. This second well pump can be operated as the primary pump in the summer when loads are lower.

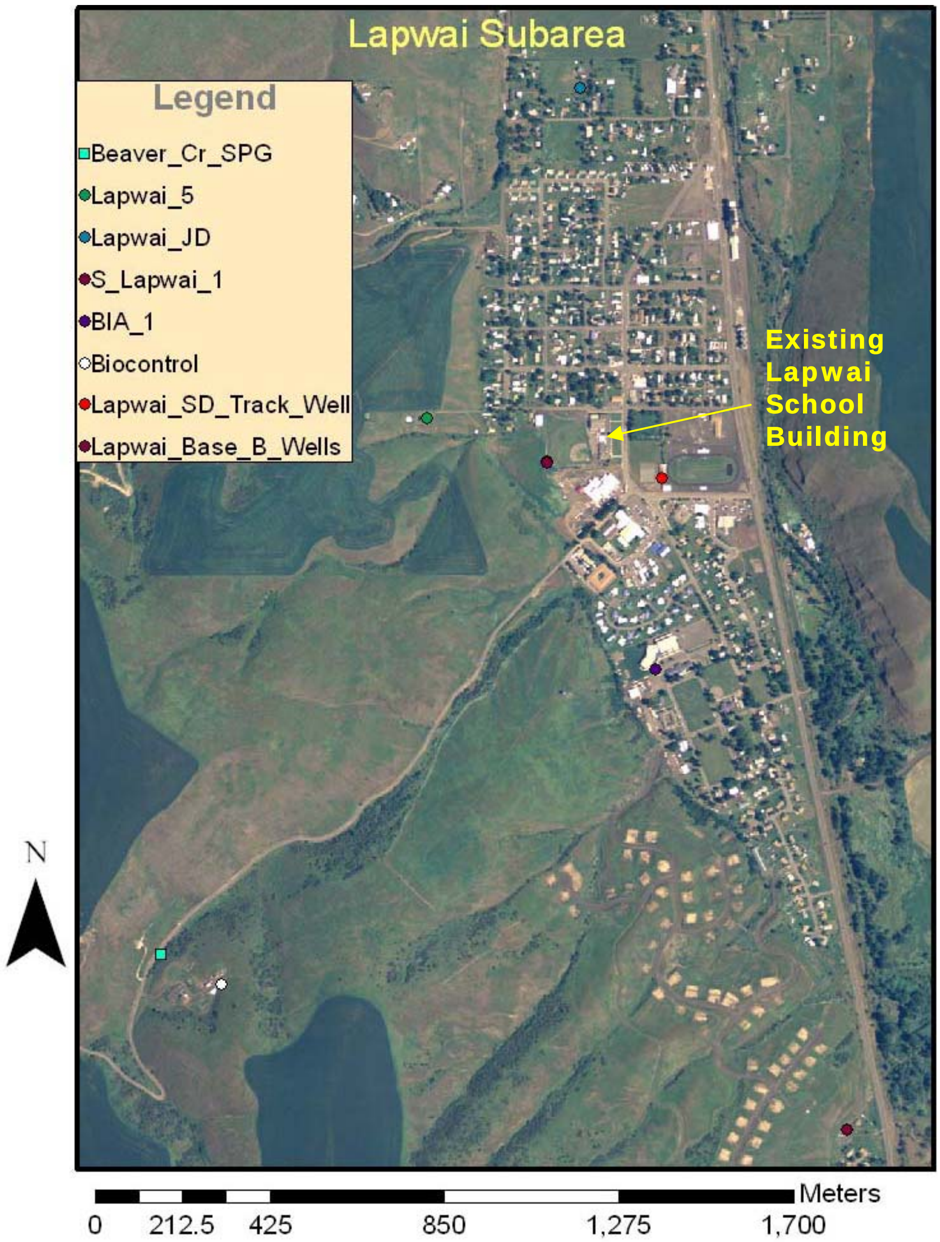

Figure 1. *Well locations in the vicinity of the Lapwai Middle-High School (modified from Brackney, 2006).*

