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).

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.](image-url)
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
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


APPENDIX A

WATER WELL LOG FOR THE WARD PROPERTY
WELL LOG AND REPORT TO THE
STATE RECLAMATION ENGINEER OF IDAHO

SIGHT WITHIN 30 DAYS AFTER COMPLETION OF WELL. SEE IDAHO STATUTES 42-228

<table>
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<th>Well No.</th>
<th>County</th>
<th>Owner</th>
<th>Address</th>
<th>Driller</th>
<th>Address</th>
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<tr>
<td></td>
<td></td>
<td>Owyhee</td>
<td></td>
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<th>lon.</th>
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<th>R</th>
<th>sec</th>
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<td>05</td>
<td>1</td>
<td>05</td>
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<th>Size of Drilled Hole</th>
<th>1200 ft</th>
<th>2100 ft</th>
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<tr>
<td>Total depth of well</td>
<td>2960</td>
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</tr>
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<table>
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<tr>
<th>Give depth to standing water from the ground</th>
<th>Water temp</th>
<th>Actual</th>
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<tr>
<td></td>
<td>142</td>
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<table>
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<tr>
<th>Test delivery was</th>
<th>gpm or cfs</th>
<th>Drawdown was</th>
<th>feet</th>
<th>Pump?</th>
<th>No</th>
<th>112</th>
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<table>
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<th>Size of pump and motor used to make test</th>
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<table>
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<tr>
<th>Length of time of test</th>
<th>hours</th>
<th>minutes</th>
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<tr>
<td></td>
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<td></td>
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<tr>
<th>If flowing, well, give flow</th>
<th>cfs</th>
<th>1458</th>
<th>p.m</th>
<th>and shut off pressure</th>
<th>72</th>
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<table>
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<tr>
<th>If flowing well, describe control works</th>
<th>11&quot; gate valve with T.E.</th>
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</thead>
</table>

<table>
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<tr>
<th>Water will be used for</th>
<th>Irrigation</th>
<th>14400</th>
<th>gpm of casing per linear foot</th>
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</table>

<table>
<thead>
<tr>
<th>Thickness of casing</th>
<th>9.0</th>
<th>Steel</th>
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</table>

<table>
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<th>Casing material</th>
<th>STEEL</th>
</tr>
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<table>
<thead>
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<th>Diameter, length and location of casing</th>
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<th>Diameter</th>
<th>Casing</th>
<th>From</th>
<th>To</th>
<th>Length</th>
<th>Remarks</th>
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<td>12</td>
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<td>1150</td>
<td>1150</td>
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</tr>
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<td>8.5</td>
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<td>1060</td>
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<td>610</td>
<td>placed with grouting on hole</td>
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<td>8.5</td>
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<td>1840</td>
<td>210</td>
<td>320</td>
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<table>
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<table>
<thead>
<tr>
<th>Number and size of perforations</th>
<th>located</th>
<th>feet to</th>
<th>foot from ground</th>
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| Sen W 5 | 10 | 55 | EE | USGS |

9
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<tr>
<th>From</th>
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<th>Drilling Time</th>
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<td>2240</td>
<td>black basalt</td>
<td></td>
</tr>
<tr>
<td>2866</td>
<td>2900</td>
<td>gray powdery rock</td>
<td>yes</td>
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</tbody>
</table>

Note: 'yes' indicates presence of water.
APPENDIX B

EXISTING WATER RIGHT FOR THE WARD PROPERTY
Ward's Greenhouse, Oreana, Idaho  
Assessment of Greenhouse Heating Options with Geothermal Energy  
Geo-Heat Center, November 2006

IDaho Department of Water Resources  
Water Right Report 57-2249A

WATER RIGHT NUMBER:  57-2249A

Owner Type          Name and Address
Current Owner       GREGORY S WARD  
15 LOMAN RD  
GARDEN VALLEY, ID  83622  
(208)462-3486

Current Owner       JACK D WARD  
15 LOMAN RD  
GARDEN VALLEY, ID  83622  
(208)462-3486

Current Owner       ORPHA G WARD  
15 LOMAN 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 LOMAN RD  
HC77 BOX 3912  
GARDEN VALLEY, ID  83622  
(208)462-3486

Priority Date:       03/04/1907

Basis:              Decreed

Status:             Active

Source              Tributary

GROUND WATER

Beneficial Use       From     To    Diversion Rate    Annual Volume
IRRIGATION          4/01 to  10/31    2.450 CFS    868.50 AF

Total Diversion:    2.450 CFS    868.50 AF

Location of Point(s) of Diversion
GROUND WATER        SE1/4SE1/4NW1/4  Sec 10,  Twp 05S,  Rgn 01E, B M  
CWYHEE County

Place of Use
IRRIGATION

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<tr>
<th>Twp Rge Sec</th>
<th>NE</th>
<th>NW</th>
<th>SW</th>
<th>SE</th>
</tr>
</thead>
</table>
IDaho Department of water resources

Water Right Report 57-2249A

05S 01E 9 | NE | NW | SW | SE | NE | NW | SW | SE | NE | NW | SW | SE | Total
| 37.0 | 29.0 | | | | | | | | | 123.0

05S 01E 10 | | 24.0 | 32.0 | 36.0 | 16.0 | 2.0 | 39.0 | 23.0 | | | 131.0

Total Acres: 284

Conditions of Approval:

1. 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 42-141(2)(b), 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. This 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 7/11/92; did not reverify any part of claim.

Comment: Non-date stamped NOA Recd, Simms & Stein representing Carol Gilbert.
Dates and Other Information:
- Licensed Date: 10/25/2002
- Decreed Date: 

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: 30575
Judicial District: FIFTH
Swan Falls Trust or Nontrust:
Swan Falls Dismissed:
DLE Act Number:
Carey Act Number:
Mitigation Plan: False

Combined Use Limits:

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Water Supply Rank: