



GEO-HEAT CENTER

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EXECUTIVE SUMMARY

The Geo-Heat Center conducted an assessment of the use of a geothermal well coupled to a radiant floor system for greenhouse heating at the planned expansion of Ward's Greenhouse, Inc. near Oreana, ID. Eventual plans call for construction of a 16-acre state-of-the-art greenhouse facility that will specialize mainly in the raising of poinsettias and other potted flowers. The proposed greenhouse design calls for a concrete floor with a flood-floor irrigation system and a radiant floor heating system. The main objective of this project was to investigate the possibility of "loading" the concrete floor with thermal energy prior to the onset of cold weather.

This work has been funded and completed under Midwest Research Institute, National Renewable Energy Laboratory (NREL) Task Order No. KLDJ-5-55052-05, "*Feasibility Studies for Projects in Utah, Nevada, and Idaho*".

Greenhouse Heating Loads and Radiant Floor Heating Performance

Heating load calculations show that the peak heating requirement for the proposed greenhouse is 76 Btu/hr/ft² of floor space during a typical weather year. Use of an isolation heat exchanger between the geothermal water and a radiant floor heating system allows flow rates through the radiant floor system to be adjusted to keep acceptable temperature drops across the floor (i.e. 10 to 20°F) while extracting an optimum amount of heat from the geothermal water.

A computer model was developed to simulate the performance of a concrete radiant floor heating system with a flood-floor irrigation system for plants. A computer model allows ease of processing the numerous interacting variables that occur simultaneously in radiant floor systems. For this study, it was assumed that the geothermal well could sustain a flow rate of 1,500 gpm, producing 140°F water. Model results show that the radiant floor system can only handle 55% of the peak load, but is capable of handling 94% of the total annual load. The annual cost of heating the full-scale greenhouse with natural gas at 80% efficiency and \$1.20/therm would amount to \$1.45 million. Therefore, the geothermal system would save about \$1.37 million annually.

Supplemental Heating System and Other Radiant Floor Options

In colder climates characteristic of southern Idaho, it is typically difficult to heat an entire greenhouse with a radiant floor system. Temperature control of the space is also challenging due to the "warm-up" and "cool-down" times required for the thermal mass of the floor. Therefore, it is more desirable to design a baseload and peaking system, regardless of whether the well could supply enough heat to the radiant floor to heat the entire greenhouse. An energy efficient means to provide peak heating would be to cascade geothermal water from the radiant floor to water-source geothermal heat pumps, which would supply a forced-air system. During a typical weather year, additional annual electrical costs to operate water-source heat pumps would be estimated at about \$22,500, while a natural gas peaking system would cost about \$84,000 annually.

Additional computer model simulations show comparable heating performance with a compacted sand radiant floor heating system with no flood-floor irrigation system. Relative to a concrete floor radiant heating system with flood-floor irrigation, the fraction of peak load handled by the sand floor decreases slightly to 50%, and the annual load fraction decreases slightly to 91%. This option still results in an attractive annual savings of \$1.32 million while saving the capital cost of a concrete floor.

Management of Geothermal Water

The existing water right for groundwater use at the Ward property could not be used for geothermal heating as is because the beneficial use of groundwater for which the existing water right was obtained is for irrigation from April 1 to October 31. The subject property is not in a groundwater management area, and consequently a new water right for year-round heating could be obtained.

With year-round extraction of groundwater from the well (i.e. irrigation plus partial heating uses in summer and large heating uses in winter), aquifer depletion can be a concern. Therefore, it would be prudent to plan on a groundwater injection well to replenish the aquifer with groundwater used by the heating system. The cost of an injection well drilled to the same depth as the production well (2,900 ft) would be on the order of \$500,000.

