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EXECUTIVE SUMMARY

WYOMING WATER DEVELOPMENT COMMISSION

HEART MOUNTAIN IRRIGATION DISTRICT RETURN FLOW LEVEL I STUDY

May 2006

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EXECUTIVE SUMMARY

HEART MOUNTAIN IRRIGATION DISTRICT
RETURN FLOW
LEVEL I STUDY

Prepared for:

Wyoming Water Development Commission
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May 2006

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EXECUTIVE SUMMARY

This Level I study was conducted for the purpose of quantifying and characterizing water uses within the Heart Mountain Irrigation District (HMID), with particular focus on those return flows leaving the District and potentially re-diverted and used by downstream water users. The primary objective of this Level I study is to quantify the location, rate, and timing of return flows.

To field-verify the modeled return flows, two District drainage ways, namely Alkali and Iron Creeks, were measured and monitored during the 2005 irrigation season. These flow data were used to calibrate the return flow model so as to most accurately serve as a prediction tool for the District.

This study was also requested to provide a review of the District’s flow measurement program and recommend modifications to the current flow measurement system (and new measurement locations as warranted) so that return flows can be monitored and recorded in the future. Included in this study is an evaluation of the District’s existing flow measurement structures and a plan for upgrading measurement capabilities.

A. PROJECT BACKGROUND

The Heart Mountain Irrigation District is located in the vicinity of the City of Cody and the City of Powell in Park County, Wyoming. The Heart Mountain Irrigation District is one of four irrigation districts which comprise the Bureau of Reclamation’s Shoshone Project. The Heart Mountain Canal diverts from Buffalo Bill Reservoir and is capable of irrigating a total service area of 31,200 acres.

Water from Buffalo Bill Reservoir is delivered to the District via tunnels and conduits to the main portion of the Heart Mountain canal which daylights from a tunnel about three miles west of the City of Cody. The District generally delivers water during the months April through October each year. The District delivers water to 448 individual farm units (some of which are actually homeowners associations comprised of many small residential lots). Typical crops in the District service area include sugar beets, dry beans, brewing barley, alfalfa, and urban landscapes.

Water users place water delivery orders with the District staff, and headgates are adjusted daily as needed to fulfill orders. All water deliveries are monitored by staff and then recorded into a Microsoft Access database. The database structure and user interface was designed by RimRoc Consulting and was first implemented in 1999. In addition to individual water orders, the District Manager records system flows into a summary spreadsheet developed by the Bureau of Reclamation. This level of record keeping and flow measurement in the District was critical to the development of the return flow model.

The District also maintains and operates an extensive drainage system within its service area. Many of the ephemeral stream systems draining off the base of Heart Mountain become live streams once they enter the District’s service area. Both open and closed drain system flows contribute to the now year-round flow of these streams. Some of these return flows are directly diverted by downstream irrigation systems, principally the Garland Irrigation District which lies between the Heart Mountain service area and the
Shoshone River. Other return flows may be manifested at the Shoshone River directly, via either surface or ground water flow regimens, or in creeks tributary to the Shoshone River.

B. MODEL DEVELOPMENT

Our modeling of the District’s overall water usage was patterned after a Bureau of Reclamation schematic that details all of the hydrologic elements presented in western irrigation districts. This schematic is reproduced in Figure E.1.

Our model is spreadsheet-based, with each of the three major components (District Distribution System, Farmed Lands System, and District Drainage System) represented as separate worksheets within the overall model. The Farmed Lands portion of the model was based in part on crop water requirements analysis included in the Colorado State University Integrated Decision Support Group’s Consumptive Use model (IDSCU).

Our model encompassed the 2005 water year only and operates on a monthly time step. We determined that a detailed investigation of a single year of operation was consistent with the fact that water flow observations would be collected during 2005 only.

The following variables were quantified for the three major model components:

District Distribution System
- Upslope drain water
- Precipitation
- Evaporation
- Riparian Evapotranspiration
- Direct surface water deliveries
- Farm deliveries
- Seepage
- Spillage
- Drainage water reuse

Farmed Lands System
- Precipitation
- Total crop evapotranspiration
- Evaporation
- Riparian evapotranspiration
- Tail water
- Tile water
- Drain water reuse
- Seepage
- Deep percolation

District Drainage System
- Upslope drain water
- Precipitation
- Riparian evapotranspiration
Figure E.1 District Water Balance Schematic

DATE: 05/2006
Aqua Engineering, Inc.