The use of an isolation heat exchanger also allows for energy-efficient control of the well pump. The building loop temperature is allowed to "float" between a heating and cooling setpoint, and when the building loop temperature reaches either of these setpoints, the well pump is energized and moderates the building loop temperature. With this type of control, the required groundwater flow rate is a function of its temperature. Assuming an average groundwater temperature of 58°F, about 200 gpm of groundwater would be required for heating and about 100 gpm would be required for cooling. For energy efficiency, the building loop circulating pump should be variable speed.

Kazemann and Whitehead (1980) used a simple approach to develop the required spacing between supply and injection wells in order to minimize thermal communication between wells. The approach uses the dominant flow rate (heating in this case) averaged over the heating season. Assuming an aquifer thickness of 50 ft and a 9-month possible heating season, the required well spacing is approximately 300 ft.

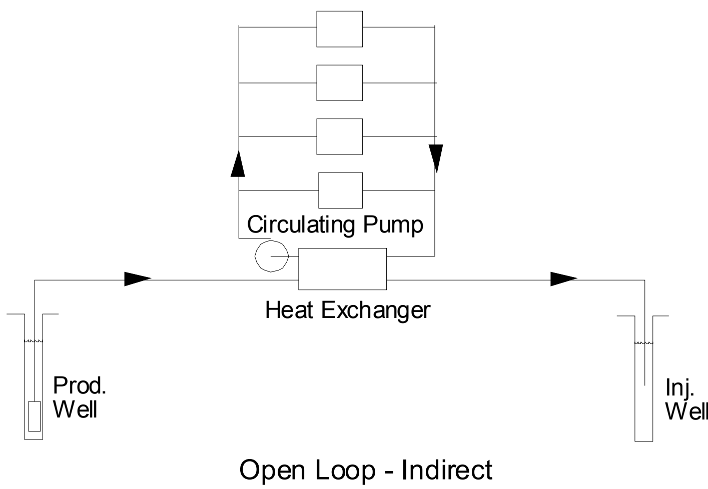

***Figure 2**. Conceptual diagram of an open-loop geothermal heat pump system.*

ANNUAL ENERGY CONSUMPTION AND OPERATING COSTS

Annual heating and cooling demands for the proposed Lapwai Middle-High school building were determined from the DOE-2 simulation software. Assumptions for estimating the annual energy cost of the conventional and GHP system are shown in Table 1.

The first section of data presented in Table 1 shows the load summaries. The second section shows the system efficiencies. The efficiencies of the conventional system were taken from specifications of the Carrier equipment selected by Elkhorn Engineers. The geothermal heat pump COPs are those typical of an open-loop system. Electricity rates were estimated at $0.06/kWh and propane costs were estimated at $1.60/gal. A well pump head of 100 ft was also assumed, in order to calculate annual well pumping costs.

The third section of Table 1 shows the annual costs of energy for each system. Since the GHP system is sized for the peak cooling load, some supplemental electric heat will be necessary. Note that if the heat pumps are sized for cooling, about 54% of the peak heating load will need to be met by electric resistance heat. Also note that, although this value seems large, the GHP system will meet about 94% of the annual heating requirements simply because the peak heating hours seldom occur throughout the year. This estimate is conservative because heat recovery units on the heat pumps will reduce outdoor air loads, thereby reducing the demand for electric resistance heat.

The annual energy cost of the HVAC systems are estimated at:

- Conventional system (split systems + rooftop units with propane heat and DX cooling): **$25,966**
- Geothermal heat pump system (open loop): **$8,086**

Thus, the GHP system can be operated with an annual energy savings of about $17,880 or about one-third of the cost of the conventional system. This operating cost reduction is mostly attributable to the much higher heat pump efficiency over fossil fuel combustion, and the relatively high propane cost relative to electricity cost.