Recommendations

The Geo-Heat Center recommends design of a radiant floor baseload heating system with a forced-air peaking system of geothermal heat pumps supplied by groundwater cascaded from the radiant floor. Some additional hydrogeological studies at the site are also recommended to re-affirm key design parameters. A step drawdown test on the well would give better insight into long-term sustainability of well flow rates and temperatures. Design of an injection well on the property in the downstream groundwater flow direction is recommended. Finally, the Idaho Department of Water Resources (IDWR) should be contacted in order to start the application process for a new water right.

INTRODUCTION

The Geo-Heat Center conducted an assessment of geothermal radiant floor heating options at the new expansion of Ward's Greenhouse, located near Oreana, ID in Owyhee County. This work has been funded and completed under Midwest Research Institute, National Renewable Energy Laboratory (NREL) Task Order No. KLDJ-5-55052-05, "*Feasibility Studies for Projects in Utah, Nevada, and Idaho*".

PROJECT BACKGROUND AND OBJECTIVE

Ward's Greenhouse, Inc. plans to build a 16-acre state-of-the-art greenhouse facility near Oreana, ID in Owyhee County, mainly specializing in growing poinsettias and other flowers. Heating of the facility is planned to be done with geothermal energy. A well existing on the property was completed in 1963, and produces about 1,500 gpm of water at approximately 140°F under artesian conditions. The water well log is attached as Appendix A.

A preliminary engineering report on the greenhouse design concluded that the well could not provide enough heat for the entire greenhouse during peak load, unless the thermal energy could be stored in some fashion. It was therefore theorized that heat could be stored in the massive concrete slab floor prior to the onset of cold weather. A concrete floor is being planned for the facility for use with a flood-floor type irrigation system. Thus, the objective of this study is to determine the feasibility of using the existing geothermal well to store thermal energy in the greenhouse concrete slab floor.

METHOD OF STUDY

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

- Visited the existing Ward's greenhouse facility in Garden Valley, ID and the site near Oreana, ID for the new expansion,
- Obtained the water well log of the existing well and met with staff of the Idaho Department of Water Resources (IDWR) to review water rights,
- Computed hourly heating loads for the proposed greenhouse using typical meteorological year (TMY) data for Boise, ID,
- Constructed a computer model of the radiant floor slab to compare heating alternatives.

GREENHOUSE HEATING LOAD CALCULATIONS

Hourly heating loads were calculated for the proposed greenhouse using typical meteorological year (TMY) data for Boise, ID. Heat transfer processes included in the calculations were: *solar heat gain, conduction through the structure, convection, infiltration, and ground conduction*. Greenhouse construction was assumed to be an inflated double polyethylene film with gables and sidewalls of glazed twin-wall polycarbonate. An interior set-point temperature of 72°F was assumed.

Hourly outdoor air temperatures for a typical year in Boise, ID are shown in Figure 1. According to ASHRAE (2005), the heating design temperature at the 99.6 percentile is 2°F, which means that, over the long term, lower air temperatures could occur about 0.4% of the time (or about 35 hours).