SHEET:

Figure E.1 District Water Balance Schematic

DESIGNED:

DRAWN:

CHECKED:

REVISION:
• (surface water and ground water returns from Distribution and Farmed Lands model components)

C. MODEL CALIBRATION

Some model elements could not be directly measured or even reliably estimated. We used these elements as variables which, when properly adjusted, resulted in modeled return flows that closely matched field-observed flows. These elements included the allocation between surface and ground water return flows and the lagged discharge of ground water return flows.

Allocation of Surface and Ground Water (Seepage) Return Flows

In the Farm Lands model component, all water not consumed by the crop or not attributable to evaporation of standing water was assumed to manifest as tributary return flow. A portion of the return flow drains off the end of the field as tail water and manifests in the stream system immediately. The remainder drains into the soil profile. A saturated soil profile will eventually drain to nearby drainage ways or creeks.

As we exercised and calibrated the model, we found that the model most closely matched the observed field conditions when 60% of the return flows were surface returns and 40% of the return flow moved into the ground water system. For those drainages south of Ralston Flats, the model was best calibrated when 30% of the return flows were surface runoff and 70% were ground water return flows.

Lagged Discharge of Ground Water (Seepage) Return Flows

Return flows that migrate into the deeper soil profiles will be considerably delayed in their return to the stream system. We assumed that return flows input to the ground water in a given month would eventually return to the stream over a subsequent twelve month period. The distribution of lagged flows was estimated based on our previous experience with stream depletion modeling.

We found that the model was best calibrated when the Ralston Flats area ground water returns peaked in the two months immediately following the ground water input. Other drainage systems were best calibrated to a slower response that peaks about four months following the ground water input.

Calibration Process

We were pleased with the already close match between modeled flows and observed flows prior to the calibration process. Relatively small adjustments were made during the calibration process, providing resultant values within the expected range of values.

The ease with which the model was calibrated is directly attributable to the careful and comprehensive program of flow measurement and recordkeeping currently accomplished by District staff. Absent the detailed records provided by the District, we would have to assume a host of additional “adjusting” variables. This would have made the entire modeling and calibration process much more difficult and in the end, far less reliable.
D. MODEL RESULTS

For the 203,963 acre-feet diverted into the Heart Mountain Irrigation District system during 2005, we have estimated that flows are attributable to the following water use categories shown in Figure E.2.

![District Water Balance Breakdown](image)

**Figure E.2** Modeled distribution of Heart Mountain Irrigation District outflows

Crop evapotranspiration occurred on 26,459 acres during 2005 at a rate of 1.39 acre-feet per acre. Additional consumptive use associated with riparian evapotranspiration totaled 1,114 acre-feet.

No model will be able to accurately account for every acre-foot diverted into the system. Crop evapotranspiration calculations and flow measurement activities all have associated error. In our model, we were unable to account for 2,627 acre-feet, or 1.3% of the system inflows.

Of the 203,963 acre-feet delivered to the District, 158,579 acre-feet went back to the hydrologic system in the form of return flows. Figure E.3 shows how the total drainage outflow is allocated to the various drainages within the system.

The contribution to the Garland Canal includes not only irrigation return flows and end spills, but also water directly diverted to Garland at the Little Yellowtail structure and at North Alkali headgate.

"Delayed returns" represents return flows from 2005 that will carryover into 2006.
Return Flow Distribution by Drainage

Figure E.3 Modeled return flows distributed according to drainage area

E. FLOW MEASUREMENT AND OBSERVATIONS

Flow measurements were collected periodically as a means of verifying our model results. After our field investigations, we determined that flows in two creeks warranted detailed flow measurement. Alkali Creek was of interest due to the size of the "watershed" and the amount of flow involved. Iron Creek discharges directly into the Garland Canal, and is also representative of many of the small, narrow drainages within the District.

The StreamPro ADCP unit, manufactured by Teledyne RD Instruments (San Diego, CA) was utilized in this project to measure flows. The StreamPro is best used to measure velocity and discharge in shallow streams of less than 10 feet in depth. The overall calculated flow measurement is estimated to be ± 2% when the recommended field procedures are followed as they were here.

Flow measurements using the ADCP unit were conducted on two dates during the irrigation season on Alkali Creek and three dates on Iron Creek. Additionally, a staff gage was placed at each measurement site to compare gage height to observed flows measured by the ADCP unit. HMID staff recorded the gage height at both measurement locations more or less weekly between the months of August and November.