TABLE 1.
Annual Energy Consumption and Energy Cost for the HVAC Systems

	Heating		Cooling		TOTALS	Comments
LOADS						
Peak Load	2,958,328	Btu/hr	114.58	ton		
	867.0	kW	403.0	kW		
Annual Load	1,041,000,000	Btu	483,283,000	Btu		
	305,100	kWh	141,642	kWh		
SYSTEMS						
Ground-Source						
COP	4.0		4.7			
Electrical energy cost	$0.060	/kWh	$0.060	/kWh		
Supplemental heating required	464	kW				
Well pumping head	100.0	ft				
Conventional						
Efficiency	0.8		3.0			- From Elkhorn specs.
Energy cost	$1.600	/gal. propane	$0.060	/kWh		
ANNUAL ENERGY COST						
% peak met by supplemental	54%					
% annual met by supplemental	6%					
Well pumps	$329		$153			
Ground-Source (+circ. pumps)	$6,122		$1,964		$8,086	
Conventional	$23,133		$2,833		$25,966	
Annual Savings	$17,011		$869		**$17,880**	

ECONOMIC ANALYSIS

A present value (PV) of 50-year life-cycle cost and a simple payback approach were chosen for comparing the HVAC system alternatives. Life-cycle costs that were considered included capital costs (or initial costs), annual costs (including operating and maintenance costs), and periodic costs (such as replacement costs). The capital cost and energy savings of the GHP system were used to estimate a simple payback period. As there is some obvious uncertainty in predicting these costs, a sensitivity analysis was conducted to quantify the effect of various cost items on the simple payback.

Capital, Annual, and Periodic Costs

Assumptions in the cost estimations are shown in Table 2.

TABLE 2.
Cost Estimate Details for the HVAC Systems

	Unit	Quantity	Unit Cost	Amount	TOTALS	Comments
INITIAL COSTS						
Design & Engineering						
Pre-design meetings, etc.	hr	24	$100	$2,400		
Engineering re-design	%	5%	$600,326	$30,016		
Construction oversight	hr	25	$50	$1,250		
				$33,666		
Equipment & Installation						
GHP installation cost	sq. ft	47212	$11.50	$542,938		- Includes all "inside the building" materials + labor
Drilling, well completion	m	152	$246.06	$37,500		- Two wells @ 250 ft
Well flow testing	lump	1	$1,500	$1,500		
Trenching and backfilling	m	100	$25.00	$2,500		
Well pumps + controls	kW	7.2	$750	$10,851		- One primary + one backup
Plate heat exchangers	kW	403	$12.50	$5,037		
Conventional system credit	sq. ft	47212	-$11.00	-$519,332		- Sq. ft costs from Means (2006)
				$80,994		
					$114,660	
ANNUAL COSTS						
Energy use savings				$17,880		
Incremental maintenance savings	sq. ft	47212	-$0.025	-$1,180		- $0.075/ft^2 for conventional, $0.10/ft^2 for GHP
					$16,700	
PERIODIC COSTS	Years					
Outdoor condenser replacement	17			$55,000		
Pumps, heat exchanger	20			$25,000		

The first section of Table 2 shows the capital or initial costs. First, additional re-design and engineering fees will be incurred. These are estimated at a typical 5% of the mechanical system cost, in addition to extra site visits and well construction oversight.

The capital cost of the conventional HVAC system was taken from construction cost data compiled by R.S. Means (2006) for school buildings. For the conventional HVAC system (split systems + rooftop units with propane heat and DX cooling), the installation cost is estimated at $11.00/sq. ft of floor space, resulting in a first cost of approximately $520,000. This value is subtracted from the GHP installation cost to obtain an incremental cost of the GHP system.

The capital cost of a GHP system was estimated from two recent case studies on new school buildings in Utah (GHC, 2005). These were closed-loop systems in schools of approximately 250,000 sq. ft, but the first cost of the "inside the building" work has been broken out separately. The mechanical work for the larger school was bid at $11.47/sq. ft, and $10.54/sq. ft for the smaller school. Thus, the mechanical portion of the overall cost of a GHP system is similar to a conventional one for schools, and could even be lower. To be conservative, we estimated the installation cost of the GHP system at the Lapwai School at $11.50/sq. ft. In addition to the "inside the building work" for the GHP system, Table 2 shows the added costs of well drilling and testing, pump costs with installation, horizontal transfer piping to the building, and the heat exchanger cost with installation. This cost estimate assumes two new wells will have to be drilled, although it is possible that one of the baseball wells could be refurbished and used. As shown in Table 2, **the total incremental capital cost of the open-loop GHP system is $114,660**.

The third section of Table 2 summarizes the annual costs. The energy savings are taken from Table 1. Maintenance and repair costs are estimated from a study by Martin et al. (2000). The GHP system is estimated to have higher maintenance costs due to the wells and heat exchanger.

The fourth section of Table 2 describes the periodic costs of the HVAC systems, which only consider equipment replacement costs (repair costs are included in maintenance costs). Rooftop units and outdoor HVAC equipment have typical expected lifetimes of 15 to 20 years. For this cost analysis, it was assumed that the outdoor condensing units of the conventional system would need replacing after 17 years of operation at an estimated cost of $15,000 (R.S. Means, 2006). The rooftop units would also need replacing after this time at a cost of $40,000. It was also assumed that the well pumps, circulating pumps, and the heat exchanger would need replacing after 20 years.

Present Value (PV) and Simple Payback Comparison of Alternatives

For the present value (PV) comparison, the following economic assumptions were made:

- Annual energy cost escalation rate = 2%
- Annual maintenance cost escalation rate = 2%
- Discount rate = 8%
- Project life = 50 years

Feasibility of a GHP system is probably better comprehended with a simple payback approach, given the volatility of current material and energy costs. The PVs and simple payback periods, along with other cost items are summarized in Table 3.

TABLE 3.
Economic Comparison of HVAC Alternatives for the New Lapwai Middle-High School

HVAC System	Total Capital Cost	Annual Costs		Periodic Costs	Simple Payback (yrs)	Net Present Value of 50-yr Life-Cycle Cost
		Energy	Maint.			
1. Conventional system (split systems + rooftops with propane heat and DX cooling)	$519,332	$25,966	$3,541	$55,000 ,Year 17	-	**$1,001,776**
2. Geothermal heat pump (open-loop wells)	$633,992	$8,086	$4,721	$25,000 ,Year 20	**6.5**	**$750,659**

As seen in Table 3, the GHP system has a 50-year life-cycle cost that is 33% lower than the conventional alternative. Based on the "base case" assumptions, **the simple payback period of the GHP systems is estimated at 6.5 years**.

In order to quantify uncertainty in the GHP system cost estimates, a sensitivity analysis was conducted on the payback period. Cost items of the GHP system were varied from -20% to +20% of the base case (where the base case costs are those described above). The results of the sensitivity analysis are shown in Figure 3.