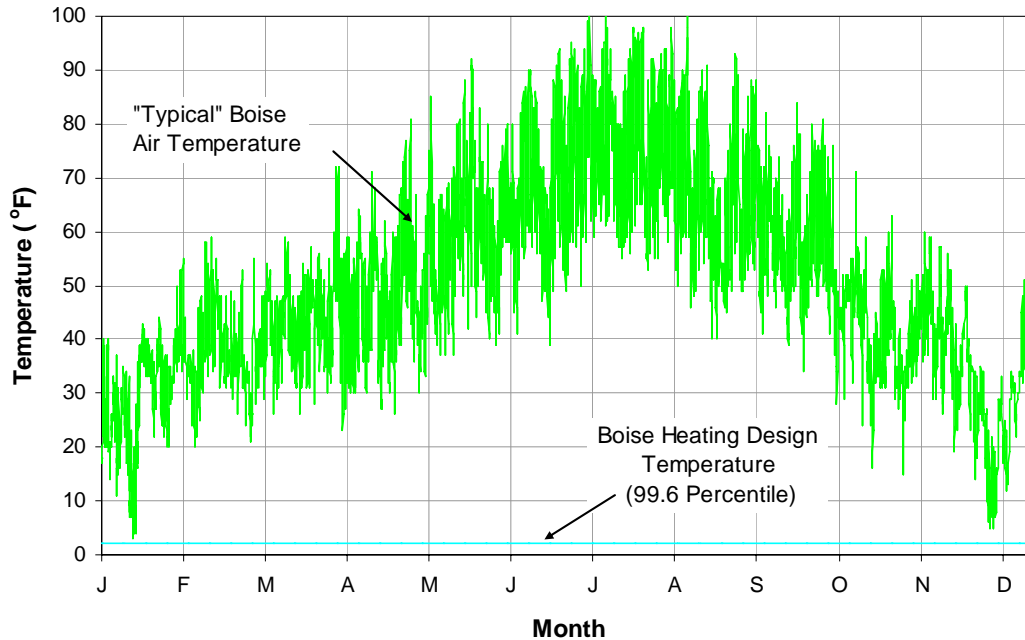


Figure 1. Outdoor air temperatures for a “typical” year in Boise, ID.

Based on heating load calculations, the peak load of the greenhouse is approximately **76 Btu/hr/ft²** of floor space during a typical year.

RADIANT FLOOR COMPUTER SIMULATION

In order to properly analyze the radiant floor heating options, we used a detailed computer model developed for TRNSYS (acronym for *transient systems simulation software*). Model documentation is described in a paper published in the Journal of Solar Energy Engineering by Chiasson et al. (2000). The advantage of such a computer model is that once developed, the heating performance of various scenarios can be examined. A model of this type is helpful in assessing situations like this where several interacting variables are involved that are difficult to process with manual calculations.

In summary, the computer model performs an hourly energy balance on a horizontal cross-section with embedded tubing. The top surface heat fluxes are due to environmental heat transfer processes. Conduction heat transfer through the concrete slab is calculated with a finite difference method. Hourly fluid temperatures from the slab are then determined by an energy balance on the fluid. Input data to the model, in addition to interior temperature data, include cross-section geometry and thermal properties of the slab and subsoil. The model was originally

developed to handle rain and snow in an outdoor environment, so the flood floor irrigation system was simulated as rain. The flood-floor irrigation system has a cooling effect on the floor, and thus represents an additional heating load.

Input data to the computer model included 3/4-in. nominal diameter polyethylene tubing at 12-in. spacing and 4-in. depth of the center-line of the tubing below the floor surface. A 4-inch concrete slab was assumed, underlain by compacted sand fill and an insulating barrier. A total flow rate of 1,500 gpm from the well was simulated at a temperature of 140°F from the well head.

Radiant floor systems are typically designed for a maximum temperature drop in the heating fluid of 20°F so that large temperature gradients do not occur across the floor and cause uneven floor temperatures. This upper limit of temperature drop essentially limits the amount of heat transfer if the geothermal fluid were to be piped directly through the floor. One way around this is to use a plate-type heat exchanger and separate the radiant floor loop from the geothermal water as shown in Figure 2. In this design concept, flow rates through the floor can be increased to match heat lost through the geothermal side while maintaining acceptable temperatures drops across the working fluid in the radiant floor and allowing a much greater temperature drop in the geothermal fluid. This was the design simulated in the computer model.

Results of the computer model simulation show that the concrete radiant floor system can handle a peak load of **41.5 Btu/hr/ft²**, or about 55% of the peak load during a typical weather year. System temperatures and flow rates are shown in Figure 2. The average surface temperature of the slab under this condition is 80.7°F.