Figure E.4 shows the two flow measurements and gage height readings for Alkali Creek. Figure E.5 shows the estimated flow measurements (average monthly) in Alkali Creek compared to model flows. The estimated flow measurements were based on the relationship between ADCP measured flow in September and gage height readings. This relationship is not likely linear, but nonetheless it gives us some indication of order of magnitude flows expected in Alkali Creek between August and November. Figures E.6 and E.7 show the same figures, respectively, for Iron Creek.
**Figure E.4** Flow measurement for Alkali Creek

**Figure E.5** Monthly estimated flow vs. modeled flow for Alkali Creek
**Iron Creek Flows**

**Figure E.6** Flow measurement for Iron Creek

**Monthly Flow Comparison for Iron Creek**

**Figure E.7** Monthly estimated flow vs. modeled flow for Iron Creek

Heart Mountain Irrigation District

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F. FLOW MEASUREMENT SITE DESIGNS

The Heart Mountain Irrigation District may elect to measure surface return flows at key locations on an ongoing basis. We evaluated the field conditions at both the Alkali Creek site and the Iron Creek site to develop conceptual designs for flow measurement structures at these locations. The Iron Creek design is intended to be suitable for other locations within the District at which flow measurement may be desired. These concept designs are included in the report.

Cost estimates and an economic analysis are also presented for these flow measurement site designs in the report and appendix.

G. WATER QUALITY ANALYSIS

The primary purpose for the water quality section of this study was to establish a base water quality profile for the District. Water quality samples were collected at several locations in the District throughout the study period. These water quality results were evaluated as they relate specifically to the suitability of the water for irrigated agriculture. In addition, water quality tests were compared to historical water quality tests from the District that were taken in the late 1940’s and early 1950’s.

Because the purpose of the Heart Mountain Canal system is to supply irrigation water to its customers, we analyzed only the constituents tested that have the potential to impact the suitability of water for irrigation. Constituents of concern to irrigated agriculture include:

- Chloride
- Nitrogen
- Sodium ion
- Sodium and Calcium ratio
- Electrical Conductivity / Total Dissolved Solids
- pH

The only constituents that exceed “recommended guidelines for irrigation” are nitrogen, electrical conductivity, and pH. These levels are not of major concern because they only slightly exceed water quality guidelines for irrigation. In addition, the guidelines assume that water quality levels will have absolutely no effect on the yield or production of crops. Values higher than the guideline might have some effect, but they are expected to be slight up until some threshold level where severe crop damage can occur.

H. OPERATING PLANS

We have constructed an Excel-based worksheet that can be installed into the District’s routine monthly spreadsheet accounting. This worksheet will extract tabulated flows from the existing spreadsheet accounting and then compute estimated flows in the principal drainages within the system. This is a simplified approach the District can implement and use to monitor return flows within the District.

An understanding of the magnitude and location of return flows throughout the District can also serve as a drought management or response tool. During times of water shortage, it may be necessary to conserve what water is available in order to make
deliveries to water users. With a comprehensive understanding of where water spills and seepage occur, the District can better and more easily determine what measures they should take, and at what priority level, to more efficiently use water. If the District is interested in implementing projects or making operational changes that will increase resiliency to drought, they should start by examining where the biggest losses are within the system. Understanding this will help prioritize where project monies are best spent.

I. RECOMMENDATIONS

Specific recommendations resulting from this Level I study follow:

1. The District should continue to leverage ArcView GIS technologies to facilitate future return flow analyses. The District should tabulate county parcel identification numbers in its database to facilitate easy linking between the District’s databases and the County’s parcel ownership database.

2. The District should request that Garland Canal measure and record flows diverted from the North Alkali headgate located northwest of their hydropower facility.

3. A spreadsheet predictive tool has been developed which the District can use to roughly estimate future return flows on an ongoing basis.

4. If the District should choose to construct additional flow measurement stations, application should be made to the WWDC for a Level III study to fund final design and construction.

5. The Ralston Chute is in need of rehabilitation/repair. Additionally or alternatively, a supplemental lateral could be constructed to relieve demand on the chute structure. Application should be made to the WWDC for a Level II study to further develop design alternatives. See Appendix D for additional information.

6. Our model suggests that distribution system losses are 47% of total canal inflows. System end spills are approximately 24% of total canal inflows. A determination of crop consumptive use for lands irrigated in the District amounts to approximately 34% of the total amount of water ordered by District landowners. The District should continue to evaluate the ultimate destination and use of water diversions. In the event of droughts or water shortage, it may be possible to alter management or operations in the canal so as to further stretch water supplies.