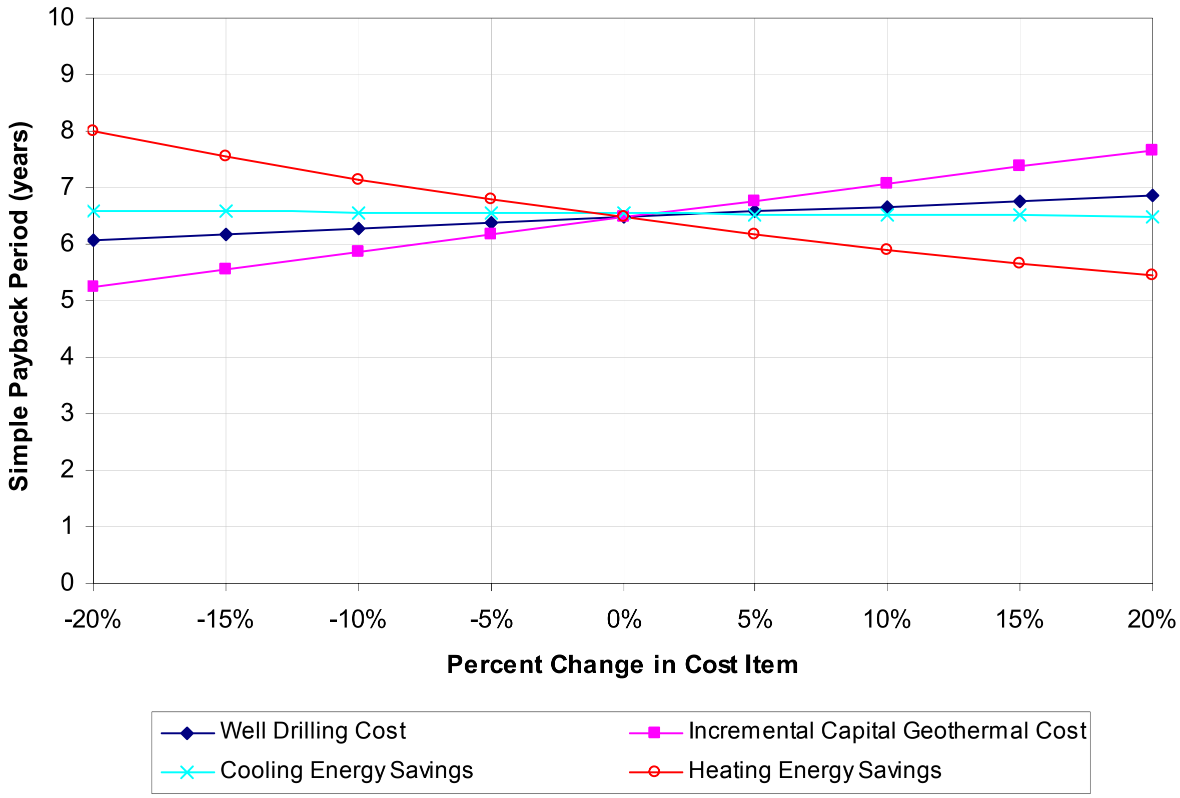

***Figure 3**. Sensitivity analysis of GHP cost items on the GHP system simple payback period.*

A review of Figure 3 reveals that the most sensitive cost items of the GHP system are the heating energy savings and the incremental GHP system capital cost. Sensitivity of the simple payback period to well drilling cost is less significant, while almost insensitive to the cooling energy savings, due to the low number of cooling hours. A 20% change in the heating energy savings or the GHP system incremental capital cost alters the simple payback period by about 1.5 years. A 20% change in the well drilling cost alters the simple payback period by about 6 months.

GREENHOUSE GAS ANALYSIS

Greenhouse gas emissions have been attributed to various negative impacts on air quality and global weather patterns. As a result, carbon emissions have become regulated in some locations throughout the world. Heating and cooling of buildings is responsible for greenhouse gas emissions through the use of electricity generated by fossil-fuel fired power plants, and by combustion of fossil-fuels directly for heat.

RetScreen software (NRC, 2005) was used to estimate the reduction in greenhouse gas emissions through the use of a GHP system at the Lapwai Middle-High School. The greenhouse gases considered included carbon dioxide (CO_2), methane (CH_4), and nitrous oxides (N_2O). Carbon emission factors from various electrical power generating methods, along with emission factors from natural gas combustion for heating are used in the software. For the Lapwai area, electricity is primarily generated by hydro sources. Therefore, a GHP system will be nearly 100% renewable.

The reduction in greenhouse gas emissions is estimated at 60 tons of equivalent CO_2 per year in using a GHP system over split systems and rooftop units with propane heat and DX cooling.

SUMMARY AND CONCLUSIONS

The Geo-Heat Center has conducted a feasibility study of a geothermal heat pump (GHP) system for the planned new Lapwai Middle-High School in Lapwai, ID, Nez Perce Reservation. A conventional heating, ventilating, and air-conditioning (HVAC) system for the new school building has already been designed by Elkhorn Engineers, and consists of split systems for classrooms, and rooftop units for common areas, each with propane heat and direct expansion (DX) cooling.

Some specific conclusions of this study are as follows:

- The “inside the building” portion of the GHP system is quite cost competitive with the conventional system, and may even be lower in cost, depending on actual bids.
- The hydrogeology of the Lapwai area is quite suitable for an open-loop GHP system. Groundwater in the area is extracted for domestic and municipal uses from the Grande Ronde Basalt, which is highly productive with some wells producing in excess of 500 gpm. Groundwater temperatures are about 58^{o}F, with a total dissolved solids (TDS) concentration of 200-220 mg/L.
- For an open-loop system at the new Lapwai Middle-High School, approximately 200 gpm of groundwater would be required for heating, and about 100 gpm would be required for cooling. Approximately 300 ft of separation distance between the supply and injection well is estimated.
- The total incremental capital cost of an open-loop GHP system for the new Lapwai Middle-High School is conservatively estimated at $114,660.
- The GHP system can be operated with an annual energy savings of about $17,880 or about one third of the cost of the conventional system. This operating cost reduction is mostly attributable to the much higher heat pump efficiency over fossil fuel combustion, and the relatively high propane cost relative to electricity cost.
- The GHP system has a 50-year life-cycle cost that is 33% lower than the conventional alternative.
- The GHP system has a simple payback period of about 6.5 years.
- The most sensitive items on the simple payback period are the heating energy savings and the incremental GHP system capital cost. Sensitivity to well drilling cost is less significant, and almost insensitive to cooling energy savings, due to the low number of cooling hours.

- A 20% change in the heating energy savings or the GHP system capital cost alters the simple payback period by about 1.5 years.
- A 20% change in the well drilling cost alters the simple payback period by about 6 months.
- Use of a GHP system at the new Lapwai Middle-High School is estimated to potentially reduce annual greenhouse gas emissions by 60 tons of equivalent CO_2 per year.

REFERENCES

Brackney, K.M., 2006. *Hydrogeologic Background for Source Water Assessment of the Lapwai Valley Sole Source Aquifer, Nez Perce Tribe, Idaho*. Nez Perce Tribe, Water Resources Division.

GHC, 2005. *Geothermal Heat Pump Case Studies of the West*, Geo-Heat Center Quarterly Bulletin, September 2005, Vol. 26, No. 3.

Hirsch, J.J., 2005. *eQUEST Energy Simulation Tool*.

Kazemann, R.G. and Whitehead, W.R., 1980. The Spacing of Heat Pump Supply and Discharge Wells, *Groundwater Heat Pump Journal*, Vol. 1, No. 2, Water Well Journal Publishing Co., Columbus, OH.

Martin, M.A., Madgett, M.G., and Hughes, P.J., 2000. Comparing Maintenance Costs of Geothermal Heat Pump Systems with Other HVAC Systems: Preventative Maintenance Actions and Total Maintenance Costs. *ASHRAE Transactions,* Vol. 106, No. 1.

Natural Resources Canada (NRC), 2005. Retscreen International, Clean Energy Project Analysis Software.

R.S. Means, 2006. *Assemblies Cost Data*, 31st Annual Edition.

York, D.A. and Cappiello, C.C., 1981. *DOE-2 Engineers Manual (Version 2.1A)*, Lawrence Berkeley Laboratory and Los Alamos National Laboratory.