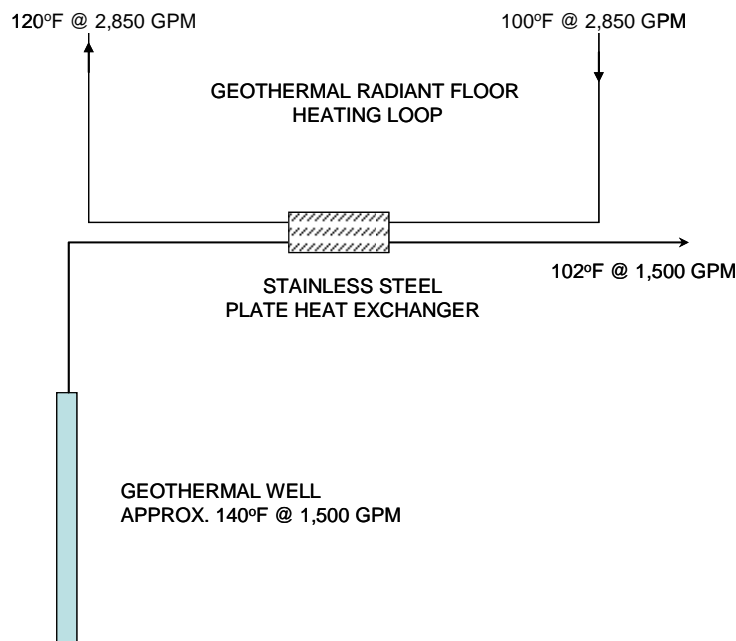


Figure 2. *Schematic of the simulated system.*

Although the radiant floor system can only handle 55% of the peak load, it handles 94% of the total annual load as shown in Figure 3, which is a graph of hourly heating loads over the year for a typical weather year. The annual cost of heating the greenhouse with natural gas at 80% efficiency and \$1.20/therm would amount to \$1.45 million. Therefore, the geothermal system would save about \$1.37 million.

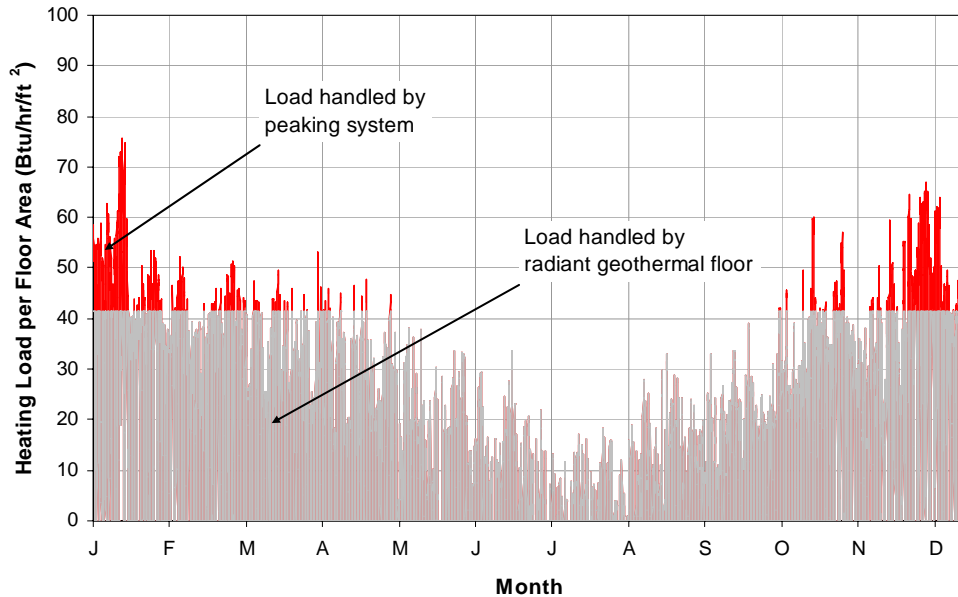


Figure 3. Hourly loads handled by the radiant floor geothermal system.

SUPPLEMENTAL HEATING SYSTEM AND OTHER RADIANT FLOOR OPTIONS

In colder climates with sunny winter days characteristic of southern Idaho, it is typically difficult to heat an entire greenhouse with a radiant floor system. Temperature control of the space is usually challenging due to the “warm-up” and “cool-down” times required for the thermal mass of the floor. Therefore, it is more desirable to design a baseload and peaking system, regardless of whether the well could supply enough heat to the radiant floor to heat the entire greenhouse.

An energy efficient means to provide peak heating would be to cascade geothermal water from the radiant floor to water-source geothermal heat pumps, which would supply a forced-air system. As seen in Figure 2, the temperature of the geothermal water exiting the heat exchanger still has plenty of thermal energy content that could be extracted by a heat pump prior to disposal of the water. The heat pumps could either be a number of water-to-air heat pumps or water-to-water heat pumps that supply fan coils. During a typical weather year, additional annual electrical costs to operate water-source heat pumps would amount to about \$22,500. A natural gas peaking system at 80% efficiency and \$1.20/therm would have annual energy costs of about \$84,000. Thus, the use of a heat pump peaking system would result in annual energy savings of

about \$61,500.

Another option for radiant floor heating of the proposed greenhouse would be to lay the tubing in a sand bedding, covered in pea gravel or some other type of material for the floor surface. We simulated this scenario also, and there is some performance tradeoff between eliminating the flood-floor irrigation system and replacing the concrete with a lower thermal conductivity material (i.e. sand and gravel). The fraction of peak load handled by this option decreases slightly to 50%, and the annual load fraction decreases slightly to 91%. This option still results in an attractive annual savings of \$1.32 million while saving the capital cost of a concrete floor. Therefore, the decision to use a concrete floor should be dictated by desired irrigation methods and not necessarily heating methods.

MANAGEMENT OF GEOTHERMAL WATER

During the course of the Geo-Heat Center's site visit, two issues arose regarding groundwater management: (1) water rights and (2) geothermal water disposal.

The existing water right for groundwater use at the Ward property (included as Appendix B) could not be used for geothermal heating as is because the beneficial use of groundwater for which the existing water right was obtained is for irrigation from April 1 to October 31. The greatest water demand for greenhouse heating would obviously be in the winter, so a new water right would be needed. Fortunately, the Ward property is not in any groundwater management area, and a new water right could be obtained.

The second issue regarding management of geothermal water is disposal. Currently, groundwater is used in the summer where it is directed from the well to a holding pond where it cools prior to being used for irrigation purposes. However, in the winter when heating demands are the greatest, there are no uses of the groundwater for irrigation at the quantity being used (i.e. 1,500 gpm) for greenhouse heating. This means that there are two disposal options: (a) discharge to the ponds for eventual disposal to the Snake River and/or (b) an injection well. Given the quantity of groundwater demands for greenhouse heating over the heating season and possible depletion of groundwater resources, it would be best management practice to inject the groundwater back to the aquifer through an injection well. The cost of an injection well drilled to the same depth as the production well (2,900 ft) would be on the order of \$500,000.

CONCLUDING SUMMARY AND RECOMMENDATIONS

This report has examined the use of a geothermal well coupled to a radiant floor system for greenhouse heating at the planned expansion of Ward's Greenhouse, Inc. near Oreana, ID. Eventual plans call for construction of a 16-acre state-of-the-art greenhouse facility, mainly specializing in poinsettias and other flowers. Some specific conclusions of this study are as follows:

- Heating load calculations show the peak load of the greenhouse to be approximately 76 Btu/hr/ft² of floor space during a typical weather year.
- With an isolation heat exchanger between the geothermal water and a radiant floor

heating system, flow rates through the radiant floor system can be adjusted to keep acceptable temperature drops across the floor while extracting an optimum amount of heat from the geothermal water.

- Computer model simulation shows that concrete radiant floor system can handle a peak load of 41.5 Btu/hr/ft², or about 55% of the total greenhouse peak load during a typical weather year.
- While a concrete radiant floor heating system only handles 55% of the peak load, it is capable of handling 94% of the total annual load. With the full 16-acre expansion, use of geothermal energy for heating results in an annual savings of \$1.37 million.
- Additional computer model simulations show comparable heating performance with a compacted sand radiant floor heating system with no flood-floor irrigation system. Relative to a concrete floor radiant heating system with flood-floor irrigation, the fraction of peak load handled by the sand floor decreases slightly to 50%, and the annual load fraction decreases slightly to 91%. This option still results in an attractive annual savings of \$1.32 million while saving the capital cost of a concrete floor.
- An energy efficient means of providing peak heating would be to cascade the geothermal water from the radiant floor to water-source geothermal heat pumps, which would supply a forced-air system. The use of a heat pump peaking system would result in annual energy savings of about \$61,500 over a natural gas peaking system.
- The existing water right for the property where the new expansion is being planned is applicable to summer irrigation, and therefore would not be applicable for winter greenhouse heating. The subject property is not in a groundwater management area, and consequently a new water right could be obtained.
- With year-round extraction of groundwater from the well (i.e. irrigation plus partial heating uses in summer and large heating uses in winter), aquifer depletion can be a concern. Therefore, it would be prudent to plan on a groundwater injection well to replenish the aquifer with groundwater used by the heating system. At the same depth as the production well, the estimated cost of an injection well is on the order of \$500,000.

The Geo-Heat Center recommends some additional study on the hydrogeology of the site to confirm details for the final design of the heating system. First, a “step test” on the well would be a good way to determine well shut-in pressures at various flow rates. Groundwater temperature should also be recorded during this test. This type of test will give better insight into long-term sustainability of well flow rates and temperatures. Second, siting and design of an injection well on the property is recommended. An injection well should be located in the downstream groundwater flow direction. Finally, the Idaho Department of Water Resources (IDWR) should be contacted in order to start the application process for a new water right.

REFERENCES

ASHRAE, 2005. American Society of Heating, Refrigerating, and Air Conditioning Engineers, *Handbook of Fundamentals*.

Chiasson, A., Spitler, J.D., Rees, S.J., and Smith, M.D., 2000. A Model for Simulating the Performance of a Pavement Heating System as a Supplemental Heat Rejecter with Closed-Loop Ground-Source Heat Pump Systems. *Journal of Solar Energy Engineering*, ASME.

APPENDIX A

WATER WELL LOG FOR THE WARD PROPERTY

Ward's Greenhouse, Oreana, Idaho
 Assessment of Greenhouse Heating Options with Geothermal Energy
 Geo-Heat Center, November 2006

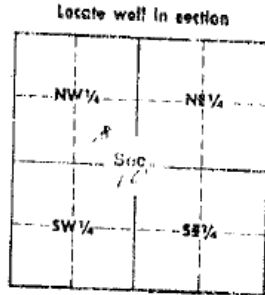
Well Log Form 1
 11-2-76

Department of Agriculture

WELL LOG AND REPORT TO THE STATE RECLAMATION ENGINEER OF IDAHO

SUBMIT WITHIN 30 DAYS AFTER COMPLETION OF WELL: SEE IDAHO STATUTES 42-238

Permit No. _____ Well No. _____ County Owyhee
 Owner Er. Lawrence
 Address Oreana, ID
 Driller Harold Steiner
 Address _____
 Well location SE 1/4 NW 1/4 Sec 10, T 05 N15, R 1 E1W
 Size of drilled hole 12" to 1080' 2100'
2100 2960 Total depth of well 2960'



Give depth to standing water from the ground _____ Water temp. 142 °Fahr.
 Test delivery was _____ g p m or _____ c f s Drawdown was _____ feet Pump? _____ Ball? _____
 Size of pump and motor used to make test _____

Length of time of test _____ hours _____ minutes
 If flowing well, give flow _____ c f s or 1450 g p m and of shut off pressure 77'
 If flowing well, described control works 11" gate valve with T.E.
(TYPE AND SIZE OF VALVE ETC.)
 Water will be used for irrigation & domestic weight of casing per lineal foot _____
 Thickness of casing 9/16" E 3/4" Casing material Steel
(STEEL CONCRETE WOOD ETC.)

Diameter, length and location of casing _____
(CASING 12" IN DIAMETER OR LESS, GIVE INSIDE DIAMETER;
 CASING OVER 12" IN DIAMETER GIVE OUTSIDE DIAMETER)

CASING RECORD

Diam Casing	From Feet	To Feet	Length	Remarks—seals, grouting, etc
12"				
10 3/4"	0	1150	1150	grouted on outside
10"	1050	1890	640	grouted on outside
18 5/8"	1040	2120	320	placed with drilling mud in hole

Number and size of perforations _____ located _____ feet to _____ feet from ground

Date of commencement of well Sept 1962 Date of completion of well Oct 1963
SENW 5 10 55 1E USGS

Ward's Greenhouse, Oreana, Idaho
 Assessment of Greenhouse Heating Options with Geothermal Energy
 Geo-Heat Center, November 2006

SHEET NO. 2

Well Driller *H. H. ...*
 Well Location *...*

WELL LOG

From feet	To feet	Type of Material	Drilling Time		Water-bearing Formation Ass. Yes or No	Casing Perforated Ass. Yes or No
			Hrs	Mins		
		<i>...</i>				
2175	2240	<i>black basalt</i>			<i>yes</i>	
		<i>...</i>				
		<i>...</i>				
		<i>...</i>				
		<i>...</i>				
		<i>...</i>				
		<i>...</i>				
		<i>...</i>				
2866	2900	<i>gray porous rock about 160" water</i>			<i>yes</i>	

A.W. 510 5815

APPENDIX B

EXISTING WATER RIGHT FOR THE WARD PROPERTY

Ward's Greenhouse, Oreana, Idaho
 Assessment of Greenhouse Heating Options with Geothermal Energy
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08/24/2006

IDAHO DEPARTMENT OF WATER RESOURCES

Water Right Report 57-2249A

WATER RIGHT NUMBER: 57-2249A

<u>Owner Type</u>	<u>Name and Address</u>
Current Owner	GREGORY S WARD 15 LOMAN RD GARDEN VALLEY, ID 83622 (208)462-3486
Current Owner	JACK D WARD 15 LOWMAN RD GARDEN VALLEY, ID 83622 (208)462-3486
Current Owner	ORPHA G WARD 15 LOWMAN RD GARDEN VALLEY, ID 83622 (208)462-3486
Original Owner	LILLIAN L EVANS , ID
Original Owner	WILLIAM D EVANS 3520 W AMITY MERIDIAN, ID 83642
Directors Report Owner	CAROL P GILBERT 24460 COLLETT RD MURPHY, ID 83650-5069 (208)834-2383
Current Owner	DAVID J WARD 15 LOWMAN RD HC77 BOX 3912 GARDEN VALLEY, ID 83622 (208)462-3486

Priority Date: 03/08/1967

Basis: Decreed

Status: Active

Source Tributary

GROUND WATER

<u>Beneficial Use</u>	<u>From</u> <u>To</u>	<u>Diversion Rate</u>	<u>Annual Volume</u>
IRRIGATION	4/01 to 10/31	2.450 CFS	868.50 AF
	<u>Total Diversion:</u>	2.450 CFS	868.50 AF

Location of Point(s) of Diversion

GROUND WATER SE1/4SE1/4NW1/4 Sec 10, Twp 05S, Rge 01E, B M
 OWYHEE County

Place of Use

IRRIGATION

Twp Rge Sec | NE | NW | SW | SE |

IDAHO DEPARTMENT OF WATER RESOURCES

Water Right Report 57-2249A

	NE	NW	SW	SE	NE	NW	SW	SE	NE	NW	SW	SE	NE	NW	SW	SE	Totals
05S 01E 9	37 0			29 0									20 0			37 0	123 0
05S 01E 10					24 0	32 0	36 0	5 0	2 0	39 0	23 0						161 0

Total Acres: 284

Conditions of Approval:

- 1 C18 THIS PARTIAL DECREE IS SUBJECT TO SUCH GENERAL PROVISIONS NECESSARY FOR THE DEFINITION OF THE RIGHTS OR FOR THE EFFICIENT ADMINISTRATION OF THE WATER RIGHTS AS MAY BE ULTIMATELY DETERMINED BY THE COURT AT A POINT IN TIME NO LATER THAN THE ENTRY OF A FINAL UNIFIED DECREE SECTION 42-1412(6), IDAHO CODE
- 2 THIS RIGHT IS LIMITED TO THE IRRIGATION OF 233.0 ACRES WITHIN THE PLACE OF USE DESCRIBED ABOVE IN A SINGLE IRRIGATION SEASON
- 3 C05 RIGHT INCLUDES ACCOMPLISHED CHANGE IN PLACE OF USE PURSUANT TO SECTION 42-1425, IDAHO CODE
- 4 THE USE OF WATER FOR IRRIGATION UNDER THIS RIGHT MAY BEGIN AS EARLY AS MARCH 1 AND MAY CONTINUE TO AS LATE AS NOVEMBER 15, PROVIDED OTHER ELEMENTS OF THE RIGHT ARE NOT EXCEEDED. THE USE OF WATER BEFORE APRIL 1 AND AFTER OCTOBER 31 UNDER THIS REMARK IS SUBORDINATE TO ALL WATER RIGHTS HAVING NO SUBORDINATED EARLY OR LATE IRRIGATION USE AND A PRIORITY DATE EARLIER THAN THE DATE A PARTIAL DECREE IS ENTERED FOR THIS RIGHT
- 5 WATER TEMPERATURE MEASURED AT 128 0 DEGREES F.

Remarks:

Comments:

- 1 MCCARTHY 1/29/1992 COPIED FROM REMARKS
 Comment: NOT TO EXCEED 1395 AF/SEASON FROM ALL SOURCES
- 2 SCHULTZ 8/12/1992 NOTICE OF ERROR (NOE)
 Comment: RECEIVED NOE FROM DONALD BARNHILL (LEASING PROPERTY) 8/11/92. CHANGED NOE FLAG FROM BLANK TO A CLAIM VERIFIED 7/17/92. DID NOT REVERIFY ANY PART OF CLAIM
- 3 SSHERMAN 8/10/1994 NOTICE OF APPEARANCE
 Comment: NON-DATE STAMPED NOA REC'D, SIMMS & STEIN REPRESENTING CAROL GILBERT

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IDAHO DEPARTMENT OF WATER RESOURCES
Water Right Report 57-2249A

Dates and Other Information:

Licensed Date:
Decreed Date: 10/25/2002
Enlargement Use Priority Date:
Enlargement Statute Priority Date:
State or Federal: S
Owner Name Connector: AND
Water District Number:
Generic Max Rate Per Acre:
Generic Max Volume Per Acre:
Decree Defendant:
Decree Plaintiff:
Civil Case Number: 39576
Judicial District: FIFTH
Swan Falls Trust or Nontrust:
Swan Falls Dismissed:
DLE Act Number:
Carey Act Number:
Mitigation Plan: False

Combined Use Limits:

<u>Rate</u>	<u>Volume</u>	<u>Acres</u>
		306

Combined Water Rights: 57-108A , 57-85A , 57-87A , 57-100A , 57-102A ,
57-112A , 57-114A , 57-115A , 57-121A , 57-135A , 57-147A , 57-162A ,
57-2249A

Water Supply Bank: