

Environmental Assessment & Public Notice for Public Comment

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**Environmental Assessment &
Public Notice for Public
Comment**

NOTICE AREA

Application No. **41G 30165036**

Regional Office # **10**

Applicant's Name **Treasured Mountains Holdings LLC**

Indian Reservation ☐ Yes ☒ No If yes, Reservation

Irrigation District ☐ Yes ☒ No If yes, District

Specialist **Lyra Reynolds**

Date **10/20/2025**

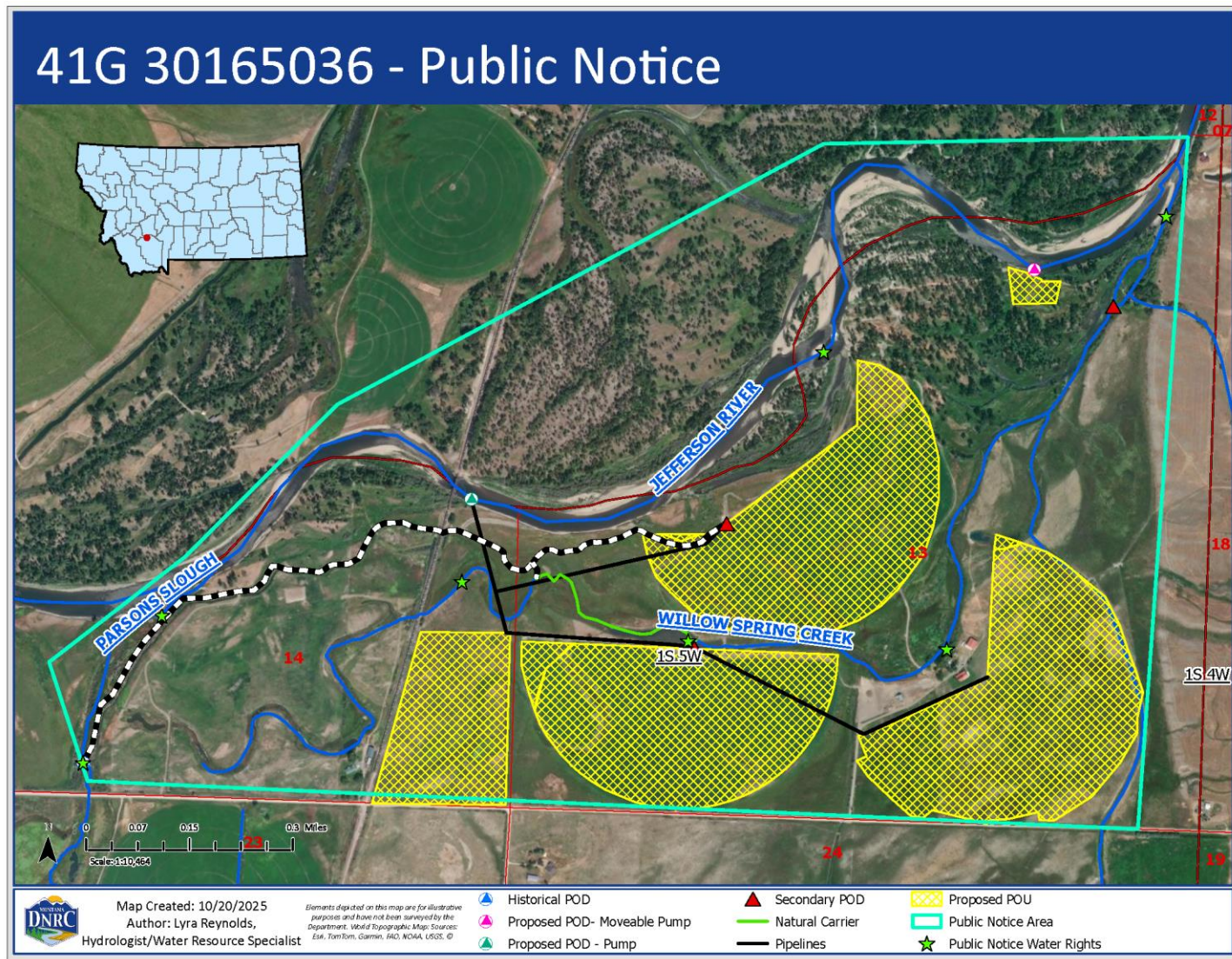


Figure 1. Map of Public Notice – Public Comment Area for Change Application No. 41G 30165036. The public notice area is marked with the green polygon; water rights in the polygon were identified for public notice - public comment. See the Remarks Section on the next page for a description of the notice area and which owners were noticed.

Water Right Owner	Water Right # (Basin, ID, and Number)
Applicant: Treasured Mountains Holdings LLC	41G 197111-00
Consultant/Attorney: Andy Brummond, MT FWP	OID 283310
0BZM DEPT OF NATURAL RESOURCES & CONSERVATION	
1BIA BUREAU OF INDIAN AFFAIRS	
1BOR US DEPT OF INTERIOR	
1DSL MONTANA BOARD OF LAND COMMISSIONERS	
1EQC ENVIRONMENTAL QUALITY COUNCIL	
1FWP DEPT OF FISH WILDLIFE & PARKS	
1NWE NORTHWESTERN ENERGY	
1SCH CANYON FERRY PROJECT OFFICE	
1TUL MT TROUT UNLIMITED	
1WQB DEPT OF ENVIRONMENTAL QUALITY	
2FWP DEPT OF FISH WILDLIFE & PARKS	
5FWS US FISH & WILDLIFE SERVICE	
OCCD MADISON CONSERVATION DISTRICT	
MONTANA, STATE OF DEPT OF FISH WILDLIFE AND PARKS	41G 30017486
G&M YAMAMOTO TRUST; FRED HIRSCHY; LYNN HIRSCHY	41G 30143701
DUSTIN LAUGHERY; YVONIE LAUGHERY	41G 2262-00

PUBLISHED IN: Madisonian

REMARKS: The following methodologies were employed to determine an appropriate public notice area:

1. All Bozeman Regional Office public notice standard for Madison County were included in the mailing.
2. The following method was used to identify water rights for public notice:

The notice area for public comment included all water rights in the area of potential adverse effect beginning in the SESESW Section 14, T1S, R5W, Madison County and ending in NENENE Section 13, T1S, R5W, Madison County. The Department considered all water rights on Parsons Slough and the Jefferson River in this reach. The Department also considered all water rights on Willow Spring Creek in the area of potential impact, from SWNESE Section 14, T1S, R5W, Madison County to NENENE Section 13, T1S, R5W, Madison County. A total of 7 water rights exist in the public notice area, as seen in the green polygon in Figure 1. Owners with multiple water rights were only noticed one time. The lowest water right number in the notice area for each owner is listed above. Owners of three water rights were noticed.

**Montana Department of Natural Resources and Conservation
Water Resources Division
Water Rights Bureau**

**ENVIRONMENTAL ASSESSMENT
For Routine Actions with Limited Environmental Impact**

Part I. Proposed Action Description

1. Applicant/Contact name and address:
TREASURED MOUNTAINS HOLDINGS LLC
5653 MONTEREY DRIVE
FRISCO, TX 75034-4076
2. Type of action: Application to Change an Existing Irrigation Water Right No. 41G 30165036 by Treasured Mountains Holdings LLC.
3. Water source name: Parsons Slough
4. Location affected by project: The proposed point of diversions (PODs) and place of use (POU) change will occur in Sections 13 and 14 all in T1S, R5W, Madison County.
5. Narrative summary of the proposed project, purpose, action to be taken, and benefits: Applicant submitted Change Application 41G 30165036 on April 25, 2025, to the Bozeman DNRC Water Resources Office. The Application proposes to add two primary PODs and modify the POU to Statement of Claim 41G 197111-00. The proposed PODs are located downstream of the historical POD in the NENESE Section 14, and SENWNE Section 13, T1S, R5W, Madison County. The proposed PODs are pump sites composed of one stationary pump and one transitory pump that will divert water from the Jefferson River. Water will be conveyed from the proposed PODs to the POU via pipelines, so conveyance losses will decrease. The applicant proposes to retire 91 acres and add 52.9 new acres to the POU for a total of 199.5 irrigated acres in SESE Section 14 and S2, SWNE, SENW, SWNENE, & SENWNE Section 13, all in T1S, R5W, Madison County. The proposed flow rate, diverted volume and conveyance losses will all be lower than the historical amounts. The DNRC shall issue a change authorization if an Applicant proves the criteria in 85-2-402 MCA are met.
6. Agencies consulted during preparation of the Environmental Assessment:
 - Montana Department of Fish, Wildlife & Parks (FWP)- Dewatered Streams Page 3 of 4 [FISHMT :: Waterbody Search](#)
 - Montana Department of Environmental Quality (DEQ)- Clean Water Act Information Center (CWAIC) [Clean Water Act Information Center](#)
 - Montana National Heritage Program (MTNHP)- National Heritage Map Viewer [NHP Generalized Observations](#)

- U.S. Fish & Wildlife Service (USFWS)- National Wetlands Inventory Wetlands Mapper [Web Soil Survey](#)
- Natural Resource Conservation Service (NRCS)- Web Soil Survey (WSS) [National Wetlands Inventory](#)

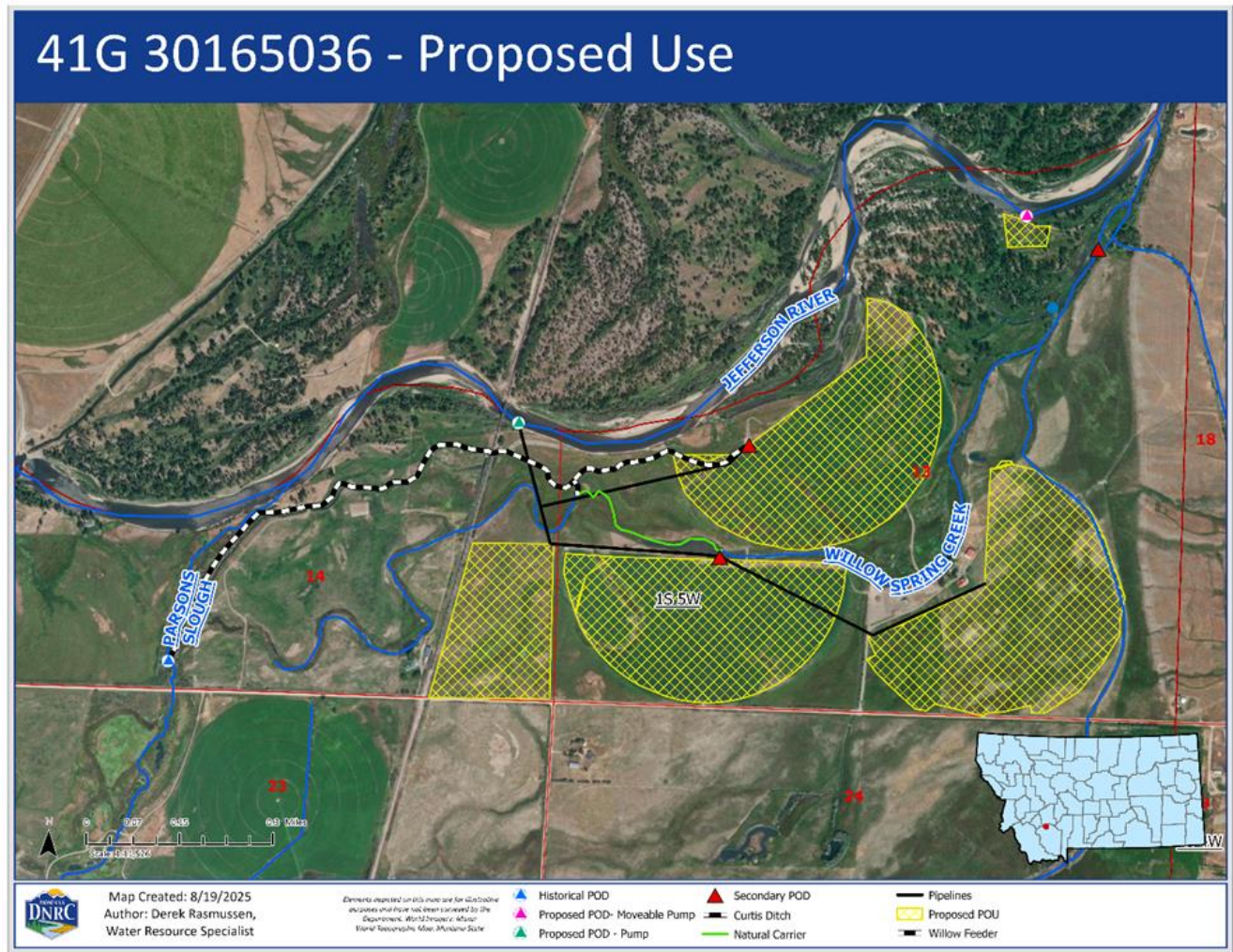


Figure 1. Proposed use for Change Application 41G 30165036

Part II. Environmental Review

1. Environmental Impact Checklist:

PHYSICAL ENVIRONMENT

WATER QUANTITY, QUALITY AND DISTRIBUTION

Water quantity - Assess whether the source of supply is identified as a chronically or periodically dewatered stream by DFWP. Assess whether the proposed use will worsen the already dewatered condition.

Determination: No significant impact.

A September 4, 2025, search of DFWP data does not list Parsons Slough or the Jefferson River as periodically or chronically dewatered. The proposed diverted volume is less than or equal to the historically diverted volume so water quantity in the source will not decrease as a result of the proposed change. Water will continue to be used for irrigation and the consumptive use associated with the fields will be 18.42 AF less than the historical consumed volume. No impact to water quantity is expected as a result of this change.

Water quality - Assess whether the stream is listed as water quality impaired or threatened by DEQ, and whether the proposed project will affect water quality.

Determination: No significant impact.

A September 4, 2025, search of DEQ Impaired Waters 2020 data on the CWAIC did not identify anything for Parsons Slough but identified the Jefferson River, headwaters to the mouth (Missouri River), was assessed for impairments. Primary Contact Recreation use was not assessed, but the search showed the source to be fully supporting Agriculture and Drinking Water use. The search showed that Aquatic Life is not supported. The impairment is suspected to be caused by the following:

- Temperature
 - Crop Production (Irrigated)
 - Hydrostructure Flow Regulation/modification
 - Loss of Riparian Habitat
 - Dam or Impoundment-Aquatic Life
 - Abandoned Mine Lands (Inactive)
 - Streambank Modifications/destabilization
- Flow Regime Modification
 - Crop Production (Irrigated)
 - Dam or Impoundment
 - Hydrostructure Flow Regulation/modification
- Iron Impacts
 - Abandoned Mine Lands (Inactive)
- Lead Impacts
 - Abandoned Mine Lands (Inactive)
- Physical Substrate
 - Crop Production (Irrigated)
 - Hydrostructure Flow Regulation/modification
 - Streambank Modifications/destabilization
- Sedimentation/Siltation
 - Crop Production (Irrigated)

- Abandoned Mine Lands (Inactive)
- Streambank Modifications/destabilization
- Loss of Riparian Habitat
- Natural Sources

The proposed project involves adding the PODs, diverting water by pipelines and changing the POU. The proposed change is not likely to affect water quality because the historical consumptive volume, diverted volume, and return flows are greater than proposed volumes.

Groundwater - Assess if the proposed project impacts ground water quality or supply. If this is a groundwater appropriation, assess if it could impact adjacent surface water flows.

Determination: No significant impact.

The proposed use does not involve a groundwater component.

DIVERSION WORKS - Assess whether the means of diversion, construction and operation of the appropriation works of the proposed project will impact any of the following: channel impacts, flow modifications, barriers, riparian areas, dams, well construction.

Determination: No significant impact.

The proposed project involves a change in PODs and POU. The proposed PODs are approximately 4,000 feet and 1.86 miles downstream of the historical POD on the Jefferson River and will convey water from the pump site by a means of a buried 10" PVC mainline for the stationary pump and a 2" flexible plastic hose for the transitory pump. There will be a small disturbance of native soils during construction, but no significant impact to the channel, flow regime, or riparian areas are expected by using the diversion works after the proposed change.

UNIQUE, ENDANGERED, FRAGILE OR LIMITED ENVIRONMENTAL RESOURCES

Endangered and threatened species - Assess whether the proposed project will impact any threatened or endangered fish, wildlife, plants or aquatic species or any "species of special concern," or create a barrier to the migration or movement of fish or wildlife. For groundwater, assess whether the proposed project, including impacts on adjacent surface flows, would impact any threatened or endangered species or "species of special concern."

Determination: No significant impact identified.

A September 4, 2025, search of the Montana Heritage Programs website for T1S, R5W, Madison County returned the following results:

- 35 Animal Species of Concern: Grizzly Bear, Little Brown Myotis, Long-eared Myotis, Long-legged Myotis, Silver-haired Bat, Wolverine, American Goshawk, American White Pelican, Baird's Sparrow, Black-necked Stilt, Bobolink, Brewer's Sparrow, Brown Creeper, Cassin's Finch, Clark's Nutcracker, Evening Grosbeak, Ferruginous Hawk, Flammulated

Owl, Golden Eagle, Great Blue Heron, Greater Sage-Grouse, Green-tailed Towhee, Harlequin Duck, Long-billed Curlew, Mountain Plover, Pinyon Jay, Solitary Sandpiper, Sprague's Pipit, Thick-billed Longspur, Trumpeter Swan, Veery, Western Toad, Arctic Grayling, Rocky Mountain Cutthroat Trout, Westslope Cutthroat Trout

- 4 Animal Potential Species of Concern: Common Poorwill, Hooded Merganser, Rufous Hummingbird, Great Gray Owl
- 1 Animal Special Status Species: Bald Eagle
- 3 Invertebrate Potential Species of Concern: Mountain Saddlecase Caddisfly, Familiar Bluet, California Darner
- 11 Plant Species of Concern: Nevada Clubbrush, Annual Indian Paintbrush, Dense-leaf Draba, Beardless Wildrye, Parry's Fleabane, Slender Cottongrass, Whitebark Pine, Five-leaf Cinquefoil, Mealy Primrose, Northern Spikemoss, Ute Ladies'-tresses
- 2 Plant Potential Species of Concern: Flat-Topped Broomrape, Austin's Knotweed
- 0 Plant Special Status Species

The proposed change will decrease the flow rate and volume of diverted water from historical values. The proposed project will continue historical irrigation practices. The proposed pump diversion is not expected to create a barrier to the migration or movement of aquatic species. The proposed project is not anticipated to have a significant impact on endangered or threatened species.

Wetlands - *Consult and assess whether the apparent wetland is a functional wetland (according to COE definitions), and whether the wetland resource would be impacted.*

Determination: No significant impact.

A September 4, 2025, search on the National Wetlands Inventory Mappers shows freshwater emergent wetlands, freshwater ponds and riverine in the project area (Figure 2). Water will be diverted in volumes less than the historical use of the water rights proposed to change. No significant impact on wetlands in the area are expected as a result of the proposed change.



September 4, 2025

Wetlands

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond

- Lake
- Other
- Riverine

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

National Wetlands Inventory (NWI)
This page was produced by the NWI mapper

Figure 2. Wetlands surrounding the proposed project area

Ponds - For ponds, consult and assess whether existing wildlife, waterfowl, or fisheries resources would be impacted.

Determination: No significant impact.

No Ponds are involved with this project.

Geology/Soil quality, stability and moisture - Assess whether there will be degradation of soil quality, alteration of soil stability, or moisture content. Assess whether the soils are heavy in salts that could cause saline seep.

Determination: No significant impact.

A September 4, 2025, search of the NRCS Web soil Survey identified surface salinization risk in the project area. The proposed project is not predicted to increase soil salinization risk. The historical POU will be modified by retiring 91 acres and adding 52.9 acres to the proposed POU. Of the 91 acres retired, 59.6 will be from flood irrigation and 31.4 will be wheel line. The 52.9 added acres will be center pivot irrigation. The installation of the pump diversion may cause temporary and minor disturbance to the soil but is not anticipated to have significant impact.

Vegetation cover, quantity and quality/Noxious weeds - Assess impacts to existing vegetative cover. Assess whether the proposed project would result in the establishment or spread of noxious weeds.

Determination: No significant impact.

The disturbance associated with construction of the pumps and pipeline structure in the Jefferson River should be minimal and should not promote the establishment of noxious weeds. Under Montana law, private landowners are responsible for noxious weed control on their property.

Air quality - Assess whether there will be a deterioration of air quality or adverse effects on vegetation due to increased air pollutants.

Determination: No significant impact.

The proposed project will not impact air quality.

Historical and archeological sites - Assess whether there will be degradation of unique archeological or historical sites in the vicinity of the proposed project if it is on State or Federal Lands. If it is not on State or Federal Lands simply state NA-project not located on State or Federal Lands.

Determination: No significant impacts.

The proposed project is not located on State or Federal Lands. The Applicant did not mention significant historical or archeological sites on the property.

Demands on environmental resources of land, water, and energy - Assess any other impacts on environmental resources of land, water and energy not already addressed.

Determination: No significant impact identified.

No impacts on environmental resources of land, water, or energy not already addressed.

HUMAN ENVIRONMENT

Locally adopted environmental plans and goals - Assess whether the proposed project is inconsistent with any locally adopted environmental plans and goals.

Determination: No significant impact identified.

This change application is to add two new PODs and change the POU for continued irrigation use which is recognized beneficial use of water within the State of Montana a (§85-2-102(5), MCA).

Access to and quality of recreational and wilderness activities - Assess whether the proposed project will impact access to or the quality of recreational and wilderness activities.

Determination: No significant impact identified.

The proposed change is located entirely on private property and will not affect access to recreational activities or the quality of recreational and wilderness activities.

Human health - Assess whether the proposed project impacts on human health.

Determination: No significant impact identified.

The project will not impact human health.

Private property - Assess whether there are any government regulatory impacts on private property rights.

Yes___ No_**X**_ If yes, analyze any alternatives considered that could reduce, minimize, or eliminate the regulation of private property rights.

Determination: No significant impact identified.

This project does not impact government regulations on private property rights.

Other human environmental issues - For routine actions of limited environmental impact, the following may be addressed in a checklist fashion.

1. Impacts on:

(a) Cultural uniqueness and diversity? No significant impact identified.

(b) Local and state tax base and tax revenues? No significant impact identified.

(c) Existing land uses? No significant impact identified.

(d) Quantity and distribution of employment? No significant impact identified.

- (e) Distribution and density of population and housing? No significant impact identified.
- (f) Demands for government services? No significant impact identified.
- (g) Industrial and commercial activity? No significant impact identified.
- (h) Utilities? No significant impact identified.
- (i) Transportation? No significant impact identified.
- (j) Safety? No significant impact identified.
- (k) Other appropriate social and economic circumstances? No significant impact identified.

2. Secondary and cumulative impacts on the physical environment and human population:

Secondary Impacts No significant secondary impacts identified.

Cumulative Impacts No significant cumulative impacts identified.

3. Describe any mitigation/stipulation measures: The proposed diversions will be located downstream of the historical POD. Water will be diverted via pump sites and conveyed into the irrigation system via a pipeline. The applicant will not exceed historical diverted volume. For the change authorization to be granted by the DNRC, the Applicant must prove the criteria in §85-2-402 MCA are met.

4. Description and analysis of reasonable alternatives to the proposed action, including the no action alternative, if an alternative is reasonably available and prudent to consider: The “no action” alternative would be to not construct additional points of diversion or change the current POU. The Applicant would continue using the historical POD to divert water from Parsons Slough for irrigation use and the POU would remain unchanged.

PART III. Conclusion

- 1. Preferred Alternative:** The preferred alternative is to grant the change application if the Applicant has proven the criteria of §85-2-402, MCA.
- 2. Comments and Responses:** None at this time
- 3. Finding:** Yes ___ No X Based on the significance criteria evaluated in this EA, is an EIS required?

If an EIS is not required, explain why the EA is the appropriate level of analysis for this proposed action: The EA is the appropriate level of analysis because the proposed project is to add the PODs and change the POU of Claim 41G 197111-00. The Applicant proposes to use the water right for irrigation use and will use a maximum diverted volume of 564.92 AF and up to a

maximum 4.26 CFS flow rate. A total of 91 acres will be retired from the historical POU, and 52.9 acres will be added to the proposed POU for a total of 199.5 acres of irrigation. Irrigation is consistent with state and local plans. None of the identified impacts for any of the alternatives are significant as defined in ARM 36.2.524.

Name of person(s) responsible for preparation of EA:

Name: Derek Rasmussen

Title: Water Resource Specialist

Date: September 5, 2025

Draft Preliminary Determinations

- Draft PD
- Draft PD cover letter
- Updated Draft PD
- Updated Draft PD cover letter
- Any correspondence with the applicant regarding the draft PDs

Draft Preliminary Determinations

**BEFORE THE DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION
OF THE STATE OF MONTANA**

* * * * *

APPLICATION TO CHANGE WATER RIGHT) NO. 41G 30165036 by TREASURED) MOUNTAINS HOLDINGS LLC)	DRAFT PRELIMINARY DETERMINATION TO GRANT CHANGE
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On April 25, 2025, Treasured Mountains Holdings LLC (Applicant) submitted Application to Change Water Right No. 41G 30165036 to change Statement of Claim 41G 197111-00 to the Bozeman Regional Office of the Department of Natural Resources and Conservation (Department or DNRC). The Department published receipt of the application on its website. A preapplication meeting was held between the Department and the Applicant's consultant (Andy Brummond) on December 17, 2024, in which the Applicant designated that the technical analyses for this application would be completed by the Department. The Applicant returned the completed Preapplication Meeting Form on January 29, 2025. The Department delivered the Department-Completed Technical Analyses on March 21, 2025. The Department sent the Applicant a deficiency letter for the application under §85-2-302, Montana Code Annotated (MCA), dated May 15, 2025. The Applicant responded with information dated June 24, 2025. The Application was determined to be correct and complete as of July 23, 2025. An Environmental Assessment for this application was completed on September 18, 2025.

INFORMATION

The Department considered the following information submitted by the Applicant, which is contained in the administrative record.

Application as filed:

- Application for Change of Appropriation Water Right, Form 606
- Attachments:
 - Notice of Filing of Application to Change an Appropriation Right letter from Applicant's Consultant to Shared Ditch Users, dated March 20, 2025
 - Narrative responses for questions 25, 30.A, 31.A, 31.B.I, 40
 - Page 79 of Montana Water Law Handbook by Ted J. Doney, October 1981
 - General Abstracts of Claims 41G 30123892 and 41G 30124720
- Maps:
 - Application #17 Historic Use, map produced by Andy Brummond (undated)

- Application #17 Historic Use by Irrigation Method, map produced by Andy Brummond (undated)
- Application #18 Proposed Use, map produced by Andy Brummond (undated)
- Application #32 System Diagrams: System under normal operation, map produced by Andy Brummond (undated)
- Application #32 System Diagrams: System if Jefferson pump site not operational, map produced by Andy Brummond (undated)
- Application #32 System Diagrams: Sample set up for 100 GPM impact sprinkler shown pumping from Jefferson River, map produced by Andy Brummond (undated)
- Department - completed technical analyses based on information provided in the Preapplication Meeting Form, dated March 21, 2025.

Information Received after Application Filed

- Application 41G 30165036 Deficiency Response, dated June 24, 2025
- Email chain from Andy Brummond to DNRC dated May 20 – June 24, 2025, RE: Deficiency letter for Change Application No. 41G 30165036.

Information within the Department's Possession/Knowledge

- Surface Water Change Technical Analyses Report – Part A, dated March 21, 2025
- Surface Water Change Technical Analyses Report – Part B, dated March 21, 2025
- Surface Water Change Technical Analyses Report – Part A Notice of Errata
- Water Resources Survey, Madison County, 1965
- Statement of Claim 41G 197111-00 file
- The Department also routinely considers the following information. The following information is not included in the administrative file for this Application but is available upon request. Please contact the Bozeman Regional Office at 406-586-3136 to request copies of the following documents.
 - “Development of Standardized Methodologies to Determine Historic Diverted Volume” (2012)
 - “Technical Memorandum - Assessment of new consumptive use and irrecoverable losses associated with change applications” (2013)
 - “Technical Memorandum: Calculating Return Flows” (2019)
 - “Technical Memorandum: Physical Availability of Surface Water with Gage Data” (2019)

- “Technical Memorandum: Distributing Conveyance Loss on Multiple User Ditches” (2020)

The Department has fully reviewed and considered the evidence and argument submitted in this Application and preliminarily determines the following pursuant to the Montana Water Use Act (Title 85, chapter 2, part 3, part 4, MCA).

For the purposes of this document, Department or DNRC means the Department of Natural Resources & Conservation; CFS means cubic feet per second; GPM means gallons per minute; AF means acre-feet; AC means acres; and AF/YR means acre-feet per year. Values presented in this document may differ up to 0.1 due to rounding.

WATER RIGHTS TO BE CHANGED

FINDINGS OF FACT

1. The Applicant seeks to change the place of use (POU) and point of diversion (POD) of Statement of Claim 41G 197111-00 in this application. Claim 41G 197111-00 is diverted from Parsons Slough at a flow rate of 9.48 CFS from May 1 to October 15 through a headgate in the SESESW Section 14, T1S, R5W, Madison County for irrigation of 250 acres. The claim is conveyed to the place of use generally located in Sections 13 and 14, T1S, R5W, Madison County by the Curtis Ditch. The water right proposed for change is seen in Table 1.

Table 1. Water right proposed for change

Water Right No.	Purpose	Flow Rate (CFS)	Maximum Volume	Period of Use	Point of Diversion	Place of Use	Priority Date	Acres
41G 197111-00	Irrigation	9.48	Historical Use Statement	5/1- 10/15	SESESW Section 14 T1S, R5W, Madison County	SESE & NESE Section 14, and NWSW, NESW, SWNE, NESE, NWSE, SWSE, & SESE Section 13 all in T1S, R5W, Madison County	9/19/1876	250

2. No other water rights historically irrigated the historical POU of Claim 41G 197111-00. Claim 41G 197111-00 is not supplemental to any other water rights.

3. The water right is owned solely by the Applicant and is not part of a bigger water right.

4. No previous change authorizations are associated with the water right proposed for change.

CHANGE PROPOSAL

FINDINGS OF FACT

5. The Applicant proposes to change the POD and POU of Statement of Claim 41G 197111-00. The Applicant proposes to add two new PODs: a permanent pump site in the Jefferson River and a moveable pump in the Jefferson River. The Applicant will continue using the historical POD following the change. The permanent pump will be located in NENESE Section 14, T1S, R5W, Madison County. The moveable pump will be located along a reach beginning in SENWNE Section 13 and ending in SENWNE Section 13, all in T1S, R5W, Madison County. The Applicant also proposes to add 52.9 acres to the POU and retire 91 acres from the historical POU, for a total 199.5 acres irrigated. The proposed POU is generally located in Sections 13 and 14, T1S, R5W, Madison County. Water will continue to be diverted from Parsons Slough from May 1 to October 15 for irrigation use. Water will be conveyed to the POU via pipelines or through the Curtis Ditch and Willow Spring Creek, which will act as a natural carrier when the ditch is in use. The proposed change is seen in Figure 1. No change in purpose or place of storage are proposed in this application.

6. Following the change, the new acres in the S2 Section 13, T1S, R5W, Madison County will overlap with the claimed POU of Claim 41G 212596-00. Claim 41G 212596-00 is owned by the Applicant. The Applicant stated all irrigation under Claim 41G 212596-00 will cease if this change is authorized. Claims 41G 212596-00 and 41G 197111-00 will not be supplemental following the change. The Applicant plans to address Claim 41G 212596-00 in a future change. This change, Change Application No. 41G 30165036, is the first change in a series of changes the Applicant has planned.

7. The following conditions will be required for this change to meet the adverse effect criteria:

WATER MEASUREMENT INFORMATION

THE APPROPRIATOR SHALL INSTALL A DEPARTMENT APPROVED MEASURING DEVICE IN PARSONS SLOUGH AT A POINT APPROVED BY THE DEPARTMENT. THE APPROPRIATOR SHALL KEEP A WRITTEN RECORD OF THE FLOW IN PARSONS SLOUGH WHEN THEY ARE IRRIGATING THE PLACE OF USE FROM THE JEFFERSON RIVER PUMP SITES. THE ABILITY TO DIVERT PARSONS SLOUGH WATER OUT OF THE JEFFERSON RIVER AS GRANTED BY THIS CHANGE AUTHORIZATION SHALL BE BASED UPON MEASUREMENTS, AND DIVERSIONS CANNOT EXCEED THE AMOUNT MEASURED IN PARSONS SLOUGH. THE APPROPRIATOR SHALL MAINTAIN THE MEASURING DEVICE SO THAT THE MEASURING DEVICE ALWAYS OPERATES PROPERLY AND MEASURES FLOW ACCURATELY. ON A FORM PROVIDED BY THE DEPARTMENT, THE

APPROPRIATOR SHALL KEEP A MONTHLY WRITTEN RECORD OF FLOW. RECORDS SHALL BE SUBMITTED TO THE DEPARTMENT BY NOVEMBER 30TH OF EACH YEAR AND UPON REQUEST AT OTHER TIMES DURING THE YEAR.

IMPORTANT INFORMATION

THE HISTORICAL DITCH DIVERSION MAY ONLY DIVERT WATER FROM PARSONS SLOUGH WHEN THE PUMP SITES IN THE JEFFERSON RIVER ARE NOT IN OPERATION.

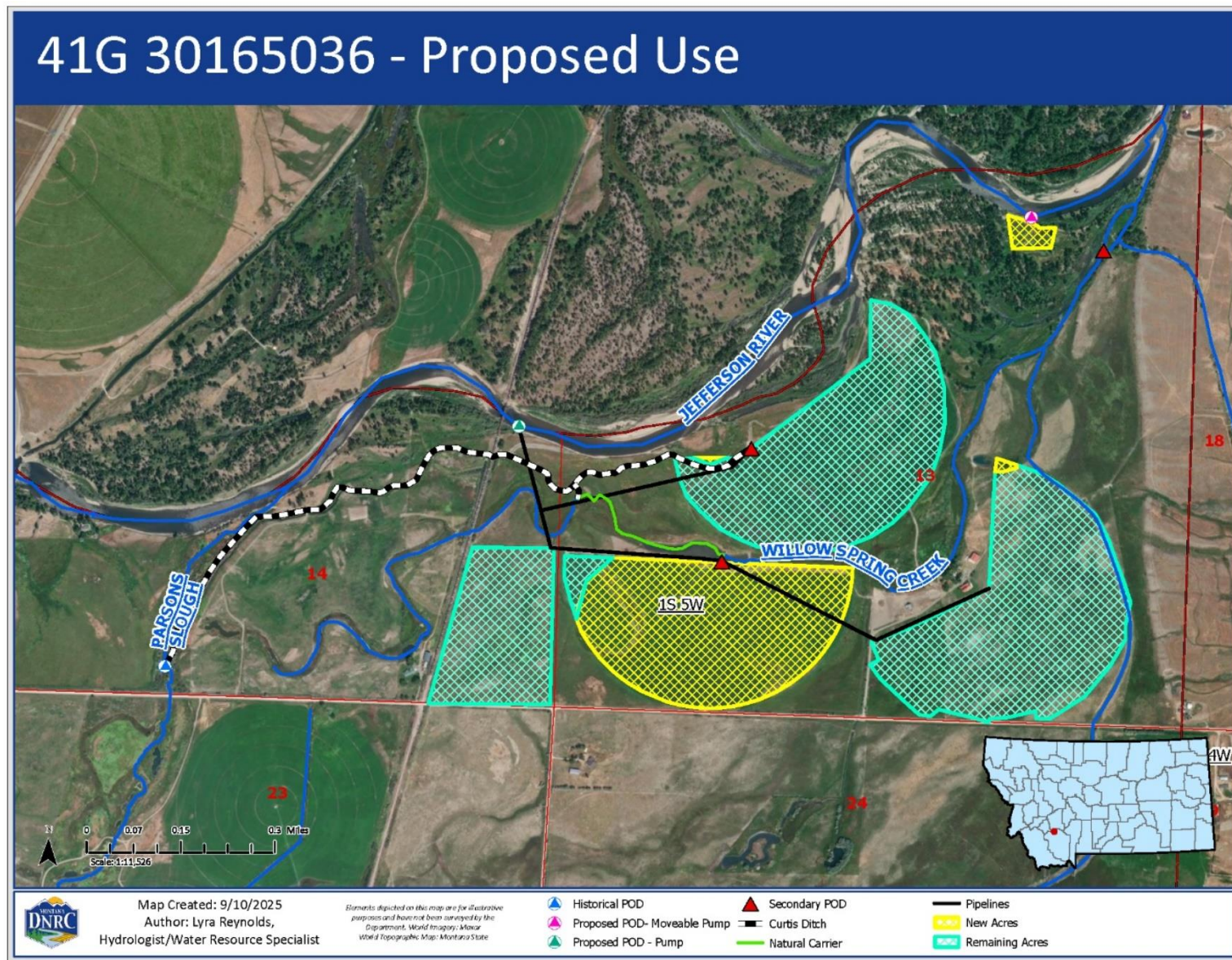


Figure 1. Proposed use for Change Application No. 41G 30165036

CHANGE CRITERIA

8. The Department is authorized to approve a change if the Applicant meets its burden to prove the applicable § 85-2-402, MCA, criteria by a preponderance of the evidence. *Matter of Royston*, 249 Mont. 425, 429, 816 P.2d 1054, 1057 (1991); *Hohenlohe v. DNRC*, 2010 MT 203, ¶¶ 33, 35, and 75, 357 Mont. 438, 240 P.3d 628 (an Applicant's burden to prove change criteria by a preponderance of evidence is "more probable than not."); *Town of Manhattan v. DNRC*, 2012 MT 81, ¶ 8, 364 Mont. 450, 276 P.3d 920. Under this Preliminary Determination, the relevant change criteria in § 85-2-402(2), MCA, are:

(2) Except as provided in subsections (4) through (6), (15), (16), and (18) and, if applicable, subject to subsection (17), the department shall approve a change in appropriation right if the appropriator proves by a preponderance of evidence that the following criteria are met:

(a) The proposed change in appropriation right will not adversely affect the use of the existing water rights of other persons or other perfected or planned uses or developments for which a permit or certificate has been issued or for which a state water reservation has been issued under part 3.

(b) The proposed means of diversion, construction, and operation of the appropriation works are adequate, except for: (i) a change in appropriation right for instream flow pursuant to 85-2-320 or 85-2-436; (ii) a temporary change in appropriation right for instream flow pursuant to 85-2-408; or (iii) a change in appropriation right pursuant to 85-2-420 for mitigation or marketing for mitigation.

(c) The proposed use of water is a beneficial use.

(d) The Applicant has a possessory interest, or the written consent of the person with the possessory interest, in the property where the water is to be put to beneficial use or, if the proposed change involves a point of diversion, conveyance, or place of use on national forest system lands, the Applicant has any written special use authorization required by federal law to occupy, use, or traverse national forest system lands for the purpose of diversion, impoundment, storage, transportation, withdrawal, use, or distribution of water. This subsection (2)(d) does not apply to: (i) a change in appropriation right for instream flow pursuant to 85-2-320 or 85-2-436; (ii) a temporary change in appropriation right for instream flow pursuant to 85-2-408; or (iii) a change in appropriation right pursuant to 85-2-420 for mitigation or marketing for mitigation.

9. The evaluation of a proposed change in appropriation does not adjudicate the underlying right(s). The Department's change process only addresses the water right holder's ability to make a different use of that existing right. *E.g.*, *Hohenlohe*, ¶¶ 29-31; *Town of Manhattan*, ¶ 8; *In the Matter of Application to Change Appropriation Water Right No.41F-31227 by T-L Irrigation Company* (DNRC Final Order 1991).

HISTORICAL USE AND ADVERSE EFFECT

FINDINGS OF FACT - Historical Use

10. Claim 41G 197111-00 is a filed right with a priority date of September 19, 1876. Claim 41G 197111-00 was part of the Temporary Preliminary Decree and Preliminary Decree for Basin 41G.

11. Claim 41G 197111-00 was originally claimed for irrigation of 250 acres in SESE and NESE Section 14, NWSW, NESW, SWNE, NESE, NWSE, SWSE, and SESE Section 13, all in T1S, R5W, Madison County. The Water Resources Survey (WRS) for Madison County does not corroborate the claimed 250-acre POU. The Applicant provided historical imagery and information about historical irrigated acres with the Preapplication Meeting Form supporting irrigation of 237.6 acres. The historical irrigation of 237.6 acres is supported by Army Map Service Image A001210366148, dated September 9, 1954, NASA AMES Research Center Image 5720005521774, dated July 26, 1972, and Photo 378-61, dated September 7, 1979. The Department finds the maximum acres irrigated by Claim 41G 197111-00 is 237.6. The historical POU can be seen in Figure 2. The Department conducted the historical use analysis based on 237.6 acres.

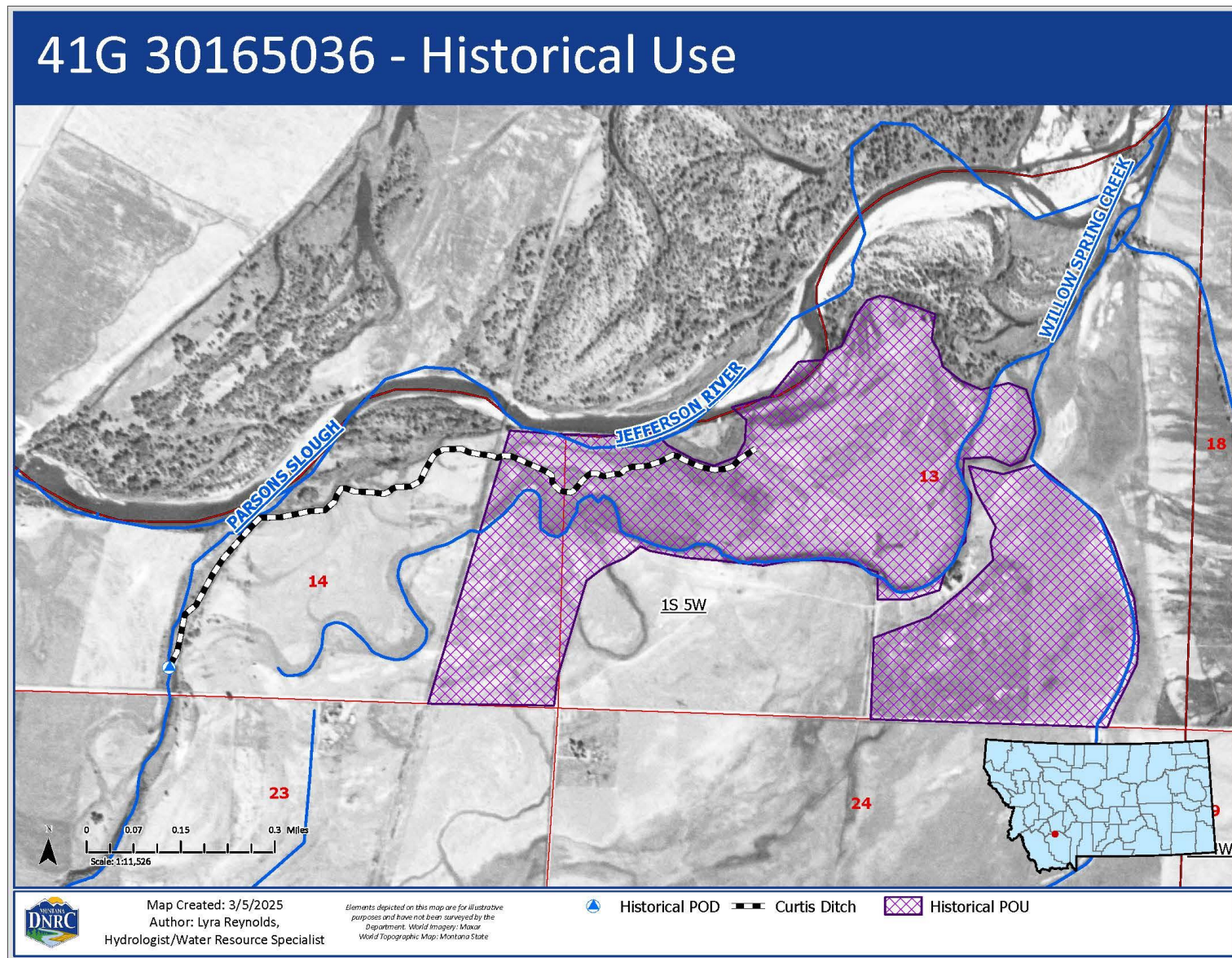


Figure 2. Historical use of Claim 41G 197111-00

12. Claim 41G 197111-00 has a claimed flow rate of 9.48 CFS. Claim 41G 197111-00 was historically diverted from Parsons Slough via a headgate at the Curtis Ditch in Section 14, T1S, R5W, Madison County for irrigation use. The Curtis Ditch conveys two water rights: Claim 41G 197111-00 and Provisional Permit 41G 2262-00. The maximum flow rate in the ditch is 11.04 CFS. The Applicant provided measurements and capacity calculations of the Curtis Ditch at the headgate and at a location along the ditch. The Applicant also provided a flow measurement at the down-ditch location, which measured 8.3 CFS. Based on measurements provided by the Applicant, the ditch capacity at the headgate is 16 CFS. The ditch profile provided with the flow measurement had a wetted width of 14 feet, an average depth of 2 feet, and a channel slope of 0.12%. Using ditch measurements collected by the Applicant's consultant and provided in the Preapplication Meeting Form materials, the capacity of the down-ditch location is 12.09 CFS. The Department finds the capacities at the headgate and the down-ditch location are sufficient to carry the maximum 11.04 CFS flow rate. The Department finds the maximum flow rate of Claim 41G 197111-00 is 9.48 CFS.

13. Water was historically diverted from May 1 to October 15 for irrigation under Claim 197111-00. The end of the period of diversion and use falls outside the standard in ARM 36.12.112 for irrigation in Climatic Area IV. The Applicant stated water has been diverted and used for irrigation until mid-October each year. Water rights that share the historical point of diversion also have a claimed period of diversion and use of May 1 to October 15. The Department finds the historical period of diversion and use for Claim 41G 197111-00 is May 1 to October 15.

14. The water right proposed for change is a Statement of Claim, and the historical use was evaluated as the right existed prior to July 1, 1973. No prior change authorizations for the water right have occurred, and no documented history of calls on Claim 41G 197111-00 exists. The Department calculated the historical volume using the Department's standard methodology, pursuant to ARM 36.12.1902.

15. Water was historically diverted from Parsons Slough at a headgate in the SESESW Section 14, T1S, R5W, Madison County and conveyed via the Curtis Ditch to irrigate a total of 237.6 acres in the historical POU. The Applicant stated 116.9 acres were historically irrigated by flood and 120.7 acres were historically irrigated by wheeline sprinklers. The Department categorized the historical irrigation methods as wild flood and sprinkler irrigation based on aerial photographs and the Applicant's description of historical practices. Water was typically diverted and used from May 1 to October 15 each year for cultivation of grass, alfalfa, and small grains. No improvements, such as field leveling, occurred prior to July 1, 1973. No other water rights

irrigate the historical POU of 41G 197111-00. Using the information about historical irrigation practices, the Department calculated historical consumptive use, summarized in Table 2 and 3, according to the rules set forth in ARM 36.12.1902 using the following equations:

$$HCV = \text{Crop Consumption} + \text{Historic Irrecoverable Losses}$$

Crop Consumption

$$= \text{Twain Bridges} * \frac{1\text{ft}}{12\text{inches}} * \text{Madison County Management Factor} \\ * \text{Historic Acres}$$

$$\text{Historic Irrecoverable Losses} = \text{Field Applied} * \text{IL}\%$$

$$\text{Field Applied} = \frac{\text{Crop Consumption}}{\text{Field Efficiency}}$$

Table 2. Historical consumptive use of historical place of use

Field ID	Irrigation Method	Acres	NIR (in)	Management Factor	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume (AF)
North Flood	Wild Flood	116.9	16.98	0.65	0.25	107.85	431.4	21.57	129.4
South Sprinkler	Wheeline	120.7	16.98	0.65	0.7	111.36	159.08	15.91	127.3

Table 3. Historical consumptive volume of Claim 41G 197111-00

Water Right No.	Crop Consumption (AF)	Applied Volume (AF)	Consumed Volume (AF)
41G 197111-00	219.2	590.5	256.7

16. Historical diverted volume is the sum of historical field applied volume and the seasonal conveyance losses attributed to a water right. The historical conveyance loss volume is equal to the sum of the historical seepage loss, vegetation loss, and ditch evaporation volumes. The Curtis Ditch historically conveyed 2 water rights: Permit 41G 2262-00 & Claim 41G 197111-00. The seasonal conveyance losses in the Curtis Ditch were calculated using ditch measurements provided by the Applicant and the equations below. The Applicant stated water was diverted from the Parsons Slough from May 1 to October 15 for all water rights in the ditch. Permit 41G 2262-00 has a POU up-ditch of the POU of Claim 41G 197111-00. To account for the differences in distance conveyed to POUs, the ditch was divided into 2 down-ditch combinations as seen in Table 3. Conveyance losses were found for each down-ditch combination and distributed to the water rights in the combination based on a flow rate proportion. The conveyance losses attributed to the water right proposed for change were found using the following equations and are summarized in Tables 4-6.

$$\text{Water Right Conveyance Loss} = \sum \text{Ditch Combo Conveyance Losses}_{WR}$$

$$\begin{aligned} \text{Ditch Combo Conveyance Losses}_{Total} \\ = \text{Seepage Loss}_{combo} + \text{Vegetation Loss}_{combo} + \text{Evaporation Loss}_{combo} \end{aligned}$$

$$\begin{aligned} \text{Seepage Loss}_{combo} \\ = (\text{Wetted Perimeter}_{combo} * \text{Ditch Length}_{combo} * \text{Ditch Loss Rate} \\ * \text{Days Diverted}_{combo}) * \frac{1 \text{ acre}}{43560 \text{ ft}^2} \end{aligned}$$

$$\begin{aligned} \text{Vegetation Loss}_{combo} \\ = 0.75\% \text{ loss per mile} * \frac{\text{Ditch Length}_{combo}}{5280 \text{ miles}} * \text{Flow Rate}_{combo} \\ * \text{Days Diverted}_{combo} * 2 \end{aligned}$$

$$\text{Ditch Evaporation Loss}_{combo} = (\text{Surface Area} * \text{Adjusted Net Evaporation}_{combo}) * \frac{1 \text{ acre}}{43560 \text{ ft}^2}$$

$$\text{Surface Area} = (\text{Wetted Width ft}) * \text{Ditch Length}_{combo}$$

$$\begin{aligned} \text{Ditch Combo Conveyance Losses}_{WR} \\ = \text{Ditch Combo Conveyance Losses}_{Total} * \text{Combo Flow Proportion}_{WR} \end{aligned}$$

$$\text{Combo Flow Proportion}_{WR} = \text{WR Flow Rate}_{ditch} * \text{Ditch Combo Total Flow Rate}$$

Table 4. Curtis Ditch down-ditch combinations

Down-Ditch Combo	Water rights in Combo	Period of Diversion Start	Period of Diversion End	Total Days in Period	Combo Flow Rate (CFS)	Combo Length (ft)
Curtis A	41G 197111-00 & 41G 2262-00	1-May	15-Oct	168	11.04	3215
Curtis B	41G 197111-00	1-May	15-Oct	168	9.48	2015

Table 5. Curtis Ditch historical conveyance losses for down-ditch combinations

Down-Ditch Combo	Length (ft)	Flow Rate (CFS)	Wetted Width (ft)	Wetted Perimeter (ft)	Ditch Loss Rate (ft ³ /ft ² /day)	No. of Days Diverted	Adj. Net Evaporation (in)	Seepage Loss (AF)	Vegetation Loss (AF)	Evaporative Loss (AF)	Total Conveyance Loss (AF)
Curtis A	3215	11.04	14	15.21	1	168	21.21	188.6	16.94	1.83	207.36
Curtis B	2015	9.48	14	15.21	1	168	21.21	118.2	9.12	1.14	128.46

Table 6. Curtis Ditch historical conveyance losses per water right

Water Right No.	Down-Ditch Combo	Water Right Flow Rate (CFS)	Water Right Conveyance Loss (AF)
41G 2262-00	Curtis A	1.56	29.3
41G 197111-00	Curtis A & B	9.48	306.5

17. The Department calculated the historical diverted volume pursuant to ARM 36.12.1902 and the Department's standard methodology (Roberts and Heffner, 2012). Conveyance losses

from the Curtis Ditch attributed to Claim 41G 197111-00, described above and seen in Table 6, were added to the historical field applied volume to find the historical diverted volume for the water right proposed for change. Water was historically diverted for irrigation of 237.6 acres from May 1 to October 15 under Claim 41G 197111-00. Water was conveyed from the headgate diversion to the POU via the Curtis Ditch. The historical diverted volume is summarized in Table 7.

Table 7. Historical diverted volume of Claim 41G 197111-00

Water Right No.	Historical Consumptive Volume (AF)	Historical Field Applied Volume (AF)	Historical Conveyance Losses (AF)	Historical Diverted Volume (AF)
41G 197111-00	256.7	590.5	306.5	897

18. The Department finds the following historical use for Claim 41G 197111-00, shown in Table 8.

Table 8. Historical use of Claim 41G 197111-00

Water Right No.	Historical Purpose	Maximum Historical Acres	Historical Place of Use	Historical Point of Diversion	Maximum Historical Flow Rate	Historically Consumed Volume	Historically Diverted Volume
41G 197111-00	Irrigation	237.6 acres	SESE, NESE Section 14, and NWSW, NESW, SWNE, NESE, NWSE, SWSE, SESE Section 13, all in T1S, R5W, Madison County	SESESW Section 14, T1S, R5W, Madison County	9.48 CFS	256.7 AF	897 AF

ADVERSE EFFECT

FINDINGS OF FACT

19. The Applicant proposes to change the POD and POU of Claim 41G 197111-00. Through the proposed change the Applicant will add two points of diversion: a permanent pump in the NENESE Section 14 and a moveable pump along a reach beginning and ending in SENWNE Section 13, all in T1S, R5W, Madison County. The Applicant will continue to use the historical POD following the change when the proposed PODs are not operational. The Applicant also proposes to add 52.9 acres outside the historical POU and retire 91 historically irrigated acres, as seen in Figure 3. The acres will be added in SWSW & SESW of Section 13, T1S, R5W, Madison County. After the proposed change, Claim 41G 197111-00 will have three authorized PODs and will be used to irrigate 199.5 acres. No change in purpose or place of storage is proposed.

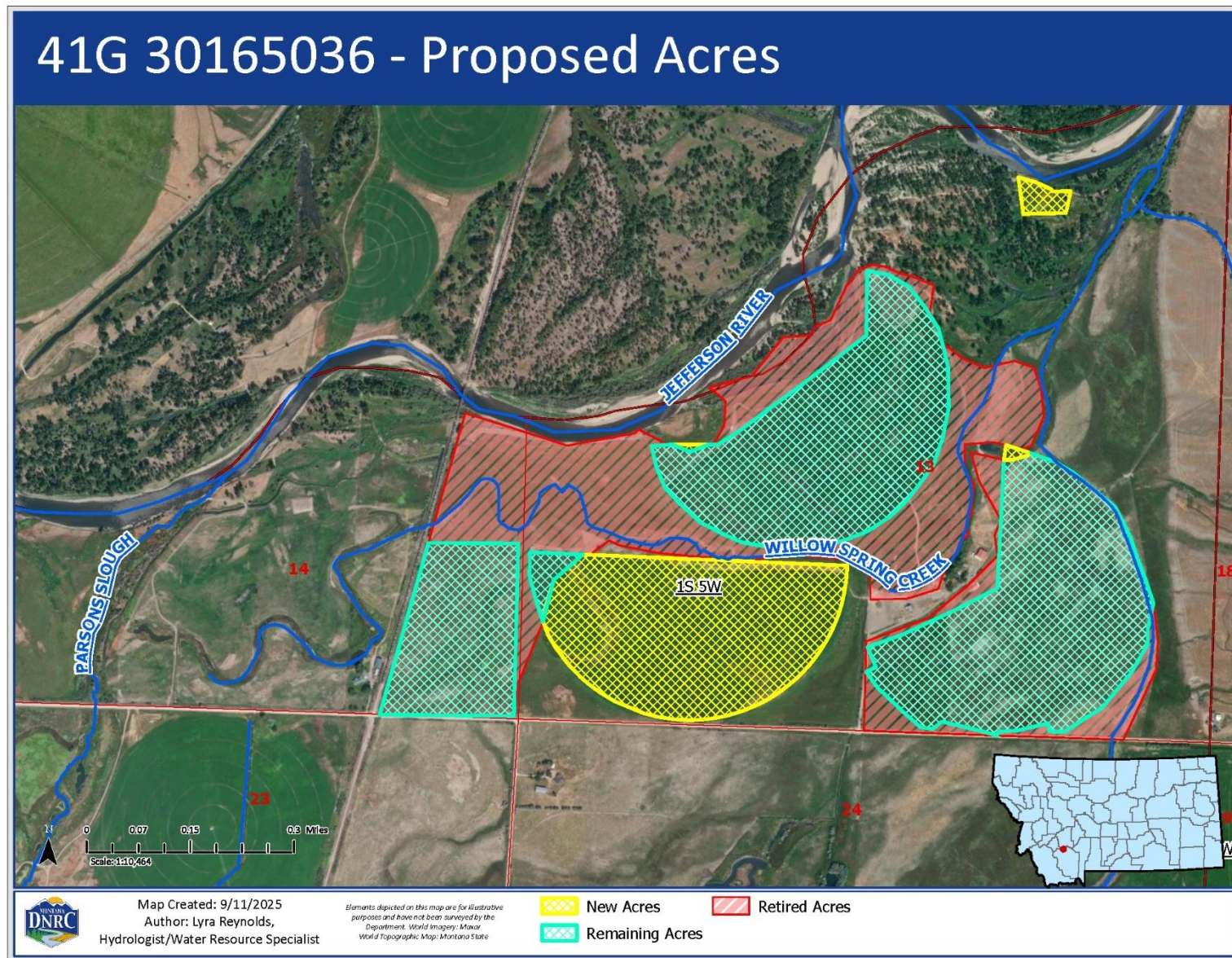


Figure 3. Proposed change in irrigated acres for Claim 41G 197111-00

20. Following the change, the Applicant will divert water from Parsons Slough at a maximum flow rate of 4.26 CFS for continued irrigation use. When the proposed PODs are in use and the system is fully operational, water will be diverted from the Jefferson River pump sites into pipelines. The pipelines will convey water to the irrigation systems on each field in the proposed POU. The proposed POU includes historical and new acres. Following the proposed change, 142.2 acres will be sprinkler irrigated, and 57.3 acres will remain flood irrigated. Irrigation use will continue from May 1 to October 15 for a total 199.5 irrigated acres. No other water rights will be used to irrigate the proposed POU after the change. Claim 41G 212596-00 is currently claimed with an irrigation POU that overlaps with the new acres in the S2 Section 13, but the Applicant stated this water right will not be used to supplement Claim 41G 197111-00 as all irrigation under this claim will be ceased if Change Application 41G 30165036 is granted. The Applicant stated Claim 41G 212595-00 will be addressed in a future change.

21. The consumptive use associated with the proposed place of use will change from the historical consumptive use. The Applicant proposes to irrigate the new 52.9 acres using sprinkler irrigation from May 1 to October 15. Water will continue to be used from May 1 to October 15 for the remaining historical acres, as done historically. The consumptive volume associated with the new 52.9 acres was found using the Department's standard outlined in ARM 36.12.1902 for proposed use, with values seen in Table 9. Consumptive use for new acres was added to the consumptive volume associated with the remaining 146.6 historical acres to find the total proposed consumptive use following the proposed change. The proposed consumptive volume of Claim 41G 197111-00 is summarized in Tables 9-11.

Table 9. Proposed consumptive volume of new acres

Field ID	Acres	Weather Station	NIR (in)	Management Factor	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume - New Acres (AF)
New Acres	52.9	Twin Bridges	19.22	0.83	0.7	70.6	100.8	10.1	80.7

Table 10. Historical consumptive volume of remaining acres

Field ID	Acres	Weather Station	NIR (in)	Management Factor	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume - Remaining Acres (AF)
Historical Flood	57.3	Twin Bridges	16.98	0.65	0.25	52.9	211.5	10.5	63.4
Historical Sprinkler	89.3	Twin Bridges	16.98	0.65	0.7	82.4	117.7	11.8	94.2

Table 11. Proposed consumptive volume of Claim 41G 197111-00

Water Right No.	Crop Consumption - All Proposed Acres (AF)	Applied Volume - All Proposed Acres (AF)	Consumed Volume - All Proposed Acres (AF)
41G 197111-00	205.9	430	238.3

22. The Applicant proposes to retire 91 historically irrigated acres and add 52.9 new acres, so Claim 41G 197111-00 is used to irrigate a total 199.5 acres after the proposed change. As a result, the proposed consumed volume of Claim 41G 197111-00 is 238.3 AF. The proposed consumptive use is 18.4 AF less than the historical consumed volume of 256.7 AF. The Department finds the proposed change in point of diversion and place of use will not increase the consumed volume of Claim 41G 197111-00.

23. The Applicant proposes to use pipelines to convey water from the proposed PODs when the system is fully operational. When the system is not fully operational, the Applicant will utilize the historical POD and Curtis Ditch. Water will be diverted using the historical POD and conveyed via the Curtis Ditch when the Jefferson River pump sites are not in use. The Applicant will use pipelines, Willow Spring Creek as a natural carrier following Curtis Ditch, and secondary PODs to convey and apply water onto three of the fields in the proposed POU; these are labeled as Fields B, D, and E on Figure 4. The Applicant will only use the secondary diversion in Willow Spring Creek when the historical ditch diversion is in use.

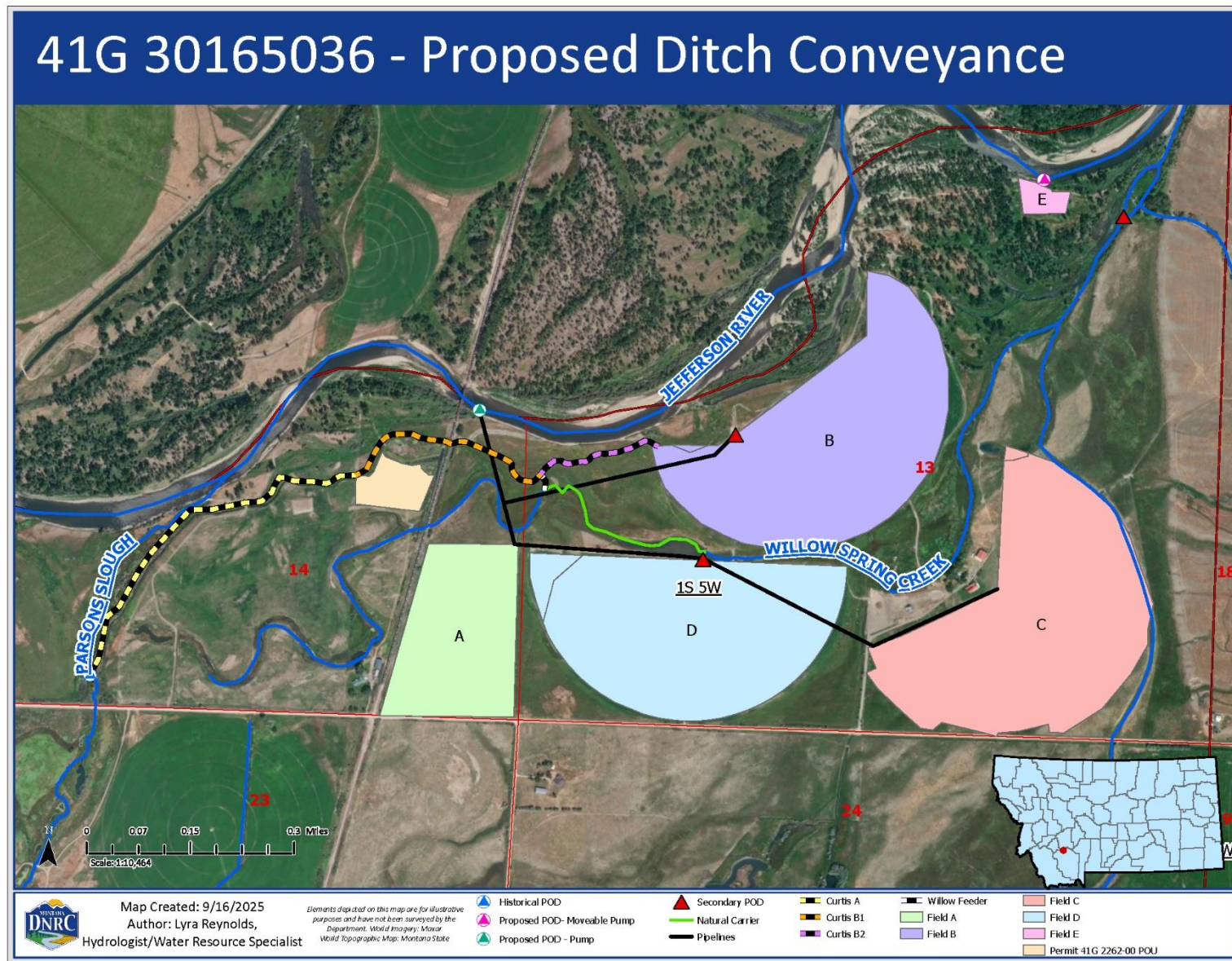


Figure 4. Claim 41G 197111-00 proposed ditch conveyance system

24. The Applicant estimated the total amount of time to deliver the field applied volume to the proposed POUs using the Curtis Ditch is 50.7 days. The time to deliver the field applied volume varies depending on the size of the field. Water will be delivered to all three fields for 6.8 days. Once the full field applied volume for Field E is delivered, water will be delivered for an additional 40.2 days only to the remaining fields. Once the full field applied volume for Field D is delivered, water will be delivered only to Field B for an additional 3.7 days. The total flow rate diverted at the POD is the amount needed to convey the field applied volume to each field. When water is diverted at a secondary diversion or delivered to a field, a portion of the flow rate is no longer being conveyed through the ditch. The differences in flow rates were also considered in calculating conveyance losses. To account for differences in distances between the headgate and the proposed fields and operational needs at the fields, the Curtis Ditch was divided into the following groups and down-ditch combinations:

Table 12. Curtis Ditch groups and down-ditch combinations

Group	Down-Ditch Combo	Water Rights Conveyed	Days	Maximum Total Flow Rate (CFS)
G1: Water being delivered to Fields B, D, and E	Curtis A	41G 197111-00 & 41G 2262-00	6.8	4.95
	Curtis B1	41G 197111-00	6.8	3.39
	Curtis B2	41G 197111-00	6.8	1.51
	Willow Feeder	41G 197111-00	6.8	1.34
G2: Water being delivered to Fields B & D	Curtis A	41G 197111-00 & 41G 2262-00	40.2	4.22
	Curtis B1	41G 197111-00	40.2	2.66
	Curtis B2	41G 197111-00	40.2	1.45
	Willow Feeder	41G 197111-00	40.2	1.11
G3: Water being delivered to Field B	Curtis A	41G 197111-00 & 41G 2262-00	3.7	3.77
	Curtis B1 & B2	41G 197111-00	3.7	2.21

25. The conveyance losses associated with Claim 41G 197111-00 were calculated for the proposed use using a similar methodology as the historical conveyance losses. The Department utilized the evaporation rate for the entire period of diversion, as the ditch may be used during the May 1 to October 15 period. Conveyance losses were distributed to Claim 41G 197111-00 using the Department's Multi-User Ditch Memo. The proposed conveyance losses are summarized in Tables 13 and 14.

Table 13. Curtis Ditch proposed conveyance losses for down-ditch combinations

Ditch ID	Length (ft)	Flow Rate (CFS)	Width (ft)	Wetted Perimeter (ft)	Ditch Loss Rate (ft ³ /ft/day)	Number of Days Irrigated	Adj. Net Evap (in)	Seepage Loss (AF)	Vegetation Loss (AF)	Evaporative Loss (AF)	Total Conveyance Loss (AF)
G1 Curtis A	3215	4.95	14	15.2	1.1	6.8	21.21	8.39	0.31	1.83	10.53
G1 Curtis B1	2305	3.39	14	15.2	1.1	6.8	21.21	6.02	0.15	1.31	7.48
G1 Curtis B2	1800	1.51	14	15.2	1.1	6.8	21.21	4.7	0.05	1.02	5.77
G1 Willow Feeder	120	1.34	14	15.2	1.1	6.8	21.21	0.31	0	0.07	0.38
G2 Curtis A	3215	4.22	14	15.2	1.1	40.2	21.21	49.61	1.55	1.83	52.98
G2 Curtis B1	2305	2.66	14	15.2	1.1	40.2	21.21	35.57	0.7	1.31	37.58
G2 Curtis B2	1800	1.45	14	15.2	1.1	40.2	21.21	27.77	0.3	1.02	29.1
G2 Willow Feeder	120	1.11	14	15.2	1.1	40.2	21.21	1.85	0.02	0.07	1.94
G3 Curtis A	3215	3.77	14	15.2	1.1	3.7	21.21	4.57	0.13	1.83	6.52
G3 Curtis B1 & B2	4105	2.21	14	15.2	1.1	3.7	21.21	5.83	0.1	2.33	8.26

Table 14. Ditch proposed conveyance losses per water right

Water Right No.	Ditch ID	WR Flow Rate (CFS)	Required Diverted Flow Rate (CFS)	Combo Total Flow Rate (CFS)	Proportion	Combo Conveyance Loss (AF)	Water Right Conveyance Loss (AF)
41G 2262-00	S1 Curtis A	1.56	1.56	4.95	0.3	10.53	3.32
	S2 Curtis A	1.56	1.56	4.22	0.4	52.98	19.59
	S3 Curtis A	1.56	1.56	3.77	0.4	6.52	2.70
41G 197111-00	S1 Curtis A	9.48	3.39	4.95	0.7	10.53	7.21
	S1 Curtis B1	9.48	3.39	3.39	1.0	7.48	7.48
	S1 Curtis B2	9.48	1.51	1.51	1.0	5.77	5.77
	S1 Willow Feeder	9.48	1.34	1.34	1.0	0.38	0.38
	S2 Curtis A	9.48	2.66	4.22	0.6	52.98	33.39
	S2 Curtis B1	9.48	2.66	2.66	1.0	37.58	37.58
	S2 Curtis B2	9.48	1.45	1.45	1.0	29.1	29.10
	S2 Willow Feeder	9.48	1.11	1.11	1.0	1.94	1.94
	S3 Curtis A	9.48	2.21	3.77	0.6	6.52	3.82
	S3 Curtis B1 & B2	9.48	2.21	2.21	1.0	8.26	8.26

26. The total proposed field applied volume was added to the proposed conveyance losses attributed to Claim 41G 197111-00 to obtain the total proposed diverted volume. The total proposed diverted volume, seen in Table 15, reflects the maximum water usage given the Applicant's proposed operational plan.

Table 15. Proposed diverted volume

Water Right No.	Consumed Volume (AF)	Applied Volume (AF)	Conveyance Losses (AF)	Total Diverted Volume (AF)
41G 197111-00	238.3	430	134.9	564.9

Table 17. Comparison of volumes associated with historical and proposed use.

Water Right No.	Historically Consumed Volume (AF)	Proposed Consumptive Volume (AF)	Historically Diverted Volume (AF)	Proposed Diverted Volume (AF)
41G 197111-00	256.7	238.3	897	564.9

27. The proposed diverted volume of Claim 41G 197111-00 is 564.9 AF, which is 332.1 AF less than the historical diverted volume of 897 AF. The Applicant proposes to leave the difference in diverted volume, equal to 332.1 AF, in Parsons Slough at the historical POD. Water left in Parsons Slough will flow downstream to the Jefferson River. The Department finds the change in point of diversion and place of use will not increase the diverted volume of Claim 41G 197111-00.

28. The Department identified an area of potential adverse effect on Parsons Slough and the Jefferson River. This reach was determined to be the area from the historical POD downstream to where Willow Spring Creek meets the Jefferson River. This reach extends from SESESW Section 14, T1S, R5W, Madison County downstream to NENENE Section 13, T1S, R5W, Madison County. Water rights that share the POD with Claim 41G 197111-00 were also considered for adverse effect. Two water rights exist in the area of potential adverse effect: Claim 41G 30143701 and Permit 41G 2262-00. The Applicant proposes to add two points of diversion to Claim 41G 197111-00 and will continue to use the historical POD following the proposed change. The proposed pump diversions will be downstream of the historical POD, and the Applicant will leave 332.1 AF in Parsons Slough at the historical POD. Water users in the area of potential adverse effect will have equal or greater access to water during the period of diversion as compared to historical conditions. The Applicant will not increase the diverted or consumed volume, nor change the timing of diversions for the water right proposed for change. The Applicant proposes to divert at flow rate of 4.26 CFS when using the pump sites in the Jefferson River. The Applicant will be required to measure Parsons Slough when the pump sites are in use. The Applicant will be able to divert from the Jefferson River pump sites at the authorized flow rate when measurements in Parsons Slough show the water is available. The amount of water diverted from the Jefferson River pump sites cannot exceed the amount measured in Parsons Slough. Water will be left instream at the historical POD, and diversions from the proposed pump sites will

occur when adequate water is measured in Parsons Slough. Water rights in the area of potential adverse effect will not be adversely affected.

29. When using the ditch, the Applicant proposes to limit diversions to 3.39 CFS. The historical ditch will only be used when the Jefferson River pump sites are inoperable. Water diverted through the historical diversion will be conveyed through the Curtis Ditch and Willow Spring Creek to secondary PODs. The secondary POD in Willow Spring Creek will operate at a maximum 100 GPM flow rate. The Applicant will decrease total diversions through the historical ditch, so no expansion will occur.

30. The Applicant stated pump diversions will be able to be controlled to limit diversions to a total 4.26 CFS flow rate, the ditch diversion can be controlled to limit flow to 3.39 CFS, and all diversions may be shut off in response to call.

31. The Department will require the Applicant to provide measurements to ensure adequate flow exists in Parsons Slough for the Jefferson River pump sites to operate. The Applicant will also only be able to operate the historical ditch diversion when the Jefferson River pump sites are inoperable. The following conditions will be placed on the water right if this change is authorized:

WATER MEASUREMENT INFORMATION

THE APPROPRIATOR SHALL INSTALL A DEPARTMENT APPROVED MEASURING DEVICE IN PARSONS SLOUGH AT A POINT APPROVED BY THE DEPARTMENT. THE APPROPRIATOR SHALL KEEP A WRITTEN RECORD OF THE FLOW IN PARSONS SLOUGH WHEN THEY ARE IRRIGATING THE PLACE OF USE FROM THE JEFFERSON RIVER PUMP SITES. THE ABILITY TO DIVERT PARSONS SLOUGH WATER OUT OF THE JEFFERSON RIVER AS GRANTED BY THIS CHANGE AUTHORIZATION SHALL BE BASED UPON MEASUREMENTS, AND DIVERSIONS CANNOT EXCEED THE AMOUNT MEASURED IN PARSONS SLOUGH. THE APPROPRIATOR SHALL MAINTAIN THE MEASURING DEVICE SO THAT THE MEASURING DEVICE ALWAYS OPERATES PROPERLY AND MEASURES FLOW ACCURATELY. ON A FORM PROVIDED BY THE DEPARTMENT, THE APPROPRIATOR SHALL KEEP A MONTHLY WRITTEN RECORD OF FLOW. RECORDS SHALL BE SUBMITTED TO THE DEPARTMENT BY NOVEMBER 30TH OF EACH YEAR AND UPON REQUEST AT OTHER TIMES DURING THE YEAR.

IMPORTANT INFORMATION

THE HISTORICAL DITCH DIVERSION MAY ONLY DIVERT WATER FROM PARSONS SLOUGH WHEN THE PUMP SITES IN THE JEFFERSON RIVER ARE NOT IN OPERATION.

Return flow analysis

32. The proposed change to Claim 41G 197111-00 will result in a change in return flow locations and volumes. The Department modeled return flows for the proposed change in the Surface Water Change Technical Analysis Report – Part B, dated March 21, 2025. Historically, 105.7 AF of return flow volume returned to the Jefferson River downstream of the NENESE Section 14, T1S, R5W, Madison County and 228.1 AF returned to Willow Spring Creek downstream of the SWNESE Section 14, T1S, R5W, Madison County. Under the proposed change, 51.8 AF of return flow volume will accrue to the Jefferson River downstream of NENWSW Section 13, T1S, R5W, Madison County and 139.9 AF will accrue to Willow Spring Creek downstream of the SWNESE Section 14, T1S, R5W, Madison County. The Applicant proposes to leave water instream, equal to 332.1 AF, in Parsons Slough at the historical POD that will flow into the Jefferson River. Water will not be left instream in Willow Spring Creek following the proposed change..

33. The timing of return flows for Willow Spring Creek is seen in Table 18 below.

Table 18. Return flows to Willow Spring Creek and the net effect of the proposed change

Months	Net Irrigation Requirement (NIR) (in)	Total Non-Consumed Volume (AF)	Total Historical Return Flows		Total Proposed Return Flows		Net Effect to Willow Spring Creek (AF)	Net Effect to Willow Spring Creek (GPM)
			Willow Spring Creek (AF)	Willow Spring Creek (GPM)	Willow Spring Creek (AF)	Willow Spring Creek (GPM)		
January	0	0.3	0.4	2.6	0.3	2.2	-0.1	-0.4
February	0	0.2	0.3	2	0.2	1.6	-0.1	-0.4
March	0	0.2	0.3	2	0.2	1.6	-0.1	-0.4
April	0	0.2	0.2	1.7	0.2	1.4	0	-0.3
May	1.48	5.6	7.9	57.4	5.6	40.9	-2.3	-16.5
June	4.93	35.8	60.1	439.2	35.8	261.8	-24.3	-177.4
July	6.44	49	81.9	598.8	49	357.9	-32.9	-240.9
August	5.31	41.4	68.8	503	41.4	302.4	-27.4	-200.6
September	1.06	5.1	6.3	46.2	5.1	37.4	-1.2	-8.8
October	0	0.8	1	7.3	0.8	6	-0.2	-1.3
November	0	0.5	0.6	4.2	0.5	3.4	-0.1	-0.8
December	0	0.4	0.5	3.3	0.4	2.6	-0.1	-0.7
TOTAL	19.22	139.9	228.1		139.9		-88.2	

Area of Potential Impact Analysis

34. The Department identified an area of potential impact (AOPI) on Willow Spring Creek, beginning at the historical location of return flows to the confluence of the Jefferson River and Willow Spring Creek. This reach extends downstream of the SWNESE Section 14, T1S, R5W, Madison County to NENENE Section 13, T1S, R5W, Madison County, as seen in Figure 5. A total of 4 water rights exist within this reach. These water rights include one Fish, Wildlife, and Parks (FWP) Water Reservation for instream fisheries use (Reservation No. 41G 30017621), and three Statements of Claim owned by the Applicant (Claims 41G 30123892, 41G 30124720, and 41G 212596-00), seen in Table 19. Claim 41G 30123892 has a priority date senior to the water right proposed for change. As such, this water right is not considered a potentially impacted water right and will not be included in the downstream legal demands for the extended return flow analysis.

Table 19. Water rights in Area of Potential Impact

Water Right No.	All Owners	Purpose	Flow Rate (GPM)	Flow Rate (CFS)	Volume (AF)	Acres	Animal Units	Priority Date
41G 30123892**	TREASURED MOUNTAINS HOLDINGS LLC	STOCK	42.30	0.09	11.76	0	350	3/20/1876
41G 30124720**	TREASURED MOUNTAINS HOLDINGS LLC	STOCK	39.80	0.09	7.73	0	230	12/31/1885
41G 30017621	MONTANA, STATE OF DEPT OF FISH WILDLIFE & PARKS	FISHERY	4128.96	9.20	6660.04	0	0	7/1/1985
41G 212596-00*	TREASURED MOUNTAINS HOLDINGS LLC	IRRIGATION	920.04	2.05	150.38	73.00	0	6/30/1973

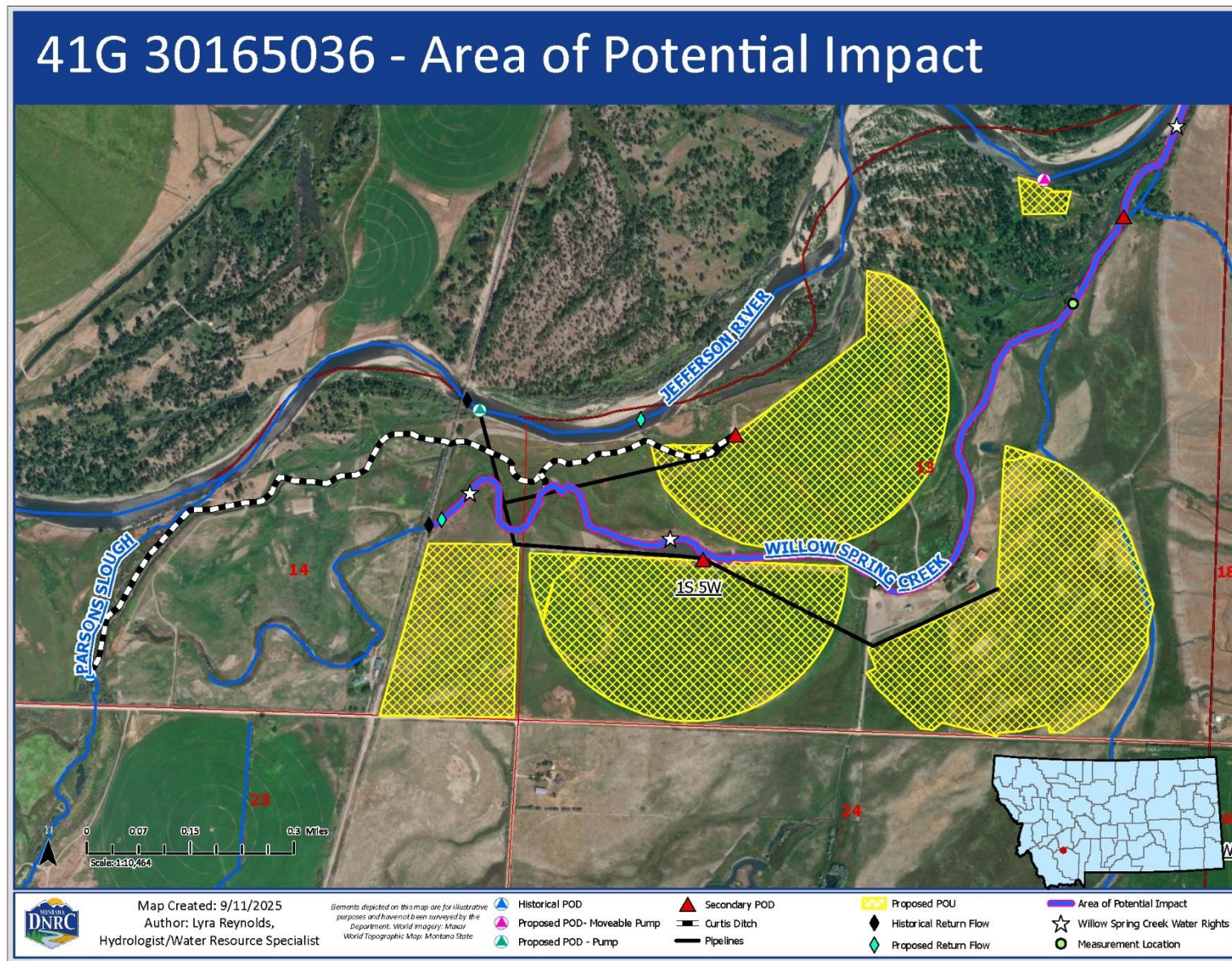


Figure 5. Area of potential impact for Change Application No. 41G 30165036

35. As water rights have been identified to be potentially impacted, the Department conducted an extended analysis of physical availability and downstream legal demands within the AOPI to analyze potential adverse effect of the proposed change. The Department utilized instantaneous streamflow measurements and linear interpolation to determine the availability of water in Willow Spring Creek. The streamflow measurements were collected by the Montana Bureau of Mines and Geology (MBMG) between 2020 and 2024. The streamflow measurements are from GWIC stream site ID 277126, Long/Lat -112.155823904°, 45.7526167° (SRID: NAD83). Using the methodology described in the Surface Water Change Report – Part A, dated March 21, 2025, and Surface Water Change Report – Part A Notice of Errata, the monthly streamflow for Willow Spring Creek was found. The Department multiplied the monthly flow rate in CFS by 1.983¹ and the number of days in the month to determine the monthly available volume in AF for each month. The monthly flow and volume based on the measurements and estimation technique for Willow Spring Creek is shown in Table 20.

Table 20. Monthly flow and volume for Willow Spring Creek

Month	Monthly Flow (CFS)	Monthly Volume (AF)
January	10.93	670.88
February	10.02	555.51
March	9.21	565.31
April	10.6	629.64
May	11.97	734.72
June	13.38	794.77
July	14.75	905.36
August	15.69	963.05
September	17.82	1058.51
October	17.95	1101.77
November	14.84	881.50
December	11.84	703.30

36. The location of return flows on Willow Spring Creek is located upstream of the location where streamflow was estimated. To estimate physical availability on the source, the flow rates and volumes of diversionary water rights between the measurement location and the return flow location were added to the monthly flow and volume. Two diversionary water rights, which are rights that do not remain instream for their beneficial use, exist between the measurement location and return flow location: Claims 41G 30123892 and 41G 212596-00. The flow rate and volume of the water rights were taken from the face value on the abstract. Water rights without an assigned flow rate or volume were quantified. Water rights requiring a volume quantification

¹ Conversion factor for CFS to AF.

are denoted with an asterisk and rights with a flow rate quantification are denoted with a plus in Table 19. The adjudication standard of 30 gallons per day per animal unit was used for stock water right volumes. Stock direct from source/ditch water rights were assigned a flow rate using 30 gallons per day per animal unit and adding 35 gallons per minute to the result. Irrigation rights were assigned a volume of 2.06 AF per acre, which is the low range of the Department's standard for applied volume at 60% efficiency in Climatic Area IV, per ARM 36.12.115. The physical availability at the return flow location on Willow Spring Creek is shown in Table 21.

Table 21. Physical availability of Willow Spring Creek

	Willow Spring Creek		Intervening Water Rights		Physical Availability	
Month	Monthly Flow (CFS)	Monthly Volume (AF)	Monthly Flow (CFS)	Monthly Volume (AF)	Flow (CFS)	Volume (AF)
January	10.93	671.90	0.1	1.0	11.0	672.9
February	10.02	556.35	0.1	0.9	10.1	557.3
March	9.21	566.17	0.1	1.0	9.3	567.2
April	10.60	630.59	0.1	1.0	10.7	631.6
May	11.97	735.83	2.1	28.7	14.1	764.6
June	13.38	795.98	2.1	27.8	15.5	823.8
July	14.75	906.73	2.1	28.7	16.9	935.5
August	15.69	964.51	2.1	28.7	17.8	993.3
September	17.82	1060.11	2.1	27.8	20.0	1087.9
October	17.95	1103.44	2.1	14.4	20.1	1117.9
November	14.84	882.83	0.1	1.0	14.9	883.8
December	11.84	704.36	0.1	1.0	11.9	705.4

37. The physical availability at the location of return flows was then compared to downstream legal demands in the AOPI and the change in return flows to assess potential adverse effect from the proposed change. The Department quantified the flow rate and volume of the downstream legal demands using the same methodology described above in FOF 31. Downstream legal demands are seen in Table 22 below.

Table 22. Downstream legal demands

Water Right No.	Flow Rate (CFS)	Volume (AF)
41G 30124720**	0.09	7.73
41G 30017621	9.20	6660.04
41G 212596-00*	2.05	150.38

38. The legal demands and loss of return flows were subtracted from the physical availability in Willow Spring Creek. The comparison of physical availability, legal demands, and net effect of return flows can be seen in Table 23 below.

Table 23. Comparison of physical availability and legal demands

Month	<u>Physical Availability</u>		<u>Intervening Water Rights</u>		<u>Loss of Return Flows</u>		<u>Net Effect</u>	
	Flow (CFS)	Volume (AF)	Monthly Flow (CFS)	Monthly Volume (AF)	Monthly Flow (CFS) ¹	Monthly Volume (AF)	Flow (CFS)	Volume (AF)
January	11.0	672.9	9.3	566.3	0.001	0.100	1.7	106.5
February	10.1	557.3	9.3	511.5	0.001	0.100	0.8	45.7
March	9.3	567.2	9.3	566.3	0.001	0.100	0.0	0.8
April	10.7	631.6	9.3	548.0	0.001	0.000	1.4	83.5
May	14.1	764.6	11.3	594.1	0.037	2.300	2.7	168.2
June	15.5	823.8	11.3	574.9	0.395	24.300	3.8	224.6
July	16.9	935.5	11.3	594.1	0.537	32.900	5.0	308.5
August	17.8	993.3	11.3	594.1	0.447	27.400	6.0	371.8
September	20.0	1087.9	11.3	574.9	0.020	1.200	8.6	511.8
October	20.1	1117.9	11.3	579.7	0.003	0.200	8.8	537.9
November	14.9	883.8	9.3	548.0	0.002	0.100	5.6	335.7
December	11.9	705.4	9.3	566.3	0.002	0.100	2.6	139.0
¹ Flow rate converted from GPM to CFS using 1 CFS = 448.8 GPM								

39. The physical availability of water exceeds or is equal to the legal demands and loss of return flows in the AOPI for all months. The Department finds the change in return flows will not adversely affect water rights in the AOPI.

40. The Applicant proposes to leave water instream at the historical POD. Water left instream will be left in Parsons Slough, which flows into the Jefferson River. Any diversions from the Jefferson River pump sites cannot exceed the measured amount of water available in Parsons Slough. Water diverted through the historical headgate will be diverted at a lower flow rate than historically. Other water rights in Parsons Slough, the Jefferson River, and Willow Spring Creek will not be adversely affected, as all diversions under Claim 41G 197111-00 will be less than historically. No adverse effect will occur in the identified areas, which includes all flow paths from the historical POD to the confluence of Willow Spring Creek and the Jefferson River.

41. The Department finds the proposed change to Claim 41G 197111-00 will not create an adverse effect.

BENEFICIAL USE

FINDINGS OF FACT

42. The Applicant is not changing the purpose of the water right proposed for change, which is remaining irrigation, a recognized beneficial use of water in the state of Montana.

43. The Applicant proposes to divert 564.9 AF at a maximum flow rate of 4.26 CFS and consume 238.3 AF for continued irrigation use. A total of 199.5 acres will be irrigated following the proposed change. The Department used the Department's standards outlined in ARM 36.12.1902 to determine the proposed use of Claim 41G 197111-00.

44. The Department finds the continued use of Claim 41G 197111-00 for irrigation of 199.5 acres is a beneficial use of water.

ADEQUATE DIVERSION

FINDINGS OF FACT

45. The Applicant proposes to add a permanent pump site and a moveable pump site to divert water under Claim 41G 197111-00. The permanent pump site in the Jefferson River is a 60 HP variable speed turbine pump that will be limited to a maximum flow rate of 4.04 CFS. Water conveyed through 10-inch and 8-inch PVC buried mainlines to either pivot sprinklers or wheeline sprinkler systems. The center pivot sprinkler systems will use low pressure drop nozzles with a 2 HP pump supplying the Nelson end guns. The wheel line sprinkler system will consist of self-leveling impulse type sprinklers spaced at the standard 40 feet apart, each supplying approximately 8.5 GPM. The moveable pump site in the Jefferson River is a 14 HP gasoline powered pump, capable of diverting up to 100 GPM, that supplies a sprinkler gun fitted with a 16mm nozzle. Water diverted at the moveable pump site is conveyed through a 2-inch flexible plastic hose to the sprinkler gun, which applies water to the 1.6-field in the NE Section 13, T1S, R5W, Madison County.

46. When the system is fully operational, only the permanent pump and moveable pump sites will be operated. Water will flow from Parsons Slough to the pump sites in the Jefferson River for diversions. Together, the new diversions have a maximum capacity of 4.26 CFS. The permanent pump site will be installed in a manner that limits its operations if the Jefferson River has a flow rate less than 100 CFS. In the event the Jefferson River is below 100 CFS and the pump sites are not operational, the Applicant will divert water through the historical point of diversion. Water will be conveyed from the historical headgate through the Curtis Ditch to secondary diversions. Some water from the Curtis Ditch will also be conveyed through Willow Spring Creek, which will act as a natural carrier, to secondary points of diversion. The secondary diversions will convey water to the sprinkler systems on three fields (Fields B, D, and E in Figure 4) for field application. Only 3.39 CFS is proposed for diversion through the historical diversion when in use because of decreased operational needs. The historical diversion can be controlled to limit flow to 3.39 CFS.

47. The Applicant proposes to limit total diversions to 4.26 CFS based on the irrigation system supply needs. The irrigation system requirements were determined by a professional sprinkler system designer. The proposed diversion structures can be adjusted to limit the flow rate that is diverted at any time. The Applicant will be required to provide measurements if this change is authorized.

48. The proposed diversion and conveyance systems have capacities capable of diverting the proposed flow rate of 4.26 CFS. The historical diversion structure can be controlled to limit flow to the proposed 3.39 CFS flow rate. The Department finds the proposed means of diversion and conveyance to be adequate.

POSSESSORY INTEREST

FINDINGS OF FACT

49. The Applicant signed the affidavit on the application form affirming the Applicant has possessory interest, or the written consent of the person with the possessory interest, in the property where the water is to be put to beneficial use. (Change Application No. 41G 30165036 file).

CONCLUSIONS OF LAW

HISTORICAL USE AND ADVERSE EFFECT

50. Montana's change statute codifies the fundamental principles of the Prior Appropriation Doctrine. Sections 85-2-401 and -402(1)(a), MCA, authorize changes to existing water rights, permits, and water reservations subject to the fundamental tenet of Montana water law that one may change only that to which he or she has the right based upon beneficial use. A change to an existing water right may not expand the consumptive use of the underlying right or remove the well-established limit of the appropriator's right to water actually taken and beneficially used. An increase in consumptive use constitutes a new appropriation and is subject to the new water use permit requirements of the MWUA. *McDonald v. State*, 220 Mont. 519, 530, 722 P.2d 598, 605 (1986) (beneficial use constitutes the basis, measure, and limit of a water right); *Featherman v. Hennessy*, 43 Mont. 310, 316-17, 115 P. 983, 986 (1911) (increased consumption associated with expanded use of underlying right amounted to new appropriation rather than change in use); *Quigley v. McIntosh*, 110 Mont. 495, 103 P.2d 1067, 1072-74 (1940) (appropriator may not expand a water right through the guise of a change – expanded use constitutes a new use with a new priority date junior to intervening water uses); *Allen v. Petrick*, 69 Mont. 373, 222 P. 451(1924) ("quantity of water which may be claimed lawfully under a prior appropriation is limited to that

quantity within the amount claimed which the appropriator has needed, and which within a reasonable time he has actually and economically applied to a beneficial use. . . . it may be said that the principle of beneficial use is the one of paramount importance . . . The appropriator does not own the water. He has a right of ownership in its use only”); *Town of Manhattan*, ¶ 10 (an appropriator’s right only attaches to the amount of water actually taken and beneficially applied).²

51. Sections 85-2-401(1) and -402(2)(a), MCA, codify the prior appropriation principles that Montana appropriators have a vested right to maintain surface and ground water conditions substantially as they existed at the time of their appropriation; subsequent appropriators may insist that prior appropriators confine their use to what was actually appropriated or necessary for their originally intended purpose of use; and, an appropriator may not change or alter its use in a manner that adversely affects another water user. *Spokane Ranch & Water Co. v. Beatty*, 37 Mont. 342, 96 P. 727, 731 (1908); *Quigley*, 110 Mont. at 505-11, 103 P.2d at 1072-74; *Matter of Royston*, 249 Mont. at 429, 816 P.2d at 1057; *Hohenlohe*, ¶¶ 43-45.³

52. The cornerstone of evaluating potential adverse effect to other appropriators is the determination of the “historic use” of the water right being changed. *Town of Manhattan*, ¶10 (recognizing that the Department’s obligation to ensure that change will not adversely affect other water rights requires analysis of the actual historic amount, pattern, and means of water use). A change Applicant must prove the extent and pattern of use for the underlying right proposed for change through evidence of the historic diverted amount, consumed amount, place of use, pattern of use, and return flow because a statement of claim, permit, or decree may not include the beneficial use information necessary to evaluate the amount of water available for change or potential for adverse effect.⁴ A comparative analysis of the historic use of the water right to the proposed change in use is necessary to prove the change will not result in expansion of the original right, or adversely affect water users who are entitled to rely upon maintenance of

² DNRC decisions are available at: <https://dnrc.mt.gov/Directors-Office/HearingOrders>

³ See also *Holmstrom Land Co., Inc., v. Newlan Creek Water District*, 185 Mont. 409, 605 P.2d 1060 (1979); *Lokowich v. Helena*, 46 Mont. 575, 129 P. 1063 (1913); *Thompson v. Harvey*, 164 Mont. 133, 519 P.2d 963 (1974) (plaintiff could not change his diversion to a point upstream of the defendants because of the injury resulting to the defendants); *McIntosh v. Graveley*, 159 Mont. 72, 495 P.2d 186 (1972) (appropriator was entitled to move his point of diversion downstream, so long as he installed measuring devices to ensure that he took no more than would have been available at his original point of diversion); *Head v. Hale*, 38 Mont. 302, 100 P. 222 (1909) (successors of the appropriator of water appropriated for placer mining purposes cannot so change its use as to deprive lower appropriators of their rights, already acquired, in the use of it for irrigating purposes); and, *Gassett v. Noyes*, 18 Mont. 216, 44 P. 959 (1896) (change in place of use was unlawful where reduced the amount of water in the source of supply available which was subject to plaintiff’s subsequent right).

⁴A claim only constitutes *prima facie* evidence for the purposes of the adjudication under § 85-2-221, MCA. The claim does not constitute *prima facie* evidence of historical use in a change proceeding under § 85-2-402, MCA. For example, most water rights decreed for irrigation are not decreed with a volume and provide limited evidence of actual historic beneficial use. Section 85-2-234, MCA

conditions on the source of supply for their water rights. *Quigley*, 103 P.2d at 1072-75 (it is necessary to ascertain historic use of a decreed water right to determine whether a change in use expands the underlying right to the detriment of other water user because a decree only provides a limited description of the right); *Royston*, 249 Mont. at 431-32, 816 P.2d at 1059-60 (record could not sustain a conclusion of no adverse effect because the Applicant failed to provide the Department with evidence of the historic diverted volume, consumption, and return flow); *Hohenlohe*, ¶ 44-45; *Town of Manhattan v. DNRC*, Cause No. DV-09-872C, Montana Eighteenth Judicial District Court, *Order Re Petition for Judicial Review*, Pgs. 11-12 (proof of historic use is required even when the right has been decreed because the decreed flow rate or volume establishes the maximum appropriation that may be diverted, and may exceed the historical pattern of use, amount diverted or amount consumed through actual use); *Matter of Application For Beneficial Water Use Permit By City of Bozeman*, *Memorandum*, Pgs. 8-22 (Adopted by DNRC *Final Order* January 9, 1985)(evidence of historic use must be compared to the proposed change in use to give effect to the implied limitations read into every decreed right that an appropriator has no right to expand his appropriation or change his use to the detriment of juniors).⁵

53. An Applicant must also analyze the extent to which a proposed change may alter historic return flows for purposes of establishing that the proposed change will not result in adverse effect.

⁵ Other western states likewise rely upon the doctrine of historic use as a critical component in evaluating changes in appropriation rights for expansion and adverse effect: *Pueblo West Metropolitan District v. Southeastern Colorado Water Conservancy District*, 717 P.2d 955, 959 (Colo. 1986)("[O]nce an appropriator exercises his or her privilege to change a water right ... the appropriator runs a real risk of requantification of the water right based on actual historical consumptive use. In such a change proceeding a junior water right ... which had been strictly administered throughout its existence would, in all probability, be reduced to a lesser quantity because of the relatively limited actual historic use of the right."); *Santa Fe Trail Ranches Property Owners Ass'n v. Simpson*, 990 P.2d 46, 55 -57 (Colo., 1999); *Farmers Reservoir and Irr. Co. v. City of Golden*, 44 P.3d 241, 245 (Colo. 2002)("We [Colorado Supreme Court] have stated time and again that the need for security and predictability in the prior appropriation system dictates that holders of vested water rights are entitled to the continuation of stream conditions as they existed at the time they first made their appropriation"); *Application for Water Rights in Rio Grande County*, 53 P.3d 1165, 1170 (Colo. 2002); Wyo. Stat. § 41-3-104 (When an owner of a water right wishes to change a water right ... he shall file a petition requesting permission to make such a change The change ... may be allowed provided that the quantity of water transferred ... shall not exceed the amount of water historically diverted under the existing use, nor increase the historic rate of diversion under the existing use, nor increase the historic amount consumptively used under the existing use, nor decrease the historic amount of return flow, nor in any manner injure other existing lawful appropriators.); *Basin Elec. Power Co-op. v. State Bd. of Control*, 578 P.2d 557, 564 -566 (Wyo, 1978) (a water right holder may not effect a change of use transferring more water than he had historically consumptively used; regardless of the lack of injury to other appropriators, the amount of water historically diverted under the existing use, the historic rate of diversion under the existing use, the historic amount consumptively used under the existing use, and the historic amount of return flow must be considered.)

The requisite return flow analysis reflects the fundamental tenant of Montana water law that once water leaves the control of the original appropriator, the original appropriator has no right to its use and the water is subject to appropriation by others. *E.g.*, *Hohenlohe*, ¶ 44; *Rock Creek Ditch & Flume Co. v. Miller*, 93 Mont. 248, 17 P.2d 1074, 1077 (1933); *Newton v. Weiler*, 87 Mont. 164, 286 P. 133 (1930); *Popham v. Holloron*, 84 Mont. 442, 275 P. 1099, 1102 (1929); *Galiger v. McNulty*, 80 Mont. 339, 260 P. 401 (1927); *Head v. Hale*, 38 Mont. 302, 100 P. 222 (1909); *Spokane Ranch & Water Co.*, 37 Mont. at 351-52, 96 P. at 731; *Hidden Hollow Ranch v. Fields*, 2004 MT 153, 321 Mont. 505, 92 P.3d 1185; ARM 36.12.101(56) (Return flow - that part of a diverted flow which is not consumed by the appropriator and returns underground to its original source or another source of water - is not part of a water right and is subject to appropriation by subsequent water users).⁶

54. Although the level of analysis may vary, analysis of the extent to which a proposed change may alter the amount, location, or timing return flows is critical in order to prove that the proposed change will not adversely affect other appropriators who rely on those return flows as part of the source of supply for their water rights. *Royston*, 249 Mont. at 431, 816 P.2d at 1059-60; *Hohenlohe*, at ¶¶ 45-46 and 55-6; *Spokane Ranch & Water Co.*, 37 Mont. at 351-52, 96 P. at 731.

55. In *Royston*, the Montana Supreme Court confirmed that an Applicant is required to prove lack of adverse effect through comparison of the proposed change to the historic use, historic consumption, and historic return flows of the original right. 249 Mont. at 431, 816 P.2d at 1059-60. More recently, the Montana Supreme Court explained the relationship between the fundamental principles of historic beneficial use, return flow, and the rights of subsequent appropriators as they relate to the adverse effect analysis in a change proceeding in the following manner:

The question of adverse effect under §§ 85-2-402(2) and -408(3), MCA, implicates return flows. A change in the amount of return flow, or to the hydrogeologic pattern of return flow, has the potential to affect adversely downstream water rights. There consequently exists an inextricable link between the “amount historically consumed” and the water that re-enters the stream as return flow. . . .

An appropriator historically has been entitled to the greatest quantity of water he can put to use. The requirement that the use be both beneficial and reasonable, however, proscribes this tenet. This limitation springs from a fundamental tenet of

⁶ The Montana Supreme Court recently recognized the fundamental nature of return flows to Montana’s water sources in addressing whether the Mitchell Slough was a perennial flowing stream, given the large amount of irrigation return flow which feeds the stream. The Court acknowledged that the Mitchell’s flows are fed by irrigation return flows available for appropriation. *Bitterroot River Protective Ass’n, Inc. v. Bitterroot Conservation Dist.*, 2008 MT 377, ¶¶ 22, 31, 43, 346 Mont. 508, 198 P.3d 219, (citing *Hidden Hollow Ranch v. Fields*, 2004 MT 153, 321 Mont. 505, 92 P.3d 1185).

western water law-that an appropriator has a right only to that amount of water historically put to beneficial use-developed in concert with the rationale that each subsequent appropriator “is entitled to have the water flow in the same manner as when he located,” and the appropriator may insist that prior appropriators do not affect adversely his rights.

This fundamental rule of Montana water law has dictated the Department’s determinations in numerous prior change proceedings. The Department claims that historic consumptive use, as quantified in part by return flow analysis, represents a key element of proving historic beneficial use.

We do not dispute this interrelationship between historic consumptive use, return flow, and the amount of water to which an appropriator is entitled as limited by his past beneficial use.

Hohenlohe, at ¶¶ 42-45 (internal citations omitted).

56. The Department’s rules reflect the above fundamental principles of Montana water law and are designed to itemize the type evidence and analysis required for an Applicant to meet its burden of proof. ARM 36.12.1901 through 1903. These rules forth specific evidence and analysis required to establish the parameters of historic use of the water right being changed. ARM 36.12.1901 and 1902. The rules also outline the analysis required to establish a lack of adverse effect based upon a comparison of historic use of the water rights being changed to the proposed use under the changed conditions along with evaluation of the potential impacts of the change on other water users caused by changes in the amount, timing, or location of historic diversions and return flows. ARM 36.12.1901 and 1903.

57. Applicant seeks to change existing water rights represented by its Water Right Claims. The “existing water rights” in this case are those as they existed prior to July 1, 1973, because with limited exception, no changes could have been made to those rights after that date without the Department’s approval. Analysis of adverse effect in a change to an “existing water right” requires evaluation of what the water right looked like and how it was exercised prior to July 1, 1973. In *McDonald v. State*, the Montana Supreme Court explained:

The foregoing cases and many others serve to illustrate that what is preserved to owners of appropriated or decreed water rights by the provision of the 1972 Constitution is what the law has always contemplated in this state as the extent of a water right: such amount of water as, by pattern of use and means of use, the owners or their predecessors put to beneficial use. . . . the Water Use Act contemplates that all water rights, regardless of prior statements or claims as to amount, must nevertheless, to be recognized, pass the test of historical, unabandoned beneficial use. . . . To that extent only the 1972 constitutional recognition of water rights is effective and will be sustained.

220 Mont. at 529, 722 P.2d at 604; *see also Matter of Clark Fork River Drainage Area*, 254 Mont. 11, 17, 833 P.2d 1120 (1992).

58. Water Resources Surveys were authorized by the 1939 legislature. 1939 Mont. Laws Ch. 185, § 5. Since their completion, Water Resources Surveys have been invaluable evidence in water right disputes and have long been relied on by Montana courts. *In re Adjudication of Existing Rights to Use of All Water in North End Subbasin of Bitterroot River Drainage Area in Ravalli and Missoula Counties*, 295 Mont. 447, 453, 984 P.2d 151, 155 (1999) (Water Resources Survey used as evidence in adjudicating of water rights); *Wareing v. Schreckendgust*, 280 Mont. 196, 213, 930 P.2d 37, 47 (1996) (Water Resources Survey used as evidence in a prescriptive ditch easement case); *Olsen v. McQueary*, 212 Mont. 173, 180, 687 P.2d 712, 716 (1984) (judicial notice taken of Water Resources Survey in water right dispute concerning branches of a creek).

59. While evidence may be provided that a particular parcel was irrigated, the actual amount of water historically diverted and consumed is critical. *E.g.*, *In the Matter of Application to Change Water Right No. 41H 1223599 by MGRR #1, LLC.*, DNRC Proposal for Decision adopted by Final Order (2005). The Department cannot assume that a parcel received the full duty of water or that it received sufficient water to constitute full-service irrigation for optimum plant growth. Even when it seems clear that no other rights could be affected solely by a particular change in the location of diversion, it is essential that the change also not enlarge an existing right. *See MacDonald*, 220 Mont. at 529, 722 P.2d at 604; *Featherman*, 43 Mont. at 316-17, 115 P. at 986; *Trail's End Ranch, L.L.C. v. Colorado Div. of Water Resources*, 91 P.3d 1058, 1063 (Colo., 2004).

60. The Department has adopted a rule providing for the calculation of historic consumptive use where the Applicant proves by a preponderance of the evidence that the acreage was historically irrigated. ARM 36.12.1902(16). In the alternative an Applicant may present its own evidence of historic beneficial use. In this case Applicant has elected to proceed under ARM 36.12.1902. (FOF No. 14).

61. If an Applicant seeks more than the historic consumptive use as calculated by ARM 36.12.1902(16), the Applicant bears the burden of proof to demonstrate the amount of historic consumptive use by a preponderance of the evidence. The actual historic use of water could be less than the optimum utilization represented by the calculated duty of water in any particular case. *E.g.*, *Application for Water Rights in Rio Grande County*, 53 P.3d 1165 (Colo., 2002) (historical use must be quantified to ensure no enlargement); *In the Matter of Application to Change Water Right No. 41H 1223599 by MGRR #1, LLC.*; *Orr v. Arapahoe Water and Sanitation Dist.*, 753 P.2d 1217, 1223-1224 (Colo., 1988) (historical use of a water right could very well be less than the duty of water); *Weibert v. Rothe Bros., Inc.*, 200 Colo. 310, 317, 618 P.2d 1367, 1371 - 1372 (Colo. 1980) (historical use could be less than the optimum utilization "duty of water").

62. Based upon the Applicant's evidence of historic use, the Applicant has proven by a preponderance of the evidence the historic use of Claim 41G 197111-00 to be a diverted volume of 897 AF, a historically consumed volume of 256.7 AF, and flow rate of 9.48 CFS. (FOF Nos. 10 - 18)

63. Based upon the Applicant's comparative analysis of historic water use and return flows to water use and return flows under the proposed change, the Applicant has proven that the proposed change in appropriation right will not adversely affect the use of the existing water rights of other persons or other perfected or planned uses or developments for which a permit or certificate has been issued or for which a state water reservation has been issued. Section 85-2-402(2)(a), MCA. (FOF Nos. 19 - 41)

BENEFICIAL USE

64. A change Applicant must prove by a preponderance of the evidence the proposed use is a beneficial use. Sections 85-2-102(4) and -402(2)(c), MCA. Beneficial use is and has always been the hallmark of a valid Montana water right: "[T]he amount actually needed for beneficial use within the appropriation will be the basis, measure, and the limit of all water rights in Montana . . ." McDonald, 220 Mont. at 532, 722 P.2d at 606. The analysis of the beneficial use criterion is the same for change authorizations under §85-2-402, MCA, and new beneficial permits under §85-2-311, MCA. ARM 36.12.1801. The amount of water that may be authorized for change is limited to the amount of water necessary to sustain the beneficial use. *E.g., Bitterroot River Protective Association v. Siebel, Order on Petition for Judicial Review*, Cause No. BDV-2002-519 (Mont. 1st Jud. Dist. Ct.) (2003) (*affirmed on other grounds*, 2005 MT 60, 326 Mont. 241, 108 P.3d 518); *Worden v. Alexander*, 108 Mont. 208, 90 P.2d 160 (1939); *Allen v. Petrick*, 69 Mont. 373, 222 P. 451(1924); *Sitz Ranch v. DNRC*, DV-10-13390,, *Order Affirming DNRC Decision*, Pg. 3 (Mont. 5th Jud. Dist. Ct.) (2011) (citing *BRPA v. Siebel*, 2005 MT 60, and rejecting Applicant's argument that it be allowed to appropriate 800 acre-feet when a typical year would require 200-300 acre-feet); *Toohey v. Campbell*, 24 Mont. 13, 60 P. 396 (1900) ("The policy of the law is to prevent a person from acquiring exclusive control of a stream, or any part thereof, not for present and actual beneficial use, but for mere future speculative profit or advantage, without regard to existing or contemplated beneficial uses. He is restricted in the amount that he can appropriate to the quantity needed for such beneficial purposes."); § 85-2-312(1)(a), MCA (DNRC is statutorily prohibited from issuing a permit for more water than can be beneficially used).

65. Applicant proposes to use water for irrigation which is a recognized beneficial use. Section 85-2-102(5), MCA. Applicant has proven by a preponderance of the evidence irrigation is a

beneficial use and that 564.9 acre-feet of diverted volume and 4.26 CFS flow rate of water requested is the amount needed to sustain the beneficial use and is within the standards set by DNRC Rule. Section 85-2-402(2)(c), MCA (FOF Nos. 42 - 44).

ADEQUATE MEANS OF DIVERSION

66. Pursuant to § 85-2-402 (2)(b), MCA, the Applicant must prove by a preponderance of the evidence that the proposed means of diversion, construction, and operation of the appropriation works are adequate. This codifies the prior appropriation principle that the means of diversion must be reasonably effective for the contemplated use and may not result in a waste of the resource. *Crowley v. 6th Judicial District Court*, 108 Mont. 89, 88 P.2d 23 (1939); *In the Matter of Application for Beneficial Water Use Permit No. 41C-11339900 by Three Creeks Ranch of Wyoming LLC* (DNRC Final Order 2002) (information needed to prove that proposed means of diversion, construction, and operation of the appropriation works are adequate varies based upon project complexity; design by licensed engineer adequate).

67. Pursuant to § 85-2-402 (2)(b), MCA, Applicant has proven by a preponderance of the evidence that the proposed means of diversion, construction, and operation of the appropriation works are adequate for the proposed beneficial use. (FOF Nos. 45 - 48)

POSSESSORY INTEREST

68. Pursuant to § 85-2-402(2)(d), MCA, the Applicant must prove by a preponderance of the evidence that it has a possessory interest, or the written consent of the person with the possessory interest, in the property where the water is to be put to beneficial use. See also ARM 36.12.1802.

69. The Applicant has proven by a preponderance of the evidence that it has a possessory interest, or the written consent of the person with the possessory interest, in the property where the water is to be put to beneficial use. (FOF No. 49).

PRELIMINARY DETERMINATION

Subject to the terms and analysis in this Preliminary Determination Order, the Department preliminarily determines that this Application to Change Water Right No. 41G 30165036 should be GRANTED subject to the following.

The Applicant is authorized to change the point of diversion and place of use of Statement of Claim 41G 197111-00. The Applicant is authorized to divert from Parsons Slough from May 1 to October 15 at three primary points of diversion, seen in Table 24. Under Claim 41G 197111-00, the Applicant may divert a maximum volume of 564.7 AF and consume a volume of 238.3 AF at a flow rate of 4.26 CFS for irrigation of 199.5 acres from May 1 to October 15. The authorized

place of use for irrigation is seen in Table 25 below. The maximum flow rate and volume that will be diverted from Parsons Slough by the water right proposed for change cannot exceed 4.26 CFS and 564.7 AF.

Table 24. Legal land descriptions for the authorized points of diversion

Diversion Means	QTR	Section	Township	Range	County	Authorized Flow Rate
Headgate	SESESW	14	1S	5W	Madison	3.39 CFS
Permanent Pump	NENESE	14	1S	5W	Madison	4.03 CFS
Moveable Pump	SEWNNE	13	1S	5W	Madison	0.23 CFS

Table 25. Legal land descriptions for the authorized place of use

Acres	QTR	Section	Township	Range	County
25.7	SESE	14	1S	5W	Madison
160.9	S2	13	1S	5W	Madison
8.1	SWNE	13	1S	5W	Madison
3.2	SEWN	13	1S	5W	Madison
0.3	SWNNE	13	1S	5W	Madison
1.3	SEWNNE	13	1S	5W	Madison

The following conditions will be placed on this authorization:

WATER MEASUREMENT INFORMATION

THE APPROPRIATOR SHALL INSTALL A DEPARTMENT APPROVED MEASURING DEVICE IN PARSONS SLOUGH AT A POINT APPROVED BY THE DEPARTMENT. THE APPROPRIATOR SHALL KEEP A WRITTEN RECORD OF THE FLOW IN PARSONS SLOUGH WHEN THEY ARE IRRIGATING THE PLACE OF USE FROM THE JEFFERSON RIVER PUMP SITES. THE ABILITY TO DIVERT PARSONS SLOUGH WATER OUT OF THE JEFFERSON RIVER AS GRANTED BY THIS CHANGE AUTHORIZATION SHALL BE BASED UPON MEASUREMENTS, AND DIVERSIONS CANNOT EXCEED THE AMOUNT MEASURED IN PARSONS SLOUGH. THE APPROPRIATOR SHALL MAINTAIN THE MEASURING DEVICE SO THAT THE MEASURING DEVICE ALWAYS OPERATES PROPERLY AND MEASURES FLOW ACCURATELY. ON A FORM PROVIDED BY THE DEPARTMENT, THE APPROPRIATOR SHALL KEEP A MONTHLY WRITTEN RECORD OF FLOW. RECORDS SHALL BE SUBMITTED TO THE DEPARTMENT BY NOVEMBER 30TH OF EACH YEAR AND UPON REQUEST AT OTHER TIMES DURING THE YEAR.

IMPORTANT INFORMATION

THE HISTORICAL DITCH DIVERSION MAY ONLY DIVERT WATER FROM PARSONS SLOUGH WHEN THE PUMP SITES IN THE JEFFERSON RIVER ARE NOT IN OPERATION.

NOTICE

The Department will provide a notice of opportunity for public comment on this Application and the Department's Draft Preliminary Determination to Grant pursuant to § 85-2-307, MCA. The Department will set a deadline for public comments to this Application pursuant to §§ 85-2-307, and -308, MCA. If this Application receives public comment, the Department shall consider the public comments, respond to the public comments, and issue a preliminary determination to grant the application, grant the application in modified form, or deny the application. If no public comments are received pursuant to § 85-2-307(4), MCA, the Department's preliminary determination will be adopted as the final determination.

Dated this 19th day of September, 2025.



Kerri Strasheim, Manager
Bozeman Regional Office
Montana Department of Natural Resources and Conservation

REVISED 12-2023

CERTIFICATE OF SERVICE

This certifies that a true and correct copy of the DRAFT PRELIMINARY DETERMINATION TO GRANT was served upon all parties listed below on this 19th day of September, 2025, by first class United States mail.

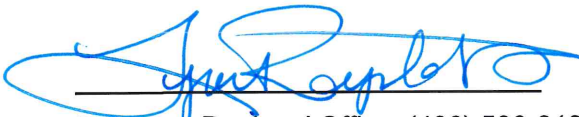
TREASURED MOUNTAINS HOLDINGS, LLC

ATTN: BILL GOULDD

5653 MONTEREY DRIVE

FRISCO, TX 75034-4076

CC, VIA EMAIL: ANDY BRUMMOND, ABRUMMOND@MT.GOV

A handwritten signature in blue ink, appearing to read "Justin Repleto", is written over a horizontal line.

Bozeman Regional Office, (406) 586-3136

THE MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

GOVERNOR GREG GIANFORTE



DNRC DIRECTOR AMANDA KASTER

DNRC

2273 Boot Hill Ct, STE 110

Bozeman, MT 59715

406-586-3136

September 19, 2025

Treasured Mountains Holdings LLC

Attn: Bill Gould

5653 Monterey Drive

Frisco, TX 75034-4076

Subject: Draft Preliminary Determination to Grant Beneficial Water Use Permit Application No. 41G 30165036

Dear Applicant:

The Department of Natural Resources and Conservation (Department or DNRC) has completed a preliminary review of your application. This review consists of an evaluation of the criteria for issuance of a change authorization found in §85-2-402, MCA. The Department has preliminarily determined that the criteria are met, and this application should be granted. A copy of the Draft Preliminary Determination to Grant your application is attached.

You have the opportunity to request an extension of time to submit additional information for the Department to consider in the decision, within 15 business days of the date of this letter. If no response is received by October 10, 2025, the Department will prepare a notice of opportunity to provide public comment per §85-2-307(4), MCA.

Please note that if you are granted an extension of time to submit additional information to the Department, additional information may be considered an amendment to your application, which may reset application timelines pursuant to ARM 36.12.1401.

Sincerely,

A handwritten signature in blue ink, appearing to read "Lyra Reynolds", is written over a horizontal line.

Lyra Reynolds

Hydrologist/Water Resources Specialist

Bozeman Water Resources Office

Water Resources Division

Cc, via email: Andy Brummond, abrummond@mt.gov



DNRC.MT.GOV



Draft Preliminary Determination to Grant Beneficial Water Use Permit Application No. 41G 30165036

From Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Date Fri 9/19/2025 3:10 PM

To Brummond, Andy <abrummond@mt.gov>

Cc Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

 1 attachment (4 MB)

606_SW_DraftPD_GRANT_41G-30165036_TreasuredMountains_Signed.pdf;

Andy-

The Department of Natural Resources and Conservation (Department or DNRC) has completed a preliminary review of Change Application 41G 30165036 by Treasured Mountains Holdings, LLC. The Department has preliminarily determined that the criteria are met, and this application should be granted. A copy of the Draft Preliminary Determination to Grant this application is attached, along with the letter sent to the Applicant today 9/19/2025.

You have the opportunity to request an extension of time to submit additional information for the Department to consider in the decision, within 15 business days of the date of this letter. If no response is received by October 10, 2025, the Department will prepare a notice of opportunity to provide public comment per §85-2-307(4), MCA.

Please do not hesitate to contact us with any questions.

-Lyra



Lyra Reynolds (they/them/she/her) | Hydrologist/Specialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-4500 **EMAIL:** lyra.reynolds@mt.gov
[Website](#) | [Facebook](#) | [X \(Twitter\)](#) | [Instagram](#)
How did we do? Let us know here: [Feedback Survey](#)

Processing Materials

- Work copies of applicant-submitted information
- Deficiency letter
- Deficiency response
- Correct & complete determination
- Any correspondence with the applicant after application receipt and prior to sending the Draft PD

Processing Materials

THE MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

GOVERNOR GREG GIANFORTE



DNRC DIRECTOR AMANDA KASTER

Bozeman Water Resources Office
2273 Boot Hill Court, Suite 110
Bozeman, MT 59715
(406) 586-3136

July 23, 2025

Treasured Mountains Holdings, LLC
Attn: Bill Gould
5653 Monterey Drive
Frisco, TX 75034-4076

Subject: Correct and Complete Application for Change No. 41G 30165036

Dear Applicant:

The Department of Natural Resources and Conservation (DNRC) has determined that your application is correct and complete pursuant to ARM 36.12.1601. Please remember that correct and complete does not mean that your application will be granted. The purpose of this letter is to indicate that the Department has enough information to analyze your water right application.

The Department will issue a Draft Preliminary Determination within 60 days of the date of this letter per §85-2-307(2)(b), MCA.

Following issuance of the Draft Preliminary Determination, you (Applicant) will have 15 business days to request an extension of time to submit additional information, if desired pursuant to §85-2-307(3)(a), MCA.

If no extension of time is requested and the Draft Preliminary Determination decision is to grant your application or grant your application in modified form, the Department will prepare a notice of opportunity to provide public comment, per §85-2-307(4)(a), MCA.



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If no extension of time is requested and the Draft Preliminary Determination decision is to deny your application, the Department will adopt the Draft Preliminary Determination as the final determination per §85-2-307(3)(d)(ii), MCA.

If you have any questions or concerns about the application process, please contact me.

Respectfully,



Derek Rasmussen

Water Resources Specialist

Bozeman Water Resources Office

Montana Department of Natural Resources and Conservation

CC, via email: Andy Brummond, abrummond@mt.gov





PO Box 938
Lewistown, MT 59457-0938

June 24, 2025

Derek Rasmussen
DNRC Bozeman Water Resources Office
2273 Boot Hill CT, STE 110
Bozeman, MT 59715
(delivered via email)

RE: Application 41G 30165036 Deficiency Response

Dear Derek:

This letter is in response to your May 15, 2025, Deficiency Letter for Change Application 41G 30165036. Following I address the issues raised in the same order as your letter:

APPLICATION DETAILS – ARM 36.12.1305

13. The flow rated needed under the proposed change is less than that historically diverted because no flood irrigation will occur under the proposed change and because the acreage irrigated is being somewhat reduced. The amount of water no longer needed for irrigation will be changed to instream flow in Parsons Slough under subsequent water right change application. In the event the new Jefferson River pump site immediately below the railroad bridge is not operable, the historic Parsons Slough point of diversion and Curtis Ditch will be used to supply only the two currently existing pivots. In this circumstance, the flow rate needed to supply these two existing pivots through the ditch along with providing 100 gpm to the new 1.6 acre-place of use near the confluence of Willow Spring Creek with the Jefferson River will be less than the full 4.26 cfs needed when the new Jefferson Pump immediately below the railroad bridge is in operation.

19.a. The following amended table includes the unchanged, existing Parsons Slough point of diversion. POD ID #4 from Willow Spring Creek is a secondary point of diversion that would be used when water is being diverted from Parsons Slough via the Curtis Ditch. The other three points of diversion are primary points of diversion.

19.a. Describe the location for all *new* and *unchanged* points of diversion to the nearest 10 acres. Label POD ID with the same POD ID number assigned for the proposed use map (question 18).

POD ID	¼	¼	¼	Sec.	Twp.	Rge.	County	Lot	Block	Tract	Subdivision	Gov. Lot	New or Unchanged
2	NE	NE	SE	14	1S	5W	Madison						New
3	SE	NW	NE	13	1S	5W	Madison						New
4	W2	E2	NE	13	1S	5W	Madison						New
1	SE	SE	SW	14	1S	5W	Madison						Unchanged

ADEQUATE MEANS OF DIVERSION AND OPERATION – ARM 36.12.1904

36. The discussion during the pre-application meeting centered on whether POD ID #4 from Willow Spring Creek could serve as a primary point of diversion for the water right being changed from Parsons Slough. Precedent cited in the change application provides that this change in source is allowable as long as no other water rights would be adversely affected. However, to avoid potential disagreement on this issue, the Willow Spring Creek POD ID #4 will operate as a secondary point of diversion when POD ID #1 is being used to supply the two existing center pivots if POD ID #2 from the Jefferson River is inoperable.

I also noticed that the Deficiency Letter was not sent to the current address for Treasured Mountains Holdings, LLC which is:

Treasured Mountains Holdings, LLC
Attn: Bill Gould
5653 Monterey Drive
Frisco, TX 75034

This is the address that Mr. Gould provided on the application. Please correct the address for Treasured Mountains Holdings, LLC.

Sincerely,



Andy Brummond
FWP Water Conservationist

C: Bill Gould, Treasured Mountains Holdings LLC (via email)

THE MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

GOVERNOR GREG GIANFORTE



DNRC DIRECTOR AMANDA KASTER

DNRC

2273 Boot Hill Ct, STE 110

Bozeman, MT 59715

May 15, 2025

TREASURED MOUNTAINS HOLDINGS LLC
4755 TECHNOLOGY WAY STE 205
BOCA RATON, FL 33431-3338

Subject: Deficiency letter for Change Application No. 41G 30165036

Dear Applicant:

The Department of Natural Resources and Conservation (DNRC or Department) has begun reviewing your application. This letter is to notify you of the deficiencies in your application as required in ARM 36.12.1501(1) and §85-2-302(5)(b), MCA. An Applicant is required to submit substantial and credible information addressing the rules and statutes that are relative to your application. You must provide the information specified below for your application to be considered correct and complete. "Correct and complete" means all of the information provided is substantial and credible and provides all of the information as required by applicable rules and statutes. The application as submitted contains deficiencies in the following section(s):

☐ **APPLICATION DETAILS - ARM 36.12.1305**

- 13. Fill out the table below for the water rights proposed for change.
 - The historical flow rate and the flow rate needed for the project are different. Please provide additional information about the need to reduce the historical flow rate. If the flow rate was not meant to be reduced, please clarify the proposed flow rate.
- 19.a. Describe the location for all *new* and *unchanged* points of diversion to the nearest 10 acres. Label POD ID with the same POD ID number assigned for the proposed use map (question 18).
 - The historical POD is not listed in this section. If you would like to keep the historical POD, please list it in the table.
 - Please also clarify whether the PODs are primary or secondary.

☐ **ADEQUATE MEANS OF DIVERSION AND OPERATION - ARM 36.12.1904**



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- 36. Describe your plan of operations, including specific information about how water is delivered within the place of use. This may include, where applicable, the range of flow rates needed for a pivot.
 - Information provided during the preapplication meeting discussed that the source of the right will remain Parsons Slough and the proposed diversions will divert by means of natural carrier. Calculations were provided during the preapplication process for down ditch flows.

As stated above, the information submitted to address the rules and statutes listed in this deficiency letter must be substantial credible information to be acceptable at the correct and complete determination. §§85-2-102 (9) and (26), MCA.

Please submit the information specified above to the Bozeman Regional Office by September 12, 2025. This is the only deficiency letter that will be sent. An application not corrected or completed within 120 days from the date of this letter is terminated per ARM 36.12.1501(2) and §85-2-302(6)(a), MCA.

Please let me know if you have any questions.

Sincerely,



Derek Rasmussen

Water Resources Specialist

Bozeman Water Resources Office

Water Resources Division

Cc, via email: Andy Brummond, abrummond@mt.gov

IMPORTANT NOTICE: This will be the final opportunity for you to provide the required information to the Department. If all of the requested information in this letter is not postmarked or submitted within 120 days of this letter, the application will be terminated within 30 days and the application fee will not be refunded.





Re: Deficiency letter for Change Application No. 41G 30165036

From Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Date Wed 6/25/2025 4:36 PM
To Brummond, Andy <abrummond@mt.gov>
Cc Strasheim, Kerri <kstrasheim@mt.gov>; Bill Gould <billgould@me.com>

Thanks Andy,

This has been received.

Respectfully,



Derek Rasmussen | Water Resource Specialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-6282 **EMAIL:** derek.rasmussen@mt.gov
Website | **Facebook** | **X (Twitter)** | **Instagram**
How did we do? Let us know here: [Feedback Survey](#)

From: Brummond, Andy <abrummond@mt.gov>
Sent: Tuesday, June 24, 2025 2:32 PM
To: Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Bill Gould <billgould@me.com>
Subject: RE: Deficiency letter for Change Application No. 41G 30165036

Hello Derek

Attached is the response to your Deficiency Letter. Thanks for taking the time to visit with Kerri about my draft response I shared previously. When we talked this morning, she conveyed your concerns, and I modified the letter accordingly.

Please let me know if you have questions.

Best Regards,

Andy Brummond | *Water Conservationist*
Land & Water Program
Montana Fish, Wildlife & Parks
Office: (406) 708-7223



THE **OUTSIDE** IS IN US ALL.

[Montana FWP](#) | [Montana Outdoors Magazine](#)



From: Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Sent: Thursday, May 15, 2025 1:26 PM
To: Brummond, Andy <abrummond@mt.gov>
Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Reynolds, Lyra <Lyra.Reynolds@mt.gov>
Subject: Deficiency letter for Change Application No. 41G 30165036

Hi Andy-

The Department of Natural Resources and Conservation (DNRC or Department) has begun reviewing Change Application No. 41G 30165036 by Treasured Mountains Holdings LLC. The attached letter is to notify you of the deficiencies in this application as required in ARM 36.12.1501(1) and §85-2-302(5)(b), MCA. The letter was sent to the applicant today, May 15, 2025.

Please submit the information specified above to the Bozeman Regional Office within 120 days, by September 12, 2025.

Please let us know if you have any further questions.

Respectfully,



Derek Rasmussen | Water Resource Specialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-6282 **EMAIL:** derek.rasmussen@mt.gov
Website | [Facebook](#) | [X \(Twitter\)](#) | [Instagram](#)
How did we do? Let us know here: [Feedback Survey](#)



Re: Receipt of Change App 41G 30165036

From Brummond, Andy <abrummond@mt.gov>

Date Fri 4/25/2025 12:48 PM

To Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Cc Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Thanks Lyra.
Andy

From: Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Sent: Friday, April 25, 2025 11:58 AM

To: Brummond, Andy <abrummond@mt.gov>

Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Subject: Receipt of Change App 41G 30165036

Andy-

We have received the signed Application to Change 41G 30165036. I have attached a copy of the first page with the received stamp.

A deficiency letter or correct and complete determination will be sent within 15 business days of receipt date (today 4/25/2025).

Please let us know if you have any questions at this time.

-Lyra



Lyra Reynolds (they/them/she/her) | Hydrologist/Specialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-4500 **EMAIL:** lyra.reynolds@mt.gov
[Website](#) | [Facebook](#) | [X \(Twitter\)](#) | [Instagram](#)
How did we do? Let us know here: [Feedback Survey](#)

Application Materials

- Application
- Any information submitted with Application including maps

Application Materials



**APPLICATION TO
CHANGE A WATER RIGHT**
§ 85-2-302, MCA
Form No. 606 (Revised 2/2025)

For Department Use Only

RECEIVED**APR 25 2025****DNRC****BOZEMAN WATER RESOURCES****FILING FEE****\$2500/\$1500 – Without/with filing fee reduction.****\$400 – (The following types do not qualify for a filing fee reduction)**

- Replacement well that exceeds 35 GPM or 10 AF per year
- Replacement municipal well that exceeds 450 GPM
- Replacement reservoir on the same source

INFORMATION

An application will be eligible for a filing fee reduction and expedited timelines if the applicant completes a preapplication meeting with the Department (ARM 36.12.1302(1)), which includes submitting any follow-up information identified by the Department (ARM 36.12.1302(3)(c)) and receiving either Department-completed technical analyses or Department review of applicant-submitted technical analyses (ARM 36.12.1302(4) and (5)). An application for the proposed project also must be submitted within 180 days of delivery of Department technical analyses or scientific credibility review and no element on the submitted application can be changed from the completed preapplication meeting form (ARM 36.12.1302(6)). If application is eligible for a filing fee reduction, \$500 paid for Form 606P-B will be credited toward filing fees shown above.

Application # 30165036 Basin 41G
 Priority Date _____ Time 11:18 AM/PM
 Rec'd By LR - via DocuSign
 Fee Rec'd \$ 1000 Check # N/A
 Deposit Receipt # IVT2520853
 Payor FWP
 Refund \$ _____ Date _____

Applicant Information: Add more as necessary.Applicant Name Treasured Mountains Holdings LLC, Attn: Bill GouldMailing Address 5653 Monterey Drive City Frisco State TX Zip 75034

Phone Numbers: Home _____ Work _____ Cell _____

Email Address billgould@me.com

Applicant Name _____

Mailing Address _____ City _____ State _____ Zip _____

Phone Numbers: Home _____ Work _____ Cell _____

Email Address _____

Applicant Name _____

Mailing Address _____ City _____ State _____ Zip _____

Phone Numbers: Home _____ Work _____ Cell _____

Email Address _____

Contact/Representative Information: Add more as necessary.Contact/Representative is: ☐ Applicant ☐ Consultant ☐ Attorney ☒ OtherContact/Representative Name Andy Brummond, Montana Fish, Wildlife & ParkMailing Address PO Box 938 City Lewistown State MT Zip MTPhone Numbers: Home _____ Work 406-708-7223 Cell _____Email Address abrummond@mt.gov

NOTE: If a contact person is identified as an attorney, all communication will be sent only to the attorney unless the attorney provides written instruction to the contrary (ARM 36.12.122(2)). If a contact person is identified as a consultant, employee, or lessee, the individual filing the water right form or objection form will receive all correspondence and a copy may be sent to the contact person (ARM 36.12.122(3)).



Answer every question and applicable follow-up questions. Use the checkboxes to denote yes ("Y"), no ("N"), or not applicable ("NA"). Questions that require items to be submitted to the Department have a submitted ("S") checkbox, which is marked when the required item is attached to the Application. Label all submitted items with the question number for which they were submitted. Narrative responses that are larger than the space provided can be answered in an attachment. If an attachment is used, specify "see attachment" on this form, and label the attachment with the question number. Constrain narrative responses to the specific question as is asked on the form; do not respond to multiple questions in one narrative. Responses in the form of a table may be entered into the table provided on this form or in an attachment. If an attachment is used, the table must have the exact headings found on this form, and "see attachment" must be entered as a response to the relevant question. Clearly label all units in tables and narrative responses.

PREAPPLICATION AND TECHNICAL ANALYSES INFORMATION

1. ☒ **Y** ☐ **N** Do you elect for Department technical analyses to be used for criteria assessment?

2. ☒ **Y** ☐ **N** Did you have a preapplication meeting AND complete a Change Preapplication Meeting Form Part A and Part B (Form 606P-A and 606P-B)?

IF QUESTION 2 IS NO, answer 2.a and 2.b:

2.a. ☐ **S** Submit the Technical Analyses Addendum (Form 606-TAA).

2.b. ☐ **S** ☒ **NA** Submit the technical analyses, if you elected in question 1 for Applicant technical analyses to be used for criteria assessment. Select "NA" if you elected for Departmental technical analyses.

IF QUESTION 2 IS YES, answer 2.c, 2.d, and 2.e:

2.c. ☐ **Y** ☒ **N** Has any element of the project described in this application changed from the mandatory elements of the project described in the completed Form 606P? **If yes,**

2.c.i. Please explain.

2.c.ii. ☐ **S** Submit the Technical Analyses Addendum (Form 606-TAA).

2.d. ☒ **Y** ☐ **N** Are the technical analyses to be used for criteria assessment exactly the same as those completed during the preapplication process? **If no:**

2.d.i. Please explain.

2.d.ii. ☐ **S** Submit the Technical Analyses Addendum (Form 606-TAA).

2.e. ☒ **Y** ☐ **N** Did you elect in question 1 for Department technical analyses to be used for criteria assessment? **If no:**

2.e.i. ☐ **S** Submit the technical analyses.



APPLICATION ADDENDA AND REVIEW

3. ☐ S ☒ NA If the proposed change involves one or more places of storage, submit a Change Storage Addendum (Form 606-SA). This does not include reservoirs, pits, pit-dams, or ponds with a capacity less than 0.1 AF; water tanks; or cisterns (ARM 36.12.113(6)).
4. ☐ S ☒ NA If the project involves an appropriation that is greater than 5.5 CFS and 4,000 acre-feet, submit a Reasonable Use Addendum (Form 606-B).
5. ☐ S ☒ NA If the project involves out-of-state water use, submit an Out-of-State Use Addendum (Form 600/606-OSA).
6. ☐ S ☒ NA If the proposed purposes include marketing or selling water, submit a Water Marketing Purpose Addendum (Form 600/606-WMA). This doesn't include marketing for mitigation/aquifer recharge.
7. ☐ S ☒ NA If the proposed purpose includes instream flow, submit a Change to Instream Flow Addendum (Form 606-IFA).
8. ☐ S ☒ NA If the proposed purposes include mitigation, aquifer recharge, or marketing for mitigation/aquifer recharge, submit a Mitigation Purpose Addendum (Form 606/606-MIT).
9. ☐ S ☒ NA If the project is in designated sage grouse habitat, submit a review letter from the Montana Sage Grouse Habitat Conservation Program.
10. ☐ S ☒ NA If you propose to add a point of diversion or place of use on State of Montana Trust Land, submit documentation of consent from DRNC Trust Lands Management Division. If you propose to add a place of use on Trust Land with all points of diversion on private land, then, at a minimum, that component of the change authorization will be temporary for the duration of the lease term (§ 85-2-441, MCA).
11. ☒ Y ☐ NA You must provide a written notice of the application to each owner of an appropriation right sharing a point of diversion or means of conveyance (e.g., canal, ditch, flume, pipeline, or constructed waterway) pursuant to § 85-2-302(4)(c), MCA. Submit a copy of this notice and the recipient list.

APPLICATION DETAILS

12. How many change applications will be needed for this project? Refer to ARM 36.12.1305 for more information. Ultimately 4 changes will be needed, all need not be filed at the same time.

13. Fill out the table below for the water rights proposed for change.

Water Right No.	Current Authorized Flow Rate			Flow Rate Needed for Project			Means of Diversion
	Flow	GPM	CFS	Flow	GPM	CFS	
41G 197111-00	9.48	☐	☒	4.26	☐	☒	Pump and Headgate
		☐	☐		☐	☐	
		☐	☐		☐	☐	
		☐	☐		☐	☐	
		☐	☐		☐	☐	



14. Is the source surface water or groundwater? Surface Water

15. What is the source name? Parsons Slough

16. Identify the water right elements proposed for change, with a checkmark, for each water right proposed for change.

Water Right No.	41G 197111-00				
Point of Diversion	☒	☐	☐	☐	☐
Place of Use	☒	☐	☐	☐	☐
Purpose of Use	☐	☐	☐	☐	☐
Place of Storage	☐	☐	☐	☐	☐

17. ☒ **S** Submit a historical use map created on an aerial photograph or topographic map that shows the following: section corners, township and range, scale bar, north arrow, all historical points of diversion (POD) labeled with a unique POD ID ("H" followed by a number), all historical places of use (POU), all historical conveyance structures, all historical places of storage, and historical place of use for all overlapping water rights. More than one map may be submitted, if necessary, to clearly convey all required information.

18. ☒ **S** Submit a proposed use map created on an aerial photograph or topographic map that shows section corners, township and range, scale bar, north arrow, and the following elements: points of diversion labeled with a unique POD ID ("P" followed by a number), places of use, conveyance structures, places of storage, and place of use for all overlapping water rights. Include all elements that will be on the water rights after the proposed change, regardless of whether the element will be modified by the change. The map should fully depict the water rights, as proposed, after the change. More than one map may be submitted, if necessary, to clearly convey all required information.

19. ☒ **Y** ☐ **N** Does the proposed change involve a change in point of diversion?

IF YES,

19.a. Describe the location for all *new* and *unchanged* points of diversion to the nearest 10 acres. Label POD ID with the same POD ID number assigned for the proposed use map (question 18).

POD ID	¼	¼	¼	Sec.	Twp.	Rge.	County	Lot	Block	Tract	Subdivision	Gov. Lot	New or Unchanged
2	NE	NE	SE	14	1S	5W	Madison						
3	SE	NW	NE	13	1S	5W	Madison						
4	W2	E2	NE	13	1S	5W	Madison						



- 19.b. ☒ NA** Describe the location of all historical PODs you propose to *retire*. Label POD ID with the same POD ID assigned for the historical use map (question 17). If none are proposed for retirement, select "NA" checkbox.

POD ID	¼	¼	¼	Sec.	Twp.	Rge.	County	Lot	Block	Tract	Subdivision	Gov. Lot

- 19.c.** What is the means of diversion for all *new* PODs? Means of diversion for surface water includes headgate, pump, dam, and others. Means of diversion for groundwater includes well, developed spring, pit pond, and others.
 The means of diversion for POD #2 is a 60 HP variable speed turbine pump. The means of diversion for the transitory PODs #3 and #4 is a 14HP gasoline driven centrifugal pump.

- 20. ☒ Y ☐ N** Does the proposed change involve a change in place of use?

IF YES,

- 20.a.** What are the geocodes of the proposed place of use?

25-0891-13-1-01-01-0000	
25-0891-13-4-01-01-0000	
25-0891-14-4-01-05-0000	

- 20.b.** Describe the legal land description of the proposed place of use, and if the water rights being changed will have an irrigation or lawn and garden purpose, list the number of irrigated acres.

Acres	Gov't Lot	¼	¼	¼	Sec.	Twp.	Rge.	County
25.7			SE	SE	14	1S	5W	Madison
160.9				S2	13	1S	5W	Madison
8.1			SW	NE	13	1S	5W	Madison
3.2			SE	NW	13	1S	5W	Madison
0.3		SW	NE	NE	13	1S	5W	Madison
1.3		SE	NW	NE	13	1S	5W	Madison
199.5	Total							



21. ☒ Y ☐ N Does the proposed change involve a change in place of use or purpose?

IF YES,

21.a. ☒ Y ☐ N Do other water rights supplement or overlap the proposed place of use?

IF YES,

21.a.i. How will the water rights be operated to serve the proposed purposes?

Claim 41G 212596-00 overlaps the place of use covered by the existing south pivot. This right will no longer be used and will be subject of a forthcoming change to provide for fishery use in a reservoir and instream use in Willow Spring Creek.

21.a.ii. For each supplemental or overlapping water right, please list the average period of diversion and use (MM/DD-MM/DD), flow rate (GPM or CFS), and the volume of water (AF) contributed.

Water Right No.	Avg. Period of Diversion	Avg. Period of Use	Flow Rate			Volume Contributed
	MM/DD-MM/DD	MM/DD-MM/DD	Flow	GPM	CFS	AF
41G 212596-00	NA	NA	NA	☐	☐	NA
				☐	☐	
				☐	☐	
				☐	☐	

22. ☐ Y ☒ N Are you filing on behalf of another entity? If yes, describe.

23. ☒ Y ☐ N Do you own the entire historical place of use for all water rights proposed for change?

IF QUESTION 23 IS NO,

23.a. ☐ Y ☐ N Was the water historically used for sale, rental, distribution, municipal use, or any other context in which water is being supplied to another and it is clear that the ultimate user would not accept the supply without consenting to the use of water on the user's place of use?

IF QUESTION 23.a IS NO,

23.a.i. ☐ Y ☐ N List the water rights for which you do not own the entire historical place of use.

23.a.ii. ☐ Y ☐ N Are the water rights listed in question 23.a.i severed from the historical place of use?

IF QUESTION 23.a.ii IS YES,

23.a.ii.1. ☐ Y ☐ N Do you own the entirety of the severed water rights proposed for change? If yes, skip to question 24. If no, answer question 23.a.iii.

IF QUESTION 23.a.ii OR 23.a.ii.1 IS NO,

23.a.iii. ☐ Y ☐ N ☐ NA Are all owners of the historical place of use or, if applicable, owners of the severed water rights, willing to sign the application?



IF QUESTION 23.a.iii IS NO,

- 23.a.iii.1.** ☐ **S** Submit a Form 641 or 642 to split the water rights being changed for which all owners will not sign.

ADVERSE EFFECT

- 24.** Explain how you can control your diversion in response to a call being made.

The new POD #2 is a variable speed pump for which the flow rate can be varied and thus reduced or ceased in response to a valid call on water. The 100 gpm portable pump (transitory PODs #3 & #4) would be shut off in response to a valid call on water. If the existing Curtis Ditch were in use in the event of the Jefferson pump site not being usable, the existing headgate would be used to regulate diversion in response to a valid call on water.

- 25.** Describe any plans you have for ensuring existing water rights will be satisfied during times of water shortage.

Please see attachement.

- 26.** ☒ **Y** ☐ **N** Are you aware of any calls that have been made on the source of supply or, if groundwater, on nearby surface water sources?

26.a. If yes, explain.

Calls have been made on junior water rights by Montana Fish Wildlife & Parks (FWP) in order to satisfy downstream instream flow water rights on the Missouri River. The right being changed is senior to the rights justifying the call by FWP and was not called.

- 27.** Describe how the proposed change will or will not affect your ability to make call.

The proposed change will not increase the diverted flow rate or volume so the likelihood of making call will not increase. The previously diverted water not to be used under this change will be changed to instream flow under a subsequent application.



28. ☐ Y ☒ N Does a water commissioner distribute water or oversee water distribution on your proposed source, or if groundwater, on nearby surface water sources?

28.a. If yes, list the sources.

29. When was the last time each water right proposed for change was appropriated and used beneficially?
2024

IF THERE HAS BEEN A PERIOD OF NONUSE,

29.a. Why was the water right not used?

29.b. Why will a resumption of use not adversely affect other water users?

29.c. ☐ Y ☐ N Is the period of nonuse greater than 10 years for any of the water rights proposed for change? If yes, list which water rights.

29.d. ☐ Y ☐ N Have new water rights been authorized to use the source during the period of nonuse for any of the water rights proposed for change? If yes, explain.



30. ☒ **Y** ☐ **N** Do you propose to add one or more points of diversion or use new or existing conveyance infrastructure that will be shared with one or more existing water rights?

30.a. If yes, describe how the capacity of the shared points of diversion and/or conveyance infrastructure is sufficient for all water rights and how the proposed project will not adversely affect these water rights.

Please see attachment

31. ☐ **NA** Answer questions 31.a to 31.b for point of diversion changes. If you do not propose a point of diversion change, mark "NA" instead.

31.a. Are the proposed points of diversion upstream or downstream of the historical points of diversion?
Please see attachment

31.b. ☒ **Y** ☐ **N** Are there intervening water users between the historical and proposed points of diversion?

31.b.i. If yes, list the water rights.
Please see attachment

ADEQUATE MEANS OF DIVERSION AND OPERATION

32. ☒ **S** Submit a diagram of how you will operate your system from all proposed points of diversion to all proposed places of use.



- 33.** Describe specific information about the capacity of all proposed diversionary structures. This may include, where applicable: pump curves and total dynamic head calculations, headgate design specifications, and dike or dam height and length.

The primary system is to be supplied from the Jefferson River by a 60 HP variable speed turbine pump that can adjust flow rate to supply any combination of the 4 sprinkler system. The pump will initially supply a 10 in. PVC buried mainline which is tapped by a 8 in. mainline to serve the north central pivot. At the corner of the wheel line field, the 10 in. mainline will be tapped to supply the risers mainline for the wheel line. The 10 in. mainline will continue to the southwest pivot center point where it will reduce to an 8in. mainline to supply the southeast pivot. The center pivots will use low pressure drop nozzles with a 2 HP pump supplying the Nelson end guns. The 1/4 mile wheel line will consist of self-leveling impulse type sprinklers spaced at the standard 40 ft. each supplying approximately 8.5 gpm each. The 1.6 ac system consists of a 14HP gasoline engine driving a centrifugal pump supplying the gun with a 16 mm nozzle through a 2-in. flexible plastic hose.

- 34.** Describe the size, materials, capacity, and configuration of infrastructure to convey water from all proposed points of diversion to all proposed places of use.

The system diagram supplied in response to part 32 shows the infrastructure layout along with pipeline dimensions. Attributes for the Curtis Ditch are found in the Department's Technical Analysis Report.

- 35.** ☐ Y ☒ N Does the proposed conveyance require easements?

35.a. If yes, explain.

36. Describe your plan of operations, including specific information about how water is delivered within the place of use. This may include, where applicable, the range of flow rates needed for a pivot.

Water would be pumped from the Jefferson River and delivered to the 4 sprinkler system via pressure pipelines from the new stationary pump site. The transitory pump diverting from either the Jefferson River or Willow Spring Creek will supply 100 gpm to the 1.6-acre field. That attachment provided in response to item 42 below provides flow rate information for the individual sprinkler systems. In the even the stationary Jefferson pump site is not operational, water would be diverted via the Curtis Ditch an supplied to the two existing pivots both pumping at 490 gpm. While possible to deliver water to the transitory pump on Willow Spring Creek via the Curtis Ditch, this mode of operation would not likely be used as the transitory point of diversion from Willow Spring Creek is intended as a primary point of diversion.

37. ☒ Y ☐ N ☐ NA If you propose to add one or more points of diversion, do you own the land where all proposed points of diversion are located? If you do not propose to add one or more points of diversion, mark "NA" instead.

37.a. ☐ S If no, submit documentation to show you have the right to use all points of diversion located on each property you do not own. This may include, but is not limited to, a well agreement, an easement, or permission of the party that owns the property where the proposed point(s) of diversion are located.

38. ☐ Y ☒ N Will your system be designed to discharge water from the project?

38.a. If yes, explain the wastewater disposal method.

38.b. ☐ Y ☐ N ☐ NA Have the necessary permits been obtained to comply with §§ 75-5-410 and/or 85-2-364, MCA?

39. ☐ Y ☒ N Is the means of diversion for any proposed point of diversion a well?

IF YES,

39.a. ☐ Y ☐ N Have all wells been drilled?

39.b. For all wells that have been drilled, what is the name of the well driller and, if available, what is their license number?

39.c. ☐ Y ☐ N ☐ NA For all wells yet to be drilled, will a licensed well driller construct the wells? If no wells are yet to be drilled, mark "NA" instead.

39.d. ☐ S ☐ NA Submit any well logs not yet submitted to the Department, such as for wells drilled after submittal of Form 606P. If all well logs have been submitted to the Department, mark "NA."



BENEFICIAL USE

40. ☒ Y ☐ N Does the Department have a standard period of diversion, period of use, flow rate, and/or volume for any of the purposes for which water is used? Department standards can be found in the DNRC Water Calculation Guide, ARM 36.12.112, ARM 36.12.115, and ARM 36.12.1902.

40.a. If yes, list the purposes for which the Department has a standard and note whether the water use falls within or outside the standard.

The purpose is for irrigation which falls within the period of use for climatic area 3 found in ARM 36-12.112. The volumes requested are consistent with ARM 36.12.115. See attach.

40.b. For any of the purposes with no Department standard or with proposed beneficial use that falls outside of Department standards, explain how the use is reasonable for that purpose.

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

41. ☐ Y ☒ N Will your proposed project be subject to Montana Department of Environmental Quality (DEQ) requirements for a public water supply (PWS) system or Certificate of Subdivision Approval (COSA)?

42. ☐ Y ☒ N Are you proposing to use surface water for in-house domestic use?

- 42.a. ☐ Y ☐ N** If yes, does a COSA exist for the proposed place of use?

- 42.a.i. ☐ S** If yes, submit the COSA.

POSSESSORY INTEREST

43. ☐ Y ☒ N Do you meet one of the exceptions to possessory interest requirements, pursuant to ARM 36.12.1802 and § 85-2-402(2)(d), MCA? Exceptions include cases where the application is for sale, rental, distribution, or is a municipal use, or in any other context in which water is being supplied to another and it is clear that the ultimate user will not accept the supply without consenting to the use of water on the user's place of use, and applications for the purposes of instream flow, mitigation, and marketing for mitigation.

43.a. If yes, explain.

44. ☒ Y ☐ N ☐ NA Do you own all proposed places of use? Mark "NA" if you meet one of the exceptions to the possessory interest requirement.

44.a. ☐ S If no, explain and submit documentation that shows you either have possessory interest or written permission of the parties with possessory interest of the proposed place of use.

PROPOSED COMPLETION PERIOD

45. How many years will be needed to complete this project and to submit to the DNRC a Project Completion Notice (Form 618)? 4 years

46. Describe why this amount of time is needed to complete this project.
Construction of the new main Jefferson River pump site is dependent on river conditions as well as availability of the contractor and new irrigation infrastructure which may delay the construction of the project.



AFFIDAVIT & CERTIFICATION

Read carefully before you sign and review with legal counsel if you have any questions. All owners (or trustees) must sign the form. ***If the owner is a business or trust, include the title of the representative(s) signing the form (i.e., president, trustee, managing partner, etc.) and provide documentation that establishes the authority of the representative to sign the application.*

I affirm the information provided for this application is to the best of my knowledge true and correct. If a preapplication meeting form was submitted, I am aware that my application for this project will not qualify for a discounted filing fee and expedited timelines if upon submittal of the application to the Department, I changed any element of the proposed application from the preapplication meeting form and follow-up materials (ARM 36.12.1302(6)(a)).

I affirm I have possessory interest, or the written consent of the person with the possessory interest, in the property where the water is to be put to beneficial use, unless this application meets an exception to the possessory interest requirements in ARM 36.12.1802(1)(b).

I understand that making a false statement under oath or affirmation in this application and official proceedings throughout the examination of my application may subject me to prosecution under § 45-7-202, MCA, a misdemeanor punishable by a jail term not to exceed 6 months or a fine not to exceed \$500, or both. I have read this Affidavit and understand the terms and conditions.

I declare under penalty of perjury and under the laws of the state of Montana that the foregoing is true and correct.

Printed Name BILL GOULDD

Applicant Signature BILL GOULDD Date: 4/25/2025

Printed Name _____

Applicant Signature _____ Date: _____

Printed Name _____

Applicant Signature _____ Date: _____



PO Box 938
Lewistown, MT 59457

March 20, 2025

Dustin Laughery
Yvonie Laughery
69 Coomont LN
Whitehall, MT 59759

RE: Notice of Filing of Application to Change an Appropriation Right

Dear Mr. and Mrs. Laughery:

As I believe you know Montana Fish, Wildlife & Parks is working with your neighbor Bill Gould on a project to divert his irrigation water from the Jefferson River instead of Parsons Slough. Ron Spoon and I visited with you about this project this past summer.

I have been working with Mr. Gould on preparing the application to change the point of diversion that must be submitted to and approved by the Department of Natural Resources and Conservation. The application will request to add a point of diversion from the Jefferson River for Mr. Gould's water right Claim 41G 197111-00 from Parsons Slough. The change will also rearrange the place of use for the water right to accommodate the sprinkler systems.

Mr. Gould is required to provide you this notice of the filing of the change application because your water right shares a diversion and ditch with the water right proposed to be changed. §85-2-302(4)(c), MCA requires that you be notified that an application to change the water right will be filed.

This is only the first step in the overall project that intends to improve and protect streamflow in Parsons Slough and Willow Spring Creek. As we discussed this past summer, we would like to explore with you the possibility of moving your diversion from Parson's Slough to the Jefferson River also. We plan to be in contact with you in the future about doing that. The first step is to get the application by Mr. Gould submitted and moving forward.

If you have any questions, please contact me by email at: abrummond@mt.gov or by telephone: 406-708-7223.

Sincerely,



Andy Brummond
FWP Water Conservationist

CERTIFICATE OF MAILING

I, Andy Brummond, do solemnly swear that on the 20th day of March, 2025, I placed a copy of this Notice of Filing of Application to Change an Appropriation Right in the U.S. Mail, postage prepaid. The copy of this Notice of Filing of Application to Change an Appropriation Right was mailed to the following water right owners:

Dustin Laughery
Yvonie Laughery
69 Coomont LN
Whitehall, MT 59759



Andy Brummond

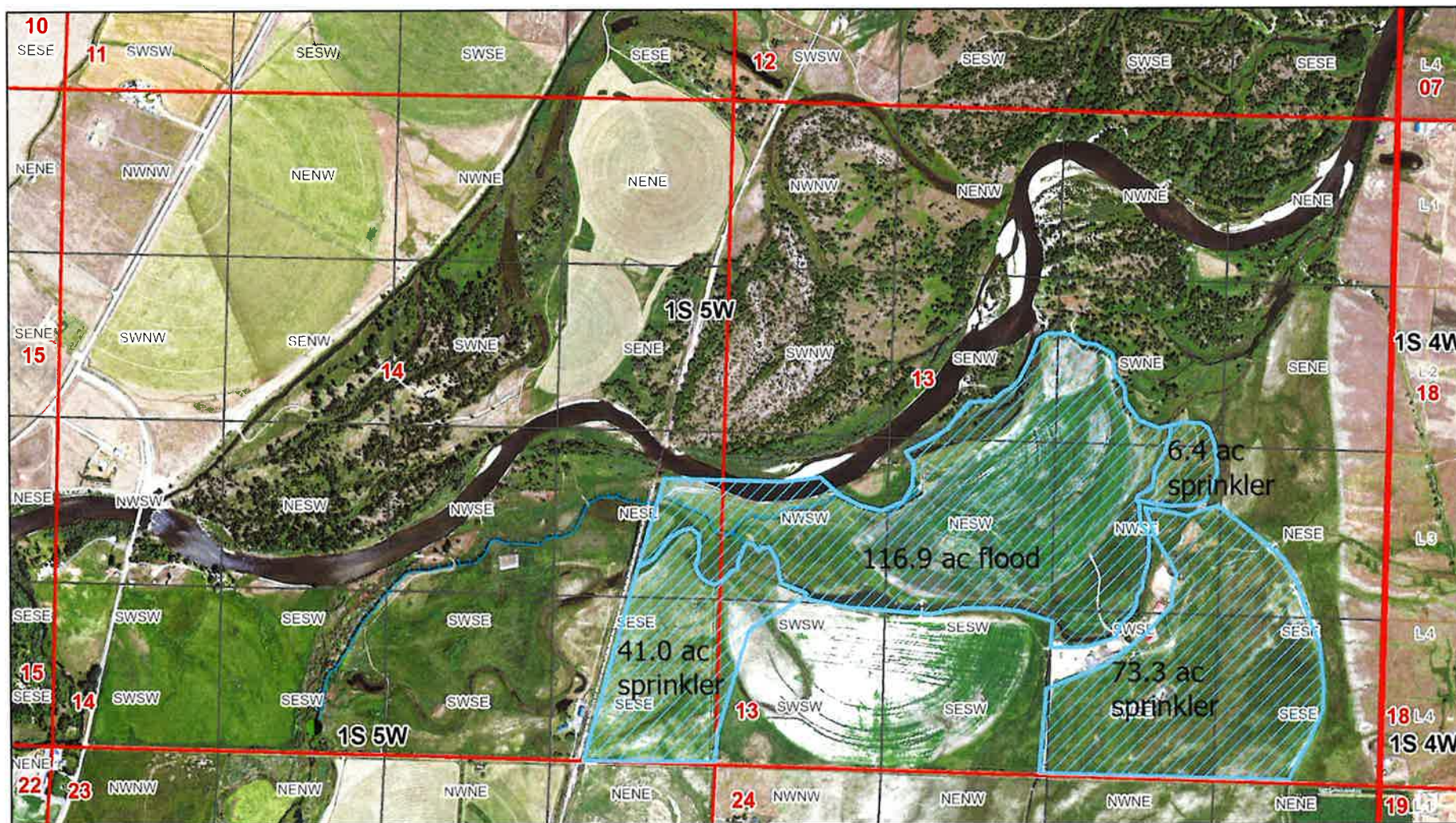
Application #17 Historic Use



0 0.25 0.5 1 Miles



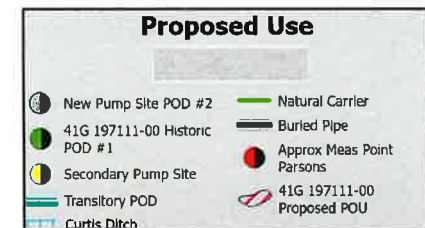
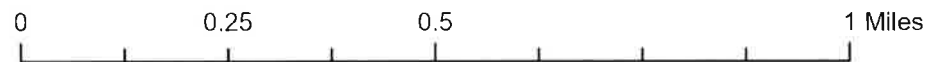
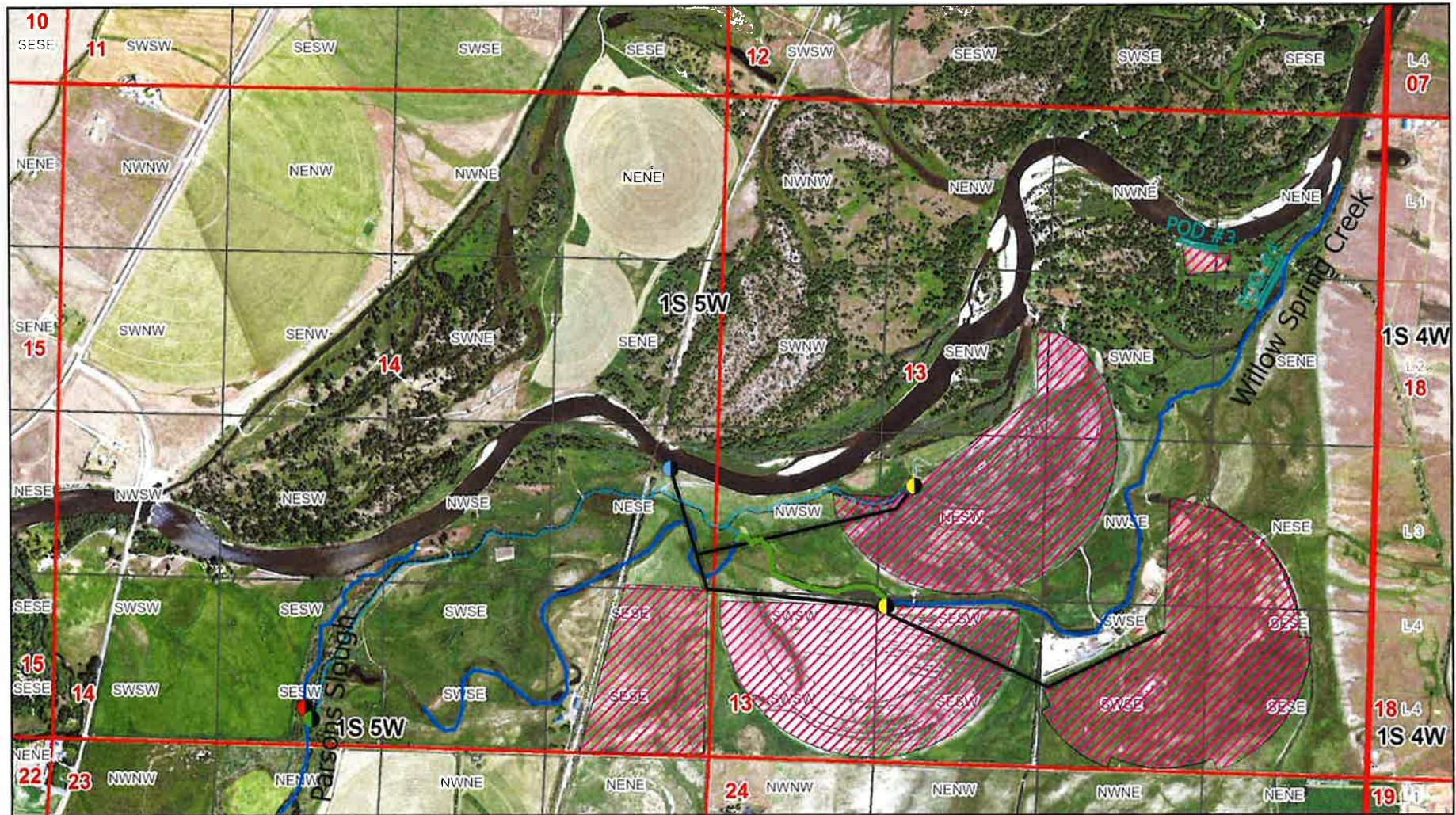
Application #17 Historic Use by Irrigation Method



0 0.25 0.5 1 Miles



Application #18 Proposed Use



Application #25 Plan of Operation

Water flowing in Parson Slough into the Jefferson River will be measured to ensure that the flow rate being diverted from the new pump sites is being met so that the burden on the Jefferson River is not increased. In the unlikely even Parson's Slough inflow is not sufficient, diversion from the Jefferson River will be reduced. If the Willow Spring Creek transitory POD #4 is in use, average discharge measurements show that flow in the creek would not drop below Montana Fish, Wildlife & Parks' (FWP) 9.2 CFS instream flow water right and would not be adversely affected. Further its use, would not interfere with livestock use from the creek.

Application #30.a Shared Ditch Adverse Effect Analysis

Permit 41G 2262-00 shares the Curtis Ditch POD #1 from Parsons Slough. At the permitted 700 gpm flow rate and a 29.3 AF conveyance loss as found in Table 6 of the Department's Technical Analysis Report, 60 AF of diversion as permitted would result in a delivery of 30.7 AF to the field which appears to be more than enough to supply the irrigation developed under the Permit. The Permit can operate independently of the right being changed and provide adequate water supply.

Application #31.a Proposed Points of Diversion

In the case of the proposed points of diversion from the Jefferson River they are downstream of the historic point of diversion from Parsons Slough as water flows from Parsons Slough into the Jefferson River above both proposed diversions. In the case of the transitory Willow Spring Creek point of diversion under normal operation when the Curtis Ditch is not used to supply this diversion it would be considered upstream as water cannot be directly delivered from Parsons Slough to this diversion via the Jefferson River.

The Water Use Act is to be given a liberal interpretation. §85-2-103, MCA. In his *Montana Water Law Handbook* (excerpt attached) Ted Doney, former Chief Legal Counsel and/or Deputy Director and later Director of the Department explained that points of diversion could theoretically be changed between source names citing the idea of changing a point of diversion from the Dillon area in the Beaverhead River basin to the Yellowstone River basin in the Glendive area as both are within the Missouri River drainage. Mr. Doney, who directly participated in drafting the Water Use Act seems to have understood the directive to use a liberal interpretation (i.e. allowing changes in named source).

The Department subsequently followed this interpretation and allowed changes to different named sources even when water could not be left instream and directly delivered to the new point of diversion. In Change Authorization No. 76F 30027218 the Department authorized a change from Beartrap Creek to Snowbank Creek, both ultimately tributary to the Blackfoot River, but neither creek was tributary to the other. In Change Authorization No. 41A 30125436 the Department authorized the diversion to be changed from Culver Springs to Narrows Creek, both ultimately tributary to Elk Creek, but Culver Springs water can never directly end up in Narrows Creek or vice versa. The request to change the point of diversion from Parsons Slough to Willow Spring Creek for transitory POD#4 is consistent with the Water Use Act and Department precedent.

Application #31.b.i Intervening Water Rights

Claim 41G 30143701 for livestock direct from Parsons Slough is co-owned by G&M Yamamoto Trust with the Trust's interest deriving from that portion of Parsons Slough below the historic point of diversion. Under the proposed change the amount of water in Parsons Slough will increase. Therefore, the Trust's water right will not be adversely affected.

Claim 41G 212596-00 for irrigation from Willow Spring is owned by the applicant historically provided irrigation from May 1 to October 15 but will no longer be used for irrigation under the proposed change. Subsequent changes will be filed to change this right to fishery use in an on-stream reservoir and instream flow in Willow Creek. Claims 41G 30123892 and 41G 30124720 for livestock direct from Willow Spring Creek are owned by the applicant. Reservations 41G 30017621 for Willow Spring Creek and 41G 30017486 for the Jefferson River are held by FWP.

During the May 1 to October 15 irrigation period, the average monthly flow estimated for Willow Spring Creek (see Table 20 of the Department's Technical Analysis Report) exceeds the total water right demand of 11.43 cfs found in Table 18 plus the added 100 gpm (0.22 cfs) diversion for irrigation of the new 1.6-acre field.

During the remainder of the year, the average discharge measurements for Willow Spring Creek exceeds FWP's instream flow water right of 9.2 cfs. Claims 41G 30123892 and 41G 30124720 currently do not have a flow rate and volume assigned in the Department's databased (see attached abstracts). Ultimately no flow rate and volume will likely be assigned with the following descriptive narratives of the flow rate and volume will be decreed:

Maximum Flow Rate:	A SPECIFIC FLOW RATE HAS NOT BEEN DECREED BECAUSE THIS USE CONSISTS OF STOCK DRINKING DIRECTLY FROM THE SOURCE, OR FROM A DITCH SYSTEM. THE FLOW RATE IS LIMITED TO THE MINIMUM AMOUNT HISTORICALLY NECESSARY TO SUSTAIN THIS PURPOSE.
Maximum Volume:	THIS RIGHT INCLUDES THE AMOUNT OF WATER CONSUMPTIVELY USED FOR STOCKWATERING PURPOSES AT THE RATE OF 30 GALLONS PER DAY PER ANIMAL UNIT. ANIMAL UNITS SHALL BE BASED ON REASONABLE CARRYING CAPACITY AND HISTORICAL USE OF THE AREA SERVICED BY THIS WATER SOURCE.

The Department's Technical Analysis Report in Table 18 reports flow rates and volumes for these two instream stock rights but does not seem to provide an explanation of how these values were derived. Taken at face values, the reported flow rates when added to FWP's instream reservation may slightly exceed the estimated average monthly flow during March. However, the combined annual volume of 19.49 AF would provide sufficient water at 30 gallons per day per animal use to water 580 animal units for an entire year. This stocking rate vastly exceeds the carrying capacity of the pastures and fields in the area including possible wintertime feeding of livestock. This water usage is consistent with a feedlot operation which is clearly not present. A more realistic estimate of maximum livestock usage would be 200 animal units at any given time which would translate to an average daily usage of 6,000 gallons at an average daily flow rate of 4.2 gpm.

As FWP is a proponent of the requested change which is being made as part of a larger water right lease and water management project, any very slight decrease below FWP's 9.2 cfs instream flow water right caused by livestock drinking directly from the source (4.2 gpm) and less than 1 gpm reduction in return

flow to Willow Spring Creek would not be considered an adverse effect to FWP's instream reservation as the overall benefits to the fishery greatly outweigh any very small drops below FWP's instream flow water reservation. As there are no other water users on Willow Spring Creek other than the applicant and FWP, a very small drop below FWP's reservation would not result in an adverse effect on other water users being created by a theoretical increase in frequency of call by FWP.

MONTANA
WATER LAW HANDBOOK

by
Ted J. Doney, Esq.

Published by
State Bar of Montana
Box 4669
Helena, Montana 59604

Kent R. Parcell
Executive Director

October, 1981

determined in each case;

- (2) Changing from a direct flow diversion to a storage appropriation is permissible, provided that the water right is not expanded; the same pattern established under the right must be followed under the change, including period of appropriation and water being appropriated;
- (3) Theoretically, the points of diversion of a water right can be changed to anyplace on the source of supply; this would mean that it is possible to move a water right from Dillon to Glendive (the source of supply being the Missouri drainage), and vice versa, provided as usual that no adverse effect occurs;²²²
- (4) Changing from flood to sprinkler irrigation, although more efficient, will usually involve expanding the acreage irrigated (a change in place of use), and an increase in the burden on the stream because the return flow is reduced (see sec. 2.3.6., supra); therefore, a water right will have to be acquired for the increased appropriation, unless it's within the existing water right through due diligence (see sec. 2.4.1., supra);²²³
- (5) It is doubtful whether water rights can be changed from an instream purpose of use,

222. See Spring Creek Irr. Co. v. Zollings, 58 Utah 90, 197 P. 737 (1921).

223. See n. 47, supra.

March 24, 2025
41G 30123892

STATE OF MONTANA
DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
1424 9TH AVENUE P.O. BOX 201601 HELENA, MONTANA 59620-1601

GENERAL ABSTRACT

Water Right Number: 41G 30123892 STATEMENT OF CLAIM
Version: 1 -- ORIGINAL RIGHT
Version Status: ACTIVE

Owners: TREASURED MOUNTAINS HOLDINGS LLC
4755 TECHNOLOGY WAY STE 205
BOCA RATON, FL 33431-3338

Priority Date: MARCH 20, 1876
Enforceable Priority Date: MARCH 20, 1876

Type of Historical Right: USE
Purpose (Use): STOCK

Maximum Flow Rate:
Maximum Volume:

Source Name: UNNAMED TRIBUTARY OF JEFFERSON RIVER
Source Type: SURFACE WATER

Point of Diversion and Means of Diversion:

<u>ID</u>	<u>Govt Lot</u>	<u>Qtr Sec</u>	<u>Sec</u>	<u>Twp</u>	<u>Rge</u>	<u>County</u>
1		SENESE	14	1S	5W	MADISON
Period of Diversion: JANUARY 1 TO DECEMBER 31						
Diversion Means: LIVESTOCK DIRECT FROM SOURCE						
2		SW	13	1S	5W	MADISON
Period of Diversion: JANUARY 1 TO DECEMBER 31						
Diversion Means: LIVESTOCK DIRECT FROM SOURCE						
3		W2SE	13	1S	5W	MADISON
Period of Diversion: JANUARY 1 TO DECEMBER 31						
Diversion Means: LIVESTOCK DIRECT FROM SOURCE						
4		NWNESE	13	1S	5W	MADISON
Period of Diversion: JANUARY 1 TO DECEMBER 31						
Diversion Means: LIVESTOCK DIRECT FROM SOURCE						
5		S2NE	13	1S	5W	MADISON
Period of Diversion: JANUARY 1 TO DECEMBER 31						
Diversion Means: LIVESTOCK DIRECT FROM SOURCE						
6		SWNESE	13	1S	5W	MADISON
Period of Diversion: JANUARY 1 TO DECEMBER 31						
Diversion Means: LIVESTOCK DIRECT FROM SOURCE						
Period of Use: JANUARY 1 to DECEMBER 31						
Place of Use:						

<u>ID</u>	<u>Acres</u>	<u>Govt Lot</u>	<u>Qtr Sec</u>	<u>Sec</u>	<u>Twp</u>	<u>Rge</u>	<u>County</u>
1			SENESE	14	1S	5W	MADISON
2			SW	13	1S	5W	MADISON
3			W2SE	13	1S	5W	MADISON
4			NWNESE	13	1S	5W	MADISON
5			S2NE	13	1S	5W	MADISON
6			SWNESE	13	1S	5W	MADISON
Geocodes/Valid:	25-0891-13-1-01-01-0000 - Y				25-0891-13-4-01-01-0000 - Y		
	25-0891-14-4-01-05-0000 - Y						

Remarks:

OWNERSHIP UPDATE RECEIVED

OWNERSHIP UPDATE TYPE 608 # 186739 RECEIVED 05/22/2019.

THIS CLAIM NUMBER WAS NOT INCLUDED IN THE BASIN 41G DECREE ISSUED 02/15/2018.

STATE OF MONTANA

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

1424 9TH AVENUE P.O. BOX 201601 HELENA, MONTANA 59620-1601

GENERAL ABSTRACT

Water Right Number:41G 30124720 STATEMENT OF CLAIM

Version:1 -- ORIGINAL RIGHT

Version Status:ACTIVE

Owners:TREASURED MOUNTAINS HOLDINGS LLC
4755 TECHNOLOGY WAY STE 205
BOCA RATON, FL 33431-3338

Priority Date:DECEMBER 31, 1885

Enforceable Priority Date:DECEMBER 31, 1885

Type of Historical Right:USE

Purpose (Use):STOCK

Maximum Flow Rate:

Maximum Volume:

Source Name:UNNAMED TRIBUTARY OF JEFFERSON RIVER

Source Type:SURFACE WATER

Point of Diversion and Means of Diversion:

<u>ID</u>	<u>Govt Lot</u>	<u>Qtr Sec</u>	<u>Sec</u>	<u>Twp</u>	<u>Rge</u>	<u>County</u>
1		E2NENE	13	1S	5W	MADISON

Period of Diversion:JANUARY 1 TO DECEMBER 31

Diversion Means:LIVESTOCK DIRECT FROM SOURCE

Period of Use:JANUARY 1 to DECEMBER 31

Place of Use:

<u>ID</u>	<u>Acres</u>	<u>Govt Lot</u>	<u>Qtr Sec</u>	<u>Sec</u>	<u>Twp</u>	<u>Rge</u>	<u>County</u>
1			E2NENE	13	1S	5W	MADISON

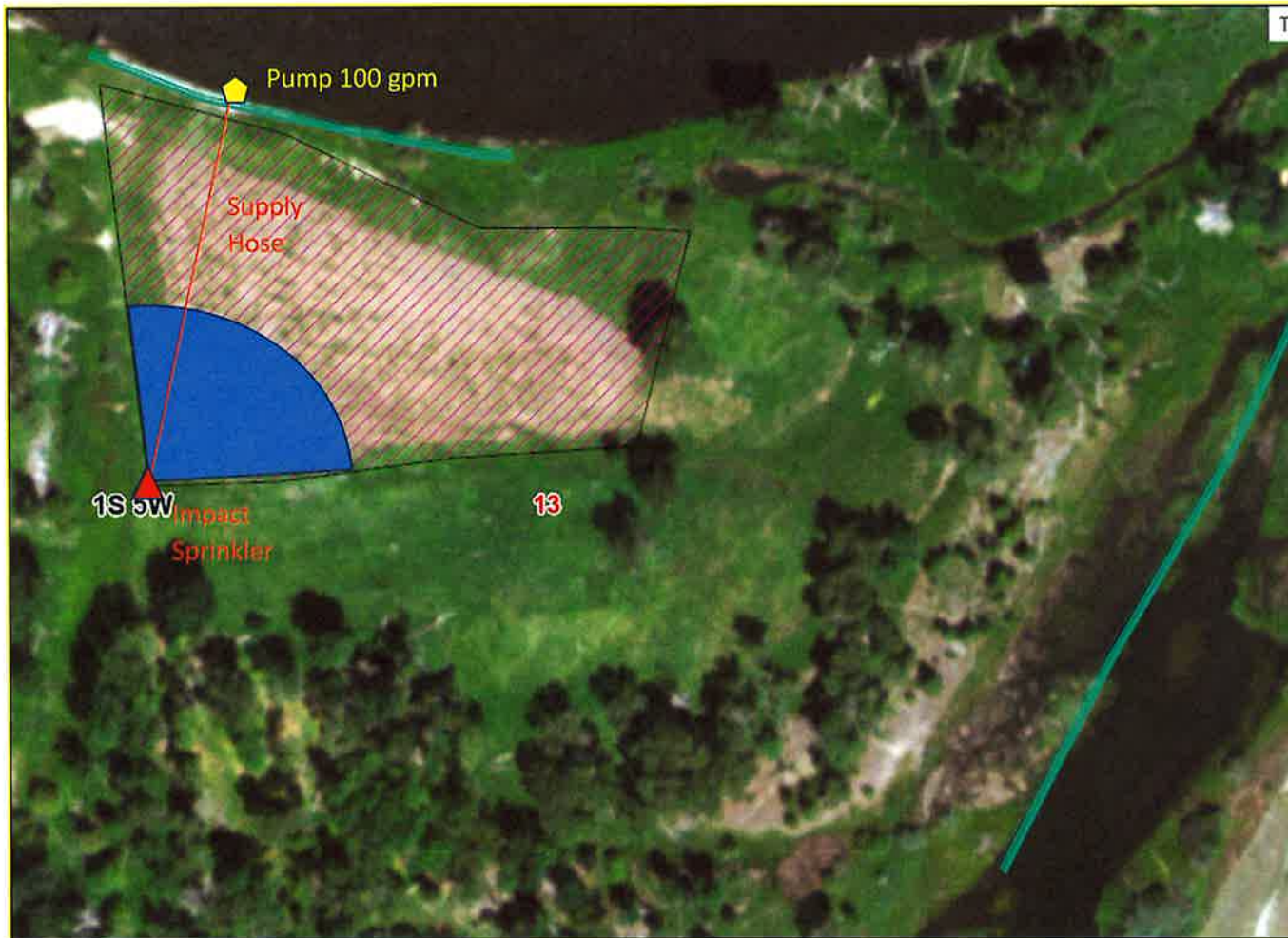
Geocodes/Valid:25-0891-13-1-01-10-0000 - Y

Remarks:

THIS CLAIM NUMBER WAS NOT INCLUDED IN THE BASIN 41G DECREE ISSUED 02/15/2018.

[illegible]

System under normal operation.



Sample set up for 100 gpm impact sprinkler shown pumping from Jefferson River. Sprinkler will be moved and arc adjusted to irrigate entire 1.6-ac place of use.

Application #40 Beneficial Use

The requested flow rates are based on the flow rate needed to supply the sprinkler systems as follows:

North Pivot (existing)	490 gpm	57.3 ac	8.6 gpm/ac
South Pivot (existing)	490 gpm	53.1 ac	9.2 gpm/ac
Southeast Pivot (new)	550 gpm	61.8 ac	8.9 gpm/ac
Wheel Line (new)	280 gpm	25.7 ac	11.2 gpm/ac
Rotating Impact Gun (new)	100 gpm	1.6 ac	62.5 gpm/ac

The four large systems (3 pivots, 1 wheel line) have been designed by Ben Lucon of Pivots Plus located in Dillon, a reputable company that designed, installs and services sprinkler systems across southwest Montana. The existing north and south pivots have been in place for a few years and have proven adequate to supply the necessary irrigation. The new pivot and wheel line have application rate capacity (gpm/ac) similar to the two existing systems.

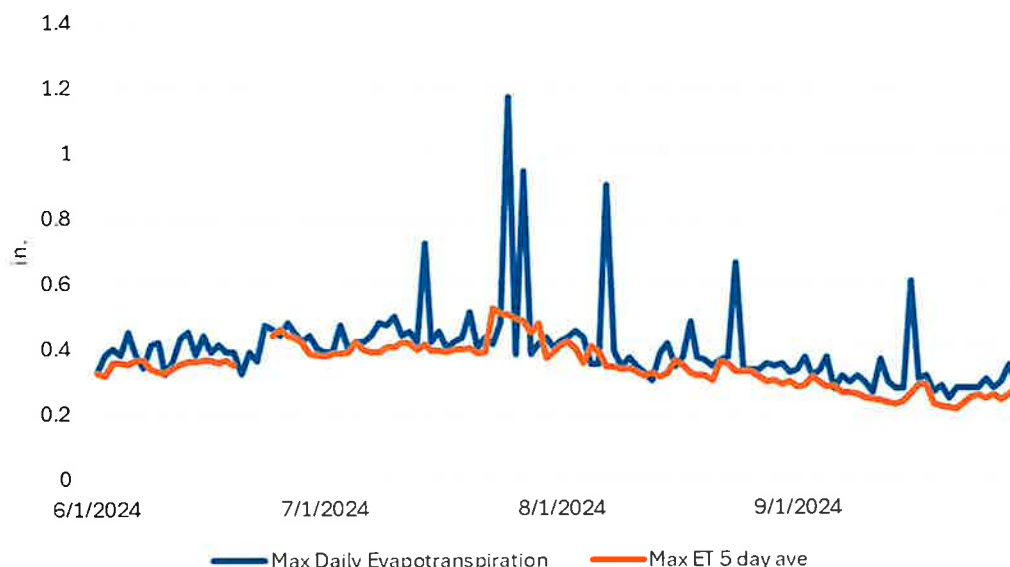
In evaluating the application rate it is useful to consider the maximum evapotranspiration expected and the ability of the system to meet that demand. The Bureau of Reclamation operates an AgriMet station just a few miles to the north of the proposed project (see map below).



Location of Bureau of Reclamation AgriMet Station.

The station records weather conditions and calculates daily evapotranspiration rates. Irrigators use this information to help schedule irrigation to match crop needs. The following chart shows the maximum daily evapotranspiration for the 2001-2024 period along with the maximum of the 5-day running average. In general, maximum evapotranspiration peaks at or a little above 0.4 in. during late June into August.

Jefferson Valley Agriment Max Daily Evapotranspiration Aug 2001 - Sep 2024



Maximum Evapotranspiration at AgriMet Station.

Using a maximum crop water demand of 0.4 in/day with a 70% irrigation efficiency, the needed peak water delivery rate is 10.8 gpm/ac.

$$(0.4 \text{ in/day} / 0.7)(1\text{ft}/12\text{in})(43560 \text{ ft}^2/\text{ac})(1 \text{ day}/1440 \text{ min})(7.48 \text{ gal}/\text{ft}^3)=10.8 \text{ gpm}/\text{ac}$$

The systems approach meeting this peak demand and are adequate given soil moisture storage that can compensate when peak demand is slightly greater than system capacity.

The rotating impact sprinkler well exceeds the peak irrigation demand, but it is intended to quickly provide irrigation of the small area that is relatively remote from the rest of the irrigation on the property. As it requires regular attention while operating, the intent is to reduce the time it takes to complete the irrigation by using a higher irrigation rate that provides the needed volume in a shorter period of time. The system is designed as complete irrigation system unit by the manufacturer and is marketed for irrigation of small acreages.

The volumes requested are based on Department's Technical Analysis Report.

Certificate Of Completion

Envelope Id: 4974148E-CA96-467D-95B0-F09FBA141530		Status: Completed
Subject: Complete with Docusign: 41G_30165036_Application_ToSign.pdf		
Source Envelope:		
Document Pages: 32	Signatures: 1	Envelope Originator:
Certificate Pages: 5	Initials: 0	Lyra Reynolds
AutoNav: Enabled		1539 11th Avenue
Envelopeld Stamping: Enabled		Helena, MT 59601
Time Zone: (UTC-07:00) Mountain Time (US & Canada)		Lyra.Reynolds@mt.gov
		IP Address: 161.7.96.143

Record Tracking

Status: Original	Holder: Lyra Reynolds	Location: DocuSign
4/22/2025 12:34:38 PM	Lyra.Reynolds@mt.gov	
Security Appliance Status: Connected	Pool: StateLocal	
Storage Appliance Status: Connected	Pool: Montana Dept of Natural Resources & Conservation	Location: Docusign

Signer Events	Signature	Timestamp
BILL GOULDD billgouldd@me.com Security Level: Email, Account Authentication (None)	 Signature Adoption: Pre-selected Style Using IP Address: 104.28.50.173 Signed using mobile	Sent: 4/22/2025 12:37:05 PM Resent: 4/25/2025 10:37:12 AM Viewed: 4/25/2025 11:10:30 AM Signed: 4/25/2025 11:13:50 AM

Electronic Record and Signature Disclosure:
Accepted: 4/25/2025 11:10:30 AM
ID: 8299eb43-43c5-4ab7-b54a-ba832aae159d

In Person Signer Events	Signature	Timestamp
Editor Delivery Events	Status	Timestamp
Agent Delivery Events	Status	Timestamp
Intermediary Delivery Events	Status	Timestamp
Certified Delivery Events	Status	Timestamp

Carbon Copy Events	Status	Timestamp
Andy Brummond abrummond@mt.gov Security Level: Email, Account Authentication (None) Electronic Record and Signature Disclosure: Not Offered via Docusign		Sent: 4/22/2025 12:37:06 PM
Lyra Reynolds lyra.reynolds@mt.gov Montana Department of Natural Resources and Conservation Security Level: Email, Account Authentication (None) Electronic Record and Signature Disclosure: Not Offered via Docusign		Sent: 4/22/2025 12:37:06 PM Resent: 4/25/2025 11:13:54 AM

Witness Events	Signature	Timestamp
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Notary Events	Signature	Timestamp
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Envelope Summary Events	Status	Timestamps
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Certified Delivered	Security Checked	4/25/2025 11:10:30 AM
Signing Complete	Security Checked	4/25/2025 11:13:50 AM
Completed	Security Checked	4/25/2025 11:13:50 AM

Payment Events	Status	Timestamps
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Electronic Record and Signature Disclosure
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Technical Analyses Report/ Scientific Credibility Review

- Departmental Technical Analyses Report/ Scientific Credibility Review
- Any correspondence relating to the Technical Analyses Report

Technical Analyses
Report /
Scientific Credibility
Review



Surface Water Change Technical Analyses Report – Part A

Department of Natural Resources and Conservation (DNRC or Department) Water Resources Division

Derek Rasmussen, Water Resource Specialist, Bozeman Regional Office

Application No.	41G 30165036	Proposed Point of Diversion	NENESE Section 14, SEWNNE & W2E2NE Section 13, all in T1S, R5W, Madison County.
Applicant	Treasured Mountains Holdings LLC		

Overview

This report is Part A of a two-part publication which analyzes data submitted by the Applicant in support of the above-mentioned water right application. This report provides technical analyses as required under the Administrative Rules of Montana (ARM) 36.12.1303 in support of the water rights criteria assessment as required in §85-2-402 Montana Code Annotated (MCA).

This Surface Water Change Technical Analyses Report – Part A contains the following sections:

Overview	1
1.0 Application Details	2
2.0 Historical Use Technical Analysis.....	3
2.1 Historical Field Consumed and Applied Volumes.....	3
2.2 Historical Conveyance Losses	6
2.3 Historical Diverted Volume	8
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3.0 Analysis of Impacted Surface Water Sources.....	9
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Surface Water Analysis of the Affected Source	16
Area of Potential Impact Analysis of the Affected Source	18
Review	20
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1.0 Application Details

The Applicant proposes to change the point of diversion (POD) and place of use (POU) of Statement of Claim 41G 197111-00. The historical elements for the claim included in this change application can be seen in **Table 1** below. The Applicant proposes to add two PODs: a permanent pump in the Jefferson River and a transitory pump in the Jefferson River or Willow Spring Creek. The proposed PODs are located downstream of the historical POD in the NENESE Section 14, and SENWNE & W2E2NE Section 13, all in T1S, R5W, Madison County. The Applicant proposes to add 52.9 acres to the POU in the S2 and NE Section 13, T1S, R5W, Madison County and retire 91 acres from the historical POU through this change. The project is in Madison County and the source is Parsons Slough. The water right will continue to be used for irrigation purposes from 5/1-10/15. No change in purpose or place of storage is proposed.

Table 1. Water right proposed for change

Water Right No.	Purpose	Flow Rate (CFS)	Volume	Period of Use	Point of Diversion	Place of Use	Priority Date	Acres
41G 197111-00	Irrigation	9.48	Historical Use Statement	5/1-10/15	SESESW Section 14 T1S, R5W, Madison County	SESE & NESE Section 14, and NWSW, NESW, SWNE, NESE, NWSE, SWSE, & SESE Section 13 all in T1S, R5W, Madison County	9/19/1876	250

41G 30165036 - Proposed Use

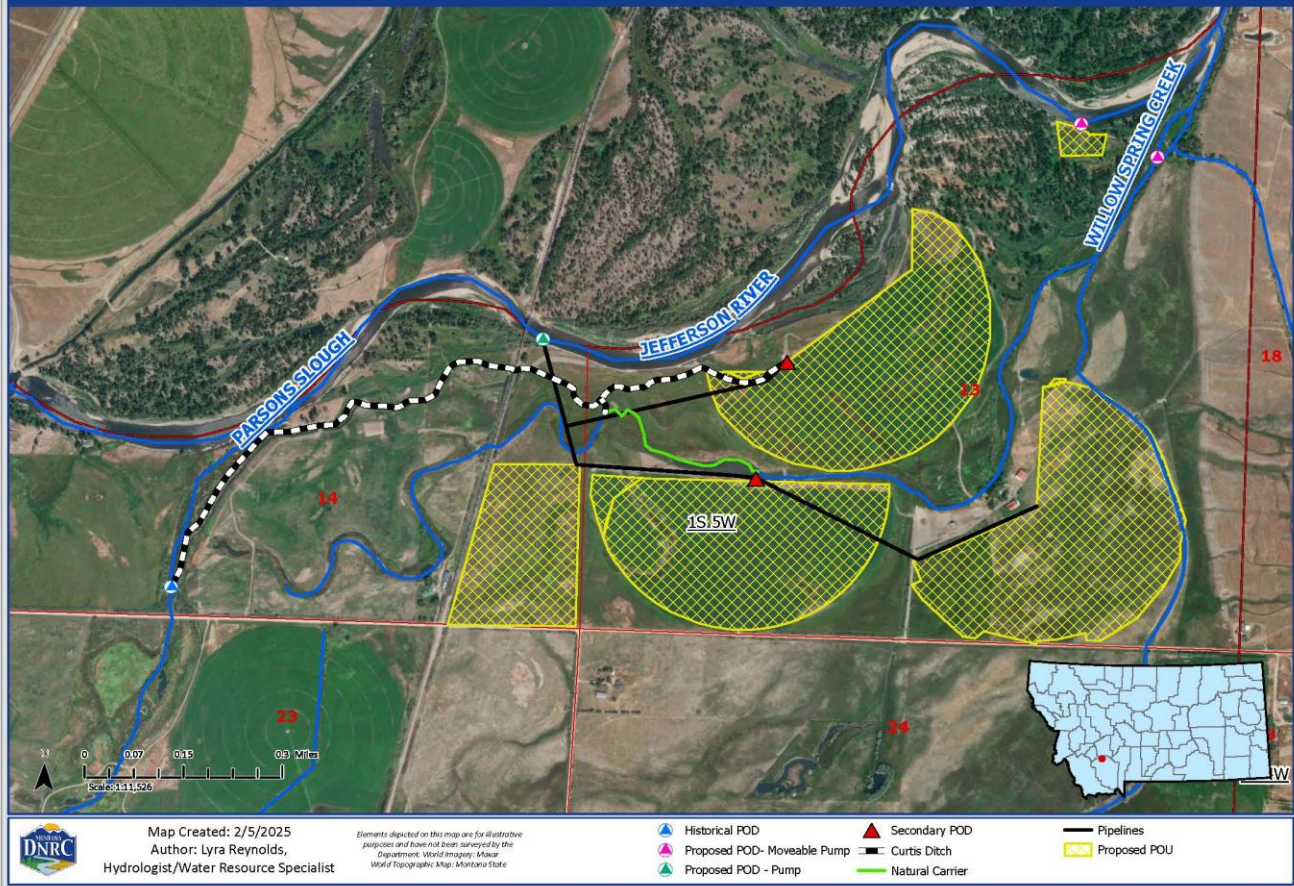


Figure 1. Proposed use for Change Application 41G 30165036. This depiction has all elements of the proposed change, including when the system is fully operational and when the ditch is in use.

2.0 Historical Use Technical Analysis

2.1 Historical Field Consumed and Applied Volumes

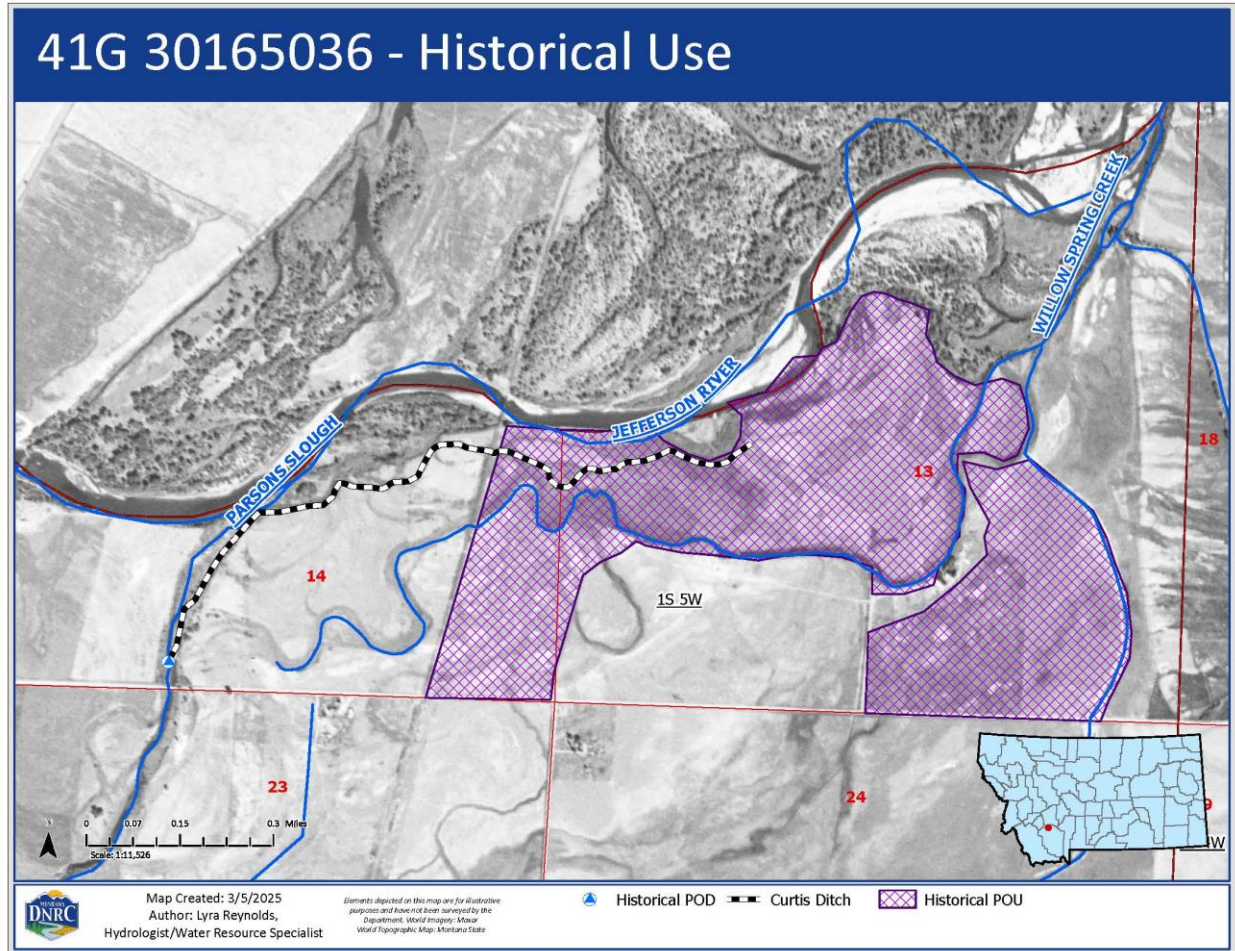


Figure 2. Historical use for Change Application 41G 30165036

Claim 41G 197111-00 was originally claimed right for surface water irrigation of 250 acres in SESE and NESE Section 14, NWSW, NESW, SWNE, NESE, NWSE, SWSE, and SESE Section 13, all in T1S, R5W, Madison County. Historical information and imagery were provided with the Preapplication Meeting Form showing POUs of 116.9 acres of wild flood irrigated acres and 120.7 acres of wheeline irrigation, for a total 237.6 historically irrigated acres. The Department used the following images to determine the maximum acres in the historical POU:

- Army Map Service Image A001210366148, dated 9/9/1954, max acres = 231
- NASA AMES Research Center Image 5720005521774, dated 7/26/1972, max acres = 237.6
- Photo 378-61, dated 9/7/79, max acres = 237.6

The maximum acres found for Claim 41G 197111-00 is 237.6 acres. The Department conducted its historical use analysis using 237.6 historically irrigated acres.



Claim 41G 197111-00 was historically diverted from Parsons Slough through a headgate and conveyed by the Curtis Ditch to the POU. The diversion is a wood structure with an 8-foot-wide opening in SESESW Section 14, T1S, R5W, Madison County. Claim 41G 197111-00 is diverted from Parsons Slough through this opening into the Curtis Ditch at a flow rate of 9.48 CFS from 5/1-10/15 for irrigation use. The Curtis Ditch conveys two water rights: Claim 41G 197111-00 and Provisional Permit 41G 2262-00. The estimated ditch capacity at the headgate is 16 CFS, based on headgate measurements provided in the Preapplication Meeting Form. The capacity was found to be 8.2 CFS down-ditch, based on water depth measurements in the ditch. The Applicant provided a ditch profile along with the measurements showing the ditch has additional capacity than what was found when 8.3 CFS of flow was in the ditch. Claim 41G 197111-00 has a maximum claimed flow rate of 9.48 CFS. The maximum flow rate conveyed by the ditch is 11.04 CFS.

The total historical consumptive volume (HCV) for the water right associated with this Change Application is 256.68 AF. The Department calculated the historical consumptive volume using the Department's standard methodology, pursuant to ARM 36.12.1902. The water right being changed is a Statement of Claim, and the historical use will be evaluated as the right existed prior to July 1, 1973. The consumed volume for irrigation is based on the net irrigation requirement (NIR) from USDA Natural Resources Conservation Service Irrigation Water Requirements (IWR) at a representative weather station. The NIR is multiplied by a county-wide management factor (from ARM 36.12.1902) to produce an adjusted NIR representative of actual crop yields in Montana. Crop consumption is determined by multiplying the adjusted NIR by the number of acres of irrigation. Crop consumption is then divided by the field efficiency identified from the irrigation method and ARM 36.12.115. Irrecoverable losses (IL) are 5% of the field applied volume for flood irrigation or 10% for sprinkler irrigation. The total consumed volume for irrigation is the crop consumption plus irrecoverable losses. The total non-consumed volume is the field applied volume minus the total consumed volume. Values seen in tables were calculated using the Department standard Irrigation and Conveyance Loss Calculator and may differ up to due to rounding.

The historical consumptive volume for the historical place of use was found using the following equations and information:

$$HCV = \text{Crop Consumption} + \text{Historic Irrecoverable Losses}$$

Crop Consumption

$$= \text{Twin Bridges} * \frac{1\text{ft}}{12\text{inches}} * \text{Madison County Management Factor} \\ * \text{Historic Acres}$$

$$\text{Historic Irrecoverable Losses} = \text{Field Applied} * \text{IL}\%$$



$$\text{Field Applied} = \frac{\text{Crop Consumption}}{\text{Field Efficiency}}$$

Crop Consumptive Use

Twin Bridges Weather Station North Field: 16.98 in

Twin Bridges Weather Station South Field: 16.98 in

Madison County Management Factor: 65%

Water Applied to Field

North field On- Farm Efficiency: 25%

South field On-Farm Efficiency: 70%

Irrecoverable Losses

North Field: 5% for flood irrigation

Irrecoverable losses = 5% x 431.4 = 21.57

South Field: 10% for sprinkler irrigation

Irrecoverable losses = 10% x 159.08 = 15.91

Total Historical Consumptive Use

North Field total = crop consumptive use + irrecoverable losses = 129.42

South Field total = crop consumptive use + irrecoverable losses = 127.26

The historical consumed and field applied volumes have been calculated with the inputs shown in **Table 2** following the methods described above and in ARM 36.12.1902.

Table 2. Historical consumptive use of historical place of use

Field ID	Irrigation Method	Acres	NIR (in)	Management Factor	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume (AF)
North Flood	Flood	116.9	16.98	0.65	0.25	107.85	431.4	21.57	129.42
South Sprinkler	Wheeline	120.7	16.98	0.65	0.7	111.36	159.08	15.91	127.26

No other water rights irrigate the historical place of use.

Table 3. Historical consumptive use for the water right proposed for change

Water Right No.	Crop Consumption (AF)	Applied Volume - (AF)	Consumed Volume - (AF)
41G 197111-00	219.21	590.5	256.68

2.2 Historical Conveyance Losses

Per ARM 36.12.1902(10), the historical conveyance loss volume is equal to the sum of the historical seepage loss, vegetation loss, and ditch evaporation volumes.



The Curtis Ditch historically conveyed 2 water rights: Permit 41G 2262-00 & Claim 41G 197111-00. The seasonal conveyance losses in the Curtis Ditch were calculated using ditch measurements provided by the Applicant and the equations below. The Applicant stated water was diverted from the Parsons Slough from 5/1-10/15 for all water rights in the ditch. Permit 41G 2262-00 has a POU up ditch of the POU of Claim 41G 197111-00. To account for the differences in distance conveyed to POUs, the ditch was divided into 2 down-ditch combinations seen in **Table 4**. Conveyance losses were found for each down-ditch combination and distributed to the water rights in the combination based on a flow rate proportion. The conveyance losses attributed to the water right proposed for change were found using the following equations and are summarized in **Tables 4-6**.

$$\text{Water Right Conveyance Loss} = \sum \text{Ditch Combo Conveyance Losses}_{WR}$$

$$\begin{aligned} \text{Ditch Combo Conveyance Losses}_{Total} \\ = \text{Seepage Loss}_{combo} + \text{Vegetation Loss}_{combo} + \text{Evaporation Loss}_{combo} \end{aligned}$$

$$\begin{aligned} \text{Seepage Loss}_{combo} \\ = (\text{Wetted Perimeter}_{combo} * \text{Ditch Length}_{combo} * \text{Ditch Loss Rate} \\ * \text{Days Diverted}_{combo}) * \frac{1 \text{ acre}}{43560 \text{ ft}^2} \end{aligned}$$

$$\begin{aligned} \text{Vegetation Loss}_{combo} \\ = 0.75\% \text{ loss per mile} * \frac{\text{Ditch Length}_{combo}}{5280 \text{ miles}} * \text{Flow Rate}_{combo} \\ * \text{Days Diverted}_{combo} * 2 \end{aligned}$$

$$\begin{aligned} \text{Ditch Evaporation Loss}_{combo} \\ = (\text{Surface Area} * \text{Adjusted Net Evaporation}_{combo}) * \frac{1 \text{ acre}}{43560 \text{ ft}^2} \end{aligned}$$

$$\text{Surface Area} = (\text{Wetted Width ft}) * \text{Ditch Length}_{combo}$$

$$\begin{aligned} \text{Ditch Combo Conveyance Losses}_{WR} \\ = \text{Ditch Combo Conveyance Losses}_{Total} * \text{Combo Flow Proportion}_{WR} \end{aligned}$$

$$\text{Combo Flow Proportion}_{WR} = \text{WR Flow Rate}_{ditch} * \text{Ditch Combo Total Flow Rate}$$

Table 4. Curtis Ditch down-ditch combinations

Down-Ditch Combo	Water rights in Combo	Period of Diversion Start	Period of Diversion End	Total Days in Period	Combo Flow Rate (CFS)	Combo Length (ft)
Curtis A	41G 197111-00 & 41G 2262-00	1-May	15-Oct	168	11.04	3215
Curtis B	41G 197111-00	1-May	15-Oct	168	9.48	2015



Table 5. Curtis Ditch historical conveyance losses for down-ditch combinations

Down-Ditch Combo	Length (ft)	Flow Rate (CFS)	Wetted Width (ft)	Wetted Perimeter (ft)	Ditch Loss Rate (ft ³ /ft ² /day)	No. of Days Diverted	Adj. Net Evaporation (in)	Seepage Loss (AF)	Vegetation Loss (AF)	Evaporative Loss (AF)	Total Conveyance Loss (AF)
Curtis A	3215	11.04	14	15.21	1	168	21.21	188.6	16.94	1.83	207.36
Curtis B	2015	9.48	14	15.21	1	168	21.21	118.2	9.12	1.14	128.46

Table 6. Curtis Ditch historical conveyance losses per water right

Water Right No.	Down-Ditch Combo	Water Right Flow Rate (CFS)	Water Right Conveyance Loss (AF)
41G 2262-00	Curtis A	1.56	29.3
41G 197111-00	Curtis A & B	9.48	306.52

2.3 Historical Diverted Volume

Per ARM 36.12.1902(10), the historically diverted volume is equal to the sum of the historical field application volume and historical conveyance loss volume. The Department calculated the historical diverted volume based on the information provided by the Applicant about the historical irrigation practices. **Table 7** below summarizes the historical diverted volume for Claim 41G 197111-00.

Table 7. Historical diverted volume of water right proposed for change

Water Right No.	Historical Consumptive Volume (AF)	Historical Field Applied Volume (AF)	Historical Diverted Volume (AF)
41G 197111-00	256.68	590.5	897

2.4 Summary of Historical Use

The Department will consider the following values when evaluating the historical use of Claim 41G 197111-00 for the adverse effect criterion:

Table 8. Summary of historical use of Claim 41G 197111-00.

Water Right No.	Historical Purpose	Maximum Historical Acres	Historical Place of Use	Historical Point of Diversion	Maximum Historical Flow Rate	Historically Consumed Volume	Historically Diverted Volume
41G 197111-00	Irrigation	237.6 acres	SESE, NESE Section 14, and NWSW, NESW, SWNE, NESE, NWSE, SWSE, SESE Section 13, all in T1S, R5W, Madison County	SESESW Section 14, T1S, R5W, Madison County	9.48 CFS	256.68 AF	897 AF



3.0 Analysis of Impacted Surface Water Sources

3.1 Summary of Proposed Use

The Applicant proposes to change the POD and POU for Claim 41G 197111-00. Through the proposed change the Applicant will add two points of diversion: a permanent pump in the NENESE Section 14 and a transitory pump in the SENWNE & W2E2NE Section 13, all in T1S, R5W, Madison County. The Applicant will continue to use the historical POD following the change when the proposed PODs are not operational. The Applicant also proposes to add 52.9 acres outside the historical POU to irrigate and retire 91 historically irrigated acres. The acres will be added in SWSW & SESW of Section 13, T1S, R5W, Madison County. After the proposed change, Claim 41G 197111-00 is able to be diverted from three PODs and used to irrigate 199.5 acres. The proposed use of Claim 41G 197111-00 is shown in **Table 9**:

Table 9. Summary of the proposed use of 41G 197111-00.

Water Right No.	Proposed Purpose	Proposed Place of Use	Proposed Point of Diversion	Proposed Flow Rate	Proposed Consumptive Volume	Proposed Diverted Volume
41G 197111-00	Irrigation (199.5 acres)	SESE Section 14 and S2, SWNE, SENW, SWNENE, & SENWNE Section 13, all in T1S, R5W, Madison County	SESESW & NENESE Section 14, and SENWNE & W2E2NE Section 13, T1S, R5W, Madison County	9.48 CFS	238.25 AF	564.92 AF

The Applicant proposes to continue to use Claim 41G 197111-00 for irrigation use. When the proposed PODs are in use and the system is fully operational, water will be diverted from the Jefferson River into pipelines. The pipelines will convey water to the irrigation systems on each field in the proposed POU. The proposed POU includes historical and proposed, new acres. Following the proposed change, 142.2 acres will be sprinkler irrigated, and 57.3 acres will remain flood irrigated. Irrigation use will continue from 5/1-10/15 for a total 199.5 irrigated acres. No other water rights will be used to irrigate the proposed POU after the change. Claim 41G 212596-00 is currently claimed with an irrigation POU that overlaps with a portion of the proposed acres in Section 13, but the Applicant stated this water right will not be used to supplement Claim 41G 197111-00. The Applicant stated further plans for Claim 41G 212596-00 will be provided with application materials.

Following the procedures outlined in the Historical Use section 2.1 above, the proposed consumed and diverted but non-consumed volumes have been calculated with the inputs shown in **Table 10** following the methods described above and in ARM 36.12.1902. The proposed consumptive volume associated with the new acres for Claim 41G 197111-00 was added to the historical consumptive volume associated with the remaining 146.6 historical acres to find the total consumptive use following the proposed change. The proposed consumptive volume of



Claim 41G 197111-00 was found using the information below and is summarized in **Tables 10-12**.

Crop Consumptive Use – new acres

Twin Bridges Weather Station: 19.22 inches

Madison County 1997-2006 (proposed use) Management Factor: 83.3%

Water Applied to Field – new acres

Field efficiency (center pivot): 70%

Irrecoverable Losses – new acres

10% for sprinkler irrigation

Irrecoverable losses = 10% x 100.83 = 10.08

Table 10. Proposed consumptive volume of new acres

Field ID	Acres	Weather Station	NIR (in)	Management Factor	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume - New Acres (AF)
New Acres	52.9	Twin Bridges	19.22	0.83	0.7	70.58	100.83	10.08	80.66

Table 11. Historical consumptive volume of remaining acres

Field ID	Acres	Weather Station	NIR (in)	Management Factor	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume - Remaining Acres (AF)
Historical Flood	57.3	Twin Bridges	16.98	0.65	0.25	52.86	211.46	10.57	63.44
Historical Sprinkler	89.3	Twin Bridges	16.98	0.65	0.7	82.39	117.69	11.77	94.16

Table 12. Proposed consumptive volume of Claim 41G 197111-00

Water Right No.	Crop Consumption - All Proposed Acres (AF)	Applied Volume - All Proposed Acres (AF)	Consumed Volume - All Proposed Acres (AF)
41G 197111-00	205.83	429.98	238.26

The Applicant proposes to use pipelines to convey water from the proposed PODs when the system is fully operational. When the system is not fully operational, the Applicant will utilize the historical POD and Curtis Ditch. Water will be diverted using the historical POD and conveyed via the Curtis Ditch when the Jefferson River pump sites are not in use. The Applicant will use secondary PODs on the Curtis Ditch and a natural carrier to apply water onto three of the fields in the proposed POU; these are labeled as Fields B, D, and E on **Figure 3**.

41G 30165036 - Proposed Ditch Conveyance

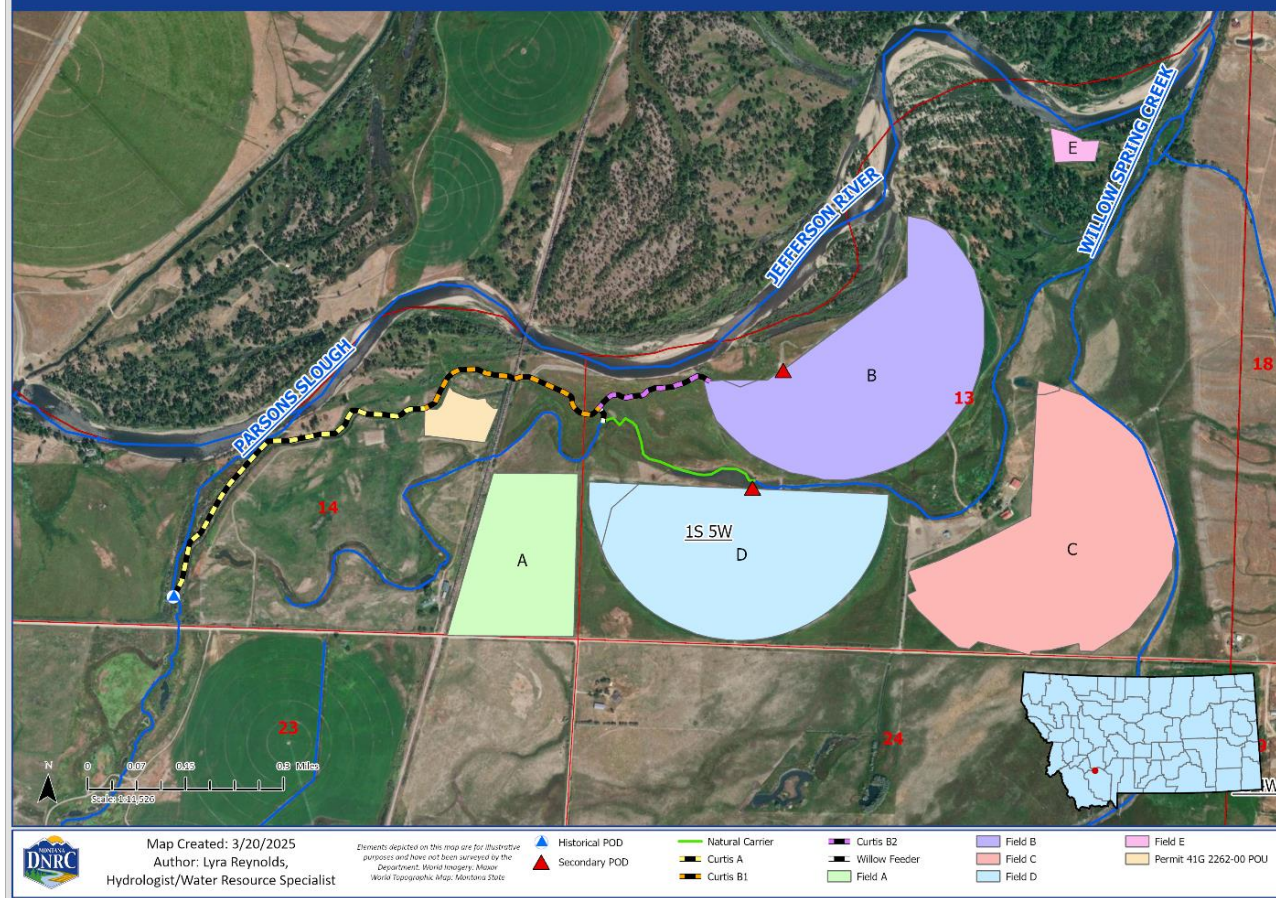


Figure 3. Claim 41G 197111-00 proposed ditch conveyance system

The Applicant estimated the total amount of time to deliver the field applied volume to the proposed POUs using the Curtis Ditch is 50.7 days. The time to deliver the field applied volume varies depending on the size of the field. Water will be delivered to all three fields for 6.8 days. Once the full field applied volume for Field E is delivered, water will be delivered for an additional 40.2 days only to the remaining fields. Once the full field applied volume for Field D is delivered, water will be delivered only to Field B for an additional 3.7 days. The total flow rate diverted at the POD is the amount needed to convey the field applied volume to each field. When water is diverted at a secondary diversion or delivered to a field, a portion of the flow rate is no longer being conveyed through the ditch. The differences in flow rates were also considered in calculating conveyance losses. To account for differences in distances between the headgate and the proposed fields and operational needs at the fields, the Curtis Ditch was divided into the following groups and down-ditch combinations:



Table 13. Curtis Ditch groups and down-ditch combinations

Group	Down-Ditch Combo	Water Rights Conveyed	Days	Maximum Total Flow Rate (CFS)
G1: Water being delivered to Fields B, D, and E	Curtis A	41G 197111-00 & 41G 2262-00	6.8	4.95
	Curtis B1	41G 197111-00	6.8	3.39
	Curtis B2	41G 197111-00	6.8	1.51
	Willow Feeder	41G 197111-00	6.8	1.34
G2: Water being delivered to Fields B & D	Curtis A	41G 197111-00 & 41G 2262-00	40.2	4.22
	Curtis B1	41G 197111-00	40.2	2.66
	Curtis B2	41G 197111-00	40.2	1.45
	Willow Feeder	41G 197111-00	40.2	1.11
G3: Water being delivered to Field B	Curtis A	41G 197111-00 & 41G 2262-00	3.7	3.77
	Curtis B1 & B2	41G 197111-00	3.7	2.21

The conveyance losses associated with Claim 41G 197111-00 were calculated for the proposed use using a similar methodology as the historical conveyance losses, described in the Historical Use Section 2.2. The Department utilized the evaporation rate for the entire period of diversion, as the ditch may be used during the entire 5/1 - 10/15 period. Conveyance losses were distributed to Claim 41G 197111-00 using the Department's Multi-User Ditch Memo. The proposed conveyance losses are summarized in **Tables 14 and 15**.

Table 14. Curtis Ditch proposed conveyance losses for down-ditch combinations

Ditch ID	Length (ft)	Flow Rate (CFS)	Width (ft)	Wetted Perimeter (ft)	Ditch Loss Rate (ft ³ /ft/day)	Number of Days Irrigated	Adj. Net Evap (in)	Seepage Loss (AF)	Vegetation Loss (AF)	Evaporative Loss (AF)	Total Conveyance Loss (AF)
G1 Curtis A	3215	4.95	14	15.2	1.1	6.8	21.21	8.39	0.31	1.83	10.53
G1 Curtis B1	2305	3.39	14	15.2	1.1	6.8	21.21	6.02	0.15	1.31	7.48
G1 Curtis B2	1800	1.51	14	15.2	1.1	6.8	21.21	4.7	0.05	1.02	5.77
G1 Willow Feeder	120	1.34	14	15.2	1.1	6.8	21.21	0.31	0	0.07	0.38
G2 Curtis A	3215	4.22	14	15.2	1.1	40.2	21.21	49.61	1.55	1.83	52.98
G2 Curtis B1	2305	2.66	14	15.2	1.1	40.2	21.21	35.57	0.7	1.31	37.58
G2 Curtis B2	1800	1.45	14	15.2	1.1	40.2	21.21	27.77	0.3	1.02	29.1
G2 Willow Feeder	120	1.11	14	15.2	1.1	40.2	21.21	1.85	0.02	0.07	1.94
G3 Curtis A	3215	3.77	14	15.2	1.1	3.7	21.21	4.57	0.13	1.83	6.52
G3 Curtis B1 & B2	4105	2.21	14	15.2	1.1	3.7	21.21	5.83	0.1	2.33	8.26



Table 15. Ditch proposed conveyance losses per water right

Water Right No	Ditch ID	WR Flow Rate (CFS)	Required Diverted Flow Rate (CFS)	Combo Total Flow Rate (CFS)	Proportion	Combo Conveyance Loss (AF)	Water Right Conveyance Loss (AF)
41G 2262-00	S1 Curtis A	1.56	1.56	4.95	0.3	10.53	3.32
	S2 Curtis A	1.56	1.56	4.22	0.4	52.98	19.59
	S3 Curtis A	1.56	1.56	3.77	0.4	6.52	2.70
41G 197111-00	S1 Curtis A	9.48	3.39	4.95	0.7	10.53	7.21
	S1 Curtis B1	9.48	3.39	3.39	1.0	7.48	7.48
	S1 Curtis B2	9.48	1.51	1.51	1.0	5.77	5.77
	S1 Willow Feeder	9.48	1.34	1.34	1.0	0.38	0.38
	S2 Curtis A	9.48	2.66	4.22	0.6	52.98	33.39
	S2 Curtis B1	9.48	2.66	2.66	1.0	37.58	37.58
	S2 Curtis B2	9.48	1.45	1.45	1.0	29.1	29.10
	S2 Willow Feeder	9.48	1.11	1.11	1.0	1.94	1.94
	S3 Curtis A	9.48	2.21	3.77	0.6	6.52	3.82
	S3 Curtis B1 & B2	9.48	2.21	2.21	1.0	8.26	8.26

The total proposed field applied volume was added to the proposed conveyance losses attributed to Claim 41G 197111-00 to obtain the total proposed diverted volume. The total proposed diverted volume, seen in **Table 16**, reflects the maximum water usage given the Applicant's proposed operational plan.

Table 16. Proposed diverted volume

Water Right No.	Consumed Volume (AF)	Applied Volume (AF)	Conveyance Losses (AF)	Total Diverted Volume (AF)
41G 197111-00	238.26	429.98	134.94	564.92

Table 17. Comparison of volumes associated with historical and proposed use.

Water Right No.	Historically Consumed Volume (AF)	Proposed Consumptive Volume (AF)	Historically Diverted Volume (AF)	Proposed Diverted Volume (AF)
41G 197111-00	256.68	238.26	897	564.92

3.2 Impacted Surface Water Sources

The Department has considered an area of potential adverse effect on Parsons Slough and the Jefferson River. This reach was determined to be the area from the historical POD downstream to where Willow Spring Creek meets the Jefferson River. This reach extends from SESESW Section 14, T1S, R5W, Madison County downstream to NENENE Section 13, T1S, R5W, Madison County. Water rights that share the POD with Claim 41G 197111-00 were also considered. The area of potential adverse effect can be seen in **Figure 4**. There are 2 water rights within the area of potential adverse effect, as illustrated in **Appendix A**.

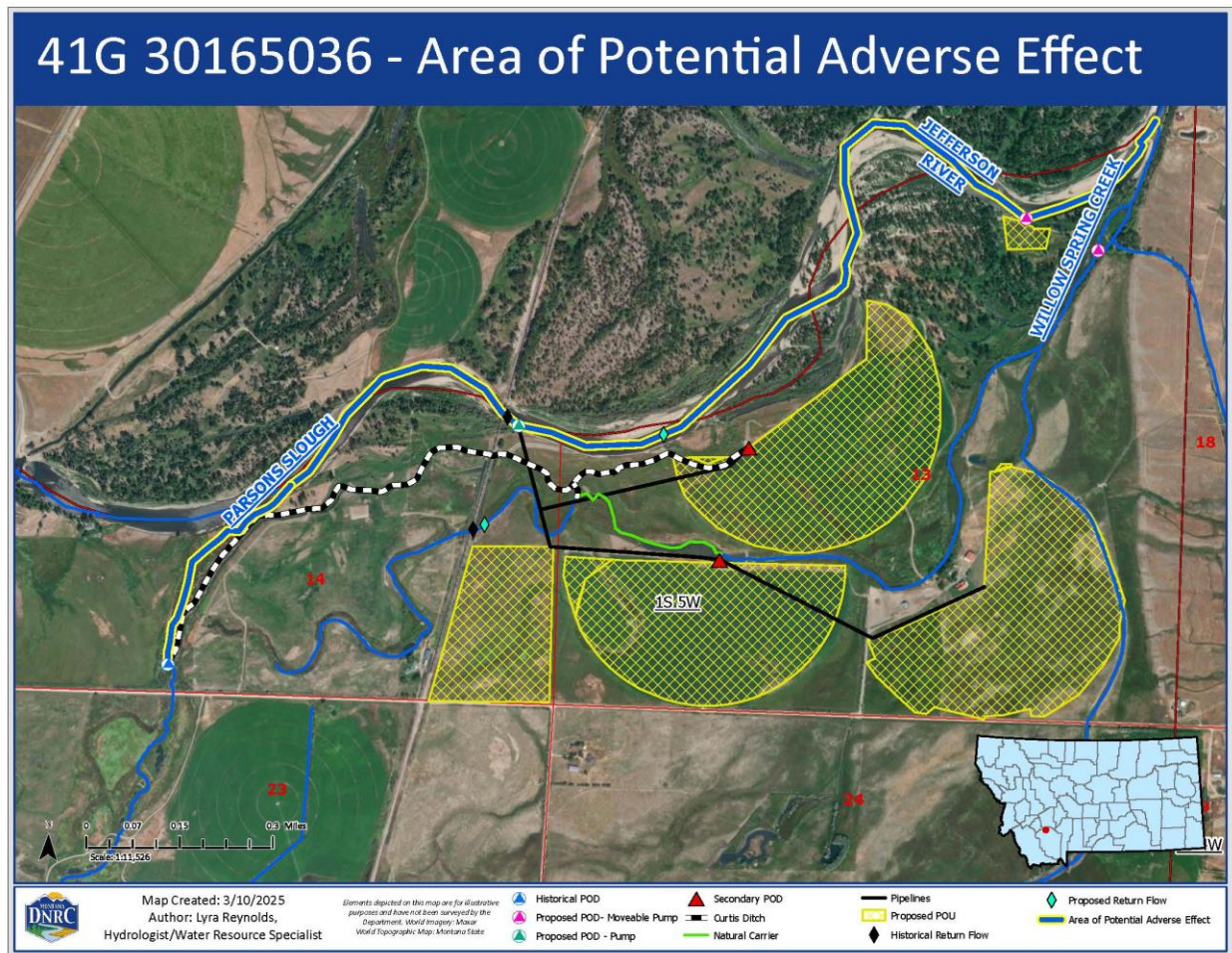


Figure 4. Area of Potential Adverse Effect

Historically, 105.7 AF of return flow volume returned to the Jefferson River downstream of the NENESE Section 14, T1S, R5W, Madison County and 228.1 AF returned to Willow Spring Creek downstream of the SWNESE Section 14, T1S, R5W, Madison County. Under the proposed change, 51.8 AF of return flow volume will accrue to the Jefferson River downstream of NENWSW Section 13, T1S, R5W, Madison County and 139.9 AF will accrue to Willow Spring Creek downstream of the SWNESE Section 14, T1S, R5W, Madison County. The

Applicant proposes to leave water instream, equal to 332.1 AF, in Parsons Slough and the Jefferson River at the historical POD. Water will not be left instream in Willow Spring Creek following the proposed change. The Department has also considered an Area of Potential Impact, seen in **Figure 5** that includes water rights in Willow Spring Creek between the historical location of return flows and the confluence of Willow Spring Creek and the Jefferson River.

Part B of the Technical Analyses Report includes the Return Flow Analysis, which describes the methodologies used to assess the historical and proposed return flows associated with this application.

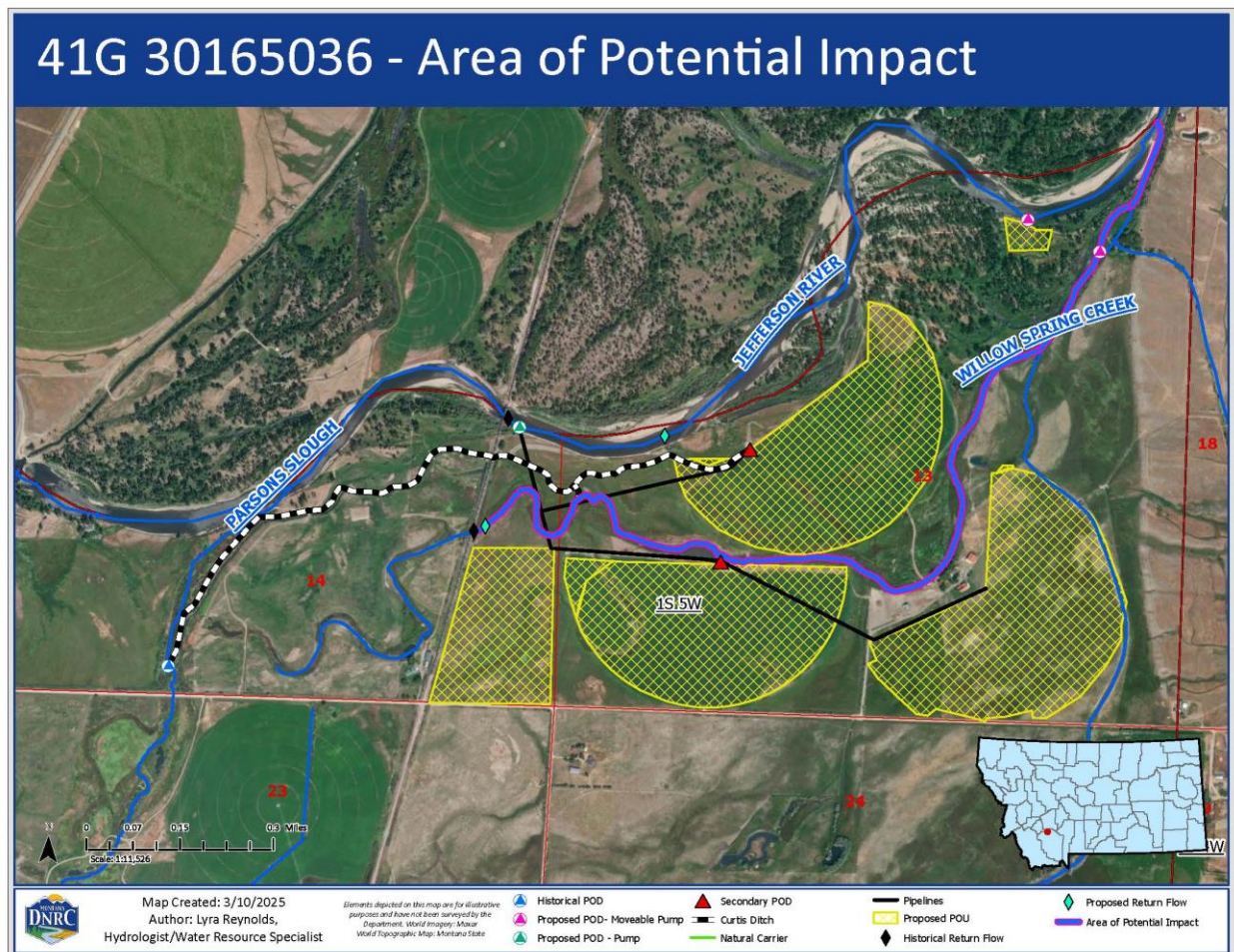


Figure 5. Area of Potential Impact

3.3 Extended Return Flow Analysis: Evaluation of Impacts to Identified Water Rights

An evaluation of the impacts to the following water rights due to projected loss of return flows is required per ARM 36.12.1303(3)(d)(iii):



Table 18. Water rights in Area of Potential Impact

Water Right No.	All Owners	Means of Diversion	Flow Rate (GPM)	Flow Rate (CFS)	Volume (AF)	Acres	Animal Units	Priority Date
41G 30123892	TREASURED MOUNTAINS HOLDINGS LLC	LIVESTOCK DIRECT FROM SOURCE	42.30	0.09	11.76	0.00	350.00	3/20/1876
41G 30124720	TREASURED MOUNTAINS HOLDINGS LLC	LIVESTOCK DIRECT FROM SOURCE	39.80	0.09	7.73	0.00	230.00	12/31/1885
41G 30017621	MONTANA, STATE OF DEPT OF FISH WILDLIFE & PARKS	INSTREAM	4128.96	9.20	6660.04	0.00	0.00	7/1/1985
41G 212596-00	TREASURED MOUNTAINS HOLDINGS LLC	IRRIGATION	920.04	2.05	150.38	73.00	0.00	6/30/1973

Surface Water Analysis of the Affected Source

Method of Estimation

Method of Measurement Used: The Department utilized instantaneous streamflow measurements collected by the Montana Bureau of Mines and Geology (MBMG) between 2020 and 2024 to validate an estimation technique. The streamflow measurements are from GWIC stream site ID 277126, Long/Lat -112.155823904, 45.7526167 (SRID: NAD83). These measurements can be seen in **Table 19** below.

Table 19. MBMG streamflow measurements on Willow Spring Creek.

Year	Streamflow Measurements (CFS)						
	March	April	July	August	September	October	December
2020			14.13			14.30	11.22
2021		10.39	11.46	13.19			
2022	8.92		14.69		11.39		
2023	9.49		18.74		24.24	25.26	12.46
2021		10.80		18.19			
Average	9.21	10.60	14.75	15.69	17.82	17.95	11.84

Method of Estimation Used: Under Arm 36.12.1702(4) physical availability of water in Willow Spring Creek was determined using linear interpolation and instantaneous streamflow measurements collected by MBMG. Linear interpolation is a method of curve fitting using linear polynomials to construct new data points within the range of a discrete set of known data points. If the two known points are given by the coordinate (xo, yo) and (x1, y1), the linear interpolant is the straight line between these two points. Using the following interpolation equation and inputs, a discharge measurement (y) was calculated for the 15th of each month measurements were not available (January, February, May, June, November).



Solving this equation for y , which is the unknown value at x , gives

$$\begin{aligned} y &= y_0 + (x - x_0) \frac{y_1 - y_0}{x_1 - x_0} \\ &= \frac{y_0(x_1 - x_0)}{x_1 - x_0} + \frac{y_1(x - x_0) - y_0(x - x_0)}{x_1 - x_0} \\ &= \frac{y_1x - y_1x_0 - y_0x + y_0x_0 + y_0x_1 - y_0x_0}{x_1 - x_0} \\ &= \frac{y_0(x_1 - x) + y_1(x - x_0)}{x_1 - x_0}, \end{aligned}$$

Inputs to estimate stream flow (y):

$Y^0 = n$ CFS

$X^0 =$ date measurement was collected ~ month.date.year (serial no. format)

$Y^1 = n$ CFS

$X^1 =$ date measurement was collected ~ month.date.year (serial no. format)

$x =$ date estimating stream flow ~ month.date.year (serial no. format)

Table 20 and **Figure 6** below identify average monthly measured and estimated stream flow for Willow Spring Creek.

Table 20. Monthly average measured flow and estimated flow for Willow Spring Creek.

Month	Monthly Average Measured Flow (CFS)	Interpolated Stream Flow (CFS)	Summary of Monthly Flow (CFS)
January		8.65	8.65
February		8.94	8.94
March	9.21		9.21
April	10.6		10.6
May		11.97	11.97
June		13.38	13.38
July	14.75		14.75
August	15.69		15.69
September	17.82		17.82
October	17.95		17.95
November		14.84	14.84
December	11.84		11.84

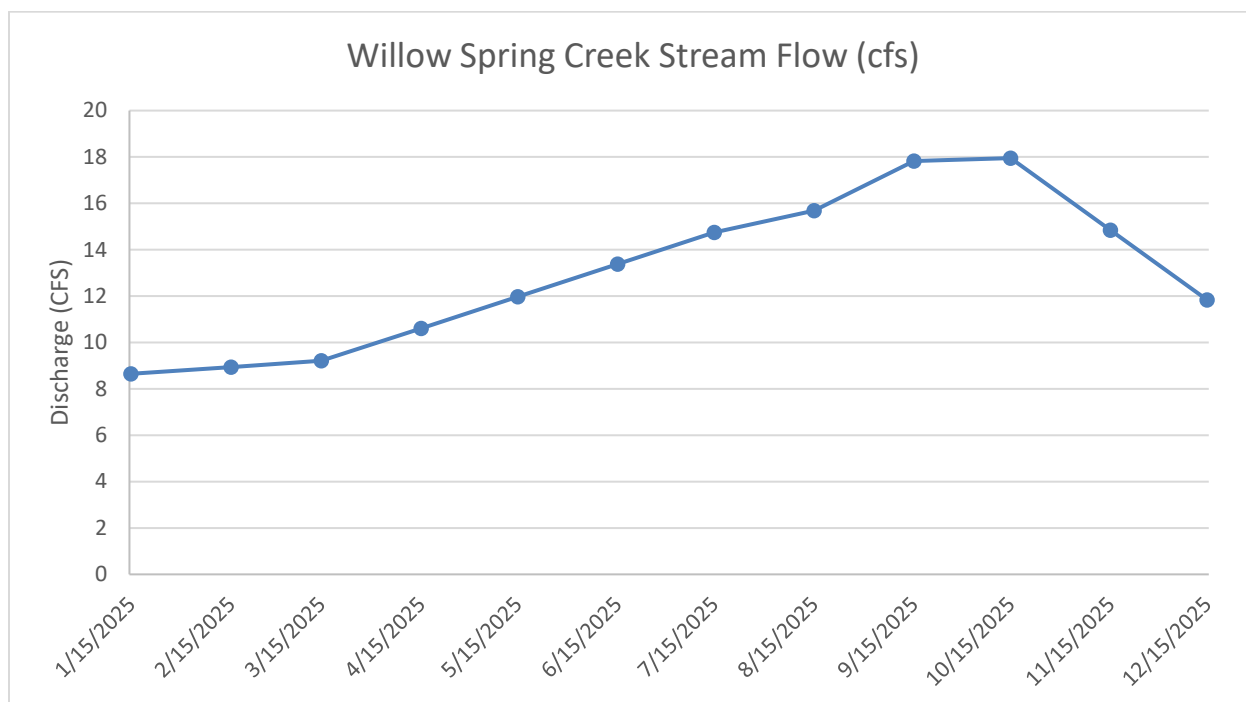


Figure 6. Average monthly measured and estimated stream flow for Willow Spring Creek. Stream flow rises in response to spring runoff and increased stage of the Jefferson River. Stream flow stays elevated until late fall as a result of return flows from nearby fields and then decreases throughout the winter.

Why this method is considered appropriate: Linear interpolation is a Department-approved estimation technique to estimate mean monthly stream flow. The Department deemed the measurements taken by MBMG adequate to validate the estimation techniques, as it meets the standards for streamflow measurements in ARM 36.12.1702(1)(b).

Area of Potential Impact Analysis of the Affected Source

The Area of Potential Impact of the affected source is: The Department has considered an area of potential impact (AOPI) on Willow Spring Creek. Return flows historically accrued to Willow Spring Creek downstream of the SWNESE Section 14, T1S, R5W, Madison County. Return flows will continue to accrue to Willow Spring Creek in the SWNESE Section 14, T1S, R5W, Madison County following the proposed change. The AOPI reach was determined to be the area from the historical location of return flows to the confluence of the Jefferson River and Willow Spring Creek. This reach extends downstream of the SWNESE Section 14, T1S, R5W, Madison County to NENENE Section 13, T1S, R5W, Madison County. A total of 4 water rights exist within this reach, as seen in **Table 18**. This reach can be seen in **Figure 5**.

Why this is an appropriate Area of Potential Impact: The Department identified the reach depicted in pink on **Figure 5** as the area of potential impact on the affected source (Willow Spring Creek) because this is a location in which historical return flows accrued. The Surface



Water Change Report – Part B states 228.1 AF of return flow volume historically accrued to Willow Spring Creek and 139.9 AF of return flow volume will accrue following the proposed change. A loss of 88.2 AF in return flow volume in Willow Spring Creek is projected. The Applicant will leave water instream in Parsons Slough and the Jefferson River. Since water rights exist in the stretch upstream of the confluence of Willow Spring Creek and the Jefferson River and the proposal does not leave any water instream in Willow Spring Creek, the Department identified this as an appropriate area of potential impact.

Methodology: The Department identified the AOPI as the reach between the historical return flow location on Willow Spring Creek and the confluence of the Jefferson River and Willow Spring Creek. This reach was delineated using information about historical and proposed return flows from the Surface Water Change Technical Analyses Report – Part. Water rights within the reach were identified using the Department’s Water Right Query System and GIS application Converge. The Department quantified the flow rate and volume of the surface water rights using the following methods:

1. The flow rate and volume for each water right was taken from the face value on the abstract.
2. Water rights without an assigned flow rate or volume were quantified using further analysis:
 - a. The adjudication standard of 30 gallons per day per animal unit was used for stock water right volumes.
 - b. Stock direct from source/ditch water rights were assigned a flow rate using 30 gallons per day per animal unit and adding 35 gallons per minute to the result.
 - c. Irrigation rights were assigned a volume of 2.06 AF per acre, which is the low range of the Department’s standard for applied volume at 60% efficiency in Climatic Area IV, per ARM 36.12.115.

A total of 4 water rights exist in the AOPI, as illustrated in **Table 18**.



Review

This document has been reviewed by the Department on March 21, 2025.

References

Department Standard Practice for Determining Historical Use
Department Standard Practice to Analyze Return Flows
Department Standard Practice for Determining Physical Availability of Surface Water
department Technical Memorandum: Distributing Conveyance Loss on Multiple User Ditches
(Water Management Bureau, 2020)



Appendix A: Water Rights within the Area of Potential Adverse Effect



Appendix A. Water rights in Area of Potential Adverse Effect

Water Right No.	Owner Names	Source	Priority Date (DD/MM/YYYY)
41G 30143701	G&M YAMAMOTO TRUST; FRED HIRSCHY; LYNN HIRSCHY	PARSONS SLOUGH	10/15/1895
41G 2262-00	DUSTIN LAUGHERY; YVONIE LAUGHERY	PARSONS SLOUGH	5/9/1974



Surface Water Change Technical Analyses Report - Part B

Department of Natural Resources and Conservation (DNRC)

Water Resource Division

Kim Bolhuis, Groundwater Hydrologist, Water Sciences Bureau

Applicant	Treasured Mountains, LLC	Point of Diversion Legal Land Description	Section 13 & 14, Township 1 South, Range 5 West
Application No.	41G 30165036		

Overview

This report is Part B of a two-part publication which analyzes data submitted by the Applicant in support of the above-mentioned water right change application. This report provides technical analyses as required under the Administrative Rules of Montana (ARM) 36.12.1303 in support of the water rights criteria assessment as required in §85-2-402, Montana Code Annotated (MCA). For applications in closed basins, this report fulfills the requirements of MCA 85-2-361.

This Surface Water Change Technical Analyses Report – Part B contains the following sections:

Overview	1
1.0 Executive Summary	2
2.0 Methodology	2
3.0 Adverse Effect – Return Flow Analysis	3
3.1. Non-Consumed Volume.....	3
3.2 Hydraulically Connected Surface Water(s).....	4
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1.0 Executive Summary

Water Right Details

The Applicant requests to add two points of diversion (POD) and change the irrigated place of use (POU) of Statement of Claim No. 41G 197111-00. The existing POD on Parsons Slough located in Section 14, Township 01 South, Range 05 West, Madison County would continue to be used. The Applicant would add two PODs on the Jefferson River. The historical use includes 116.9 acres of flood irrigation and 120.7 acres of sprinkler irrigation. The proposed change in POU includes 52.9 acres outside the historical POU irrigated by a center-pivot sprinkler, 57.3 acres inside the historical POU flood irrigated and 89.3 acres within the historical POU irrigated by wheel line sprinklers. 332.1 AF will be left instream during the historical period of diversion below the point of diversion. The period of diversion is May 1st through October 15th.

DNRC - WSB Technical Findings

Based on information submitted, the WSB quantified the historical non-consumed volume and location of historical return flows. These analyses are in support of the following criteria assessment: adverse effect. A summary of WSB findings described in subsequent sections are listed below.

TECHNICAL ANALYSES FINDINGS

ADVERSE EFFECT (RETURN FLOWS)	The <u>historical non-consumed volume for 237.6 acres is 333.8 acre-feet (AF)</u>. The location of historical return flows as identified in Figure 2 to the Jefferson River began at a point in the NE$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$, Section 14, Township 01 South, Range 05 West; return flows to Willow Spring Creek began at a point in the SW$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$, Section 14, Township 01 South, Range 05 West. Annual historical return flows to the Jefferson River and Willow Spring Creek were 105.7 AF and 228.1 AF, respectively. Under the proposed change, <u>the non-consumed volume for 199.5 acres is 191.7 AF</u>. The location of proposed return flows as identified in Figure 3 is to the Jefferson River beginning at a point in the NE$\frac{1}{4}$NW$\frac{1}{4}$SW$\frac{1}{4}$, Section 13, Township 01 South, Range 05 West and to Willow Spring Creek beginning as a point in the SW$\frac{1}{4}$NE$\frac{1}{4}$SE$\frac{1}{4}$, Section 14, Township 01 South, Range 05 West. Annual proposed return flows to the Jefferson River and Willow Spring Creek would be 51.8 AF and 139.9 AF, respectively.
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2.0 Methodology

DNRC will analyze the change to determine if:

- Return flows will enter back into the source where they have historically returned upstream of or at the location of the next downstream appropriator; or,
- Water is left instream so historically diverted flows are available during the historical period of diversion either below the point of diversion or where return flows historically returned to the source.



If the change in return flows impacts existing water rights, the return flow analysis must include a monthly breakdown of the rate and timing of return flows and evaluate impacts to the identified rights.

Return flows are evaluated by determining the volume of water that infiltrates past the root zone and identifying the likely receiving stream(s). The assumption is made that water applied for irrigation that is not consumed by a crop infiltrates to groundwater becoming return flow and does not run off. The amount of water not consumed is the difference between the amount of water consumed and the amount of water applied to a field. The receiving stream is determined by proximity and evidence of hydraulic connection to groundwater and generally does not depend on groundwater flow direction or land slope (Leake, 2011).

Historical consumed volumes for irrigation are calculated following the procedures described in DNRC consumptive use rules in ARM 36.12.1902. The amount of water consumed at the field is equal to crop consumption plus irrecoverable losses calculated as a percent of applied amounts. The amount of water applied to a field is determined from estimates of application efficiency and crop consumption. The amount of water not consumed is the difference between the amount of water consumed and the amount of water applied to a field.

3.0 Adverse Effect – Return Flow Analysis

3.1. Non-Consumed Volume

The consumed volume for irrigation is based on the net irrigation requirement (NIR) from USDA Natural Resources Conservation Service Irrigation Water Requirements (IWR) at a representative weather station. The NIR is multiplied by a county-wide management factor (from ARM 36.12.1902) to produce an adjusted NIR representative of actual crop yields in Montana. Crop consumption is determined by multiplying the adjusted NIR by the number of acres of irrigation. Crop consumption is then divided by the field efficiency identified from the irrigation method and ARM 36.12.115. Irrecoverable losses (IL) are 5% of the field applied volume for flood irrigation or 10% for sprinkler irrigation. The total consumed volume for irrigation is the crop consumption plus irrecoverable losses. The total non-consumed volume is the field applied volume minus the total consumed volume.

The historical and proposed consumed and non-consumed volumes have been calculated with the inputs shown in **Table 1** and **Table 2** following the methods described above and in ARM 36.12.1902.



Table 1: Historical use.

Irrigation Method	Acres	IWR (in)¹	Mgmt. Factor²	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume (AF)	Non-Consumed Volume (AF)
Flood	116.9	16.98	0.65	0.25	107.85	431.4	21.57	129.42	301.98
Wheel line	120.7	16.98	0.65	0.7	111.36	159.08	15.91	127.26	31.82
Total	237.6				219.21	590.5	37.48	256.68	333.8

¹Twin Bridges IWR Weather Station

²Madison County Historical Use Management Factor

Table 2: Proposed Use.

Irrigation Method	Acres	IWR (in)¹	Mgmt. Factor²	Field Efficiency	Crop Consumption (AF)	Applied Field Volume (AF)	IL (AF)	Total Consumed Volume (AF)	Non-Consumed Volume (AF)
Center Pivot - New Acres	52.9	19.22	0.83	0.7	70.58	100.83	10.08	80.66	20.17
Flood - Historical Acres	57.3	16.98	0.65	0.25	52.86	211.46	10.57	63.44	148.02
Wheel line - Historical Acres	89.3	16.98	0.65	0.7	82.39	117.69	11.77	94.16	23.54
Total	199.5				205.83	429.98	32.42	238.26	191.73

¹Twin Bridges IWR Weather Station

²Madison County Proposed Use Management Factor

3.2 Hydraulically Connected Surface Water(s)

The receiving stream is determined by proximity and evidence of hydraulic connection to ground water. Mounding beneath irrigated fields propagates in all directions independent of ground water flow rate or direction and generally does not depend on surface topography (Leake, 2011). Return flows may accrete to more than one receiving reach or to a different stream than the source water is diverted from. Hydraulic connection of individual stream reaches to groundwater is evaluated by comparing streambed elevations to static groundwater elevations measured in wells less than 50 ft deep and within 1,000 ft of surface water or from published water table maps (DNRC, 2019). Surface water within that area is considered hydraulically connected to the unconfined aquifer if static groundwater elevations are above or within 10 ft of the elevation of the streambed (DNRC, 2019).

As shown in **Figure 1**, the historical and proposed POUs are adjacent to the Jefferson River and Willow Spring Creek, which overlay unconsolidated basin-fill alluvium. Flood and sprinkler



irrigation occurred on areas overlying modern alluvial sands and gravels of the Jefferson River floodplain (Vuke et al., 2004; Gebril and Bobst, 2004).

Per DNRC (2019) wells were queried from the Montana Bureau of Mines and Geology (MBMG) Groundwater Information Center (GWIC) database to investigate hydraulic connection of nearby surface water to groundwater. Numerous wells in the vicinity of the Jefferson River with static water levels of 10 ft or less and total depths of 50 ft or less were identified: GWIC IDs 107042, 288719, 276103, 276112, 276285, and 277868.

The historical and proposed POUs overlay the Quaternary alluvium of the Jefferson River, north of Waterloo, MT, and a Quaternary alluvial terrace deposit to the east (Brancheau, 2015; Vuke, 2004). Two spring-fed perennial streams are close to the POUs: Parsons Slough and Willow Spring Creek. Willow Spring Creek runs through the historical and proposed POUs while Parsons Slough flows 2,180 ft west of the POUs and enters the Jefferson River upstream of the existing and proposed PODs (**Figure 1**). A study by MBMG was conducted in the area and concluded there is a strong connection between the modern alluvium on which the POUs exist, and the Jefferson River, Parsons Slough, and Willow Spring Creek (Gebril and Bobst, 2021).

As shown in **Figure 1**, DNRC identifies the Jefferson River and Willow Spring Creek as the connected perennial surface water bodies to the historical and proposed places of use and the receiving streams for return flows. Willow Spring Creek is between the historical POUs and Parsons Slough, therefore Parsons Slough is not considered to have received return flows from irrigation of the historical irrigated POU.

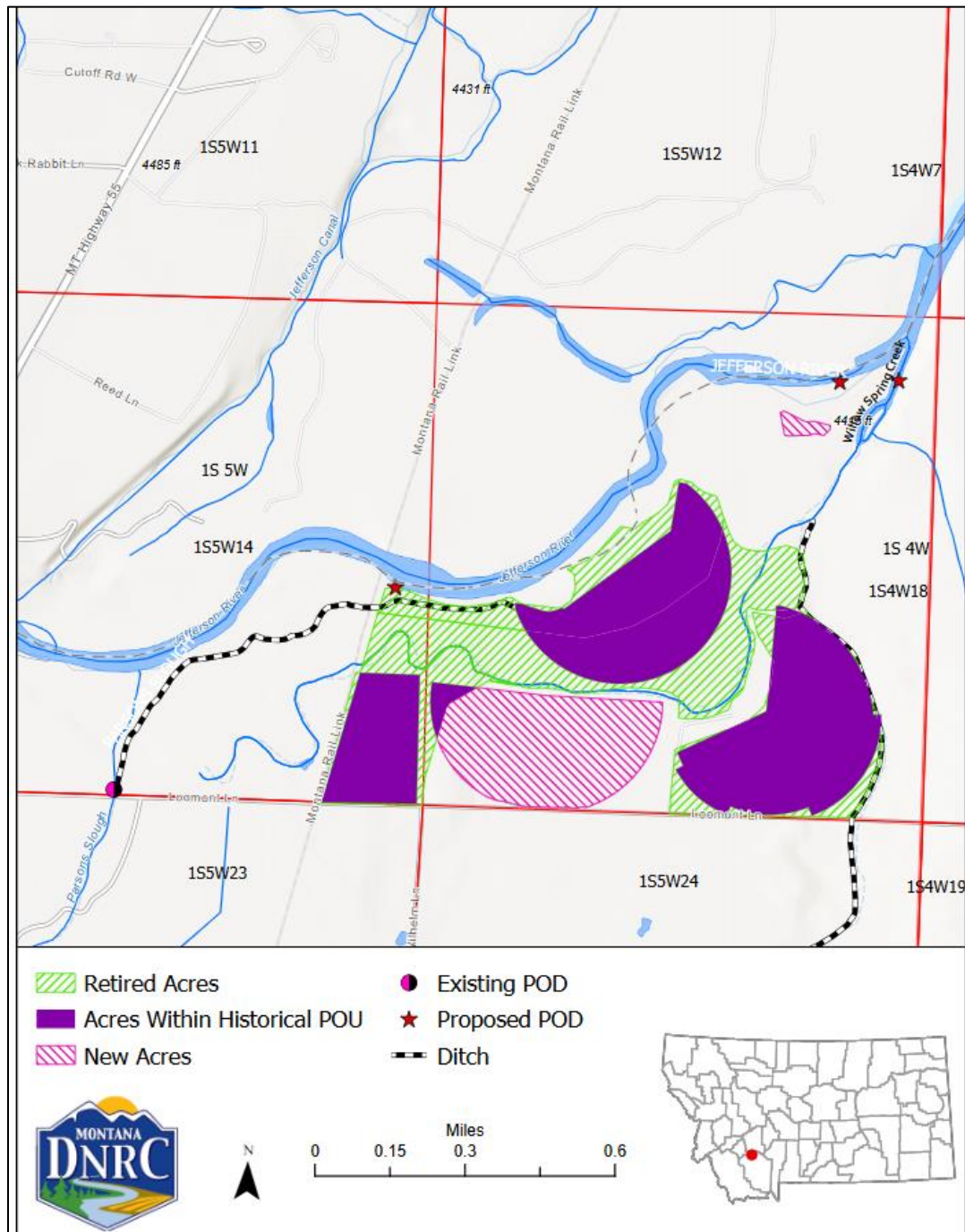


Figure 1: Location of historical and proposed irrigated POU.

Since two surface water sources are identified as receiving historical return flows or would receive proposed return flows, each field was given a label to identify which field or portion of a field would contribute return flows to either source. As illustrated in **Figure 2**, Field B of the historical POU lies between the Jefferson River and Willow Spring Creek. Therefore, return flows would return to both the Jefferson River and Willow Spring Creek. Following the inverse distance



weighted (IDW) method described in DNRC (2019) and Section 3.2 of the guidance document developed by the Province of British Columbia (2016), return flow volumes apportioned to the Jefferson River and Willow Spring Creek are 35% and 65%, respectively (**Table 3**). The distance used for the IDW method are from the centroid of each field. For the proposed change, the proposed POU of Field B (**Figure 3**) lies within the historical POU of Field B with the same apportionment of return flow volumes. The return flow volumes from the historical and proposed POUs south of Willow Spring Creek return only to Willow Spring Creek (**Figures 2 and 3**). Return flow volume proportions for the proposed change in POU are outlined in **Table 4**.

Table 3: Distance to hydraulically connected surface water and Inverse Distance Weighting proportions used to apportion historical return flows to each source.

Field ID	Distance to Stream (ft)		IDW Percentages	
	Willow Spring Cr.	Jefferson R.	Willow Spring Cr.	Jefferson R.
A	221	N/A	100%	0%
B	229	310	65%	35%
B – East of Willow	232	0	100%	0%
C	227	N/A	100%	0%

Table 4: Distance to hydraulically connected surface water and Inverse Distance Weighting proportions used to apportion proposed return flows to each source.

Field ID	Distance to Stream (ft)		IDW Percentages	
	Willow Spring Cr.	Jefferson R.	Willow Spring Cr.	Jefferson R.
A	221	N/A	100%	0%
B	229	310	65%	35%
C	227	N/A	100%	0%
D – Inside Historical	210	N/A	100%	0%
D – Outside Historical	210	N/A	100%	0%
E	552	98	0%	100%

3.3 Location of Return Flows

As identified in **Figure 2** the location of historical return flows from 47.0 irrigated acres is the Jefferson River beginning at a point in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$, Section 14, Township 01 South, Range 05 West, Madison County. The location of historical return flows from 190.6 irrigated acres in Willow Spring Creek beginning at a point in the SW $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$, Section 14, Township 01 South, Range 05 West. The volume of return flows from each field to the respective source for the historical use, using the proportions in **Table 3**, is given in **Table 5**.

Under the proposed change, return flows from 30.3 acres of irrigation would accrue to the Jefferson River downstream of NE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$, Section 13, Township 01 South, Range 05 West. The location of return flows from 169.2 acres of irrigation would accrue to Willow Spring Creek



downstream of SW $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$, Section 14, Township 01 South, Range 05 West (**Figure 3**). The volume of return flows from each field to the respective source for the proposed use is given in **Table 6**.

The Applicant proposes to leave 332.1 AF of historically non-consumed water instream at the historical point of diversion.

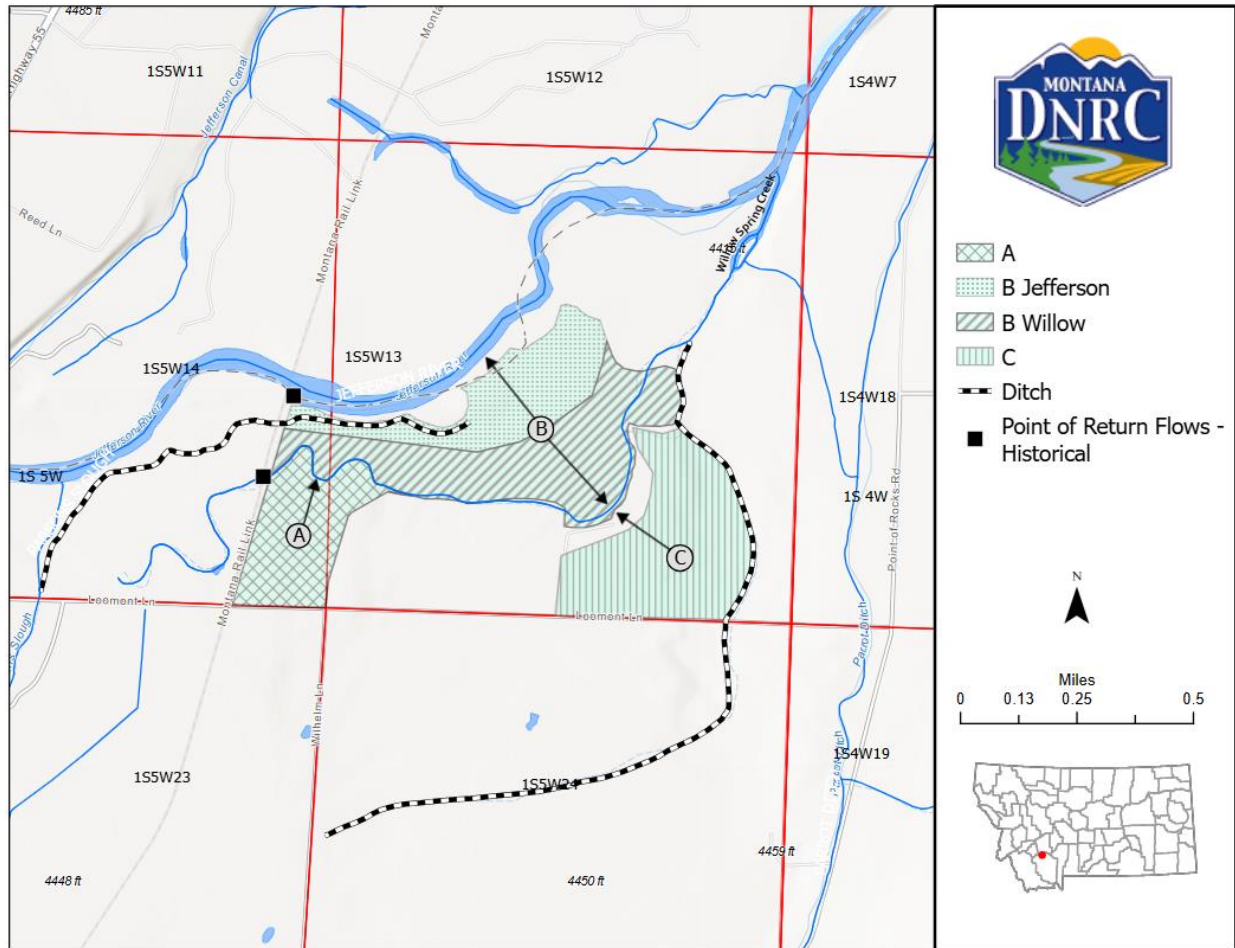


Figure 2: Location of historical return flows.

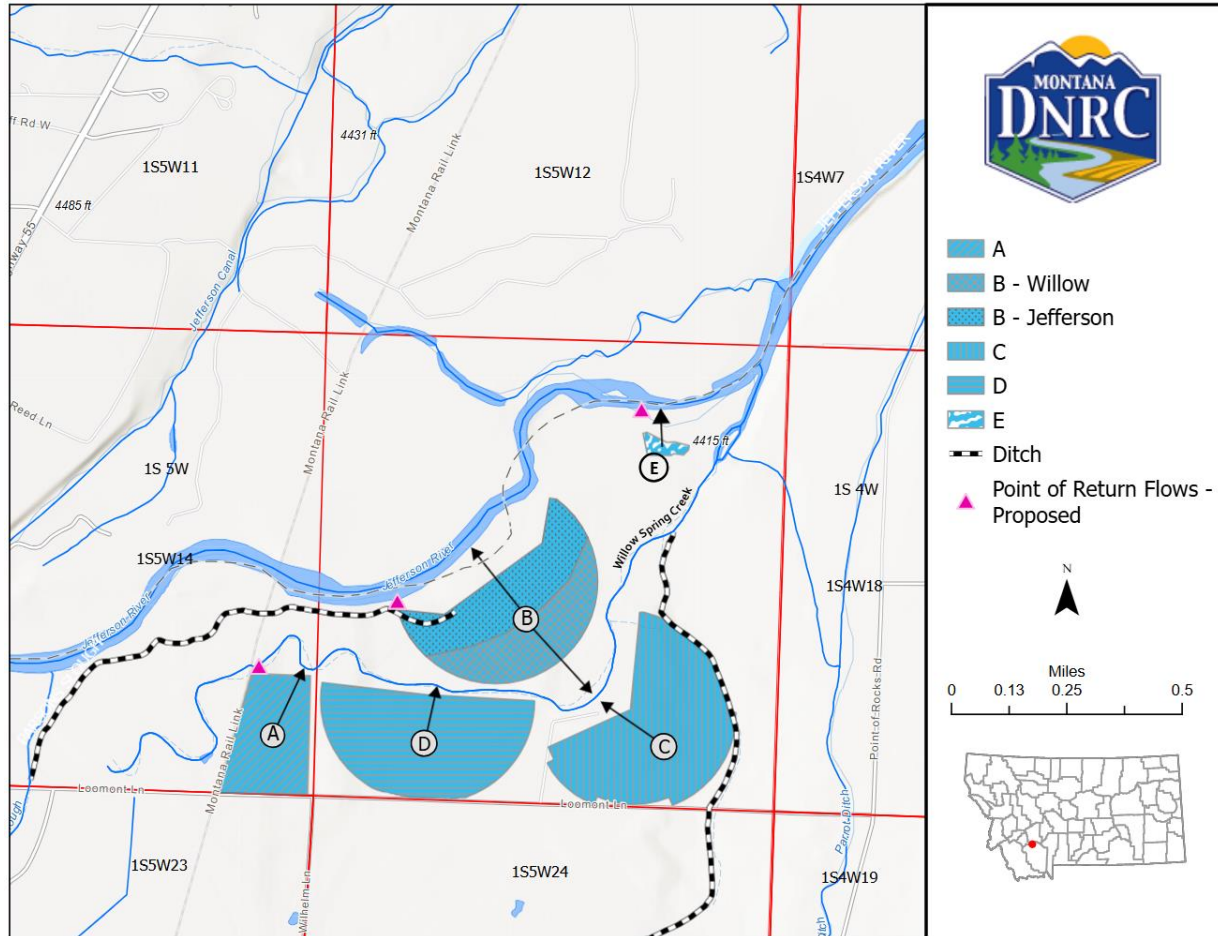


Figure 3: Location of proposed return flows.

Table 5: Return flow volumes from each field per surface water source for the historical use.

Field ID	Irrigation Method	Acres	Total Consumed Volume (AF)	Non-Consumed Volume (AF)	Return Flow Volume (AF)	
					Willow Spring Creek	Jefferson River
A	Wheel line	41.0	43.2	10.8	10.8	0.0
B - East of Willow Spring Creek	Wheel line	6.4	6.7	1.7	1.7	0.0
B	Flood	116.9	129.4	302.0	196.3	105.7
C	Wheel line	73.3	77.3	19.3	19.3	0.0
Total	-	237.6	256.7	333.8	228.1	105.7



Table 6: Return flow volume from each field per surface water source for the proposed use.

Field ID	Irrigation Method	Acres	Total Consumed Volume (AF)	Non-Consumed Volume (AF)	Return Flow Volume (AF)	
					Willow Spring Creek	Jefferson River
A	Sprinkler	25.7	27.1	6.8	6.8	0.0
B	Flood	57.3	63.4	148.0	96.2	51.8
C	Sprinkler	61.14	64.5	16.1	16.1	0.0
D - Within Historical	Sprinkler	2.46	2.6	0.6	0.6	0.0
D – Outside ^{1,2} Historical	Sprinkler	51.3	78.2	19.6	19.6	0.0
E ^{1,2}	Sprinkler	1.6	2.4	0.6	0.6	0.0
Total	-	199.5	238.3	191.7	139.9	51.8

¹Fields *D – Outside Historical* and *E* are proposed sprinkler irrigation both outside of the historical POU and therefore use the IWR center pivot irrigation consumptive inches (36.12.1902).

² Fields *D – Outside Historical* and *E* are both outside of the historical POU and therefore use the current Management Factor as opposed to the historical Management Factor (36.12.1902).

3.4 Rate and Timing of Return Flows (Non-Consumed Water)

The rate and timing of return flows for historical and changed conditions are determined by modeling accretions of return flows to the receiving surface water. The monthly timings of accretions of return flows to the identified receiving reach are modeled using analytical models such as the Alluvial Water Accounting System (AWAS) (AWAS, 2003), the Glover parallel drain model (Glover, 1977), or a numerical model. The choice of model depends on the availability of data on aquifer properties and the geometry of the receiving aquifer and stream(s). These modeling methods are believed to be suitable for common hydrogeologic settings, are appropriate to the limited data available for most locations, and adequate to provide information to evaluate criteria under §85-2-402, MCA. They may not be suitable in more complex geologic settings or where return flows to multiple streams must be considered.

Inputs to AWAS (2003) include specific yield, transmissivity, distance from recharge wells to the receiving reach, distance from other model boundaries to the receiving reach (optional) and a monthly pump schedule based on the volume of non-consumed water. AWAS (2003) can model accretions from a single location, represented by a recharge well, to one source with simple aquifer boundaries. AWAS allows multiple recharge wells to be modeled simultaneously. Assumptions for AWAS include:

- the aquifer is homogeneous, isotropic, and of uniform thickness
- the affected surface water fully penetrates the source aquifer
- the river is straight and infinitely long
- boundaries to the aquifer include the connected surface water and bedrock.



Monthly return flows for historical and proposed use were evaluated for Willow Spring Creek using the return flow proportions outlined in **Table 4**. Inputs for the AWAS (2003) model for this evaluation include a transmissivity of 306,701.3 gallons per day per foot (41,000 ft²/day) derived from an aquifer test conducted on alluvial well GWIC ID 279259 by Bobst and Gebril (2020) approximately one mile south of the proposed POUs, a specific yield value of 0.1 from Lohman (1972), and monthly non-consumed values for each field in **Table 5** and **6**.

Historical return flows to Willow Spring Creek associated with the non-consumed irrigated volume identified in **Table 5** are modeled as six recharge wells representing the centroid of each field (**Figure 4**). Distances from each recharge well to Willow Spring Creek are shown in **Table 7**. The return flows to Willow Spring Creek from the proposed irrigated area are modeled as four recharge wells representing the non-consumed irrigated volumes (**Table 6**) associated with the proposed POUs bordering Willow Spring Creek, with the distance from each recharge well to the Creek shown in **Table 7** and illustrated in **Figure 5**.

Table 7: Distances of each recharge well to Willow Spring Creek.

Field ID	Recharge Wells - Historic Return Flows						Recharge Wells - Proposed Return Flows			
	A	B1	B2	B3	B - East	C	A	B	C	D
Distance to Willow Spring Creek (ft)	221	76	116	229	232	227	221	229	227	210

As identified in **Table 8**, positive values of net effect in **columns 8 and 9** correspond to increased stream flows, while negative values correspond to reduced flows.

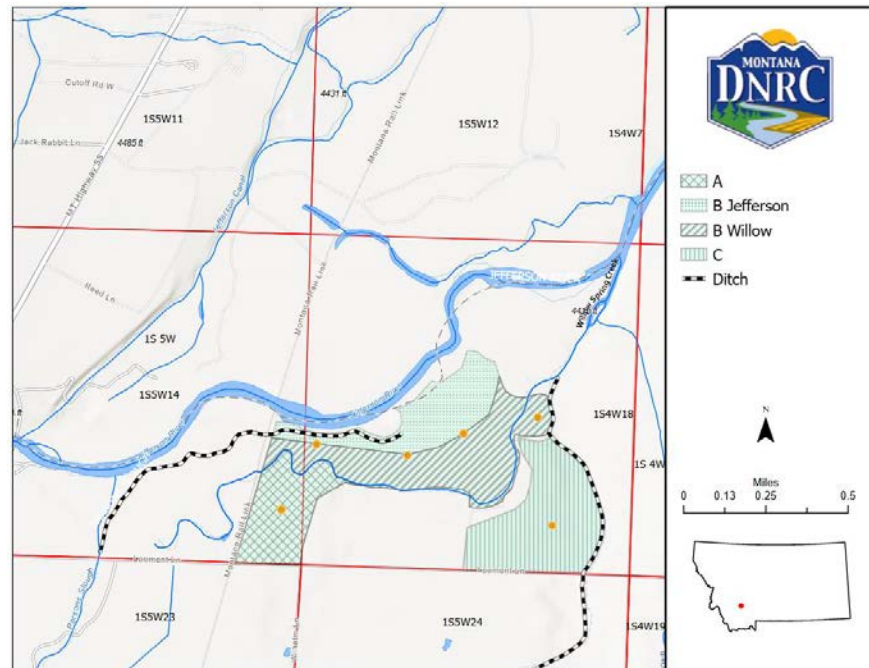


Figure 4: Map of the recharge wells (orange dots) representing non-consumed volumes from each field where historical return flows to Willow Spring Creek were modeled.

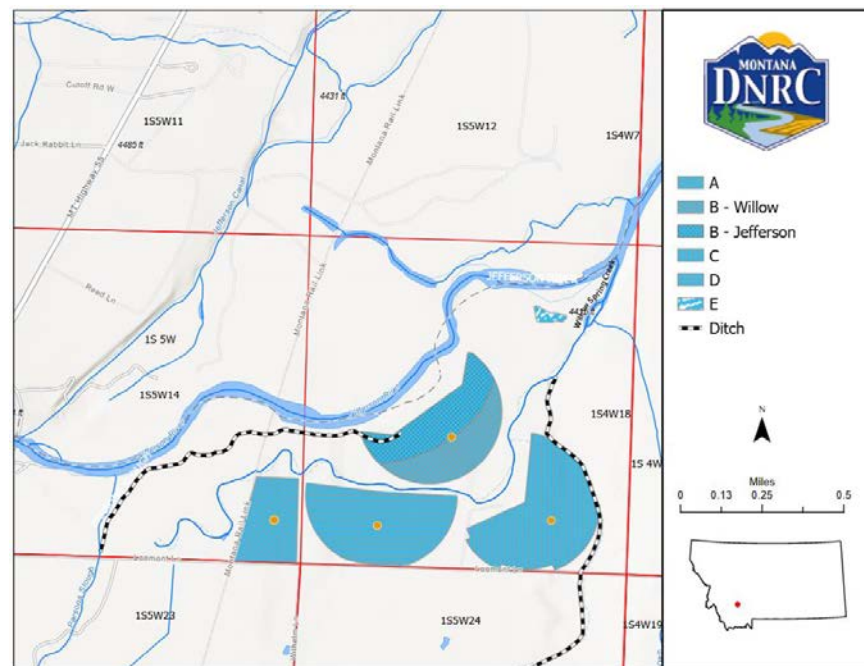


Figure 5: Map of the recharge wells (orange dots) representing non-consumed volumes from each field where proposed return flows to Willow Spring Creek were modeled.



Table 8: Return flows to Willow Spring Creek and the net effect of the proposed change.

Months	Net Irrigation Requirement (NIR) (inches)	Total Non-Consumed Volume (AF)	Total Historical Return Flows		Total Proposed Return Flows		Net Effect to Willow Spring Creek (AF)	Net Effect to Willow Spring Creek (gpm)
			Willow Spring Creek (AF)	Willow Spring Creek (gpm)	Willow Spring Creek (AF)	Willow Spring Creek (gpm)		
January	0	0.3	0.4	2.6	0.3	2.2	-0.1	-0.4
February	0	0.2	0.3	2	0.2	1.6	-0.1	-0.4
March	0	0.2	0.3	2	0.2	1.6	-0.1	-0.4
April	0	0.2	0.2	1.7	0.2	1.4	0	-0.3
May	1.48	5.6	7.9	57.4	5.6	40.9	-2.3	-16.5
June	4.93	35.8	60.1	439.2	35.8	261.8	-24.3	-177.4
July	6.44	49	81.9	598.8	49	357.9	-32.9	-240.9
August	5.31	41.4	68.8	503	41.4	302.4	-27.4	-200.6
September	1.06	5.1	6.3	46.2	5.1	37.4	-1.2	-8.8
October	0	0.8	1	7.3	0.8	6	-0.2	-1.3
November	0	0.5	0.6	4.2	0.5	3.4	-0.1	-0.8
December	0	0.4	0.5	3.3	0.4	2.6	-0.1	-0.7
TOTAL	19.22	139.9	228.1		139.9		-88.2	



Review

This document has been reviewed on March 20, 2025 in accordance with Category 7 of [DNRC's Water Sciences Bureau Minimum Standards of Review](#), Version 2, February 2024.

References

- Alluvial Water Accounting System (AWAS), 2003. Integrated Support System at Colorado State University, <http://www.ids.colostate.edu/projects.php?project=awas>.
- Bobst, A.L., and Gebril, A., 2020, Aquifer tests in the Upper Jefferson Valley: Montana Bureau of Mines and Geology Open-File Report 727, 52 p.
- Brancheau, N. L. ,2015. A hydrogeologic evaluation of the Waterloo area in the Upper Jefferson River Valley, Montana (Master's thesis, Montana Tech of The University of Montana).
- DNRC, 2016. Technical Memorandum: Policy Memo – Return Flows. April 1, 2016.
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- Gebril, A.F., and Bobst, A.L., 2021, Hydrogeologic investigation of the Upper Jefferson River Valley, Madison and Jefferson Counties, Montana: Waterloo groundwater modeling report: Montana Bureau of Mines and Geology Report of Investigation 29, 101 p.
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- Natural Resources Conservation Service (NRCS), 2003. Irrigation Water Requirement (IWR) computer program, <http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/?cid=stelprdb1044890>.
- Vuke, S.M., Coppinger, W.W., and Cox, B.E., 2004, Geologic map of Cenozoic deposits in the Upper Jefferson Valley, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 505, 35 p., 1 sheet, scale 1:50,000.

THE MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

GOVERNOR GREG GIANFORTE



DNRC DIRECTOR AMANDA KASTER

DNRC

2273 Boot Hill Ct, STE 110
Bozeman, MT 59715
406-556-4500

April 21, 2025

Treasured Mountains Holdings LLC
5653 Monterey Drive
Frisco, TX 75034

Subject: Notice of Errata for Technical Analyses Report for Change Preapplication No. 41G 30165036

Dear Applicant:

This letter is to inform you of corrections made to the Surface Water Change Technical Analyses Report – Part A prepared for Application No. 41G 30165036 that was completed on March 21, 2025. Please replace the original sections with the corrected information found in the included Notice of Errata. A description of the corrections can be found in the Notice of Errata.

The Notice of Errata does not impact the date by which the Water Right Change Application Form 606 must be submitted to the Bozeman Regional Office. The application must still be submitted within 180 days of the original Technical Analyses, which was completed on March 21, 2025. If the Application Form is not submitted to the Bozeman Regional Office by September 17, 2025, a new preapplication meeting will be required to process the Application with expedited timelines (ARM 36.12.1302(6)(b)). If any details described in the submitted Application are changed from that of the submitted Preapplication Meeting Form, the discounted filing fee and expedited timelines will not apply (ARM 36.12.1302(6)(a)). Please note that the technical analyses will expire one year from March 21, 2025 (ARM 36.12.1302(8)).

Please let me know if you have any questions.

Sincerely,

A handwritten signature in blue ink that reads "Lyra Reynolds". The signature is fluid and cursive, with the first name "Lyra" being more prominent.

Lyra Reynolds

Hydrologist/Water Resources Specialist
Bozeman Water Resources Office
Water Resources Division

CC, via email: Andy Brummond, abrummond@mt.gov



DNRC.MT.GOV



Re: 41G 30165036 Technical Analyses Notie of Errata

From Brummond, Andy <abrummond@mt.gov>
Date Fri 4/25/2025 10:36 AM
To Reynolds, Lyra <Lyra.Reynolds@mt.gov>
Cc Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Lyra
Could you resend it to Bill? It seems the link has expired. He requested a new link but it didn't come through.
Thanks
Andy

From: Reynolds, Lyra <Lyra.Reynolds@mt.gov>
Sent: Tuesday, April 22, 2025 12:32 PM
To: Brummond, Andy <abrummond@mt.gov>
Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Subject: RE: 41G 30165036 Technical Analyses Notie of Errata

Hi Andy-

Yes, I will get that uploaded and sent to Mr. Gould today.

Did you initiate the payment the first time you had sent the email?

-Lyra



Lyra Reynolds (they/them/she/her) | Hydrologist/Specialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-4500 **EMAIL:** lyra.reynolds@mt.gov
[Website](#) | [Facebook](#) | [X \(Twitter\)](#) | [Instagram](#)
How did we do? Let us know here: [Feedback Survey](#)

From: Brummond, Andy <abrummond@mt.gov>
Sent: Monday, April 21, 2025 7:29 PM
To: Reynolds, Lyra <Lyra.Reynolds@mt.gov>
Cc: Strasheim, Kerri <kstrasheim@mt.gov>
Subject: RE: 41G 30165036 Technical Analyses Notie of Errata

Lyra

Now that the Technical Analysis Report is correct, could you please send the application I previously sent you to Mr. Gould for his electronic signature?

The application fee has been transferred to DNRC. The attached email shows information regarding this transaction.

Thanks

Andy

From: Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Sent: Monday, April 21, 2025 11:01 AM

To: Brummond, Andy <abrummond@mt.gov>

Cc: Rasmussen, Derek <Derek.Rasmussen@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Strasheim, Kerri <kstrasheim@mt.gov>; Baumgardner, Shannon <Shannon.Baumgardner@mt.gov>; Brickl, Melissa <Melissa.Brickl@mt.gov>; Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>

Subject: 41G 30165036 Technical Analyses Notice of Errata

Hi Andy-

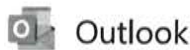
Attached are the corrections made to the Surface Water Change Technical Analyses Report – Part A prepared for Application No. 41G 30165036 that was completed on March 21, 2025. Please replace the original sections with the corrected information found in the included Notice of Errata. A description of the corrections can be found in the attached Notice of Errata.

I have sent the attached letter and document to the Applicant today, April 21, 2025. The Notice of Errata does not impact the date by which the Water Right Change Application Form 606 must be submitted to the Bozeman Regional Office. The application must still be submitted within 180 days of the original Technical Analyses, which was completed on March 21, 2025.

Please let me know if you have any questions. Thank you for your patience with this process!
-Lyra



Lyra Reynolds (they/them/she/her) | Hydrologist/Specialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-4500 **EMAIL:** lyra.reynolds@mt.gov
[Website](#) | [Facebook](#) | [X \(Twitter\)](#) | [Instagram](#)
How did we do? Let us know here: [Feedback Survey](#)



RE: Completed Technical Analyses Report for Change Preapplication No. 41G 30165036

From Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>

Date Wed 3/26/2025 1:59 PM

To Reynolds, Lyra <Lyra.Reynolds@mt.gov>; Brummond, Andy <abrummond@mt.gov>

Cc Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

 1 attachment (55 KB)

Interpolation_willow_spring Ck 1.xlsx;

Good afternoon, Andy,

Regarding your question on the linear interpolation for the months of January and February, those values were lower since we assumed the beginning of the "measurement period" was January and the end was December of the same year. The back-calculation of discharge from March to the preceding two months used the average monthly flows from March (Y1 and X1) and December (Y0 and X0). Because of the assumption that the measurement period began in January, the linear interpolation using December to predict the flows in January and February results in a lower discharge estimate that increases to the average measured flow in March. The estimated monthly average hydrograph produced is generally consistent with stream hydrographs in Western Montana, which typically decrease in flows throughout the winter until increasing in discharge in early spring due to snowmelt.

I have attached the worksheet used to estimate the missing average monthly discharges to this email. Please let me know if you have any further questions on the interpolation used.

Best,
Kim



Kim Bolhuis | Groundwater Hydrologist

Water Sciences Bureau, Groundwater Studies, Water Resources Division

Montana Department of Natural Resources and Conservation

1424 9th Ave, Helena, MT 59601

MOBILE: 503-547-7789 **EMAIL:** kimberly.bolhuis@mt.gov

Website | **Facebook** | **X (Twitter)** | **Instagram**

How did we do? Let us know here: [Feedback Survey](#)

From: Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Sent: Tuesday, March 25, 2025 9:40 AM

To: Brummond, Andy <abrummond@mt.gov>

Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>; Ellis, Kendrew

<Kendrew.Ellis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Subject: RE: Completed Technical Analyses Report for Change Preapplication No. 41G 30165036

Andy-

As the Technical Analysis is not a stand-alone document and is not what a public comment/notice is based on, we believe the description is sufficient for this stage. The Technical Analysis along with documentation in the Preapplication Meeting Form and what would be submitted for an application should be able to show the proposed change adequately. We will make a note for application processing and decision document on our end to further explain the proposed use and future operation of the system with the clarification of the flood and sprinkler acres.

For the interpolation for Willow Springs Creek, we will need to reach out to our Water Sciences Bureau to get information as WSB helped with the interpolation.

We will get back to you once we have the answers.

-Lyra



Lyra Reynolds (they/them/she/her) | Hydrologist/Specialist
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Montana Department of Natural Resources and Conservation
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DESK: 406-556-4500 **EMAIL:** lyra.reynolds@mt.gov
[Website](#) | [Facebook](#) | [X \(Twitter\)](#) | [Instagram](#)
How did we do? Let us know here: [Feedback Survey](#)

From: Brummond, Andy <abrummond@mt.gov>

Sent: Monday, March 24, 2025 10:54 AM

To: Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Cc: Reynolds, Lyra <Lyra.Reynolds@mt.gov>; Strasheim, Kerri <kstrasheim@mt.gov>; Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>

Subject: RE: Completed Technical Analyses Report for Change Preapplication No. 41G 30165036

Derek

Thank you for sending the Technical Analysis Report. I have one comment and one question.

On page 9 of Part A in the paragraph below Table 9 there is a statement, "Following the proposed change, 142.2 acres will be sprinkler irrigated and 57.3 acres will remain flood irrigated." Because the 57.3 acres is already irrigated under the water right, I understand that the proposed use is evaluated as if it is still flood irrigated. However, this area will be sprinkler irrigated so the statement above is not factually correct. This could confuse other water users reviewing the change application or confuse future administration of the water rights if issues arise. Could this statement be changed to not contradict will be occurring on the ground?

In Table 20 on page 17 of Part A you provide interpolate estimates for average monthly streamflow for those months in which no flow measurements are available. For January and February your estimates of 8.65 cfs and 8.94 cfs respectively are lower than the actual December and March average measurement values of 11.84 cfs and 9.21 cfs respectively that bound the linear interpolation. Maybe I am not understanding something, but it seems the interpolated values could not be lower than the values between which the interpolation is occurring. Are these January and February estimates correct?

Thanks for your work on this application.
Regards,
Andy

From: Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Sent: Friday, March 21, 2025 3:11 PM
To: Brummond, Andy <abrummond@mt.gov>
Cc: Reynolds, Lyra <Lyra.Reynolds@mt.gov>; Strasheim, Kerri <kstrasheim@mt.gov>; Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>
Subject: Completed Technical Analyses Report for Change Preapplication No. 41G 30165036

Hello Andy,

The Department of Natural Resources and Conservation (DNRC or Department) has completed the technical analyses for Change Preapplication No. **41G 30165036** based on the information provided in your Preapplication Meeting Form accepted by the Department on **2/5/2025**. The technical analyses can be found in the attached report. Please note this Surface Water Change Technical Analyses Report is a two-part publication, comprised of a Part A completed by **Derek Rasmussen**, and a Part B completed by **Kim Bolhuis**.

The technical analyses reports and letter sent to the Applicant today (**3/21/2025**) are attached to this email. The change application needs to be submitted within 180 days of the letter by (**9/17/2025**).

Please let us know if you have any questions

Respectfully,



Derek Rasmussen | Water Resource Specialist

Bozeman Water Resources Office

Montana Department of Natural Resources and Conservation

2273 Boot Hill Court, Suite 110; Bozeman, MT 59715

DESK: 406-556-6282 **EMAIL:** derek.rasmussen@mt.gov

Website | [Facebook](#) | [X \(Twitter\)](#) | [Instagram](#)

How did we do? Let us know here: [Feedback Survey](#)



Fw: Ditch Information

From Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Date Thu 3/20/2025 10:56 AM

To Reynolds, Lyra <Lyra.Reynolds@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>

 1 attachment (22 KB)

Proposed Use Ditch Analysis.xlsx;

Version #2....



Derek Rasmussen | Water Resource Specialist

Bozeman Water Resources Office

Montana Department of Natural Resources and Conservation

2273 Boot Hill Court, Suite 110; Bozeman, MT 59715

DESK: 406-556-6282 **EMAIL:** derek.rasmussen@mt.gov

[Website](#) | [Facebook](#) | [X \(Twitter\)](#) | [Instagram](#)

How did we do? Let us know here: [Feedback Survey](#)

From: Brummond, Andy <abrummond@mt.gov>

Sent: Thursday, March 20, 2025 10:54 AM

To: Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Cc: Strasheim, Kerri <kstrasheim@mt.gov>

Subject: RE: Ditch Information

Derek

Please use this version. I noticed one of my notes referenced the wrong pivot in explaining the Curtis B2 ditch reach.

Thanks

Andy

From: Brummond, Andy

Sent: Thursday, March 20, 2025 10:50 AM

To: Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Cc: Strasheim, Kerri <kstrasheim@mt.gov>

Subject: RE: Ditch Information

Derek

Attached is my analysis of the use of water to supply the two existing center pivots and the new 1.6 ac field near the mouth of Willow Spring Creek. This operation would occur if the new Jefferson River pump site were not functional. It represents the maximum annual usage.

I attempted to replicate DNRC's approach to ditch loss analysis consistent with the spreadsheet you provided me. I considered that all three sprinkler systems would be operated simultaneously until such time the needed applied volume was first reached for one of the systems, with the 1.6 ac field needing the least time to reach its

needed volume. Next, I evaluated the two pivot systems together until the south pivot reached its needed volume leaving the north pivot to operate alone for the remaining period.

Using this approach I found the following:

Days	Flow Diverted (cfs)	Volume Diverted (AF)
6.8	3.39	45.7
42.6	2.66	212.0
5.8	2.21	16.2

Please let me know if you have questions.

Thanks for your work on this application.

Andy

From: Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Sent: Wednesday, March 19, 2025 5:13 PM

To: Brummond, Andy <abrummond@mt.gov>

Subject: Re: Ditch Information

Please reference the below tables. I have not calculated it out individually per field though.

Table 2. Historical consumptive use of historical place of use

Field ID	Irrigation Method	Acres	NIR (in)	Management Factor	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume (AF)
North Flood	Flood	116.9	16.98	0.65	0.25	107.85	431.4	21.57	129.42
South Sprinkler	Wheel line	120.7	16.98	0.65	0.7	111.36	159.08	15.91	127.26

Table 10. Proposed consumptive volume of new acres

Field ID	Acres	Weather Station	NIR (in)	Management Factor	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume - New Acres (AF)
New Acres	52.9	Twin Bridges	19.22	0.83	0.7	70.58	100.83	0.1	80.66

Table 11. Historical consumptive volume of remaining acres

Field ID	Acres	Weather Station	NIR (in)	Management Factor	Field Efficiency	Crop Consumption (AF)	Applied Volume (AF)	IL (AF)	Total Consumed Volume - Remaining Acres (AF)
Historical Flood	57.3	Twin Bridges	16.98	0.65	0.25	52.86	211.46	0.05	63.44
Historical Sprinkler	89.3	Twin Bridges	16.98	0.65	0.7	82.39	117.69	0.1	94.16

Respectfully,



Derek Rasmussen | Water Resource Specialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-6282 **EMAIL:** derek.rasmussen@mt.gov
Website | **Facebook** | **X (Twitter)** | **Instagram**
How did we do? Let us know here: [Feedback Survey](#)

From: Brummond, Andy <abrummond@mt.gov>
Sent: Wednesday, March 19, 2025 4:50 PM
To: Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Subject: RE: Ditch Information

Derek

What are the volumes that you have calculated that will be delivered to each field under the proposed change?

Thanks

Andy

From: Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Sent: Wednesday, March 19, 2025 3:28 PM
To: Brummond, Andy <abrummond@mt.gov>
Subject: Re: Ditch Information

It was my understanding that the ditch segments were obtained from information you provided to Lyra Reynolds when she asked about the ditch length.

I believe Curtis A is the segment that starts at the POD on Parsons Slough and the Curtis B segment begins at the POD for the neighbors water right.



Derek Rasmussen | Water Resource Specialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-6282 **EMAIL:** derek.rasmussen@mt.gov
Website | **Facebook** | **X (Twitter)** | **Instagram**
How did we do? Let us know here: [Feedback Survey](#)

From: Brummond, Andy <abrummond@mt.gov>
Sent: Wednesday, March 19, 2025 3:17 PM
To: Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Subject: RE: Ditch Information

Or is the segment difference at the diversion for the permit on the ditch?

From: Brummond, Andy
Sent: Wednesday, March 19, 2025 3:15 PM
To: Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Subject: RE: Ditch Information

Thanks Derek. Do you have a map or diagram that shows the ditch segments?

Andy

From: Rasmussen, Derek <Derek.Rasmussen@mt.gov>
Sent: Wednesday, March 19, 2025 2:35 PM
To: Brummond, Andy <abrummond@mt.gov>
Subject: Ditch Information

Hi Andy,

Here is the ditch information.

Respectfully,



Derek Rasmussen | Water Resource Specialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-6282 **EMAIL:** derek.rasmussen@mt.gov
Website | **Facebook** | **X (Twitter)** | **Instagram**
How did we do? Let us know here: [Feedback Survey](#)

THE MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION

GOVERNOR GREG GIANFORTE



DNRC DIRECTOR AMANDA KASTER

DNRC

2273 Boot Hill Ct, STE 110

Bozeman, MT 59715

406-556-6282

3/21/2025

Treasured Mountains Holdings LLC

5653 Monterey Drive

Frisco TX 75034

Subject: Completed Technical Analyses Report for Change Preapplication No. 41G 30165036

Dear Applicant:

As designated on the submitted Preapplication Meeting Form per §85-2-302(3)(b), MCA, the Department of Natural Resources and Conservation (DNRC or Department) has completed the technical analyses for Change Preapplication No. **41G 30165036** based on the information provided in your Preapplication Meeting Form accepted by the Department on **2/5/2025**. The technical analyses can be found in the attached report. Please note this Surface Water Change Technical Analyses Report is a two-part publication, comprised of a Part A completed by **Derek Rasmussen**, and a Part B completed by **Kim Bolhuis**.

This Technical Analyses Report IS: A collection of facts that the DNRC has gathered, including content provided in the Preapplication Meeting Form materials. The Department will use these data to analyze the criteria in §85-2-402, MCA if you submit an application for the project described in the completed Preapplication Meeting Form.

This Technical Analyses Report IS NOT: An analysis or discussion of whether the Preapplication Meeting Form as filed meets the criteria (§85-2-402, MCA).

You have 180 days to submit the Water Right Change Application Form 606 considering the information provided in the technical analyses and Preapplication Meeting Form. If the Application Form is not submitted to the Bozeman Regional Office by **9/17/2025**, a new preapplication meeting will be required to process the



DNRC.MT.GOV

Application with expedited timelines (ARM 36.12.1302(6)(b)). If any details described in the submitted Application are changed from that of the submitted Preapplication Meeting Form, the discounted filing fee and expedited timelines will not apply (ARM 36.12.1302(6)(a)). Please note that the technical analyses will expire one year from the date of this letter (ARM 36.12.1302(8)).

Please let me know if you have any questions.

Sincerely,



Derek Rassmussen
Water Resources Specialist
Bozeman Water Resources Office
Water Resources Division

CC, via email: Andy Brummond (Consultant)
abrummond@mt.gov



Preapplication Materials

- Preapplication Meeting Request
- Preapplication Meeting Form
- All attachments
- All correspondence prior to application receipt

Preapplication Materials



PREAPPLICATION MEETING FORM CHANGE

§ 85-2-302(3)(b)
Form No. 606P (Revised 2/2024)

PREAPPLICATION MEETING FEE

\$ 500

FILING FEE REDUCTION & EXPEDITED TIMELINE

An application will be eligible for a filing fee reduction and expedited timelines if the applicant completes a preapplication meeting with the Department (ARM 36.12.1302(1)), which includes submitting any follow-up information identified by the Department (ARM 36.12.1302(3)(c)) and receiving either Department-completed technical analyses or Department review of applicant-submitted technical analyses (ARM 36.12.1302(4) and (5)). An application for the proposed project also must be submitted within 180 days of delivery of Department technical analyses or scientific credibility review and no element on the submitted application can be changed from the completed preapplication meeting form (ARM 36.12.1302(6)).

For Department Use Only

Application # 30165036 Basin 41G
Meeting Date 12/17/2024 Time 9:00 AM/PM
Completed Form Deadline 6/15/2025

RECEIVED
JAN 29 2025
DNRC
BOZEMAN WATER RESOURCES

Completed Form Received 1/29/25
Fee Rec'd \$ 500 Check #
Deposit Receipt # IVT2512147
Payor FWP
Refund \$ Date

The Department will fill out Form No. 606P and will identify follow-up during the preapplication meeting. The Department and Applicant will sign the Preapplication Meeting Affidavit and Certification within five business days. Within 180 days of the preapplication meeting, the Applicant will complete identified follow-up on a separate document with the question numbers clearly labeled.

Applicant Information: Add more as necessary.

Applicant Name Treasured Mountains Holdings LLC, Attn: Bill Gould
Mailing Address 5653 Monterey Drive City Frisco State TX Zip 75034
Phone Numbers: Home Work Cell
Email Address billgould@me.com

Applicant Name
Mailing Address City State Zip
Phone Numbers: Home Work Cell
Email Address

Contact/Representative Information: Add more as necessary.

Contact/Representative is: ☐ Applicant ☐ Consultant ☐ Attorney ☒ Other (describe)
Contact/Representative Name Andy Brummond, Montana Fish, Wildlife & Parks
Mailing Address PO Box 938 City Lewistown State MT Zip 59457
Phone Numbers: Home Work 406-708-7223 Cell
Email Address abrummond@mt.gov

NOTE: If a contact person is identified as an attorney, all communication will be sent only to the attorney unless the attorney provides written instruction to the contrary. If a contact person is identified as a consultant, employee, or lessee, the individual filing the water right form or objection form will receive all correspondence and a copy may be sent to the contact person.

Meeting Attendees: Add more as necessary.

Name	Organization	Position
Andy Brummond	Montana Fish, Wildlife & Parks	Water Conservation Specialist
Kerri Strasheim	DNRC	Regional Manager
Lyra Reynolds	DNRC	Hydrospecialist
Derek Rasmussen	DNRC	Water Resource Specialist
Kendrew Ellis	DNRC	Water Resource Specialist
Kimberly Bolhuis	DNRC	Groundwater Hydrologist

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Application Details

The following questions are mandatory and must be filled out before the Preapplication Meeting Form is determined to be complete. Narrative responses that are larger than the space provided can be answered in an attachment. If an attachment is used, mark the see attachment ("A") checkbox on this form and label the attachment with the question number. Constrain narrative responses to the specific question as is asked on the form; do not respond to multiple questions in one narrative. Label units in narrative responses. Responses in the form of a table may be entered into the table provided on this form or in an attachment. Responses in the form of a table that are larger than the table provided on this form should be placed in an attachment. If an attachment is used, the table must have the exact headings found on this form, and the see attachment ("A") checkbox must be marked. For tables in this form, circle correct unit at header of column when faced with a choice of units. For tables in attachments, label all units. Questions that require Applicant to submit items to the Department have a submitted ("S") checkbox, which is marked when the required item is attached to the Preapplication Meeting Form. Label all submitted items with the question number for which they were submitted. For all questions where follow-up is necessary, mark the "F" checkbox in the "Follow-Up" column and write the question number on the "Follow-Up Page".

<u>Questions, Narrative Responses, and Tables</u>		<u>Check-boxes</u>	<u>Follow-Up</u>
1. Do you elect to have DNRC conduct Technical Analyses?		☒ Y ☐ N	☐ F
2. Which water right(s) are proposed for change? Include water right number, currently authorized flow rate (GPM or CFS), and flow rate needed for project (GPM or CFS).		☐ A	☐ F
Water Right Number	Current Flow Rate (GPM or CFS)	Flow Rate Needed for Project (GPM or CFS)	
41G 197111-00	9.48 CFS	4.26 CFS	
3. Is the proposed change on a non-filed water project?		☐ Y ☒ N	☐ F
a. If yes, please submit a Non-Filed Water Project Addendum (Form 606/634-NFWPA). The project must meet the requirements of the addendum. The addendum is required before the Preapplication Meeting Form is completed.		☐ S	☐ F
4. How many change applications will be needed for this project? Please refer to ARM 36.12.1305 for more information. One permanent and one temporary change to instream flow will be needed for both Parsons Slough and Willow Spring (4)			☐ F
5. Please submit a historical use map created on an aerial photograph or topographic map that shows the following: section corners, township and range, a north arrow, all historical points of diversion (POD) labeled with a unique POD ID letter, all historical places of use (POU), all historical conveyance structures, all historical places of storage, and historical place of		☒ S	☐ F



use for all overlapping water rights.		
6. Please submit a proposed use map created on an aerial photograph or topographic map that shows the following: section corners, township and range, a north arrow, all proposed points of diversion labeled with a unique POD ID number, all proposed places of use, all proposed conveyance structures, all proposed places of storage, and proposed place of use for all overlapping water rights.	☐ S	☒ F
7. Identify the water right elements proposed for change, with an "X", for each water right proposed for change.	☐ A	☐ F

Water Right #	41G 197111-00						
Point of diversion	x						
Place of use	x						
Purpose of use							
Place of storage							

8. Does the change involve a change in point of diversion?	☒ Y ☐ N	☐ F
a. If yes, describe the proposed location of the new point(s) of diversion to the nearest 10 acres, if source is groundwater (GW) or surface water (SW), source name, and means of diversion (e.g., pump, headgate, well). Label POD ID with the same numbers as the proposed use map (Question 6).	☐ A	☐ F

POD #	¼	¼	¼	Sec	Twp	Rge	County	Lot	Block	Tract	Subdivision	Gov Lot	GW or SW	Source Name	Means
2	NE	NE	SE	14	1S	5W	Madison						SW	Jefferson River	Pump
3	SE	NW	NE	13	1S	5W	Madison						SW	Jefferson River	Pump- transitory
4	W2	E2	NE	13	1S	5W	Madison						SW	Willow Spring Creek	Pump-transitory

9. Does the change involve a change in place of use?	☒ Y ☐ N	☐ F
a. If yes,		
i. What are the geocodes of the proposed place of use?	☐ A	☐ F

25-0891-13-1-01-01-0000	
25-0891-13-4-01-01-0000	
25-0891-14-4-01-05-0000	



ii. Describe the legal land description of the proposed place of use and, if the water rights being changed will have an irrigation or lawn and garden purpose, list the number of irrigated acres.								☐ A	☐ F
Acres	Gov't Lot	1/4	1/4	1/4	Sec	Twp	Rge	County	
25.7			SE	SE	14	1S	5W	MADISON	
160.9				S1/2	13	1S	5W	MADISON	
8.1			SW	NE	13	1S	5W	MADISON	
3.2			SE	NW	13	1S	5W	MADISON	
0.3		SW	NE	NE	13	1S	5W	MADISON	
1.3		SE	NW	NE	13	1S	5W	MADISON	
199.5	Total								

b. Are you proposing to add a place of use on State of Montana Trust Land?	☐ Y ☒ N	☐ F
i. If yes, you must submit an Authorization for Temporary Change in Appropriation Right Consent Form from the DNRC Trust Lands Management Division before the Preapplication Meeting Form is complete. A change authorization to add a POU on Trust Land will be temporary for the duration of the lease term. Answer project-specific questions for temporary changes (question 99 to 105).	☐ S	☐ F
10. Does the proposed change include a change in purpose of use? If yes, answer questions 106 to 109 for change in purpose of use.	☐ Y ☒ N	☐ F
11. Do you propose to add or modify one or more place(s) of storage (reservoir or pond) with a storage capacity greater than 0.1 acre-feet? If yes, answer questions 110 to 119.	☐ Y ☒ N	☐ F
12. Are conveyance ditches used for historical or proposed uses? If yes, answer ditch-specific questions 120 to 126.	☒ Y ☐ N	☐ F
13. Do you have ownership of the entire historical POU for the water right(s) being changed?	☒ Y ☐ N	☐ F
a. If no,		
i. List the water right(s) for which you do not own the entire historical POU. _____		☐ F
ii. Are the water right(s) listed in question 13.a.i severed from the historical POU?	☐ Y ☐ N	☐ F
1. If yes, do you own the entirety of the severed water right(s) proposed for change?	☐ Y ☐ N	☐ F



iii. Are you filing on behalf of another entity? If yes, describe. _____	☐ Y ☐ N	☐ F
iv. Are all owners of the historical place of use willing to sign the application?	☐ Y ☐ N	☐ F
1. If no,		
a. A Form 641 or 642 to split the water right(s) being changed must be received and processed by the Department prior to application submittal	☐ S	☐ F
b. Describe how the water right(s) will be split, and which part of the split water right(s) will be proposed for change. _____ _____	☐ A	☐ F
14. Is the proposed use temporary? If yes, answer questions 99 to 105 for temporary changes.	☐ Y ☒ N	☐ F
15. Is the application to change the purpose of use or place of use of an appropriation of 4,000 or more acre-feet (AF) of water a year and 5.5 or more cubic feet per second (CFS)? If yes, you must submit a Reasonable Use Addendum (Form 606-B) with the application. The reasonable use criteria are found in §85-2-402(4-5), MCA.	☐ Y ☒ N	☐ F
16. Will you be transporting water for use outside of Montana? If yes, you will need submit an Out-of-State Use Addendum (Form 600/606- OSA) with the application. The out-of-state use criteria are outlined in §85-2-402(6), MCA.	☐ Y ☒ N	☐ F
17. Is the project located in designated sage grouse habitat? If yes, you must have a consultation with and review of your project by the Montana Sage Grouse Habitat Conservation Program. The review letter will be required at application submittal.	☐ Y ☒ N	☐ F
18. Does the application include the water marketing purpose? If yes, answer questions 127 to 134 for water marketing. A Water Marketing Purpose Addendum (Form 600/606-WMA) will be required with application submittal.	☐ Y ☒ N	☐ F
19. Does the proposed purpose include instream flow? If yes, answer questions 135 to 145 for Instream Flow Changes. A Change to Instream Flow Addendum (Form 606-IFA) will be required with application submittal.	☐ Y ☒ N	☐ F
20. Will the proposed use include salvage water? If yes, answer questions 146 to 150 for Salvage Water.	☐ Y ☒ N	☐ F



Historical Use

The following questions are mandatory and must be filled out for both Surface Water and Groundwater Applications before the Preapplication Meeting Form is determined to be complete.

<u>Questions, Narrative Responses, and Tables</u>					<u>Check- boxes</u>	<u>Follow -Up</u>
21. What type of water right(s) are proposed for change? Answer question 22 for each Statement of Claim, 23 for each Provisional Permit, and 24 for other types of water rights. <u>Statement of Claim</u> _____					☐ A	☐ F
22. In the table below, write the water right number for each Statement of Claim proposed for change in the "Statement of Claim" column. If there is one or more previous change authorizations, write the application numbers for the change authorizations in the "Previous Change Authorization" column and if there are no previous change authorizations, write "none" instead. Write the date of the Project Completion Notice for each previous change authorization in the "Project Completion Notice" column and if the previous change authorization does not have a Project Completion Notice, write "none" instead. In the "Previous Historical Use Analysis" column, write "full" or "partial" if a historical use analysis was conducted for the previous change authorization, and "none" if no previous historical use analysis was conducted. In the "Use Historical Use Analysis for Current Application" column, write "yes" if the previous historical use analysis will be used for the current application and "no" if a new historical use analysis will be conducted.					☐ A	☐ F
Statement of Claim	Previous Change Authorization	Project Completion Notice	Previous Historical Use Analysis	Use Historical Use Analysis for Current Application		
41G 197111-00	none	none	none	no		
23. In the table below, write the water right number for each Provisional Permit proposed for change in the "Provisional Permit" column. If a Project Completion Notice has been submitted, write the date in the "Project Completion Notice" column, and if no Project Completion Notice has been submitted, write "none" instead. For each Provisional Permit proposed for change, if there are one or more previous change authorizations, write the application number for the change authorizations in the "Previous Change Authorization" column. If there are no previous change authorizations, write "none" in the "Previous Change Authorization" column and "NA" in all the remaining columns. Write the date of the Project					☐ A	☐ F



Completion Notice for each previous change authorization in the “Previous Change Project Completion Notice” column and if the previous change authorization does not have a Project Completion Notice, write “none” instead. In the “Previous Change Historical Use Analysis” column, write “full” or “partial” if a historical use analysis was conducted for the previous change authorization, and “none” if no previous historical use analysis was conducted. In the “Use Historical Use Analysis for Current Application” column, write “yes” if the previous historical use analysis will be used for the current application, “no” if a new historical use analysis will be conducted.						
Provisional Permit	Project Completion Notice	Previous Change Authorization	Previous Change Project Completion Notice	Previous Change Historical Use Analysis	Use Historical Use Analysis for Current Application	

24. In the table below, write the water right number for each water right with another type proposed for change, the type of water right, and the date of issuance.					☐ A	☐ F
Other Water Right Type Number	Other Water Right Type Description		Date of Issuance			

25. Are there previous Montana Water Court approved stipulations, Water Master reports, or prior Montana Water Court or Department decisions related to the water right(s) being changed?					☐ Y ☒ N	☐ F
a. If yes, explain. 					☐ A	☐ F



26. Fill in the table below based on ARM 36.12.1902(1) and the information provided in questions 21 to 25. In column “Water Right Number” list all water rights proposed for change. Select one of the three options from column “Historical Use Analysis Options” and fill in the “Information Required for Historical Use” associated with that option. Select “Full Historical Use Analysis NA” only if an unperfected Provisional Permit will be used to serve as historical use in lieu of analysis. If the “Existing Historical Use Analysis” or “Full Historical Use Analysis NA” option is selected, skip to question 42 because this section is complete.		☐ A	☐ F
Water Right No. Proposed for Change	Historical Use Analysis Option and Information Required for Historical Use		
41G 197111-00	☒ New Historical Use Analysis. Date for new Historical Use Analysis: <u>July 1, 1973</u>		
	☐ Existing Historical Use Analysis. Change authorization number with existing Historical Use Analysis: _____		
	☐ Full Historical Use Analysis NA. Water right number serving as historical use in lieu of analysis: _____		
	☐ New Historical Use Analysis. Date for new Historical Use Analysis: _____		
	☐ Existing Historical Use Analysis. Change authorization number with existing Historical Use Analysis: _____		
	☐ Full Historical Use Analysis NA. Water right number serving as historical use in lieu of analysis: _____		
	☐ New Historical Use Analysis. Date for new Historical Use Analysis: _____		
	☐ Existing Historical Use Analysis. Change authorization number with existing Historical Use Analysis: _____		
	☐ Full Historical Use Analysis NA. Water right number serving as historical use in lieu of analysis: _____		



	☐ New Historical Use Analysis. Date for new Historical Use Analysis: _____		
	☐ Existing Historical Use Analysis. Change authorization number with existing Historical Use Analysis: _____		
	☐ Full Historical Use Analysis NA. Water right number serving as historical use in lieu of analysis: _____		
	☐ New Historical Use Analysis. Date for new Historical Use Analysis: _____		
	☐ Existing Historical Use Analysis. Change authorization number with existing Historical Use Analysis: _____		
	☐ Full Historical Use Analysis NA. Water right number serving as historical use in lieu of analysis: _____		
	☐ New Historical Use Analysis. Date for new Historical Use Analysis: _____		
	☐ Existing Historical Use Analysis. Change authorization number with existing Historical Use Analysis: _____		
	☐ Full Historical Use Analysis NA. Water right number serving as historical use in lieu of analysis: _____		
27. Do you have actual knowledge of historical use?		☒ Y ☐ N	☐ F
a. If yes,			
i. Is this firsthand knowledge?		☐ Y ☒ N	☐ F
ii. Who has this knowledge and what was their role? <u>Dating back to the early 1990s FWP staff have worked on this property and have some knowledge</u>		☐ A	☐ F



b. If no,		
i. Where will the historical use data be derived? <u>Knowledge of historical use does not predate June 30, 1973. Historical data will be derived based on the nature of the irrigation at that time as well as observations by FWP staff and others since that time</u>	☐ A	☐ F

Historical Use: Place of Use

28. The historical use map provided for question 5 must clearly identify the entire place of use for each overlapping water right that intersects the historical place of use. Does your historical use map meet this requirement?	☒ Y ☐ N	☐ F
29. Are you proposing to change all water right(s) associated with the historical place of use?	☒ Y ☐ N	☐ F
a. If no, identify the water right(s) associated with the historical place of use that are not included in this application. Provide the priority date for each water right and explain why all overlapping water rights are not included in the application. Include water received via contract from a company, district, or water users' association.	☐ A	☐ F

Water Right No.	Priority Date	Reason Not Included in Change

30. Answer the questions below related to the historical purpose for each of the water right(s) being changed.		
a. Irrigation		
i. Is the water right being changed a Statement of Claim?	☒ Y ☐ N	☐ F
1. If yes,		
a. Does the Water Resources Survey corroborate the acres irrigated listed on the abstract?	☐ Y ☒ N	☐ F
i. If no, provide aerial photograph(s) that can corroborate the historical place of use.	☒ S	☐ F
b. Does the legal land description from the abstract match the actual location of the historical place of use?	☐ Y ☐ N	☒ F
i. If no, provide documentation of a written request submitted to the Water Court for amendment of the Claim as well as information to substantiate the requested amendment.	☐ S	☐ F



2. If no, provide one or more aerial photographs that can corroborate the historical place of use.	☐ S	☐ F
b. Lawn and garden		
i. Provide aerial photographs that can corroborate the historical place of use.	☐ S	☐ F
c. Stock		
i. Provide aerial photographs, grazing records, or other records to corroborate the historical place of use.	☐ S	☐ F
ii. Did the stock drink direct from source or direct from ditch?	☐ Y ☐ N	☐ F
1. If no, provide data sources that make clear the location of the stock watering infrastructure.	☐ S	☐ F
d. Multiple domestic, domestic, municipal, mining, commercial, and other purposes		
i. Provide aerial photographs, deeds, other recorded documents or records, affidavits, or other published documents, such as magazine articles, to corroborate the historical place of use.	☐ S	☐ F

Historical Use: Point of Diversion

31. For all historical point(s) of diversion, identify the means, location (¼ ¼ ¼ section), and if they are proposed for change. Label using the same POD ID letter as for the Historical Use Map (question 5).			☒ A	☐ F
POD ID	Means	Location (¼ ¼ ¼ Section)	Proposed for Change?	
1	Headgate	SESESW Sec 14, T1S, R5W	No	

32. Does the legal land description from the abstract match the actual location of the historical point(s) of diversion?	☒ Y ☐ N	☐ F
a. If no, do you have aerial photograph(s) that clearly show the location of the historical point(s) of diversion?	☐ Y ☐ N	☐ F
i. If yes,		
1. Provide the photograph(s).	☐ S	☐ F
2. Provide an explanation for the discrepancy and, if a Statement of Claim, provide documentation of a written request submitted to the Water Court for amendment of the Claim.	☐ S	☐ F
33. Answer questions below related to the diversion means for each of the historical point(s) of diversion.		
a. Headgate		
i. For each headgate, provide dimensions in feet (FT), slope of the channel at the headgate (%), material of the headgate, estimated historical capacity in gallons per minute (GPM) or CFS and the method used to estimate historical capacity. Label using the same POD ID letter as for the Historical Use Map (question 5).	☐ A	☐ F



POD ID	Dimensions (FT)	Slope (%)	Material	Estimated Capacity (GPM or CFS)	Method
1	2 at 4 ft x 4ft	0.12	Wood	16+ CFS	Pin and Plank 2 slots, each 4ft wide

b. Pump, dike, dam, or other surface water point of diversion		
i. For each pump, dike, dam, or other surface water point of diversion, provide an estimate of the historical capacity (GPM or CFS) and the method used to estimate the historical capacity. Label using the same POD ID letter as for the Historical Use Map (question 5).	☐ A	☐ F

POD ID	Estimated Capacity (GPM or CFS)	Method

c. Well, pit, or other groundwater point of diversion		
i. For each well, pit, or other groundwater point of diversion, provide an estimate of the historical capacity (GPM or CFS) and the method used to estimate the historical capacity. Label using the same POD ID letter as for the Historical Use Map (question 5).	☐ A	☐ F

POD ID	Estimated Capacity (GPM or CFS)	Method

34. Do other water rights share the point(s) of diversion?	☒ Y ☐ N	☐ F
a. If yes, list the water rights, their flow rates (GPM or CFS), and the nature of the relationship. Label using the same POD ID letter as for the Historical Use Map (question 5).	☒ A	☐ F



POD ID	Water Right No.	Flow (GPM or CFS)	Relationship
1	Permit 41G 2262-0	700 gpm	shared diversion and ditch

Historical Use: Period of Diversion

35. Are the period of diversion and the period of use the same?		☒ Y ☐ N	☐ F
a. If no,			
i. Why are they different?		☐ A	☐ F

ii. Is there a place of storage?		☐ Y ☐ N	☐ F
36. When was water diverted for the purpose(s) of the water right(s) being changed?		☐ A	☐ F
Start Date (Month (MM)/Day (DD))		End Date (MM/DD)	
5/01		10/15	
37. Does the Department have a standard, found in ARM 36.12.112, for the period of diversion for the purposes for which water is used?		☒ Y ☐ N	☐ F
a. If yes, does the period of diversion fall within Department standards?		☒ Y ☐ N	☐ F
b. If no or if the period of diversion falls outside Department standards, explain how the period of diversion is reasonable for the purpose.		☐ A	☐ F

38. If the water right(s) being changed have an irrigation purpose, answer the following questions.			
a. What were the crop(s) grown? <u>grass, alfalfa, small grains</u>			☐ F



i. If the crop(s) grown include hay, how many cuttings were there per season and how many days did they last? <u>One or two cuttings based on crop. Diversion remained continuous as haying moved between fields</u>		☐ F
b. Did diversions ever temporarily cease within the period of use? This may include water shortages or calls based on priority date.	☐ Y ☒ N	☐ F
i. If yes, please explain. _____ _____ _____	☐ A	☐ F

Historical Use: Historical Diverted Volume

39. Answer the questions below related to the historical purposes of the water rights being changed.		
a. Irrigation		
i. Do you want ARM 36.12.1902(11) to be used to calculate historical diverted volume?	☒ Y ☐ N	☐ F
1. If no, provide a Historical Water Use Addendum (Form 606-HUA). Form 606-HUA must be submitted to the Department before the Preapplication Meeting Form is completed.	☐ S	☐ F
b. Non-irrigation		
i. How often was water historically diverted? _____		☐ F
ii. What was the duration of each historical diversion? _____		☐ F
iii. Was wastewater historically discharged? If yes, what amount was discharged? _____	☐ Y ☐ N	☐ F
iv. What is the volume of water historically diverted (AF)? _____		☐ F
v. How did you determine the volume of water historically diverted? _____ _____ _____	☐ A	☐ F
vi. Did the historical diverted volume serve more than one purpose of use?	☐ Y ☐ N	☐ F



1. If yes, how much of the diverted volume served each purpose of use and how did you determine this? _____ _____ _____ _____	☐ A	☐ F
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Historical Use: Historical Consumed Volume

40. Answer the questions below related to the historical purpose of the water rights being changed.		
a. Irrigation		
i. Will you use Department standards for historical consumptive use as defined in ARM 36.12.1902?	☒ Y ☐ N	☐ F
1. If no,		
a. What method will you use to determine historical consumptive use? _____ _____	☐ A	☐ F
b. Provide a Historical Water Use Addendum (Form 606-HUA) to the Department. Form 606-HUA must be submitted to the Department before the Preapplication Meeting Form is completed.	☐ S	☐ F
2. If yes,		
a. What is the historical irrigation method type and subtype? Irrigation method types include flood and sprinkler. Flood irrigation subtypes include level border, graded border, furrow, contour ditch, or wild flood. Sprinkler subtypes include wheel line and center pivot. <u>historic irrigation included flood irrigation north of Willow Spring Creek and sprinkler</u> <u>irrigation south of Willow Spring Creek</u>	☐ A	☒ F
b. What was the slope of the historical place of use? <u>approx 0.3% flood, approx 0.1% sprinkler</u>		☐ F
c. Are there any factors beyond irrigation method type/subtype and place of use slope that may influence percent efficiency of irrigation?	☐ Y ☒ N	☐ F
i. If yes, provide evidence to support the modified percent efficiency of irrigation in the Historical Water Use Addendum (Form 606-HUA). These factors may include infrastructure age, soil characteristics, or field improvements. Form 606-HUA must be submitted to the Department before the Preapplication Meeting Form is	☐ S	☐ F



completed.					
d. Based on answers to the above questions, what is the percent efficiency of irrigation? 25% for flood irrigation (wild flood), 70% for sprinkler irrigation					☐ F
e. What is the County Management Factor? 65.2%					☐ F
f. What is evapotranspiration (ET) based on the irrigation method and county? 16.98 in					☐ F
g. What percent of applied water are irrecoverable losses per ARM 36.12.1902(17)? 5% for flood, 10% sprinkler					☐ F
h. Do other water rights supplement or overlap the historical place of use that contribute to the irrigation water demand?				☐ Y ☒ N	☐ F
i. If yes,					
1. How were the water rights operated to serve the irrigation purpose?				☐ A	☐ F
2. For each supplemental or overlapping water right, please list the average period of diversion and use (MM/DD-MM/DD), flow rate (GPM or CFS), and the volume of water (AF) contributed to the total irrigation water demand.				☐ A	☐ F
Water Right No.	Avg. Period of Diversion (MM/DD-MM/DD)	Avg. Period of Use (MM/DD-MM/DD)	Flow Rate (GPM or CFS)	Volume Contributed (AF)	



b. Lawn and garden			
i. Will you use the Department standards for historical consumptive use volume for lawn and garden? Department standards include 2.5 acre-feet per acre, or a calculated volume based on Irrigation Water Requirements for turf grass.		☐ Y ☐ N	☐ F
1. If yes, which standard? _____			☐ F
2. If no, please provide an estimate of historical water use based on expert analysis and methods used to determine this estimate. _____ _____		☐ A	☐ F
c. Stock			
i. Which volume standard for animal units applies to historical use and why? The standards are either 15 or 30 gallons per animal unit per day. _____			☐ F
ii. How many animal units were historically served? _____			☐ F
iii. Did these animal units rely entirely on the water right(s) proposed for change for their full water demand?		☐ Y ☐ N	☐ F
1. If no, explain. _____ _____		☐ A	☐ F
d. Domestic and multiple domestic			
i. How many households were served? _____			☐ F
ii. Will the Department standard of 1 acre-foot per household be used? The same standard shall be applied to historical and proposed uses.		☐ Y ☐ N	☐ F
1. If no, what standard will be used? _____			☐ F
iii. Did the historical use include wastewater disposal and treatment?		☐ Y ☐ N	☐ F



1. If yes, which of the following best describes the wastewater disposal and treatment system? Individual drain fields, central treatment facility with minimal consumption, or evaporation basin or land application? _____	☐ A	☐ F
e. Municipal		
i. What is the volume of water (AF) historically consumed for municipal purposes? _____		☐ F
ii. Provide evidence to support historical municipal use such as commercial, lawn and garden, and/or multiple domestic uses. The data sources may include records that tie water use to the U.S Census, estimates of historical system capacity and estimates of leakage.	☐ S	☐ F
f. Other		
i. What is the volume of water (AF) historically consumed for other purposes? _____		☐ F
ii. Please submit to the Department evidence to support the volume of water historically consumed.	☐ S	☐ F

Historical Use: Historical Places of Storage

41. Did the historical use include one or more place(s) of storage, which may include reservoirs, ponds, and pits that are greater than 0.1 acre-feet in volume?	☐ Y ☒ N	☐ F		
a. If yes, for each historical place of storage please provide the surface area in acres (AC), capacity (AF), annual net evaporation (FT/year), and number of times per year the place of storage was filled.	☐ A	☐ F		
ID	Surface Area (AC)	Capacity (AF)	Annual Net Evaporation (FT/YR)	# of Annual Fillings



Surface Water

☒ **Applicable**, move on to question 42. ☐ **Not Applicable**, skip to question 67.

The following questions are mandatory for changes to surface water rights and must be filled out before the Preapplication Meeting Form is determined to be complete.

Surface Water: Return Flow Analysis

<u>Questions, Narrative Responses, and Tables</u>	<u>Check-boxes</u>	<u>Follow-Up</u>
42. Do the purposes of the water rights proposed for change include irrigation?	☒ Y ☐ N	☐ F
a. If yes, does the proposed change include a change in place of use <i>and/or</i> a change in purpose? A change in place of use includes retiring acres in the historical place of use and adding any new acres outside the historical place of use.	☒ Y ☐ N	☐ F
i. If yes, a return flow analysis is required. Move on to answer question 43.		
ii. If no, this section is complete, and you may skip to question 51.		
43. Does the proposed change include a change in purpose?	☐ Y ☒ N	
a. If yes, what is the consumptive use for the proposed non-irrigation purpose? Please explain. _____ _____ _____ _____ _____	☐ A	☐ F
44. Does the proposed change include a change in place of use? If yes, move on to question 45. If no, this section is complete, and you may skip to question 51.	☒ Y ☐ N	
45. Provide a map showing the historical and proposed places of use created on an aerial photograph or topographic map with section corners, township and range, and a north arrow.	☐ S	☒ F
46. How many acres, if any, will be retired from the historical place of use? <u>91</u>		☐ F
47. Are irrigated acres proposed that are outside the historical place of use?	☒ Y ☐ N	☐ F
a. If yes,		
i. How many acres? <u>52.9</u>		☐ F



ii. What is the proposed irrigation method type (e.g., flood or sprinkler) and subtype (e.g., level border, graded border, furrow, contour ditch, wild flood, center pivot, or wheel line) for the new acres? center pivot sprinkler, large impact sprinkler on car, field to Southwest will be wheelines			☐ F	
iii. What is the slope of the new place of use? 0.7%			☐ F	
iv. Based on 47.a.ii to 47.a.iii, what is the percent efficiency of irrigation for the new acres? 70%			☐ F	
v. What is the County Management Factor for the new acres? 83.3%			☐ F	
vi. What is the ET based on the irrigation method and county for the new acres? center pivot - 19.22 in, wheelline - 16.98 in			☐ F	
vii. What percent of applied water are irrecoverable losses for new acres per ARM 36.12.1902(17)? 10%			☐ F	
viii. Do other water rights supplement or overlap the new place of use that contribute to the irrigation water demand?		☐ Y ☒ N	☐ F	
1. If yes,				
a. How will the water rights be operated to serve the irrigation purpose?		☐ A	☐ F	
b. For each supplemental or overlapping water right, please list the average period of diversion and use (MM/DD-MM/DD), flow rate (GPM or CFS), and the volume of water (AF) contributed to the total irrigation water demand.		☐ A	☐ F	
Water Right No.	Avg. Period of Diversion (MM/DD-MM/DD)	Avg. Period of Use (MM/DD-MM/DD)	Flow Rate (GPM or CFS)	Volume Contributed (AF)



48. Do you have information for the Department to consider about the source and location where return flows historically accrued?	☒ Y ☐ N	☐ F
a. If yes, explain. <u>The return flow accrues to the Jefferson River and Willow Spring Creek</u> _____ _____ _____	☐ A	☐ F
49. Based on the preliminary data provided by the Department at this preapplication meeting, to what surface water sources do return flows accrue before and after the proposed change? <i>*Return flow data provided by the Department at the preapplication meeting is preliminary and is subject to change during the Technical Analysis.</i> <u>The Jefferson River and Willow Spring Creek</u> _____ _____	☐ A	☐ F
50. If an analysis of impacts to identified surface water rights is required as part of the return flow analysis, pursuant to ARM 36.12.1303(3)(c)(iii), do you elect to answer non-mandatory questions 161 to 163 to provide information required for this extended return flow analysis?	☒ Y ☐ N	☐ F
a. If yes, go to question 161. If an analysis of impacts to identified surface water rights is required, this information will be used for the analysis.		
b. If no, did you elect in question 1 for the Department to conduct technical analyses?	☐ Y ☐ N	☐ F
i. If yes, do you elect for the Department to use publicly available water quantity data for the analysis of impacts to identified surface water rights? If the extended return flow analysis is required and sufficient publicly available water quantity data is not available, then the Department will not be able to conduct the extended analysis. You will still have to prove a lack of adverse effect from the proposed change.	☐ Y ☐ N	☐ F
ii. If no, an analysis of impacts to identified surface water rights will need to be completed as part of the extended return flow analysis. The Department will include the extended analysis in its scientific credibility review of the Technical Analyses.		

Surface Water: Mitigation Analysis

51. Are you changing the purpose to mitigation to meet the criteria of issuance for another application? If yes, answer the questions in this section (questions 52 to 60). If no, this section is complete, and you can skip to question 61.	☐ Y ☒ N	☐ F
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52. Identify the water right(s) proposed for change to a mitigation purpose, the water right(s) identified as needing mitigation and the application number for the water right(s) identified as needing mitigation. 	☐ A	☐ F																																																								
53. What source(s) have been identified as needing mitigation water? 		☐ F																																																								
54. By what means will mitigation water be made available (e.g., infiltration gallery, water left instream)? You must provide a copy of all relevant discharge permits at application submittal (§85-2-364, MCA). 	☐ A	☐ F																																																								
55. What is the location (¼ ¼ ¼ section of start and end of reach) and length (FT) of the mitigation reach? 		☐ F																																																								
56. What is the amount, timing, and location (¼ ¼ ¼ section) of water needed for mitigation? 	☐ A	☐ F																																																								
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 12.5%;">Month</th> <th style="width: 12.5%;">Days</th> <th style="width: 12.5%;">Amount</th> <th style="width: 12.5%;">Location</th> <th style="width: 12.5%;">Month</th> <th style="width: 12.5%;">Days</th> <th style="width: 12.5%;">Amount</th> <th style="width: 12.5%;">Location</th> </tr> </thead> <tbody> <tr><td>January</td><td></td><td></td><td></td><td>July</td><td></td><td></td><td></td></tr> <tr><td>February</td><td></td><td></td><td></td><td>August</td><td></td><td></td><td></td></tr> <tr><td>March</td><td></td><td></td><td></td><td>September</td><td></td><td></td><td></td></tr> <tr><td>April</td><td></td><td></td><td></td><td>October</td><td></td><td></td><td></td></tr> <tr><td>May</td><td></td><td></td><td></td><td>November</td><td></td><td></td><td></td></tr> <tr><td>June</td><td></td><td></td><td></td><td>December</td><td></td><td></td><td></td></tr> </tbody> </table>	Month	Days	Amount	Location	Month	Days	Amount	Location	January				July				February				August				March				September				April				October				May				November				June				December					
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57. How do the priority dates of the water rights proposed for change to mitigation compare to other water rights on the source? 	☐ A	☐ F																																																								
58. Do you have measurement records or Water Commissioner records that show the reliability of the water right(s) proposed for change to a mitigation purpose?	☐ Y ☐ N	☐ F																																																								



a. If yes, describe and submit them to the Department.				☐ S		☐ F	
59. Do the water rights proposed for change to mitigation have a period of use that is greater than or equal to the period when mitigation is necessary?				☐ Y ☐ N		☐ F	
a. If no, how will mitigation water be made available during the entire period when mitigation is necessary?				☐ A		☐ F	
60. Will other water rights contribute to mitigation water?				☐ Y ☐ N		☐ F	
a. If yes, what amount, at what timing, and at which location (1/4 1/4 1/4 section) will they contribute?				☐ A		☐ F	
Month	Days	Amount	Location	Month	Days	Amount	Location
January				July			
February				August			
March				September			
April				October			
May				November			
June				December			

Surface Water: Aquifer Recharge Analysis

61. Are you changing the purpose to aquifer recharge to serve a current purpose or changing the purpose to marketing for mitigation/aquifer recharge for a future mitigation purpose? If yes, answer the questions in this section (questions 62 to 66). If no, this section is complete, and you can skip to question 67.		☐ Y ☒ N	☐ F
62. Is this aquifer recharge for a current mitigation need or marketing for mitigation/aquifer recharge for a future mitigation need?			☐ F
63. What sources have been identified as having net depletions in need of mitigation or as benefiting from marketing for mitigation/aquifer recharge water?			☐ F



64. By what means will aquifer recharge water be made available? You must provide a copy of all relevant discharge permits at application submittal (§85-2-364, MCA). _____ _____ _____ _____ _____	☐ A	☐ F
65. How do the priority dates of the water rights proposed for change to aquifer recharge compare to other water rights on the source? _____ _____ _____	☐ A	☐ F
66. Do you have measurement records or Water Commissioner records that show the reliability of the water rights proposed for change to aquifer recharge?	☐ Y ☐ N	☐ F
a. If yes, describe and submit them to the Department. _____ _____ _____ _____	☐ S	☐ F



Groundwater

☐ **Applicable**, move on to question 67. ☒ **Not Applicable**, skip to question 99.

The following questions are mandatory for changes to groundwater rights and must be filled out before the Preapplication Meeting Form is determined to be complete.

Groundwater: Adequacy of Diversion

Questions, Narrative Responses, and Tables					Check-boxes	Follow-Up
67. What is the flow rate (GPM or CFS), volume (AF), and period of diversion (MM/DD-MM/DD) required at each new groundwater point of diversion? Label using the same POD ID number as the Proposed Use Map (question 6) to match this information with the location information.					☐ A	☐ F
POD #	Flow Rate (GPM or CFS)	Volume (AF)	Period of Diversion (MM/DD-MM/DD)			
68. Will the monthly pumping schedule differ from an allocation of diverted volume by the number of days in the month for year-round uses or the IWR 80% net irrigation requirements for irrigation/lawn & garden uses (IWR, NRCS 2003)?					☐ Y ☐ N	☐ F
a. If yes, provide the monthly pumping schedule in the table below. Label using the same POD ID number as the Proposed Use Map (question 6).					☐ A	☐ F
Month	POD #	Volume (AF)	Month	POD #	Volume (AF)	
January			July			
February			August			
March			September			
April			October			
May			November			
June			December			
69. Answer the following questions specific to the means of groundwater diversion.						
Well/Pit	Questions 70 to 71	Developed Spring	Question 72	Pond	Questions 73 to 76	



Groundwater: Adequacy of Diversion: Well/Pit

☐ Applicable ☐ Not Applicable

70. Have you submitted a completed Form 633 to DNRC for review?	☐ Y ☐ N	☐ F
a. If no, submit Form 633 to DNRC for review. Form 633 is required by the time the Preapplication Meeting Form is deemed complete.	☐ S	☐ F
b. If yes, did the Department identify deficiencies?	☐ Y ☐ N	☐ F
1. If yes, are variances from ARM 36.12.121 needed?	☐ Y ☐ N	☐ F
a. If yes,		
i. Do you have data for aquifer characteristics?	☐ Y ☐ N	☐ F
1. If yes, provide the data to the Department.	☐ S	☐ F
ii. Have you submitted Form 653 to the Department?	☐ Y ☐ N	☐ F
1. If yes, was the variance granted?	☐ Y ☐ N	☐ F
71. Have all the wells/pits been constructed?	☐ Y ☐ N	☐ F
a. If yes, provide a map with the location of each well/pit labeled, the well/pit depth, and, if available, the GWIC ID. Create map on an aerial photograph or topographic map and include the following: well/pit location, well/pit depth, GWIC ID (if available), section corners, township and range, and a north arrow.	☐ S	☐ F
b. If no,		
i. When will the wells/pits be constructed? _____		☐ F
ii. Do you have an initial map with the proposed location of wells/pits?	☐ Y ☐ N	☐ F
1. If yes, provide an initial map to the Department. Create map on an aerial photograph or topographic map and include the following: proposed well/pit location, section corners, township and range, and a north arrow.	☐ S	☐ F
iii. What is the anticipated depth for each new well/pit? Label on the initial map if the proposed location is known. Otherwise provide the depth(s) here: _____ _____	☐ S	☐ F
iv. Is the requested volume for each new well/pit known?	☐ Y ☐ N	☐ F
1. If no, what is the total requested volume (AF) and the number of new PODs? _____		☐ F



Groundwater: Adequacy of Diversion: Developed Spring

☐ Applicable ☐ Not Applicable

72. Have you measured the source?	☐ Y ☐ N	☐ F
a. If yes,		
i. Submit measurements to the Department.	☐ S	☐ F
ii. With what method were measurements collected? _____ _____	☐ A	☐ F
iii. What is the interval of measurements? _____		☐ F
iv. Is the interval of measurements sufficient to comply with ARM 36.12.1703(1)?	☐ Y ☐ N	☐ F
b. If no, or if measurements do not comply with ARM 36.12.1703(1),		
i. When do you plan to measure? _____		☐ F
ii. With what method and at what interval will measurements be collected? _____ _____	☐ A	☐ F

Groundwater: Adequacy of Diversion: Pond

☐ Applicable ☐ Not Applicable

73. Have you submitted Form 653 to apply for a variance from ARM 36.12.121 for the Aquifer Test?	☐ Y ☐ N	☐ F
a. If yes, did the Department approve the variance request?	☐ Y ☐ N	☐ F
74. Submit pond bathymetry data, survey, or engineering plans to the Department.	☐ S	☐ F
75. Submit a map identifying the location of the proposed pond to the Department. Create map on an aerial photograph or topographic map and include the following: pond location, section corners, township and range, and a north arrow.	☐ S	☐ F
76. If you are conducting Technical Analyses, what is your plan to determine depth, surface area, and net evaporation of the pond? If the Department is conducting Technical Analyses, write N/A. _____ _____	☐ A	☐ F



Groundwater: Adverse Effect to Existing Groundwater Rights

All information to calculate the one-foot drawdown contour was collected in previous questions.

Groundwater: Adverse Effect to Surface Water Rights

Groundwater: Adverse Effect to Surface Water Rights: Surface Water Depletion Analysis

77. Does the proposed change include a change in point of diversion or a change in place of use or purpose that will lead to a change in consumptive use or pumping schedule? If you do not know if a change in place of use or purpose will lead to a change in consumptive use or pumping schedule, work through this with the Department. If yes, a surface water depletion analysis is required; move on to question 78. If no, this section is complete; skip to question 80.	☐ Y ☐ N	☐ F
78. Based on the preliminary data provided by the Department at this preapplication meeting, what are the hydraulically connected surface water sources before and after the proposed change? <i>*Net depletion data provided by the Department at the preapplication meeting is preliminary and is subject to change during the Technical Analysis.</i> _____ _____ _____ _____	☐ A	☐ F
79. If an analysis of impacts to identified surface water rights is required as part of the surface water depletion analysis, pursuant to ARM 36.12.1903(2)(f), do you elect to answer non-mandatory questions 166 to 168 to provide information required for this extended surface water depletion analysis?	☐ Y ☐ N	☐ F
a. If yes, go to question 166. If an analysis of impacts to identified surface water rights is required for the surface water depletion analysis, this information will be used for the analysis.		
b. If no, did you elect in question 1 for the Department to conduct technical analyses?	☐ Y ☐ N	☐ F
i. If yes, do you elect for the Department to use publicly available water quantity data for the analysis of impacts to identified surface water rights for the surface water depletion analysis? If this extended surface water depletion analysis is required and sufficient publicly available water quantity data is not available, then the Department will not be able to conduct the extended surface water depletion analysis. You will still have to prove a lack of adverse effect from the proposed change.	☐ Y ☐ N	☐ F
ii. If no, you may still include the analysis of impacts to identified surface water rights with the surface water depletion analysis. The Department will include the extended analysis in its scientific credibility review of the Technical Analyses.		



Groundwater: Adverse Effect to Surface Water Rights: Return Flow Analysis

80. Do the purposes of the water rights proposed for change include irrigation?	☐ Y ☐ N	☐ F
a. If yes, does the proposed change include a change in place of use <i>and/or</i> a change in purpose? A change in place of use includes retiring acres in the historical place of use and adding any new acres outside the historical place of use.	☐ Y ☐ N	☐ F
i. If yes, a return flow analysis is required. Move on to answer question 81.		
ii. If no, this section is complete, and you may skip to question 89.		
81. Does the proposed change include a change in purpose?	☐ Y ☐ N	
a. If yes, what is the consumptive use for the proposed non-irrigation purpose? Please explain. _____ _____ _____ _____ _____ _____	☐ A	☐ F
82. Does the proposed change include a change in place of use? If yes, move on to question 83. If no, this section is complete, and you may skip to question 89.	☐ Y ☐ N	
83. Provide a map showing the historical and proposed places of use. Create map on an aerial photograph or topographic map that shows the following: section corners, township and range, and a north arrow.	☐ S	☐ F
84. How many acres, if any, will be retired from the historical place of use? _____		☐ F
85. Are irrigated acres proposed that are outside the historical place of use?	☐ Y ☐ N	☐ F
a. If yes,		
i. How many acres? _____		☐ F
ii. What is the proposed irrigation method type and subtype (e.g., level border, graded border, furrow, contour ditch, or wild flood) for the new acres? _____		☐ F
iii. What is the slope of the new place of use? _____		☐ F
iv. Based on question 85.a.ii to 85.a.iii, what is the percent efficiency of irrigation for the new acres? _____		☐ F



v. What is the County Management Factor for the new acres? _____		☐ F
vi. What is the ET based on the irrigation method and county for the new acres? _____		☐ F
vii. What percent of applied water are irrecoverable losses for new acres? _____		☐ F
viii. Do other water rights supplement or overlap the new place of use that contribute to the irrigation water demand?	☐ Y ☐ N	☐ F
1. If yes,		
a. How will the water rights be operated to serve the irrigation purpose? _____ _____ _____ _____ _____ _____ _____	☐ A	☐ F
b. For each supplemental or overlapping water right, please list the average period of diversion and use (MM/DD-MM/DD), flow rate (GPM or CFS), and the volume of water (AF) contributed to the total irrigation water demand.	☐ A	☐ F

Water Right No.	Avg. Period of Diversion (MM/DD-MM/DD)	Avg. Period of Use (MM/DD-MM/DD)	Flow Rate (GPM or CFS)	Volume Contributed (AF)

86. Do you have information for the Department to consider about the source and location where return flows historically accrued?	☐ Y ☐ N	☐ F
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a. If yes, explain. _____ _____ _____	☐ A	☐ F
87. Based on the preliminary data provided at this preapplication meeting, to what surface water sources will return flows accrue before and after the proposed change? <i>*Return flow data provided by the Department at the preapplication meeting is preliminary and is subject to change during the Technical Analysis.</i> _____ _____ _____	☐ A	☐ F
88. If an analysis of impacts to identified surface water rights is required as part of the return flow analysis, pursuant to ARM 36.12.1303(5)(d)(iii), do you elect to answer non-mandatory questions 161 to 163 to provide information required for this extended analysis?	☐ Y ☐ N	☐ F
a. If yes, go to question 161. If an analysis of impacts to identified surface water rights is required as part of the return flow analysis, this information will be used for the analysis.		
b. If no, did you elect in question 1 for the Department to conduct technical analyses?	☐ Y ☐ N	☐ F
i. If yes, do you elect for the Department to use publicly available water quantity data for the analysis of impacts to identified surface water rights? If this extended return flow analysis is required and sufficient publicly available water quantity data is not available, then the Department will not be able to conduct the extended analysis. You will still have to prove a lack of adverse effect from the proposed change.	☐ Y ☐ N	☐ F
ii. If no, an analysis of impacts to identified surface water rights will need to be completed as part of the return flow analysis. The Department will include the extended analysis in its scientific credibility review of the Technical Analyses.		

Groundwater: Mitigation

89. Do you require mitigation water to meet the criteria of issuance for this change application or for a different application? If yes, answer the questions in this section (questions 90 to 98). If no, this section is complete, and you can skip to question 99.	☐ Y ☐ N	☐ F
90. Please identify the water rights proposed for change to a mitigation purpose and the water rights identified as needing mitigation. _____	☐ A	☐ F



91. What sources have been identified as needing mitigation water? 		☐ F
92. By what means will mitigation water be made available? 	☐ A	☐ F
93. What is the location (¼ ¼ ¼ section of start and end of reach) and length (feet) of the mitigation reach? 		☐ F
94. What is the amount, timing, and location (¼ ¼ ¼ section) of water needed for mitigation?	☐ A	☐ F

Month	Days	Amount	Location	Month	Days	Amount	Location
January				July			
February				August			
March				September			
April				October			
May				November			
June				December			

95. How do the priority dates of the water rights proposed for change to mitigation compare to other water rights on the source? 	☐ A	☐ F
96. Do you have measurement records or Water Commissioner records that show the reliability of the water right(s) proposed for change to a mitigation purpose?	☐ Y ☐ N	☐ F
a. If yes, describe and submit them to the Department. 	☐ S	☐ F
97. Do the water rights proposed for change to mitigation have a period of use that is greater than or equal to the period when mitigation is necessary?	☐ Y ☐ N	☐ F



a. If no, how will mitigation water be made available during the entire period when mitigation is necessary?				☐ A		☐ F	
98. Will other water rights contribute to mitigation water?				☐ Y ☐ N		☐ F	
a. If yes, what amount, at what timing, and at which location (¼ ¼ ¼ section) will they contribute?				☐ A		☐ F	
Month	Days	Amount	Location (¼ ¼ ¼ Section)	Month	Days	Amount	Location (¼ ¼ ¼ Section)
January				July			
February				August			
March				September			
April				October			
May				November			
June				December			

Project-Specific Questions

The following questions are mandatory when applicable and must be filled out before the Preapplication Meeting Form is determined to be complete.

Temporary Change

<u>Questions, Narrative Responses, and Tables</u>	<u>Check-boxes</u>	<u>Follow-Up</u>
99. Does the proposal include a temporary change? If yes, please answer the questions in this section (questions 100 to 105) for each water right being changed. If no, or if you answered these questions earlier in the preapplication meeting, this section is complete and you can skip to question 106.	☐ Y ☒ N	☐ F
100. What element(s) of the water right(s) are being temporarily changed? _____		☐ F
101. For how many years will the water right(s) be temporarily changed? _____		☐ F
102. Will the temporary change be intermittent over the years?	☐ Y ☐ N	☐ F
a. If yes, explain. _____	☐ A	☐ F
103. For what purpose will the water rights be temporarily used? _____		☐ F



104. Is the quantity of water subject to the temporary change being made available from the development of a new water conservation or storage project?	☐ Y ☐ N	☐ F
a. If yes, explain the water conservation or storage project. _____ _____ _____	☐ A	☐ F
105. If you are answering Project Specific Questions as they are referenced in Application Details, return to question 10 if you are proposing to add a place of use on State of Montana Trust Land and question 15 if you are proposing a temporary change that does not involve State of Montana Trust Land. If you are answering in consecutive order, go to question 106.		

Change in Purpose

106. Does the project involve a change in purpose? If yes, answer the questions in this section (questions 107 to 109). If no, of if you answered these questions earlier in the preapplication meeting, this section is complete and you can skip to question 110.	☐ Y ☒ N	☐ F
107. Identify the proposed new purpose, flow rate (GPM or CFS), volume (AF), and period of use (MM/DD-MM/DD) for each purpose.	☐ A	☐ F

Purpose	Flow Rate (GPM or CFS)	Volume (AF)	Period of Use Start (MM/DD-MM/DD)	Period of Use End (MM/DD-MM/DD)

108. Explain why the requested flow rate and volume is the amount needed for the purpose. _____ _____ _____	☐ A	☐ F
109. If you are answering Project Specific Questions as they are referenced in Application Details, return to question 11 and if you are answering in consecutive order, go to question 110.		



Change in Place of Storage

110. Does the project involve a change in place of storage? If yes, answer the questions in this section (questions 111 to 119) for each individual place of storage (use additional Change in Place of Storage sheet for additional places of storage). If no, or if you answered these questions earlier in the preapplication meeting, this section is complete; skip to question 120.	☐ Y ☒ N	☐ F
111. Submit a map showing the location of the place of storage. Create map on an aerial photograph or topographic map that shows the following: place of storage, section corners, township and range, and a north arrow.	☐ S	☐ F
112. Is this application to add a new place of storage or change an existing place of storage? _____		☐ F
a. If application is to change an existing place of storage, list the water rights that include the place of storage and a short description of the proposed change. _____ _____	☐ A	☐ F
113. Is the place of storage located on-stream?	☐ Y ☐ N	☐ F
a. If no, explain the conveyance means to and from the off-stream place of storage and any losses that may occur with that conveyance. _____ _____	☐ A	☐ F
114. What is the proposed capacity of the place of storage? Use bathymetry data, survey, or engineering plans for capacity. Submit the data source used with this form. In lieu of these data sources, use the following equation: <i>Surface Acres x Maximum Depth (FT) x 0.5 (0.4-0.6 depending on side slope) = Capacity (AF)</i> _____	☐ S	☐ F
115. Will the place of storage include primary and/or emergency spillways? Preliminary design specifications for primary and emergency spillways must be included with application submittal (ARM 36.12.113).	☐ Y ☐ N	☐ F
116. Will the place of storage be lined?	☐ Y ☐ N	☐ F
117. What is the annual net evaporation of water from the place of storage using the standards in ARM 36.12.116(1) and the Department's Gridded Net Evaporation Layer? _____		☐ F
118. Is the place of storage capacity calculated to be greater than 50 acre-feet?	☐ Y ☐ N	☐ F
a. If yes, have you made an application to the DNRC Water Operations Bureau for a determination of whether the dam or reservoir is a high-hazard dam?	☐ Y ☐ N	☐ F



119. If you are answering Project Specific Questions as they are referenced in Application Details, return to question 12 and if you are answering in consecutive order, go to question 120.		
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Ditch-Specific Questions

120. Does the historical use of water include at least one conveyance ditch? If yes, answer questions 121 to 122. If no, or if you answered these questions earlier in the preapplication meeting, skip to question 123.	☒ Y ☐ N	☐ F
121. Submit a Historical Use Ditch Map that shows every ditch conveying water for the historical use of all water right(s) proposed for change. Label the ditch name(s), POD(s), the POU(s), and the ditch measurement locations (requested in question 122.d). The map should be created on an aerial photograph or topographic map with the following: section corners, township and range, and a north arrow.	☒ S	☐ F
122. For each historical conveyance ditch, answer question 122.a to 122.h. If there is more than one historical conveyance ditch, use an Additional Historical Ditch Sheet for each additional ditch.		
a. What is the ditch name? <u>Curtis Ditch</u>		☐ F
b. List the water right(s) proposed for change that were conveyed by the ditch. <u>41G 197111-00</u>		☐ F
c. What is the distance water was historically carried by the conveyance ditch? Only include segments between the POD and start of the POU; do not include segments within the POU. <u>5,230 ft</u>	☐ A	☐ F
d. Provide at least one set of ditch measurements, which include width (FT), depth (FT), and slope (%). Discuss ditch characteristics with DNRC to determine the minimum number of ditch measurements. Include the location of each measurement, labeled with the 2-digit measurement ID number, used on the map submitted for question 121.	☒ S	☐ F

ID #	Width (FT)	Depth (FT)	Slope (%)	Date of Measurement
Curtis	14.0	2.0	.12	7/18/2024

e. What is a reasonable Manning's n value? List the factors used for estimation. If you do not know this value, please work through estimation with the Department. <u>see attached ditch profile and analysis. Calculated Manning's n of 0.16 is extremely high and likely due to difficulty in precisely measuring slope under slow velocity conditions due to aquatic vegetation in ditch</u>	☒ A	☐ F
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f. What type of soils compose the historical conveyance ditch? For lined ditches, write “lined” instead. <u>Silty clay loam transitioning to loam. 86- Neen silty clay loam, 327-Chaffee, 110-Tyell-Rivra complex</u>	☒ A	☐ F
g. Are other water rights conveyed by the historical conveyance ditch?	☒ Y ☐ N	☐ F
i. If yes,		
1. What are the water right numbers? <u>Permit 41G 2262-00 - Not yet verified by DNRC</u>	☐ A	☐ F
2. What is the sum of the flow rates (GPM or CFS) for all water rights conveyed? <u>11.04 CFS</u>	☐ A	☐ F
3. Provide a map with your best estimate of the historical POUs for the other water rights conveyed by the historical conveyance ditch. Include only POUs between the historical POD and your historical POU. If you do not know this information, the Department can help you create the map. The map should be created on an aerial photograph or topographic map and show the following: section corners, township and range, and a north arrow.	☒ S	☐ F
h. Were any water rights proposed for change part of one historical water right that was split?	☐ Y ☒ N	☐ F
i. If yes, were all split water rights split in such a way to ensure each post-split water right could stand alone and not be reliant on the others for carriage water?	☐ Y ☐ N	☐ F
1. If no, do any of the water right(s) proposed for change have a carriage water requirement?	☐ Y ☐ N	☐ F
a. If yes,		
i. List the water right(s) with a carriage water requirement		☐ F
ii. Update your Historical Use Ditch Map to label the ditch segments where a carriage water requirement exists for a water right proposed for change. Also, use your best estimate to label the POUs for all water rights included in the carriage water requirement. If you do not know this information, the Department can help you update the map.	☐ S	☐ F
123. Does the proposed use include at least one existing or new conveyance ditch? If yes, answer questions 124 to 126. If no, or if you answered these questions earlier in the preapplication meeting, this section is complete; skip to question 127.	☒ Y ☐ N	☐ F



124. Submit a Proposed Use Ditch Map that shows every ditch conveying the water right(s) proposed for change, including any unchanged portions. Label all unchanged and proposed PODs, all unchanged and proposed POUs, and additional ditch measurement locations (requested in question 125.e). The map should be created on an aerial photograph or topographic map with the following: section corners, township and range, and a north arrow.	☒ S	☐ F
125. For each proposed use conveyance ditch, answer the questions 125.a to 125.i. If there is more than one proposed use conveyance ditch, use an Additional Proposed Use Ditch Sheet for each additional ditch.		
a. What is the ditch name? <u>Curtis Ditch</u>		☐ F
b. Is this ditch a historical conveyance ditch detailed in questions 121 to 122?	☒ Y ☐ N	☐ F
i. If yes, have any of the following details changed, to the best of your knowledge, from historical conditions: ditch length, distance water conveyed, ditch lining, or water rights conveyed by the ditch?	☒ Y ☐ N	☐ F
1. If yes, answer questions 125.c to 125.i using current data.		
2. If no, do not answer questions 125.c to 125.i for this ditch because the information remains unchanged. Move on to the next proposed use conveyance ditch, or if none remain, skip to question 127.		
c. List the water right(s) proposed for change that are going to be conveyed by the ditch. <u>41G 197111-00</u>		☐ F
d. What is the distance water will be carried by the conveyance ditch? Only include segments between the POD and start of the POU; do not include segments within the POU. <u>7,960 ft to secondary POD near Jefferson River, 6,160 ft to the secondary POD from the fishpond</u>	☐ A	☒ F
e. Provide at least one set of ditch measurements, which include width (FT), depth (FT), and slope (%). Discuss ditch characteristics with DNRC to determine the minimum number of ditch measurements. Include the location of each measurement, labeled with the 2-digit measurement ID number, used on the map submitted for question 124.	☒ S	☐ F

ID #	Width (FT)	Depth (FT)	Slope (%)	Date of Measurement
Curtis	14	2	0.12	7/18/2024



f. What is a reasonable Manning's n value? List the factors used for estimation. If you do not know this value, please work through estimation with the Department. <u>See attached ditch profile and analysis</u>	☒ A	☐ F
g. What type of soils compose the proposed conveyance ditch? For lined ditches, write "lined" instead. <u>Silty clay loam transitioning to loam, 86-Neen silty clay loam, 327- Chaffee, 110-Tylee-Rivra complex</u>	☒ A	☐ F
h. Are other water rights conveyed by the proposed conveyance ditch?	☒ Y ☐ N	☐ F
i. If yes,		
1. What are the water right numbers? <u>Permit 41G 2262-00</u>	☐ A	☐ F
2. What is the sum of the flow rates (GPM or CFS) for all water rights conveyed? <u>11.04 CFS</u>	☐ A	☐ F
3. Provide a map with your best estimate of the current POUs for the other water rights conveyed by the proposed conveyance ditch. Include only POUs between the POD and your proposed POU. If you do not know this information, the Department can help you create the map. The map should be created on an aerial photograph or topographic map and show the following: section corners, township and range, and a north arrow.	☒ S	☐ F
i. Were any water right(s) proposed for change identified as having a carriage water requirement in question 122.h.i.1.a.i?	☐ Y ☒ N	☐ F
i. If yes, update your Proposed Use Ditch Map to label the ditch segments where a carriage water requirement exists for a water right proposed for change. Also, use your best estimate to label the POUs for all water rights included in the carriage water requirement. If you do not know this information, the Department can help you update the map.	☐ S	☐ F
126. If you are answering Project Specific Questions as they are referenced in Application Details, return to question 13 and if you are answering in consecutive order, go to question 127.		



Water Marketing

127. Does this project involve water marketing? If yes, answer the questions in this section (questions 128 to 134). If no, or if you answered these questions earlier in the preapplication meeting, this section is complete; skip to question 135.	☐ Y ☒ N	☐ F
128. Identify the flow rate (GPM or CFS) and volume of water (AF) that will be marketed. _____		☐ F
129. Will the marketed water return to the source?	☐ Y ☐ N	☐ F
a. If yes, explain how that determination was made. _____ _____ _____	☐ A	☐ F
130. For what purpose(s) will the marketed water be used? _____ _____	☐ A	☐ F
131. How will you control or limit access to the water? _____ _____	☐ A	☐ F
132. Do you have contracts for the entire volume and flow rate sought?	☐ Y ☐ N	☐ F
133. Provide a service area map. Create map on an aerial photograph or topographic map and shows the following: general service area boundary, section corners, township and range, and a north arrow.	☐ S	☐ F
134. If you are answering Project Specific Questions as they are referenced in Application Details, return to question 19 and if you are answering in consecutive order, go to question 135.		

Instream Flow Change

135. Does the project involve an instream flow change? If yes, answer the questions in this section (questions 136 to 145). If no, or if you answered these questions earlier in the preapplication meeting, this section is complete; skip to question 146.	☐ Y ☒ N	☐ F
136. Is the proposal to retire all the use from the historical purpose throughout the entire period of use?	☐ Y ☐ N	☐ F
a. If no, describe why not in detail. _____ _____ _____	☐ A	☐ F



137. What is the name of the source of water where streamflow will be maintained or enhanced? _____		☐ F
138. Provide specific information on the location (¼ ¼ ¼ section of start and end of reach) and length (FT) of the stream reach in which the streamflow is to be maintained or enhanced. _____	☐ A	☐ F
139. Does the protected reach begin at the existing point of diversion?	☐ Y ☐ N	☐ F
a. If no, does the proposed protected reach begin upstream of or downstream from the existing point of diversion? _____		☐ F
140. Does return flow go back to the source of supply? The Department provides an initial estimate of the sources where return flow historically accrued at the preapplication meeting.	☐ Y ☐ N	☐ F
141. Describe the way the streamflow is to be maintained or enhanced. _____ _____ _____	☐ A	☐ F
142. Provide initial details about a streamflow measuring plan, which include the points where measurements occur, the interval of measurement, and the methods and equipment used. A complete streamflow measuring plan will be required for the application. _____ _____ _____ _____ _____	☐ A	☐ F
143. Provide initial details about an operation plan, which include the proposed flow rate (GPM or CFS) to be protected up to the proposed volume (AF) and the period when protection is to occur. If there is a “trigger flow” associated with your operation plan, please explain. A complete operation plan, based on the Technical Analysis, will be required for the application. _____ _____ _____ _____ _____	☐ A	☐ F



144. Is the amount of water proposed for change in the application made available through creation of a “water saving method,” as defined in ARM 36.12.101?	☐ Y ☐ N	☐ F
a. If yes, complete the Salvage Water section (questions 146 to 150).	☐ S	☐ F
145. If you are answering Project Specific Questions as they are referenced in Application Details, return to question 20 and if you are answering in consecutive order, go to question 146.		

Salvage Water

146. Does this project involve salvage water? Salvage water does not include destroying phreatophytes, removing vegetation, converting to a less consumptive crop, or converting to a partial irrigation schedule. If yes, answer the questions in this section (questions 147 to 150). If no, or if you answered these questions earlier in the preapplication meeting, this section is complete and you can skip to question 151.	☐ Y ☒ N	☐ F
147. What water saving method was implemented? This may include lining an unlined ditch or canal, converting unlined ditch or canal to pipeline, converting high profile or high-pressure sprinklers to low pressure, and other (explain). _____ _____	☐ A	☐ F
148. How much water was salvaged from creation of the water saving method? Include flow rate (GPM or CFS) and volume (AF). _____		☐ F
149. How did you determine the amount of water salvaged? _____ _____ _____ _____ _____	☐ A	☐ F
150. If you are answering Project Specific Questions as they are referenced in Application Details, return to question 21 and if you are answering in consecutive order, go to question 151.		



Non-Mandatory Questions for Criteria Analysis

The following questions are not mandatory. They should be discussed in the Preapplication Meeting, but do not need to be filled out before the Preapplication Meeting Form is determined to be complete.

Adverse Effect

<u>Questions, Narrative Responses, and Tables</u>	<u>Check-boxes</u>
151. Once the historical use analysis is complete for the application, be ready to compare the historical use with the proposed use. Do you have evidence the proposed use exceeds the historical use for flow rate, consumed volume, or diverted volume?	☐ Y ☒ N
a. If yes, what is your plan to address this with the permitting process? _____ _____	☐ A
152. Describe your plan to ensure that existing water rights will be satisfied during times of water shortage. <u>Diversion will be reduced or ceased to respond to a valid call on water or in response to the order of a water commissioner. This is unlikely given the seniority of the water right. Water will be measured in Parsons Slough when the Jefferson pump is in use to ensure the flow rate being pumped is flowing in Parsons Slough to the Jefferson River</u>	☐ A
153. Explain how you can control your diversion in response to call being made. <u>The pump flow rate would be reduced or pumping stopped if a valid call is received. If the headgate and Curtis Ditch is in use in the event of the Jefferson pump not being operational, the headgate will be adjusted to reduce or cease diversion in response to a valid call on water.</u>	☐ A
154. Are you aware of any calls that have been made on the source of supply or depleted surface water source?	☐ Y ☒ N
a. If yes, explain. _____ _____	☐ A
155. Does a water commissioner distribute water or oversee water distribution on your proposed source or depleted surface water source?	☐ Y ☒ N
156. Will the proposed use change the ability for you to make call?	☐ Y ☒ N



157. When was the last time water was appropriated and used beneficially? <u>2024 - water used every year since priority date</u> If there has been a period of nonuse, explain below:	
a. Why the water right was not used. _____ _____	☐ A
b. Why a resumption of use will not adversely affect other water users. _____ _____	☐ A
c. Is the period of nonuse greater than 10 years?	☐ Y ☐ N
d. Have water rights been authorized to use the source during the period of nonuse?	☐ Y ☐ N
158. For point of diversion changes:	
a. Is the proposed point of diversion upstream or downstream of the historical point of diversion? <u>downstream</u>	
b. Are there intervening water users between the historical and proposed point of diversion?	☐ Y ☒ N
c. Does the proposed point of diversion allow for diverting water longer during times of shortage?	☐ Y ☒ N
159. For place of use changes, will changes to the rate, location, volume, or timing of return flows adversely affect other appropriators?	☐ Y ☒ N

Adverse Effect: Evaluation of Impacts to Identified Water Rights for Return Flow Analysis

160. Respond to questions in this section if you elected in questions 50 or 88 to answer optional questions 161 to 163. If you did not elect to answer these questions or answered these questions earlier in the preapplication meeting, this section is complete; skip to question 165.	
161. For each surface water source receiving return flows, is gage data available?	☐ Y ☒ N
a. If yes, answer the following questions for the number of stream gages that are available.	
i. One stream gage is available	
1. What is the gage name? <u>06027600 Jefferson River at Parsons Bdg nr Silver Star, MT</u>	
2. Who operates and maintains the gage? <u>USGS</u>	



3. Is the stream gage upstream or downstream of the point(s) of diversion? <u>Upstream of confluence of Parsons Slough and the Jefferson River.</u>	
4. Is there a limiting or controlling factor that would make the Drainage Area Method not practical? This includes dams that control the flow and streams with large gaining and/or losing reaches. If you have questions about this, please contact the Regional Hydro-Specialist or the Water Sciences Bureau.	☒ Y ☐ N
5. Is the period of record greater than or equal to 10 years?	☒ Y ☐ N
6. How frequently is stage data recorded? <u>15 min.</u>	
7. If data gaps were to occur, are they identified and left unfilled or estimated using interpolation, ice correction, or indirect discharge measurements methods?	☒ Y ☐ N
8. Was the rating curve established and maintained throughout the duration of the period of record using measurements taken near the reference gage and stage recorder according to USGS protocols?	☒ Y ☐ N
9. Were there requirements for maintaining a permanent gage datum and meeting specified accuracy limits?	☒ Y ☐ N
10. Does the gage data meet the Department's standard to be sufficient to calculate the median of the mean monthly flow rate and volume during the proposed months of diversion?	☐ Y ☒ N
a. If yes, skip to question 163.	
b. If no, answer question 161.b.	
ii. More than one stream gage is available	
1. List the gage names. <u>06026500 Jefferson River near Twin Bridges MT , 06036650 Jefferson River near Three Forks MT</u>	
2. Who operates and maintains the gages? <u>USGS</u>	
3. Is one stream gage upstream and one downstream of point(s) of diversion?	☒ Y ☐ N
4. Do the stream gages have similar periods of record?	☒ Y ☐ N
5. Are the periods of record each greater than or equal to 10 years?	☒ Y ☐ N
6. How frequently is stage data recorded at each gage? <u>15 min.</u>	
7. For each gage, if data gaps were to occur, are they identified and left unfilled or estimated using interpolation, ice correction, or indirect discharge measurements methods?	☒ Y ☐ N



8. Were the rating curves established and maintained throughout the duration of the period of record using measurements taken near the reference gages and stage recorders according to USGS protocols?	☒ Y ☐ N
9. For each gage, were there requirements for maintaining a permanent gage datum and meeting specified accuracy limits?	☒ Y ☐ N
10. Does the gage data meet the Department's standard to be sufficient to calculate the median of the mean monthly flow rate and volume during the proposed months of diversion?	☒ Y ☐ N
a. If yes, skip to question 163.	
b. If no, answer question 161.b.	
b. If no gage data is available or if available gage data does not meet the Department's standard to be sufficient to calculate the median of the mean monthly flow rate and volume during the proposed months of diversion, is the source otherwise measured?	☒ Y ☐ N
i. If yes,	
1. Submit measurements to the Department.	☒ S
2. Who collected the measurements? <u>See Attached Reports.</u>	☒ A
3. With what method was the data collected? <u>See Attached Reports.</u>	☒ A
4. What is the period of record? <u>See Attached Reports.</u>	
5. What is the frequency of measurement? <u>See Attached Reports.</u>	
6. Are there gaps in the data?	☐ Y ☐ N
a. If yes, what is the nature of the gaps and how are gaps handled to ensure data quality? <u>See Attached Reports.</u>	☐ A
7. Is there a process for maintaining the data and meeting specified accuracy limits?	☐ Y ☐ N



a. If yes, explain. <u>MBMG published study/reports</u> _____ _____ _____	☐ A
8. Does available measurement data meet the Department's standard to be sufficient to calculate the median of the mean monthly flow rate and volume during the proposed months of diversion?	☐ Y ☐ N
a. If yes, skip to question 163.	
b. If no, answer question 162.	
162. For each surface water source receiving return flows, does the available measurement data, gage and/or otherwise measured, meet the Department's standard of including a minimum of high, moderate, and low flows to be sufficient to use for validation of a department-accepted estimation technique?	☐ Y ☐ N
a. If yes, describe the estimation technique. _____ _____ _____	☐ A
b. If no, will measurements be collected prior to submission of a completed Form No. 606P that meet the Department's standard of including a minimum of high, moderate, and low flows to be sufficient to use for validation of a department-accepted estimation technique?	☐ Y ☐ N
i. If yes,	
1. With what method will the data be collected? _____ _____ _____	☐ A
2. What will be the interval of measurement? _____	



3. Describe the proposed estimation technique. _____ _____ _____ _____	☐ A
ii. If no, describe your plan supply measurements for return flow receiving sources. _____ _____ _____	☐ A
163. If you are conducting Technical Analysis, how will the Area of Potential Adverse Effect be defined for evaluating return flow impacts? If the Department is conducting Technical Analyses, write N/A. _____ _____ _____ _____	☐ A
164. If you went straight to this section when referenced, go back to question 51 for surface water changes and question 88 for groundwater changes. If you waited to answer in consecutive order and have completed all prior sections, move to question 165.	

Adverse Effect: Evaluation of Impacts to Identified Water Rights for Surface Water Depletion Analysis

165. Respond to questions in this section if you elected in question 79 to answer optional questions 166 to 168. If you did not elect to answer these questions or answered these questions earlier in the preapplication meeting, this section is complete; skip to question 170.	
166. For each hydraulically connected surface water source, is gage data available?	☐ Y ☐ N
a. If yes, answer the following questions for the number stream gages are available.	
i. One stream gage is available	
1. What is the gage name? _____	



2. Who operates and maintains the gage? _____	
3. Is the stream gage upstream or downstream of the start of the depletion? _____	
4. Is there a limiting or controlling factor that would make the Drainage Area Method not practical? This includes dams that control the flow and streams with large gaining and/or losing reaches. If you have questions about this, please contact the Regional Hydro-Specialist or the Water Sciences Bureau.	☐ Y ☐ N
5. Is the period of record greater than or equal to 10 years?	☐ Y ☐ N
6. How frequently is stage data recorded? _____	
7. If data gaps were to occur, are they identified and left unfilled or estimated using interpolation, ice correction, or indirect discharge measurements methods?	☐ Y ☐ N
8. Was the rating curve established and maintained throughout the duration of the period of record using measurements taken near the reference gage and stage recorder according to USGS protocols?	☐ Y ☐ N
9. Were there requirements for maintaining a permanent gage datum and meeting specified accuracy limits?	☐ Y ☐ N
10. Does the gage data meet the Department's standard to be sufficient to calculate the median of the mean monthly flow rate and volume during the proposed months of diversion?	☐ Y ☐ N
a. If yes, skip to question 168.	
b. If no, answer question 166.b.	
ii. More than one stream gage is available	
1. List the gage names. _____	
2. Who operates and maintains the gages? _____	
3. Is one stream gage upstream and one downstream of the start of the depletion?	☐ Y ☐ N
4. Do the stream gages have similar periods of record?	☐ Y ☐ N
5. Are the periods of record each greater than or equal to 10 years?	☐ Y ☐ N
6. How frequently is stage data recorded at each gage? _____	



7. For each gage, if data gaps were to occur, are they identified and left unfilled or estimated using interpolation, ice correction, or indirect discharge measurements methods?	☐ Y ☐ N
8. Were the rating curves established and maintained throughout the duration of the period of record using measurements taken near the reference gages and stage recorders according to USGS protocols?	☐ Y ☐ N
9. For each gage, were there requirements for maintaining a permanent gage datum and meeting specified accuracy limits?	☐ Y ☐ N
10. Does the gage data meet the Department's standard to be sufficient to calculate the median of the mean monthly flow rate and volume during the proposed months of diversion?	☐ Y ☐ N
a. If yes, skip to question 168.	
b. If no, answer question 166.b.	
b. If no gage data is available or if available gage data does not meet the Department's standard to be sufficient to calculate the median of the mean monthly flow rate and volume during the proposed months of diversion, is the source otherwise measured?	☐ Y ☐ N
i. If yes,	
1. Submit available measurements to the Department	☐ S
2. Who collected the measurements? _____	☐ A
3. With what method was the data collected? _____ _____	☐ A
4. What is the period of record? _____	
5. What is the frequency of measurement? _____	
6. Are there gaps in the data?	☐ Y ☐ N
a. If yes, what is the nature of the gaps and how are gaps handled to ensure data quality? _____ _____ _____ _____	☐ A
7. Is there a process for maintaining the data and meeting specified accuracy limits?	☐ Y ☐ N



a. If yes, explain. _____ _____ _____	☐ A
8. Does available measurement data meet the Department's standard to be sufficient to calculate the median of the mean monthly flow rate and volume during the proposed months of diversion?	☐ Y ☐ N
a. If yes, skip to question 168.	
b. If no, answer question 167.	
167. For each hydraulically connected surface water source, does the available measurement data, gage and/or otherwise measured, meet the Department's standard of including a minimum of high, moderate, and low flows to be sufficient to use for validation of a department-accepted estimation technique?	☐ Y ☐ N
a. If yes, describe the estimation technique. _____ _____ _____ _____	☐ A
b. If no,	
i. Will measurements be collected prior to submission of a completed Form No. 606P that meet the Department's standard of including a minimum of high, moderate, and low flows to be sufficient to use for validation of a department-accepted estimation technique?	☐ Y ☐ N
1. If yes,	
a. With what method will the data be collected? _____ _____ _____	☐ A
b. What will be the interval of measurement? _____	



c. Describe the proposed estimation technique. _____ _____ _____ _____	☐ A
2. If no, describe your plan to comply with the measurement requirements for hydraulically connected surface water sources. _____ _____ _____	☐ A
168. If you are conducting Technical Analysis, how will the Area of Potential Adverse Effect be defined for evaluating changes to net depletions? If the Department is conducting Technical Analyses, write N/A. _____ _____ _____ _____	☐ A
169. If you went straight to this section when referenced, go back to question 80. If you waited to answer in consecutive order and have completed all prior sections, move to question 170.	

Adequate Means of Diversion and Operation

170. Provide a diagram of how you will operate your system from the point of diversion to the place of use.	☒ S
171. Describe specific information about the capacity of the diversionary structure(s). This may include, where applicable: pump curves and total dynamic head calculations, headgate design specifications, and dike or dam height and length. <u>The primary system is to be supplied from the Jefferson River by a 60 HP variable speed turbine pump that can adjust flow rate to supply any combination of the 4 sprinkler system. The 1.6 ac system consists of a 14HP gasoline engine driving a centrifuga pump</u>	☐ A
172. Is the diversion capable of providing the full amount requested through the period of diversion?	☒ Y ☐ N



173. Describe the size and configuration of infrastructure to convey water from point of diversion to place of use. This may include, where applicable: ditch capacity and/or pipeline size and configuration. <u>The pump will initially supply a 10 in. PVC buried mainline which is tapped by a 8 in. mainline to serve the north central pivot. At the corner of the wheel line field, the 10 in. mainline will be tapped to supply the risers mainline for the wheel line. The 10 in, mainline will continue to the southwest pivot center point where it will reduce to an 8 in. mainline to supply the southeast pivot.</u>	☐ A
174. Describe any losses related to conveyance. <u>No losses are anticipated for the additional points of diversion</u>	☐ A
175. Is the conveyance infrastructure capable of providing the required flow and volume and any losses?	☒ Y ☐ N
176. Does the proposed conveyance require easements?	☐ Y ☒ N
a. If yes, explain.	☐ A
177. Describe any places of storage, including whether drainage devices will be installed, and provide preliminary designs, if available. Preliminary designs will be required at application submittal.	☐ A
178. Describe specific information about how water is delivered within the place of use. This may include, where applicable, the range of flow rates needed for a pivot and output and configuration of sprinkler heads. <u>The center pivots will use low pressure drop nozzles with a 2 HP pump supplying the Nelson end guns. The 1/4 mile wheel line will consist of self-leveling impulse type sprinklers spaced at the standard 40 ft. each supplying approximately 8.5 gpm each. The 1.6 ac system supplies a impact sprinkler on a cart through a 2 in. flexible plastic hose using a 16 mm nozzle.</u>	☐ A
179. Is the water delivery system capable of providing the requested beneficial use?	☒ Y ☐ N
180. Will your system be designed to discharge water from the project?	☐ Y ☒ N
a. If yes, explain the way water will be discharged and the wastewater disposal method.	☐ A



181. Provide a plan of operations. The system is to be supplied from the Jefferson River by a 60 HP variable speed turbine pump that can adjust flow rate to supply any combination of the 4 sprinkler system. Irrigation will be adjusted based on soil moisture conditions and crop water demand. The 1.6 ac system will be used as needed to provide adequate soil moisture for the crop	☐ A
182. Can the plan of operations deliver the flow rate and volume for the beneficial use being requested?	☒ Y ☐ N
183. Do you have any plans to measure your diversion and use?	☒ Y ☐ N
a. If yes, describe the plan and the type of measurements you will take. Water will be measured in Parsons Slough to ensure the up to 4.26 CFS being diverted from the Jefferson River is flowing in Parsons Slough and reaching the Jefferson River	☐ A
184. Is the means of diversion a well?	☐ Y ☒ N
a. If yes, are well log(s) available?	☐ Y ☐ N
i. If yes, submit well log(s) to DNRC	☐ S
ii. If no, who drilled the well?	

Beneficial Use

185. Why is the requested flow rate and volume the amount needed for the purpose? The requested flow rate and volume is necessary to adequately supply the proposed irrigation system	☐ A
186. Does the Department have a standard for the purposes for which water is used? Department standards can be found in ARM 36.12.112.	☒ Y ☐ N
a. If yes, does the proposed beneficial use fall within Department standards?	☒ Y ☐ N
187. If no standard or if proposed beneficial use falls outside of Department standards, explain how the use is reasonable for the purpose. _____ _____ _____ _____	☐ A
188. Will your proposed project be subject to DEQ requirements for a public water supply (PWS) system or Certificate of Subdivision Approval (COSA)?	☐ Y ☒ N



a. If yes,	
i. Have you researched or consulted with DEQ regarding those requirements?	☐ Y ☐ N
189. Are you proposing to use surface water for in-house domestic use?	☐ Y ☒ N
a. If yes, does a COSA exist for the proposed place of use?	☐ Y ☐ N
i. If yes, please submit the COSA.	☐ S
ii. If no, have you researched or consulted with DEQ regarding their requirements?	☐ Y ☐ N

Possessory Interest

190. Do you have possessory interest, or the permission of the party with possessory interest, of the proposed place of use? Proof of possessory interest or permission of the party with possessory interest is required at application submittal.	☒ Y ☐ N
a. If no, explain. _____ _____ _____	☐ A



PREAPPLICATION MEETING AFFIDAVIT & CERTIFICATION

“We attest that the information on this form accurately describes the proposed project discussed during the preapplication meeting and that the items marked for follow-up will require the applicant to provide additional information before the form is deemed complete.”

“Applicant acknowledges that any information provided by the Department during the preapplication is preliminary and subject to change.”

“Applicant acknowledges that if the follow-up information provided to the Department substantially changes the proposed project, for example in a way that alters which sections of the form are applicable or which technical analyses are required, or who is to complete the technical analyses, the applicant will need to schedule a new preapplication meeting so that the department can identify any additional information necessary for completion of the technical analyses (ARM 36.12.1302(3)(c)).”

Upon Department receipt of the completed form (within 180 days following the meeting), the Department reserves the first five days of the 45-day period in ARM 36.12.1302(4) or (5) to return the form to the applicant if:

- 1 – the completed form does not include all necessary follow-up information identified in the meeting, OR
- 2 – the completed form is not adequate for the Department to proceed with technical analyses, OR
- 3 – the applicant has elected to complete technical analyses and has not submitted each piece of technical analysis required, OR
- 4 – the applicant has substantially changed the details of the proposed project, such as in a way that alters which sections of the form are applicable, which technical analyses are required, or who is to complete the technical analyses.

If the Department returns the form to the Applicant within these five days due to reasons 1-3 above, the Applicant can use the balance of their 180-day period in ARM 36.12.1302(4) or (5) to gather the remaining follow-up information needed. If there is no time remaining in the 180-day period, the Applicant can submit a written request for a new preapplication meeting, pursuant to ARM 36.12.1302(2). Even if there is still time remaining, the Applicant can choose to schedule a new preapplication meeting. The Department shall transfer the \$500 payment received to the new preapplication meeting, or refund the payment to the Applicant if the Applicant desires. If the Department returns the form to the Applicant within these five days due to reason (4) above, the Applicant must submit a written request for a new preapplication meeting, pursuant to ARM 36.12.1302(2). The Department shall transfer the \$500 payment received to the new preapplication meeting, or refund the payment to the Applicant if the Applicant desires.

Applicant Signature

Date

Applicant Signature

Date

Department Signature

Date



FOLLOW-UP PAGE

Applicant will provide all responses to questions marked for follow-up on a separate document entitled "Follow-up Responses" with the question number labeled. Answer questions in the same format as the form. For responses in the form of checkboxes, write "Y", "N", or "S". Constrain narrative responses to the specific question as is asked on the form; do not respond to multiple questions in one narrative. Label units in narrative responses and tables. Tables must have the exact headings found on the form. Questions that require items to be submitted to the Department may be marked "S" when the required item is attached to the Preapplication Meeting Form. Label all submitted items with the question number for which they were submitted. The Applicant may not alter the Preapplication Meeting Form signed at the Preapplication Meeting. Instead, the Applicant must use the Amended Responses procedure defined below. Do not include additional information for questions not marked for follow-up here; instead include any additional information pursuant to the process for amending responses defined below.

Questions marked for follow-up

-6	-
-30.a.i.1.b	-
-40.a.i.2.a	-
-45	-
-125.d	-
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AMENDED RESPONSES PAGE

The Applicant may not alter the Preapplication Meeting Form signed at the Preapplication Meeting or the Follow-up Page. If a response has changed to a question answered at the preapplication meeting, the Applicant can provide a new response in a separate document entitled "Amended Responses" with the question number labeled. Answer questions in the same format as the form. For responses in the form of checkboxes, write "Y", "N", or "S". Constrain narrative responses to the specific question as is asked on the form; do not respond to multiple questions in one narrative. Label units in narrative responses and tables. Tables must have the exact headings found on the form. Questions that require items to be submitted to the Department may be marked "S" when the required item is attached to the Preapplication Meeting Form. Label all submitted items with the question number for which they were submitted. The Applicant will mark all question numbers with an amended response in the table below and note for each question whether the response will replace the response given at the preapplication meeting or will provide additional information to consider in conjunction with the response given at the preapplication meeting. The Applicant will return the "Amended Responses" document with the "Follow-up Responses" document and the signed Preapplication Meeting Form.

Questions with amended responses

-	-	-	-
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FOLLOW-UP PAGE AFFIDAVIT & CERTIFICATION

“I/we attest that this preapplication meeting form, follow-up page, and amended responses page accurately portray my proposed project. I am aware that my application for this project will not qualify for a discounted filing fee and expedited timelines if upon submittal of the application to the department, I change any element of the proposed application from the preapplication meeting form and follow-up materials (ARM 36.12.1302(6)(a)).”

Applicant Signature

Date

Applicant Signature

Date

“We confirm that the preapplication form and follow-up information are adequate for the Department to proceed with technical analyses in ARM 36.12.1303. If the applicant has elected to complete technical analyses, we confirm they have submitted each piece of technical analysis required based on the proposed project and the Department is able to proceed with the scientific credibility review (ARM 36.12.1303(8)).”

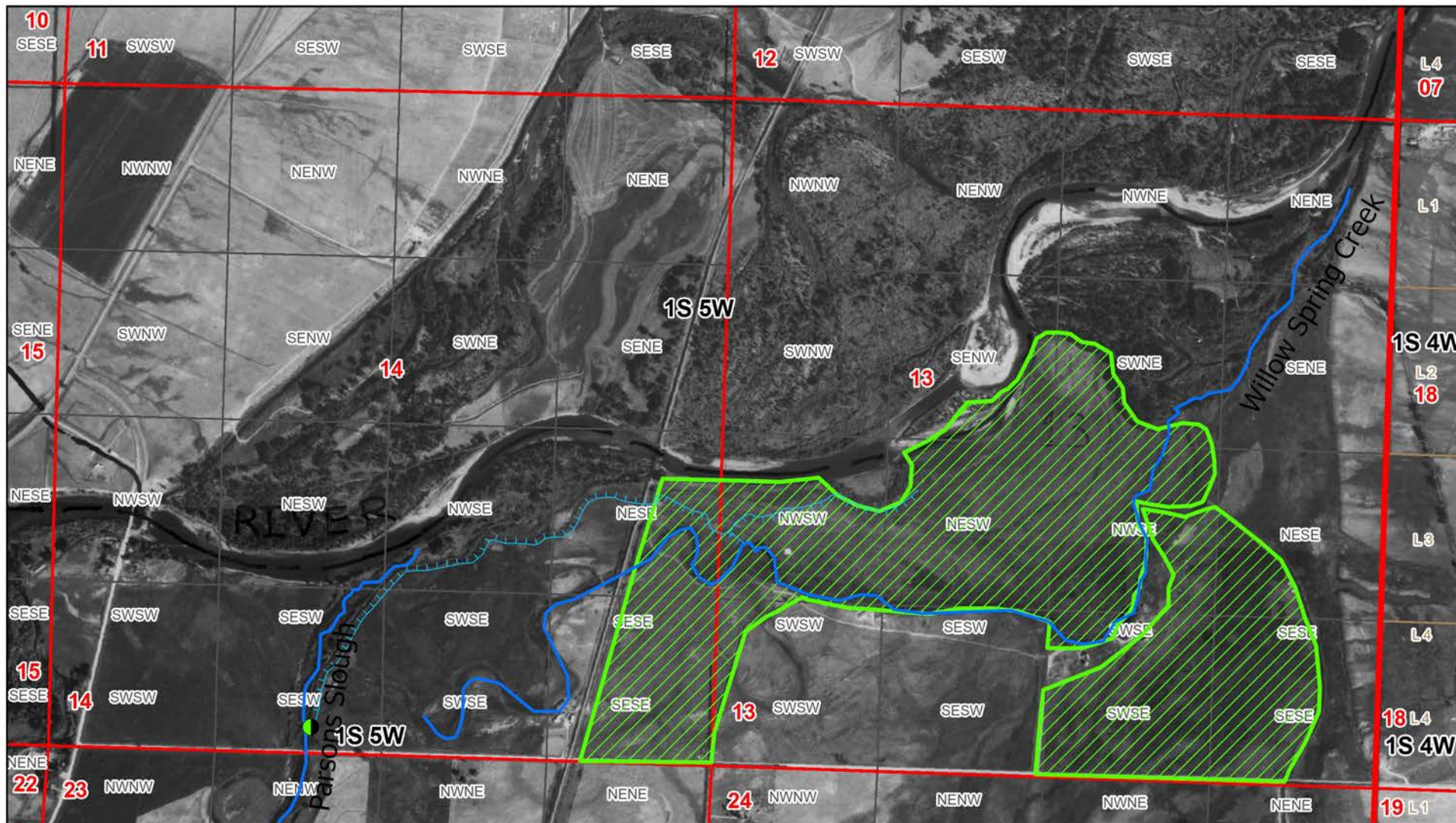
Department Signature

Date

Department Signature

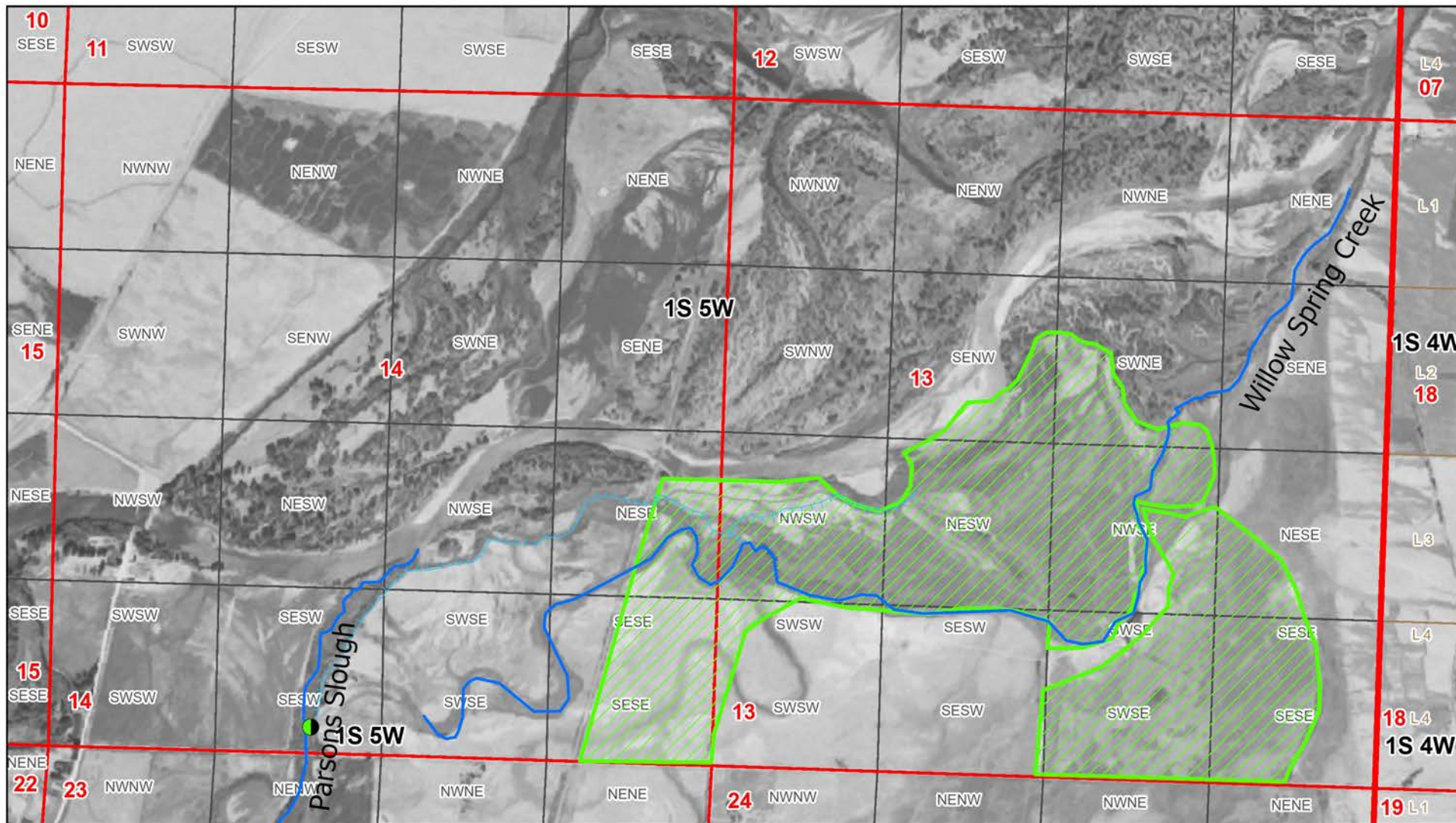
Date





Historic Use Pre App #5

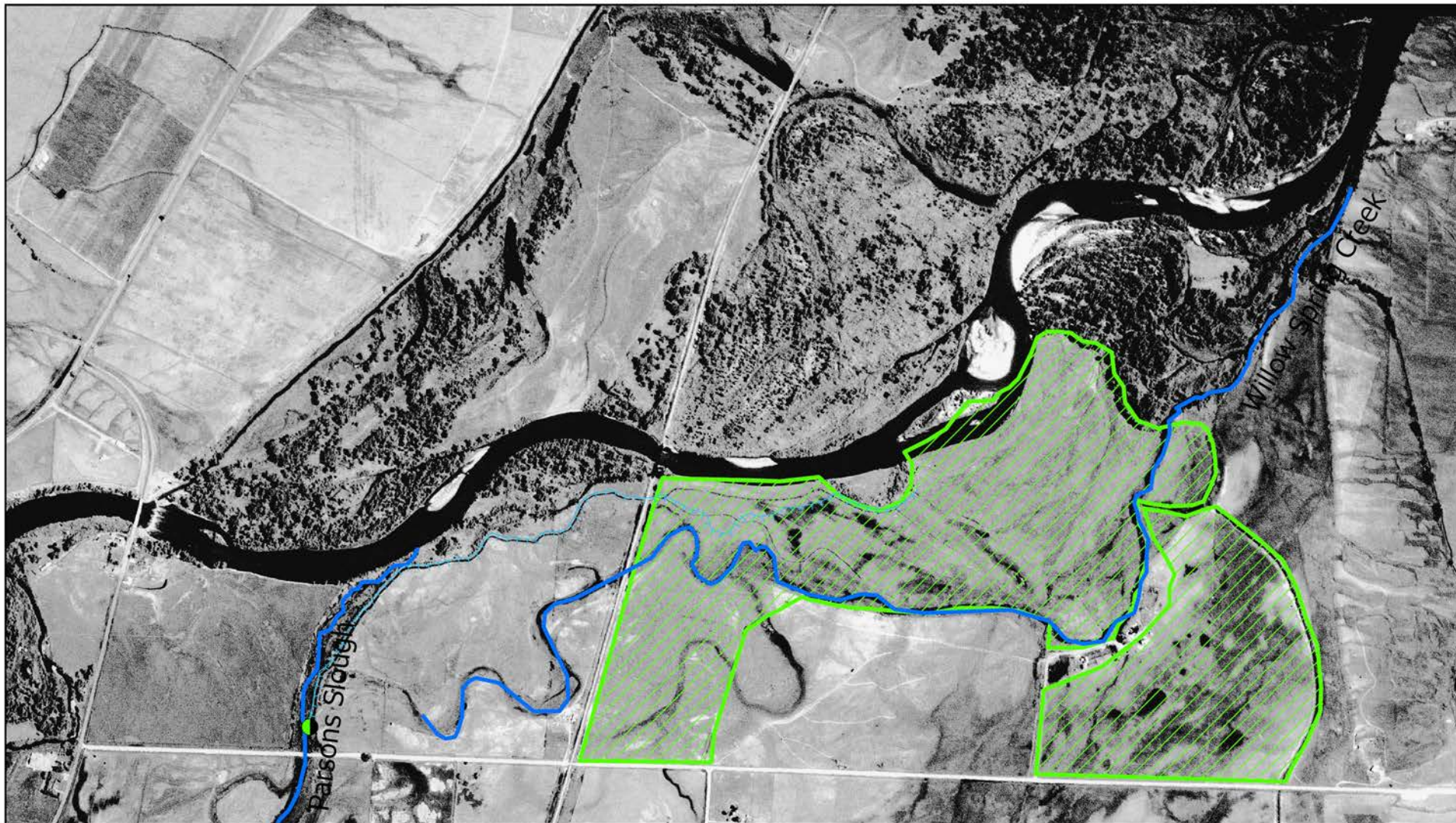
- 41G 197111-00 Historic POD #1
- Ditch
- ▬ 41G 197111-00 Historic POU



8-28-1960 Aerial Photo

- 41G 197111-00 Historic POD #1
- Curtis Ditch
- ▨ 41G 197111-00 Historic POU



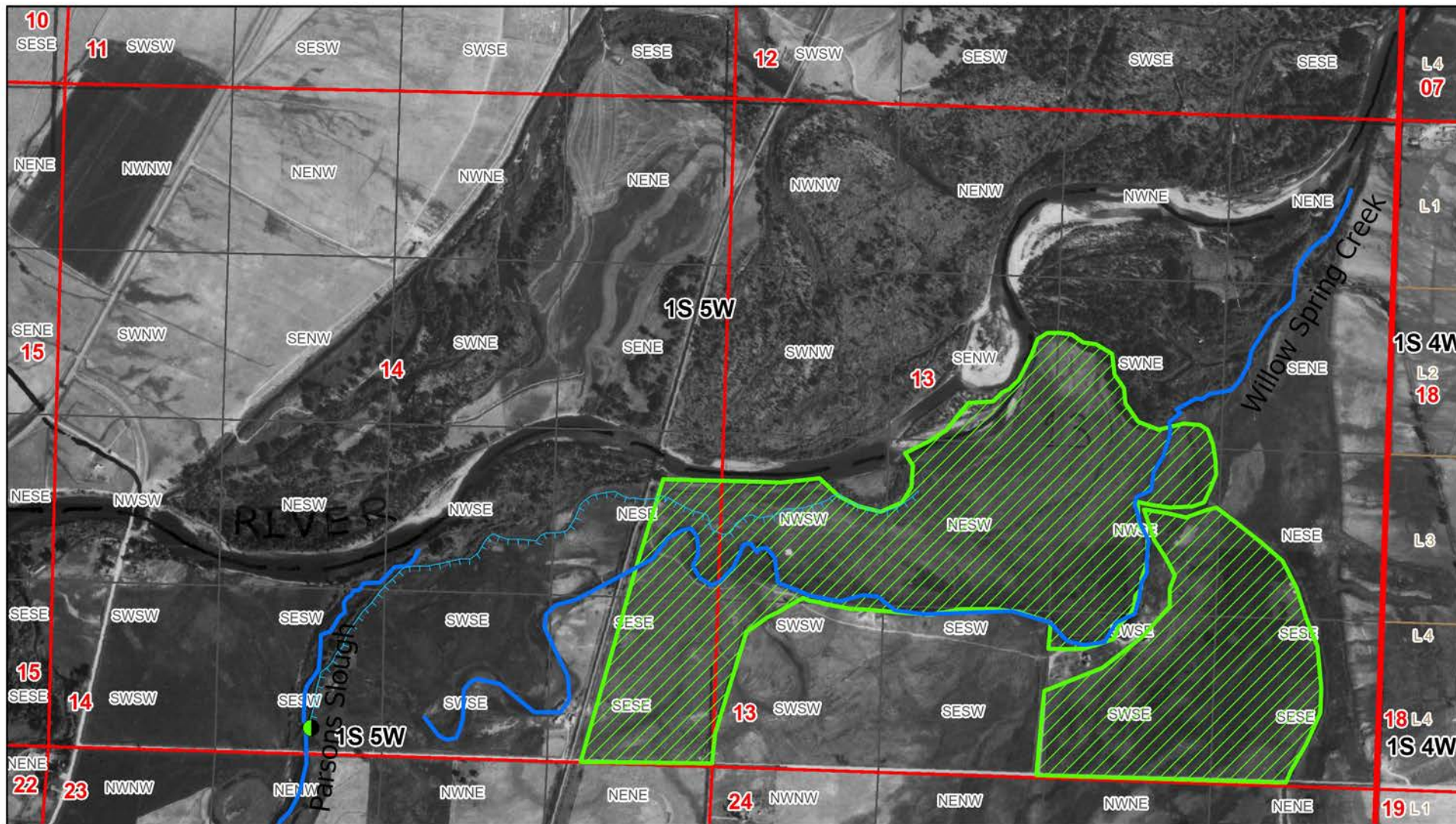


**7-26-1976
Aerial Photo**

 Ditch

 41G 197111-00 Historic POU

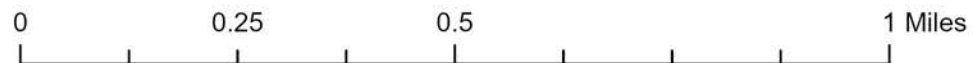
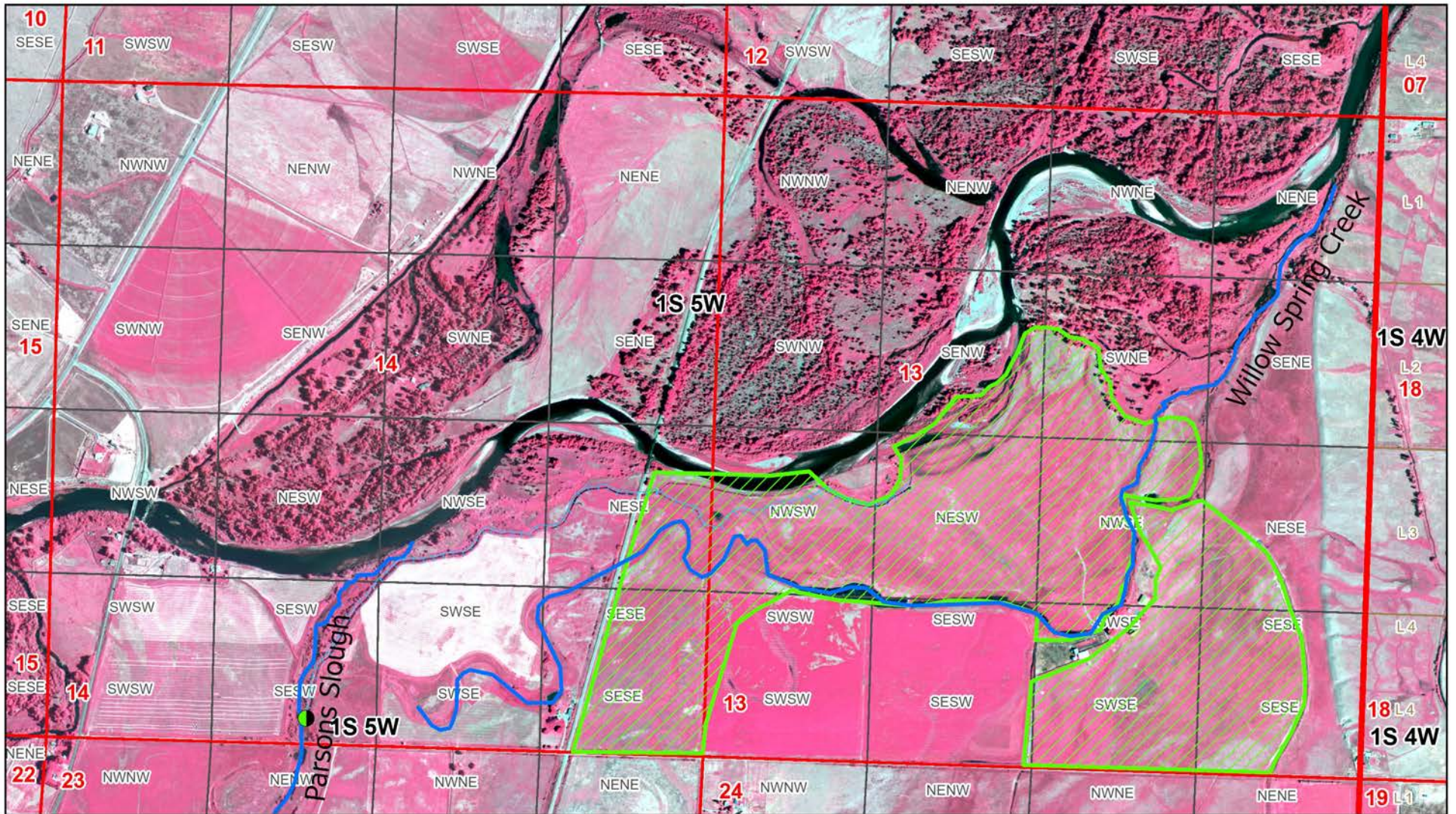
 41G 197111-00 Historic POD



0 0.25 0.5 1 Miles

1979 Aerial Photo

-  Ditch
-  41G 197111-00 Historic POU
-  41G 197111-00 Historic POD



**2005
Aerial Photo**

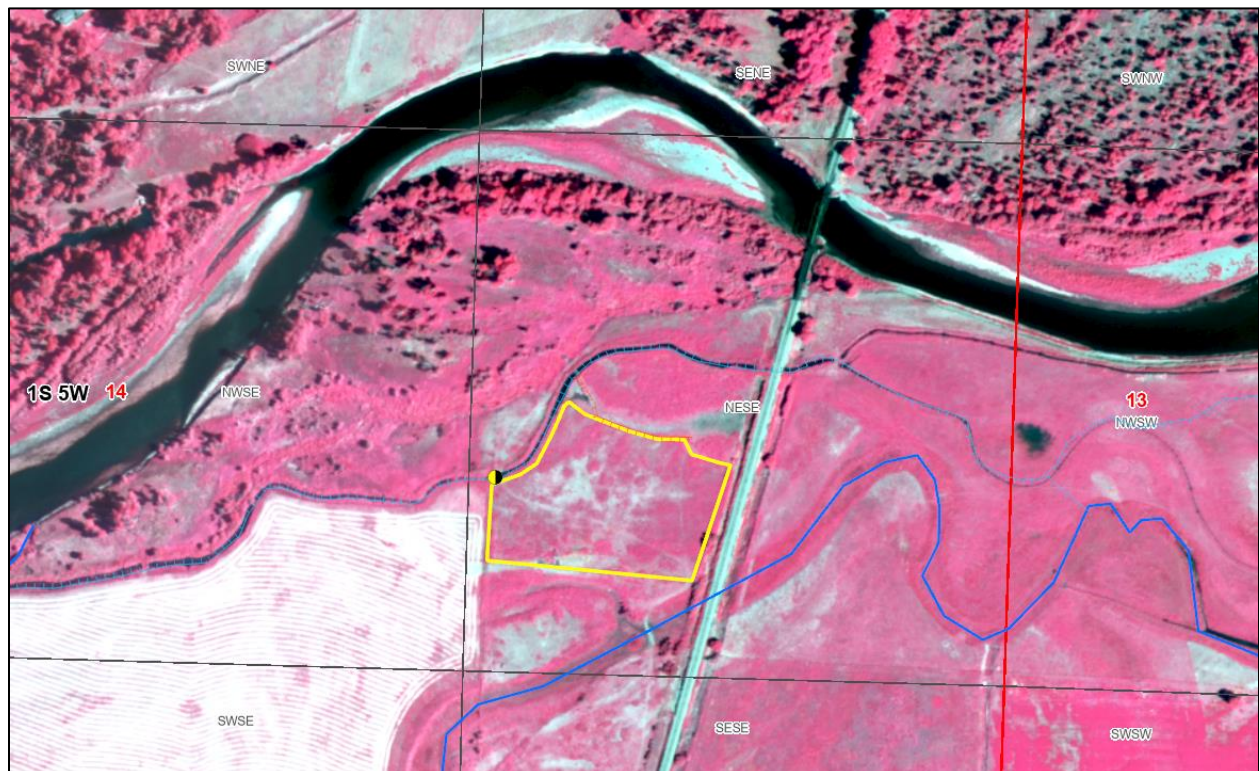
- Ditch
- 41G 197111-00 Historic POU
- 41G 197111-00 Historic POD

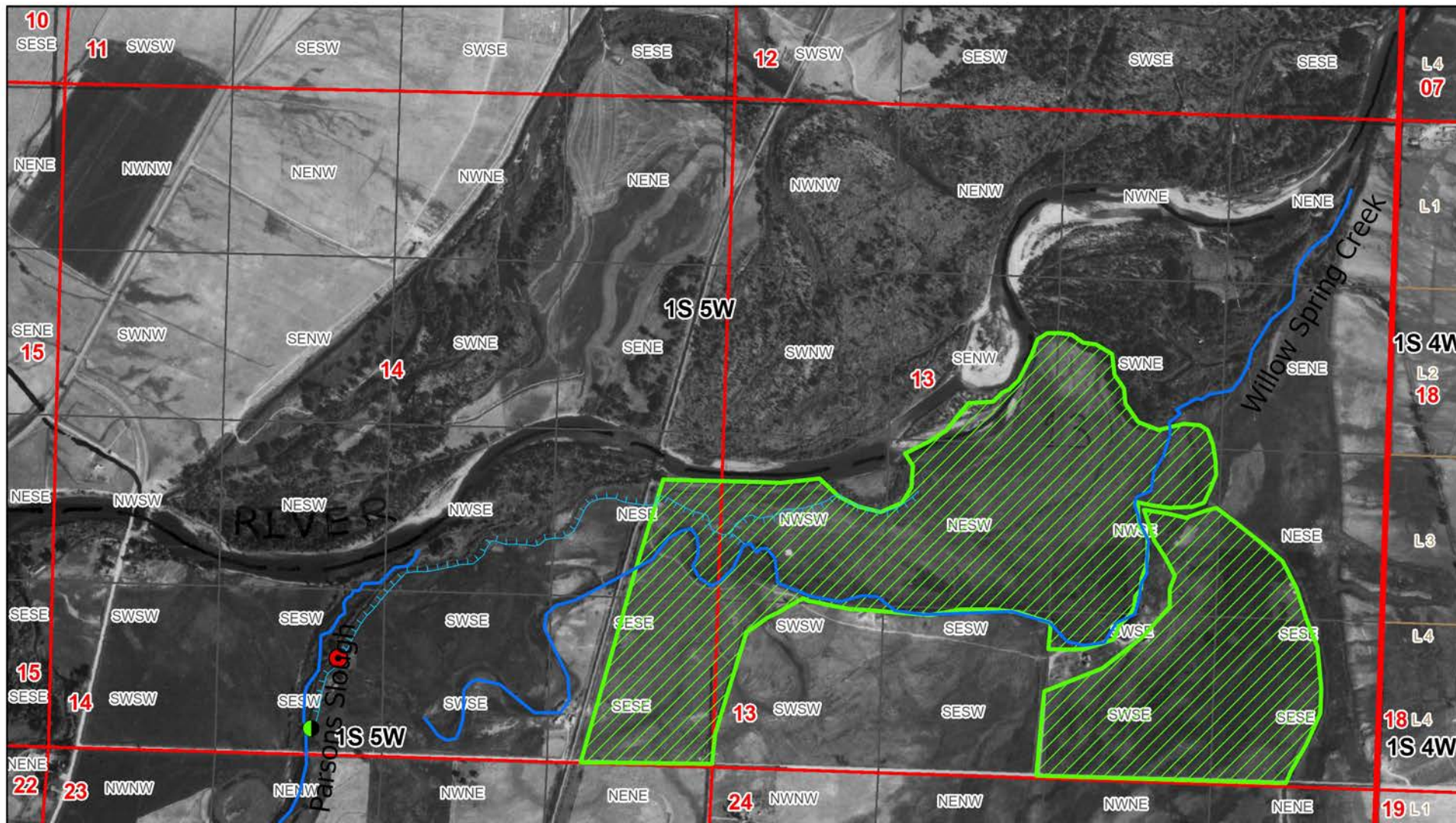
Permit 41G 2262-00

Permit 41G 2262-00 is an unverified permit issued in 1975. Initially the applicant identified the Curtis Ditch as Parsons Slough. This mistake likely occurred because at the time most of the flow in Parsons Slough was always diverted into the Curtis Ditch. This is reflected in Waterloo Quadrangle topographic map based on 1956 aerial photographs and field checked in 1956. Ultimately DNRC corrected this error after an August 12, 1975 field investigation identifying the correct point of diversion. In 2007 FWP completed a project to restore the Parsons Slough channel below the point of diversion and installed diversion structures to better control the flow into the Curtis Ditch.

The permit application describes a pump being placed in the Curtis Ditch to supply water for flood irrigation of 30 acres. This is contradictory to the Notice of Completion that indicates a headgate had been installed with some ditching yet to be completed. A note in the file dated 8-7-1985 seems to indicate that irrigation occurred at that time by backing water up in the ditch at the railroad tracks with water spilling over the banks. This apparently occurred twice a year.

The 2005 aerial photo following seems to show that water may have been diverted by a structure in the ditch into a ditch. The outline in yellow follows what appear to be field boundaries at the time. The yellow outline covers 4 acres. A larger map on the next page shows Permit 41G 2622 in relation to the Curtis Ditch supplying 41G 197111-00. Currently the ongoing sprinkler irrigation is supplied by a pump located where the Curtis Ditch enters adjacent to the place of use.





**Historic Use
Ditch Map
Pre App #121**

- Curtis Ditch measurement point
- 41G 197111-00 Historic POD #1
- Curtis Ditch
- 41G 197111-00 Historic POU

122.d & 122.e
125.e & 125.f

Curtis Ditch
Cross Section

Sta	Depth	HI	Elev
0	0	100	100.00
1	0.2	100	99.80
2	0.6	100	99.40
3	1	100	99.00
4	1.4	100	98.60
5	1.75	100	98.25
6	2.3	100	97.70
7	2.85	100	97.15
8	3.95	100	96.05
9	4.35	100	95.65
10	4.4	100	95.60
11	4.6	100	95.40
12	4.65	100	95.35
13	4.7	100	95.30
14	4.75	100	95.25
15	4.85	100	95.15
16	4.8	100	95.20
17	4.7	100	95.30
18	4.5	100	95.50
19	4.35	100	95.65
20	3.2	100	96.80
21	2.85	100	97.15
22	2.1	100	97.90
23	1.55	100	98.45
24	1.25	100	98.75
25	1.1	100	98.90
26	1.85	100	98.15
27	1.75	100	98.25
28	1.7	100	98.30
29	1.7	100	98.30
30	0.7	100	99.30
35	0	100	100.00

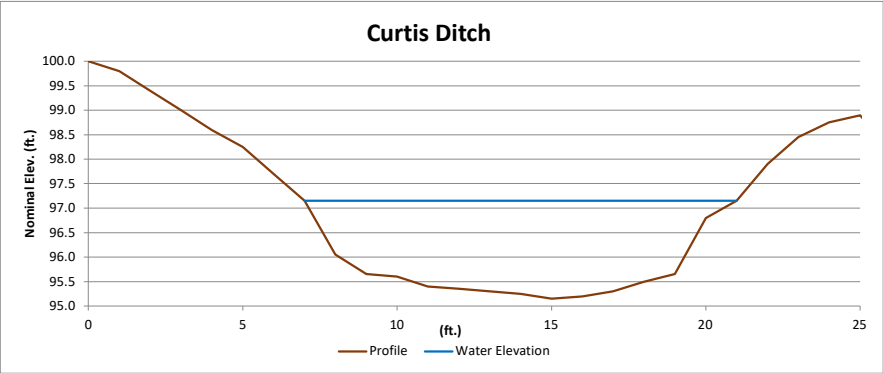


Sta	Depth	HI	Elev	water depth	P _w	Area	water elev
6	2.3	100	97.70				97.15
7	2.85	100	97.15	0.00			97.15
8	3.95	100	96.05	1.10	1.4866069	0.55	97.15
9	4.35	100	95.65	1.50	1.077033	1.3	97.15
10	4.4	100	95.60	1.550	1.0012492	1.525	97.15
11	4.6	100	95.40	1.75	1.0198039	1.65	97.15
12	4.65	100	95.35	1.80	1.0012492	1.775	97.15
13	4.7	100	95.30	1.85	1.0012492	1.825	97.15
14	4.75	100	95.25	1.90	1.0012492	1.875	97.15
15	4.85	100	95.15	2.00	1.0049876	1.95	97.15
16	4.8	100	95.20	1.95	1.0012492	1.975	97.15
17	4.7	100	95.30	1.85	1.0049876	1.9	97.15
18	4.5	100	95.50	1.65	1.0198039	1.75	97.15
19	4.35	100	95.65	1.50	1.0111874	1.575	97.15
20	3.2	100	96.80	0.35	1.5239751	0.925	97.15
21	2.85	100	97.15	0.00	1.059481	0.175	97.15
22	2.1	100	97.90				97.15

total 15.21 20.75 wetted width 14.00

slope= 0.0012
Hydraulic radius= 1.363865
Mannings Equation n= 0.160
V(ft/s)= 0.395674

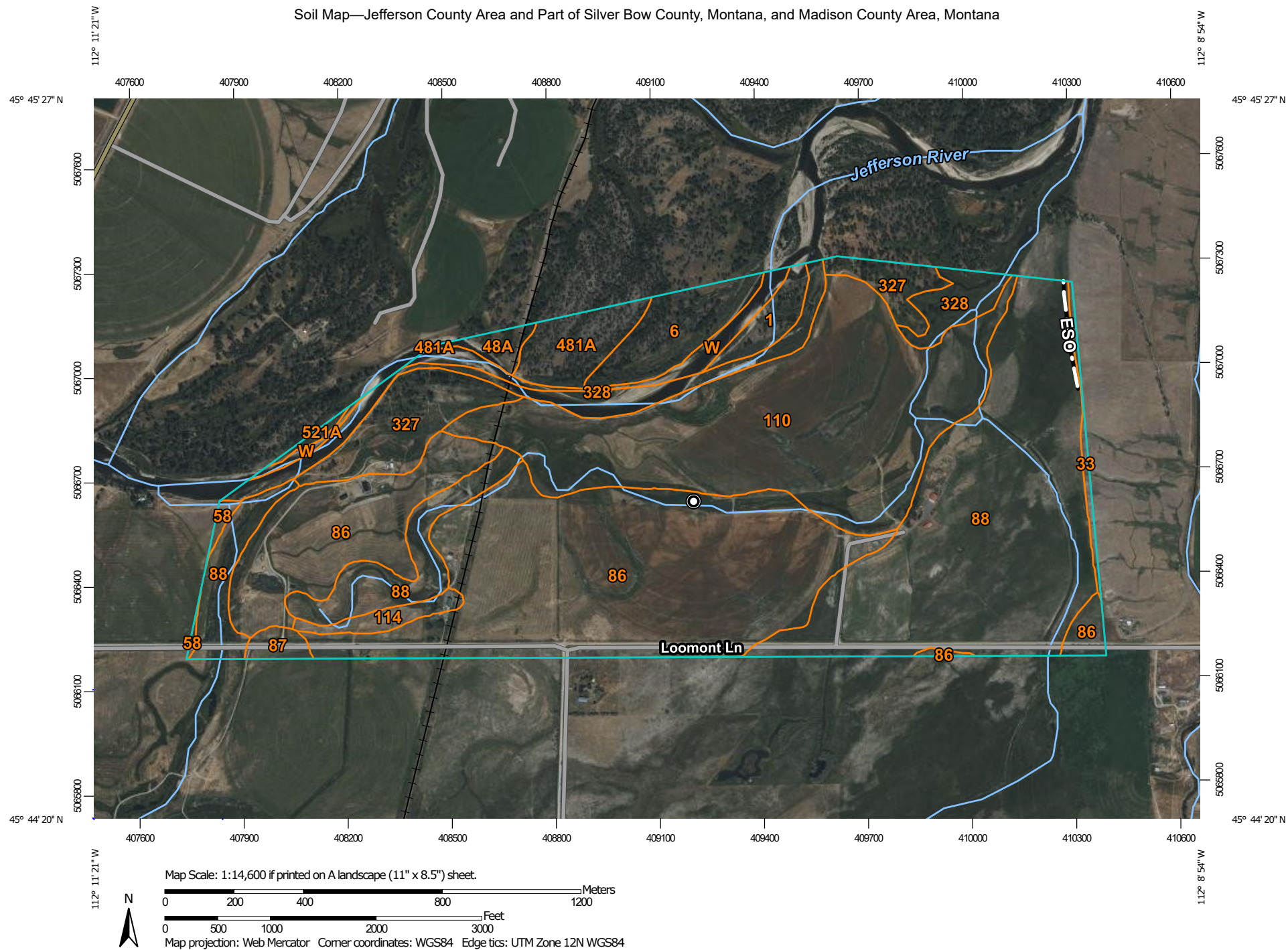
Discharge Q (cfs)= 8.210 Measured flow rate 8.3 cfs



Parson Slough Photos: Parsons Slough channel on left. Ditch entrance on Right. The creek channel opening on left is about 4 ft wide and the ditch opening is about 8 feet wide.



Soil Map—Jefferson County Area and Part of Silver Bow County, Montana, and Madison County Area, Montana



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Unit Polygons

 Soil Map Unit Lines

 Soil Map Unit Points

Special Point Features



Blowout



Borrow Pit



Clay Spot



Closed Depression



Gravel Pit



Gravelly Spot



Landfill



Lava Flow



Marsh or swamp



Mine or Quarry



Miscellaneous Water



Perennial Water



Rock Outcrop



Saline Spot



Sandy Spot



Severely Eroded Spot



Sinkhole



Slide or Slip



Sodic Spot



Spoil Area



Stony Spot



Very Stony Spot



Wet Spot



Other



Special Line Features

Water Features



Streams and Canals

Transportation



Rails



Interstate Highways



US Routes



Major Roads



Local Roads

Background



Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL:

Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Jefferson County Area and Part of Silver Bow County, Montana

Survey Area Data: Version 23, Aug 30, 2022

Soil Survey Area: Madison County Area, Montana

Survey Area Data: Version 25, Aug 26, 2022

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

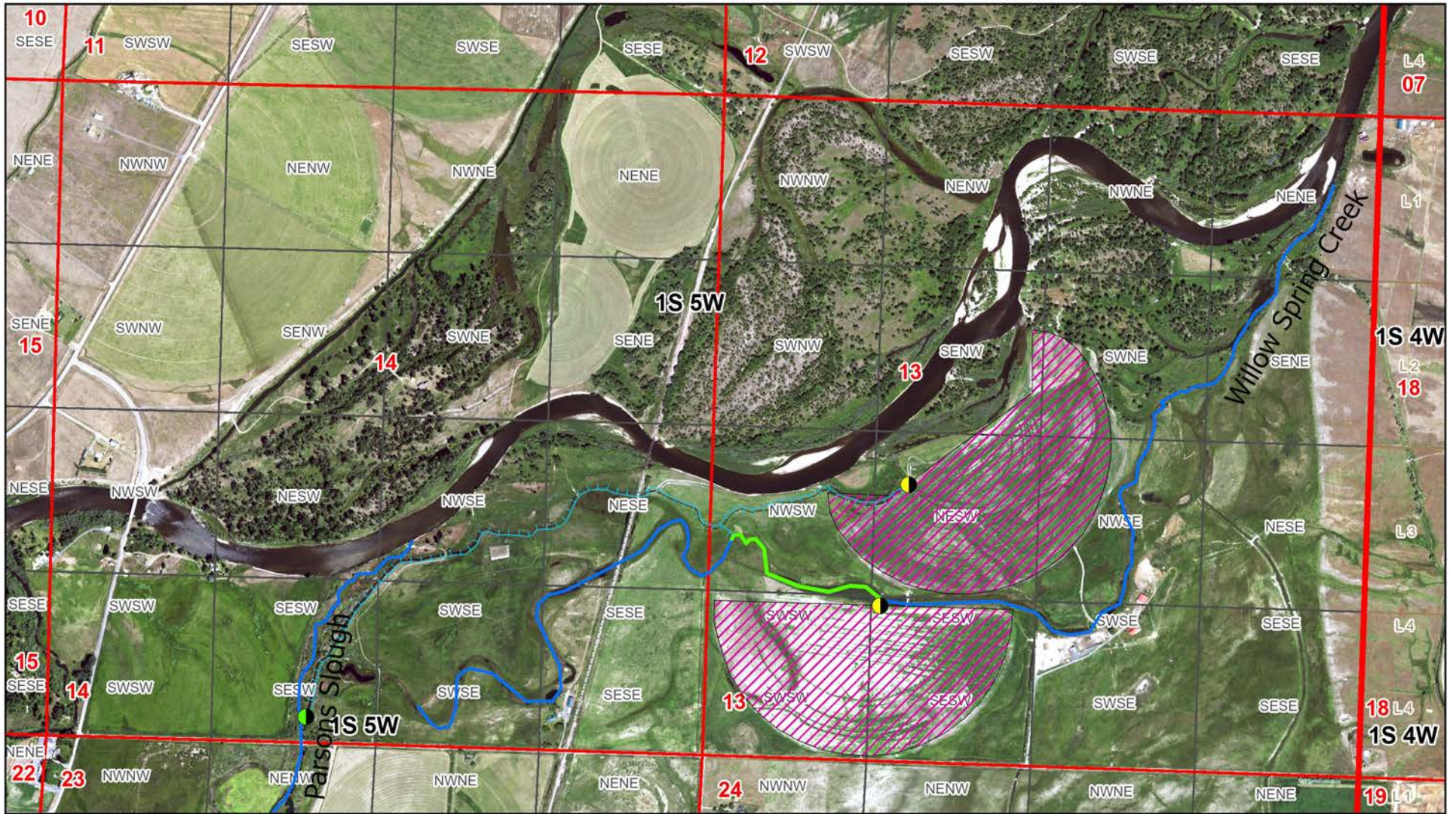
Date(s) aerial images were photographed: Aug 17, 2022—Aug 23, 2022

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Riverwash	7.4	1.2%
6	Wetsand, Cardwell, and Clunton soils, 0 to 8 percent slopes, channeled	17.9	3.0%
48A	Riverrun sandy loam, 0 to 2 percent slopes	4.1	0.7%
481A	Riverrun gravelly sandy loam, 0 to 2 percent slopes	14.1	2.3%
521A	Cardwell-Riverrun complex, 0 to 2 percent slopes	1.2	0.2%
W	Water	11.2	1.8%
Subtotals for Soil Survey Area		55.9	9.2%
Totals for Area of Interest		605.0	100.0%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
33	Crago gravelly loam, cool, 0 to 8 percent slopes	2.7	0.5%
58	Havre loam, cool, 0 to 2 percent slopes	1.6	0.3%
86	Neen silty clay loam, 0 to 2 percent slopes	186.6	30.8%
87	Neen silty clay loam, drained, 0 to 2 percent slopes	3.6	0.6%
88	Neen silty clay loam, wet, 0 to 2 percent slopes	159.2	26.3%
110	Ryell-Rivra complex, cool, 0 to 2 percent slopes	130.2	21.5%
114	Scravo sandy loam, cool, 2 to 8 percent slopes	5.6	0.9%
327	Chaffee, occasionally flooded-Beavrock, rarely flooded, Dillon families, complex 0 to 2 percent slopes	30.5	5.0%
328	Riverrun, frequently ponded family-Riverwash-Water, complex, 0 to 2 percent slopes	29.2	4.8%
Subtotals for Soil Survey Area		549.1	90.8%
Totals for Area of Interest		605.0	100.0%



0 0.25 0.5 1 Miles

Proposed Use Ditch Map Pre App #124

- 41G 197111-00 Historic POD #1
- Secondary Pump Site
- Curtis Ditch
- Natural Carrier

161

attachments

GROUNDWATER/SURFACE-WATER STUDY IN THE UPPER JEFFERSON VALLEY, MONTANA

Modeling the Effects of Changing Irrigation Practices and Increased Residential Development on Low Streamflows

Andrew Bobst, Ali Gebril, and Jenna Dohman

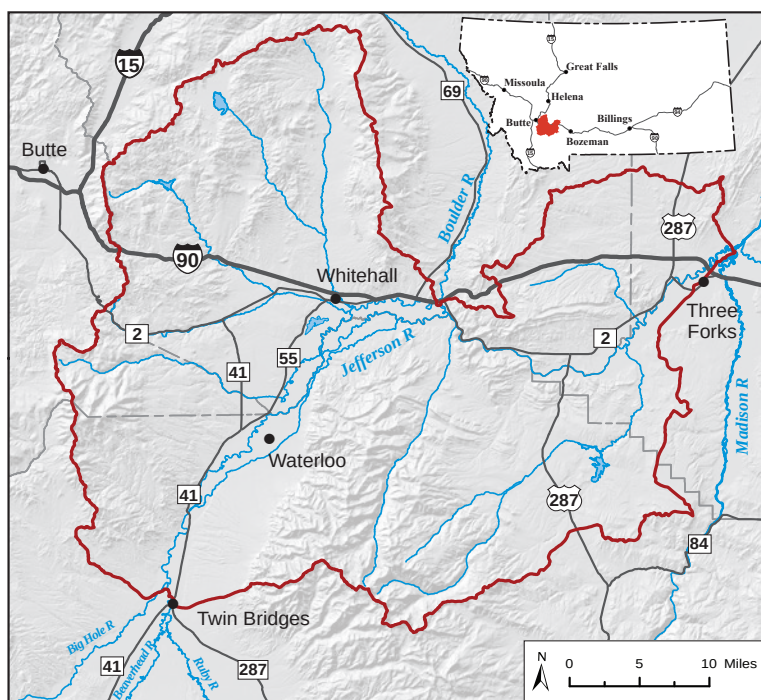


Figure 1. The Upper Jefferson Watershed in southwest Montana.

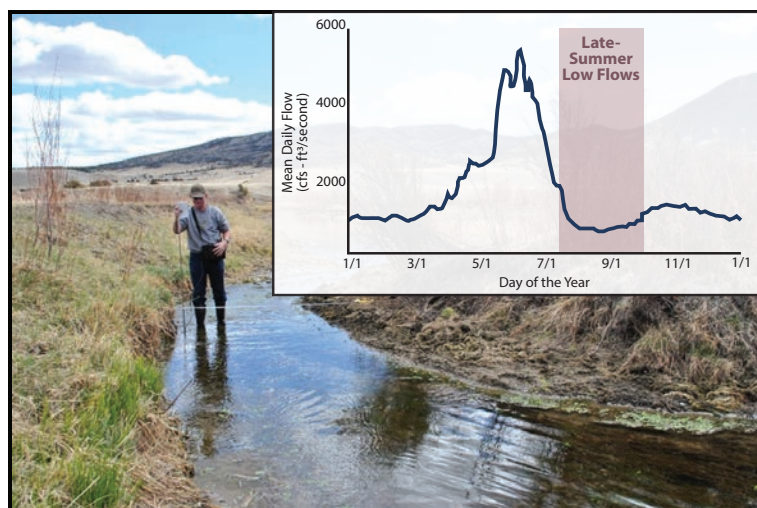


Figure 2. Surface-water monitoring was conducted at 53 locations. Average stream flows on the Jefferson River near Twin Bridges, Montana (USGS gage 06026500) are shown over the period of record 1940–2019. High flows occur in the spring and early summer due to snowmelt and spring rains. Irrigation diversions, evaporation, and plant water use contribute to low flows in the late summer. Photo credit: John Wheaton, MBMG.

INVESTIGATING LOW STREAMFLOWS IN THE UPPER JEFFERSON RIVER

During the late summer, low flows and elevated water temperatures often result in fishing closures on the Jefferson River. The Montana Department of Fish, Wildlife and Parks designated this fishery as “chronically dewatered,” meaning that virtually every year, water levels in the Jefferson River are below what is adequate for fish habitat. Agriculture in the Upper Jefferson Valley also relies on sufficient streamflow and groundwater availability. Groundwater discharge to streams typically occurs year-round, and is often the only source of water to streams during the late-summer low-flow season. As such, having adequate groundwater recharge and storage to sustain river flows during late summer is critical for agriculture and healthy fisheries. Local communities have grown concerned about how current and future land-use practices may affect flow in the Jefferson River.

To address these questions, the Montana Bureau of Mines and Geology Ground Water Investigation Program (GWIP) developed site-specific groundwater models focused on how changing irrigation management activities (such as lining canals or installing pivot systems) and increasing residential development would affect surface flows in the Jefferson River. These models require an understanding of (1) the distribution of hydrogeologic units (the geologic units where groundwater flows) and (2) the groundwater budget (an estimation of the inflows and outflows of the groundwater system). Model simulations were developed based on stakeholder input. Simulations focused on late-summer streamflows, which are characterized by low surface-water flows, high groundwater consumption rates, and high rates of evaporation and plant water use (fig. 2). This pamphlet highlights these findings; for more detail, refer to the “Additional Information” section.

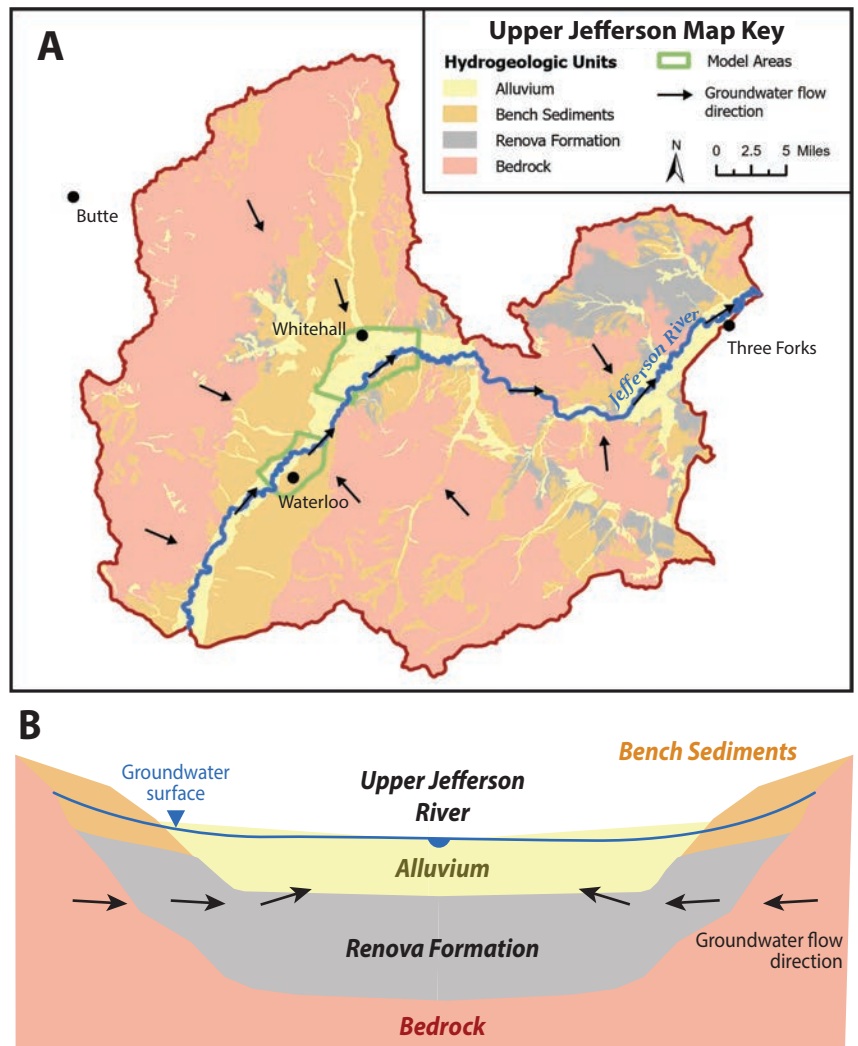
HYDROGEOLOGIC SETTING

The geologic units in the Upper Jefferson Valley were grouped into four hydrogeologic units (fig. 3). Each unit constitutes an aquifer, but they have different properties; for example, sediments such as sand and gravel are more permeable, allowing water to move easily between grains, resulting in higher well yields. Based on these different properties, these aquifers are distinct, but groundwater still flows between them.

Unit	Description	Well Yields
Alluvium	Unconsolidated gravel and sand with some silt and clay	50–100 gpm*
Bench Sediments	Unconsolidated to semi-consolidated sand and gravel with some mudstones	10–50 gpm
Renova Formation	Semi-consolidated mudstones with some sand lenses	10–15 gpm
Bedrock	Consolidated bedrock; water moves through fractures	<10 gpm

*gpm, gallons per minute

Figure 3. (A) Surficial hydrogeologic units in the Upper Jefferson Valley, shown in map view. Groundwater flows through the aquifer system from the mountainous areas toward the Jefferson River. Note that both model areas are located in regions with alluvium and bench sediments, the two most productive units. (B) Idealized cross-section showing how these hydrogeologic units overlie one another.



GROUNDWATER BUDGET COMPONENTS

Groundwater budgets are used to aid in understanding the components of groundwater recharge and discharge, and their relative importance. The components of a groundwater budget are described below (fig. 4). Groundwater budgets were developed for the Waterloo and Whitehall model areas.

Groundwater Recharge	Groundwater Discharge
Groundwater Inflow Water that flows through the sub-surface into the study area	Groundwater Outflow Water that flows through the sub-surface out of the study area
Irrigation Recharge Excess precipitation or irrigation water that is not used by crops and infiltrates to groundwater	Well Withdrawals Groundwater pumped from wells
Surface-Water Recharge Water that flows to groundwater from surface water (e.g., infiltration)	Discharge to Surface Water Water that flows to surface water from groundwater (e.g., springs)
Canal Leakage Water that infiltrates from unlined canals to the subsurface	Riparian Evapotranspiration Evaporation and water use by plants

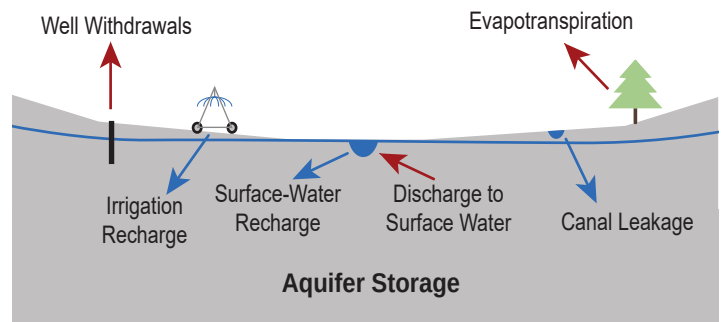


Figure 4. Groundwater recharge pathways → send water into the aquifer and increase aquifer storage. Groundwater discharge pathways → send water out of the aquifer, decreasing aquifer storage.

CHANGING IRRIGATION PRACTICES

In Waterloo (fig. 3), stakeholders were curious about how different irrigation practices may affect flows in the Jefferson River. The groundwater flow model simulates how lining irrigation canals, switching from flood to center-pivot irrigation, and employing split-season irrigation would affect late-summer streamflows in the Jefferson River (fig. 5). Split-season irrigation is a technique that uses flood irrigation rates when irrigation water is plentiful, and uses center-pivot irrigation rates when water is scarce.

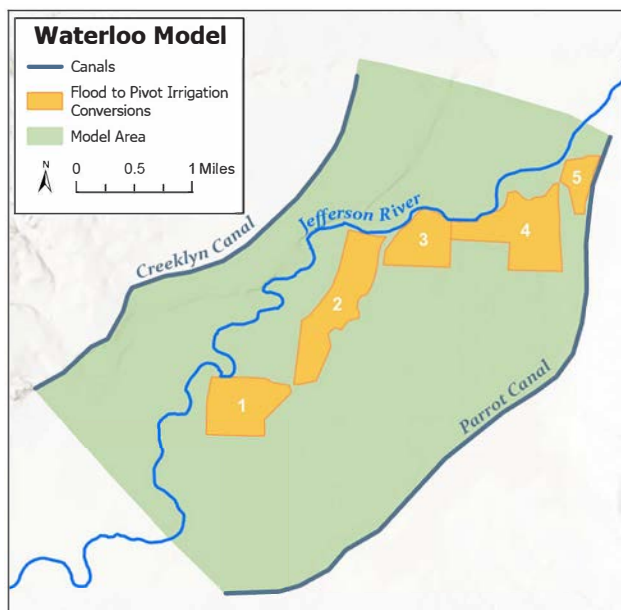


Figure 5. The effects of lining the Parrot and Creeoklyn Canals and changing irrigation practices were modeled. Photo credits at right: Ginette Abdo, MBMG, lined canal in Lower Beaverhead; Kirk Waren, MBMG, flood irrigation in Stevensville, MT.

Lined Irrigation Canals

Lining Parrot and Creeoklyn Canals reduced simulated late-summer flows in the Jefferson River by about 17 cubic feet per second, or cfs (2.4%). This indicates that water from these canals recharges groundwater that later discharges into the river.

Flood vs. Center-Pivot Irrigation

Converting five flood-irrigated fields (fig. 5) to center-pivots reduced simulated late-summer flows in the Jefferson River by 13 cfs (1.8%). This demonstrates that more recharge occurs from flood irrigation than from center-pivots.

Split-Season Irrigation

Simulated split-season irrigation was more effective when applied to fields further from the river. The increased distance from the river resulted in excess applied irrigation water discharging to the river during late summer.



INCREASED RESIDENTIAL DEVELOPMENT

In Whitehall (fig. 3), stakeholders were concerned about residential development. The groundwater flow model simulates how late-summer streamflows in the Jefferson River would be affected by groundwater pumping from different aquifers, changes in housing density, and converting irrigated vs. non-irrigated areas to housing developments (fig. 6).

Shallow vs. Deep Wells

Simulations of the same number of wells in the shallow alluvium compared to wells in the deeper Renova Formation showed late-summer streamflow depletion was nearly identical. This suggests that measurable increases to late-summer flows would not be gained by installing deeper wells.

Housing Density

Simulated reductions in late-summer streamflow were directly proportional to the total pumping rate from all wells. This demonstrates that it is the total amount of groundwater pumped from wells, not the number of wells that water is pumped from, that affects discharge to streams.

Irrigated vs. Non-Irrigated Development

Development in irrigated areas reduced simulated late-summer streamflows 12x more than development in non-irrigated areas. In addition to adding groundwater pumping, development in irrigated areas reduced irrigation recharge to the aquifer.

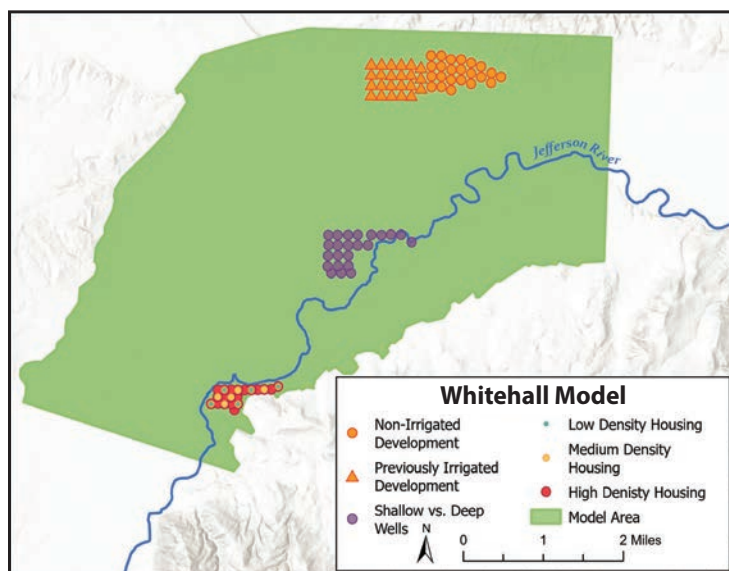


Figure 6. Multiple scenarios simulating residential development were modeled, focusing on well depth, housing density, and development of irrigated and non-irrigated lands.

IRRIGATION RECHARGE IS KEY FOR MAINTAINING LATE-SUMMER STREAMFLOWS IN THE UPPER JEFFERSON RIVER

◇ Flood-irrigated fields and unlined canals provide substantial groundwater recharge.

Converting irrigated lands to almost any other use, or lining canals, will decrease groundwater recharge, seasonal groundwater storage, and late-summer streamflows.

◇ Split-season irrigation may be useful for increasing or maintaining late-summer streamflows.

The application of excess water early in the irrigation season, while water is abundant, and using more efficient irrigation methods when water is scarce, can help maintain late-summer flows. The site-specific setting of each field, its soil types, and effects on ranch operations should be evaluated before applying these techniques.

◇ Adding wells through residential development has less of an effect on streamflows than changing irrigation practices.

However, if development occurs on previously irrigated fields, the reduction in groundwater recharge is likely to have a larger effect on streamflows.

ADDITIONAL INFORMATION

For more information on the research, models, and interpretations conducted by GWIP in the Upper Jefferson Valley, refer to the following reports:

Bobst, A., and Gebril, A., 2021, Hydrogeologic investigation of the Upper Jefferson Valley–Montana: Interpretive report: MBMG Report of Investigation 28, 130 p.

Gebriel, A., and Bobst, A., 2021, Hydraulic investigation of the Upper Jefferson River Valley: Waterloo modeling report: MBMG Report of Investigation 29, 101 p.

Gebriel, A., and Bobst, A., 2020, Hydraulic investigation of the Upper Jefferson River Valley: Whitehall modeling report: MBMG Report of Investigation 27, 93 p.

Bobst, A., and Gebriel, A., 2020, Upper Jefferson aquifer tests: MBMG Open-File Report 727, 52 p.

FIGURE REFERENCES

Center Pivot, United States Geologic Survey, available at <https://www.usgs.gov/media/images/center-pivot-irrigation-system-arizona-usa> [Accessed Sept 2022].



Photo credit: Ali Gebriel, MBMG, Jefferson River.

The **Ground Water Investigation Program (GWIP)** encompasses site-specific studies of groundwater resource concerns that support statewide and local decisions regarding water. The Montana Legislature established GWIP in 2009, with a design that allows local communities or other stakeholders to nominate projects for study. The interagency Ground Water Assessment Steering Committee ranks and prioritizes project nominations every 3 years. MBMG hydrogeologists bring data-driven scientific analyses that address important questions to Montana's citizens, business communities, and agricultural and industrial/commercial stakeholders.

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Spring 2015

A Hydrogeologic Evaluation of the Waterloo Area in the Upper Jefferson River Valley, Montana

Nicole Brancheau

Montana Tech of the University of Montana

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A HYDROGEOLOGIC EVALUATION OF THE WATERLOO AREA IN THE
UPPER JEFFERSON RIVER VALLEY, MONTANA

by

Nicole L. Brancheau

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science in General Engineering:
Civil Engineering Option

Montana Tech

2015



Abstract

The Upper Jefferson River is one of the most dewatered rivers in Montana. The river exists in an intermontane basin filled with sediment transported from the Highland Mountains to the west, the Tobacco Root Mountains to the east, and the Jefferson River from the south. The Upper Jefferson River Valley is highly dependent on the Jefferson River as the main industry in the valley is agriculture. A majority of the valley is irrigated and used to grow crops, and a good portion is also used for cattle grazing. The residents of the Upper Jefferson River Valley use the aquifer as the main source of potable water. The Jefferson River is also widely used for recreation.

This study took place in the Waterloo area of the Upper Jefferson River Valley, approximately 20 miles south of Whitehall, Montana. The Waterloo area provides significant groundwater base flow to the Jefferson River, which is particularly important during the late irrigation season when the river is severely dewatered, and elevated surface-water temperatures occur, creating irrigation water shortages and poor trout habitat. This area contains two spring-fed streams, Willow Springs and Parson's Slough, which discharge to the Jefferson River providing cool water in the late season as well as providing the most important trout spawning habitat in the valley. The area is bordered on both the east and west by irrigation ditches, and about 60% of the study area is irrigated. Tile drains were installed in the study area in close proximity to Parsons Slough causing some concern by neighboring residents.

This study evaluated relationships between surface water, groundwater, and irrigation practices so that water managers and others can make informed management decisions about the Upper Jefferson River. Data was collected via a network of groundwater wells and surface-water sites. Additionally, water-quality samples were taken and an aquifer test was conducted to determine aquifer properties. The field data were analyzed and a groundwater budget was created in order to evaluate the aquifer.

Results of the groundwater budget show that seepage from the irrigation canals and irrigation recharge have the biggest influence on recharge of the aquifer. There is significant groundwater outflow from the aquifer in the spring-fed streams as well as discharge to the Jefferson River. In comparing previous study results to this study's results, there is no evidence of the water table decreasing due to irrigation practice changes or tile drain installation. However, given the amount of recharge irrigation practices contribute to the aquifer, if significant changes were made, they may affect groundwater elevations. Also lining the irrigation ditches would have a significant impact on the aquifer, as the amount of seepage would be greatly reduced.

Keywords: hydrogeology, groundwater budget, Waterloo, Jefferson River, Montana

Dedication

To my loving husband Ted. Without your immense encouragement and support I could not have completed this graduate degree.

Acknowledgements

Thank you to the Montana Bureau of Mines and Geology for providing the opportunity to work on the Upper Jefferson River Valley groundwater investigation project. Particularly, thank you to Andy Bobst, Ginette Abdo, Corey Swisher, and the employees in the Groundwater Investigation Program.

Thank you to Butch Gerbrandt for serving as my graduate advisor and chair of my thesis committee. Thank you to Andy Bobst and Glenn Shaw for serving as committee members as well.

I am grateful to the General Engineering Department for their financial support, without which I could not have begun my graduate degree.

Thank you to Dean Hunt and his family for their overwhelming kindness and acceptance of this project. Dean provided a wealth of information about the area and went above and beyond to help, as well as providing access to his land.

Thank you to my parents, Jim and Beth, for their unrelenting support throughout my entire life in every endeavor I undertake.

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1. Introduction

The Jefferson River is one of the most critically dewatered rivers in Montana, and as such has been subject to numerous closures over the years (JRW, 2013). Severe dewatering and elevated temperatures typically occur during the irrigation season, causing irrigation water shortages and trout population declines during drought years. By studying the water resources in the Upper Jefferson River valley, more informed decisions can be made toward future development and conservation efforts. It is necessary to understand the interaction between surface water and groundwater in this valley in order to make informed decisions and manage this valuable resource properly.

1.1. Background

The Jefferson River begins at the confluence of the Beaverhead, Big Hole and Ruby Rivers near Twin Bridges, Montana. A critical area of the Upper Jefferson River Valley is the Waterloo area. The area, as outlined in Figure 1 below, begins just north of the Parrot Ditch diversion and ends just north of the Jefferson Canal Diversion. The study area is bordered on the east by the Tobacco Root Mountains and on the west by the Highland Mountains.

The major tributary to the Jefferson River within the Waterloo study area is Fish Creek. There are three major irrigation canals which divert water from the Upper Jefferson River: the Parrot Ditch, Jefferson Canal, and Creeklyn Ditch. Other significant water features in the study area include Parson's Slough and Willow Springs.

The main water use in the Upper Jefferson River Valley is agriculture. The valley is heavily irrigated during the summer months when ranchers are growing and cutting hay. The entire valley is reliant on the aquifer as a source of potable water. There is also an important sport fishing industry in the valley.

The groundwater/surface water interactions in the Waterloo area are complex. There is a balance between the Jefferson River, the alluvial aquifer, natural springs and irrigation practices. Parson's Slough and Willow Springs are naturally occurring spring fed creeks in the Waterloo area. These creeks feed into the Jefferson River. The spring fed creeks are an important source of recharge to the Jefferson River during low flows which are typical during the late summer months when temperatures are high and irrigation is at its peak. The spring fed creeks provide cool groundwater when the river temperatures are warmer during these times. Willow Springs and Parsons Slough also provide a very important trout spawning habitat.

In Parson's Slough recent stream remediation work was done to enhance trout spawning habitat. Tile drains were installed with the purpose of providing more water to the stream. Deeper pools were also constructed in the stream. The drains also serve the purpose of draining excess water from the field they were installed in. The presence of these tile drains has caused some concern among neighboring landowners due to the effect they may have on groundwater levels.

All three major irrigation canals (Creeklyn Ditch, Parrot Ditch, and the Jefferson Canal) are diverted from the Jefferson River either below or in the Waterloo study area. It is believed that irrigation in the area is an important source of recharge, and it becomes increasingly significant during critical low flow periods (typically from July to September; WET, 2006). There are also four ephemeral streams in the study area: Dry Boulder Creek, Beall Creek, Spring Creek, and Mill Creek. These creeks originate in the Tobacco Root Mountains and are diverted for irrigation. On the rare occasion that all the water in the ephemeral creeks is not used, they discharge to the Parrot Ditch.

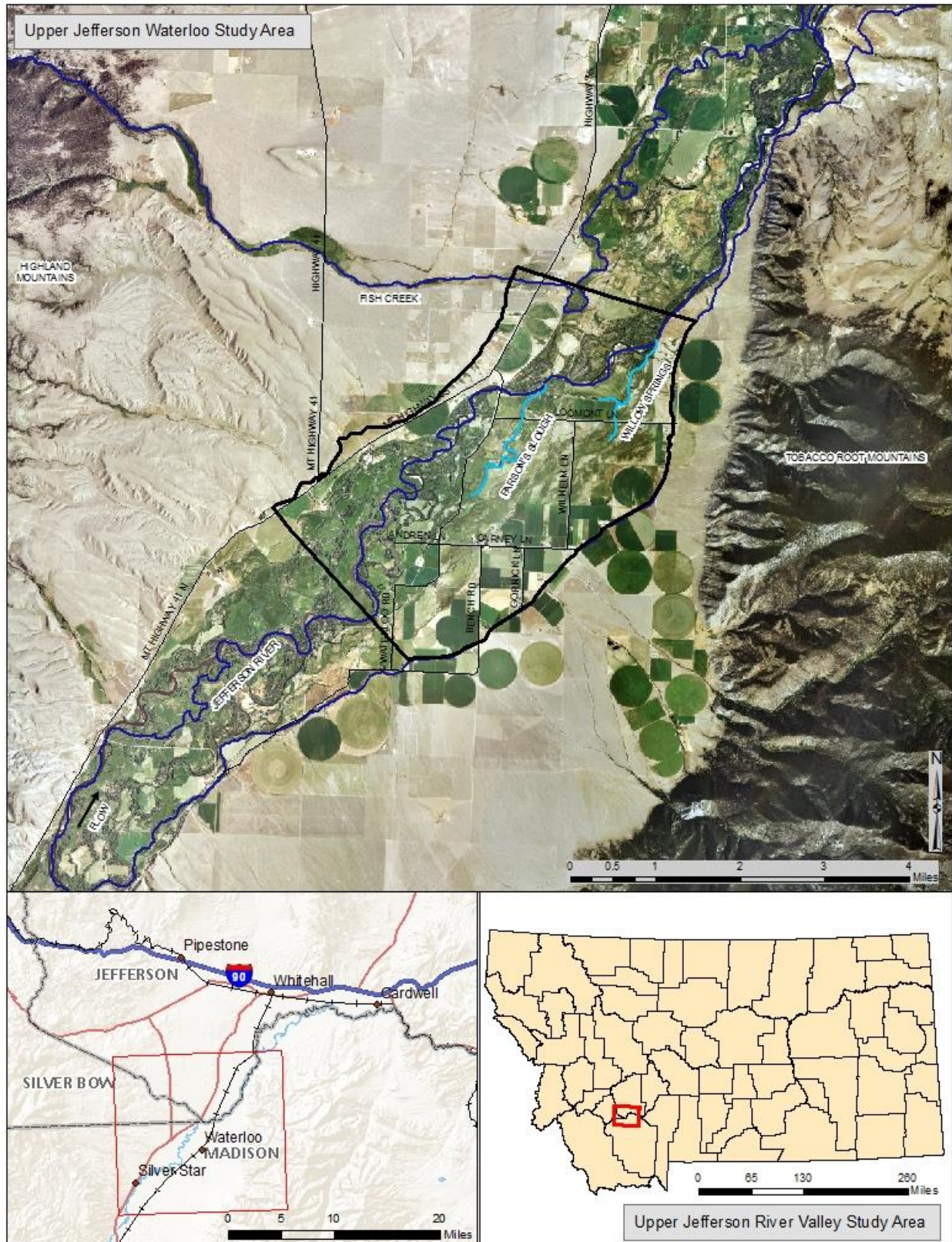


Figure 1. Waterloo Area Location Map

1.2. Purpose and Scope

The purpose of this project is to better understand the relationship between surface and groundwater with regard to irrigation in the Waterloo area. Since groundwater inputs sustain the Jefferson River during drought years, it is important to understand how changing conditions will affect the hydrogeological system of Waterloo. The spring fed creeks are the largest trout spawning habitat contributing to trout populations in the Jefferson River, making it an important study to the ecological system as well. The main focus of this study was to understand the link between irrigation practices and groundwater, and to determine the effects of the new tile drains.

1.3. Study Area Overview

1.3.1. Physiography

The Waterloo area is located in southwest Montana in the Upper Jefferson River Valley near Silver Star, approximately 20 miles south of Whitehall and 10 miles north of Twin Bridges. The average annual flow at the Twin Bridges United States Geological Survey (USGS) gaging station 06026500 between 1941 and 2014 was 1,107 cubic feet per second (cfs). The average annual peak flow is 9,467 cfs with the lowest mean monthly flow of 770 cfs in August.

The Waterloo study area is approximately 12 square miles. This area provides significant groundwater base flow to the Jefferson River, which is particularly important during the late irrigation season when the river is severely dewatered, and elevated surface-water temperatures typically occur. The lowest flows typically occur during the month of August with a mean monthly flow of 399 cfs measured at the USGS gaging station 06027600 on the Jefferson River near Parsons Bridge (Silver Star, MT). The lowest recorded monthly flow was in 2006 with a mean monthly flow of only 50.6 cfs. This gaging station lies in the central region of the Waterloo study area.

The two spring fed creeks, Willow Springs and Parsons Slough, are the main source of surface water contribution to the Jefferson River within the Waterloo study area and carry an average of about 20 cfs. The Kurnow Ditch, which is an irrigation ditch blow off used to divert excess water from the Parrot Ditch, also discharges to the Jefferson River in the study area. The Parrot Ditch is the largest irrigation ditch, which runs almost the entire length of the Upper Jefferson Valley. The Parrot Ditch is diverted from the Jefferson River approximately 7 miles south of the southern border of the study area and forms the western boundary of the Waterloo Study area. The Creeklyn Ditch is diverted from the Jefferson River just south of the Parrot diversion near Hell's Canyon and forms the eastern side of the study area. The Jefferson Canal is diverted from the Jefferson River within the study area just upstream of the Parsons Bridge gaging station. The MBMG monitoring site Jefferson River at Silver Star is used as the southern boundary surface water inflow into the study area, with the MBMG monitoring site Jefferson River at Corbett's used for the northern boundary surface water outflow from the study area (Figure 8).

1.3.2. Geologic Framework

Understanding the fluvial geomorphology of the valley is an important factor in understanding the groundwater flow in the aquifer. The Upper Jefferson valley is an intermontane basin filled with sediment transported from the Highland Mountains to the west, the Tobacco Root Mountains to the east, and the Jefferson River from the south. The Tobacco Root Range is formed mainly of Precambrian basement rock and a large granite batholith (Alt & Hyndman, 1986). The east side of the valley is covered by middle Pleistocene or younger alluvial fan deposits (Vuke et al., 2004). There is also an alluvial fan on the west side near the mouth of Fish Creek with large boulders believed to be the result of glacial outburst flooding.

The seismically active valley contains numerous faults including the Silver Star Fault and the Waterloo Fault. The thickness of the basin fill over the basement high has been estimated at varying depths ranging from 600 to 3000 meters (Vuke et al., 2004). The depth to the bottom of the Jefferson Basin is estimated to change from sea level near Dry Boulder Canyon over the basement high to 3,000 feet near Hell's Canyon which is north of the horst. The sudden change is attributed to the Silver Star fault, which is a northwest-striking fault bounding the north side of the basement high and down-dropped to the northeast.

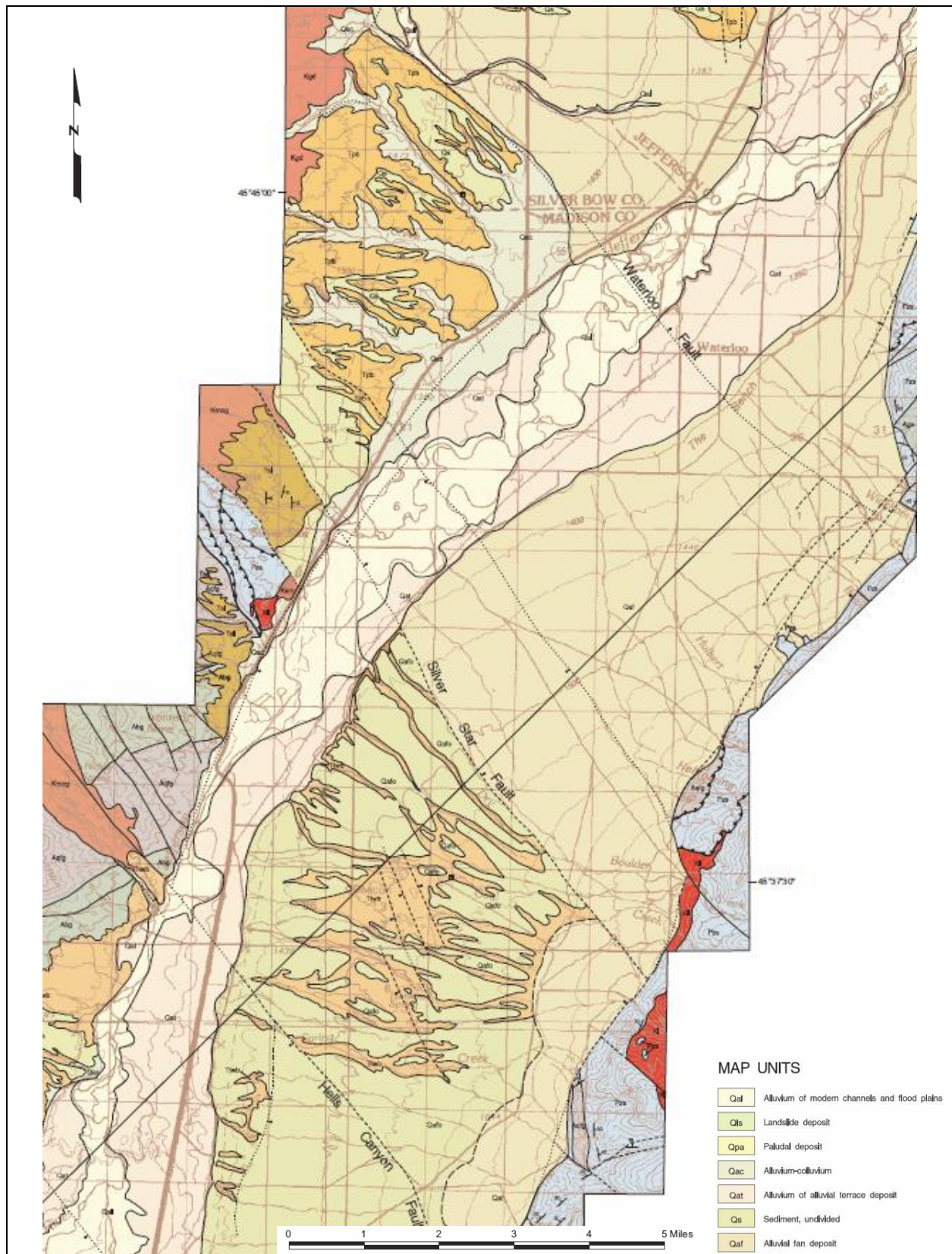


Figure 2. Geologic Map of the Upper Jefferson Valley (Map from Vuke et al., 2004)

1.3.3. Climate

Two climate stations are located near the study area in the Upper Jefferson valley. AgriMet station JVWM (Jefferson Valley, MT) is located approximately 6.5 miles southwest of Whitehall, Montana ($45^{\circ} 47' 52''$, $112^{\circ} 09' 55''$) at an elevation of 4,415 feet. National Oceanic and Atmospheric Administration (NOAA) climate station USC00248430 is located near Twin Bridges approximately 12 miles southwest of the Waterloo study area ($45^{\circ} 32' 49.9194''$, $-112^{\circ} 19' 33.9594''$) at an elevation of 4,625 feet.

Additionally, 30 year normal precipitation data were obtained from Oregon State's Parameter-Elevation Regressions on Independent Slopes Model (PRISM). The current PRISM normal data are calculated from the most recent three full decades, 1981-2010. The average annual precipitation within the Waterloo study area is 10 inches. The wettest month of water year 2014 within the study area was June, with a total of 1.7 inches. The driest month of water year 2014 was November with a total of 0.18 inches (Agrimet station JVWM). The bordering mountains average 18 to 19 inches per year. The Highland mountains to the west receive as much as 32 inches per year while the Tobacco Root Mountains to the east receive as much as 42 inches of precipitation per year.

1.3.4. Land Use

The majority of the land, about 60%, within the Waterloo area is used for irrigation and is flood, pivot, or sprinkler irrigated. Alfalfa, hay and natural grass make up the majority of what is grown in the valley. Of the irrigated land, approximately 44% of the area is flood irrigated, and 56% is pivot or sprinkler irrigated. Most of the irrigated fields use surface water (the irrigation ditches) but there are three irrigation wells within the study area that pump water from the

aquifer. There are approximately 110 residential wells within the study area according to the GWIC data base. A significant amount of the area is also used for cattle grazing.

2. Previous Studies

2.1. Water Environmental Technologies

Water Environmental Technologies previously performed a study to define the groundwater/surface water interaction of the Waterloo Area in 2006 (WET, 2006). WET collected data from the end of the irrigation season in 2004 through the irrigation season in 2005. For their data analysis WET organized the data into three seasons: pre-irrigation, mid-irrigation, and late irrigation. A pump test was also completed within the study area to assist in defining geologic properties of the aquifer.

WET used a groundwater monitoring network consisting of 13 private wells and 22 piezometers to collect monthly groundwater elevation data. Water quality data was also collected and analyzed. A surface water network consisting of six surface water sites equipped with a staff gauge and aquarod, as well as five additional sites with staff gauges were used to monitor discharge on the Jefferson River, Parrot Ditch, Willow Springs and Parson's Slough. The ephemeral tributaries (Dry Boulder Creek, Beall Creek, Spring Creek, and Mill Creek) in the Tobacco Root Mountains were also monitored periodically for discharge.

An aquifer test was performed in the alluvial aquifer in the study area in order to determine aquifer properties such as transmissivity and storativity. From the aquifer test data a hydraulic conductivity of 634 feet per day was estimated for the alluvial aquifer, however no data on the aquifer test were made available for this study.

WET collected water quality data from various wells. The samples were analyzed for pH, conductivity, dissolved oxygen and total dissolved solids. Lab analyses were for alkalinity, sulfate, bicarbonate, carbonate, chloride, hardness, nitrogen, calcium, magnesium, potassium, sodium and iron.

WET evaluated their data based on pre-irrigation, mid-irrigation, and late irrigation seasons. Methods used to analyze the data include groundwater elevation and temperature contour maps, precipitation and irrigation timing comparisons, a conceptual water budget, and water quality analysis. From the analysis a conceptual map was created to visualize groundwater and surface water interaction in the Waterloo Area.

Contour maps of groundwater elevations display groundwater flow parallel to the Jefferson River flowing from the southwest to the northeast (downstream). The majority of groundwater discharge to the Jefferson River occurs in the lower reach of the study area where the valley width decreases. Seasonal groundwater elevation fluctuations varied from 21 feet to 1 foot depending on the well location. Contour maps of temperature data in early irrigation season (April) show cooler zones near the Jefferson River, indicating river water flowing into groundwater. During the irrigation season (July) uniform temperatures were seen indicating groundwater and surface water interaction. In the late irrigation season (October) temperatures are well mixed, showing significant impact from irrigation. Temperature data also revealed mountain recharge in cold groundwater coming from the Tobacco Root Mountains. Rising conductivity through the season indicates increasing groundwater contribution to surface water.

WET's surface water budget showed gaining and losing reaches of the Jefferson River. The river was separated into three separate reaches for the analysis. As the project was developing and flows increased, additional surface water discharge measurements were taken in order to better quantify contributing surface water, however, all potential sources were not quantified.

A major conclusion of the WET study was that changes in irrigation practices in the Waterloo area may not have a desirable outcome. WET concluded that the fields that were flood

irrigated provided groundwater recharge to the aquifer, which provides a delayed discharge to the Jefferson River during critical months. If irrigation practices were changed from flood irrigation to sprinkler or pivot irrigation, less water would be stored in the groundwater system and late summer return flows would be less.

Two goals of the study were to improve understanding and management of agriculture and irrigation operations, which would lead to fewer water shortages on the Jefferson River, and prevent any significant upset to the water balance in the area. In order to accomplish these goals WET recommended that the current water management (i.e. drought management plan) stay in place and that new practices be enacted to divert less water while still having an adequate supply of water for irrigation. Among WET's recommendations were also to increase on-site ditch oversight from mid-July to mid-September to reduce ditch spill (more water being taken than needed), and increase monitoring which would shorten the reaction time of needed adjustments and reduce the amount of excess water being diverted.

2.2. Seepage Studies

The Montana DNRC conducted a seepage study on the three main irrigation canals in the Jefferson Valley by taking synoptic discharge measurements from 2001 to 2003. The aim of the study was to identify ditch reaches where high levels of seepage occurred with the intent for future research in those stretches.

Synoptic flow measurements were taken on all three ditches at specified distances on two separate occasions. All diversions were shut down prior to the measurements to eliminate these variables. Stretches of significant loss were identified for each irrigation ditch which ranged from 1 to 9.6 cubic feet per second per mile (Amman, 2005).

Van Mullem (2006) completed an irrigation delivery improvement project in the Upper Jefferson River Valley with the intent of increasing flow in the Jefferson River during drought years. This study also expanded on Amman's (2005) seepage investigation. As part of the study, a seepage analysis was done for each of the main irrigation ditches in the Upper Jefferson Valley. Different methods for improving irrigation delivery were then investigated depending on results of the seepage analysis.

Methods used by Van Mullem were synoptic discharge measurements and ponding tests. The ponding test method consists of damming a defined area of the ditch, filling the reach with water and timing how fast water seeps from the ditch. Different methods of analysis were also taken into account to compare the data results. One way data was compared was dividing daily loss rates by the wetted perimeter. However due to inconsistent measurements, the data was also graphed as discharge versus river mile to illustrate the general trend in loss.

Tests on the Creeklyn ditch took place north of Silver Star near the Waterloo area. Two ponding tests were done on the ditch in consecutive years, 2004 and 2005. These showed 0.65 and 0.88 feet lost per day, respectively (Van Mullem, 2006). The increase in loss is possibly due to the use of polyacrylamide (PAM) to treat the ditch in 2004. A ponding test was also done on the Parrot ditch in 2004 near Loomont Road in the Waterloo area that yielded results of 0.43 feet per day. Overall the study showed fairly low seepage rates throughout all the ditches. It was also concluded from the graph data comparisons that seepage is approximately the same throughout the length of the ditch.

3. Methods

Groundwater and surface water monitoring was a crucial aspect of this study.

Groundwater elevations were monitored in order to examine the water table in the study area and the seasonal changes that occur. Surface water discharge was monitored to quantify the incoming and outgoing flows from the study area, which was essential in determining the groundwater recharge to the Jefferson River within the study area. The MBMG drilled three wells within the study area which were used to conduct an aquifer test which enabled aquifer properties to be estimated. Every well and surface water site was assigned a unique identification number (GWIC ID), and all of the data collected was entered in to the MBMG Groundwater Investigation Center (GWIC) database.

3.1. Groundwater Monitoring

The groundwater monitoring network consisted of 36 residential wells and piezometers spread throughout and surrounding the study area. Groundwater elevation data was collected from August 2013 through May 2015 by the MBMG (Table 1). The wells were selected according to hydrogeologic setting, geographic location, and landowner permission. The depth to water (DTW) was measured monthly from a specific measuring point on the top of each well casing using an electronic tape meter. The measuring points were surveyed by professional surveyors contracted by the MBMG. The measuring point elevation was used in addition to the DTW readings to calculate groundwater elevations. Pressure transducers were installed in eight of the wells within the study area. The data loggers recorded pressure and temperature hourly, and were downloaded once a month. The pressure data was corrected using a barometric pressure logger located within the study area and calibrated according to the manual DTW taken

at the time the data was downloaded. The hourly data enabled the smaller fluctuations not reflected in monthly measurements to be identified.

Table I. Monitoring Well Identification, Location and Type

Well Name	GWIC ID	Type	Location	Data Type
Richard & Pam Smith	237587	Residential	Within Study Area	Monthly
Harry Townes	209718	Residential	Within Study Area	Monthly
Willow 1	276103	Piezometer	Within Study Area	Monthly
Willow 2	276105	Piezometer	Within Study Area	Monthly
Willow 3	276106	Piezometer	Within Study Area	Monthly
Willow 4	276107	Piezometer	Within Study Area	Monthly
Willow 5	276108	Piezometer	Within Study Area	Monthly
Willow 6	276127	Piezometer	Within Study Area	Monthly
Willow 7	276109	Piezometer	Within Study Area	Monthly
Willow 8	276111	Piezometer	Within Study Area	Monthly
Willow 9	276285	Piezometer	Within Study Area	Digital Logger
Willow 10	276112	Piezometer	Within Study Area	Monthly
Willow Springs Stock Well	277868	Stock	Within Study Area	Monthly
Laurie & Scott Corbett	230730	Residential	Within Study Area	Digital Logger
Alex Bauerle	107080	Irrigation	Within Study Area	Monthly
Phil & Cheryl Mulhulin	276041	Residential	Within Study Area	Monthly
Bob Pierson	259547	Residential	Within Study Area	Monthly
Dave Schuit	276038	Residential	Within Study Area	Monthly
MBMG HA-OW1	279258	Stock	Within Study Area	Digital Logger
MBMG HA-OW2	279260	Stock	Within Study Area	Monthly
MBMG HA-PW	279259	Stock	Within Study Area	Monthly
Parson - 2	277329	Piezometer	Within Study Area	Monthly
Parson - 3	276287	Piezometer	Within Study Area	Digital Logger
Bench- 1	276113	Piezometer	Within Study Area	Digital Logger
Bench- 3	276114	Piezometer	Within Study Area	Monthly
Jerry & Sharon Engle	195941	Residential	Within Study Area	Monthly
Lori Armstrong/Dwyer	261912	Residential	Within Study Area	Monthly
Hunt- 1	277080	Stock	East of Study Area	Monthly
Hunt-2	107055	Residential	East of Study Area	Monthly
Todd Nelson	257377	Residential	Southwest of Study Area	Monthly
HCC Ranch (Railroad)	107330	Residential	South of Study Area	Monthly
MBMG HCC OW1	277403	Stock	South of Study Area	Digital Logger
MBMG HCC OW2	277404	Stock	South of Study Area	Monthly
MBMG HCC OW3S	277406	Stock	South of Study Area	Digital Logger
MBMG HCC PW	277405	Stock	South of Study Area	Monthly
Fish Creek House	107023	Residential	Northwest of Study Area	Digital Logger

3.2. Surface Water Monitoring

Surface water monitoring was conducted throughout the study area at various sites along the irrigation ditches and the Jefferson River, as well as the spring fed creeks. In addition to these MBMG sites, data from two USGS sites along the Jefferson River were also used. Data was collected at a total of 16 sites within the study area from April to November 2014 (Figure 3). Staff gauges and stilling wells containing a pressure transducer were installed at each of the sites in order to obtain stage data. The staff gauges were surveyed by the professional surveyors. Discharge measurements were taken biweekly using a Marsh McBirney acoustic Doppler velocity meter where flow conditions allowed. During high flows or in deep cross sections, a SonTek acoustic Doppler river profiler was used. Flow from the Marsh McBirney was calculated by using the measured cross section, depth and velocity readings. Flow is calculated internally by the SonTek river profiler. The flow values along with stage measurements were used to create rating curves at each of the sites. From the rating curves and hourly stage data logged by the transducers, hourly flow was estimated (Appendix B).

Figure 3. Groundwater and Surface Water Monitoring Network

3.3. Water Quality

Water quality samples were collected at 10 sites throughout the study area. Data were obtained from three groundwater wells, and seven surface water sites including Parson's Slough, Willow Springs, Parrot Ditch, and the Jefferson River. The sites were sampled periodically throughout the year (August 2014, November 2014, January 2015 and March 2015). A minimum of three well volumes was pumped from the groundwater wells and pH and specific conductivity values were allowed to stabilize before the samples were collected. Grab samples were collected at the surface water sites from the center of the stream. Field temperature, pH and specific conductivity were recorded, and samples were collected following the MBMG standard operating procedure for collecting water quality data. The samples were submitted to the MBMG water quality lab for analysis. Analyses were performed for major ions, trace metals, nutrients and water isotopes (Appendix D).

3.4. Aquifer Test

An aquifer test was conducted by the MBMG in March 2015 in the southeast corner of the study area. The test took place in the alluvium at a location determined by hydrogeologic setting and landowner permission. The MBMG drilled three wells at the site, one pumping well (HA PW) and two observation wells (HA OW1 and HA OW2). A step-drawdown test was performed first to determine pumping performance including well loss and pump efficiency. A 72 hour aquifer test was then attempted; however it was terminated after 55 hours due to equipment problems. Well recovery was also monitored. Results of the aquifer test analyzed using Aqtesolv are included in Appendix A.

4. Groundwater Budget

The hydrologic system describes the continuous movement of water on, above and below the Earth's surface. Fresh water makes up only a very small percentage (about 3%) of the total water supply on Earth. About 98% of the available fresh water is groundwater (Fetter, 2001). Flow paths of varying length move groundwater through the subsurface, transferring water from areas of recharge to areas of discharge.

The magnitude of the individual components of the hydrologic cycle varies significantly depending on different variables such as the climate and terrain of a region. Therefore, a groundwater budget can be a useful tool in quantifying the different components and estimating components that cannot be easily measured or quantified. There is inherent uncertainty associated with every component of a water budget; however, by combining the different elements reasonable values for each component can be calculated. Using the law of conservation, the total inflows to a system are equal to the total outflows in combination with the change in storage.

$$Inflow = Outflow \pm \Delta S$$

Where ΔS is change in storage.

A groundwater budget for 2014 was created for this study with the purpose of better quantifying the amount of groundwater recharge to the Jefferson River within the study area. This included considering all of the flows coming in to the study area and all of the flows leaving the study area. By quantifying the inflows and outflows to the aquifer in the Waterloo area we can estimate the amount of groundwater leaving the aquifer and flowing in to the Jefferson River.

Inflows to the aquifer include a groundwater flux from the south boundary, precipitation recharge, irrigation recharge, mountain front recharge, and seepage from the irrigation ditches. The outflows from the aquifer include a groundwater flux out of the north boundary, evapotranspiration, groundwater discharge to the Jefferson River, and spring fed streams (Willow Springs and Parsons Slough). Assuming a steady state, the groundwater budget for the Waterloo area becomes

$$Inflow = Outflow$$

$$P + Darcy\ Flux_{in} + S + MFR + IR = ET + Darcy\ Flux_{out} + SP + JR_{recharge}$$

where P is precipitation recharge, Darcy Flux_{in} is the groundwater flux into the study area, S is ditch seepage, MFR is mountain front recharge, IR is irrigation recharge, ET is evapotranspiration, Darcy Flux_{out} is the groundwater flux out of the study area, SP is groundwater leaving the aquifer as spring fed streams, and JR_{recharge} is groundwater flowing out of the aquifer to the Jefferson River (Figure 4).

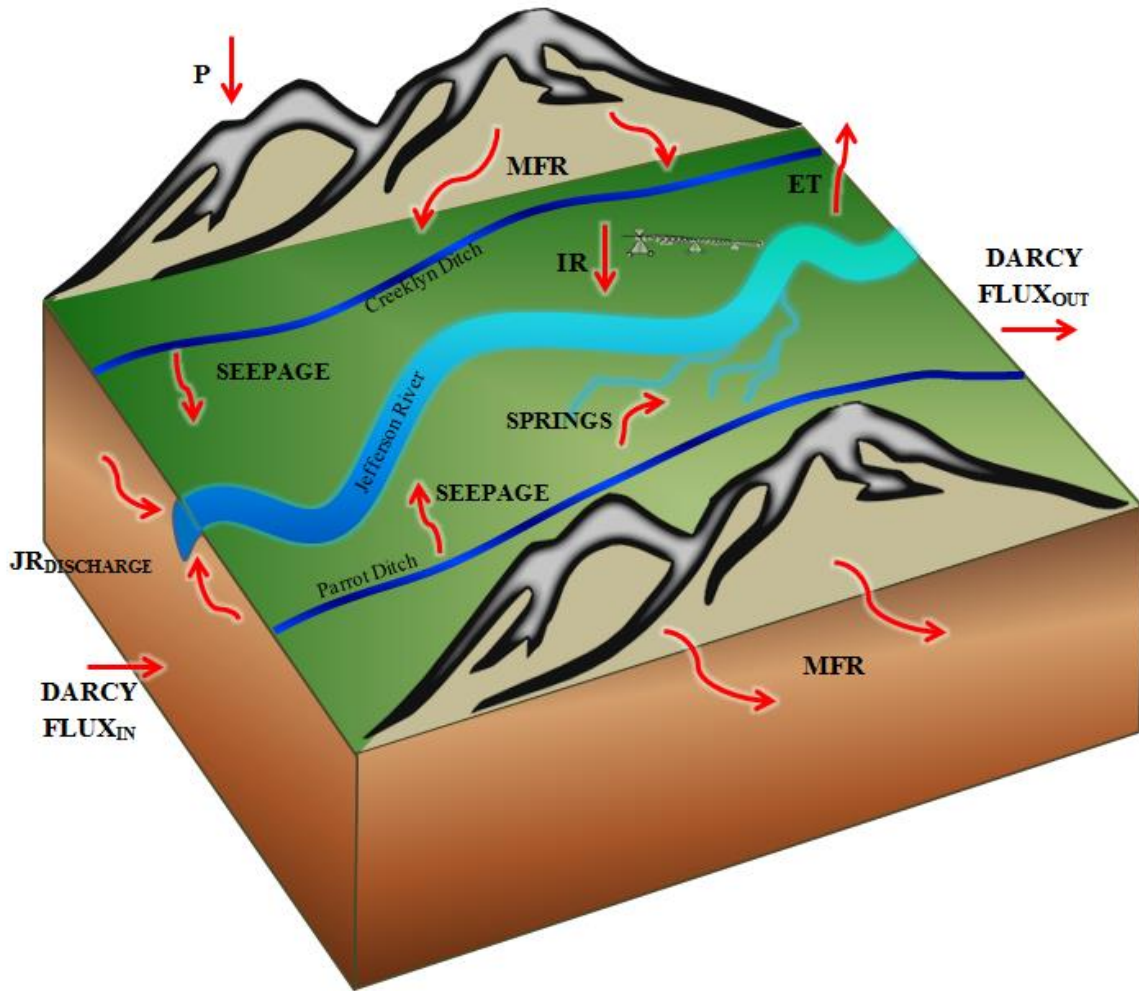


Figure 4. Conceptual Groundwater Budget of the Waterloo Study Area

4.1. Precipitation

Precipitation, including both rain and snow, is the main source of freshwater in the hydrologic cycle (Winter et al., 1998). However, the distribution of precipitation is highly variable; therefore it is important to collect data from more than one weather station to get an accurate estimate. For a groundwater budget, only the diffuse infiltration, or amount of precipitation that recharges the aquifer, is included. In order to quantify this, evapotranspiration has to be taken into account as well.

Precipitation data was acquired from the PRISM Climate Group, Oregon State University, Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM is an analytical model that produces gridded estimates of monthly annual (or 30 year climatological average values) using point data and an underlying grid such as a digital elevation model (DEM). It was developed with the intention to improve climate estimates in mountainous regions where complex variations occur. The model incorporates a conceptual framework that addresses the spatial scale and pattern of orographic processes, making it a good estimate for mountainous terrain (PRISM Climate Group, 2014). The annual average precipitation from the PRISM data ranged from 9.8 to 10.5 inches per year within the study area, with an average of 10 inches per year.

Since precipitation is already taken into account in calculating irrigation recharge (see section 4.6), infiltration from precipitation is only calculated for the non-irrigated areas. A study done by USGS found that the relationship between precipitation and recharge becomes linear when mean annual precipitation exceeds 30 inches, however when precipitation values are less than this most of the infiltrating water is used to replenish soil moisture (Dugan & Peckenpaugh, 1985). This was found to be particularly true for semiarid climates, such as the Waterloo study area. The non-irrigated land in the study area is primarily grass and sagebrush, which have an evapotranspiration rate of about 12 inches per year. With the assumption that only a small percentage of precipitation goes into the ground as recharge due to evapotranspiration, this parameter is negligible to the groundwater budget for this study.

4.2. Evapotranspiration

Evapotranspiration in terms of a groundwater budget is important when considering diffuse recharge from precipitation as mentioned earlier, but also important when considering

phreatophytes. Phreatophytes are deep rooted plants that pull water from the saturated zone of the aquifer. Since evapotranspiration is already taken into account in irrigated areas when irrigation recharge is calculated, the amount of water the phreatophytes are taking from the aquifer is the main concern for this groundwater budget.

For this study Landscape Fire and Resource Management Planning Tools (LANDFIRE) data was used to evaluate vegetation types in the study area. LANDFIRE is a collaborative program between the wildland fire management bureaus of the U.S. Department of Agricultural Forest Service and U.S. Department of the Interior, which provides landscape scale geo-spatial products.

The LANDFIRE data was used to identify type and quantity of phreatophytes that exist in the alluvial area. The LANDFIRE data revealed that phreatophytes in the study area include aspen, cottonwood and willows. As can be seen in Figure 5 below, they exist primarily in the riparian zone, which is consistent with field observation acres of phreatophytes. A rate of 22 inches per year (Bobst et al., 2014) was used to quantify the amount of ET from these phreatophytes which resulted in total evapotranspiration of about 1,000 acre feet per year.

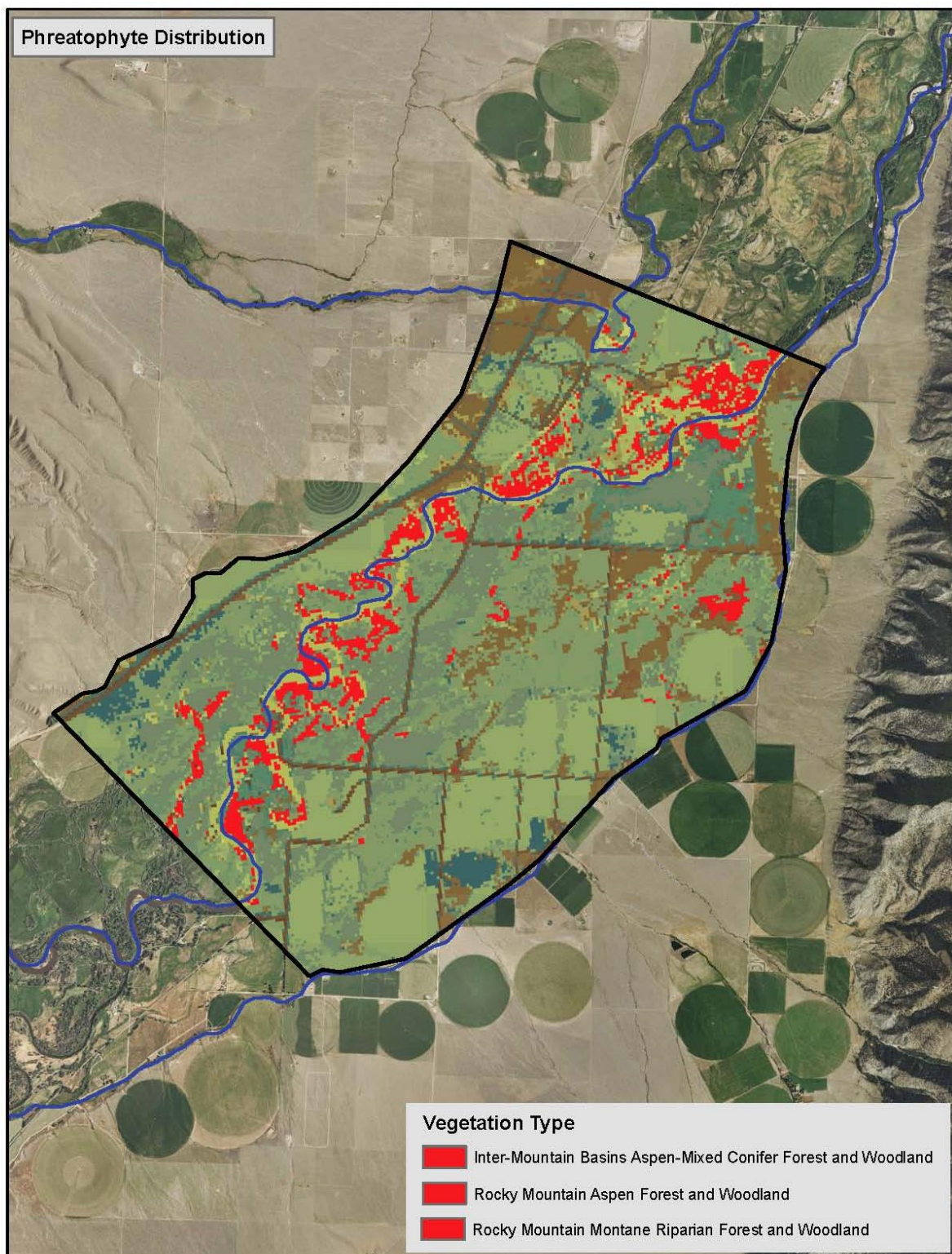


Figure 5. Phreatophyte Distribution in the Waterloo Area

4.3. Groundwater Flux

Groundwater flux is the amount of groundwater moving horizontally through a specific cross section of the aquifer. The amount of flux can be calculated using Darcy's law (Fetter, 2001):

$$Q = KiA$$

where Q is the total flow (cfs), K is the hydraulic conductivity (ft/s), i is the groundwater gradient (unitless), and A is the cross-sectional area of the aquifer (ft²).

The cross-sectional area of the aquifer depends on the saturated thickness of the aquifer. The aquifer thickness was estimated based on well logs from wells within the study area. The majority of wells in the alluvium were completed around 60 feet below ground surface. An assumed saturated aquifer thickness of 100 feet was used for calculations as that was the depth of the deepest well (MBMG HCC OW1) drilled in the study area.

The cross sectional area was calculated using this assumed aquifer thickness and the measured distance of both the north and south boundary within the alluvium. The geologic map of the study area (Figure 2) reveals that the northern boundary consists of a much narrower cross section than the southern boundary. As such the groundwater flux out of the study area is much smaller than the groundwater flux into the area. The groundwater flux estimates are likely over estimates since the actual geometry of the aquifer is most likely not rectangular. Typically the aquifer is deeper in the middle and shallower on the sides, however, the study area boundary only encompasses the alluvium and as such a rectangular area is sufficient. A cross section near the southern boundary of the study area is shown below.

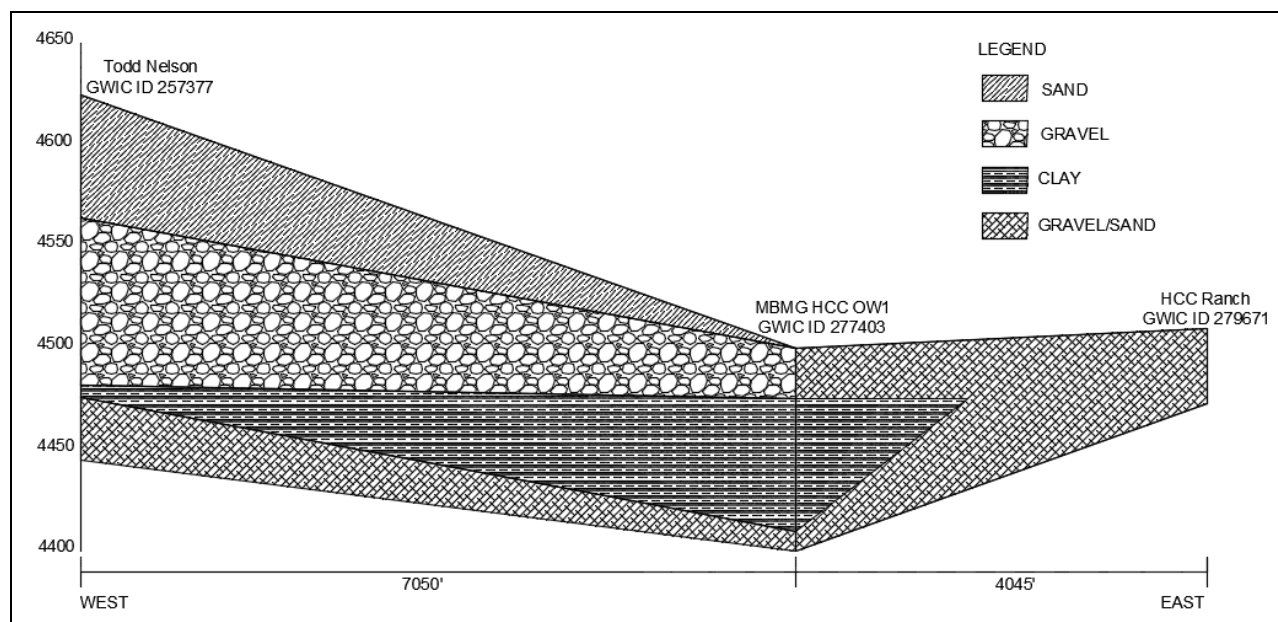


Figure 6. Geologic Cross Section Near Southern Study Area Boundary

Hydraulic conductivity was estimated from the aquifer test and well log data. The aquifer test data in the alluvium resulted in a transmissivity value of 110,000 square feet per day using a confined leak aquifer model (Hantush-Jacob) which allowed for the inefficiency of the pumping well to be taken into account. Using the assumed 100 ft saturated thickness the resulting hydraulic conductivity is 1,100 feet per day. This is a reasonable value based on lithology records of the wells showing primarily gravel. The groundwater gradient was calculated using the potentiometric surface created from the static water elevation data collected in 2014. This resulted in a groundwater flux in of 22,364 acre-ft/yr and a groundwater flux out of 13,503 acre-ft/yr.

4.4. Mountain-Front Recharge

Mountain-front recharge is generally defined as the contribution of recharge from mountain regions to adjacent basin aquifers. Wilson and Guan 2004 suggest a more specific definition of Mountain Front Recharge as “all water entering the basin aquifer with its source in

the mountain block and mount front (zone).” It is particularly important in semi-arid and dry climates due to its significant contribution to the basin aquifer which can be greater than four times the river basin discharge (Wilson & Guan, 2004).

There are many different methods to estimate Mountain-front Recharge. Typical basin-centered methods treat the mountain front as a boundary condition instead of analyzing the actual hydrologic system of the mountain. Mountain-centered methods consider the mountain as a whole and not just as a boundary condition. Mountain-centered methods consider recharge from rainfall, snowmelt, surface runoff, as well as through fractures and faults, along with water returned to the atmosphere through vegetation-controlled evapotranspiration (Wilson & Guan, 2004).

For this study, a mountain-centered water balance method was used to quantify the Mountain-front Recharge contribution. Mountain-front Recharge is pertinent to the groundwater budget as it is a major inflow into the east and west boundaries of the study area. The water balance method assumes that precipitation is the only input in the water budget. Subtracting surface-water runoff and evapotranspiration results in groundwater as the only output. For purposes of this study all surface water runoff exiting both mountain regions is intercepted for irrigation use and never makes it to the basin aquifer. In the event all the water is not intercepted it would discharge to the irrigation canals. Also, assuming a steady state, there is no storage. By making these assumptions the groundwater leaving the mountain front system is equal to the Mountain-front Recharge and can be quantified with the water budget equation below.

$$In = Out \pm \Delta S$$

$$PCP + SW_{in} + GW_{in} = ET + SW_{out} + GW_{out} \pm \Delta S$$

$$PCP - ET = GW_{out}$$

$$GW_{out} = MFR$$

where PCP is precipitation, SW is surface water, GW is groundwater, ET is evapotranspiration, and ΔS is change in storage.

The boundary used to analyze each hydrologic section of the water budget was delineated using topographic maps to determine the divides. It is assumed for this case that the groundwater divides follow the topography of the mountains. Therefore the area used to evaluate precipitation and evapotranspiration was sectioned according to divides near the north and south flux boundaries of the study area and run all the way from the mountain peak to the alluvium boundary of the study area (Figure 7). The resulting areas for the Highland and Tobacco Root Mountains were 39,939 and 28,193 acres, respectively.

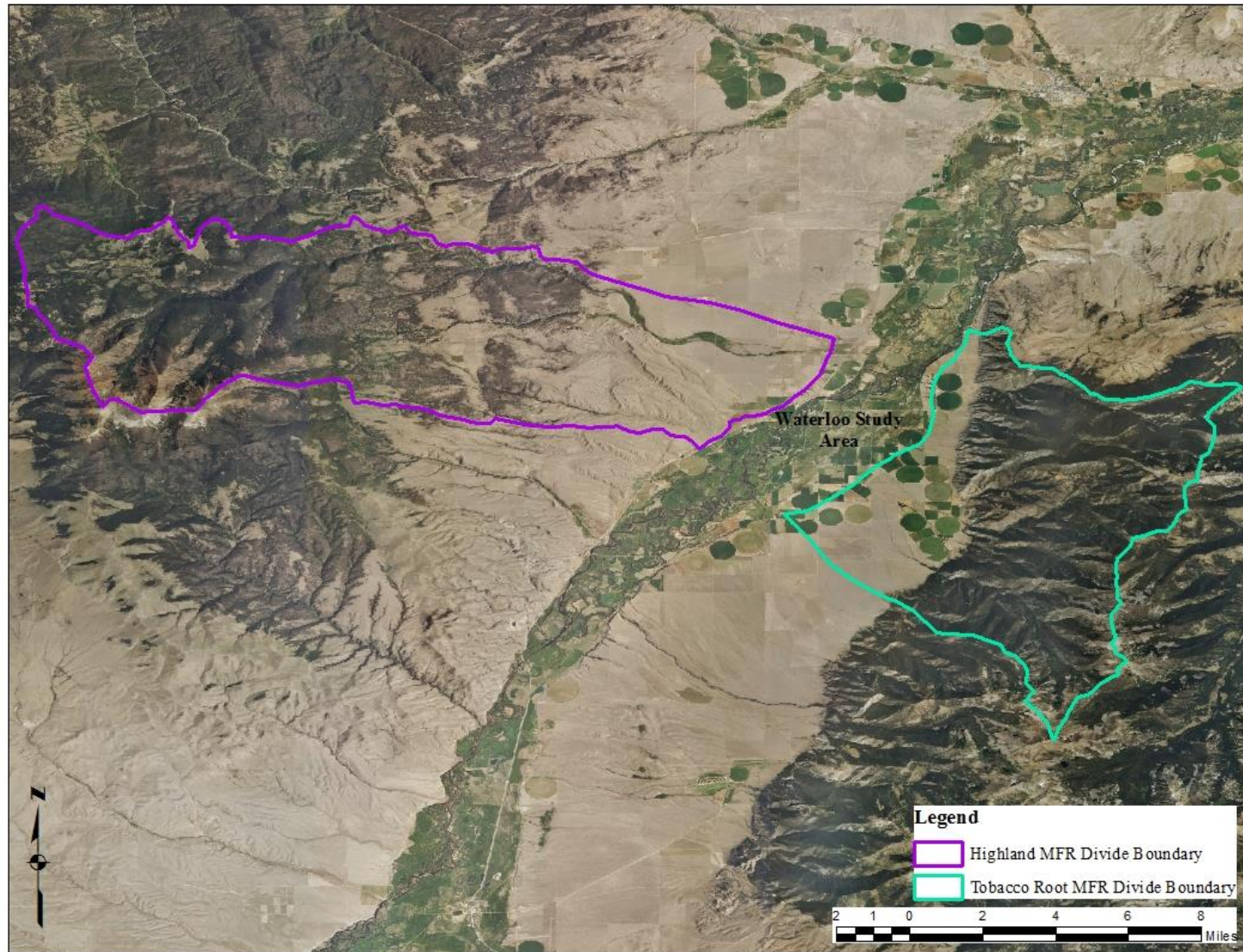


Figure 7. Divide Boundaries for MFR Estimate (Delineated using topographic maps)

4.4.1. Mountain Peak Precipitation

The 30 year normal data from PRISM was used to estimate the amount of precipitation over the delineated mountain areas contributing to the study area. The 30 year normal data were taken from the time period 1981-2010. Evaluation of the annual average precipitation data for the Highland Mountain region shows a range of 9.95 inches to 32.27 inches, averaging 18.36 inches per year. The Tobacco Root Mountain region shows a range of 10.02 inches to 42.20 inches, averaging 19.02 inches per year. This converted to 61,116 acre-feet of precipitation per year for the Highland Mountains and 44,676 acre-feet of precipitation per year for the Tobacco Root Mountains.

4.4.2. Mountain Evapotranspiration

The estimation of evapotranspiration is crucial to the accuracy of the water balance approach, which can be difficult to quantify (Wilson & Guan, 2004). LANDFIRE vegetation data was acquired for the specified mountain regions to determine the amount and variation of different vegetation. Vegetation type was divided according to 11 different categories for which literature values of evapotranspiration rates were used (Johns, 1989). The total area of each type of vegetation was determined and used to calculate total evapotranspiration rates for each mountain region. The evapotranspiration rates ranged from 1.0 foot (shrub/grass lowlands) to 2.2 feet (Whitebark pine) per year. Evapotranspiration estimates totaled 56,674 acre-feet per year and 41,715 acre-feet per year for the Highland Mountains and Tobacco Root Mountains, respectively (Table 2).

Table II. Vegetation Type and Evapotranspiration Rates

Vegetation Group	Highland Mountains			Tobacco Root Mountains		
	Acres	ET Rate (ft/yr)	Acre-ft/yr	Acres	ET Rate (ft/yr)	Acre-ft/yr
Upland Sagebrush	5,350	1.1	5,885	4,593	1.1	5,053
Douglas Fir	8,477	1.4	11,868	12,941	1.4	18,118
Shrub/Grass Lowlands	9,765	1.0	9,765	2,046	1.0	2,046
Mixed Evergreen	8,290	1.8	14,923	3,215	1.8	5,787
High Xeric Grasses	2,472	1.2	2,967	343	1.2	412
Ag lands	309	2.1	650	1,995	2.1	4,190
Mesic Meadow	1,216	1.7	2,067	757	1.7	1,287
Whitebark Pine	2,838	2.2	6,244	1,492	2.2	3,283
Alpine Rangeland, Deciduous Shrubs	864	2.0	1,728	181	2.0	361
Developed	186	1.0	186	206	1.0	206
Riparian	170	2.3	392	422	2.3	971
TOTAL	39,939		56,674	28,193		41,715

4.4.3. Mountain Front Recharge Estimate

The total mountain front recharge using the water budget approach resulted in 4,443 acre feet per year and 2,961 acre feet per year from the Highland and Tobacco Root Mountains, respectively. This is a high end estimate of the amount of recharge from the mountains. This method does not take surface water runoff, soil moisture retention, or sublimation into account. The surface water runoff is a variable output; there are times it is not completely intercepted for irrigation.

Since snow is the majority of the precipitation that occurs in the alpine region, sublimation may have a significant impact on the water balance of the mountain. Sublimation occurs, in order of decreasing efficiency, due to wind transported snow, intercepted snow, and from the snow pack. In a study done to evaluate the effect of sublimation on a snow mass balance in the Canadian Rocky Mountains, snow mass loss to sublimation as a percentage of cumulative snowfall ranged from 20 to 32% (MacDonald, Pomeroy, & Pietroniro, 2010).

Sublimation was estimated through blowing snow models simulating a transect of hydrological response units (HRU's) along a ridgeline in the Rockies. Of the total snow mass loss 17 to 19% was due to blowing snow.

Numerical modeling of the Boulder River Valley, a region just north of the Upper Jefferson Valley, used the same water budget approach for mountain front recharge. The results of the investigation found the actual mountain front recharge to be about half of the calculated value (Bobst et al., in preparation). Preliminary numerical modeling of the Waterloo area was also done, and the calibration stage of a steady state model showed this same result. Consequently, the calculated values for mountain front recharge were halved for this groundwater budget. The total Mountain-front Recharge was 3,702 acre-ft/year.

4.5. Irrigation Ditch Seepage

Accurate seepage estimates were needed for this groundwater budget since irrigation ditches act as the east and west boundaries of the study area. The study area is bordered by the Parrot Ditch on the east and the Creeklyn Ditch on the west. In order to quantify the ditch seepage, a synoptic discharge measuring event was conducted on August 13, 2014 to analyze seepage from the Parrot Ditch. All irrigation pumps drawing from two reaches were turned off at 8am that morning and the measurements were taken consecutively with minimum time in between measurements. Discharge was taken at four sites and seepage was calculated for the two reaches. Results ranged from 3 to 8 cubic feet per second per mile (cfs/mi) for the Parrot Ditch.

Since the synoptic sampling event was only one instance it is not representative of the whole season. To better estimate, seepage hydrographs from surface water monitoring for consecutive sites on both the Parrot and Creeklyn Ditch were analyzed. It is assumed that when the flows at each site are closest in value, minimal pumping occurs and a good estimate of

seepage can be calculated. It is recognized, however, that some pumping may still be occurring. During times of minimal loss, flows were compared and the average loss was calculated to be about 2 cfs/mi and 4 cfs/mi for the Creekllyn and Parrot Ditch, respectively (Appendix A). The total seepage was calculated for the approximate 6 months when the irrigation ditches are operating (May – October). These estimates resulted in a total seepage inflow of about 12,800 acre feet per year into the study area from both irrigation ditches.

4.6. Irrigation Recharge

Irrigation recharge is the amount of recharge to the aquifer as a result of irrigation. It is dependent on the type of irrigation as well as type of crop being irrigated. The three types of irrigation used in this study area are flood irrigation, pivot irrigation, and sprinkler irrigation. Efficiency ranges for each type of irrigation were determined from the NRCS National Engineering Handbook (2008) and a mid-range was selected: 25% for flood, 65% for sprinkler, and 80% for pivot irrigation. The NRCS Irrigation Water Requirements program (IWR) was used to determine certain parameters used as inputs in the following equation to calculate irrigation recharge:

$$IR = [(NIR/IME + P_{eff}) - ET \times DP_{ex}]$$

where IR is irrigation recharge, NIR is net irrigation requirement, IME is irrigation method application efficiency, P_{eff} is effective precipitation, ET is evapotranspiration and DP_{ex} is the applied water in excess of ET that results in deep percolation. NIR, P_{eff} and ET were estimated from the IWR program.

A weather station in Twin Bridges was selected to use for climate data as it was the closest to the study area. The climate data is used by the program to determine the effective

precipitation, and a 30 year normal data set is required. Only weather stations with adequate records can be used.

In an interview conducted with landowner Dean Hunt, irrigation methods and crop types were discussed focusing on the land inside the study area boundary. Crop types within the area include native grass, native alfalfa grass (a 50/50 mix of alfalfa and grass), alfalfa, barley, peas, potatoes, corn, sod and conifer trees (D. Hunt, personal communication, 2014). Approximate irrigation dates and cutting frequency was also discussed. The different crop types were split into four different categories for the purpose of this study: native grass, native alfalfa grass, alfalfa and other. The “other” category encompasses all of the remaining crop types as they have similar irrigation requirements and ET rates, and cover a small percentage of the area in comparison to the other three main crop types. It should be noted that the IR calculations were made using current irrigation type and crop data for 2014.

In addition to crop type and climate data, soil type is also an important input into the IWR program. According to the NRCS Web Soil Survey sandy loam is the predominant soil type within the study area and was selected for the soil type (Appendix A). The value for the DP_{ex} term was based off a study by the Idaho Department of Water Resources (Idaho Department of Water Resources, 2013) which took place in the eastern Snake Plain Aquifer. The variable ranges from 0 to 1 depending on evidence of surface water return flows. For this study DP_{ex} was set to 0.5 for flood irrigated areas and 1 for pivot and sprinkler irrigated areas.

Based on the IWR results the irrigation recharge for each month of the year was estimated. The numbers were then multiplied according to the mid-range average irrigation efficiency values. Tables containing the irrigation recharge values can be found in Appendix A.

Once the areas for each crop and irrigation type were totaled the resulting table was created with the total irrigation recharge estimate for the groundwater budget.

Table III. Irrigation Recharge

Irrigation & Vegetation Type	Area (acres)	IR Rate (ft/yr)	IR (acre-ft/yr)
Pivot (Pasture Grass, Alfalfa Hay, 50/50, Other)	1,498	0.29	432
Sprinkler (Pasture Grass, 50/50, Other)	810	0.67	539
Sprinkler (Alfalfa Hay)	214	1.67	357
Flood (Pasture Grass, Other)	1,333	4.69	6,252
Flood (50/50)	602	5.23	3,149
Flood (Alfalfa Hay)	64	5.77	367
Total			11,096

4.7. Spring Fed Streams

Willow springs and Parsons Slough both originate within the study area and are groundwater fed springs, essentially groundwater discharging from the aquifer as surface water. In a field visit conducted with landowner Dean Hunt, a house near Willow Springs was toured. The house gets its water from a spring under the house, with the overflow discharging to the stream. Water quality data also shows evidence of these streams being spring fed. In order to quantify this outflow for the groundwater budget, the hydrographs created from field observations were analyzed (Appendix B). The resulting estimate was approximately 22 cfs, or 16,360 acre feet per year.

4.8. Groundwater Discharge to the Jefferson River

As stated earlier the Waterloo area is historically identified as the main source of recharge to the Jefferson River, which becomes extremely important in the late summer months when flows are low and temperatures are elevated. Therefore it is important to quantify this for

the groundwater budget. A surface water budget analysis was used in order to estimate the recharge.

Since the reach of the Jefferson River between the USGS gaging station at Parsons Bridge and the MBMG site Jefferson River at Corbett's has no major diversions, only additions from Parsons Slough and Willow Springs, it is an ideal stretch of river to analyze for the groundwater recharge in the Waterloo area (Figure 8). The groundwater contribution can be estimated by quantifying the flows coming in to this stretch of river and subtracting the outgoing flows with the following surface water budget equation:

$$Q_{out} = Q_{in} + Q_{gw}$$

$$Q_{gw} = Q_{out} - Q_{in}$$

$$Q_{gw} = Q_{JR@Corbett's} - (Q_{USGS\ Parson's\ Bridge} + Q_{Parson's\ Slough} + Q_{Willow\ Springs} + Q_{Kurnow\ Ditch})$$

where Q_{gw} is the groundwater discharge, and the remaining terms are surface flow at their respective sites. Flows were also analyzed in the southern stretch from the MBMG site Jefferson River at Silver Star to the USGS Parson's Bridge site. The only major diversion known in this stretch is the Jefferson Canal irrigation ditch. The recharge to this stretch of river can be quantified by the following equation:

$$Q_{gw} = Q_{JR@Silver\ Star} - (Q_{USGS\ Parson's\ Bridge} + Q_{Jefferson\ Canal@Diversion})$$



Figure 8. Surface Water Flows for Estimation of Groundwater Discharge to the Jefferson River

Using the above equation the groundwater discharge to the Jefferson River was calculated based on the discharge recorded at the surface water monitoring sites. Peak runoff season results in high flows which are not only hard to measure due to field equipment constraints but also make it extremely difficult to distinguish between surface runoff and groundwater recharge. Because of the measurement constraints, the rating curve for Jefferson River at Corbett's has very high uncertainty for high flows. Therefore, the late summer months during low flow (August and September) give the best estimate of actual groundwater discharge.

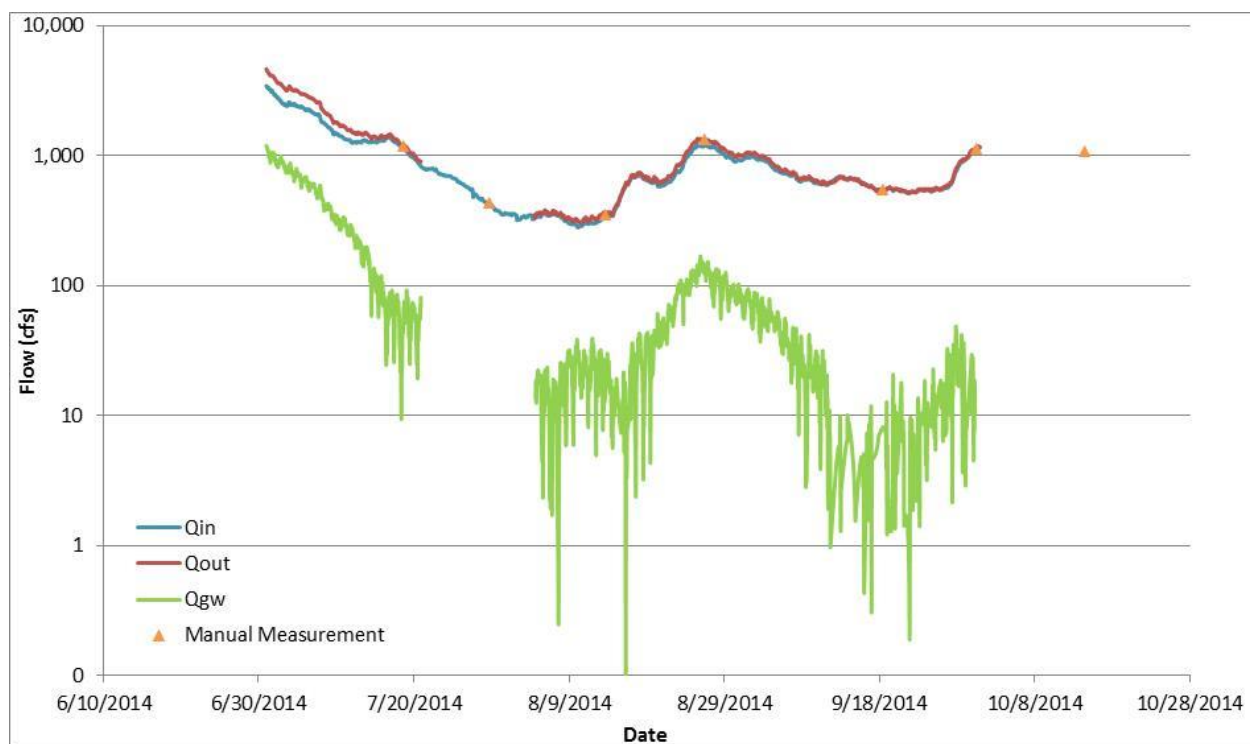


Figure 9. Hydrograph comparison of Jefferson River at Silver Star and Jefferson River at Parson's Bridge showing direct discharge of groundwater

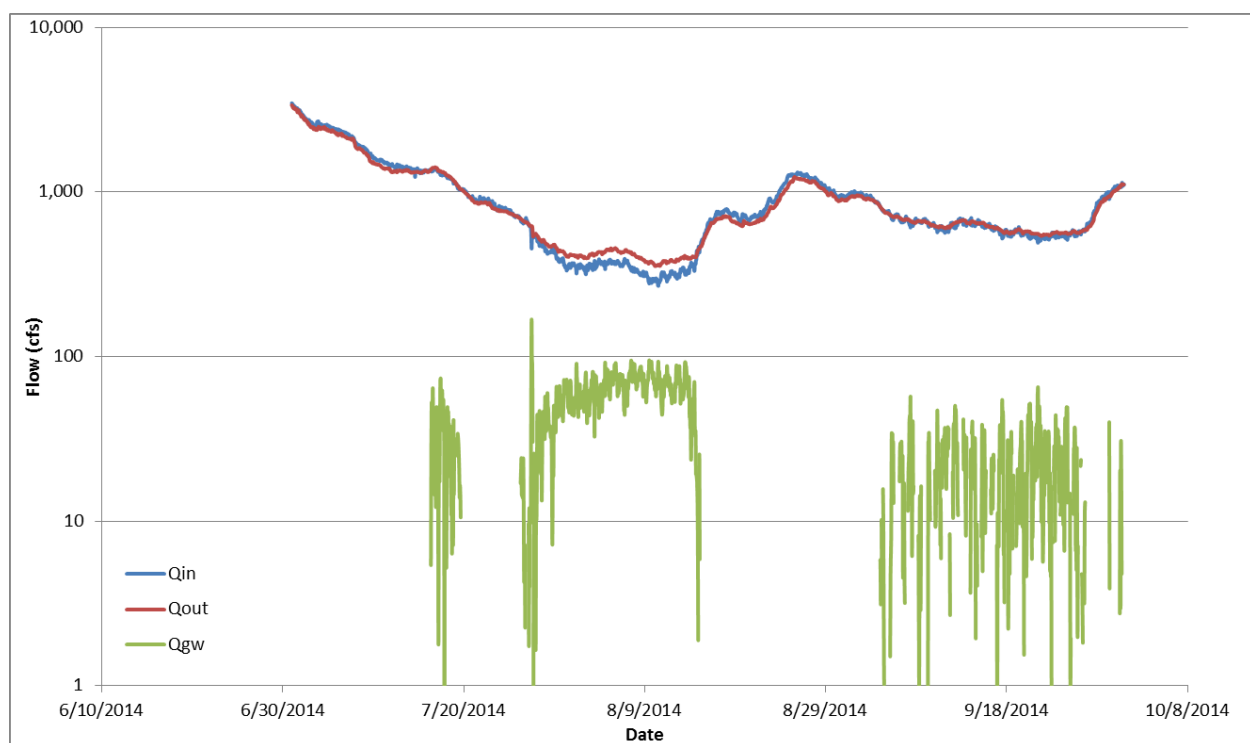


Figure 10. Hydrograph comparison of Jefferson River at Parson's Bridge and Jefferson River at Corbett's showing direct discharge of groundwater

The average groundwater discharge to the Jefferson River from Silver Star to Parsons Bridge for 2014 was about 20 cfs, and about 12 cfs in the stretch from Parsons Bridge to the Corbett's. These values equate to 14,779 acre-ft/year and 8,831 acre-ft/year, respectively. The greatest gain occurs at the lowest stage, when the stage increases the river flows into bank storage. The manual measurements for Jefferson River at Corbett's were also plotted on Figure 9, with the highest measured flow at about 1,300 cfs. The highest flow in the hydrograph for Jefferson River at Corbett's was over 3,200, over twice the flow that was measured which is past the acceptable 1.5 factor for extending rating curves (A. Bobst, personal communication, 2015).

5. Water Budget Assessment

The final groundwater budget shows that initial estimated inflows to the aquifer totaled 49,991 acre-ft per year and estimated outflows equaled 54,479 acre-ft per year, which comes to about a 4.3% difference (Table 4). The estimated uncertainty for each component of the groundwater budget must also be taken into account. The uncertainty was used to create a range of values for each factor, and with that range a balanced budget can be created. For this study a groundwater budget was estimated for the year 2014, this budget cannot be used as an accurate representation of inflow and outflow of the system for any other year, although it may be similar. Given that any variation in water levels is believed to result from climatic variability, change in storage is believed to be zero. As such, a weighted adjustment was applied to the budget so that it balances.

Table IV. Groundwater Budget for Waterloo

G_{Win}	Initial Estimate (acre-ft/yr)	Uncertainty (%)	Range (acre-ft/yr)		Adjusted Estimate (acre-ft/yr)
			low	high	
Darcy Flux _{in}	22,364	10%	20,128	24,601	3,371
MFR	3,702	10%	3,332	4,072	3,869
Seepage	12,829	5%	12,187	13,470	13,406
IR	11,096	5%	10,541	11,651	11,595
<i>TOTAL IN</i>	49,991				52,241
G_{Wout}					
Darcy Flux _{out}	13,503	10%	12,153	14,853	12,963
Spring Fed Streams	16,365	5%	15,547	17,183	15,670
ET	1,002	10%	902	1,102	957
J _r _{recharge}	23,609	10%	21,248	25,970	22,653
<i>TOTAL OUT</i>	54,479				52,242

Due to a number of limitations in estimating the groundwater budget, it is important to note the uncertainty of this evaluation. In an ideal steady state situation the percent error would

be zero: all flow into the system would equal the flow out of the system. However, there is no such thing in the real world as true steady state. Averaging the flows and fluxes throughout an entire year helps to estimate the steady state, but there is never a time that the aquifer is at a true steady state.

There are many different variables which affect the inflows and outflows to the aquifer. For instance, historical climate change will affect the budget. 2014 had near normal precipitation and temperatures. In 2005 during the WET study the valley experienced a drought year with less precipitation and higher temperatures than normal. There were also limits to the amount and type of groundwater and surface water monitoring that could be accomplished. Ideally data would be collected for more than one year. Other constraints included budget, access, acquiring landowner permission, and equipment limitations. Measuring surface water discharge during high flows was extremely difficult at both the south and north boundary sites on the Jefferson River (Jefferson River at Funston and Jefferson River at Corbett's). Therefore the rating curves at both of these sites have high uncertainty during high flows.

There is also uncertainty in assuming a homogenous hydraulic conductivity in the aquifer across the entire study area. The aquifer test that was conducted is only an accurate representation of the hydraulic conductivity in the area the wells are located. The uncertainty of the Darcy flux strongly relies on the saturated thickness. In order to accurately estimate the saturated thickness of the aquifer, a deeper well would be needed to identify the true saturated layer. A breakdown of the percentages of the inflows and outflows can be seen in Figure 11 below.

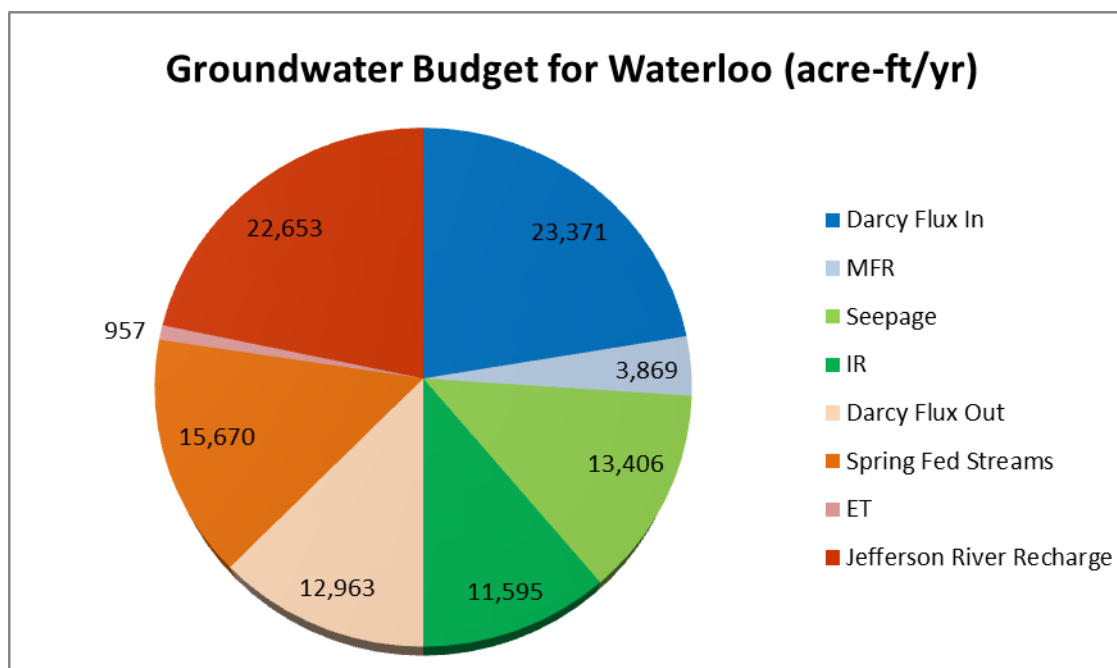


Figure 11. Groundwater Budget for Waterloo

The major sources of inflow (aside from the darcy flux) are seepage and irrigation recharge. This is not surprising given that almost the entire area is irrigated land and the east and west borders of the area are irrigation ditches carrying over 200 cubic feet per second of water at times. The major outflows are groundwater discharge to the Jefferson River and the spring fed streams that originate within the study area.

5.1. WET – MBMG SWE Comparison

Groundwater elevations from the WET study in 2005 were compared to groundwater elevations collected from the same wells by the MBMG in 2014. Graphs of all of the well comparisons can be found in Appendix C. It is important to note that these comparisons only show the difference between the water elevations in the year the data was collected, and are dependent on many different variables. Water level elevations change as the inflows and outflows of the water budget change throughout time. Although there are limitations, these

graphs do provide important information of the water table trends in the Waterloo aquifer and some conclusions can still be drawn.

In evaluating the graph comparisons it is apparent that the water table in 2014 was at a higher elevation than the water table in 2005. The main reason for this is most likely that 2005 was considered a “drought” year with significantly lower flows in the Jefferson River compared to 2014 data. However, the general trend of the water table, steadily decreasing during the winter months and peaking May – June, then decreasing again throughout the rest of the year, has remained the same. There is no evidence to support the presumption that the water table in the Waterloo area is decreasing.

5.2. Irrigation Practice Change Evaluation

As irrigation recharge makes up about 22% of the inflows in the groundwater budget, irrigation practice changes have the potential to impact groundwater levels. As WET presumed from their study, flood irrigation early in the season is an important source of recharge to the Jefferson River in the late summer months. Although many of the fields in the area are still currently flood irrigated, a field just south of Loomont Road was converted from flood to pivot irrigation sometime after 2005. Two of the wells monitored by the MBMG are in close proximity to the field. Looking at these two graph comparisons there is no evidence to support the fact that switching this field from flood to pivot irrigation caused less recharge to the aquifer. Since this is an area where groundwater discharge occurs it could be that it is not sensitive to these changes, while practices in recharge areas would cause more of a change.

However, flood irrigation requires approximately three times the amount of water as sprinkler or pivot irrigation. Although changing one field from flood to pivot irrigation

seemingly had no impact, if all fields were switched the impact may be significant enough to noticeably alter the groundwater budget.

In a predictive scenario analysis, the irrigation recharge was recalculated to visualize the effect of changing irrigation practices. The fields that are currently flood irrigated were calculated as if they were changed to pivot irrigation. The resulting irrigation recharge value was calculated to be 1,904 acre feet per year. This is a drastic reduction, over 80%, in irrigation recharge as opposed to the current calculated value of 11,096 acre feet per year. Although it is not typical, due to size and expense, that all fields would be converted to pivot, it is the most conservative prediction of how the groundwater budget could be altered by changing irrigation practice.

5.3. Ditch Lining Evaluation

As seepage makes up approximately 26% of the inflows of the groundwater budget, it has the potential to have a major impact on the Waterloo aquifer. It is widely known that lining ditch canals will result in water conservation, as less water is required to be diverted from the river with reduced seepage. Conversely, from an aquifer standpoint, lining the ditch canals could have an adverse effect on aquifer recharge. Without seepage from the irrigation canals recharging the aquifer, it is likely that not as much recharge to the Jefferson River would occur later in the summer when it is most needed.

5.4. Tile Drain Effect

The tile drains that were installed in the Waterloo area have caused some concern among neighboring residents. The major concern is that the presence of these tile drains is causing the water table to lower in that area. Two wells were monitored (Shuit and Parson 2) in close proximity to where the tile drains were installed. There is no evidence to support the presumption

that the water table has been lowered in this area. Although no evidence was seen in the water elevations of these wells, some quick calculations can be made to support this theory.

Freeze and Cherry wrote in relation to developing tunnels that if groundwater inflows could be predicted it was possible to design an adequate drainage system. They theorized that tunnels essentially acted as drains. With a known hydraulic conductivity the rate of groundwater inflow per unit length of tunnel can be calculated from a quantitative analysis of the net flow (Freeze & Cherry, 1979). Using this approach, an estimated flow from the tile drains can be made.

Agricultural subsurface drains are installed depending on field topography and soil permeability. Typical depths range from 3 to 4 feet (Wright & Sands, 2001) with more permeable soil at deeper depths. In order to serve their purpose and discharge to Parson's Slough, the drains would also have to be fairly shallow. Drain material and diameter are dependent on how much water is required to drain. Although exact dimensions and placement of the tile drains in the Waterloo area is unknown, with assumptions, an estimate can be made of the amount of water being drained. Using an approximate depth of 4 feet and aquifer characteristics from the aquifer test a cumulative transient inflow per unit length of drain after a specified time can be determined. From the calculation, approximately 23 square feet of water per linear foot of drain would be drained after one year. If there were 3,000 linear feet of tile drains this would equate to about 5 acre-ft/year after 10 years, which, in comparison to the water budget, is extremely small.

To estimate the effect of the tile drains on nearby wells the Theis method was used. When aquifer properties are known a Theis curve can be used to estimate hydraulic head drawdown in a well at a specified distance and time in a confined aquifer. Using this method and

the aquifer properties from the aquifer test a time-drawdown curve for a radius of 100 feet from the tile drains was developed.

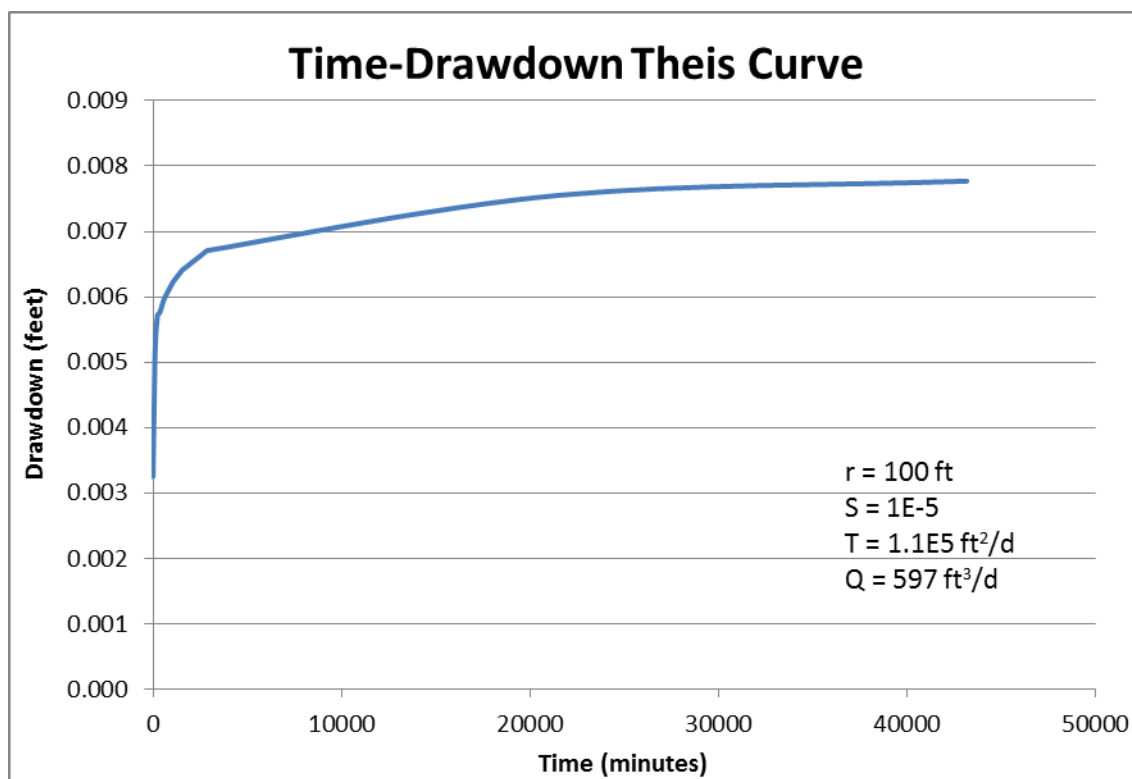


Figure 12. Time-drawdown Theis Curve for Tile Drain Influence Prediction

The tile drains likely have little to no influence on neighboring wells, as drawdown even after one month is extremely insignificant at less than 0.01 feet. The drawdown was calculated as if the tile drains were a pumping well at the edge of the field. Since the closest neighboring well is greater than 100 feet from the field where the tile drains are installed, it is not likely neighboring wells will see any effect from the tile drains.

5.5. Water Quality Evaluation

Four sampling events were performed during the duration of this study in August 2014, November 2014, January 2015, and March 2015. Piper diagrams were created in order to analyze the results of the sampling events (Appendix D). The predominant water type in both surface

water and groundwater samples is calcium-bicarbonate. Since there is only subtle change in the marker placement from the different sampling dates, it is hard to determine if there are different sources of water in each location. However, it is apparent that the Hunt-1 well is a different water type, magnesium-bicarbonate, and from a different source. This result is expected as it is in the alluvial fan at the base of the Tobacco Root Mountains, likely strongly influenced by mountain front recharge.

The total dissolved solids (TDS) ranged from 235.34 mg/l in the west fork of Willow Springs and 360.67 mg/l in Parsons Slough. A simple comparison of the lab specific conductivity results from each sampling event is a good indicator of how water composition changes throughout the season. For example, there is little change in the Hunt-1 or Willow Springs Stock wells, indicating that not much change occurs in the composition of the water. However, in all three sites in Willow Springs, the specific conductivity values decrease steadily after the irrigation season. This could be an indication of irrigation recharge or seepage.

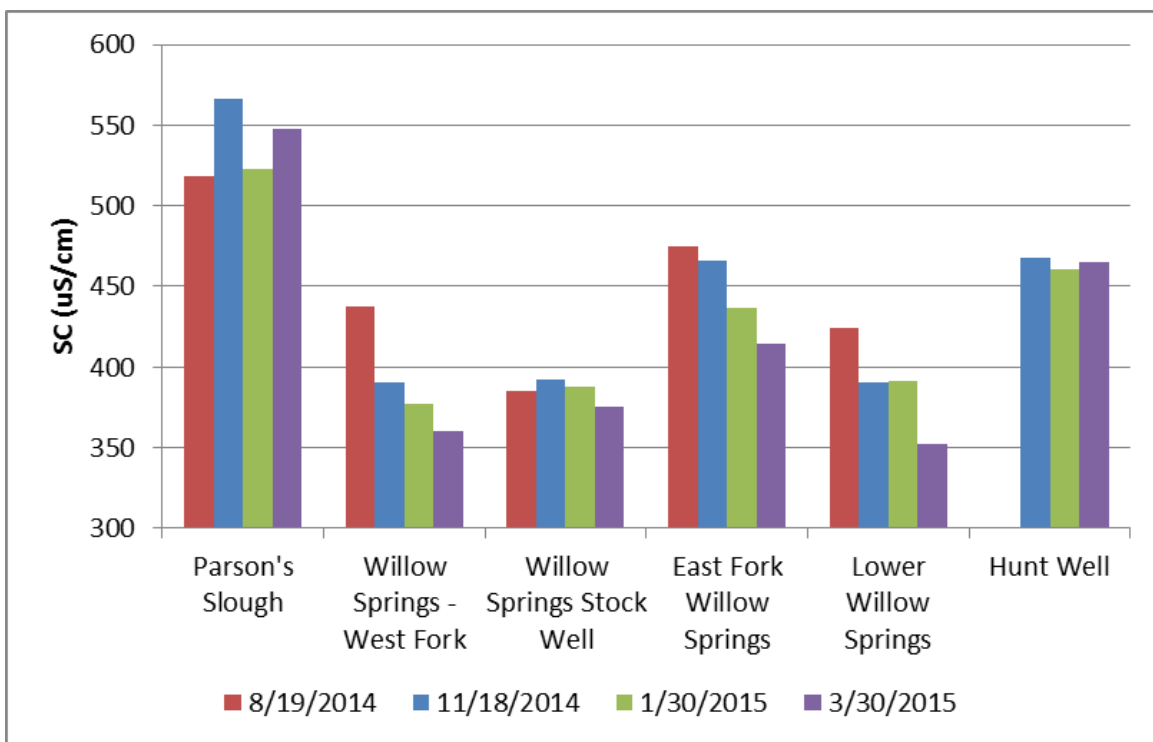


Figure 13. Seasonal Specific Conductivity Measurements of Sites within the Waterloo Area

6. Conclusion

There are many factors that could alter the water table and cause significant changes to groundwater flow in the Waterloo area. The biggest factors affecting the groundwater budget in the Waterloo study area are irrigation ditch seepage, irrigation recharge, and groundwater discharge to the Jefferson River. As such, lining the irrigation ditches could cause significant impact as seepage would be greatly reduced. In addition, major changes to the type of irrigation could also have a significant impact.

There is no evidence of a decline in water levels within the past 9 years to the aquifer. With continual change both in irrigation practices and climate changes are possible, however, more detailed groundwater modeling will be needed to predict the magnitude of the effects. From the groundwater budget, it is evident that seepage and irrigation recharge have the biggest impact on the inflows to the aquifer, and therefore these factors have the potential to make a large impact on the groundwater system. Continued water conservation efforts and monitoring are recommended for the welfare of the Jefferson River.

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Appendix A: Groundwater Budget Data, Graphs & Charts

MOUNTAIN FRONT RECHARGE:

Table A-1. Highland Mountain Vegetation Distribution and ET

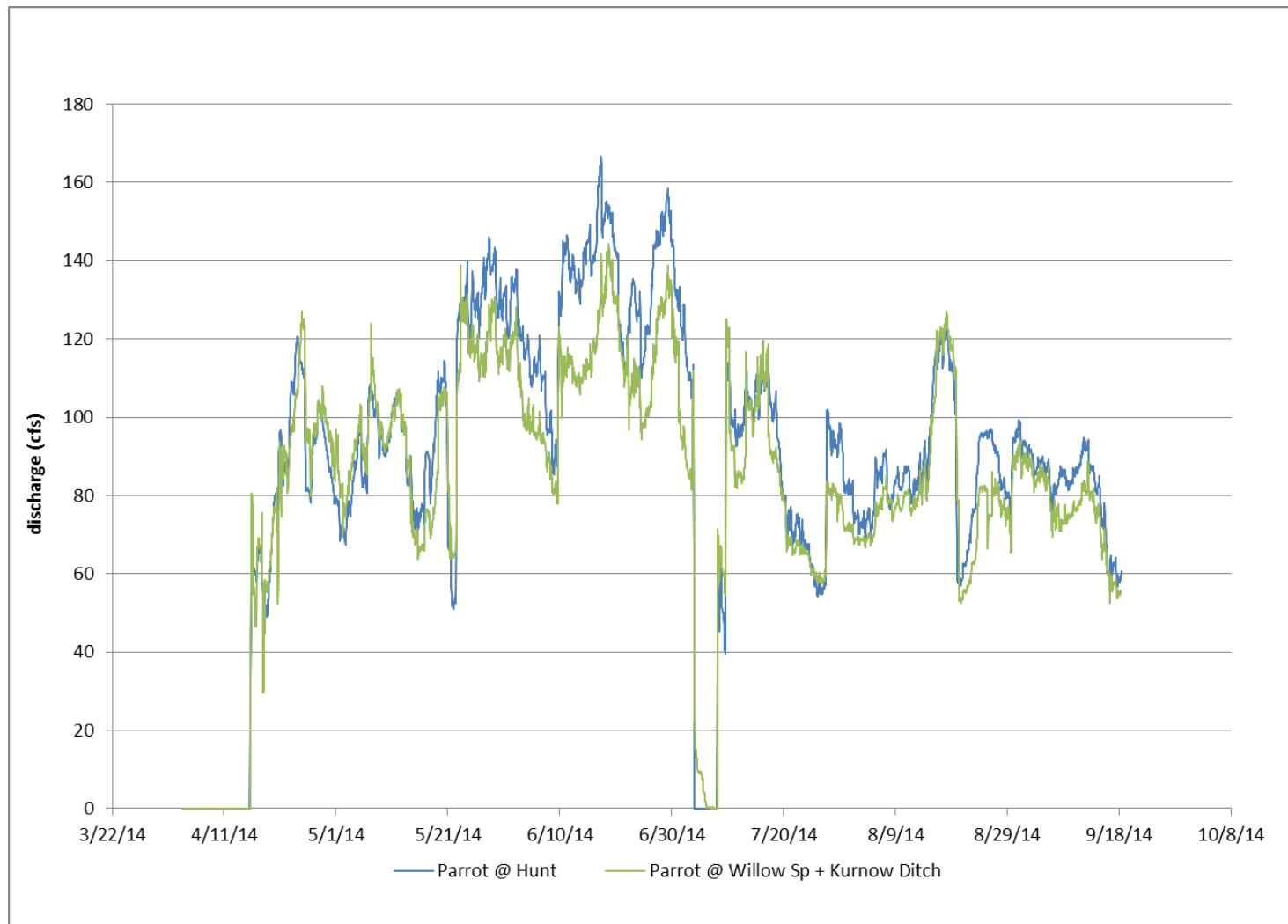
Vegetation Group	Area (Acres)	Evapotranspiration Rate (ft/yr)	ET (Acre-ft/yr)
Upland Sagebrush	5350	1.1	5885
Douglas Fir	8477	1.4	11868
Shrub/Grass Lowlands	9765	1.0	9765
Mixed Evergreen	8290	1.8	14923
High Xeric Grasses	2472	1.2	2967
Ag lands	309	2.1	650
Mesic Meadow	1216	1.7	2067
Whitebark Pine	2838	2.2	6244
Alpine Rangeland, Deciduous Shrubs	864	2.0	1728
Developed	186	1.0	186
Riparian	170	2.3	392
TOTAL	39939		56674

Table A-2. Tobacco Root Mountain Vegetation Distribution and ET

Vegetation Group	Area (Acres)	Evapotranspiration Rate (ft/yr)	ET (Acre-ft/yr)
Upland Sagebrush	4593	1.1	5053
Douglas Fir	12941	1.4	18118
Shrub/Grass Lowlands	2046	1.0	2046
Mixed Evergreen	3215	1.8	5787
High Xeric Grasses	343	1.2	412
Ag lands	1995	2.1	4190
Mesic Meadow	757	1.7	1287
Whitebark Pine	1492	2.2	3283
Alpine Rangeland, Deciduous Shrubs	181	2.0	361
Developed	206	1.0	206
Riparian	422	2.3	971
TOTAL	28193		41715

Table A-3. Precipitation in the Highland and Tobacco Root Mountains

Precipitation	Highland Mountains	Tobacco Root Mountains
Minimum (in/yr)	9.95	10.02
Maximum (in/yr)	32.27	42.20
Average (in/yr)	18.36	19.02
Area (acres)	39,939	28,193
Total Precipitation (acre-ft/yr)	61,106	44,686

SEEPAGE:**Figure A-1. Parrot Ditch Seepage Hydrograph**

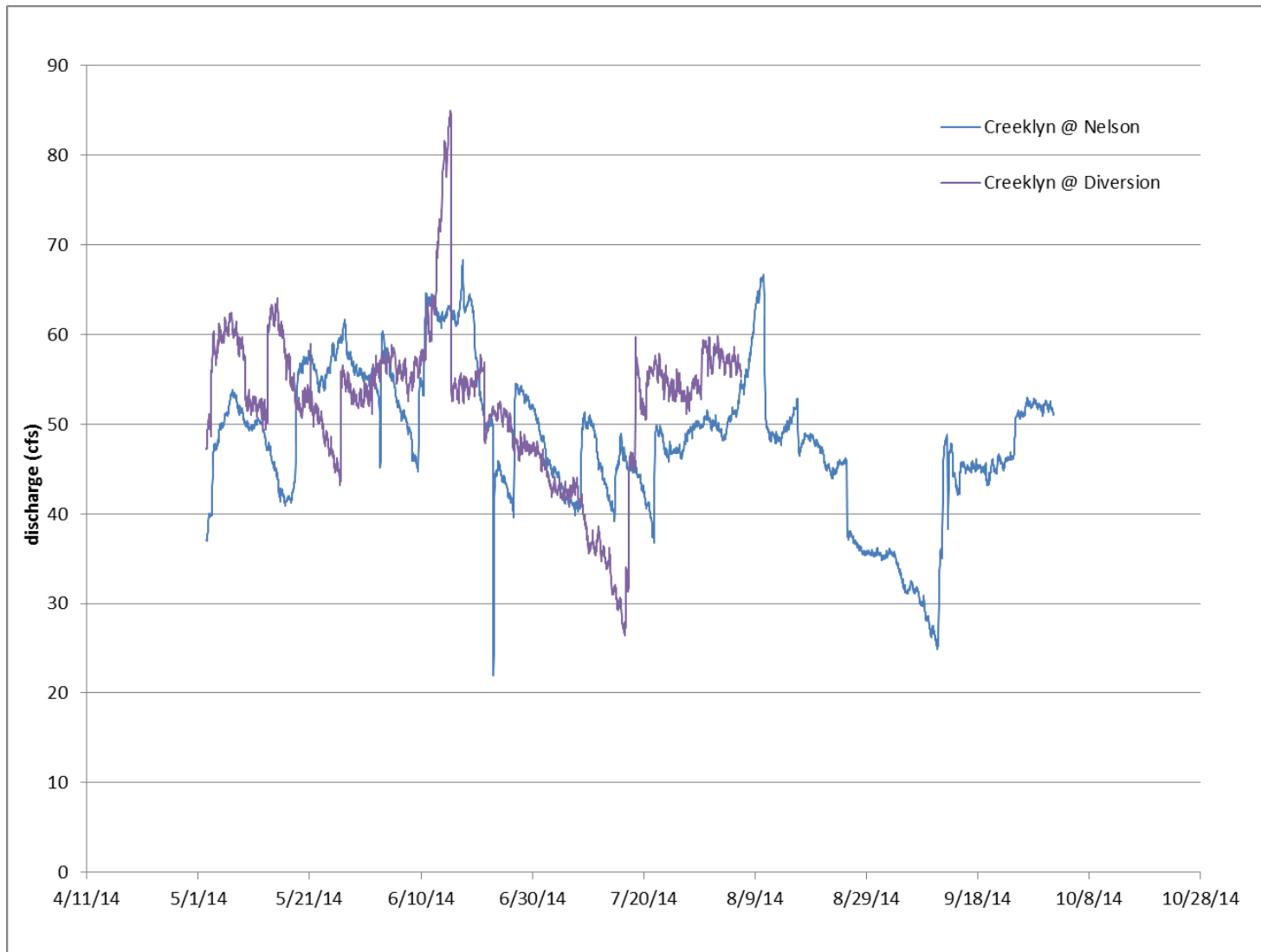


Figure A-2. Creeklyn Ditch Seepage Hydrograph

IRRIGATION RECHARGE:**Table A-4.1. IWR Outputs for Pasture Grass**

Irrigation Method	Flood			Sprinkler			Pivot		
	Min	Mid-range	Max	Min	Mid-range	Max	Min	Mid-range	Max
Application Efficiency	35%	25%	15%	75%	65%	60%	85%	80%	70%
	inches	inches	inches	inches	inches	inches	inches	inches	inches
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	2.48	3.60	6.21	0.00	0.03	0.15	-0.33	-0.26	-0.08
June	8.98	13.11	22.74	1.20	1.94	2.41	0.64	0.90	1.55
July	12.25	18.02	31.49	1.68	2.72	3.37	0.89	1.26	2.16
August	10.38	15.28	26.69	1.43	2.30	2.85	0.76	1.07	1.83
September	4.24	6.27	11.02	0.15	0.52	0.75	-0.13	0.00	0.32
October	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Annual	38.33	56.28	98.14	4.47	7.51	9.53	1.83	2.99	5.79

Table A-4.2. IWR Outputs for Alfalfa Hay

Irrigation Method	Flood			Sprinkler			Pivot		
	Min	Mid-range	Max	Min	Mid-range	Max	Min	Mid-range	Max
Application Efficiency	35%	25%	15%	75%	65%	60%	85%	80%	70%
	inches	inches	inches	inches	inches	inches	inches	inches	inches
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	3.56	5.21	9.05	-0.03	0.27	0.45	-0.26	-0.15	0.11
June	11.22	16.45	28.63	4.26	5.20	5.78	0.76	1.09	1.91
July	14.86	21.92	38.37	5.46	6.73	7.52	1.04	1.49	2.59
August	12.28	18.10	31.67	4.52	5.57	6.22	0.87	1.24	2.15
September	5.13	7.60	13.36	1.84	2.28	2.56	-0.07	0.09	0.48
October	0	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Annual	47.05	69.26	121.07	16.05	20.03	22.52	2.34	3.77	7.24

Table A-4.3. IWR Outputs for Natural Grass (50/50 Alfalfa and Grass)

Irrigation Method	Flood			Sprinkler			Pivot		
	Min	Mid-range	Max	Min	Mid-range	Max	Min	Mid-range	Max
Application Efficiency	35%	25%	15%	75%	65%	60%	85%	80%	70%
	inches	inches	inches	inches	inches	inches	inches	inches	inches
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	3.02	4.40	7.63	-0.10	0.15	0.30	-0.29	-0.20	0.01
June	10.10	14.78	25.68	1.34	2.18	2.70	0.70	1.00	1.73
July	13.56	19.97	34.93	1.85	3.00	3.72	0.96	1.38	2.38
August	11.33	16.69	29.18	1.55	2.51	3.11	0.81	1.16	1.99
September	4.68	6.93	12.19	0.21	0.62	0.87	-0.10	0.05	0.40
October	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Annual	42.69	62.77	109.61	4.84	8.44	10.70	2.08	3.38	6.51

Table A-4.4. IWR Outputs for Other (Including barley, corn, & oats)

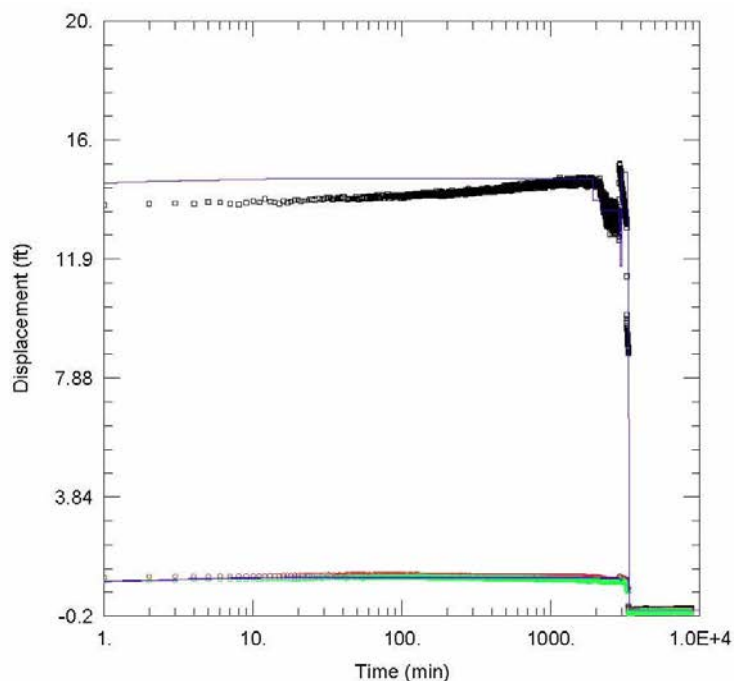
Irrigation Method	Flood			Sprinkler			Pivot		
	Min	Mid-range	Max	Min	Mid-range	Max	Min	Mid-range	Max
Application Efficiency	35%	25%	15%	75%	65%	60%	85%	80%	70%
	inches	inches	inches	inches	inches	inches	inches	inches	inches
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	0	0	0
April	0	0	0	0	0	0	0	0	0
May	0.21	0.21	0.21	-0.42	-0.42	-0.42	-0.42	-0.42	-0.42
June	8.37	12.20	21.14	1.09	1.78	2.21	0.57	0.82	1.41
July	16.04	23.67	41.46	2.15	3.52	4.38	1.11	1.60	2.79
August	11.72	17.26	30.19	1.59	2.59	3.21	0.83	1.19	2.06
September	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
October	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
Annual	36.85	53.86	93.53	4.95	8.00	9.90	2.61	3.71	6.36

Figure A-3. NRCS Web Soil Survey Soil Type Map (Soil types listed on pg 61)

Table A-5. NRCS Web Soil Survey Soil Types for Waterloo

Jefferson County Area and Part of Silver Bow County, Montana (MT627)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
1	Riverwash	11.6	0.10%
6	Wetsand, Cardwell, and Clunton soils, 0 to 8 percent slopes, channeled	119.9	1.50%
48A	Riverrun sandy loam, 0 to 2 percent slopes	53.5	0.70%
52A	Ryell loam, 0 to 2 percent slopes	120.7	1.50%
232A	Clunton-Wetsand-Bonebasin complex, 0 to 2 percent slopes	90.7	1.20%
274A	Bronec complex, 0 to 2 percent slopes	6.2	0.10%
341A	Pieriver-Cardwell-Riverrun loams, 0 to 2 percent slopes	26.9	0.30%
481A	Riverrun gravelly sandy loam, 0 to 2 percent slopes	203	2.60%
521A	Cardwell-Riverrun complex, 0 to 2 percent slopes	153.4	1.90%
781A	Vendome sandy loam, 0 to 8 percent slopes	618.5	7.90%
W	Water	36.2	0.50%
	Subtotals for Soil Survey Area	1,440.4	18.30%
Madison County Area, Montana (MT636)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
33	Crago gravelly loam, cool, 0 to 8 percent slopes	201.1	2.60%
37	Crago-Scravo complex, cool, 15 to 45 percent slopes	39.3	0.50%
58	Havre loam, cool, 0 to 2 percent slopes	381.6	4.80%
61	Kalsted sandy loam, 0 to 2 percent slopes	837.1	10.60%
62	Kalsted sandy loam, 2 to 8 percent slopes	126.8	1.60%
86	Neen silty clay loam, 0 to 2 percent slopes	1,201.6	15.30%
87	Neen silty clay loam, drained, 0 to 2 percent slopes	26.9	0.30%
88	Neen silty clay loam, wet, 0 to 2 percent slopes	794.5	10.10%
106	Rivra, cool-Fluvaquents complex, 0 to 2 percent slopes	857.2	10.90%
107	Rivra-Ryell-Havre complex, cool, 0 to 2 percent slopes	480.1	6.10%
110	Ryell-Rivra complex, cool, 0 to 2 percent slopes	744.3	9.40%
114	Scravo sandy loam, cool, 2 to 8 percent slopes	161.8	2.10%
132	Thess loam, cool, 2 to 8 percent slopes	51.7	0.70%
143	Trudau loam, 2 to 8 percent slopes	1.5	0.00%
147	Varney clay loam, 2 to 8 percent slopes	52.9	0.70%
150	Villy silty clay loam, cool, 0 to 2 percent slopes	63.8	0.80%
217	Bronec-Amesha complex, 2 to 8 percent slopes	0.5	0.00%
230	Vendome sandy loam, 0 to 8 percent slopes	290.6	3.70%
231	Water	123.9	1.60%
	Subtotals for Soil Survey Area	6,437.1	81.70%
	Totals for Area of Interest	7,877.5	100.00%

AQUIFER TEST RESULTS:



HUNTA AQUIFER TEST

Data Set: M:\...HuntA_CR_all_Leaky.aqt
Date: 04/03/15

Time: 15:04:27

PROJECT INFORMATION

Company: MBMG
Client: HuntA
Project: BWIPUJ
Location: Upper Jefferson
Test Well: PW
Test Date: 2/24/15

AQUIFER DATA

Saturated Thickness: 100. ft
Aquitard Thickness (b'): 1. ft

Anisotropy Ratio (Kz/Kr): 0.1
Aquitard Thickness (b''): 1. ft

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
PW	0	0	□ PW	0	0
			◊ OW1	-1.112	22.767
			▲ OW2	-21.792	2.695

SOLUTION

Aquifer Model: Leaky

Solution Method: Hantush-Jacob

$T = 1.1E+5 \text{ ft}^2/\text{day}$
 $1/B = 8.55E-5 \text{ ft}^{-1}$
 $C = 0.00012 \text{ min}^2/\text{ft}^5$

$S = 1.0E-5$
 $Sw = 2.02$
 $P = 2.78$

Step Test Model: Jacob-Rorabaugh

$s(t) = 0.06485Q + 0.00012Q^{2.78}$

Time (t) = 1. min Rate (Q) in cu. ft/min

W.E. = 31.53% (Q from last step)

Figure A-4. MBMG HA1 Aquifer Test Results for Leaky Hantush-Jacob Model (Bobst, personal communication, 2015)

Appendix B: Surface Water Hydrographs

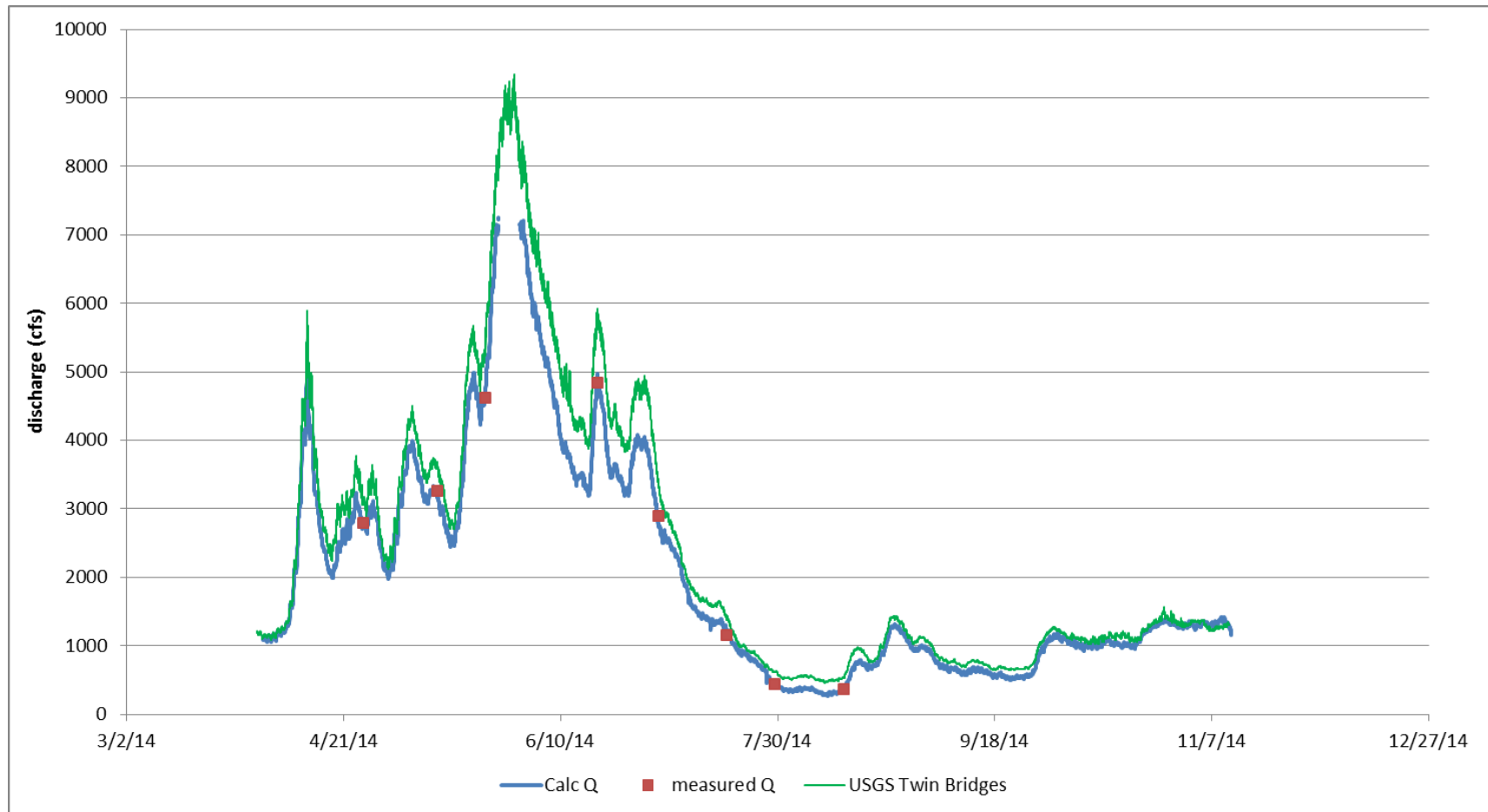


Figure B-1. Surface Water Hydrograph of Calculated Flow and Manual Measurements at Jefferson River at Silver Star and USGS Twin Bridges Flow

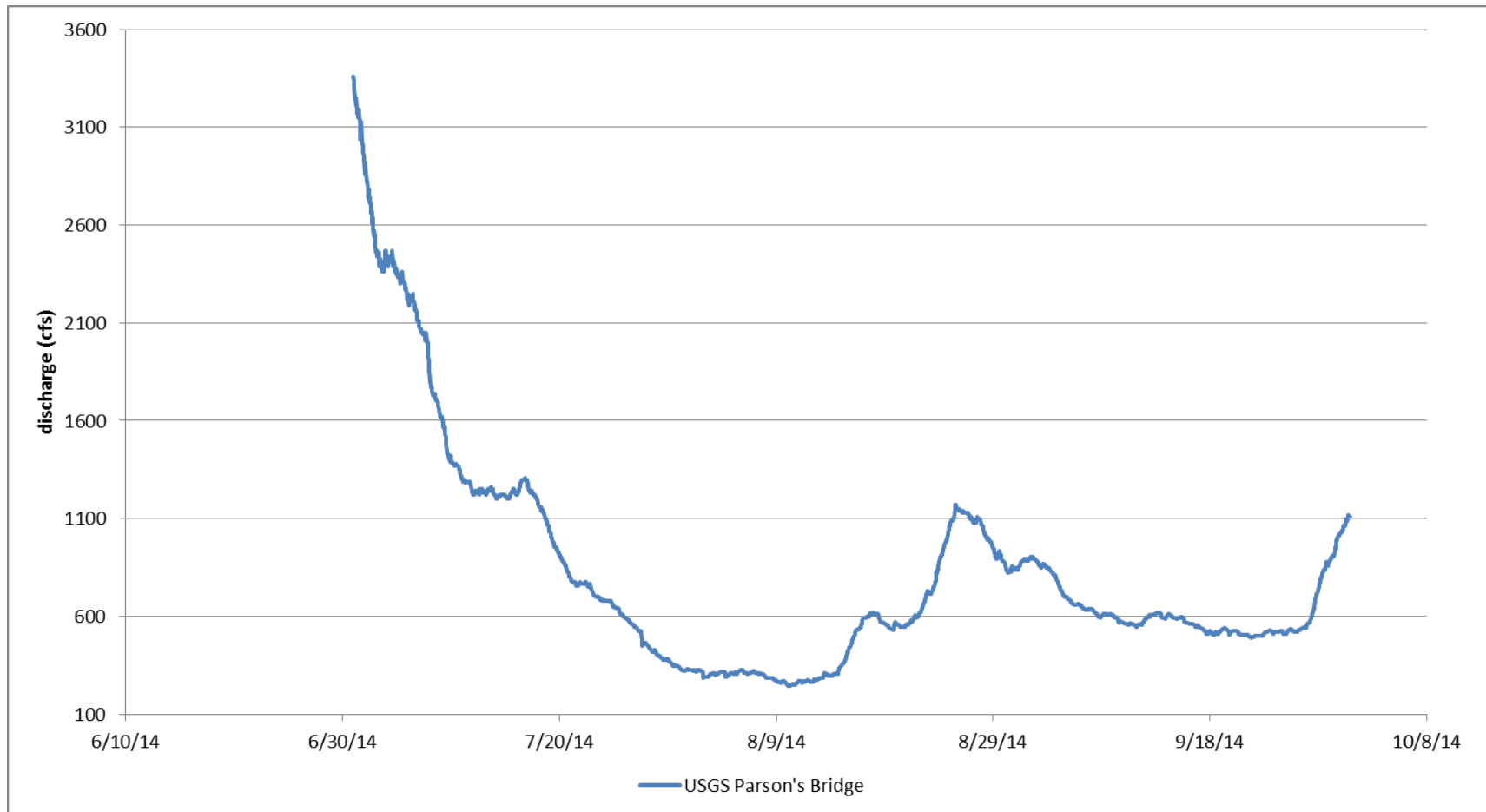


Figure B-2. Surface Water Hydrograph of Jefferson River at USGS Parson's Bridge

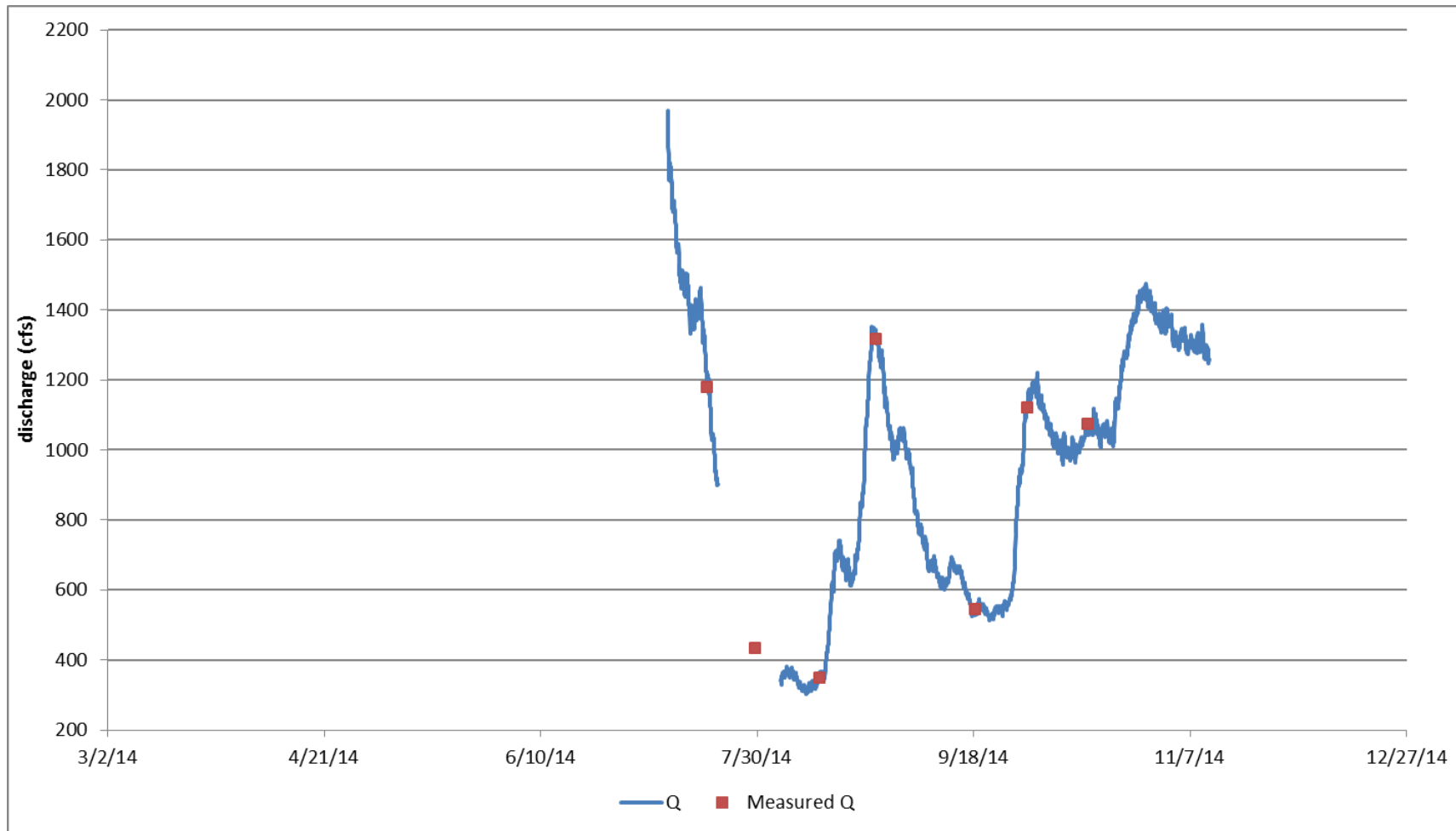


Figure B-3. Surface Water Hydrograph of Jefferson River at Corbett's

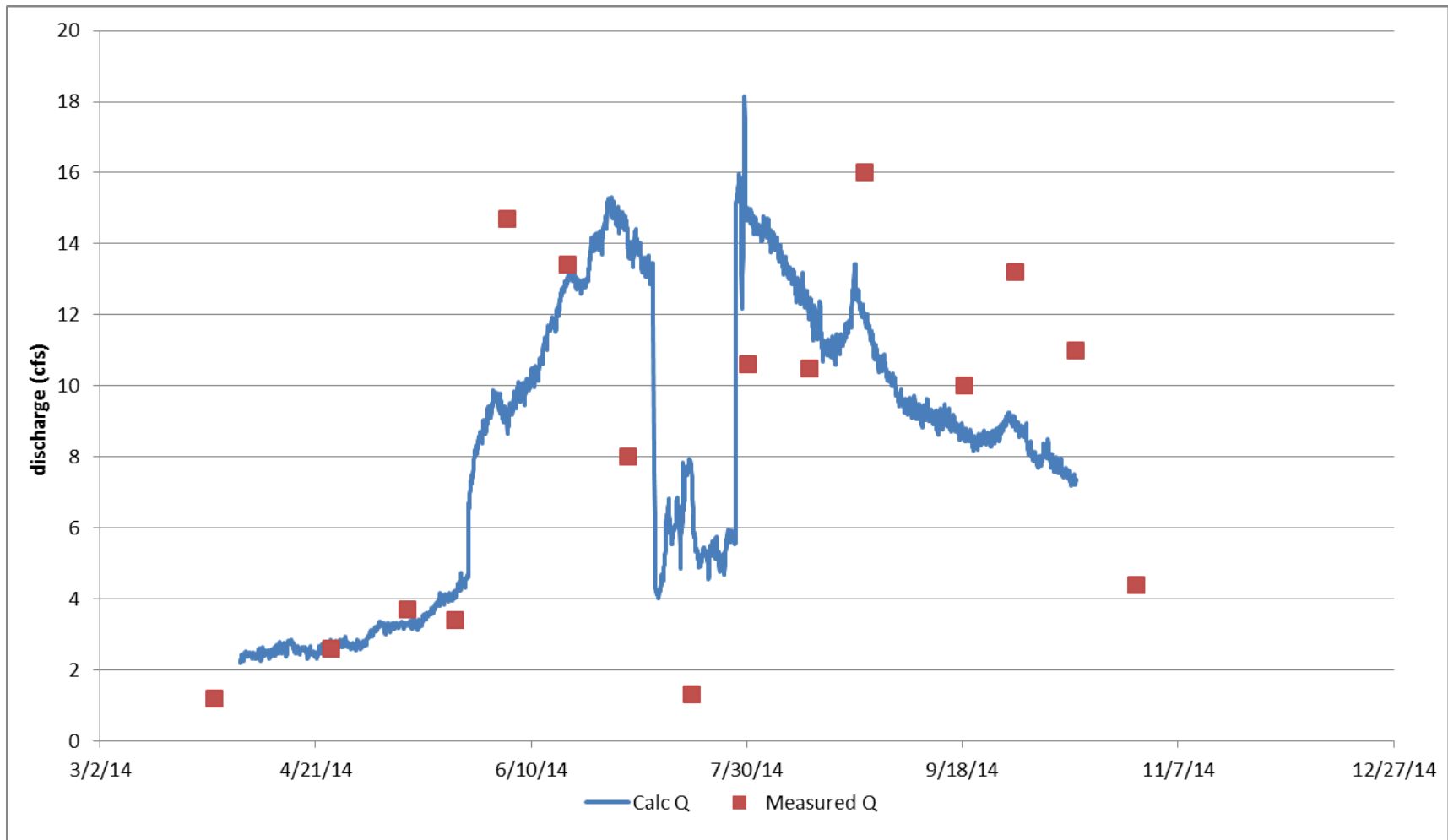


Figure B-4. Surface Water Hydrograph of Parson's Slough at Loomont Road

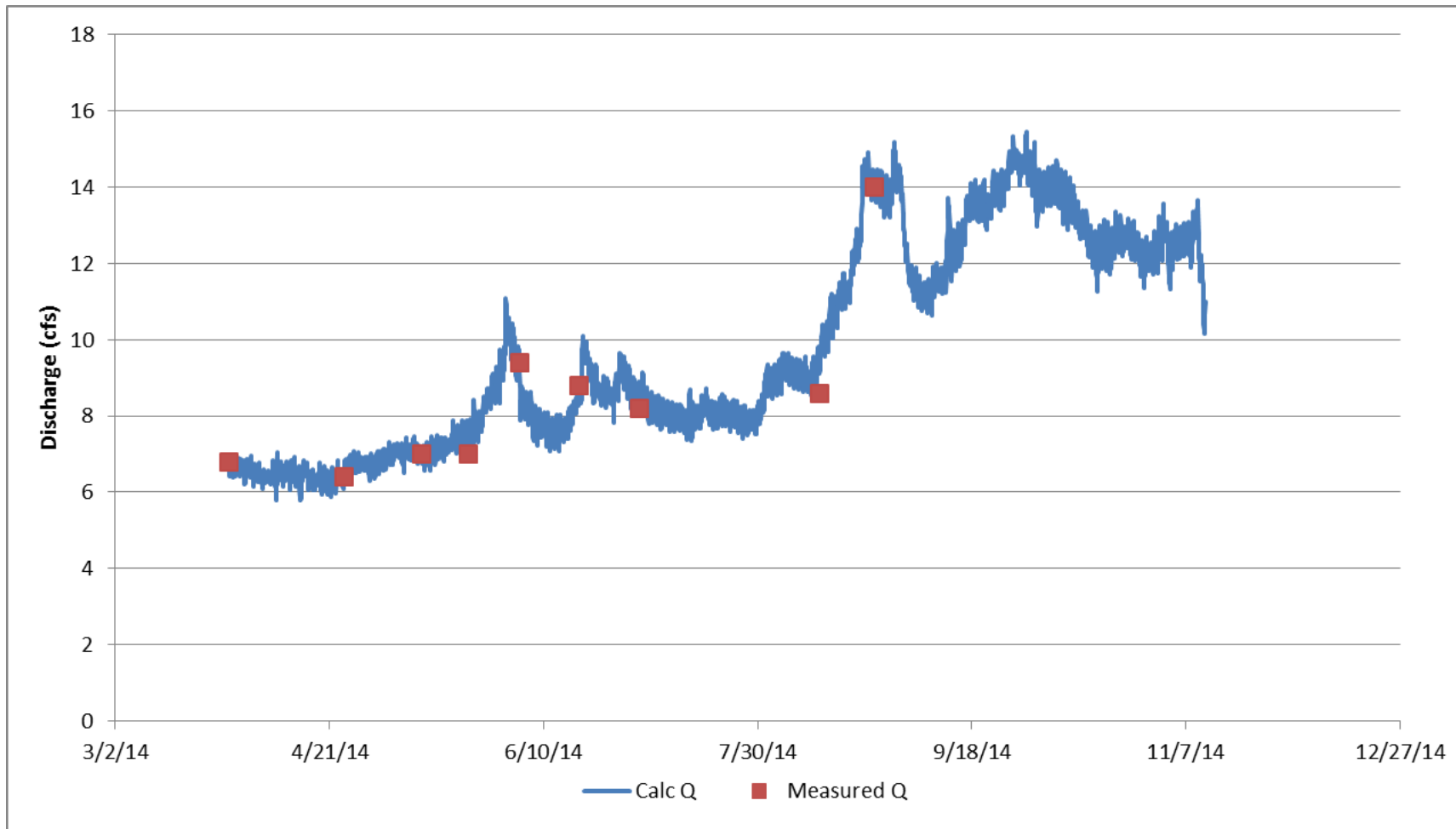


Figure B-5. Surface Water Hydrograph of West Fork of Willow Springs

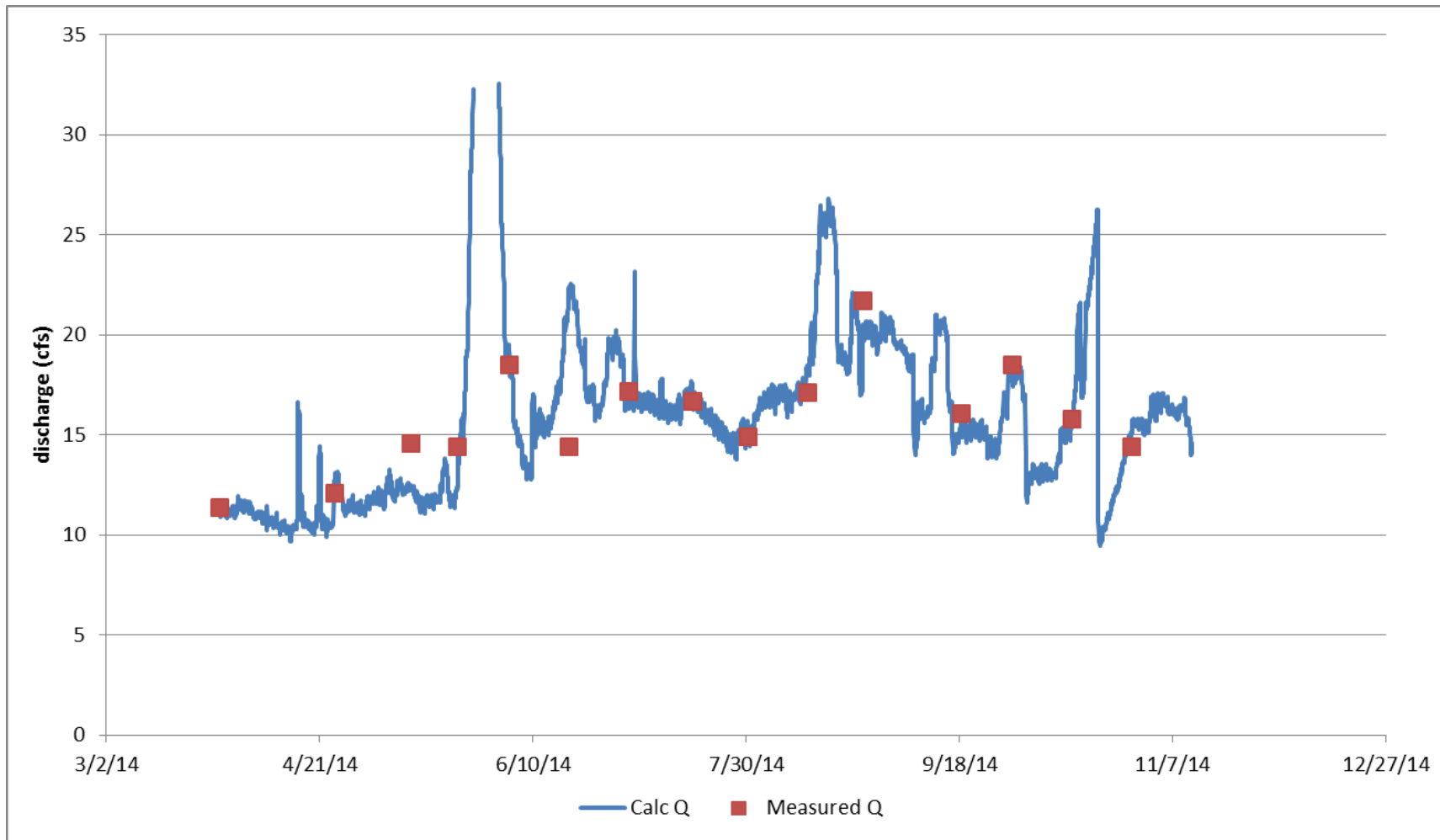


Figure B-6. Surface Water Hydrograph of Lower Willow Springs

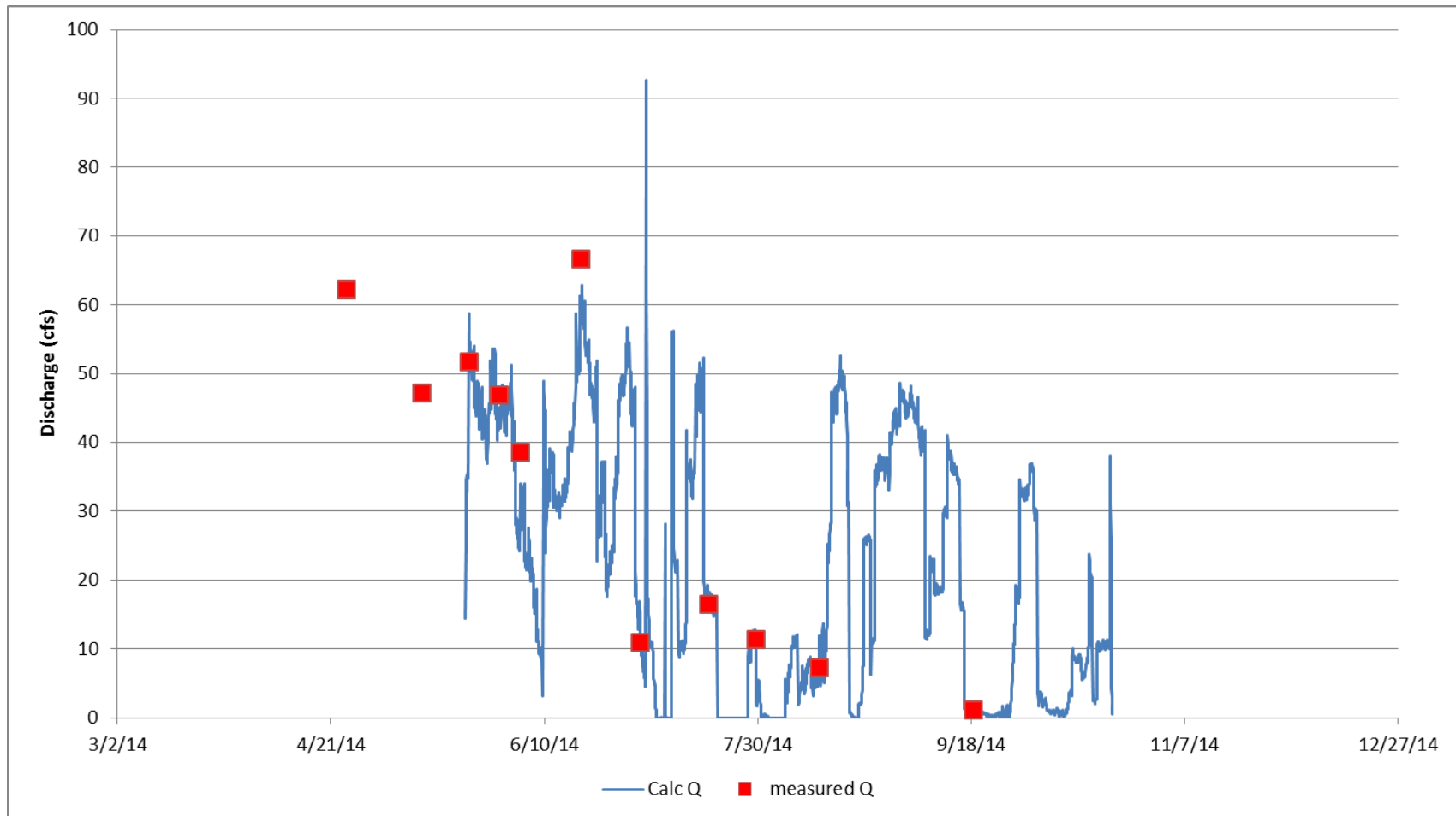


Figure B-7. Surface Water Hydrograph of Kurnow Ditch (Parrot Ditch Blowoff)

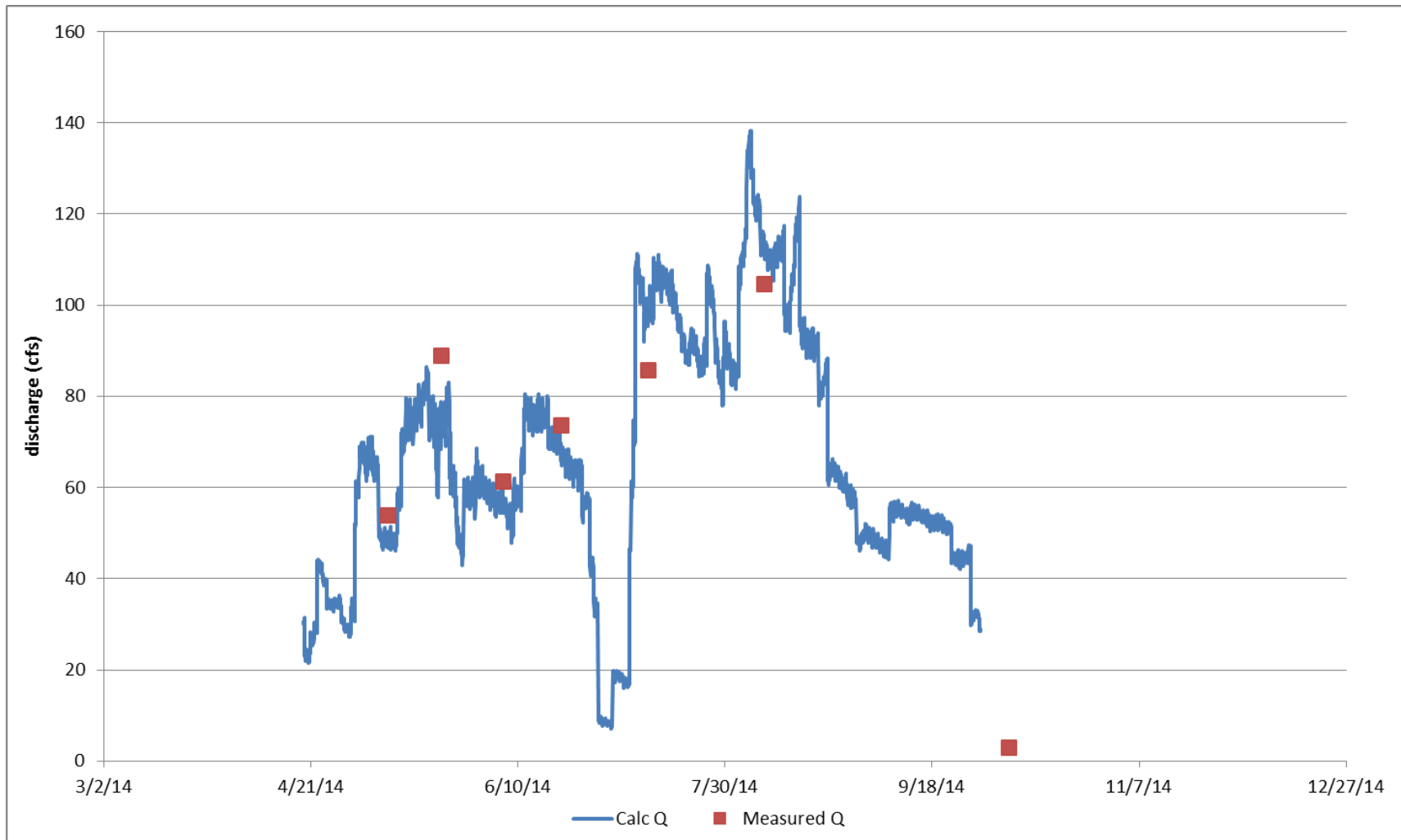


Figure B-8. Surface Water Hydrograph of Jefferson Canal at Diversion

Appendix C: Static Water Elevations (MBMG – WET Comparison)



Figure C-1. Static Water Elevations for Willow 1

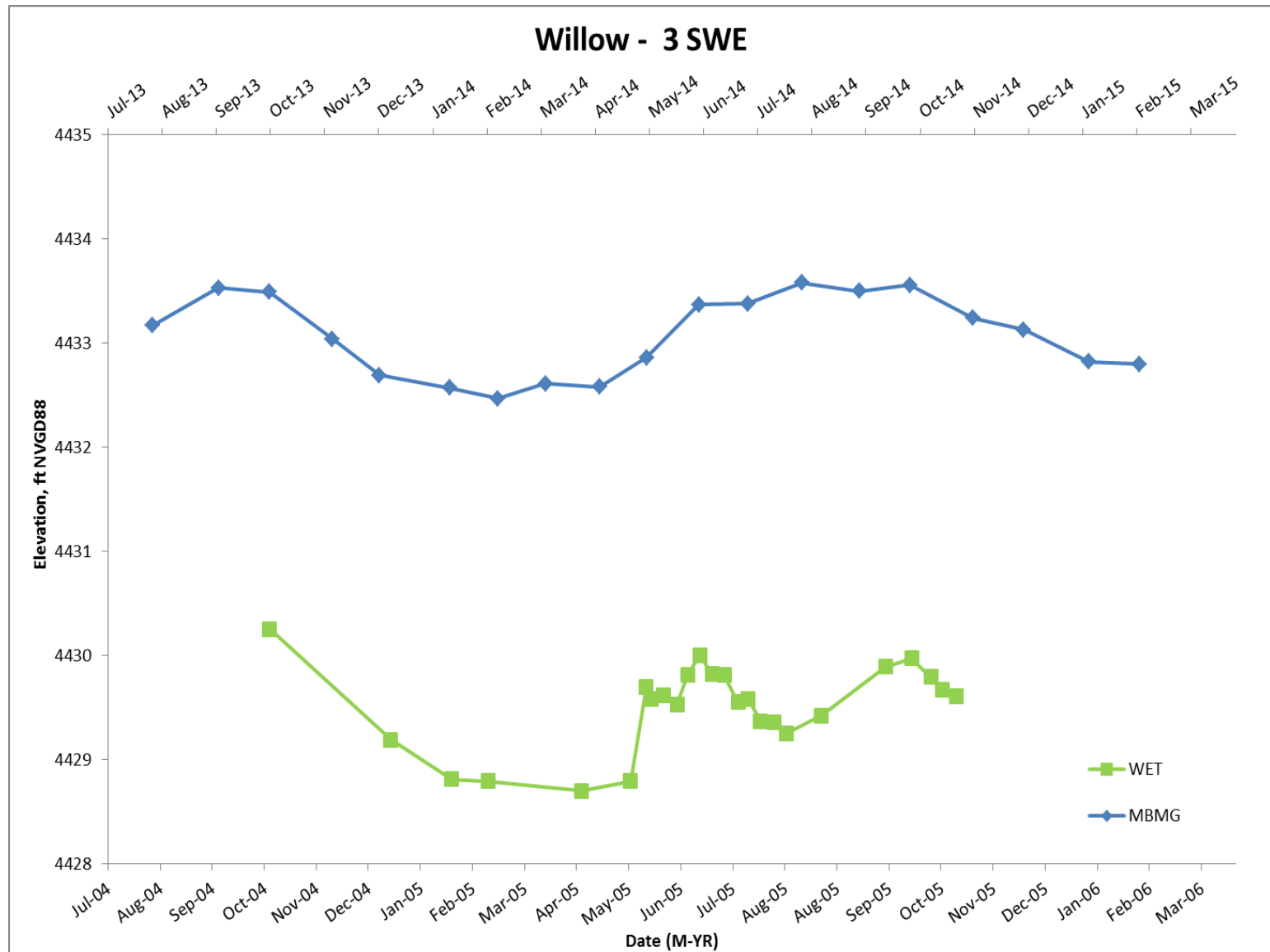


Figure C-2. Static Water Elevations for Willow 3

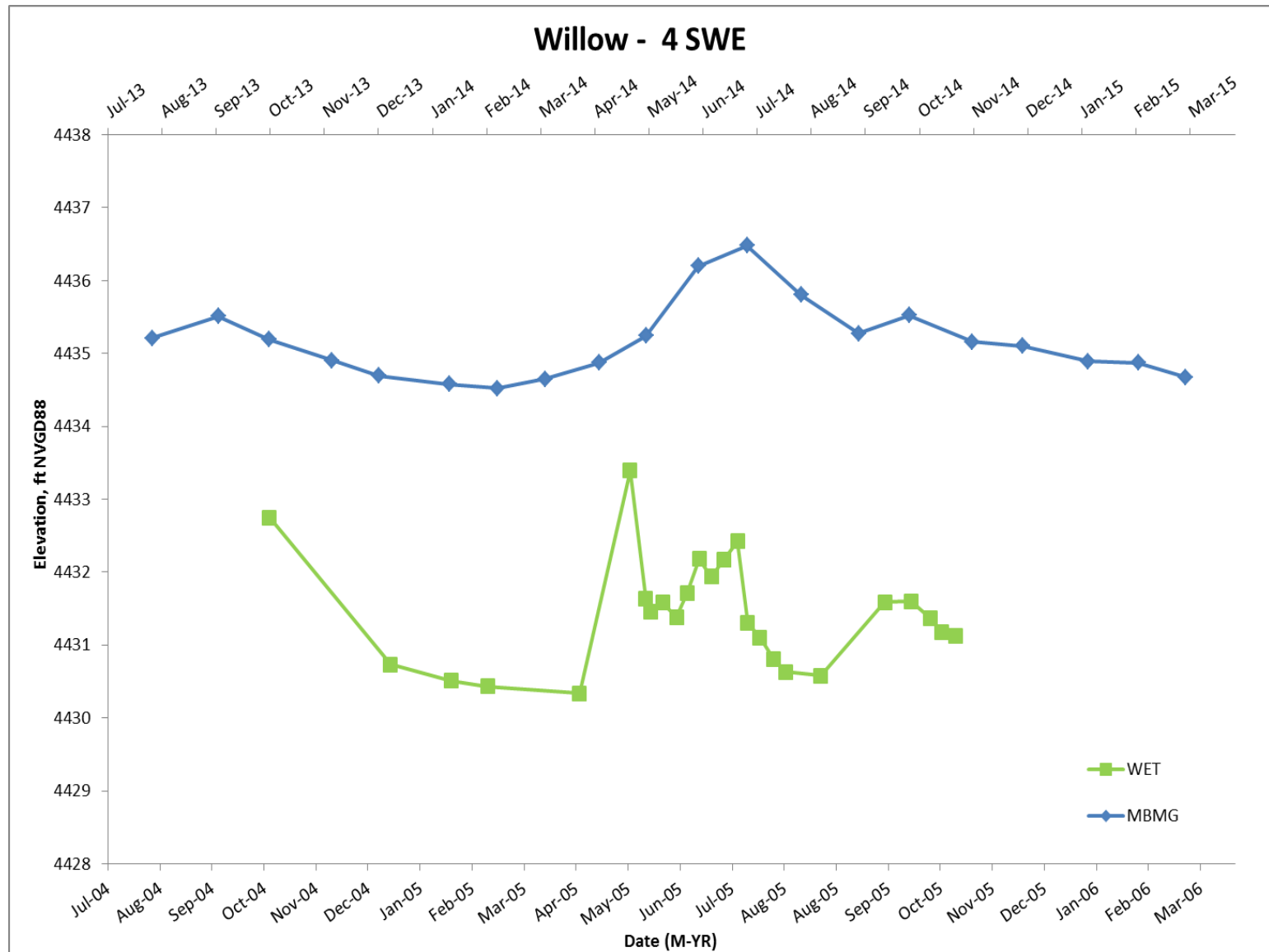


Figure C-3. Static Water Elevations for Willow 4

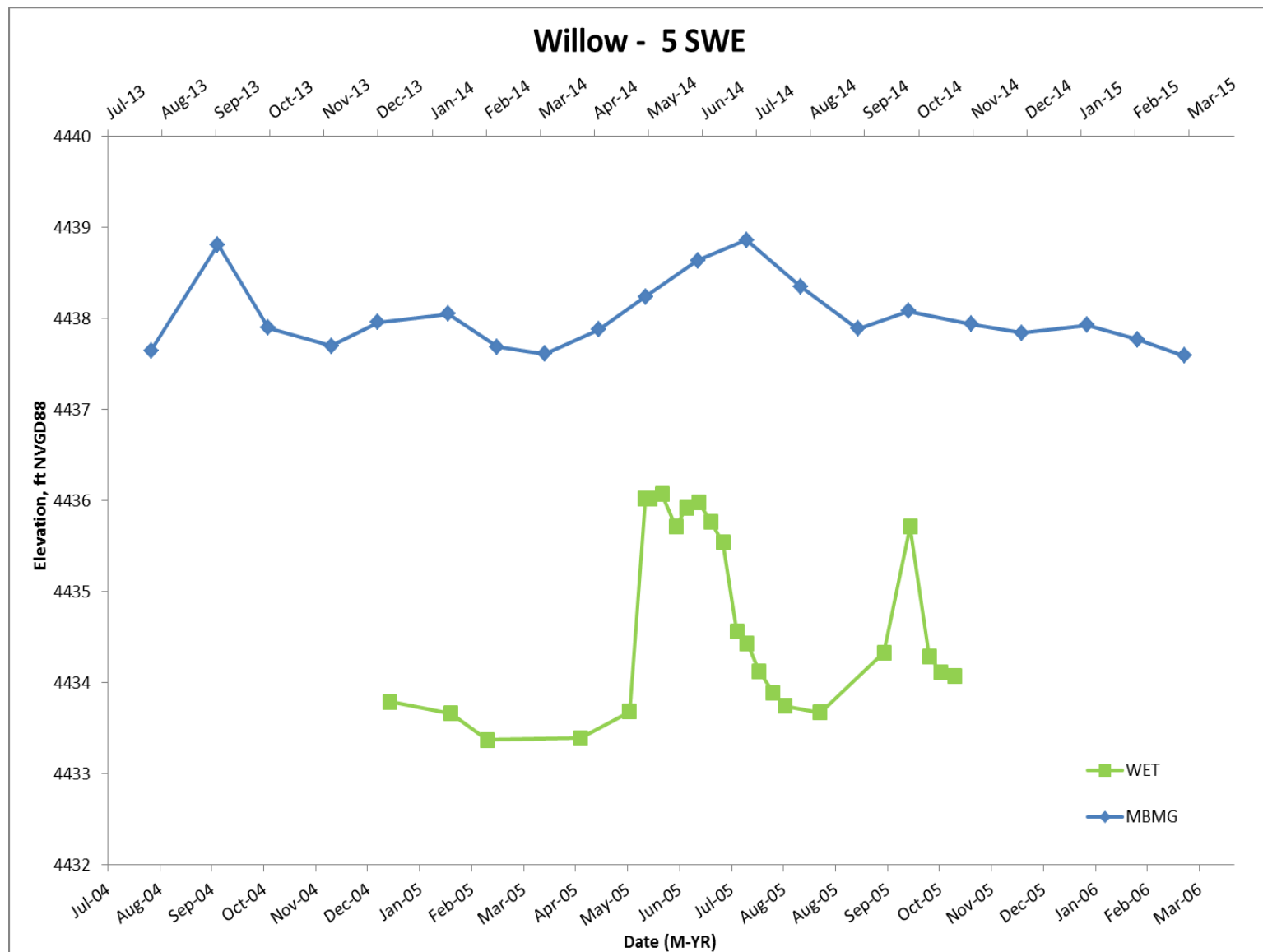


Figure C-4. Static Water Elevations for Willow 5



Figure C-5. Static Water Elevations for Willow 6

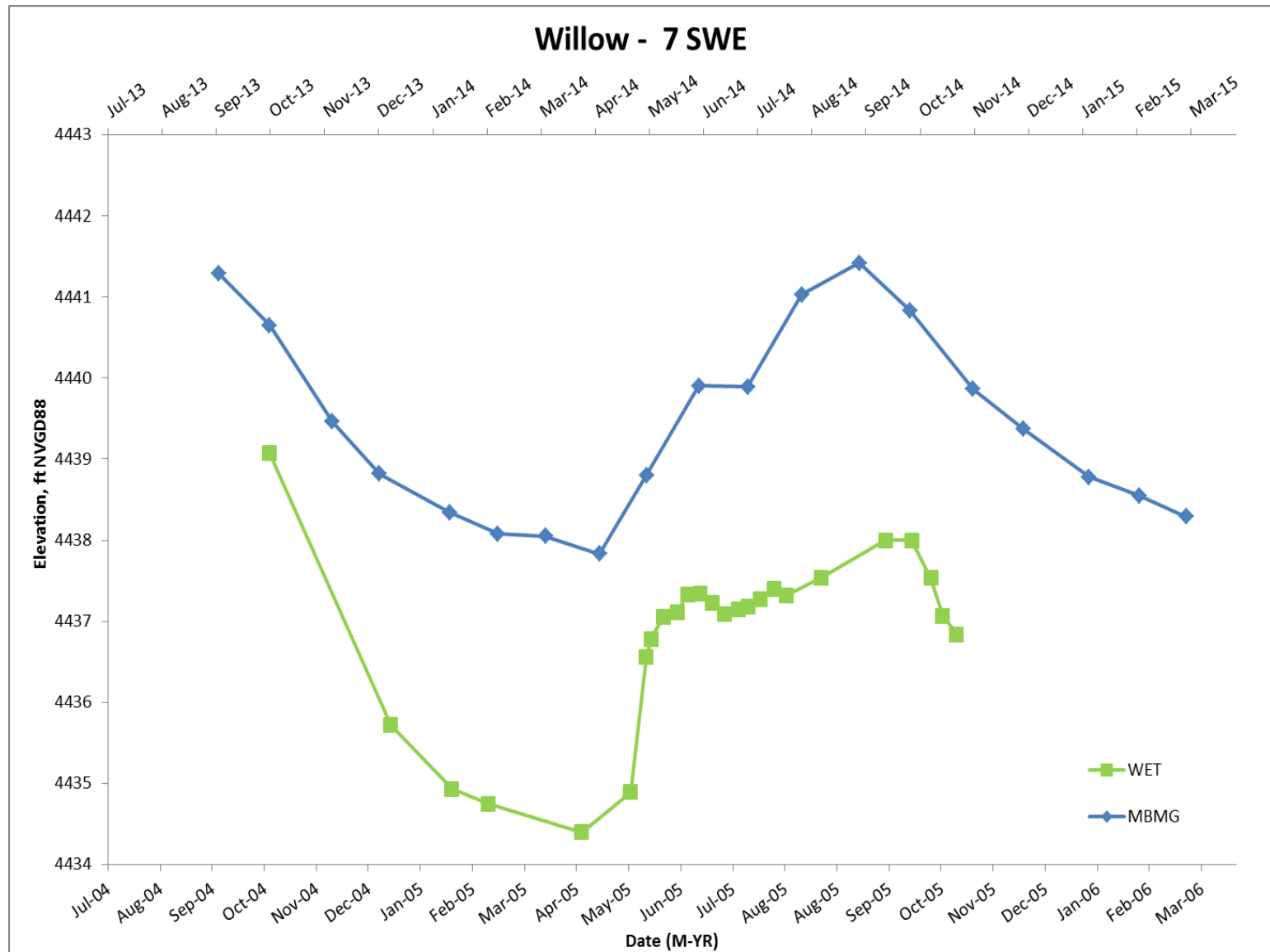


Figure C-6. Static Water Elevations for Willow 7

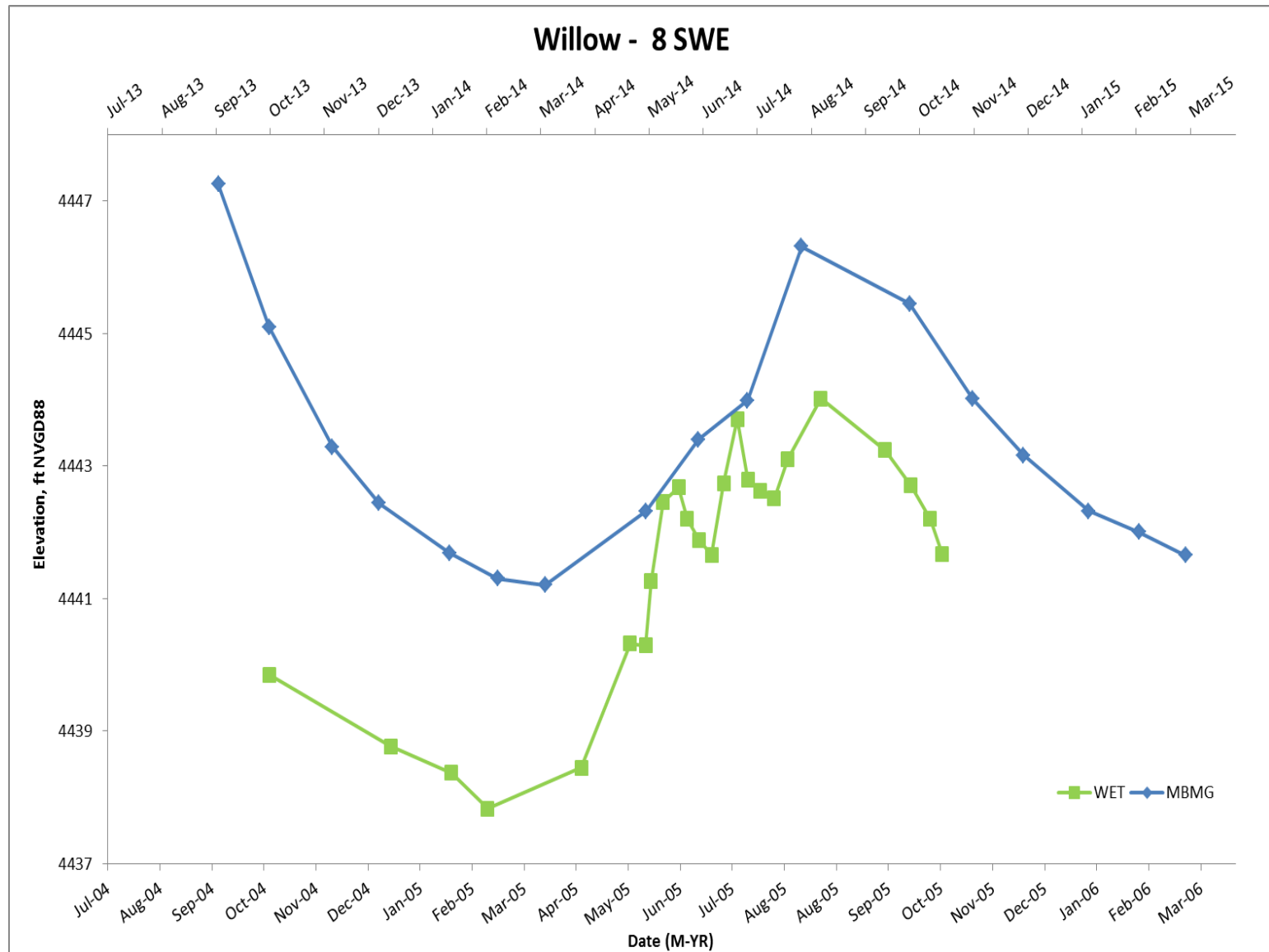


Figure C-7. Static Water Elevations for Willow 8

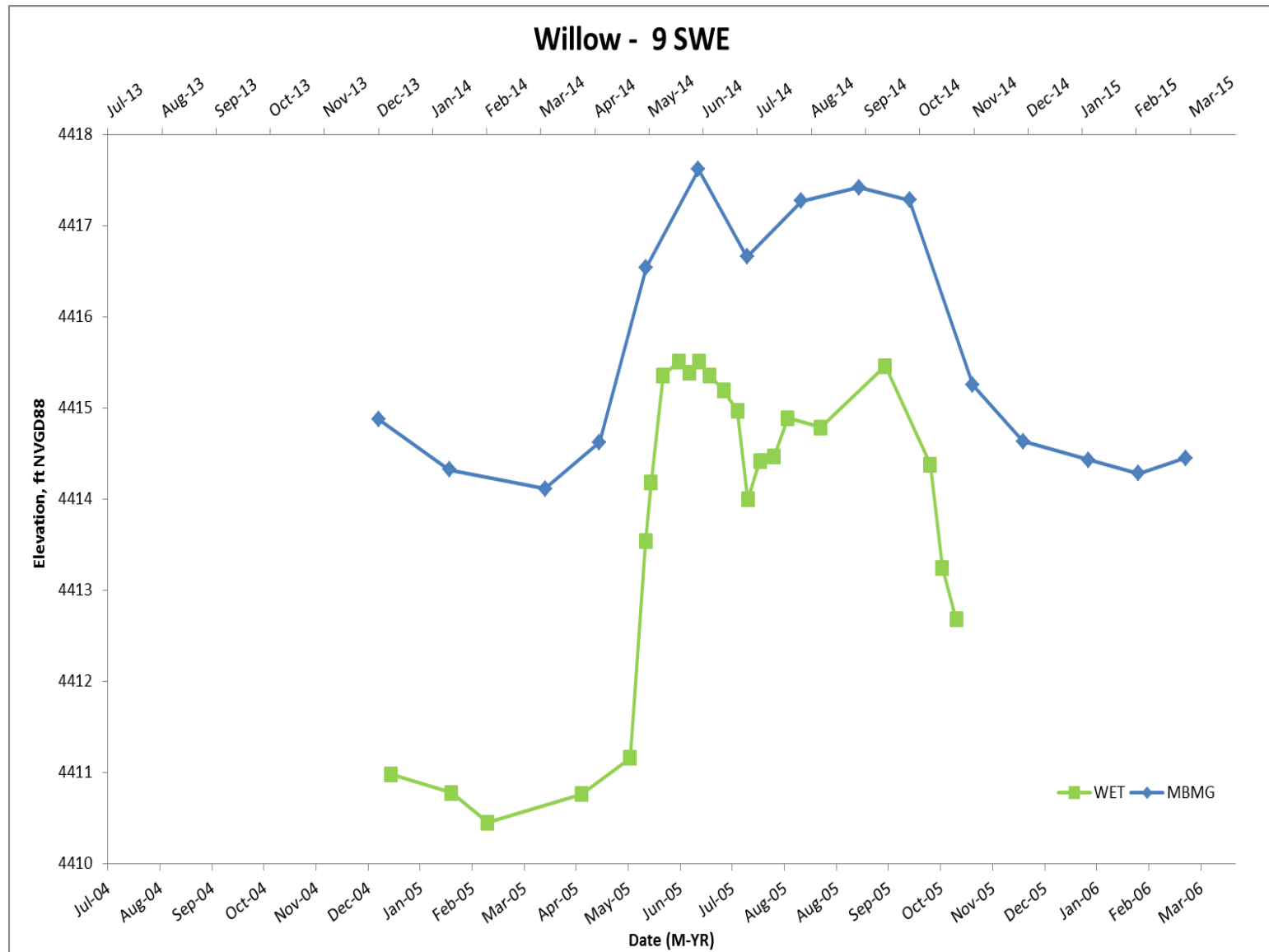


Figure C-8. Static Water Elevations for Willow 9

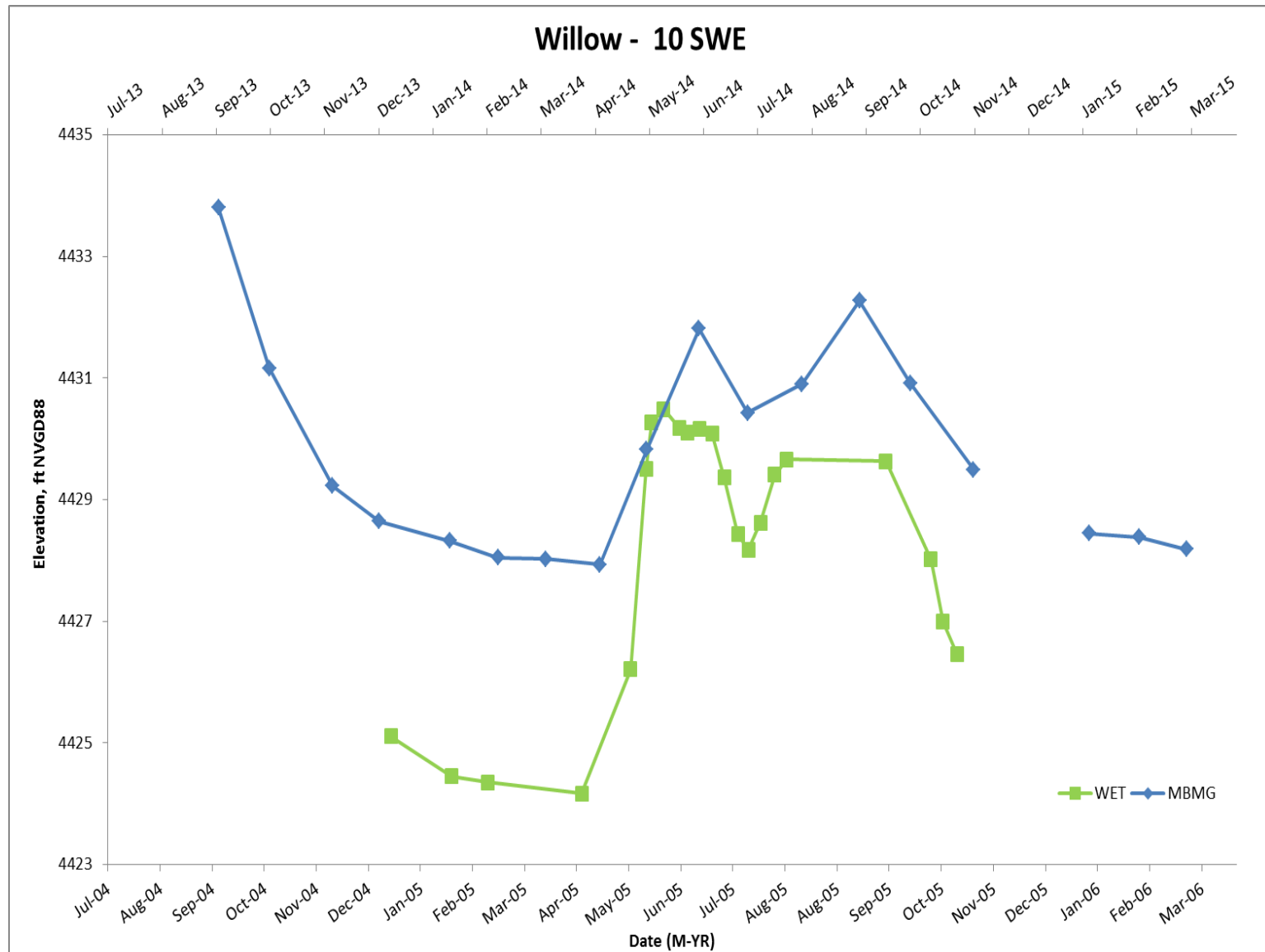


Figure C-9. Static Water Elevations for Willow 10

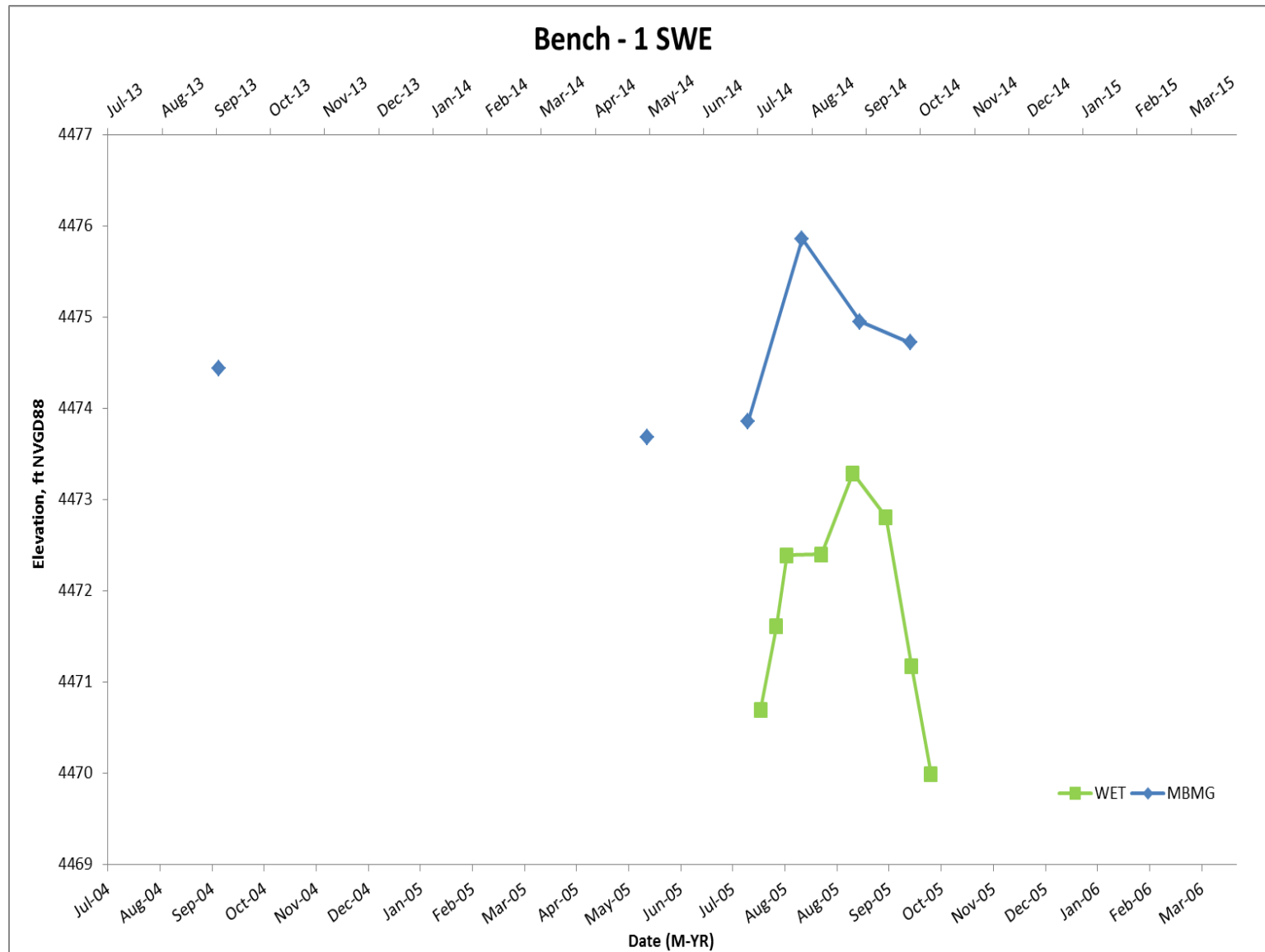


Figure C-10. Static Water Elevations for Bench 1

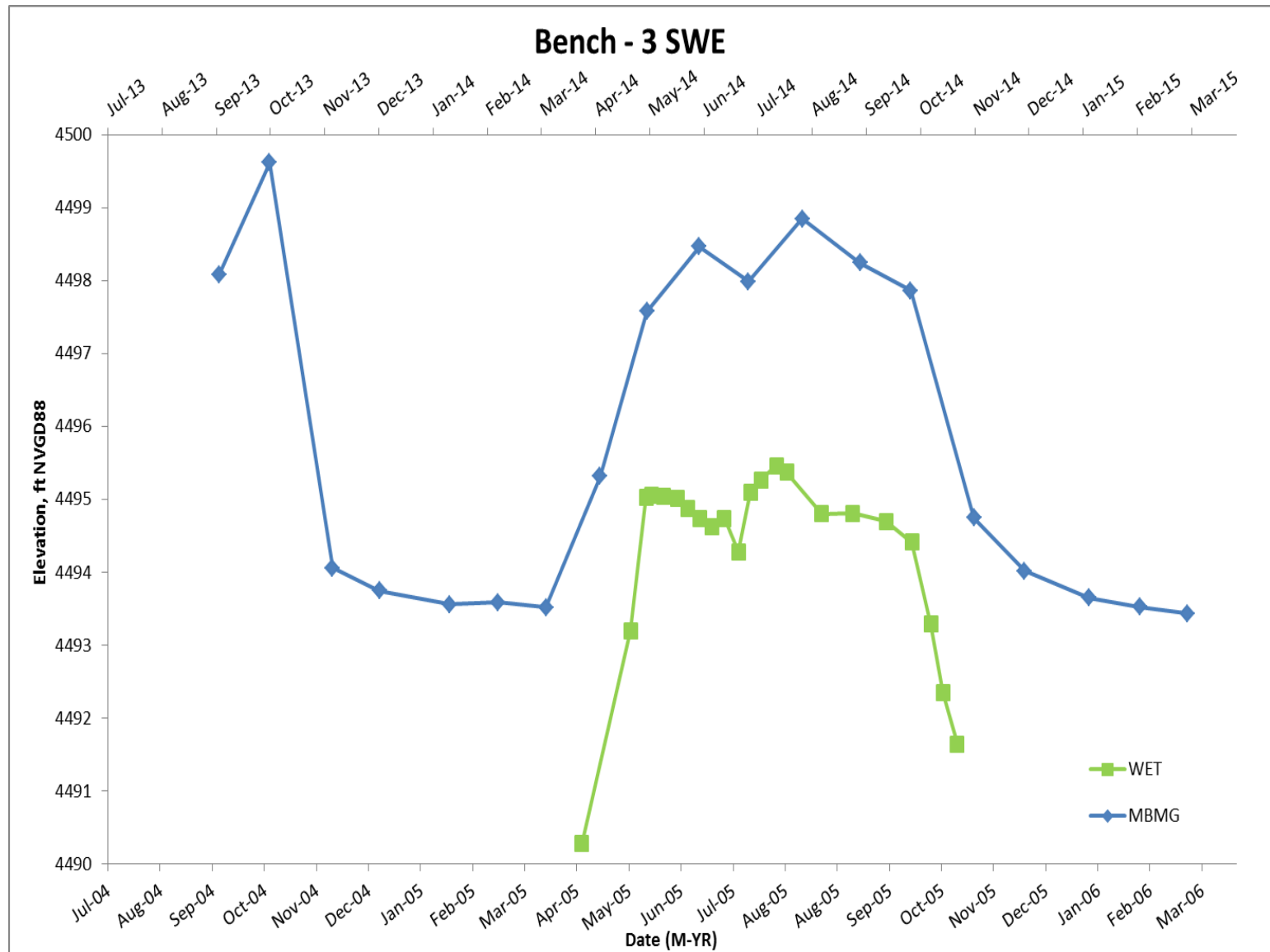


Figure C-11. Static Water Elevations for Bench 3

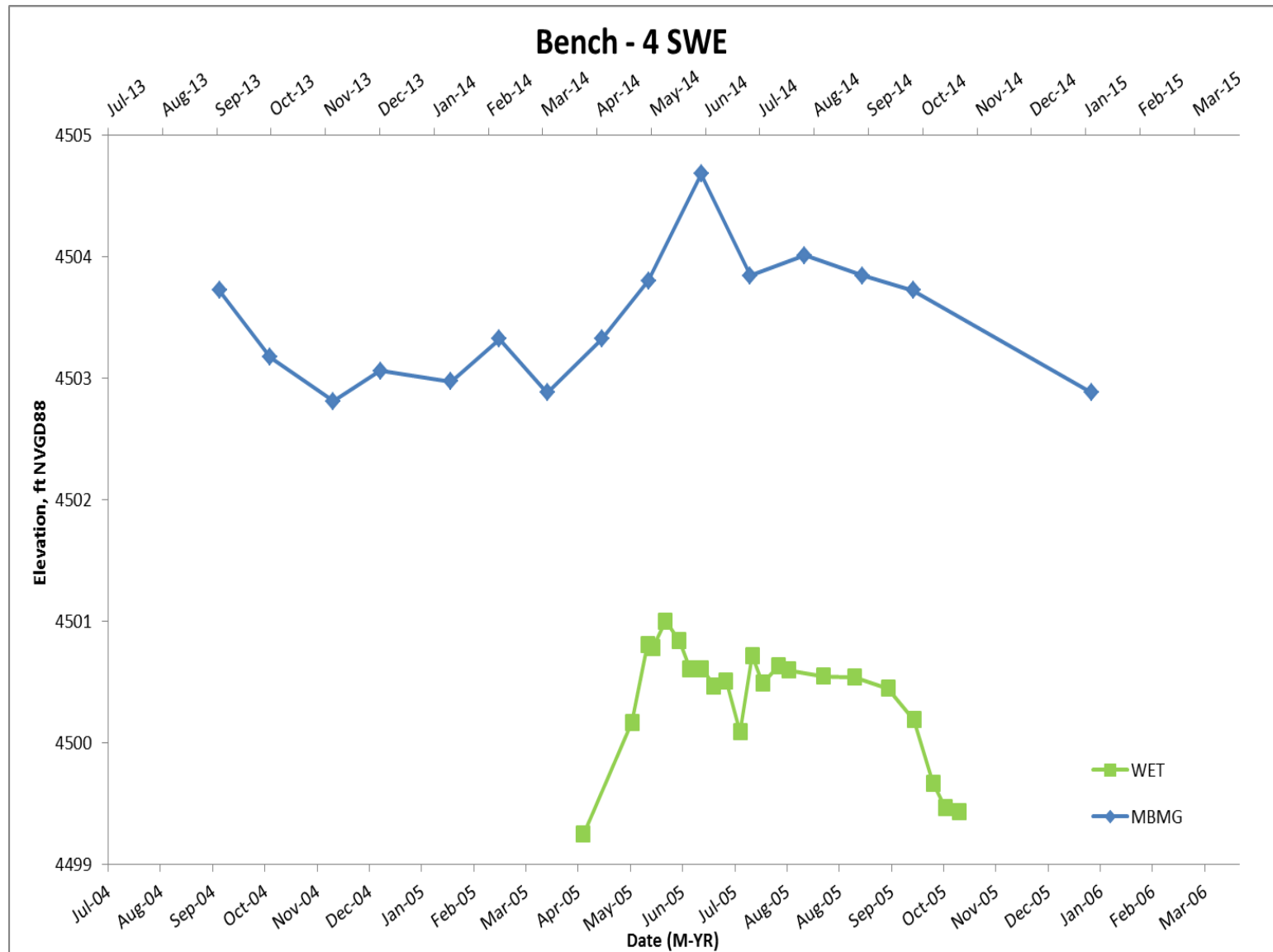


Figure C-12. Static Water Elevations for Bench 4

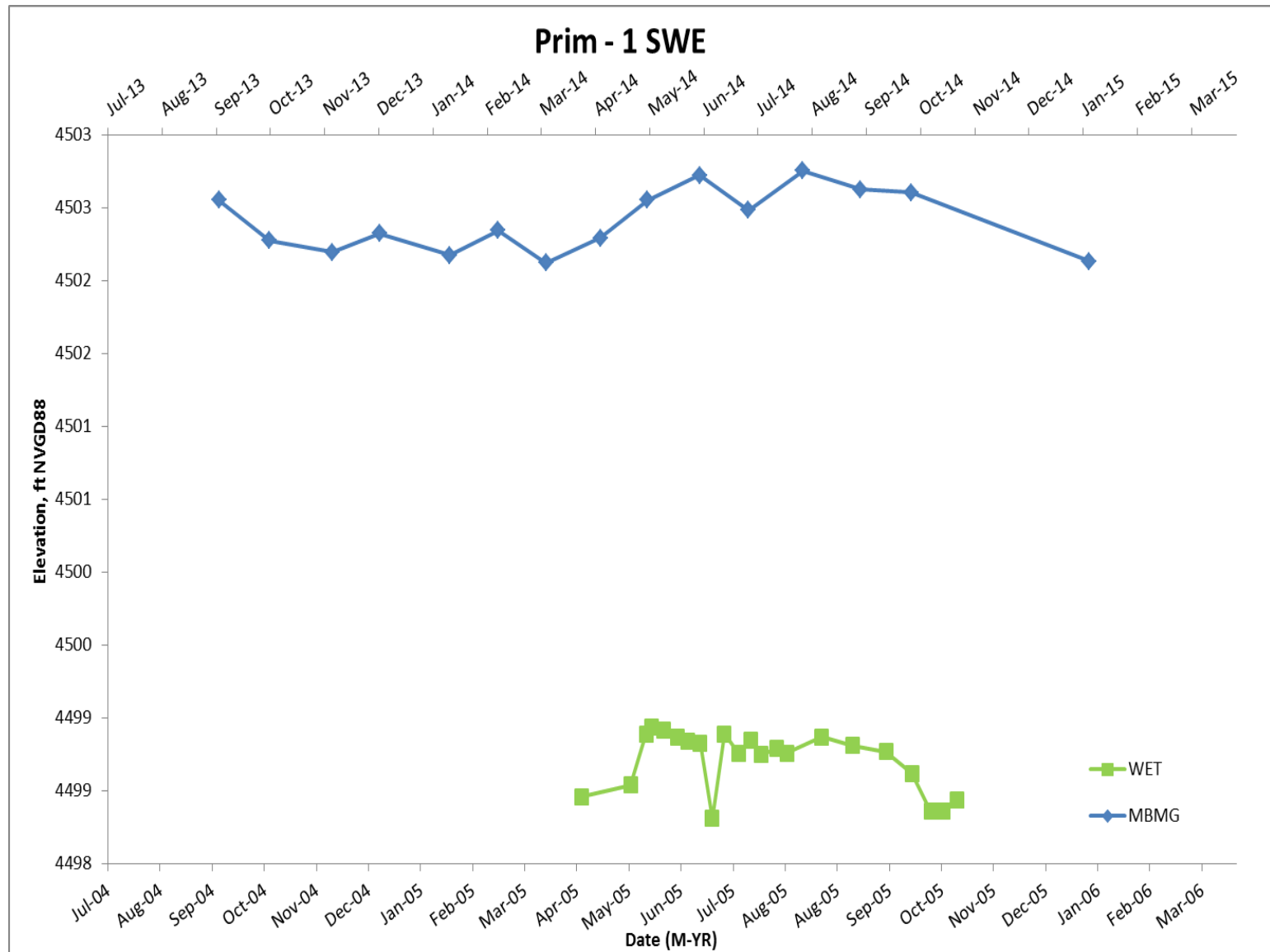


Figure C-13. Static Water Elevations for Prim 1

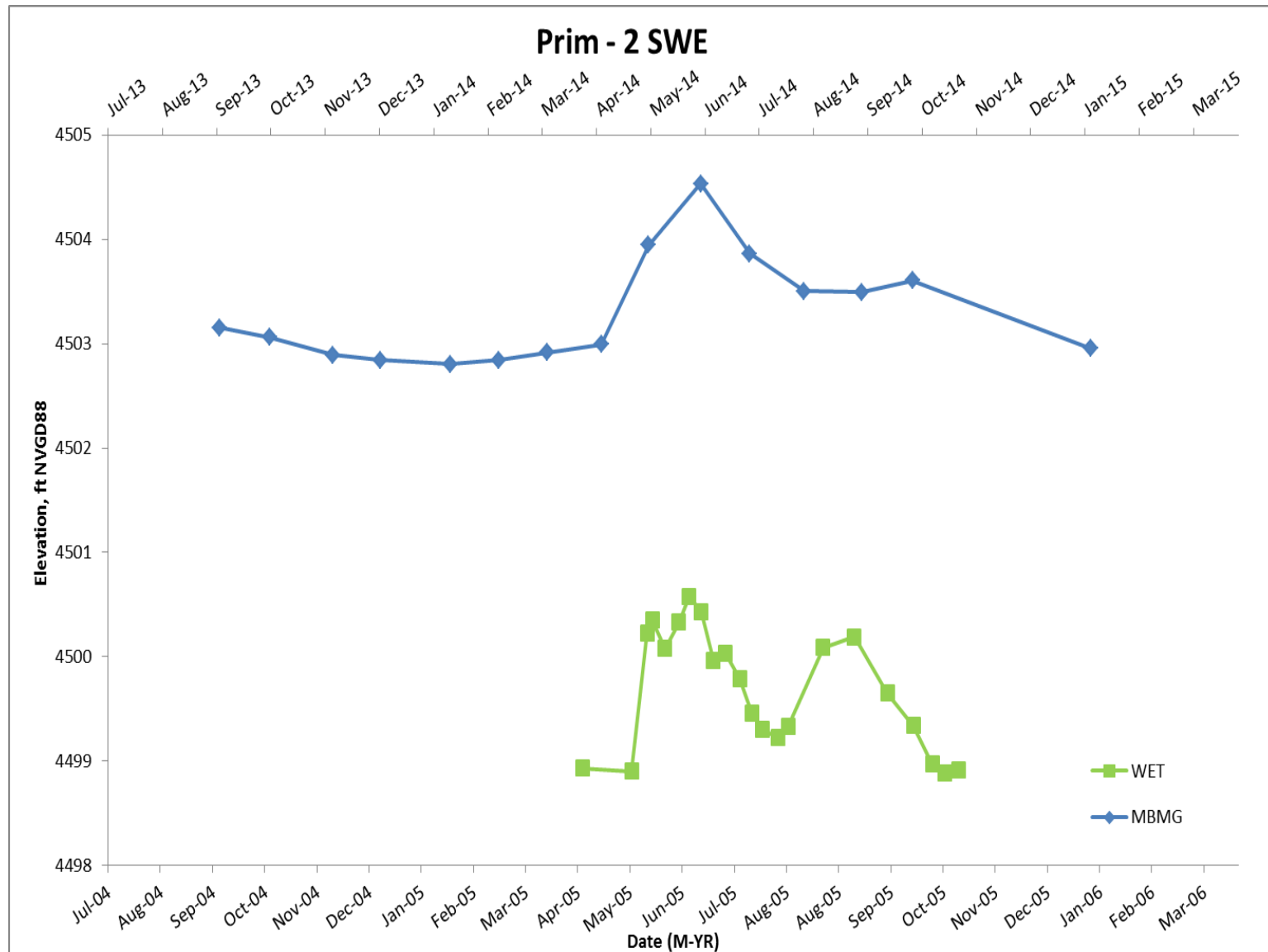


Figure C-14. Static Water Elevations for Prim 2

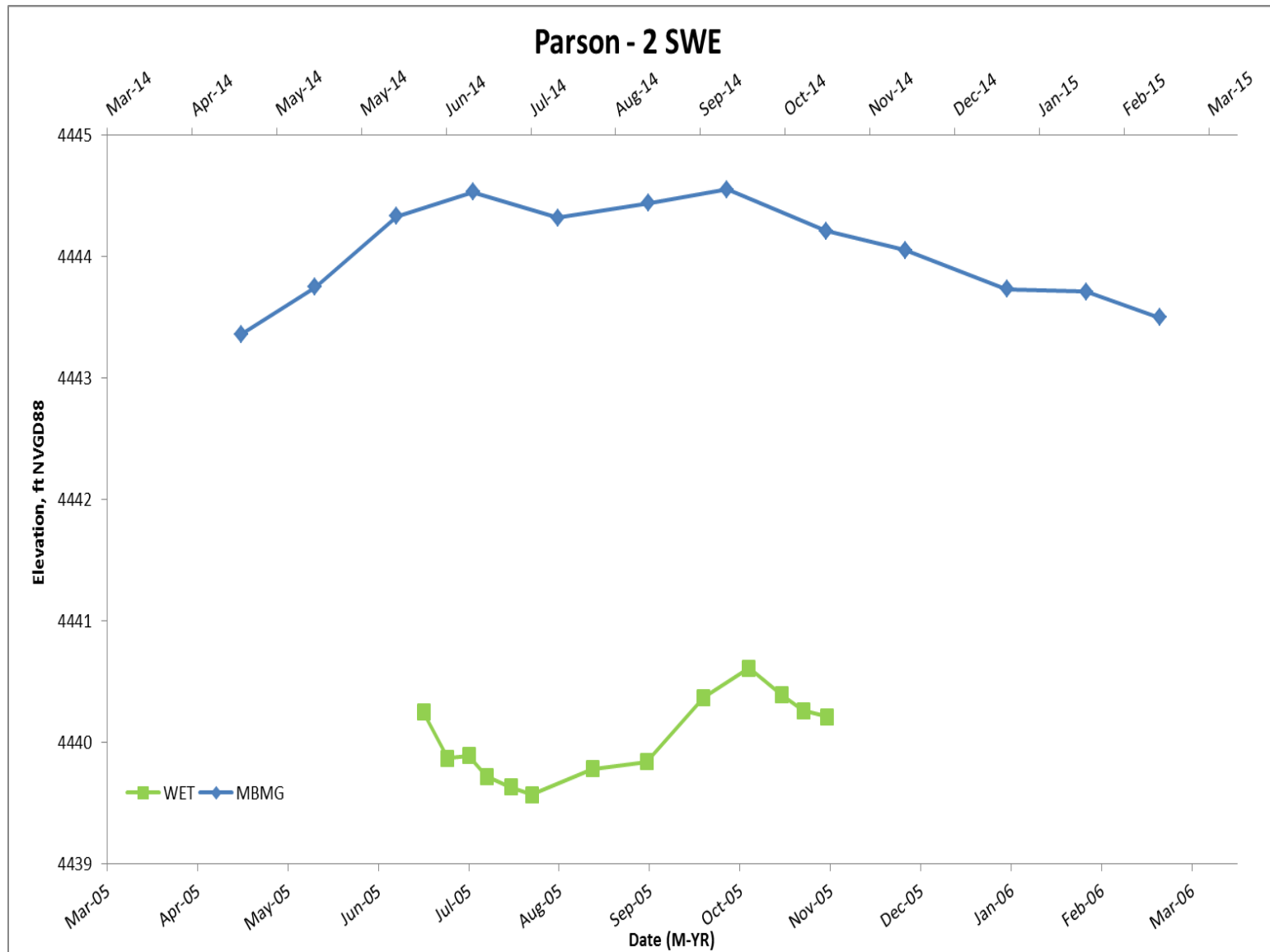


Figure C-15. Static Water Elevations for Parson 2

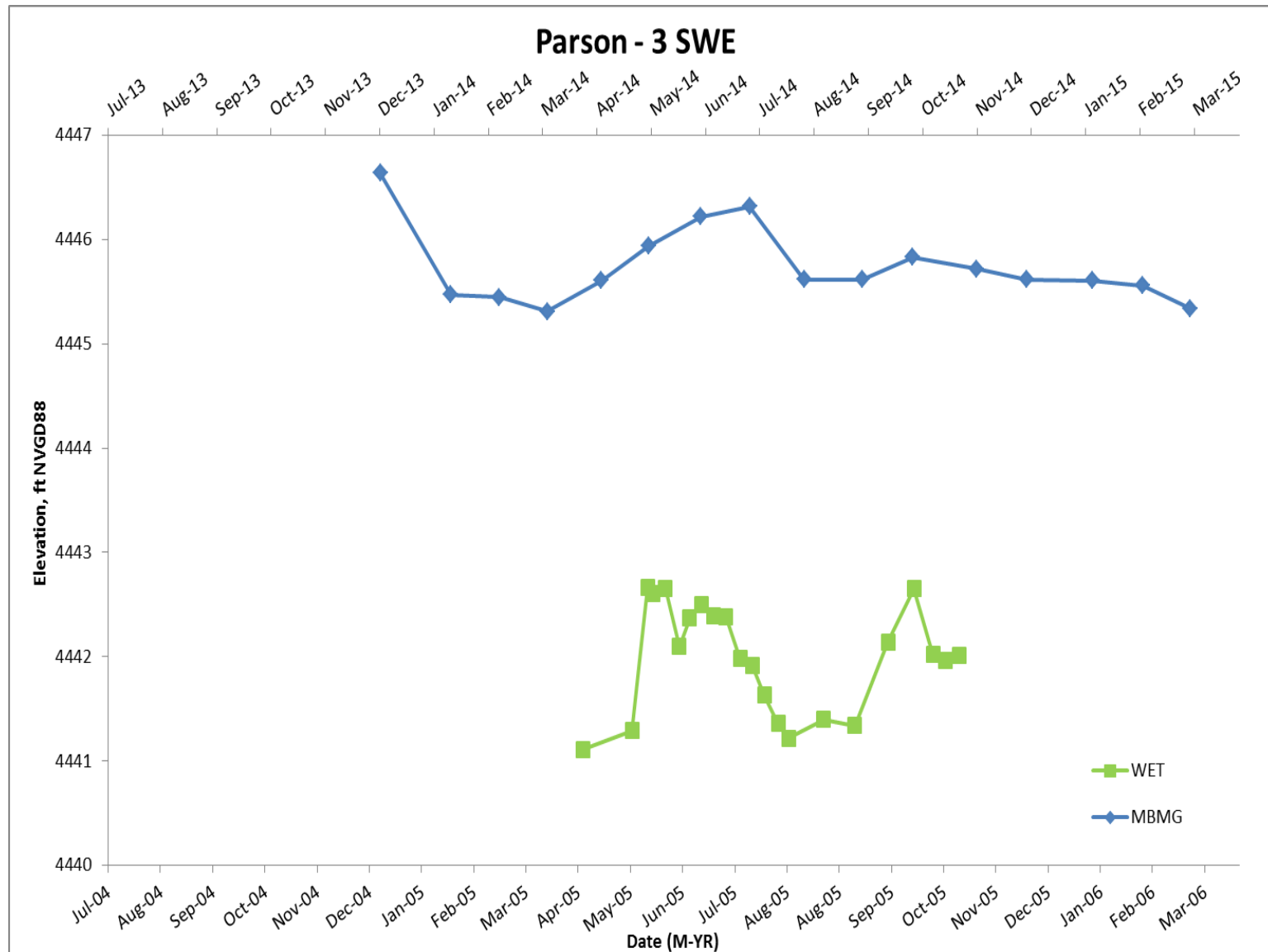


Figure C-16. Static Water Elevations for Parson 3

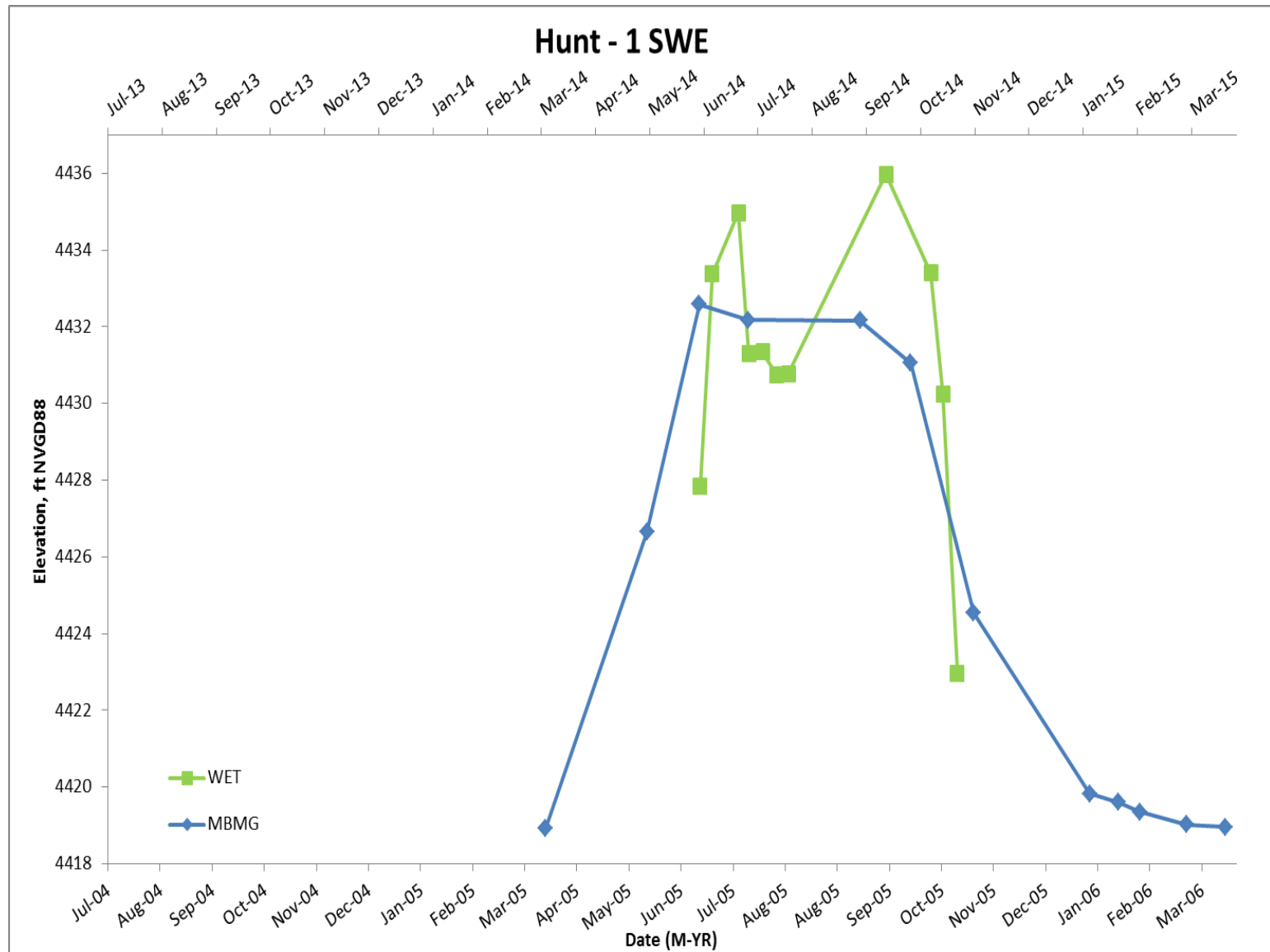


Figure C-17. Static Water Elevations for Hunt 1

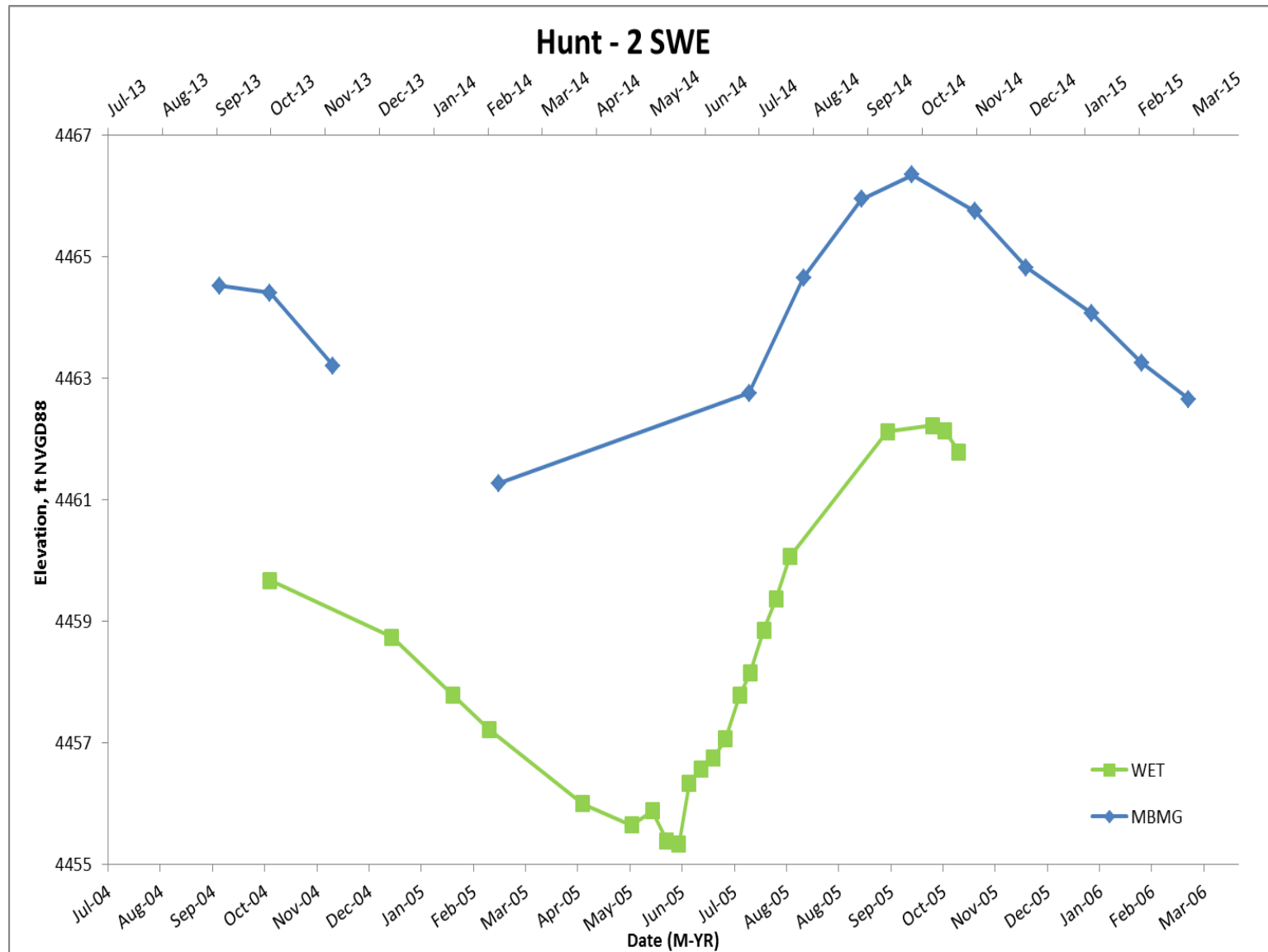


Figure C-18. Static Water Elevations for Hunt 2

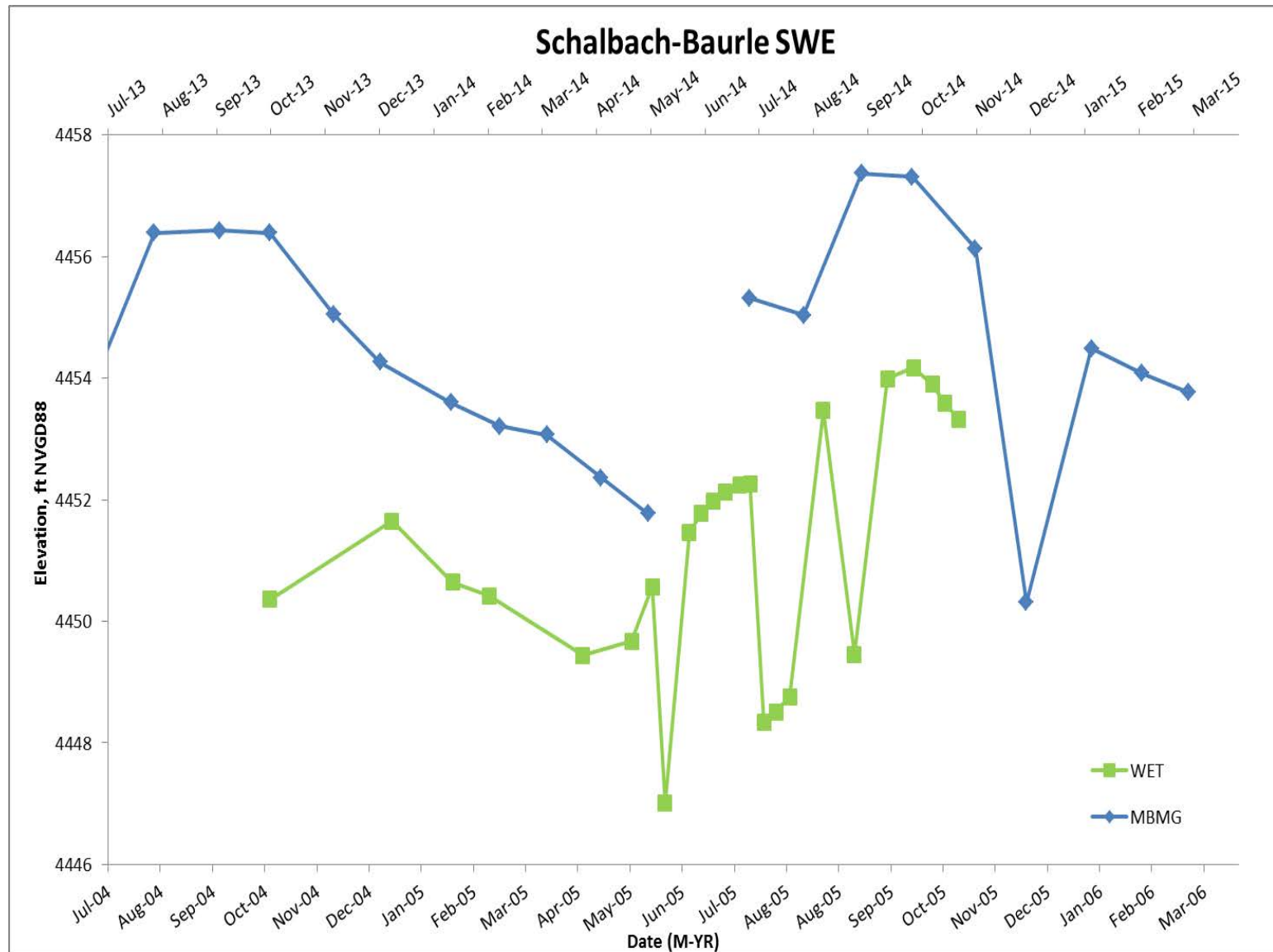


Figure C-19. Static Water Elevations for Schalbach-Baurle

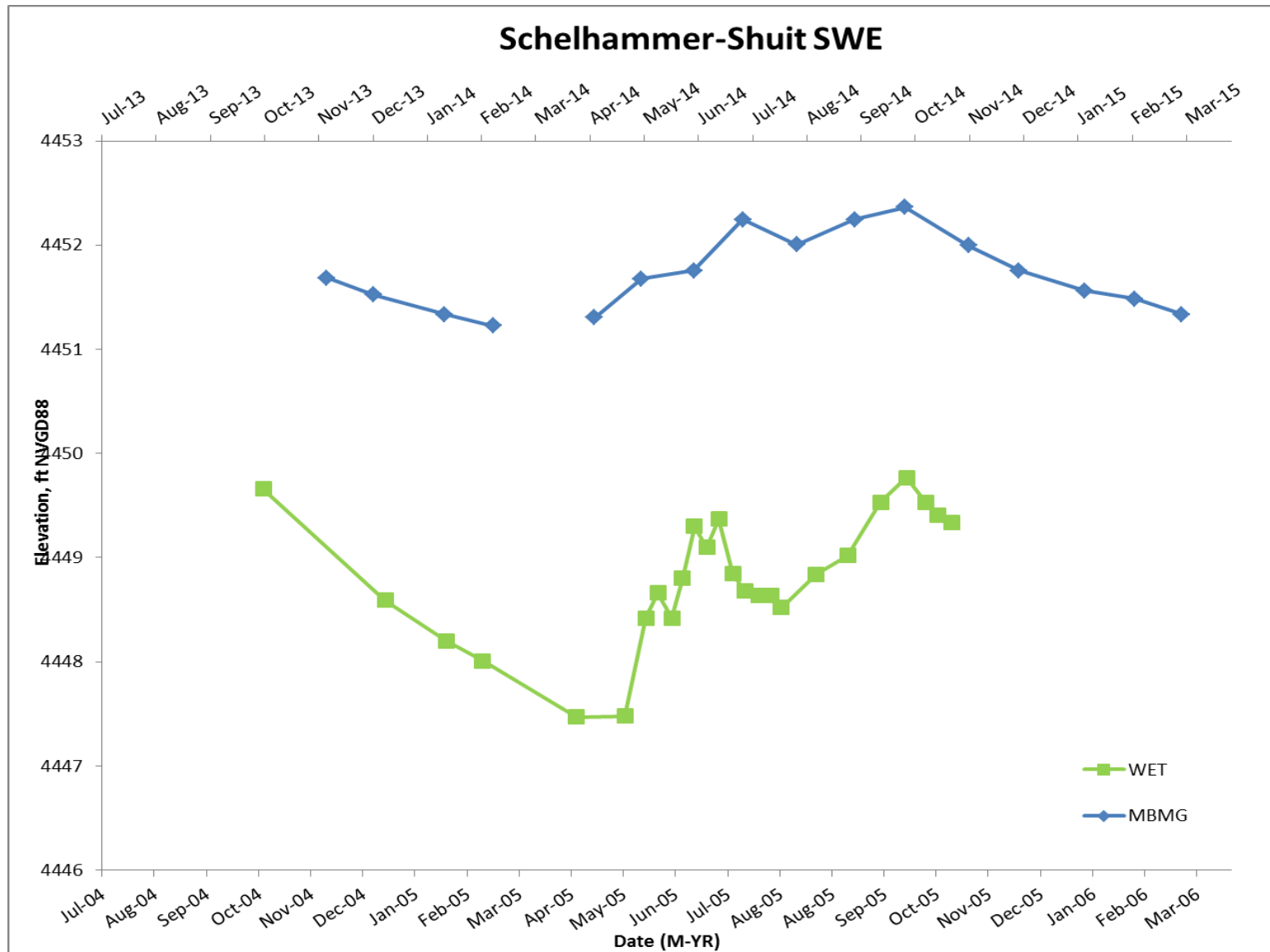


Figure C-20. Static Water Elevations for Schelhammer-Shuit

Appendix D: Water Quality Data and Piper Diagrams

Table D-1: Major Ion Water Quality Data

Site	Date	Lab pH	Lab SC	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	SiO ₂ (mg/l)	HCO ₃ (mg/l)	SO ₄ (mg/l)	Cl (mg/l)
Parson's Slough at Loomont Rd	8/19/2014	8.18	518.39	69.03	20.00	19.11	3.51	18.01	277.36	64.58	11.34
	11/18/2014	7.35	566.41	73.55	21.71	22.28	3.03	17.69	283.44	70.88	12.12
	1/30/2015	7.51	522.65	72.43	20.48	19.79	3.19	16.83	267.58	68.46	12.10
	3/30/2015	7.48	547.43	69.97	20.67	19.03	9.15	16.21	270.98	65.09	16.72
West Fork of Willow Springs	8/19/2014	8.12	437.76	54.84	19.81	14.64	3.21	14.66	245.11	45.74	7.59
	11/18/2014	7.82	390.80	47.19	18.06	13.42	2.97	13.26	219.66	37.44	5.62
	1/30/2015	8.01	377.04	46.66	16.72	11.25	4.69	12.22	209.28	33.04	7.19
	3/30/2015	8.18	354.12	44.82	16.44	10.61	2.96	11.23	200.44	32.18	4.96
	3/30/2015	8.21	360.40	45.41	16.69	10.58	3.02	11.36	200.18	31.30	4.80
Lower Willow Springs	8/19/2014	8.30	424.63	52.68	19.89	14.53	3.52	15.68	238.19	44.09	7.56
	11/18/2014	8.22	390.14	46.97	18.33	14.20	3.20	14.24	216.50	38.02	6.82
	11/18/2014	8.03	415.19	47.10	18.64	14.32	3.17	13.85	231.47	37.98	5.78
	1/30/2015	8.23	391.03	46.43	17.39	12.69	10.38	12.75	202.63	35.04	11.20
	3/30/2015	8.29	352.25	44.22	16.47	11.24	3.11	11.47	195.97	32.77	5.12
East Fork of Willow Springs	8/19/2014	8.24	474.98	55.12	23.13	17.27	4.70	18.34	262.82	48.05	8.04
	11/18/2014	8.13	465.86	53.17	23.43	17.00	4.70	16.92	256.31	50.44	8.26
	1/30/2015	8.12	436.29	50.96	23.14	16.64	5.33	16.13	240.02	46.84	8.62
	3/30/2015	8.20	414.70	47.22	22.17	15.52	4.92	14.18	227.87	43.68	7.40
Willow Springs Stock Well	8/19/2014	7.86	385.02	47.18	16.30	11.37	2.98	14.31	215.70	32.72	5.44
	11/18/2014	7.72	392.12	48.74	17.64	13.41	3.06	13.92	219.18	33.85	5.21
	1/30/2015	7.82	387.75	48.09	16.68	12.12	3.00	14.44	215.67	33.24	5.20
	3/30/2015	7.85	375.38	46.41	16.10	11.42	3.76	14.07	211.54	31.34	5.27
Hunt-1 Well	11/18/2014	7.81	467.94	47.13	30.59	6.14	1.33	10.45	189.16	46.71	39.29
	1/30/2015	7.85	460.67	47.33	30.85	6.00	1.25	10.29	190.03	46.60	39.71
	3/30/2015	7.90	465.04	46.79	30.17	5.72	1.64	10.52	188.61	44.05	37.69

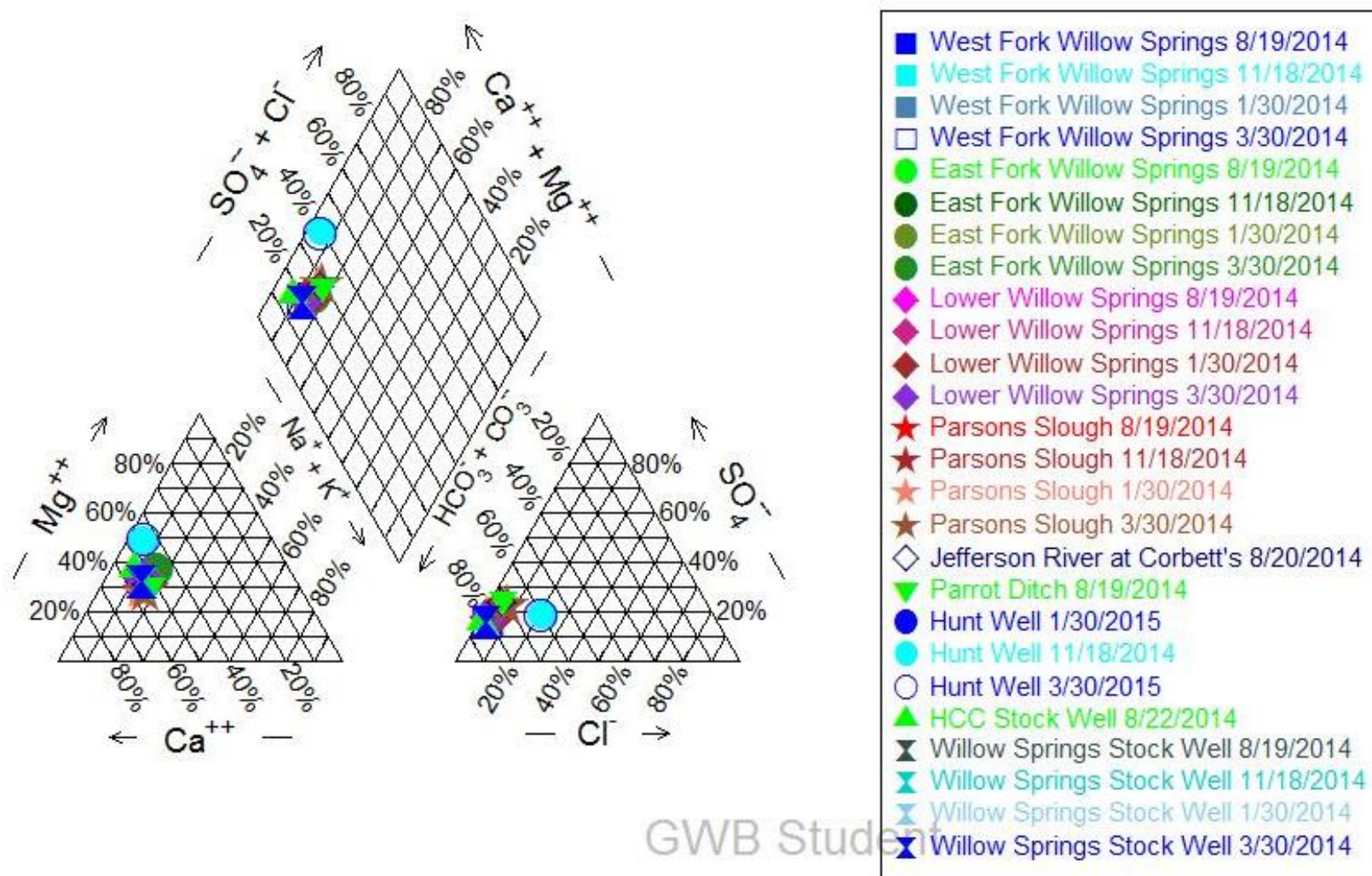
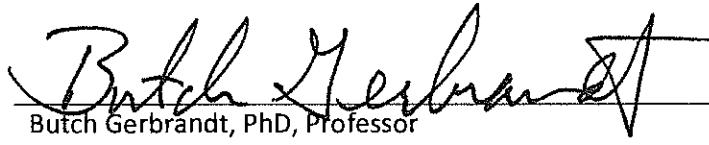


Figure D-1. Piper Diagram of all Sites Sampled

SIGNATURE PAGE

This is to certify that the thesis prepared by Nicole Brancheau entitled "A Hydrogeologic Evaluation of the Waterloo Area in the Upper Jefferson River Valley, Montana" has been examined and approved for acceptance by the Department of General Engineering, Montana Tech of The University of Montana, on this 1st day of May, 2015.

A handwritten signature in black ink, reading "Butch Gerbrandt", written over a horizontal line.

Butch Gerbrandt, PhD, Professor
Department of General Engineering
Chair, Examination Committee

A handwritten signature in black ink, reading "Glenn Shaw", written over a horizontal line.

Glenn Shaw, PhD, Associate Professor
Department of Geological Engineering
Member, Examination Committee

A handwritten signature in black ink, reading "Andrew Bobst", written over a horizontal line.

Andrew Bobst, Associate Hydrogeologist
Montana Bureau of Mines and Geology
Member, Examination Committee

HYDROGEOLOGIC INVESTIGATION OF THE UPPER JEFFERSON RIVER VALLEY, MADISON AND JEFFERSON COUNTIES, MONTANA: WATERLOO GROUNDWATER MODELING REPORT



Ali F. Gebril and Andrew L. Bobst

**Montana Bureau of Mines and Geology
Ground Water Investigation Program**

**HYDROGEOLOGIC INVESTIGATION OF THE UPPER JEFFERSON RIVER
VALLEY, MADISON AND JEFFERSON COUNTIES, MONTANA:
WATERLOO GROUNDWATER MODELING REPORT**

August 2021

Ali F. Gebril and Andrew L. Bobst

**Montana Bureau of Mines and Geology
Ground Water Investigation Program**

Montana Bureau of Mines and Geology Report of Investigation 29



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ABSTRACT

This modeling study focuses on the area near Waterloo in the Upper Jefferson River Valley. Groundwater discharges to the Jefferson River in this area, and is important during late summer, low-flow conditions. Willow Springs and Parson's Slough also rely on groundwater discharge; these streams provide late summer flows of 40 to 60 cubic feet per second (cfs) of cool water to the Jefferson River.

Leakage from the Parrot, Creeklyn, and Jefferson Canals contributes groundwater recharge to the alluvial aquifer. Excess water applied to irrigated fields also provides substantial groundwater recharge. This irrigation-related recharge eventually discharges to the Jefferson River, Willow Springs, and Parson's Slough. There are concerns that changes in irrigation management practices, such as lining canals or changing from flood to center-pivot irrigation, may alter the volume and timing of groundwater discharge to this river and streams.

We developed a numerical groundwater flow model to evaluate the effects of changing irrigation practices on surface waters during low-flow periods. The model design was based on a conceptual model derived from the analysis of groundwater and surface-water monitoring data, aquifer tests, well logs, and GIS analysis of soil, climate, vegetation, land-use, and water-rights data.

A steady-state version of the model replicated the long-term average groundwater and surface-water flow conditions in the study area. This model was most sensitive to aquifer transmissivity and the streambed conductance assigned to Parson's Slough and Willow Springs. A transient version of the groundwater model was calibrated to conditions observed from 2013 to 2015, using time-dependent stresses (seasonal irrigation activities and changes in Jefferson River flow).

Following calibration, the transient model simulation time was extended from 2005 to 2025 to (a) verify model-simulated groundwater heads compared to data collected in 2005, and (b) run predictive scenarios. The scenarios included lining irrigation canals, converting fields from flood to pivot irrigation, and split season irrigation techniques (apply flood irrigation recharge through the middle of the irrigation season followed by pivot irrigation). The estimated reduction in groundwater discharge to Willow Springs and Parson's Slough in late summer ranged from 6 to 12 cfs (12% to 24% percent of the 50 cfs of average baseflow). More severe effects are expected in drought years. Model results demonstrate that split season irrigation would augment aquifer storage for later release to surface water; however, the timing of this additional groundwater discharge to streams is influenced by the proximity of fields to surface waters, hydraulic gradient, and aquifer transmissivity.

INTRODUCTION

The Jefferson River, located in southwest Montana, regularly experiences low-flow conditions (JRWC, 2013; MTFWP, 2012). The lowest flows and highest temperatures occur during the irrigation season, triggering irrigation water shortages and trout population declines—especially in drought years. Evaluating the water resources in the Upper Jefferson River Valley can inform decisions about future development and conservation efforts in the valley. This involves understanding and quantifying the complex interactions between surface water and groundwater. One of the objectives of the Upper Jefferson Groundwater Investigation (Bobst and Gebril, 2021) is to evaluate the effects of changes in irrigation practices in the area near Waterloo on groundwater discharge

to surface water, particularly Parson's Slough, Willow Springs, and the Jefferson River. The Waterloo groundwater flow model, documented in this report, directly addresses this objective.

Background

The Jefferson River begins at the confluence of the Beaverhead, Big Hole, and Ruby Rivers near Twin Bridges, Montana. The largest use of surface water in the Upper Jefferson River Valley is irrigated agriculture; residents of the valley rely on groundwater from the alluvial aquifer for potable water. The river is also important for the sport fishing industry. This modeling effort focuses on the area near Waterloo, a region that is critical to providing groundwater baseflow to the

Upper Jefferson River. The Waterloo model area, also referred to in this report as the Waterloo area, begins approximately 3.2 mi north of Silver Star, and extends to approximately 2.7 mi downstream from Parson's Bridge (fig. 1).

The model area, at about 2.5 mi wide by 5 mi long, covers a total area of 12.4 mi². The Highland and Tobacco Root Mountains bound the valley on the west and east, respectively. The Creeklyn and Parrot Canals bound the model area on the west and east, respectively. The Jefferson River runs through the middle of the model area, and water is diverted from the Jefferson River into the Jefferson Canal, between Parson's Bridge and the mouth of Parson's Slough (fig. 2).

Purpose and Scope

The Montana Bureau of Mines and Geology (MBMG) developed a numerical groundwater model to understand and quantify interactions between surface water and groundwater in the Waterloo area. This model is a field-validated tool that will allow managers and planners to simulate various water management practices and examine the effects on the area water resources, such as the Jefferson River. Hydrogeologic conditions during critical low flow periods—late summer months or drought years—are of particular interest. This report complements the Upper Jefferson Interpretive Report, which presents additional detail on the hydrogeology and geological settings of the study area (Bobst and Gebril, 2021).

Previous Studies

Water and Environmental Technologies (WET) characterized groundwater/surface-water interactions in the Waterloo area (WET, 2006). WET collected water levels monthly from 13 private wells and 22 piezometers from December 2004 through November 2005. Stage and discharge measurements were collected from 11 surface-water sites located on the Jefferson River, Parrot Canal, Parson's Slough, and Willow Springs. Periodic discharge measurements were made on several ephemeral tributaries (Dry Boulder Creek, Beall Creek, Spring Creek, and Mill Creek) in the Tobacco Root Mountains. A surface-water budget was developed from these data. Analysis of aquifer test data conducted in alluvial deposits yielded a hydraulic conductivity of 634 ft/d. Groundwater and surface-water monitoring networks were sampled for water quality and temperature. WET concluded that changes in

irrigation practices in the Waterloo area may adversely affect late summer flows in Willow Springs. Flood irrigation recharges the aquifer, which in turn provides delayed recharge to the Jefferson River during critical low-flow periods.

A Montana Tech Master's thesis (Brancheau, 2015) prepared in association with this GWIP investigation evaluated the relationships among surface-water, groundwater, and irrigation practices in the study area. The GWIP investigation included surface-water and groundwater monitoring (water levels, river stage, discharge, and water-quality measurements) using a network of wells and surface-water sites (fig. 3). A groundwater budget was developed to evaluate the components of the flow system, and to estimate the net groundwater discharge to the Jefferson River (table A22, appendix A). Results from the Brancheau work showed that:

- groundwater flow from the aquifer discharges to several groundwater-fed streams and directly to the Jefferson River;
- changing flood irrigation to other types of irrigation applications may lower the water table and reduce groundwater discharge to those streams;
- leakage from the irrigation canals and irrigation recharge increase aquifer recharge; and
- lining the irrigation canals would reduce leakage and therefore reduce recharge to the aquifer.

Study Area Overview

Physiography

The Waterloo model area is within the relatively flat alluvial valley of the Jefferson River, with the Tobacco Root Mountains to the east and the Highland Mountains to the west. Surface elevations range from 4,452 ft (amsl) near the northern boundary where the Jefferson River flows out of the model area to 4,525 ft (amsl) along the Creeklyn irrigation canal on the western boundary (fig. 2).

The United States Geological Survey (USGS) maintains gaging stations on the Jefferson near Twin Bridges, approximately 15 mi south of the study area (station 06026500, period of record 1941–2014) and at Parson's Bridge (station 06027600, period of record

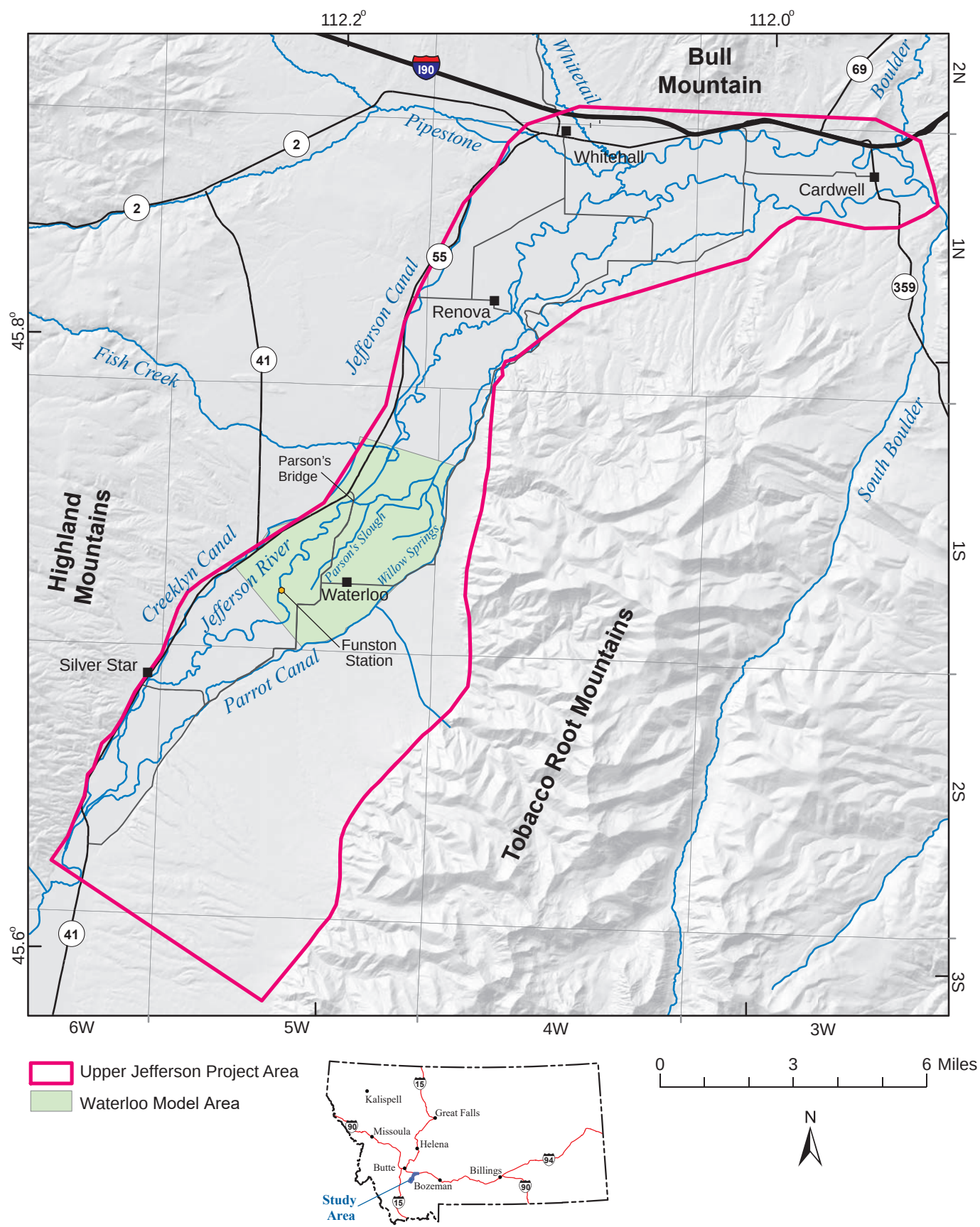


Figure 1. The Waterloo model area is located within the Upper Jefferson River Valley, within the groundwater investigation project area.

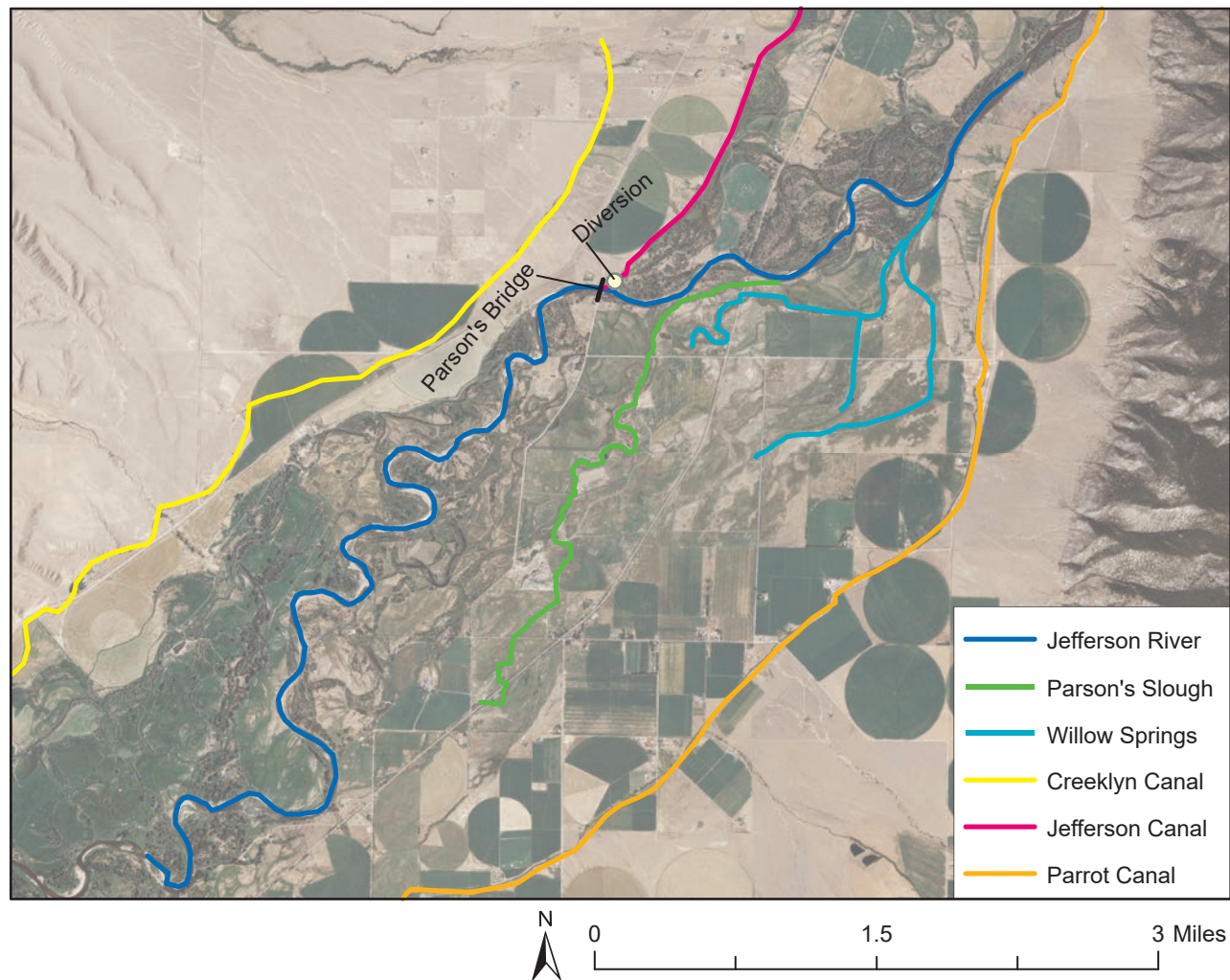


Figure 2. In the Waterloo model area, the main surface-water features include the Jefferson River, Parson's Slough, and Willow Springs (groundwater-fed streams), and the three irrigation canals: Parrot, Creeklyn, and Jefferson.

2006–2020, typically from July to September). The average flow of the Jefferson River near Twin Bridges for the period of record was 1,107 cubic feet per second (cfs), with an average annual peak flow of 9,467 cfs. Low flows occur in August, which has a mean flow of 770 cfs. The lowest mean monthly flow at the Parson's Bridge station, located downstream of the Jefferson Canal diversion and above Parson's Slough (fig. 3), was 40.5 cfs in August 2016; the lowest reported daily mean flow at Parson's Bridge was also in August 2016, at 19.9 cfs.

Climate

Modeled 30-yr normal precipitation values (PRISM, 2014; Daly and others, 2008) show that the average annual precipitation within the Waterloo study area is about 10 in. The PRISM model indicates that precipitation in this area increases with elevation; the Highland Mountains to the west receive as

much as 32 in per year while the Tobacco Root Mountains to the east receive as much as 42 in per year. Approximately 15 mi south of the study area, in Twin Bridges, the average annual precipitation is 9.55 in (NWS Cooperative Network Station 248430-2; period of record 1950–2016); June is the wettest month in Twin Bridges (1.9 in), and February is the driest (0.2 in).

Vegetation

Vegetation within the Waterloo area varies based on water availability. Within the alluvial floodplain and along some tributaries, riparian vegetation includes willows, cottonwoods, and wetland grasses. These phreatophyte vegetation types grow where roots can access shallow groundwater. Grass and sagebrush cover non-irrigated areas of the valley bottom and adjacent benches. Forests in the adjacent mountains include ponderosa pine, Douglas fir, lodgepole pine,

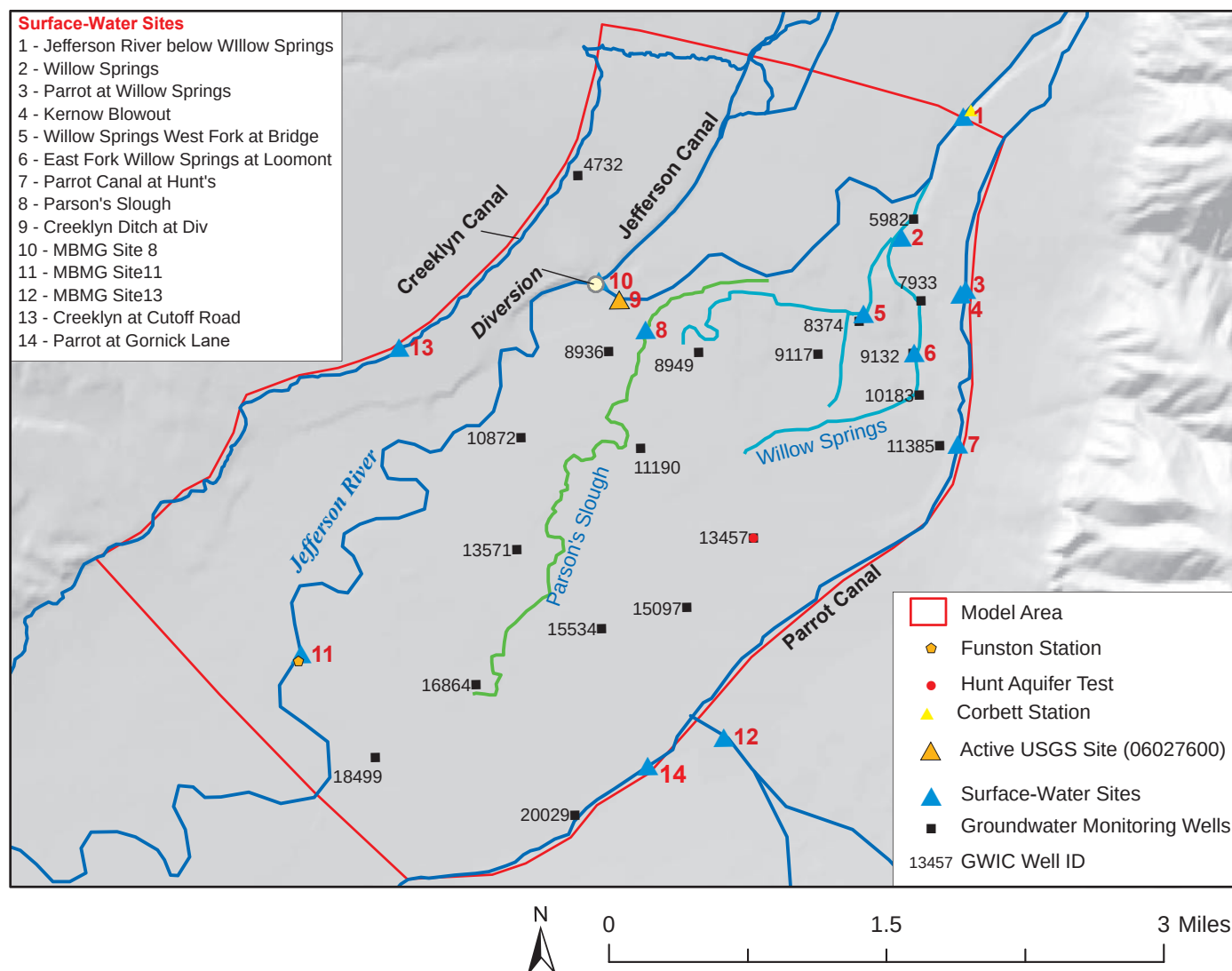


Figure 3. Groundwater and surface-water monitoring network within the model area.

Engleman spruce, and whitebark pine. Irrigated agricultural areas support mainly alfalfa and grass hay. Information from the LANDFIRE Existing Vegetation Type database (USGS, 2010a), the National Land Cover database (USGS, 2011), air photographs, field visits, and landowner interviews were used to develop a simplified map of vegetation for the study area (Brancheau, 2015).

Land Use

About 60% of the land in the Waterloo area supports irrigated agriculture. Of the irrigated area, approximately 44% is flood irrigated, and 56% is pivot or sprinkler irrigated. Most irrigated fields use surface water diverted from the Jefferson River (via the irrigation canals). The major crops are alfalfa and grass hay. A large portion of the non-irrigated land is used for cattle grazing.

Water Infrastructure

Within the Waterloo model area, water infrastructure includes irrigation canals (fig. 2), irrigation wells, domestic and stock wells, and septic systems. There are no public water supply or wastewater systems within the model area. The Jefferson River provides water for irrigation canals, and most irrigated fields.

Three major irrigation canals run through the model area (fig. 2). All of these canals receive water diverted from the Jefferson River. Diversions to the Parrot and Creeklyn Canals are approximately 2.8 and 4.4 mi upstream (south) of Silver Star, respectively (fig. 1). The Jefferson Canal, which runs through the north-central portion of the model area, receives diverted water immediately downstream of Parson's Bridge. Irrigation is an important source of groundwater recharge, particularly during low-flow periods (summer months

from July to September; WET, 2006). Canal leakage recharges the underlying alluvial aquifer; in addition, irrigated fields provide infiltration recharge when water is applied in excess of crop demand.

There are 61 domestic wells in the study area. In general, wells extract (pump) groundwater and septic systems return domestic wastewater to the groundwater system. For this study, we estimated domestic well pumping rates based on their net consumptive use rates; that is, the pumping rate less the amount of water returned to the groundwater system via septic systems. In addition to these domestic wells, there are 15 stock wells and 3 irrigation wells completed in the alluvial aquifer.

CONCEPTUAL MODEL

The conceptual model for the study area describes the characteristics and dynamics of the physical process within the groundwater and surface-water flow system, based on available hydrogeologic information. The conceptual model includes the system's geologic framework, aquifer properties, groundwater flow directions, locations and rates of recharge and discharge, and the locations and hydraulic characteristics of natural boundaries (ASTM, 1995; Mandle, 2002).

Geologic Framework

The Upper Jefferson Valley is an intermontane basin, filled with sediment transported from surrounding mountains and from the Jefferson River drainage area to the south. Tertiary and Quaternary pediment gravels occur at the base of the mountains, and Quaternary alluvium underlies the modern floodplain (Vuke and others, 2004; fig. 4). Estimates of the thickness of unconsolidated basin-fill material in the valley bottom range from about 2,000 to 10,000 ft (Brancheau, 2015). The depth to bedrock changes dramatically over short distances due to vertical offsets where faults cross the valley. These valley-crossing faults, such as the Waterloo Fault, generally trend northwest (fig. 4).

Hydrogeologic Setting

Literature review, geologic maps, and well logs contributed to our understanding of the hydrogeologic setting. Eighty-seven well logs were reviewed from the MBMG's Ground Water Information Center (GWIC) and can be accessed through the Groundwater Investigation Program (GWIP) project page, available at <http://mbmg.mtech.edu>. Detailed information on the methods and hydrogeologic interpretation are included in Bobst and Gebril (2021).

The surficial geologic units are classified into the Quaternary alluvium in modern channels and floodplains (Q_{al}), Quaternary alluvial terrace (Q_{at}), and the Quaternary bench sediments (Q_{af} ; fig. 4; table 1). Unconsolidated to poorly consolidated Tertiary sediments (T_s) underlie these units (fig. 4). Bedrock does not crop out within the model area. There are no geographically extensive confining units in the area, and the Quaternary and Tertiary sediments constitute hydrogeologic units with distinct hydrologic properties within a single alluvial aquifer.

Groundwater Flow System

A potentiometric surface map was developed from groundwater levels measured in April 2015 (fig. 5). The map shows that on the eastern side of the study area some contours are perpendicular to the model's boundaries, generally following topography. Groundwater flows from the topographic highs—where there is relatively high groundwater recharge (mountain front recharge)—toward the center of the floodplain. The Jefferson River is slightly losing in the upstream portion of the model area, and strongly gaining in the downstream area (Bobst and Gebril, 2021). Groundwater discharges to the Jefferson River if the river is gaining, or flows approximately parallel to the river through the alluvial aquifer where the river is losing. In the floodplain, groundwater in the alluvial aquifer flows from the southwest (southern boundary) to the northeast (northern boundary). To the northeast, the

Table 1. General stratigraphy, hydrostratigraphy, and model layers.

Stratigraphy			Hydrostratigraphy	Model Layers
Quaternary bench sediments (Q_{af})	Modern floodplain	Quaternary alluvial terrace (Q_{at})	Alluvial aquifer	Layer 1
	Quaternary alluvium (Q_{al})			
Tertiary sediment	Tertiary sediment	Tertiary sediment	Base of alluvial aquifer	Not simulated
Bedrock formations	Bedrock formations	Bedrock formations	Bedrock aquifer	Not simulated

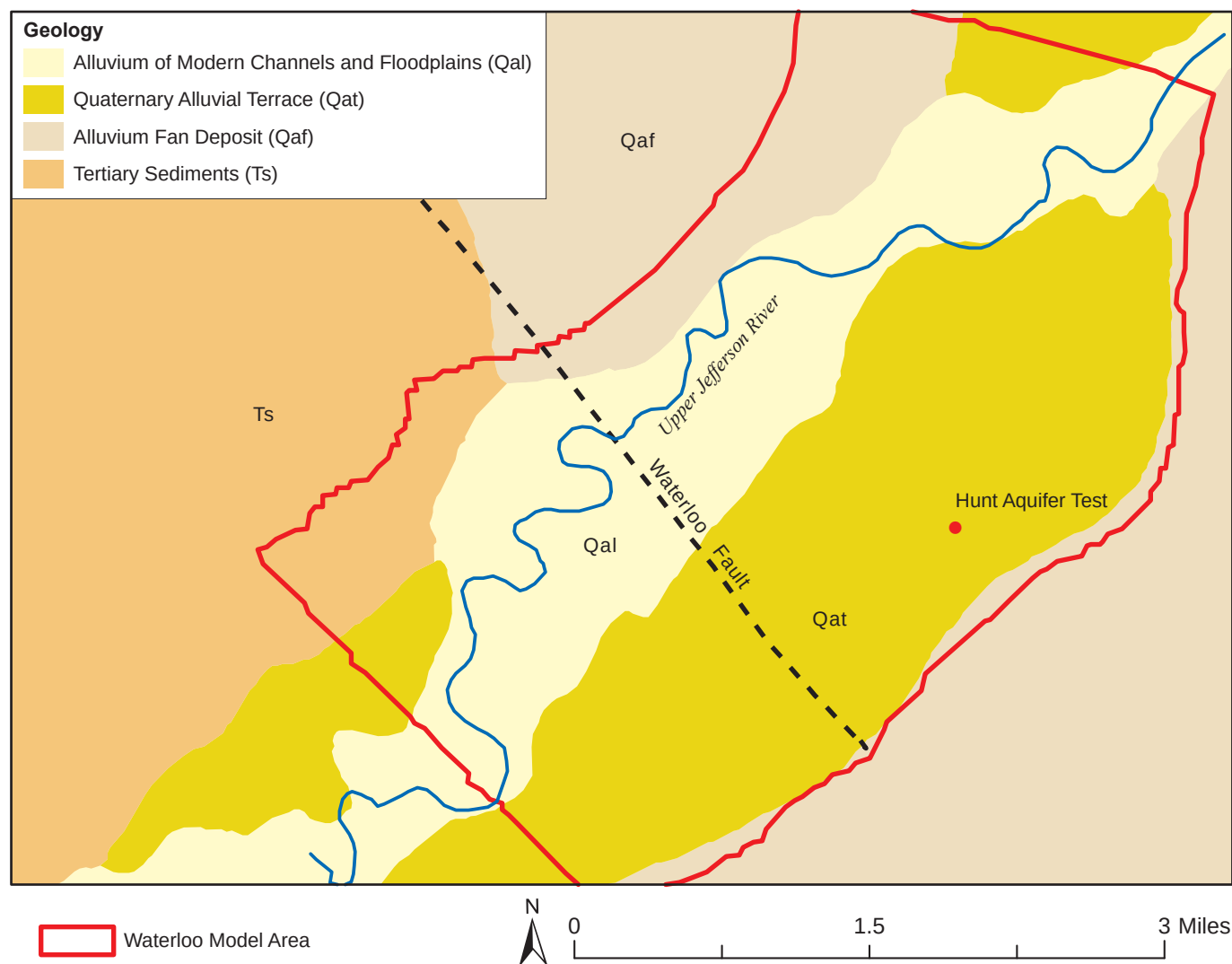


Figure 4. Simplified geologic map of the Upper Jefferson River Valley near Waterloo model area (based on Brancheau, 2015 and Vuke, 2004).

course-grained alluvium (Qal on fig. 4) narrows (fig. 4), and the potentiometric contours become more closely spaced as the hydraulic gradient increases due to decreased cross-sectional transmissivity.

Hydrologic Boundaries

Hydrologic boundaries are features that convey water into or out of the hydrologic system, in this case, the alluvial aquifer (fig. 6). These boundaries include the Jefferson River, with an average flow of about 1,100 cfs from the southwest to the northeast. The river loses water to the aquifer along a reach upstream from the Jefferson Diversion (fig. 2), while it gains groundwater downstream of the Jefferson Diversion (Bobst and Gebril, 2021).

The Parrot and Creeklyn irrigation canals form hydrologic boundaries along the east and west sides of the valley, respectively. Leakage from both canals

provides water to the aquifer. Lateral groundwater inflow (influx) and irrigation recharge from irrigated lands upgradient of the canals also contribute water to the model area along these boundaries.

Groundwater also flows into the alluvium on the upgradient (south) side of the model area, and discharges through the alluvium on the downgradient (north) side. These boundaries are perpendicular to the Parrot and Creeklyn Canals (fig. 3) but are limited to the floodplain. Therefore, a no-flow boundary exists perpendicular to potentiometric lines between the floodplain and the canals (along portions of the northeast edge of the model area; fig. 5 and appendix A). Since this is a single-layer model (table 1), the bottom of the alluvial aquifer is also modeled as no-flow due to it being underlain by the less permeable Tertiary Renova Formation (fig. 6; Bobst and Gebril, 2021).

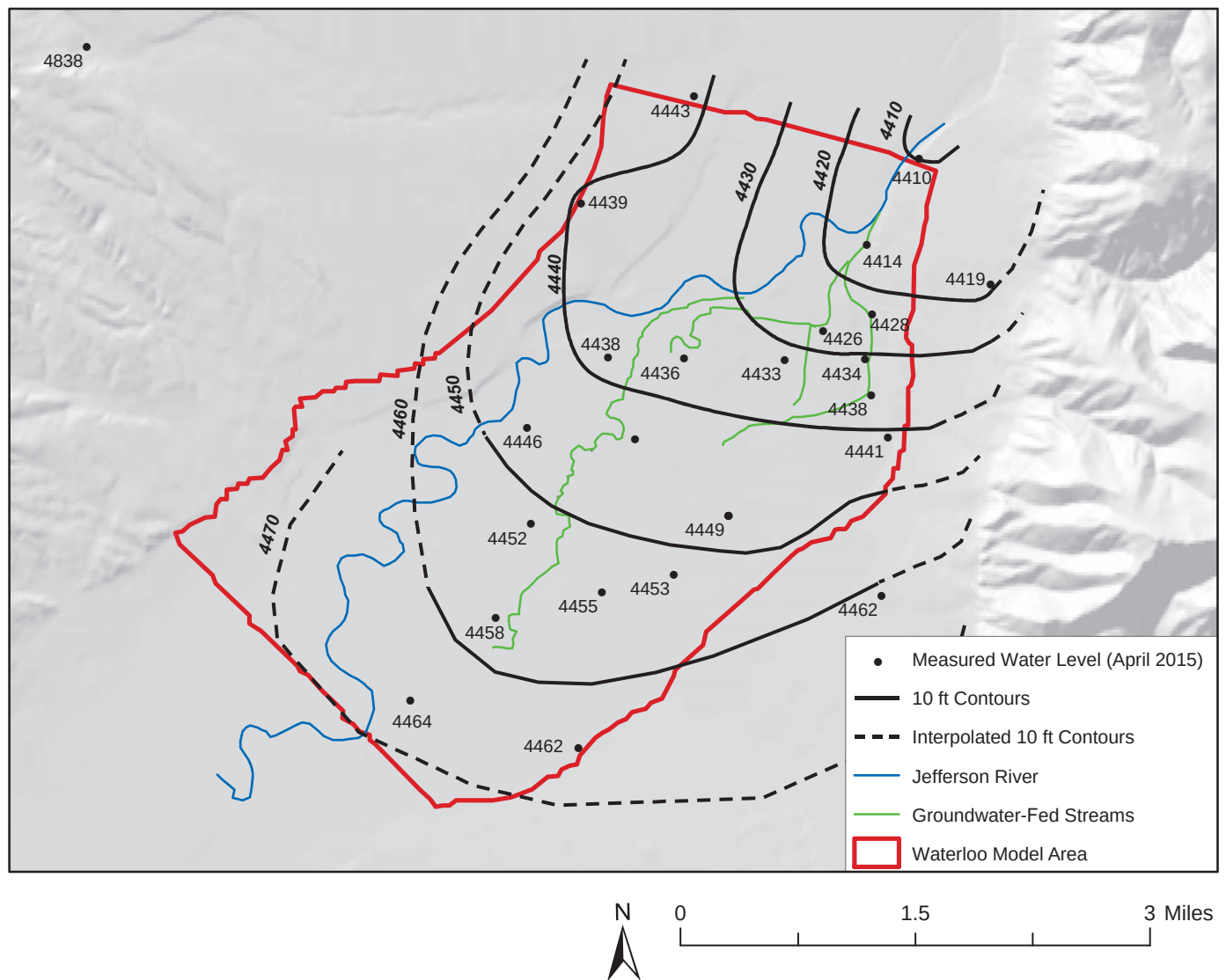


Figure 5. Potentiometric surface of the alluvial aquifer in the model area based on April 2015 groundwater-level measurements.

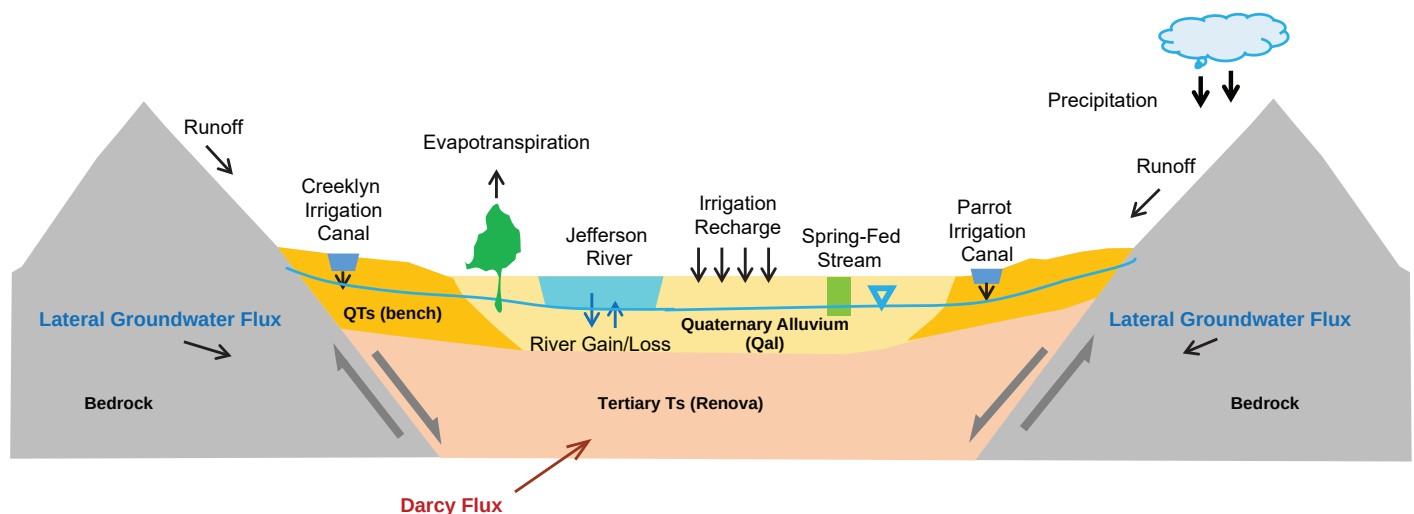


Figure 6. Flow components of the conceptual water budget. The Waterloo model focused on the top Quaternary alluvium and bench Tertiary sediments, where groundwater/surface-water interactions take place. The one-layer model extends from land surface to the bottom of the Quaternary alluvial sediments. Groundwater flow (Darcy flow) is perpendicular to the cross section.

Sources and sinks for water are also located within the model domain. Irrigation recharge, and leakage from the Jefferson Canal, add water to the aquifer. Water is lost from the aquifer via extraction wells, evapotranspiration by riparian phreatophytes and wetland grasses, and through discharge to the Jefferson River, Parson's Slough, and Willow Springs.

Storage of water in the alluvial aquifer sustains baseflow to the Jefferson River, Parson's Slough, and Willow Springs, especially during low-flow periods (e.g., late summer). A considerable amount of the water diverted from the Jefferson River to irrigation canals recharges the underlying aquifer via canal leakage and excess applied irrigation. This irrigation-related recharge causes groundwater elevations in the alluvium to rise. In low-flow periods, the aquifer discharges more water to the Jefferson River and to the groundwater-fed streams than in other periods. The rate and timing of the groundwater's release from storage depends on the gradient between the aquifer and boundaries, the transmissivity of the aquifer, and the distance between recharge areas and discharge areas.

Aquifer Properties

Aquifer test analysis provides a range of aquifer properties such as transmissivity (T), hydraulic conductivity (K), and storativity (S). We conducted one aquifer test in the alluvial aquifer within the floodplain at the Hunt Ranch, 1.6 mi southeast of Parson's Bridge (Bobst and Gebril, 2020). The wells were screened in the gravel deposits within the floodplain alluvium (Qal; table 1; fig. 4). Data analysis indicated an unconfined aquifer with a K of about 2,225 ft/d, and a specific yield S_y of 0.14 (appendix C). This hydraulic conductivity is representative of clean gravel in the floodplain alluvium (Qal). Variations in aquifer properties are expected within each hydrogeologic unit, and this value may be on the high end of the overall range for the alluvium since specific capacity data indicate these wells were more productive than other wells completed in the alluvium (GWIC, 2019). WET (2006) estimated a K of 634 ft/d for alluvium in this area. We used published values (Freeze and Cherry, 1979; Heath, 1983; Driscoll, 1986; Fetter, 2001) and aquifer test results from outside the model domain (Bobst and Gebril, 2020) to estimate the aquifer properties of the bench sediments. These values were set as the model's initial hydraulic conductivities.

Groundwater Budget

We developed a preliminary groundwater budget for the Waterloo area to constrain the steady-state model. We based this on modifications from previous work (WET, 2006; Brancheau, 2015; appendix A). The preliminary water budget has total inflows and outflows comparable to those calculated by Brancheau (2015). Our preliminary water budget assumed quasi-steady-state conditions (no change in storage) based on groundwater-level monitoring from 2005 to 2015 (Bobst and Gebril, 2021). In addition, we calculated a monthly groundwater budget to compare it with the transient model's monthly budget (appendix A).

Inflows to the aquifer include groundwater influx from the alluvium in the south, groundwater influx from the adjacent mountain blocks, irrigation recharge, and canal leakage. Outflows are groundwater outflow through the alluvium in the north, evapotranspiration by riparian plants, well pumping, and net discharge to surface waters (Jefferson River, Parson's Slough and Willow Springs; fig. 6). This budget can be expressed as:

$$GW_{in-al} + GW_{in-lat} + CL + IR = GW_{out-al} + ET_r + WEL + SW_{net}$$

where GW_{in-al} is alluvial groundwater influx; GW_{in-lat} is lateral groundwater influx; CL is canal leakage; IR is irrigation recharge; GW_{out-al} is alluvial groundwater outflow; ET_r is riparian evapotranspiration; WEL is well pumping; and SW_{net} is net groundwater discharge to surface waters.

These budget components are summarized in table 2, with details provided in appendix A. The "flux" term used in this study refers to the volumetric flux.

Some of the separate components in the water budget were lumped into a single boundary in the model. For instance, a single specified flux boundary that extends along the Parrot Canal represents lateral groundwater inflow, upgradient irrigation recharge, and canal leakage.

MODEL DESIGN AND CONSTRUCTION

Table 2. Preliminary conceptual groundwater budget.

INFLOW (acre-ft/yr)			OUTFLOW (acre-ft/yr)		
	Preliminary Budget	Water-Budget Study (Brancheau, 2015)		Preliminary Budget	Water-Budget Study (Brancheau, 2015)
Irrigation Recharge (IR)	11,096	11,595	Evapotranspiration (ET)	501	957
Groundwater Influx ¹	45,947	23,371	Net discharge to surface waters*	38,556	38,323
Canal Leakage (CL)	5,600	13,406	Groundwater Outflux	27,154	12,963
Lateral Groundwater Influx ²	3,702	3,869	Pumping Wells (PW)	134	0
Total:	66,345	52,241	Total:	66,345	52,243

¹Groundwater Influx is the Darcy flow through the southern model boundary.

²Lateral Influx is groundwater inflow from the eastern and western model boundaries.

*Net discharge to surface water is the difference between aquifer recharge from surface water and aquifer discharge to surface water

Mathematical Framework (Governing Equation)

In saturated groundwater conditions, a combination of continuity (mass conservation) and Darcy's Law leads to the following mathematical description of groundwater flow (Anderson and others, 2015):

$$\frac{\partial}{\partial x} \left(K_x \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left(K_y \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left(K_z \frac{\partial h}{\partial z} \right) = S \frac{\partial h}{\partial t} - W^* \quad (1)$$

In this equation the dependent variable is the hydraulic head, h , which is defined in the traditional (x , y , z) Cartesian coordinate system. The horizontal (K_x , K_y) and vertical hydraulic conductivities (K_z) and storage coefficient (S) are specified. Boundary conditions (W^*) and initial head conditions must also be specified to solve equation 1. The boundary conditions may be specified head (Dirichlet), specified flux (Neumann), or head-dependent flux (Cauchy).

Numerical Model Approximation and Computer Codes

We used the USGS groundwater flow modeling software MODFLOW-2000 (Harbaugh and others, 2000), which provides a means to solve equation 1 and simulate the groundwater flow. MODFLOW applies the finite-difference method to approximate the solution. Groundwater Vistas (version 6.77, build 9; Environmental Simulations Incorporated, 2011) was used as the graphical-user interface (GUI) for MODFLOW. We relied on PEST, a general-purpose param-

eter estimation utility (Doherty, 2010, 2013a,b), to aid in model calibration.

Spatial Discretization

The model grid was overlain on a map of the Waterloo area and was set to the North American Datum 1983 Montana State Plane coordinate system, in units of International Feet. The rectangular grid frame encompassed the Jefferson River Valley study area near Waterloo, and cells outside of the model area were inactivated. The model consisted of a single layer representing the unconfined Quaternary aquifer. In single layer, there is no vertical hydraulic gradient ($\partial h / \partial z$), therefore, the *vertical* flow term is not calculated. This approach provides simplicity and maintains reasonable solution stability, and reduces run times for PEST and model execution. The grid consisted of 150 rows and 150 columns (22,500 cells) with uniform grid spacing of 178.18 ft x 188.66 ft (fig. 7). This refined cell size avoided placing multiple boundary conditions (such as a well located close to a stream) in a single cell. The model layer thickness ranged from 199 ft to 215 ft based on topography of the land surface. Additional details on the model grid are in appendix D and table D1.

Initially the top elevation of the grid was set using a Digital Elevation Model (DEM) derived from the USGS 1-arc second National Elevation Dataset (USGS, 2009). The DEM data point spacing was about 98 ft (30 m). Survey data from several wells in

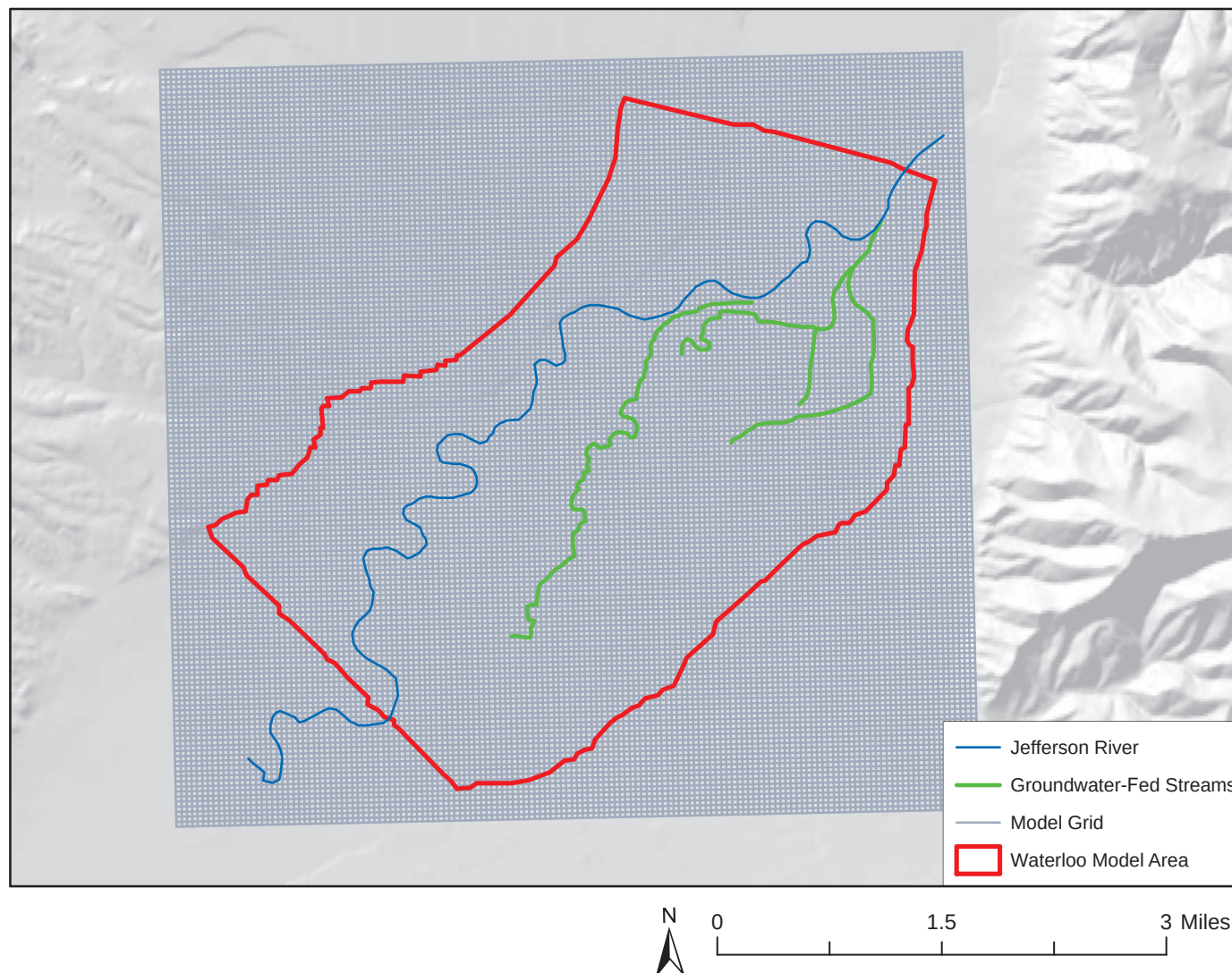


Figure 7. The model grid consisted of 150 rows and 150 columns (22,500 cells) with a cell size of about 178 ft x 188 ft.

the model area were not in agreement with the DEM. To correct the top elevations, the difference between the survey data and the DEM were defined and extrapolated by kriging with linear variogram (using Surfer 9 software). The DEM-based cell-top elevations were adjusted using the extrapolated differences (fig. D1, appendix D).

Temporal Discretization

Steady-state models generally reflect average conditions and do not consider time-dependent parameters (storage coefficient, pumping schedules, seasonality of incoming boundary fluxes, irrigation rate changes, etc.). Transient simulations support time-dependent parameters that vary throughout the simulation period. Transient models can be used to verify past conditions and to simulate future predictive scenarios. Table 3 summarizes the Waterloo model simulations.

The transient model imposes monthly stress periods to simulate variations in seasonal stresses, such as irrigation recharge. Each stress period consists of six time steps to accommodate field observations, help numerical stability, and minimize run times. The duration of each time step depends on the length of the month, and ranges from 4.7 to 5.2 days (table D2, appendix D).

The transient calibration period included 31 monthly stress periods (2 yr and 7 mo) from April 1, 2013 to October 31, 2015. A one-day steady-state simulation was included as the first stress period of the transient simulation, resulting in 32 stress periods in the calibrated model. Thus, the heads from the one-day steady-state model were used as initial heads for the transient model.

Table 3. Simulations applied to the Waterloo model.

Simulation Type	Stress Periods	Duration	Simulation Period	Notes
Steady-State	1	Day	Not applicable	Simulates equilibrium state using average boundary conditions (e.g., pumping rates, recharge, etc.)
Transient Calibration	31	Months	April 2013 through October 2015	Simulate changes in groundwater heads and average monthly river flows for comparison to monitoring data collected during this study (2013–2015)
Model Verification	141	Months	April 2004 through October 2015	Simulates changes in heads for comparison to data collected by WET (2004–2005)
Prediction (future scenarios)	260	Months	April 2005 through October 2025	Simulates changes in groundwater levels, and Jefferson River flow and spring-fed stream discharge caused by different scenarios

Hydraulic Parameters

Prior to steady-state model calibration, we divided the active grid cells into four aquifer property zones, representing the floodplain alluvium (Qal; zone 1), the alluvial terrace (Qat; zone 2), and the western (zone 3) and eastern (zone 4) bench sediments (Q_{at} , Q_{af} and Ts ; figs. 4, 8). Anisotropy for this study is assumed equal to 1 ($K_x = K_y$) based on the aquifer test data; we used K_h to express horizontal hydraulic conductivity and K_v for vertical hydraulic conductivity instead of K_z . Initial values for K_h were assigned to these zones (fig. 8) as described in the Aquifer Properties section. We assumed a vertical hydraulic conductivity (K_v) of 10% of the horizontal (K_h); however, since there is no vertical hydraulic gradient ($\partial h / \partial z$) within the model cells, the vertical flow term is zero (eq. 1). These initial parameter values were modified during model calibration (see Calibration section).

Boundary Conditions

Flow model boundary conditions control the addition or removal of water (mass) from the model. Boundary conditions are mathematical expressions of the state of the aquifer system that constrain the model equations; they are assigned to the edges of the model domain and to internal sources and sinks (ASTM,

1995). In the Waterloo model, boundary conditions (fig. 9) follow the conceptual model discussed in the Hydrologic Boundaries section.

Head-Dependent Flux Boundaries

We applied head-dependent flux boundaries (Cauchy boundary type) to represent surface-water features in contact with groundwater, and the removal of groundwater by plants through evapotranspiration (ET). Assuming the Jefferson River is hydraulically connected with the underlying aquifer, we simulated the Jefferson River with MODFLOW's stream package (STR), and used the drain package (DRN) to simulate Parson's Slough and Willow Springs. Evapotranspiration was calculated with MODFLOW's EVT package.

During model execution, solving the groundwater flow equation involves calculations of the exchanged flow rates between the groundwater and the head-dependent flux boundaries. The STR package allows water to flow from the groundwater to the stream (gaining stream), or from the stream to groundwater (losing stream). The DRN and EVT packages only remove water from the model; groundwater-fed streams simulated with the DRN package cannot lose flow to the groundwater system. In the transient model, the

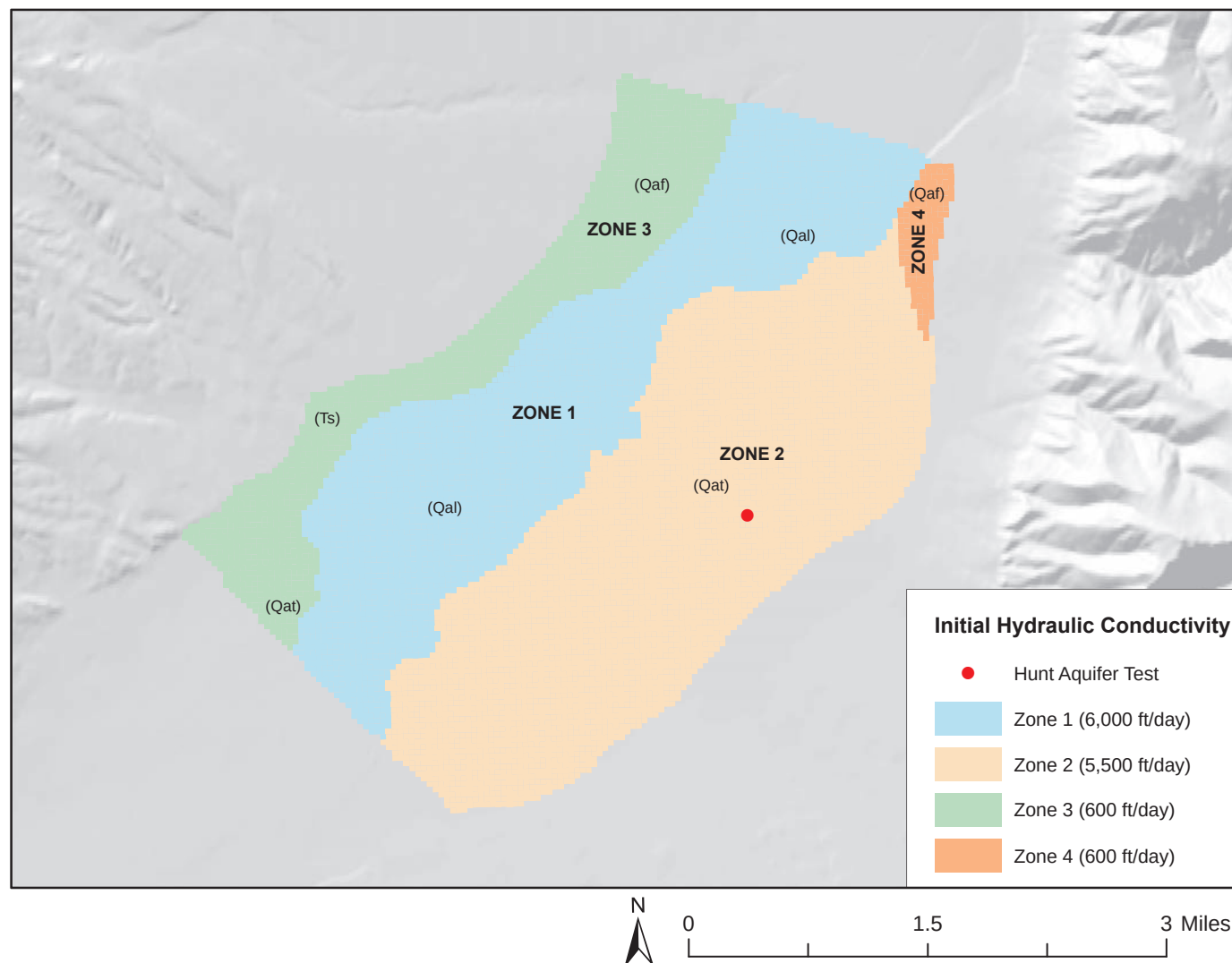


Figure 8. The initial aquifer properties were designated into zones based on horizontal hydraulic conductivity (K_h). Figure 4 and table 1 show geologic units.

rates at which water flows to or from these boundaries can change over time as a result of changing stresses. Thus, when head-dependent boundaries are used, the model quantifies changes in flow to one part of the system due to changes in other parts within the model domain. For instance, the model will simulate a reduction in groundwater flow to a stream as a result of a decrease in nearby canal leakage.

Jefferson River

In reality, the Jefferson River loses flow to groundwater in some areas, and gains groundwater as base-flow in other areas. Gaining and losing stretches of the river may also change seasonally. MODFLOW STR package terminology defines a “reach” as the portion of the stream specific to a grid cell (fig. D2, appendix D). A series of connected reaches with uniform or linearly changing properties that have tributary inputs to

the first reach and/or a diversion from the final reach is a “segment.” A group of one or more connected segments is a “network.” In the Waterloo model, the Jefferson River is divided into three stream segments (fig. D3, appendix D).

The STR package requires the specification of several variables, including flow entering the segment, streambed top elevation, hydraulic conductivity (K_v) of the riverbed sediments, length (L), width (W), bed thickness (M), streambed roughness, and channel slope (S). The STR package does not explicitly account for direct precipitation. Evaporation from the river is assumed negligible.

The STR Package (fig. D4, appendix D) calculates flux across the streambed as:

$$Q_b = C (h_b - h_{ijk}),$$

where Q_b is the flux across the streambed, C is the streambed conductance, h_b is the head in the stream, and h_{ijk} is the head in the aquifer. C is a function of riverbed material thickness, riverbed vertical hydraulic conductivity K_v , stream width, and the length of the stream reach. We set the starting value of the streambed conductance equal to K_v , about 10% of the initial estimate of aquifer horizontal hydraulic conductivity—these values were later adjusted during model calibration.

The STR package routes water through the stream network by applying Manning's equation to determine depth as function of flow and assumes rectangular channel dimensions. Manning's equation requires a roughness coefficient (n), which is defined as:

$$n = \frac{\phi}{Q} AR^{2/3} S^{1/2},$$

where ϕ is a constant (L^3/T ; in English Units 1.486

cfs); Q is the stream discharge (L^3/T ; cfs); A is the cross-sectional area (L^2 ; ft^2); R is the hydraulic radius (cross-sectional area divided by the wetted perimeter; L ; ft); and S is the channel slope (L/L ; ft/ft ; unitless).

Manning's coefficient n was estimated for the Corbett monitoring site on the Jefferson River (GWIC 278156; fig. D3, appendix D) based on survey data and measured stage and flow. The estimated n value of 0.040 was assigned to all cells representing the river. Our estimate is similar to coefficients developed by the USGS for similar streams, such as the Middle Fork Flathead River near Essex, Montana (0.041; Barnes, 1967).

Streambed elevations were specified for each cell. Surveyed elevations at the Funston (GWIC 278427) and Corbett (GWIC 278156) surface-water stations were applied to calculate an average riverbed slope of 0.001732 ft/ft (appendix B). Applying the same

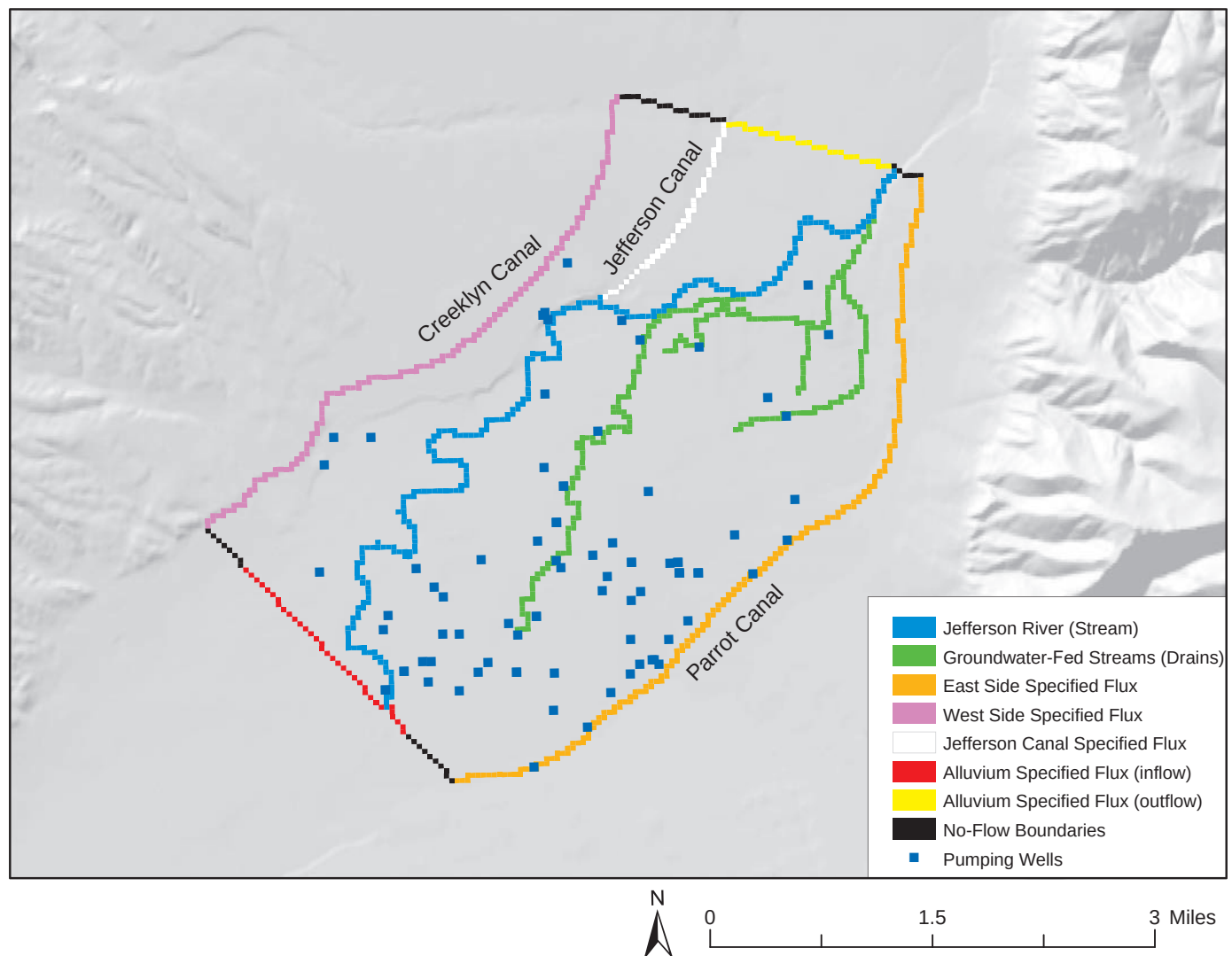


Figure 9. The model boundaries are based on the conceptual model (fig. 6); they include specified heads (drains), mixed specified heads and specified flux (stream), specified flux (wells used to simulate canal leakage and groundwater flux), and no-flow boundaries.

method, the slope between the Funston station and the upstream station near Silver Star (GWIC 277191; fig 1) was estimated as 0.001362 ft/ft (appendix B). These slopes were used to estimate streambed elevations for the Jefferson River through the Waterloo model domain.

Three segments were used in the STR package (fig. D3, appendix D). Segment 1 represents the Jefferson River from the southern model boundary to the Jefferson Canal. Segment 2 was a single cell simulating diversion from the Jefferson River into the Jefferson Canal, at the location of staff gage GWIC 274575. Segment 3 represents the Jefferson River from the Jefferson Canal to the northern model boundary, near Corbett station.

Segments 1 and 3 consist of a number of grid cells (reaches). The STR package calculates surface-water stage in each reach using Manning's equation for open channel flow. STR also calculates the exchange between the stream and groundwater (gain and loss) in each cell based on the head difference between surface-water and groundwater, and streambed conductance. The net surface-water flow is then

routed to the next reach in the segment. The STR package either routes all the water in the last reach (cell) to the next downstream segment, or splits the water between the downstream segment and a diversion.

In the model, flow enters the simulated Jefferson River at the first upstream cell in segment 1. In the steady-state simulation, an average flow of 1,724 cfs was the input flow (table 4). The input goes into the first upstream cell and the STR package calculates how much flow enters the next cells. In transient simulations, the monthly average flow was varied based on estimates from data collected between April 2013 and May 2015 (table 4). At the Jefferson Canal diversion (the downstream end of segment 1) water is diverted to the Jefferson Canal, an outflow through segment 2, or routed to segment 3 (the downstream reach of the Jefferson River), or split between diversion outflow and routed flow through segment 3. Diversion flow at segment 2 is input to the model as the average monthly flow obtained from available diversion records at GWIC 274575 (table 4).

Table 4. Transient model—Jefferson River inflows to the model domain and diversion rates.

Month	Multiplier	Monthly Inflow (cfs)	Inflow* (ft ³ /d)	Month	Diversion** (cfs)	Diversion (ft ³ /d)
Jan	0.80	1,031	7.13E+07	Jan	0	0
Feb	0.80	1,072	7.41E+07	Feb	0	0
Mar	0.80	1,256	8.68E+07	Mar	0	0
Apr	1.10	2,130	2.02E+08	Apr	13	1.09E+06
May	1.10	3,442	3.27E+08	May	64	5.50E+06
June	1.00	4,690	4.05E+08	June	59	5.11E+06
July	1.00	1,742	1.51E+08	July	77	6.61E+06
Aug	1.05	664	6.02E+07	Aug	93	8.00E+06
Sept	1.15	835	8.29E+07	Sept	47	4.05E+06
Oct	1.00	1,286	1.11E+08	Oct	0	0
Nov	0.90	1,378	1.07E+08	Nov	0	0
Dec	0.80	1,164	8.04E+07	Dec	0	0

Note. Average Monthly Inflow(cfs)** = 1,724. Average Monthly Diversion (cfs)** = 29. The average monthly flow of 1,724 cfs and diversion of 29 cfs are applied in the steady-state model.

*Inflow, the monthly inflow in cfs adjusted by a multiplier and converted to CFD.

**Flows obtained from GWIC 274575.

Groundwater-Fed Streams

Groundwater-fed streams were modeled using the Drain Package (DRN). Drains remove water from a model cell whenever the groundwater elevation is higher than the elevation of the drain bed. The drainage flux is calculated from the drain conductance and the difference between the groundwater and drain elevations (fig. D5, appendix D). This flux calculation is the same as in the STR package, except that drains never add water to the aquifer, whereas the STR package allows streams to lose flow to the aquifer.

We modeled Parson's Slough and Willow Springs as drains (285 drain cells; fig. D3, appendix D) since they are formed by groundwater discharge, and there is no evidence that they lose water to the aquifer. The drain cells were grouped into nine reaches. Parson's Slough has two reaches (1 and 9) and Willow Springs has seven reaches (2 to 8). Note that the STR and DRN packages both use the term "reach," but in the STR package a reach is a single cell, while in the DRN package a reach denotes a group of cells.

Drain elevations were set initially at 2 ft below ground surface based on air photos and survey data. These elevations were adjusted during steady-state calibration. The DRN package calculates bed conductance in the same way the STR package calculates the streambed conductance. Initial K_v values were 10% of the initial estimate of K_h and were later adjusted during model calibration.

Evapotranspiration

The MODFLOW EVT Package simulates riparian evapotranspiration (ET_r) as a flux equal to the portion of groundwater consumed by riparian vegetation. This flux depends on the head in the cell and on three user-specified variables: maximum extinction depth, the ET_r surface elevation, and maximum ET_r rates. The extinction depth was set to 10 ft below ground surface in cells with riparian vegetation land cover (phreatophytes and grasses; Leenhouts and others, 2006; Scott and others, 2004; Shah and others, 2007). The ET_r surface elevation was set equal to the land surface elevation (the top) of each cell. As shown in figure 10, maximum ET_r rates were set to 22 in/yr for woody plants and 3 in/yr for riparian grasses (similar to Bobst and others, 2016).

Specified Flux Boundaries

Specified flux boundaries add or remove a specified amount of water. In this model specified flux boundaries were implemented as injection or extraction wells (WEL package), or recharge (RCH package). These boundaries simulated alluvial groundwater flow into and out of the model along portions of the southern and northern edges, respectively, lateral groundwater inflows from east side and west side boundaries, irrigation recharge, leakage from irrigation canals, and pumping from wells.

Alluvial Groundwater Influx and Outflux

As discussed in appendix A (appendix A, fig A1, tables A5, A6, A11, and A12), groundwater flow into and out of the alluvial aquifer was calculated using Darcy's Law. At the southern model boundary, inflow was initially set as 46,742 acre-ft/yr and later reduced to 37,781 acre-ft/yr during calibration. This adjusted value was within the range of the uncertainty inherent in this calculation. The outflow at the northern model boundary was set as 25,962 acre-ft/yr, based on the preliminary water budget (appendix A). These rates were used in both the steady-state and the transient models.

Lateral Groundwater Influx, Upgradient Irrigation Recharge, and Canal Leakage

Along the eastern and western edges of the model, specified flux boundaries (injection wells) supplied water to the model along the Creeklyn and Parrot Canals. These boundary flows combine lateral groundwater inflow, upgradient irrigation recharge, and canal leakage. The combined inflow was estimated in the preliminary water budget. The long-term average inflow was used in the steady-state simulation, while the rates varied monthly according to changes in canal leakage and irrigation recharge in the transient simulation. We divided the Parrot Canal boundary into five segments, and the Creeklyn Canal into three segments to account for spatial variation in both canal leakage and irrigation recharge from upgradient irrigated fields (fig. 11).

Jefferson Canal

Canal leakage from the Jefferson Canal was also simulated as specified flux, using injection wells (fig. 11). This canal differs from the Creeklyn and Parrot Canals, in that it only represented canal leakage. The

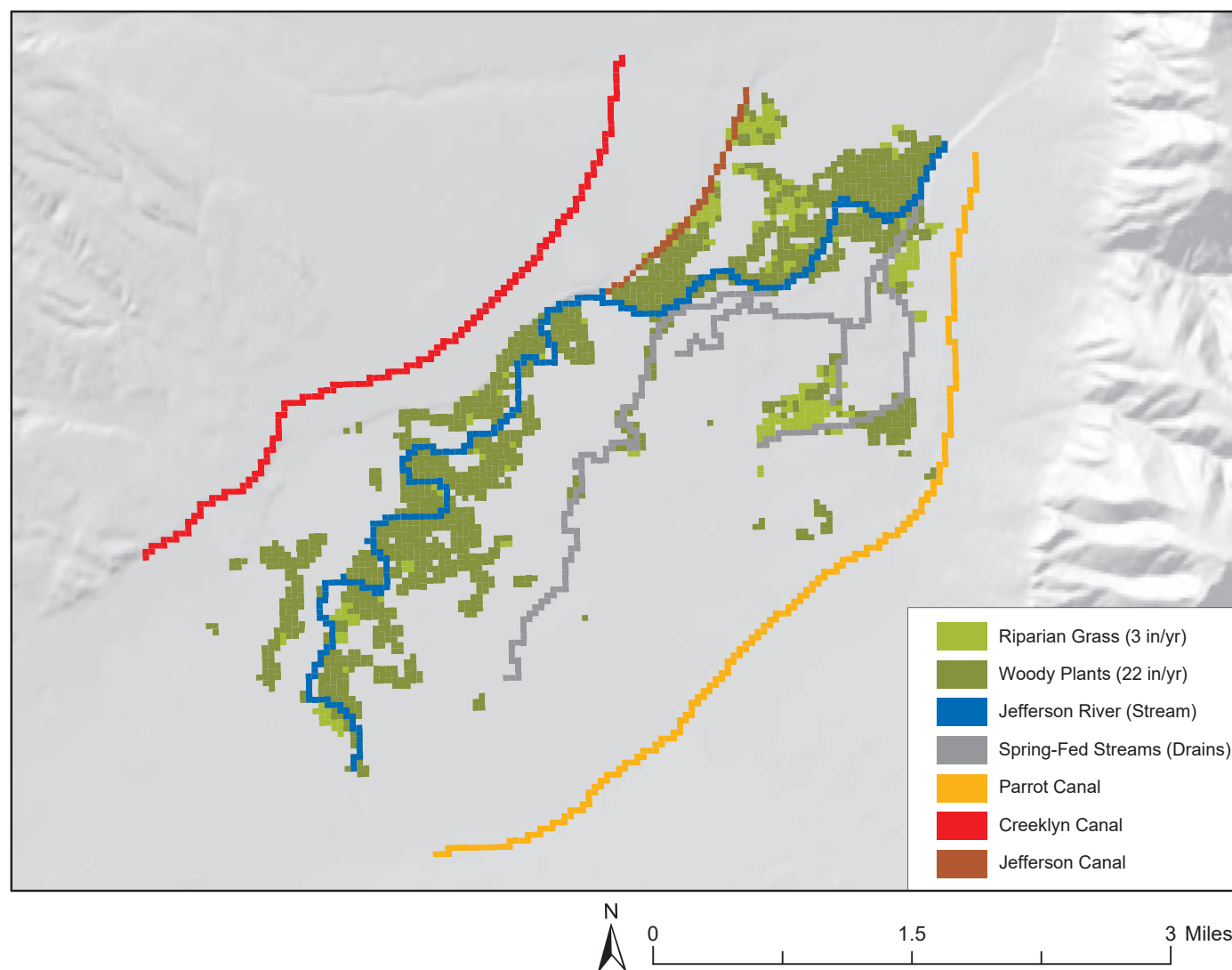


Figure 10. The distribution of the riparian evapotranspiration rates (ET_r), limited to areas with riparian grass and woody plants, concentrated along the Jefferson River, Parson's Slough, and Willow Springs.

Jefferson Canal was assigned the average leakage rate applied to the Parrot and Creeklyn Canals (appendix A).

Irrigation Recharge

Irrigation recharge supplies water to the model through the MODFLOW Recharge package (RCH), which is a specified flux boundary. The RCH package applies flux in units of length over time (L/T) applied over an area (L²). We applied irrigation recharge rates to portions of the model where land use was designated as irrigated fields. These areas were derived from the Statewide Final Land Unit classification database [Montana Department of Revenue (MDOR), 2012], field visits, and landowner interviews. The rate applied varied by irrigation method, crop type, and source water (appendix A; tables A9, A10). We estimated an annual recharge rate for each of six irrigation and crop types in the model area; initial values are shown in

table 5. Figure 12 shows the calibrated average irrigation recharge rates for the crop types and application methods. For the transient models, this recharge was only applied during the irrigation season, and the rate was slightly adjusted during calibration (Transient Calibration section).

Pumping Wells

The MODFLOW WEL package simulated pumping from domestic, stock, and irrigation wells (fig. 9) with overall water consumption of about 134 acre-ft/yr. The annual consumption is made of 76% irrigation water, 22% domestic water, and 2% for livestock (appendix A). The domestic well average annual consumptive is 435 gallons per day (gpd; or 58.15 ft³/d) per residence, based on rates determined for the North Hills, located near Helena, Montana, with a climate similar to that of the Waterloo area (Waren and others, 2013).

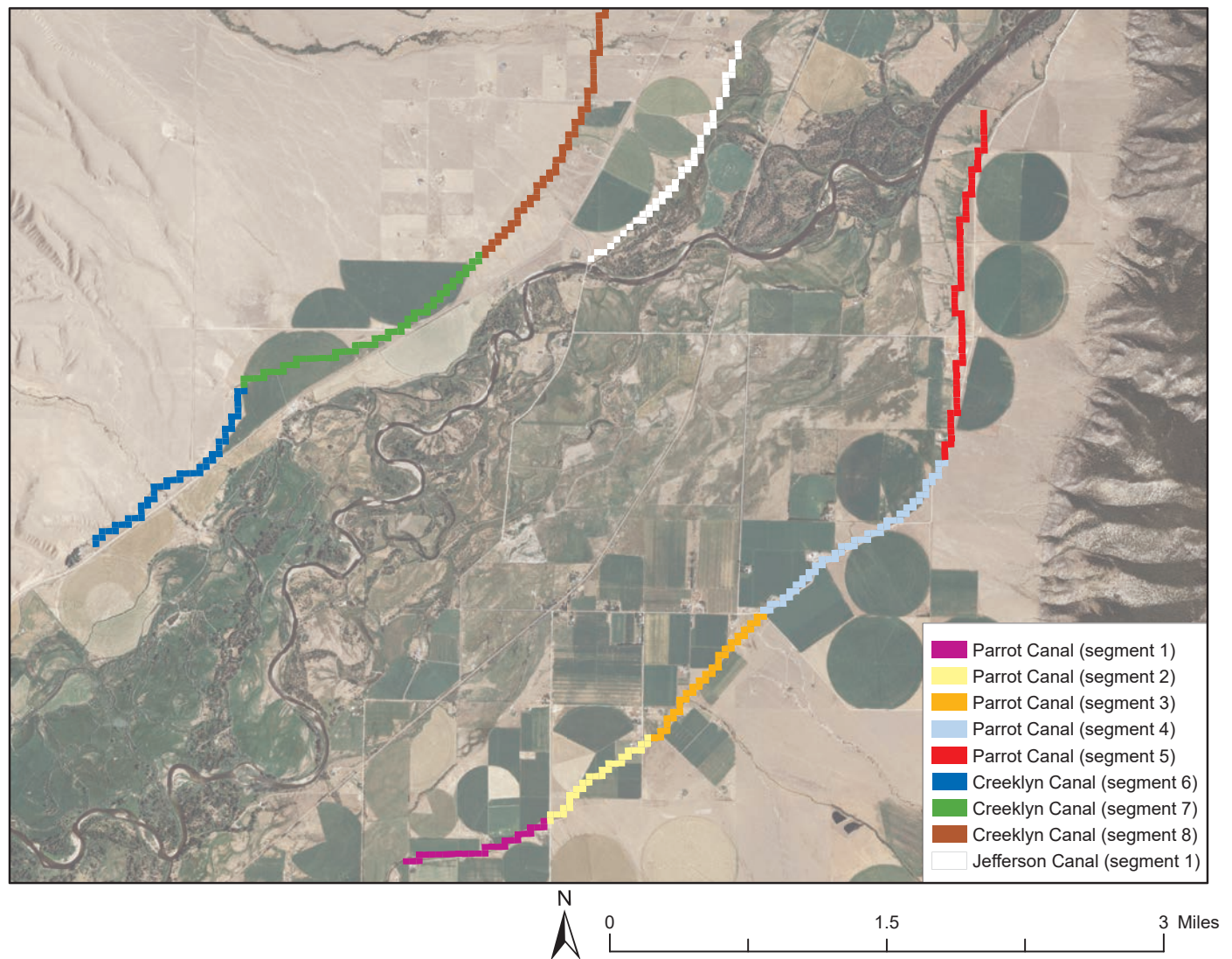


Figure 11. Dividing the Parrot and Creeklyn irrigation canals into segments helped to improve the model transient calibration. Segments correspond to the location and the extent of the irrigated fields outside the model area.

Table 5. Irrigation recharge rates initially applied to the Waterloo model.

		Flood	Sprinkler	Pivot
		Avg. Recharge (ft/d)*	Avg. Recharge (ft/d)*	Avg. Recharge (ft/d)*
Month**	Multiplier	6.33E-03	9.16E-04	5.06E-04
Apr	1	6.33E-03	9.16E-04	5.06E-04
May	2	1.27E-02	1.83E-03	1.01E-03
Jun	2	1.27E-02	1.83E-03	1.01E-03
Jul	2	1.27E-02	1.83E-03	1.01E-03
Aug	2	1.27E-02	1.83E-03	1.01E-03
Sep	2	1.27E-02	1.83E-03	1.01E-03
Oct	1	6.33E-03	9.16E-04	5.06E-04

*The average recharge for each irrigation type is applied in the steady-state model.

**Recharge rates for each irrigation type are applied from April through October in transient simulations.

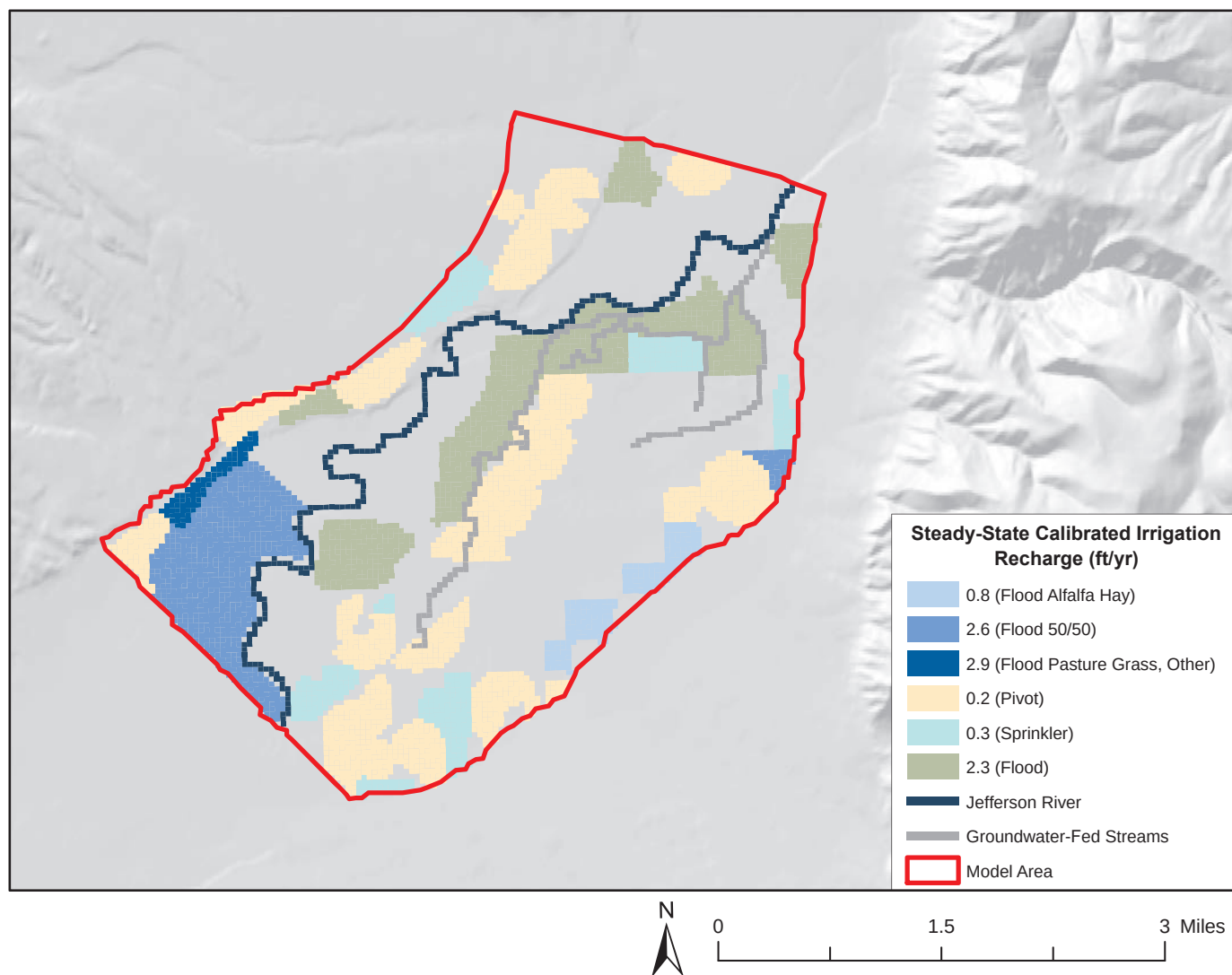


Figure 12. Calibrated steady-state annual irrigation recharge rates.

No-Flow

No-flow boundaries are a type of specified-flux boundary where the flux is zero. No-flow boundaries were used along portions of the southern and northern sides of the model, where flow lines are parallel to the model boundaries (figs. 5, 9). These boundaries are set in areas where the potentiometric surface suggests little to no flow entering or leaving the model domain. At the southern edge of the model, no-flow boundaries extended from the Parrot and Creeklyn Canals to the alluvium. At the northern edge of the model, they extended from the Creeklyn Canal to the Jefferson Canal and from the Parrot Canal to the Jefferson River (fig. 9).

MODEL CALIBRATION

In model calibration, changes are systematically made to model parameters in order to match field observations within some acceptable error. For this

model field observations included groundwater elevations, stream elevations, and stream flows. The ultimate goal of model calibration is to find a set of model parameters that make the model useful to predict future system behavior with confidence. One challenge in model calibration is commonly known as the *non-uniqueness problem*: the possibility that different combinations of model parameters may provide an equally good match to field measurements, resulting in another version of the calibrated model. For this model, we used field observations, the settings of the hydrogeologic units, aquifer test results, published values for aquifer properties, and the preliminary groundwater budget (appendix A) to reduce the possibility of creating a non-unique model.

Initial Heads

April 2015 water levels were the basis for initial heads in the model (fig. 5). The values were extrapo-

lated over the modeling domain using Surfer 9 to make an initial-head surface. During the steady-state calibration, the head results from one run were used as the initial heads for the next run to improve model run times. The final steady-state calibrated heads were set as the initial heads for the transient simulations.

Steady-State Calibration

A steady-state model simulates the groundwater flow system in equilibrium with its boundary stresses. The goal of the steady-state calibration was to estimate the model's parameters, within a reasonable range of field observations and published values, to simulate the mid-April 2015 heads distribution, while maintaining a water budget consistent with observations (appendix A). A steady-state simulation can be useful in predicting the effect to the groundwater flow system from potential stress changes; quantifying the total groundwater budget; and estimating stream and drain conductance independently from storage parameters (Doherty and Hunt, 2010). In this study, we calibrated the steady-state model by adjusting hydraulic conductivities (K_h), streambed conductance, and drain conductance. The steady-state calibrated model produced a set of heads and boundary fluxes applied to the first stress period (1-d steady-state period) in the transient simulations.

Calibration Targets

Calibration targets included observed groundwater elevations, stream flows, groundwater discharge to the Jefferson River between Parson's Bridge and Corbett's station, and groundwater discharge to Parson's Slough and Willow Springs.

The groundwater-monitoring network initially was composed of 25 wells in the Waterloo area. Groundwater-level data were generally collected monthly from July 2013 through October 2015. To avoid the effects of snowmelt and irrigation, data from April 13, 2015 were selected as the steady-state (average) head calibration targets. Four wells (GWIC 276103, 276127, 276041, 276113) were dry on April 13, 2015; therefore, they were excluded from the target list. Only heads from the remaining 21 wells were used (fig. 13); table E1 in appendix E lists the selected target wells.

The calibration criterion for groundwater head was set as a ± 5 ft head residual, approximately 10% of the 50 ft range (maximum head - minimum head)

observed in April 2015. We evaluated the steady-state model calibration using overall error statistics of the head residuals, i.e., the residual mean (ME); the mean of the absolute value of the residuals (MAE), and the root mean square (RMS) error.

It is worth noting that there are no calibration targets in the west and southwest regions of the model domain (hachured lines in fig. 13). Although the lack of targets in these areas may have affected the estimation of streambed conductance, the model was insensitive to this parameter (sensitivity analysis section). In addition, the eastern and northeastern portions of the model domain are the primary focus of this modeling study, where Parson's Slough and Willow Springs originate and groundwater discharges to the Jefferson River.

Groundwater flux and streamflow targets facilitated the calibration of the bed and streambed conductance in DRN and STR packages, respectively. A surface-water flow target was set at the last stream cell, representing Corbett's station on the Jefferson River. Groundwater discharge targets were assigned along the stream segments (fig. 13). During calibration, discharge to the stream segments was compared to the average net groundwater discharge to the river that was calculated in the preliminary water budget.

The ability of the model to simulate the average groundwater discharge to Parson's Slough and Willow Springs was important for evaluating the steady-state calibration. We compared the simulated steady-state discharge to the drains (Parson's Slough and Willow Springs) to their average flow (from field data); the average target ranged between 35 cfs and 60 cfs.

Calibration Methods

Calibration of the steady-state model involved the use of the automated parameter estimation software PEST and limited manual adjustments of hydraulic conductivity (K_h). PEST is executed independently of MODFLOW, and it is not involved in solving the governing flow equation. In order to determine the quality of fit to observed data, PEST automatically varies one—or a group—of the model's input parameters (e.g., hydraulic conductivity, conductance, recharge, etc.) within a specified range, runs the MODFLOW flow model, and then evaluates the model's output (e.g., heads) by minimizing an objective function (ME, RSS, RMS, etc.).

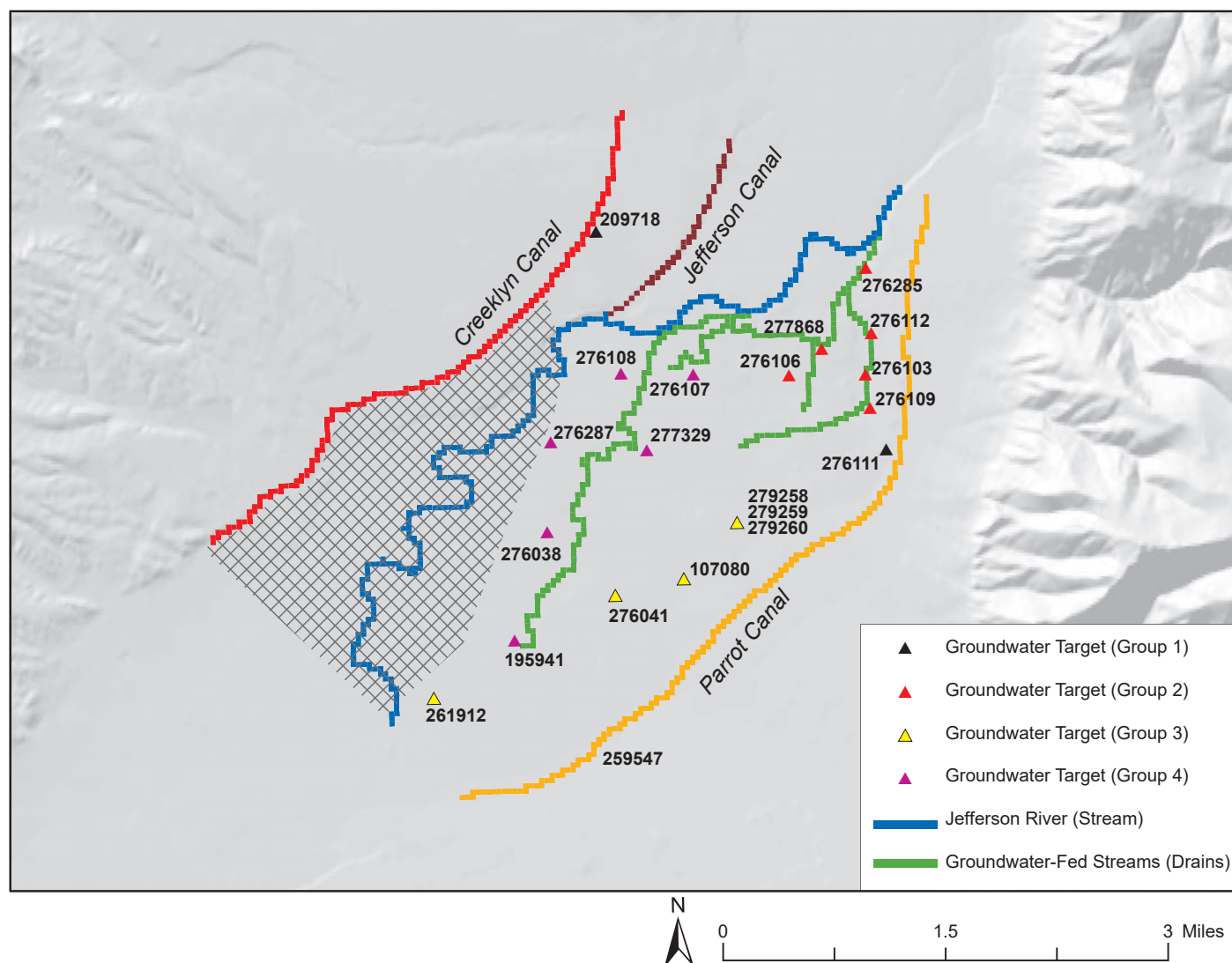


Figure 13. Model calibration groundwater wells (targets) divided into four groups based on location. The hachured lines show the part of the model domain without target wells.

The objective of calibration is to minimize the difference between the model output and observed values (i.e., to minimize the residuals). For groundwater heads, the goal was to minimize the sum of squared residuals (RSS), consequently reducing the average simulation error, typically presented as the root mean squared error (RMS). For Jefferson River flows, the goal was to minimize the difference between simulated average monthly flow and the measured average monthly flow at Corbett's station. For the groundwater-fed streams, the objective was reducing the difference between the simulated discharge to the drains and the measured combined average discharge for Parson's Slough and Willow Springs.

In the steady-state model calibration, we applied PEST to estimate the horizontal hydraulic conductivity distribution (K_h), Jefferson River bed conductance (segments 1 and 3), and Parson's Slough and Willow

Springs bed conductance. The K_h was initially divided into four zones determined by the geology (figs. 4, 8). However, with this set up, PEST could not produce a calibrated model; simulated heads did not meet calibration criteria even within the same hydraulic zone, suggesting a greater heterogeneity in aquifer properties. Therefore, the calibration was repeated using the PEST pilot points method. The pilot points method generates parameter values at selected points (pilot points) within the model grid, which in turn serve as surrogate parameters, and their values are interpolated onto the model domain. The interpolation method is specified by the user. For this model, we selected the ordinary kriging interpolation method with an exponential variogram, utilizing default values provided by Groundwater Vistas, and an applied search radius of 2,500 ft. A uniform grid was initially used to create PEST (K_h) pilot points. Additional pilot points were

added in areas near the drain to enhance calibration in those areas. Seventy-eight pilot points helped to achieve the calibrated steady-state model (fig. 14). Pilot point values were constrained by upper and lower bounds established for the geologic setting in the area (floodplain, bench, etc.). The bounds established for each area were typically within an order of magnitude of those defined by the aquifer test data (Bobst and Gebril, 2020), the conceptual model, and by published values (Freeze and Cherry, 1979; Fetter, 2001). Most pilot points in the floodplain alluvium fell within hydraulic conductivity values of 1,000 and 6,000 ft/d. However, pilot points near Parson's Slough and Willow Springs (drains) had a lower range (100 to 500 ft/d); for the bench sediments (within zone 3, fig. 8), the range was from 1 to 285 ft/d.

Steady-State Calibration Results

The calibrated model simulates the Jefferson River with a steady-state flow of 1,727 cfs at segment 3, comparable to the long-term average flow at Corbett's station (~1,690 cfs). The average simulated net groundwater discharge to the Jefferson River (stream segments 1 and 3) was 8 cfs, which is about 70% of 12 cfs, the average groundwater discharge estimated for 2014 (Broncheau, 2015). Streambed conductance averaged 1.3×10^7 ft²/d in stream segment 1, and 5.6×10^6 ft²/d in segment 3. Simulated discharge to Parson's Slough and Willow Springs (combined) was 47 cfs, which is within the established range of 35 to 60 cfs.

The model reasonably simulated the potentiometric surface in the model area (fig. 15). Qualitatively, the potentiometric contours show the expected in-

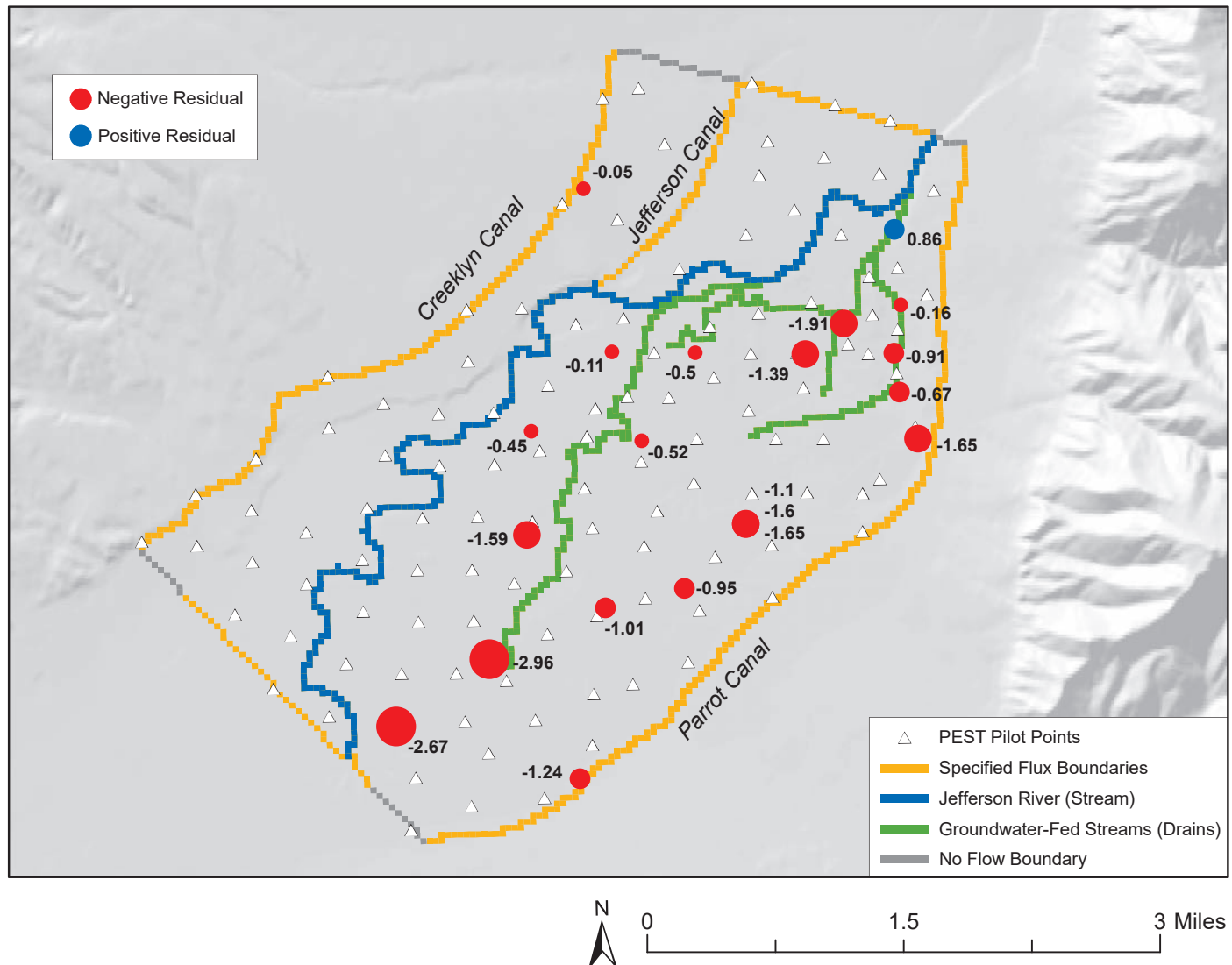


Figure 14. PEST pilot points and calibrated steady-state residuals. Placing 78 pilot points enabled PEST to estimate the heterogeneous hydraulic conductivity within the model domain. The steady-state calibrated head residuals from 21 target wells were all below 5 ft (calibration criteria).

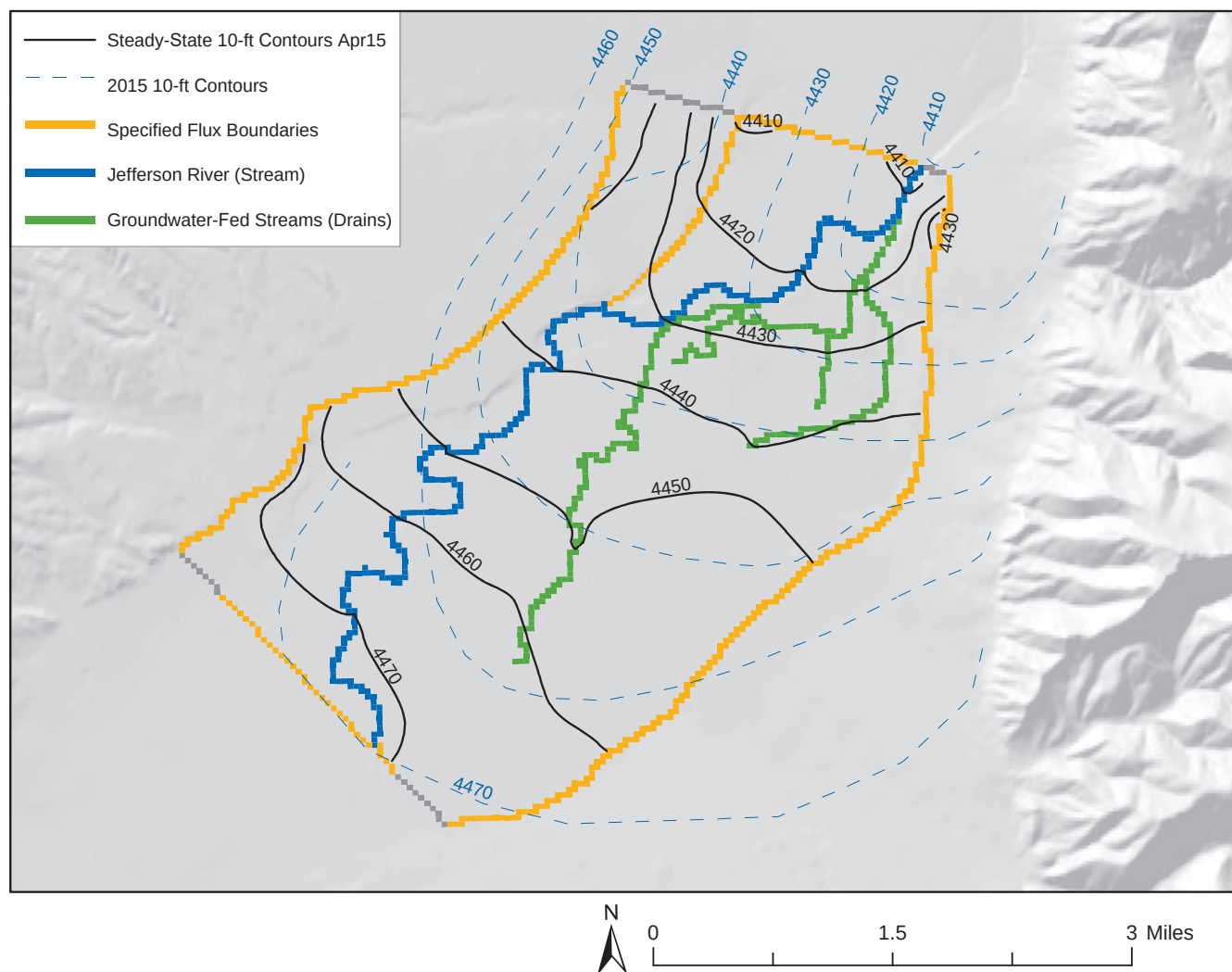


Figure 15. Calibrated steady-state potentiometric surface compared to conditions observed in April 2015. The potentiometric contours display interaction among the alluvial aquifer and surface water, Jefferson River, Parson's Slough, and Willow Springs, and demonstrate the gaining and losing segments of the river and the groundwater-fed streams.

teraction among groundwater and Parson's Slough and Willow Springs (drains), and the Jefferson River (stream); i.e., reaches of gaining and losing are consistent with the conceptual model. The modeled heads closely match the observed values in the 21 target wells (fig. 16). Head residuals (the difference between observed and modeled heads) were all below the 5 ft criteria (fig. 14; table E1, appendix E); however, they are slightly on the high side almost everywhere in the domain, still not affecting the quality of the calibration. Thirteen head residuals (61.9%) were less than 1 ft, six residuals (28.6%) were between 1 and 2 ft, and two residuals (9.5%) were between 2 and 3 ft. The RMS calibration statistic was 1.38 ft, a much lower value than the 5 ft error criteria.

As shown in figure 17, the steady-state model water budget is generally comparable to the Waterloo preliminary water budget. The numerical model

simulated more canal leakage and lateral groundwater influx than initially estimated, and less irrigation recharge and groundwater influx. The calibrated model discharged less groundwater to the Jefferson River than estimated, but discharged more to Parson's Slough and Willow Springs. Overall, the calibrated model simulated less net groundwater discharge to surface waters than the preliminary budget.

The distribution of calibrated K_h indicates a more heterogeneous distribution than was originally conceptualized (fig. 8 vs. fig. 18). The K_h values in the floodplain alluvium (initially zone 1) ranged from 11 to 6,270 ft/d, with a geometric mean of 1,140 ft/d. The alluvial terrace (initially zone 2) has K_h values ranging from 15 to 7,620 ft/d, with a geometric mean of 20 ft/d. The western bench (initially zone 3) has K_h values ranging from 1 to 5,000 ft/d, with a geometric mean of 187 ft/d. The K_h values in the eastern bench (initially

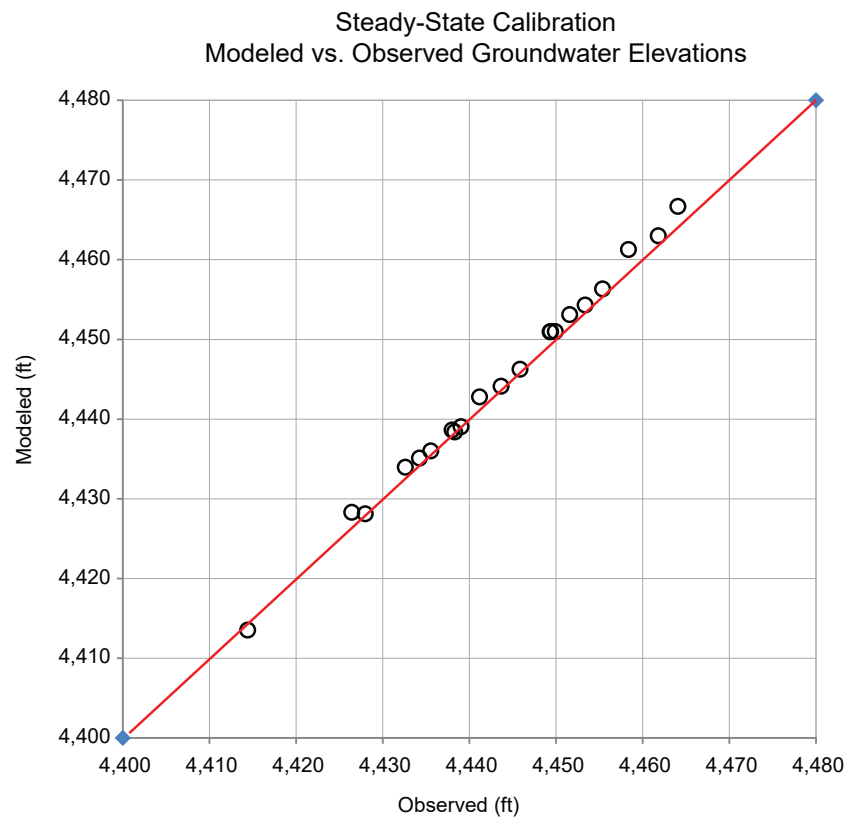


Figure 16. The steady-state calibrated heads closely match the observed heads. Each point represents a target well plotted using its observed head (horizontal axis) and modeled head (vertical axis). Points located along or near the 1:1 line (red) indicate a close match between observed and modeled heads.

zone 4) ranged from 1 to 345 ft/d, with a geometric mean value of 20 ft/d. From the calibration results, it appears that (a) conductive fluvial sediments underlie some portions of the alluvial terrace, and (b) most of the lower conductivity in zone 2 are near Parson's Slough and Willow Springs (fig. 18), consistent with field observations of marshy wet conditions, indicating an elevated water table due to a lower transmissivity.

Transient Calibration

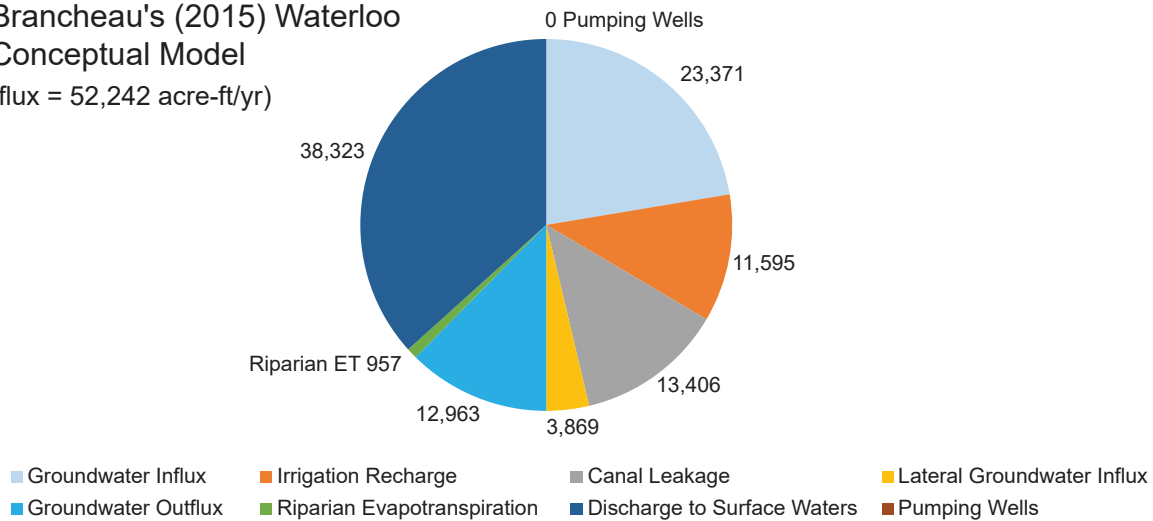
Transient calibration of a groundwater model aims to adjust the model's time-dependent parameters to reasonably reproduce groundwater heads and fluxes, and surface-water flows that respond to time-dependent changes in boundary conditions and/or applied stresses. Calibration was achieved by adjusting aquifer storage properties and boundary conditions until observed water-level changes were reasonably simulated by the model. We used PEST to estimate the model's storativity, storage coefficient S_s , and/or specific yield S_y ; other boundary parameters (e.g., canal leakage) were modified manually.

Calibration Targets

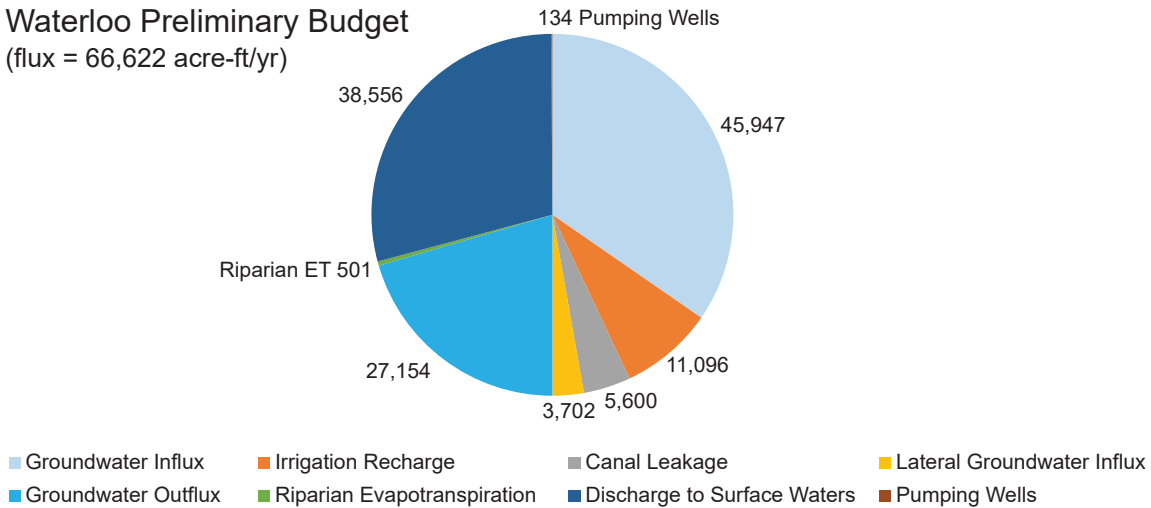
Nineteen target wells had data suitable for the transient calibration. Ten wells have data from 2004 to 2005, with a data gap from 2005 to 2013, and additional data from April 2013 to June 2015. Data from eight wells are limited to April 2013 to June 2015. One well (GWIC 107080) has a continuous record from 2004 to 2015. Due to these data gaps, we calibrated the transient model to the 2013–2015 period, and used data from 2004 to 2005 for model validation.

The three surface-water monitoring sites located on the Jefferson River are the Funston station, USGS station at Parson's Bridge, and the Corbett station (fig. 3). Corbett station operated from April 29, 2014 to November 11, 2014. Funston station operated from July 9, 2014 to November 10, 2014, and the USGS station at Parson's Bridge operated from July 1 to September 30 in 2013 and 2014. Corbett station was selected as the surface-water calibration target because (a) it has the longest record in 2014, and (b) it is located at the model's downstream boundary, where it receives all flows from the Jefferson River, Parson's Slough, Willow Springs, and the net groundwater discharged to the Jefferson River.

Brancheau's (2015) Waterloo Conceptual Model (flux = 52,242 acre-ft/yr)



Waterloo Preliminary Budget (flux = 66,622 acre-ft/yr)



Waterloo Numerical Model (flux = 50,305 acre-ft/yr)

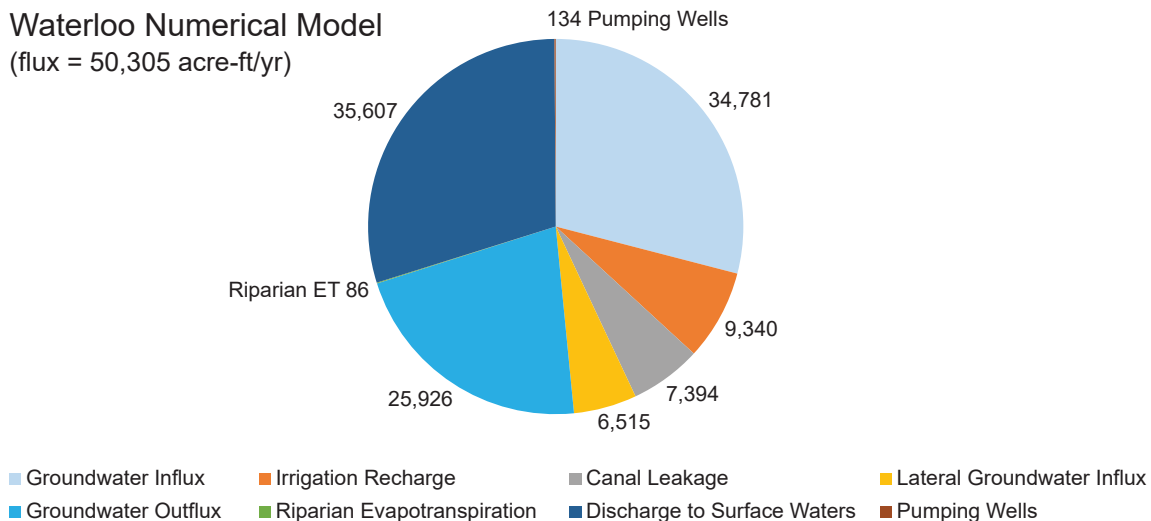


Figure 17. Comparison of three water budgets (Brancheau's 2015 budget, the preliminary budget, and the calibrated steady-state numerical model). The numerical model water budget is comparable to the preliminary water budget with some differences in the distribution of inflow to the aquifer. The three budgets show that outflow is primarily divided between discharge to surface water and groundwater outflow.

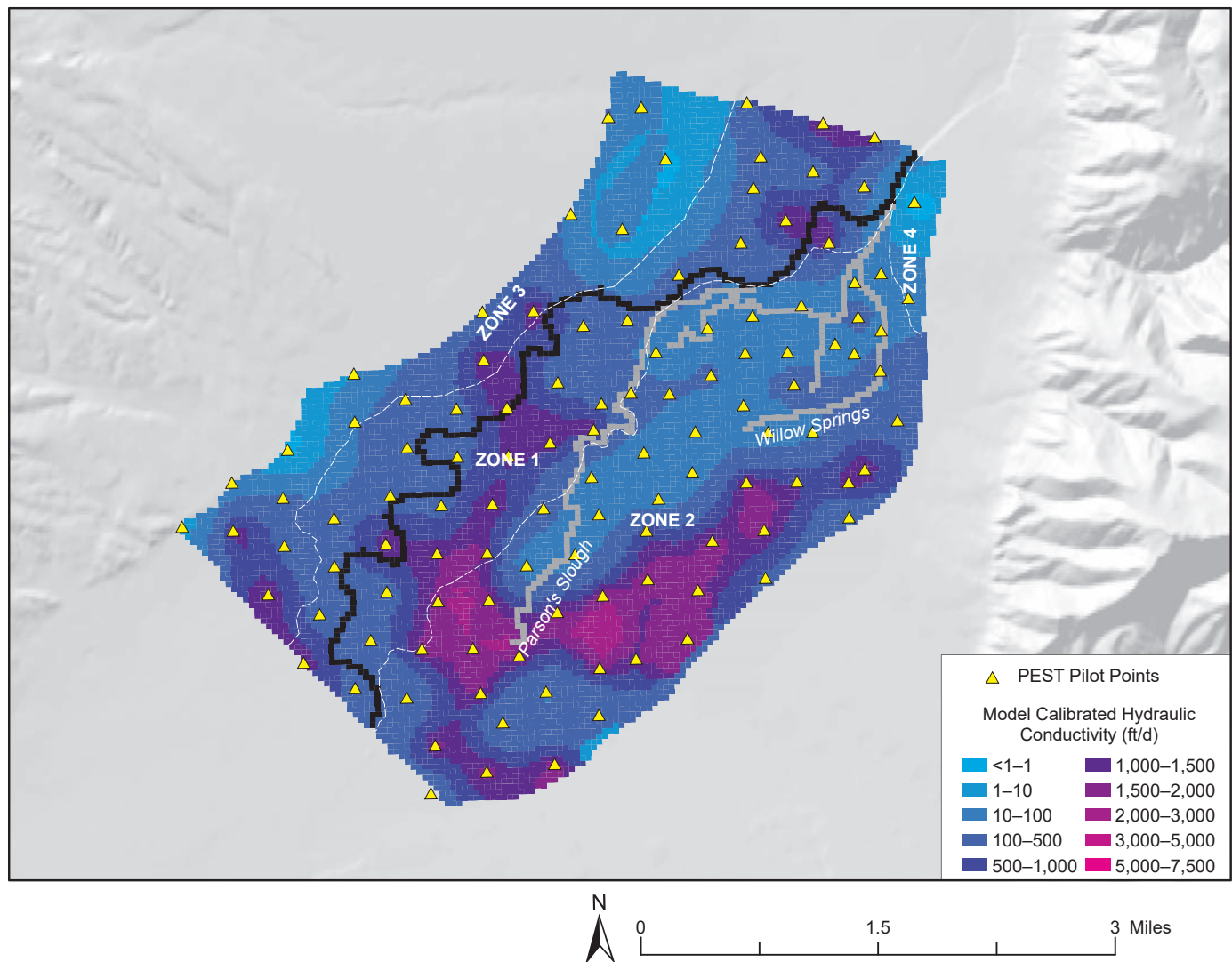


Figure 18. Distribution of horizontal hydraulic conductivity (K_h) in the calibrated steady-state model. This distribution of K_h is more heterogeneous than that based on geologic units (fig. 8).

Transient Calibration Methods

Stress Periods

The transient model was initiated with a 1-d stress period (corresponds to March 31, 2013) as a steady-state period, with its output, like the heads and boundary stresses, becoming the initial conditions for the subsequent transient simulation. Starting the simulation in April, the beginning of the irrigation season and 3 mo ahead of the data collection period (July 2013), provided the numerical model with enough time to stabilize and adjust to seasonal changes.

After the first stress period, boundary stresses varied monthly from April 2013 through October 2015 to replicate seasonal changes. These stresses include irrigation recharge rate, canal leakage, lateral groundwater inflow along the Parrot and Creeklyn Canals, evapotranspiration, river flow entering the model

area, diversions, and pumping from irrigation wells. Domestic and stock wells were kept at constant pumping rates (appendix A). The groundwater inflow and outflow through the alluvial aquifer across the southern and northern boundaries remained constant at their steady-state rates throughout the transient simulation.

Aquifer Storage Estimation Using PEST

Storage parameters in MODFLOW were specified using the layer property-flow (LPF) package, with a layer type “LAYCON” equals 1, which is unconfined layer type, applying specific yield (S_y) to calculate changes in storage within each cell.

For the transient calibration, we identified four geologic zones for which PEST estimated S_y : the western bench (zone 1), the alluvial valley (zone 2), and two zones representing the eastern bench (zones 3 and 4, fig. 19). The eastern bench zones were designed

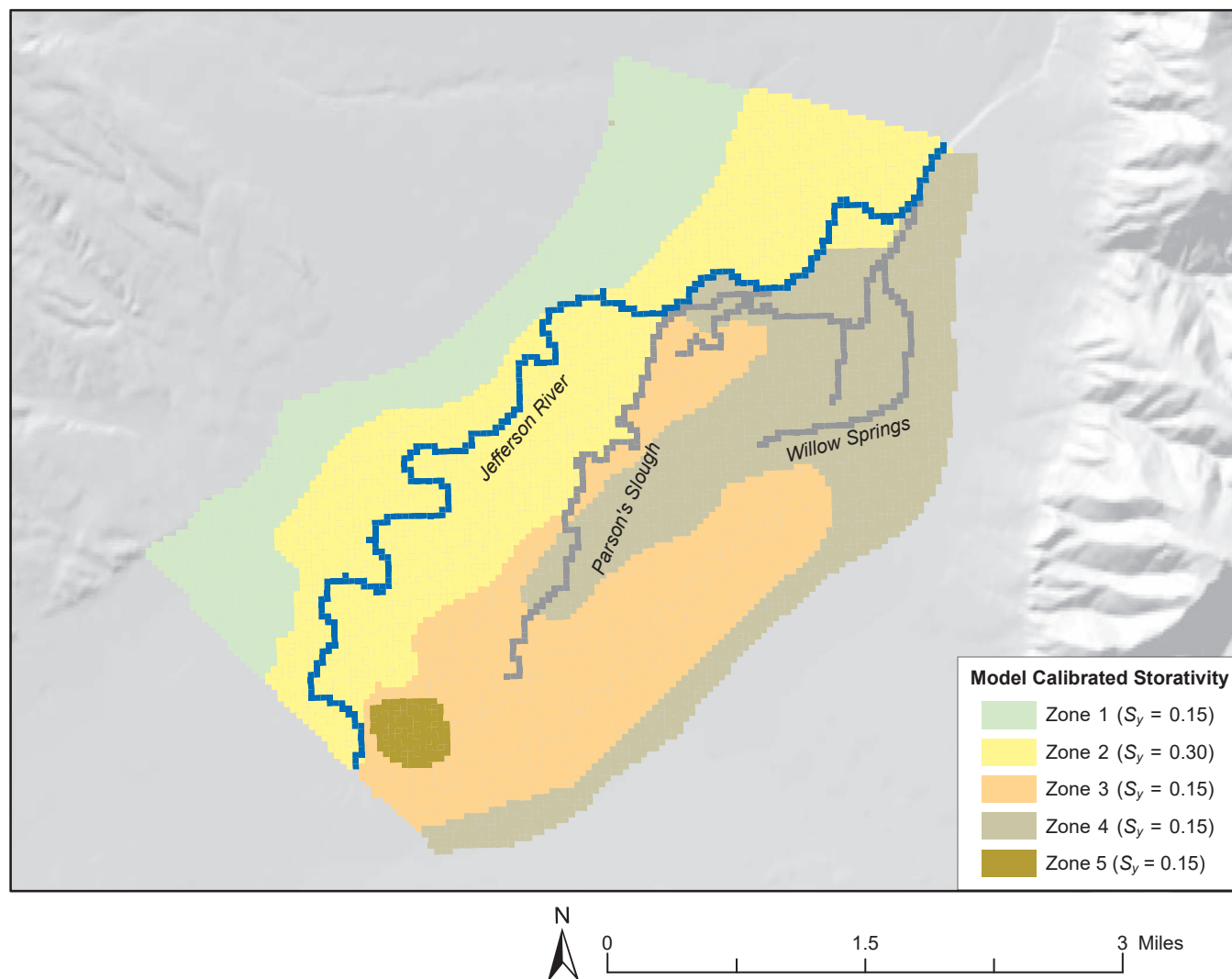


Figure 19. Transient model calibrated aquifer storage coefficients produced by PEST using the zonal approach. The property zones include the western bench (zone 1), the alluvial valley (zone 2), and the eastern bench (zones 3, 4). Zone 5 was added to improve the calibration close to the south (upgradient) end of the Jefferson River.

to generally account for the apparent variation in K_h distribution in that area. PEST produced similar storage coefficients S_y for zones 3 and 4, suggesting these act as one zone. Additional adjustment of S_y needed to improve the calibration in targets near the southwest boundary of the model, was accomplished by adding a fifth zone within zone 3 (fig. 19), in which S_y was modified manually.

Irrigation Recharge Estimation

As shown in the Model Construction section of this report and documented in appendix A (appendix A, tables A9, A10), several irrigation recharge zones simulated pivot, sprinkler, and flood irrigation. During the transient calibration, the average irrigation recharge rates applied to the steady-state model were systematically changed—with multipliers—to generate monthly irrigation recharge rates over the calendar

year (table 5). The model was run with the adjusted recharge rates and the results were compared to observed head changes at target wells. This process was repeated until there was a good match with observations. Additional recharge zones representing different rates were added during the transient simulation to adjust groundwater levels to match target hydrographs (table 6, fig. 20).

Evapotranspiration Estimation

The steady-state evapotranspiration rates were applied to the transient model. A multiplier was applied for the months April through September, and a multiplier of zero was used for the rest of the calendar year. This approach was used for both riparian grass and woody plant zones. The multipliers were adjusted for April through September to produce monthly rates reflecting seasonal variations in ET_p (table 7). The

Table 6. Transient calibration—Recharge rates applied to the Waterloo model.

Month	Multiplier	Zone 1	Zone 2	Transient Recharge Rates (ft/d)										Multiplier	Transient Recharge Rates (ft/d)				
				Zones 3, 14–18	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13					
Apr	0.9	0	7.38E-05	5.70E-03	4.55E-04	8.24E-04	7.20E-03	6.45E-03	1.94E-03	6.40E-04	1.00E-02	4.72E-03	2.22E-03	8.10E-03	1.25	1.00E-02	4.72E-03	2.22E-03	8.10E-03
May	1.8	0	1.48E-04	1.14E-02	9.10E-04	1.65E-03	1.44E-02	1.29E-02	3.89E-03	1.28E-03	2.01E-02	9.45E-03	4.44E-03	1.62E-02	2.5	2.01E-02	9.45E-03	4.44E-03	1.62E-02
Jun	1.8	0	1.48E-04	1.14E-02	9.10E-04	1.65E-03	1.44E-02	1.29E-02	3.89E-03	1.28E-03	2.01E-02	9.45E-03	4.44E-03	1.62E-02	2.5	2.01E-02	9.45E-03	4.44E-03	1.62E-02
Jul	1.8	0	1.48E-04	1.14E-02	9.10E-04	1.65E-03	1.44E-02	1.29E-02	3.89E-03	1.28E-03	2.01E-02	9.45E-03	4.44E-03	1.62E-02	2.5	2.01E-02	9.45E-03	4.44E-03	1.62E-02
Aug	1.8	0	1.48E-04	1.14E-02	9.10E-04	1.65E-03	1.44E-02	1.29E-02	3.89E-03	1.28E-03	2.01E-02	9.45E-03	4.44E-03	1.62E-02	2.5	2.01E-02	9.45E-03	4.44E-03	1.62E-02
Sep	1.8	0	1.48E-04	1.14E-02	9.10E-04	1.65E-03	1.44E-02	1.29E-02	3.89E-03	1.28E-03	2.01E-02	9.45E-03	4.44E-03	1.62E-02	2.5	2.01E-02	9.45E-03	4.44E-03	1.62E-02
Oct	0.9	0	7.38E-05	5.70E-03	4.55E-04	8.24E-04	7.20E-03	6.45E-03	1.94E-03	6.40E-04	1.00E-02	4.72E-03	2.22E-03	8.10E-03	1.25	1.00E-02	4.72E-03	2.22E-03	8.10E-03
Average Recharge (ft/d)		0.00	8.20E-05	6.33E-03	5.06E-04	9.16E-04	8.00E-03	7.16E-03	2.16E-03	7.11E-04	8.04E-03	3.78E-03	1.78E-03	6.48E-03	Average Recharge (ft/d)				

Note. Zone 1 recharge was zero (not shown in the table). Recharge applied to zones 14 and 18 is identical to zone 3 recharge.

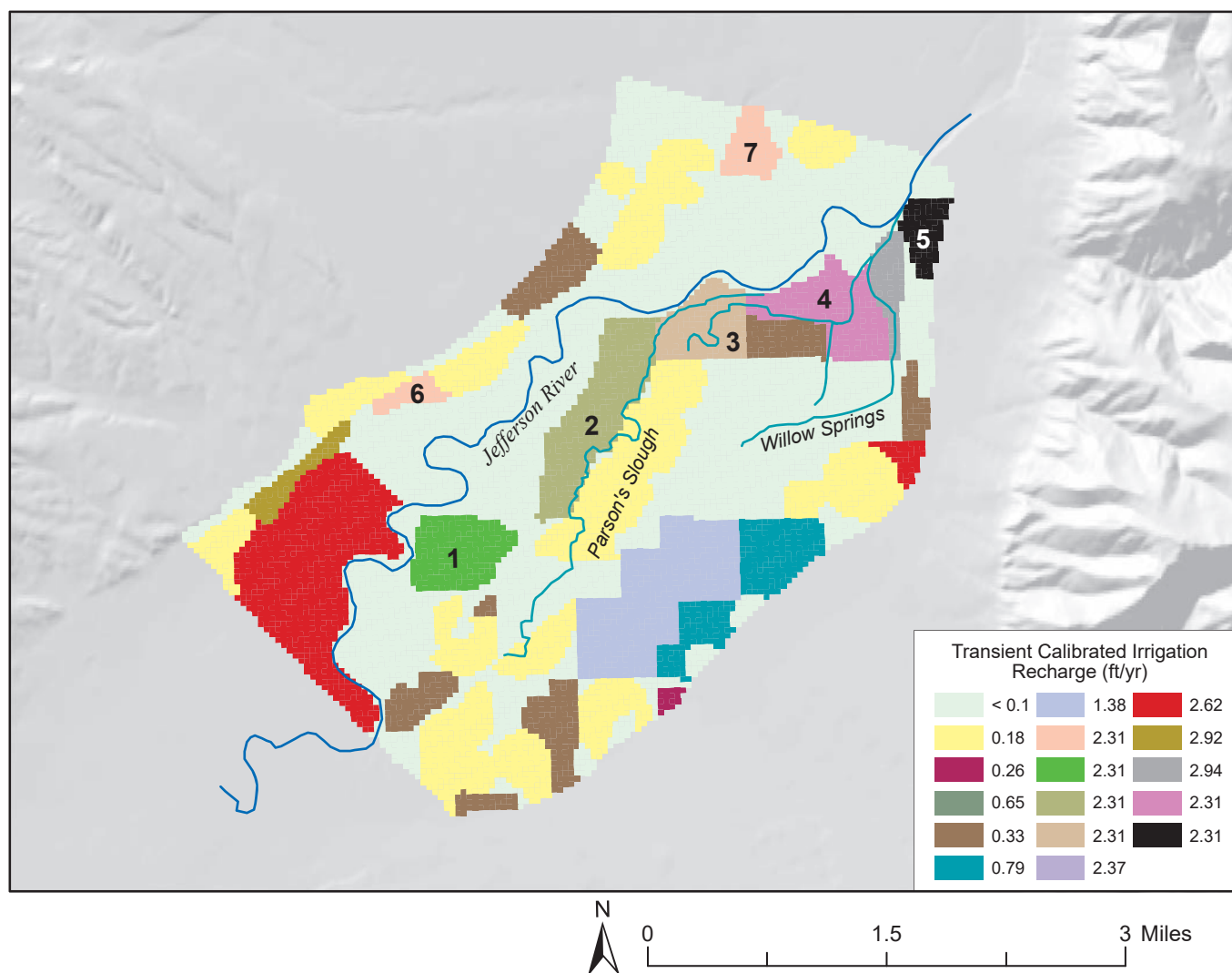


Figure 20. Transient model calibrated irrigation recharge. Areas 1 to 7 are flood-irrigated zones with annual average recharge rate of ~2.3 (ft/yr). These areas were converted to pivot irrigation (~0.2 ft/yr) to simulate effects of changes to irrigation practices.

Table 7. Evapotranspiration rates applied to the transient calibration.

	Woody Plants Zone	Riparian Grass Zone
	Average ET (22 in/yr)	Average ET (3 in/yr)
Month	Multiplier	Multiplier
Apr	0.09	0.00
May	0.21	0.09
Jun	0.30	0.21
Jul	0.27	0.30
Aug	0.14	0.27
Sep	0.00	0.14

Note. ET rates are applied through growing season only, April–September.

model was run with the adjusted ET_p rates, and the simulated hydrographs at target wells were compared to measured data. This process was repeated until the results were considered satisfactory.

Canal Leakage and Lateral Groundwater Inflow

The Parrot and Creeklyn Canals were initially modeled as single segments with uniform leakage rates, but this yielded a poor match to target hydrographs. We divided both canals into smaller segments (fig. 11) with its own specified flux rate. The rate represents the sum of canal leakage, lateral groundwater inflow, and irrigation recharge from adjacent upgradient irrigated areas outside the model domain (figs. 21, 22). The segments adequately simulate variation in canal leakage along the canal length, and account for changes in lateral groundwater influx and upgradient irrigation recharge. The Jefferson Canal was represented with a single segment because the specified flux represents canal leakage only (figs. 11, 22).

Jefferson River Flows

In the steady-state model, the average monthly flow in the Jefferson River (1,724 cfs) was based on data from the three surface-water stations in the

model domain (fig. 3), and the year-round USGS gage between Twin Bridges and Silver Star (USGS 06026500). During calibration of the transient model, we adjusted monthly multipliers applied to the average flow at the beginning of the Jefferson River (stream reach 1) to improve the model's match to groundwater head targets and average monthly river flows at Corbett station, at the downgradient end of the river (table 4, fig. 23).

Jefferson River Diversions

The diversion from the Jefferson River to the Jefferson Canal occurs immediately downstream of Parson's Bridge. For the steady-state model, we estimated a steady-state average diversion rate of 29 cfs based on monitoring records for the Jefferson Canal (GWIC 274575; Jefferson Canal at Diversion). In the transient model, we calculated average monthly diversion rates (table 7, fig. 24) from monitoring data and adjusted them during calibration.

Calibration Results

The calibrated transient model simulates head changes with time that matched well with observations (figs. 25–28). Grouping target wells according to their

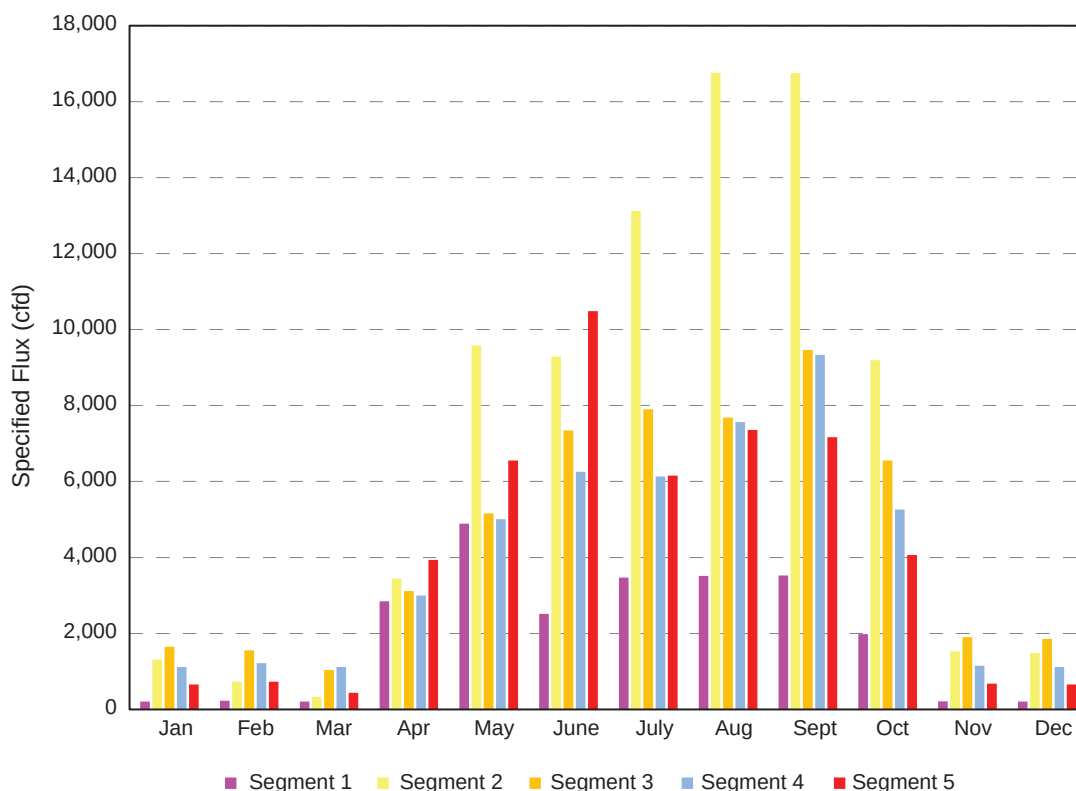


Figure 21. Transient model calibrated specified flux per well along Parrot Canal. The boundary was divided into five segments (fig. 11). The applied flux represents the sum of canal leakage, lateral groundwater influx, and irrigation recharge from irrigated fields outside of the model domain.

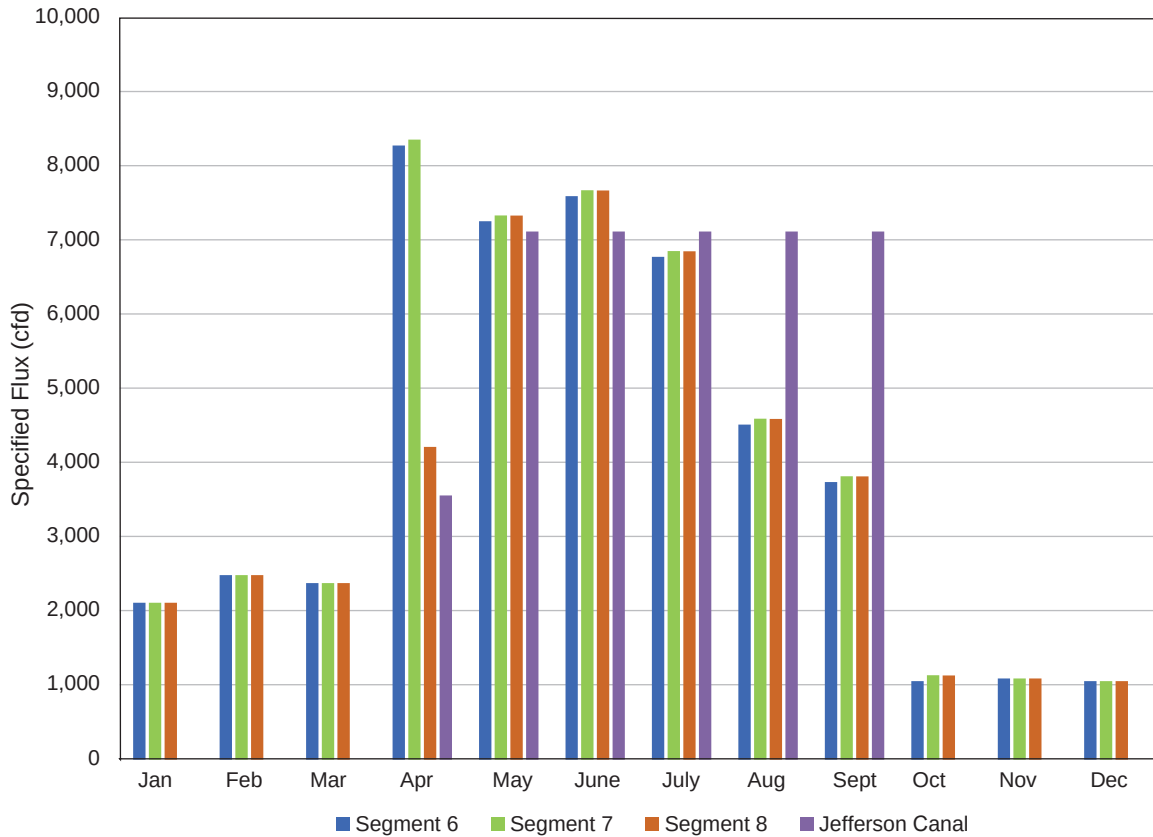


Figure 22. Transient model calibrated specified flux per well along Creeklyn and Jefferson Canals. The canals were divided into segments (fig. 16). For Creeklyn Canal, the applied flux represents the sum of canal leakage, lateral groundwater influx, and irrigation recharge from irrigated fields outside of the model domain. For Jefferson Canal the applied flux represents canal leakage.

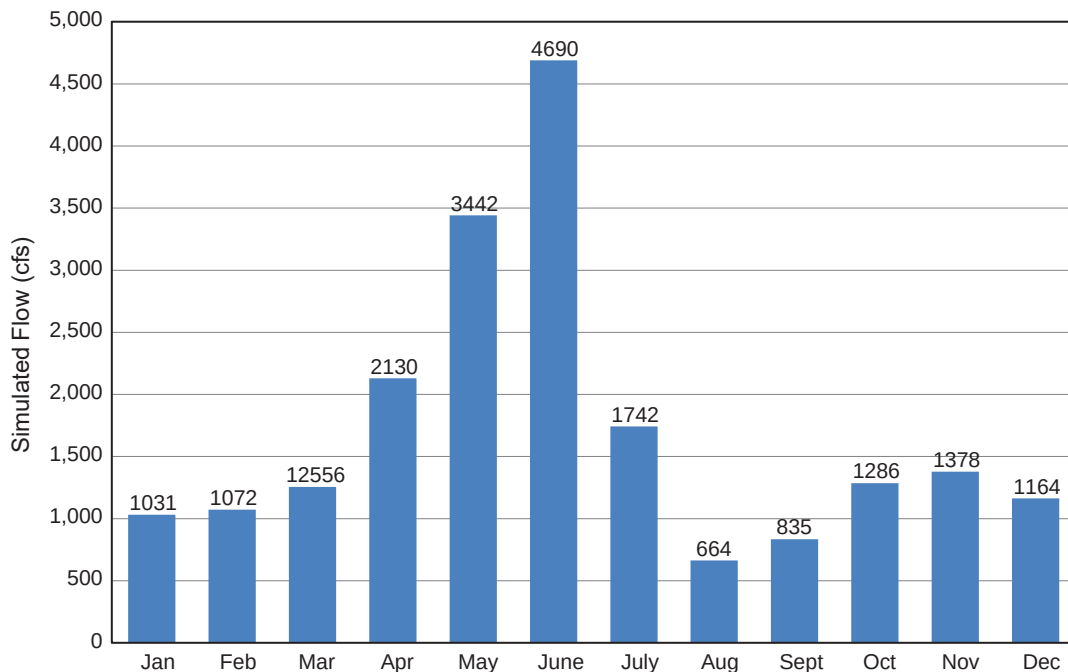


Figure 23. Transient model average monthly flows at the upstream end of the Jefferson River. River input flows were slightly adjusted during calibration with multipliers.

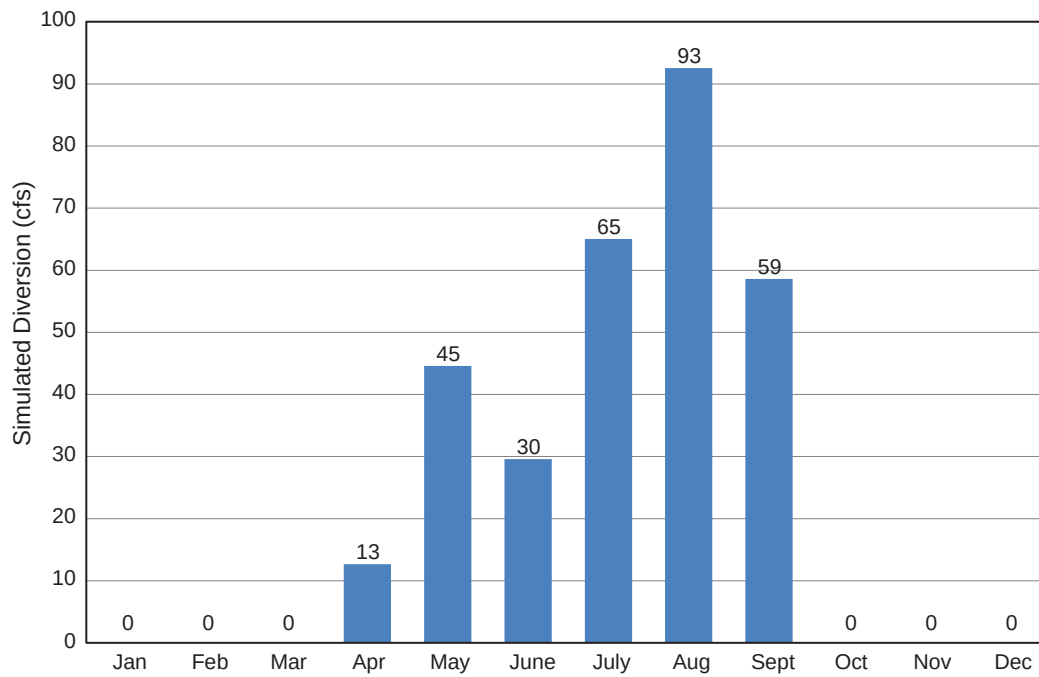


Figure 24. Transient model average monthly diversion from the Jefferson River to the Jefferson Canal during the irrigation season (April through September).

proximity to the model's boundaries (i.e., irrigation canals, groundwater-fed streams, river, etc.) revealed a common response to stresses within each group. Qualitatively, transient calibration results show the following:

1. Simulated groundwater levels at target wells near the Parrot and Creeklyn Canals (group 1) show a good match to observed data and captured seasonal head fluctuations (fig. 25). Canal leakage, lateral groundwater inflow, and irrigation recharge influenced groundwater heads in these areas.
2. Simulated groundwater levels at target wells close to Parson's Slough and Willow Springs (group 2) generally matched the observed hydrographs (fig. 26). They reflect the effect of seasonal recharge and a damping effect of groundwater discharge to the drains that shield them from the river's influence.
3. Target wells located between the Parrot Canal and Parson's Slough (group 3) show a good match to field observations (fig. 27). It appears that irrigation recharge strongly influenced these wells, as demonstrated by mid-summer peaks in hydrographs when the demand for irrigation is high.
4. The hydrographs for target wells in the floodplain, west of Parson's Slough (group 4), show a good match to observed heads, with a capture of seasonal head changes, caused by increased river flow due to snowmelt, and increased irrigation recharge (fig.

28). Hydrographs of wells 276287 and 276108, both located in flood-irrigated areas, demonstrate the combined influence of the Jefferson River and irrigation recharge.

We used the Nash Sutcliffe coefficient of efficiency (Nash and others, 1970) to quantify the fit between simulated and measured heads. The Nash Sutcliffe efficiency coefficient (*NS*) ranges from $-\infty$ to 1; a positive *NS* means a good fit (1 is the best fit), while a negative *NS* indicates poor matching (Anderson and others, 2015). A detailed example of the *NS* calculation is presented in appendix E. As shown in transient calibration results (figs. 25–28), 13 of 19 hydrographs (68% of the targets) have positive *NS* coefficients, meaning an overall good fit between simulated and observed conditions. Well 277868 and well 276038 in groups 2 and 4, respectively, showed large negative *NS* coefficients. Close proximity of well 277868 to Willow Spring (modeled as a drain) may have caused the higher heads at that well. Heads simulated at well 276038 appear to be influenced by the Jefferson River. Improving the fit to those targets was not possible without degrading the quality of the rest of the model calibration.

The simulated Jefferson River flow at the end of stream reach 3 is the sum of instream flow and net groundwater discharge to the river; however, it does not include groundwater discharge to Parson's Slough

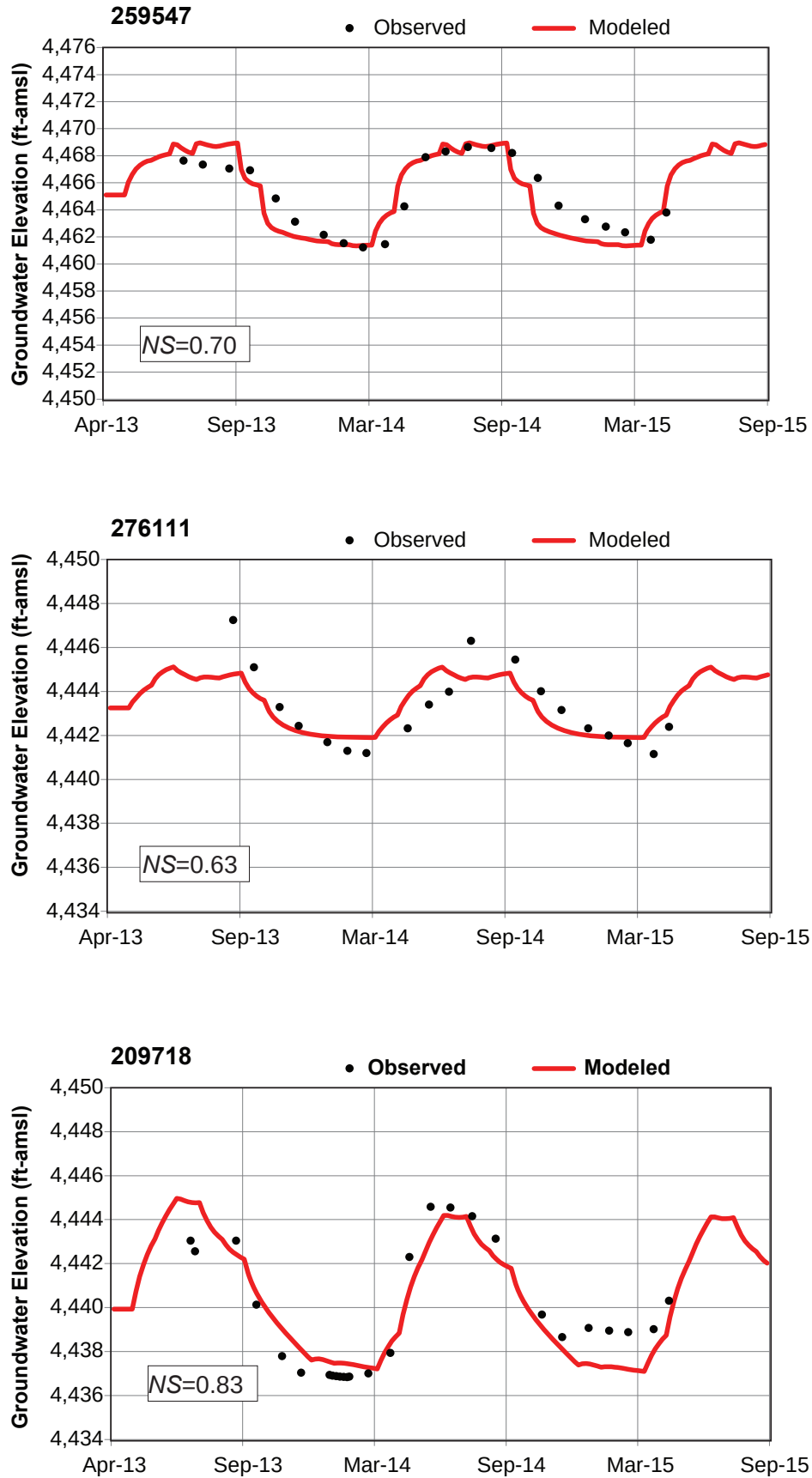


Figure 25. Transient model calibrated groundwater hydrographs (groundwater elevations) for three target wells (Group 1). Results show that the model captured seasonal head changes with a good fit indicated by positive *NS* number (*NS*, Nash Sutcliffe coefficient of efficiency).

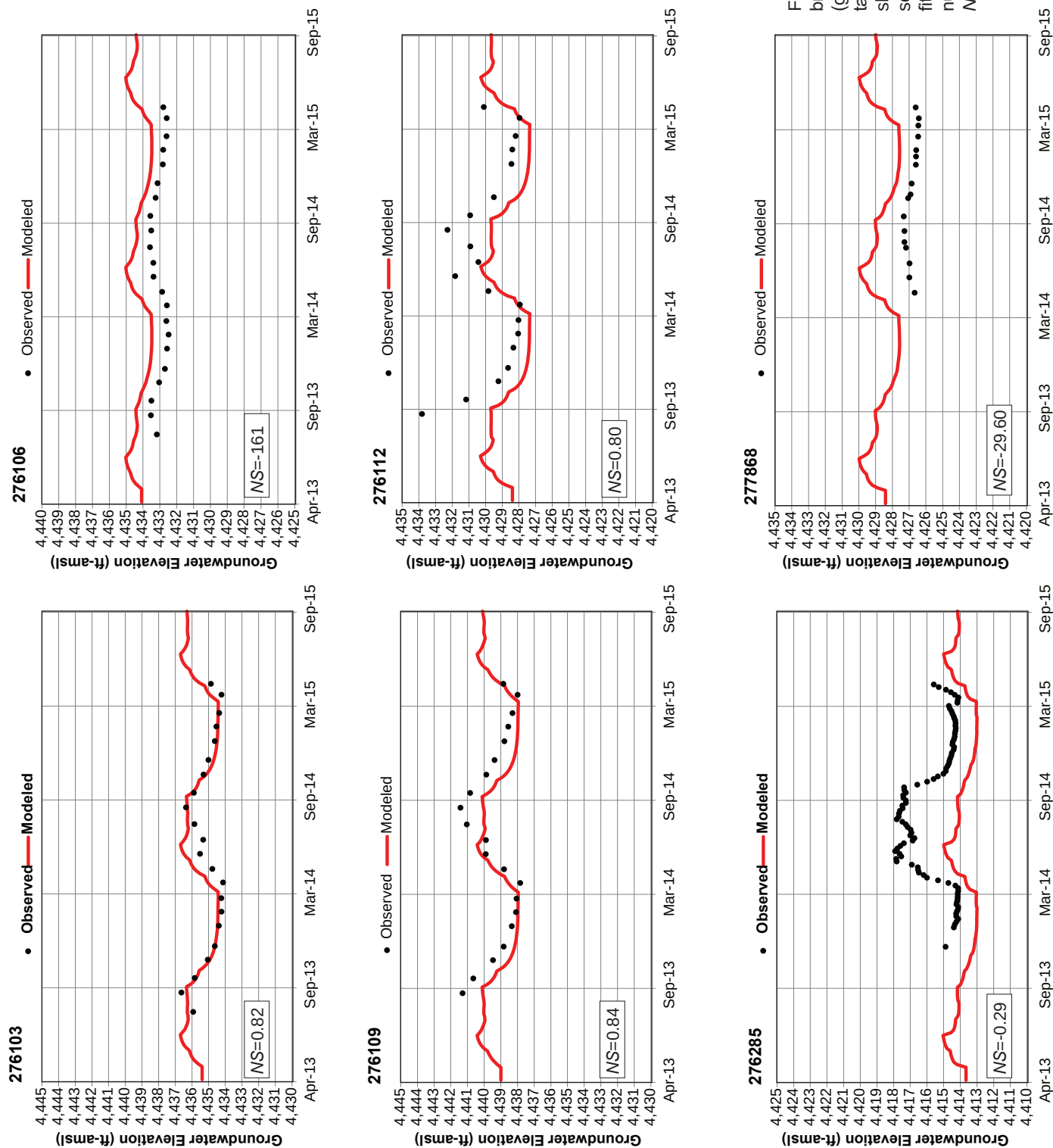


Figure 26. Transient model calibrated groundwater hydrographs (groundwater elevations) for six target wells (Group 2). Results show that the model captured seasonal head changes with a good fit in three of the wells (positive NS number), and three with negative NS number (poor fit).

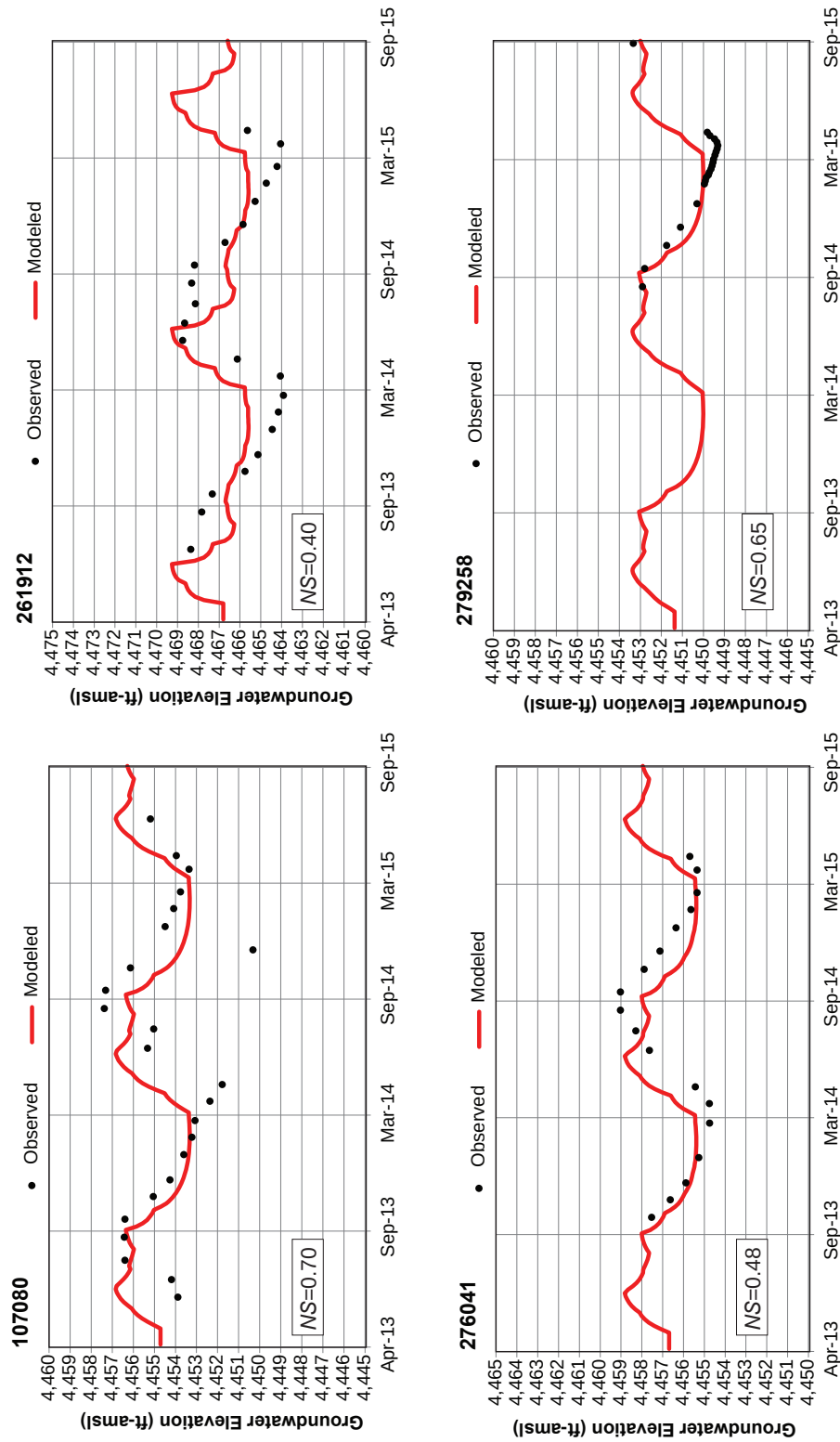


Figure 27. Transient model calibrated groundwater hydrographs (groundwater elevations) for four target wells (Group 3). Results show that the model captured seasonal head changes with a good fit indicated by positive NS number. Effects of boundary (Jefferson River) and irrigation recharge are noticed on the simulated heads (well 261912).

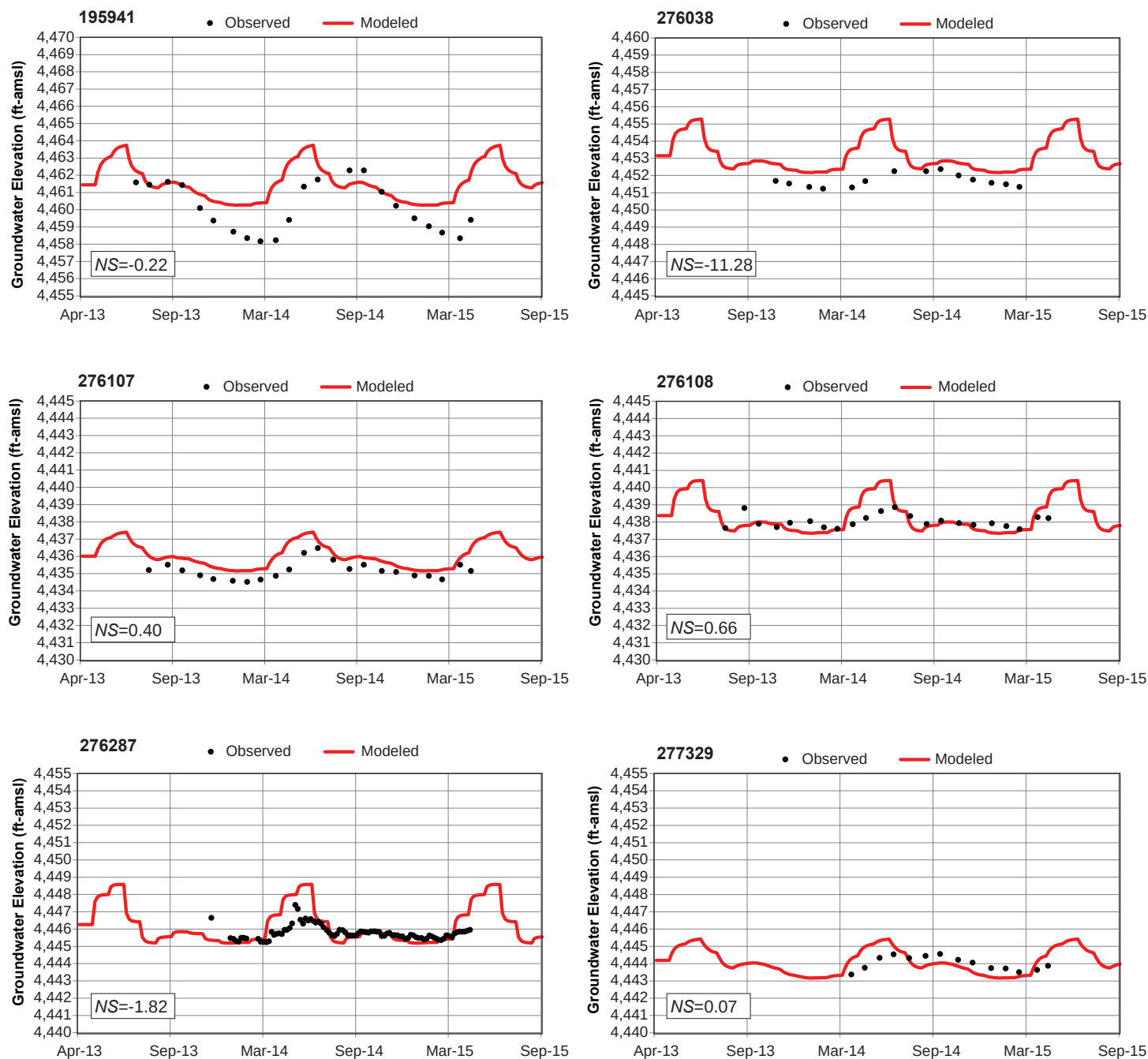


Figure 28. Transient model calibrated groundwater hydrographs (groundwater elevations) for six target wells (Group 4). Results show that the model captured seasonal head changes with a good fit in three of the wells (positive NS number), and three with negative NS number (poor fit). Simulated hydrographs from wells of this group show strong effect of simulated leakage from Jefferson River and irrigation recharge during the irrigation season.

and Willow Springs. In reality it feeds directly into the Jefferson and becomes part of the measured flow at Corbett station (exit point). In order to account for all flows at the river exit point, we added the simulated groundwater discharge to the drains (Parson's Slough and Willow Springs) to the flow at the end of the river (stream reach 3). This combined flow was compared to observed flows at Corbett station from May 2014 to November 2014. The transient simulation of the monthly average flows closely matched measured monthly average flows at Corbett station (fig. 29).

MODEL VERIFICATION

A calibrated model applies a selected set of hydrogeological parameters, sources and sinks, and boundary conditions to match historical field data. Model verification includes testing the calibrated model by simulating other field data (targets) deliberately excluded during calibration. If successful, the model verification is a process that can increase confidence in the model, especially the use of the model to predict hydrological responses to future changes in applied stresses, such as the addition of wells or changes in irrigation recharge.

We verified the model performance using 11 target wells with water levels from the years 2004–2005. The model was run forward from 2003 to 2015. Simulated

groundwater hydrographs compared to observed heads show that in most target wells the model reasonably simulated head changes during the verification period, and captured seasonality (fig. 30). Several target wells showed a close match to historic observed water levels (e.g. wells 107080, 276103, 276108, 276287, and 277329). Therefore, in general, the transient model was considered to be verified. However, the model underpredicted heads at two wells (276285 and 276112). These wells are likely influenced by flood irrigation practices at adjacent fields, and by the management of the Parrot Canal (figs. 12, 13). For instance, the water-regulating structure for the Kurnow blowout immediately uphill from these wells (fig. 3) was upgraded to minimize leakage between 2006 and 2013. Thus, in the area near these wells, the calibration period of 2013 to 2015 was dissimilar to conditions during the verification period (2004–2005).

SENSITIVITY ANALYSIS

A calibrated groundwater model contains the best estimates of the hydrogeologic parameters that produce results in good agreement with target values, or other calibration criteria. The objective of the sensitivity analysis is to “quantify the uncertainty of the calibrated model caused by uncertainty of aquifer parameters, stresses, and boundary conditions” (Anderson and others, 2015). Sensitivity analysis involves

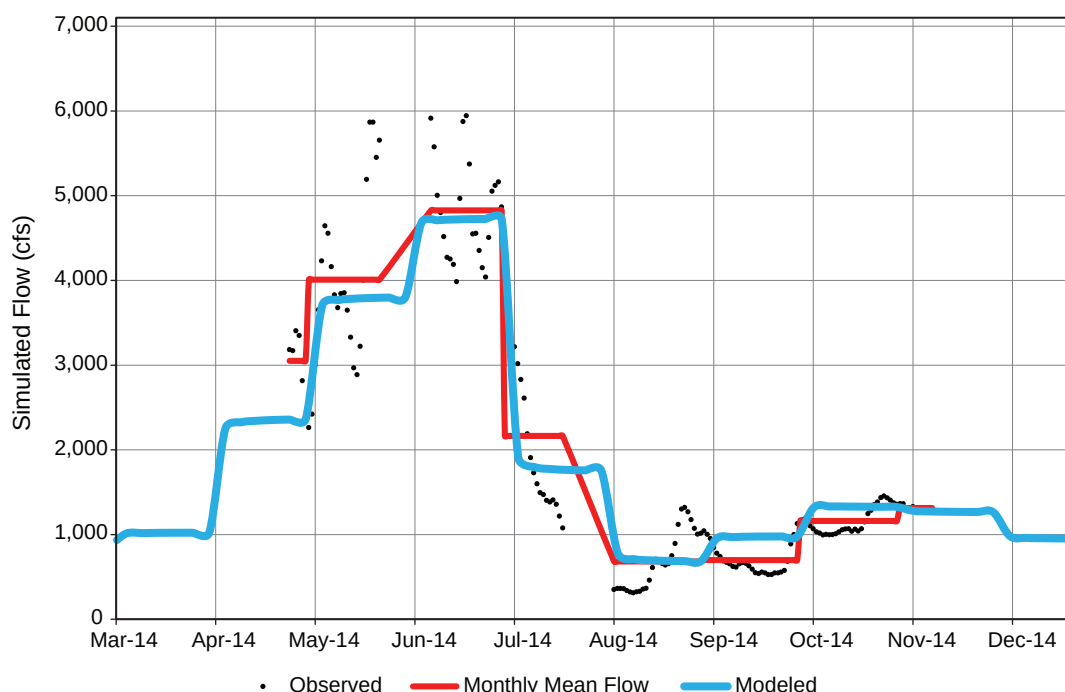
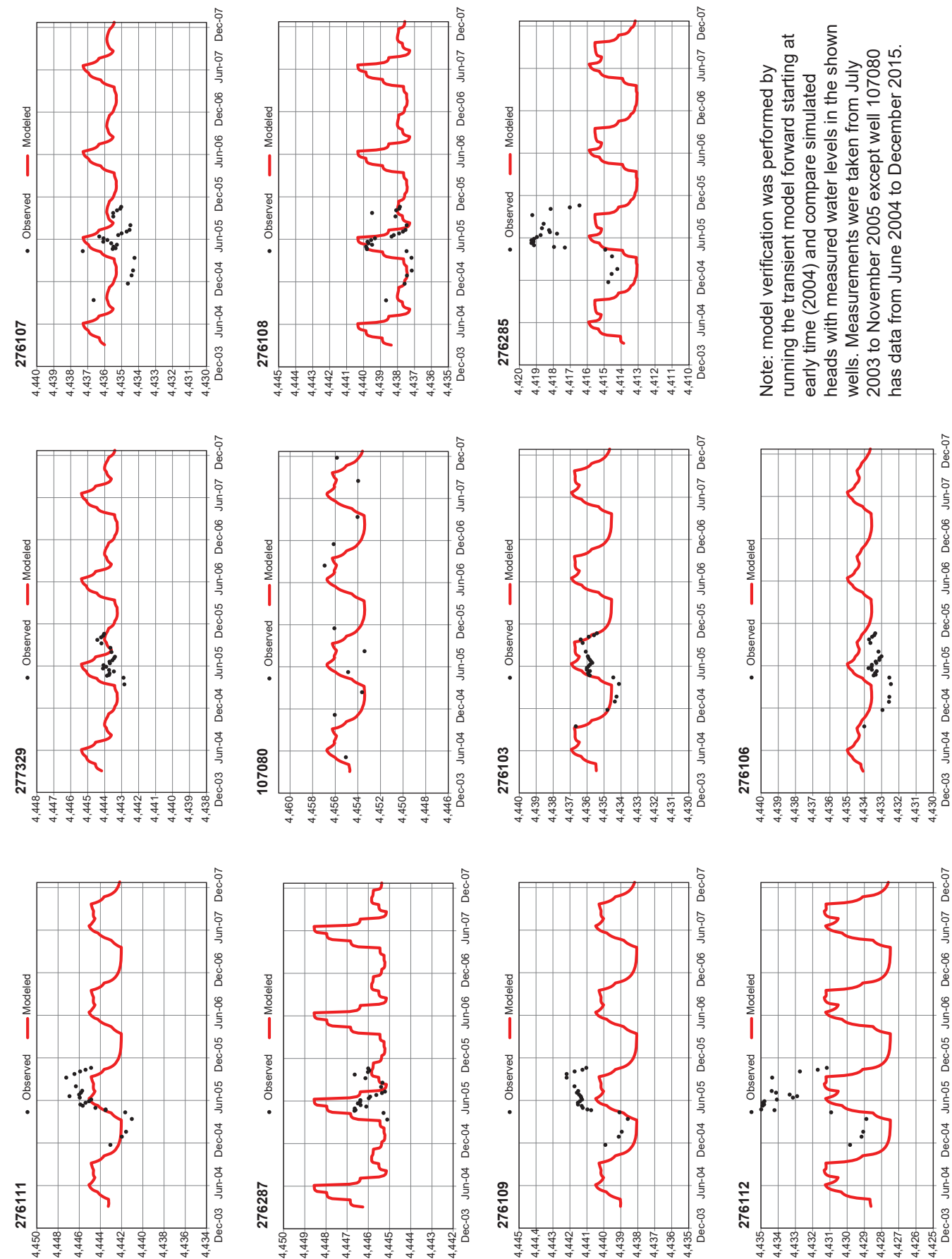


Figure 29. Transient model calibrated average monthly flows in the Jefferson River at Corbett's Station matched closely with the monthly average flows measured at the station.



Note: model verification was performed by running the transient model forward starting at early time (2004) and compare simulated heads with measured water levels in the shown wells. Measurements were taken from July 2003 to November 2005 except well 107080 has data from June 2004 to December 2015.

Figure 30. Transient model verification compared the modeled groundwater elevations in the 3 yr (2003–2005) with historic data collected in the same period.

running the calibrated model many times while varying model parameters or boundary stresses—one by one—over a reasonable range, and observing changes in model response (e.g., simulated heads) and/or calibration criteria (e.g. RMS error).

In the sensitivity analysis, 10 parameters were tested with the steady-state model. Parameters included horizontal hydraulic conductivity, Jefferson River stream conductance, Parson's Slough and Willow Springs drain conductance, aquifer thickness, irrigation recharge, canal leakage, lateral groundwater influx, evapotranspiration rates, alluvial groundwater inflow across model boundaries, and well pumping rates (table 8). The analysis was limited to the steady-state simulation in order to test model sensitivity under average long-term conditions. The process involved modifying the calibrated steady-state model (i.e., the

base run) using incremental changes to the various parameters (table 8). For each parameter value, a unique model was executed, for a total of 82 runs. For each model run, we documented groundwater discharge to Parson's Slough and Willow Springs, Jefferson River streamflow at Corbett station, and the calibration statistics RMS and RSS.

Sensitivity results (figs. 31–34) showed that the quantity of groundwater discharge to the groundwater-fed streams (drains) and river flow (streams) and calibration statistics RMS and RSS are all sensitive to (a) changes in horizontal hydraulic conductivity, (b) drain bed conductance, and (c) aquifer thickness.

Table 8. Sensitivity analysis setup and results.

Tested Parameters	Multipliers	Sensitivity Results				
		Drains Flow		River Flow	RMS	RSS
		Zone 1 and	Zone 2	Zone 1	Zones 1, 2, and 3	Zone 1 and Zone 2
Horizontal Hydraulic Conductivity	0.1, 0.5, 1, 2, 10					
Canal Leakage (Parrot)	0.75, 0.9, 1.0, 1.1, 1.25	NS		NS	NS	NS
Canal Leakage (Creeklyn)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
Canal Leakage (Jefferson)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
Lateral Groundwater Flux (Eastside)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
Lateral Groundwater Flux (Westside)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
GW Flux (South Boundary)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
GW Flux (North Boundary)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
Riverbed Conductance (reaches 1 & 3)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
Drain Conductance (all reaches)	0.1, 0.5, 1.0, 2.0, 10	Multipliers (<1 & >1)		"	Multipliers (<1 & >1)	Multipliers (<1 & >1)
Evapotranspiration (ET rate)	0.75, 0.9, 1.0, 1.1, 1.25	NS		"	NS	NS
Evapotranspiration (ET depth)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
Irrigation Recharge (Flood)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
Irrigation Recharge (Sprinkle)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
Irrigation Recharge (Pivot)	0.75, 0.9, 1.0, 1.1, 1.25	"		"	"	"
Aquifer Thickness	0.5, 0.8, 1.0, 1.2, 1.5	Multipliers (<1 & >1)		"	Multipliers (<1 & >1)	Multipliers (<1 & >1)
Pumping Wells (rate)	0.75, 0.9, 1.0, 1.1, 1.25	NS		"	NS	NS

Note. NS, Not sensitive.

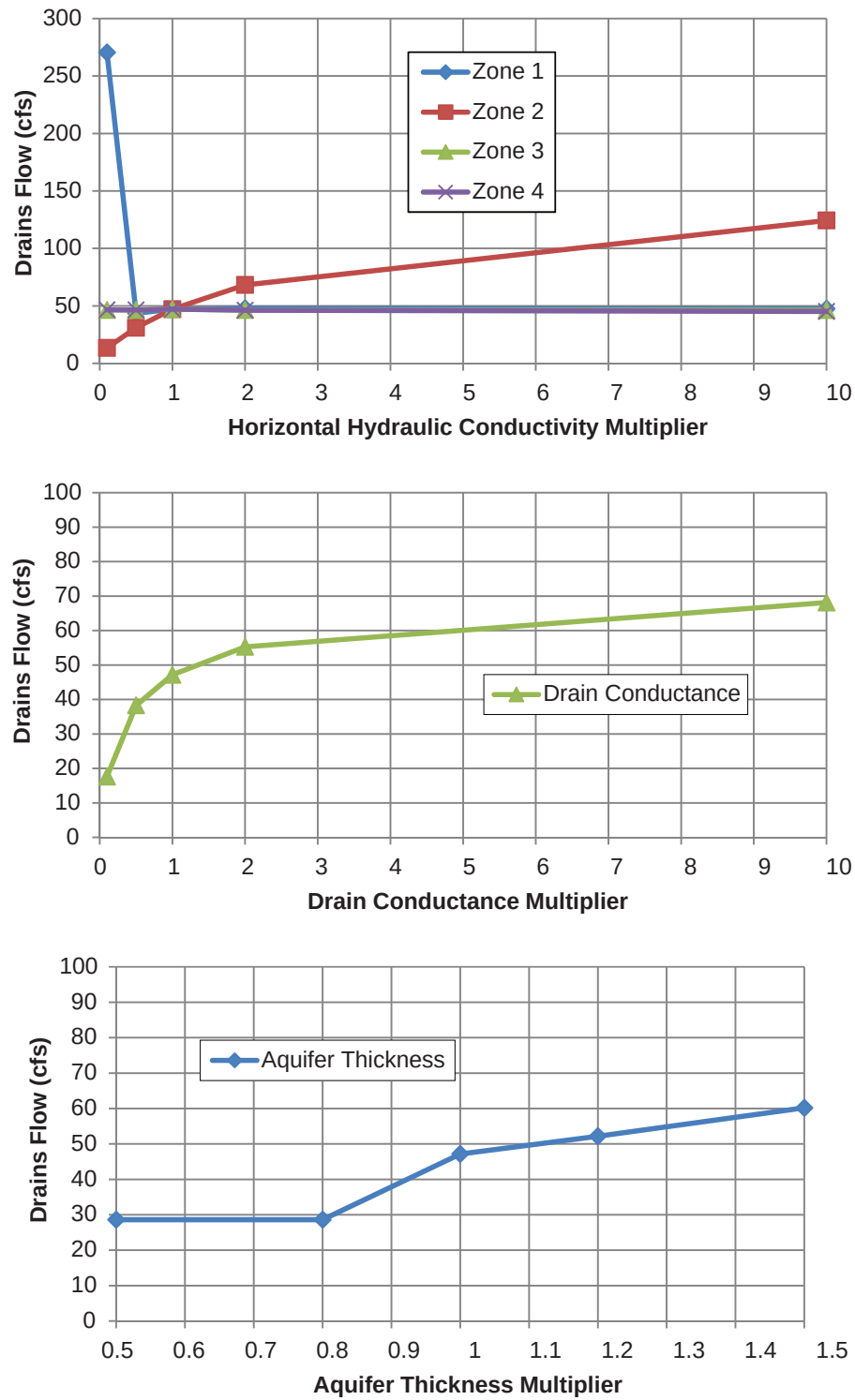


Figure 31. The sensitivity analysis done for the groundwater-fed streams (drains) indicates that the discharge is most sensitive to zone 2 hydraulic conductivity, drain bed conductance, and aquifer thickness.

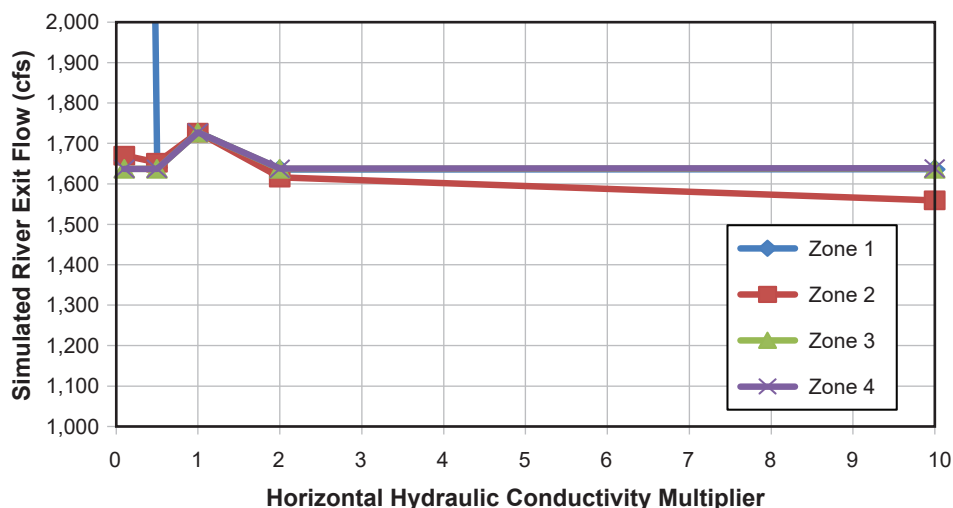


Figure 32. The Jefferson River flow at Corbett's station is sensitive to zone 1 hydraulic conductivity.

MODEL PREDICTIONS (FUTURE SCENARIOS)

The objective of the Waterloo model was to evaluate how potential changes in irrigation practices would affect surface waters, with emphasis on late summer flows. For each surface-water feature, the effect of a scenario was measured as the difference between the simulated surface-water flows under the scenario conditions and the flows simulated by the *base-run model*. The base-run model is the calibrated transient model with an extended 20-yr simulation time, from January 2005 to December 2024.

It is important to note the limitations of these predictive scenarios. We did not set out to predict effects of specific proposals. Rather, the scenarios were intended to predict groundwater levels and streamflows under hypothetical conditions. This analysis assumes that all stresses and boundary conditions except for the hypothetical *canal lining and changing irrigation type* remain constant. In reality, future conditions will inevitably differ from the simulated base run due to changes in climate, land use, and other factors. The value of this analysis is to understand the types and relative magnitude of effects on surface water that would result from changes in irrigation practices. Although the model allows us to quantify these effects, future conditions will be affected by many variables. In spite of that, these simulations allow us to better understand the behavior of the system as opposed to precisely quantifying the effects of those changes.

Since Parson's Slough and Willow Springs discharge into the Jefferson River, the effects of each

scenario on the Jefferson River implicitly include effects on Parson's Slough and Willow Spring as well as effects on groundwater discharge (baseflow) to the Jefferson River. Particularly in late summer (August), these effects are important because they in turn affect pool connectivity and river temperature, which are both vital to fish and ecological health. We tested four combinations of changes in irrigation practices:

- Lining some or all of the Parrot and Creeklyn Canals. Simulated by setting canal leakage to zero.
- Converting some or all flood-irrigated areas to center pivot irrigation. Simulated by replacing the flood irrigation recharge rate with that of pivot irrigation (fig. 20).
- Combining canal lining (a) and conversion to pivot irrigation (b).
- Applying split season irrigation on flood-irrigated areas (fig. 20). In those areas, we used flood irrigation recharge rates in the first half of the irrigation season (April through June), then applied pivot recharge rates in the second half of the season (July through September). These scenarios test recharging the aquifer during the first half of the season to mitigate reduction in irrigation recharge by changing to pivot irrigation in the late summer (fig. 35).

Eighteen model runs were completed to understand the potential effects on late summer flows due to changing irrigation practices (tables 9, 10):

- Three scenarios represent extreme changes: lining all canals (scenario C1), converting all flood irrigation to pivot (scenario F1), and combining the two scenarios, lining all canals and converting all flood irrigation into pivot irrigation (scenario CF).

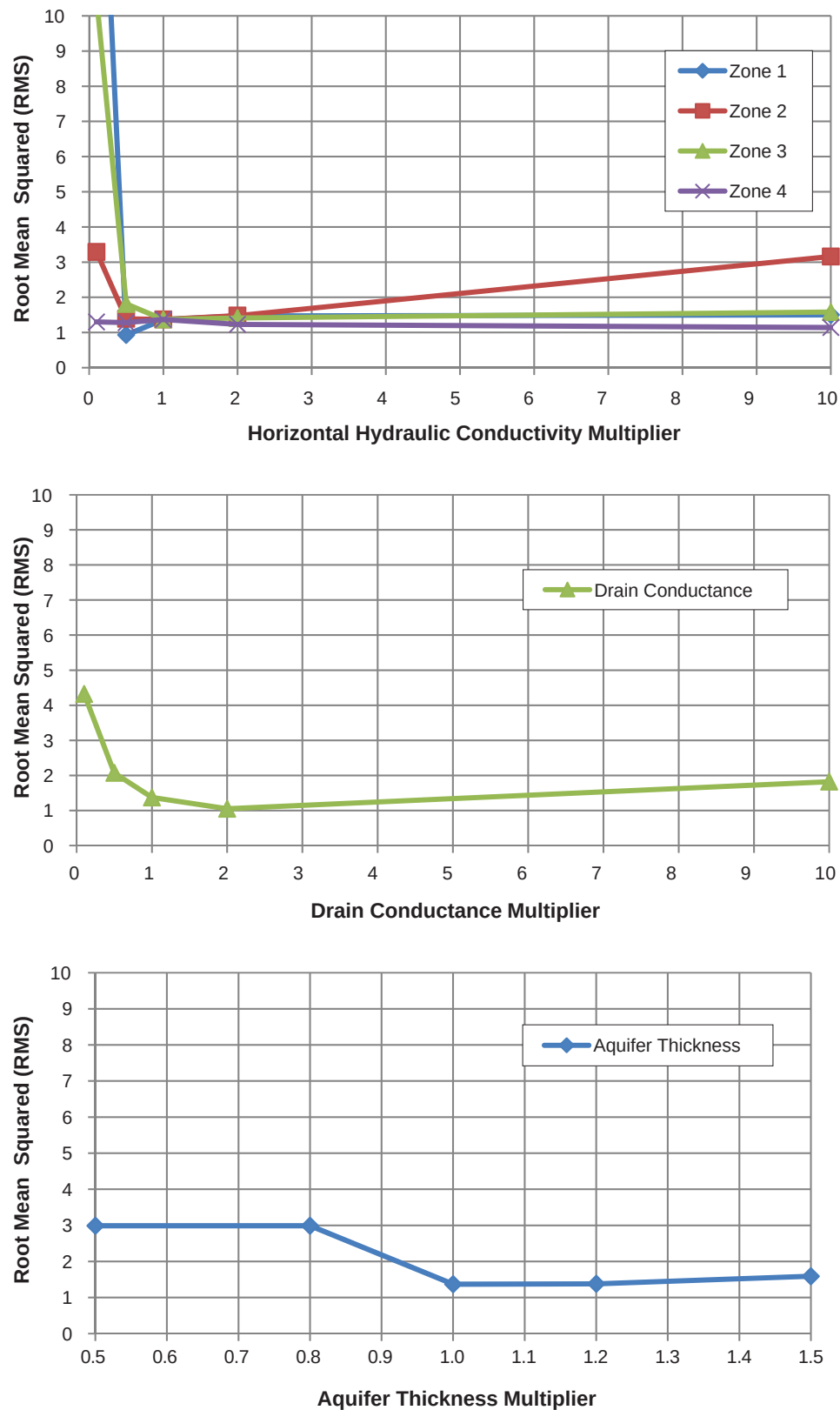


Figure 33. The model sensitivity analysis shows that the calibration statistic RMS is most sensitive to hydraulic conductivity in zones 1, 2, and 3, drain bed conductance for Parson's Slough and Willow Spring, and aquifer thickness.

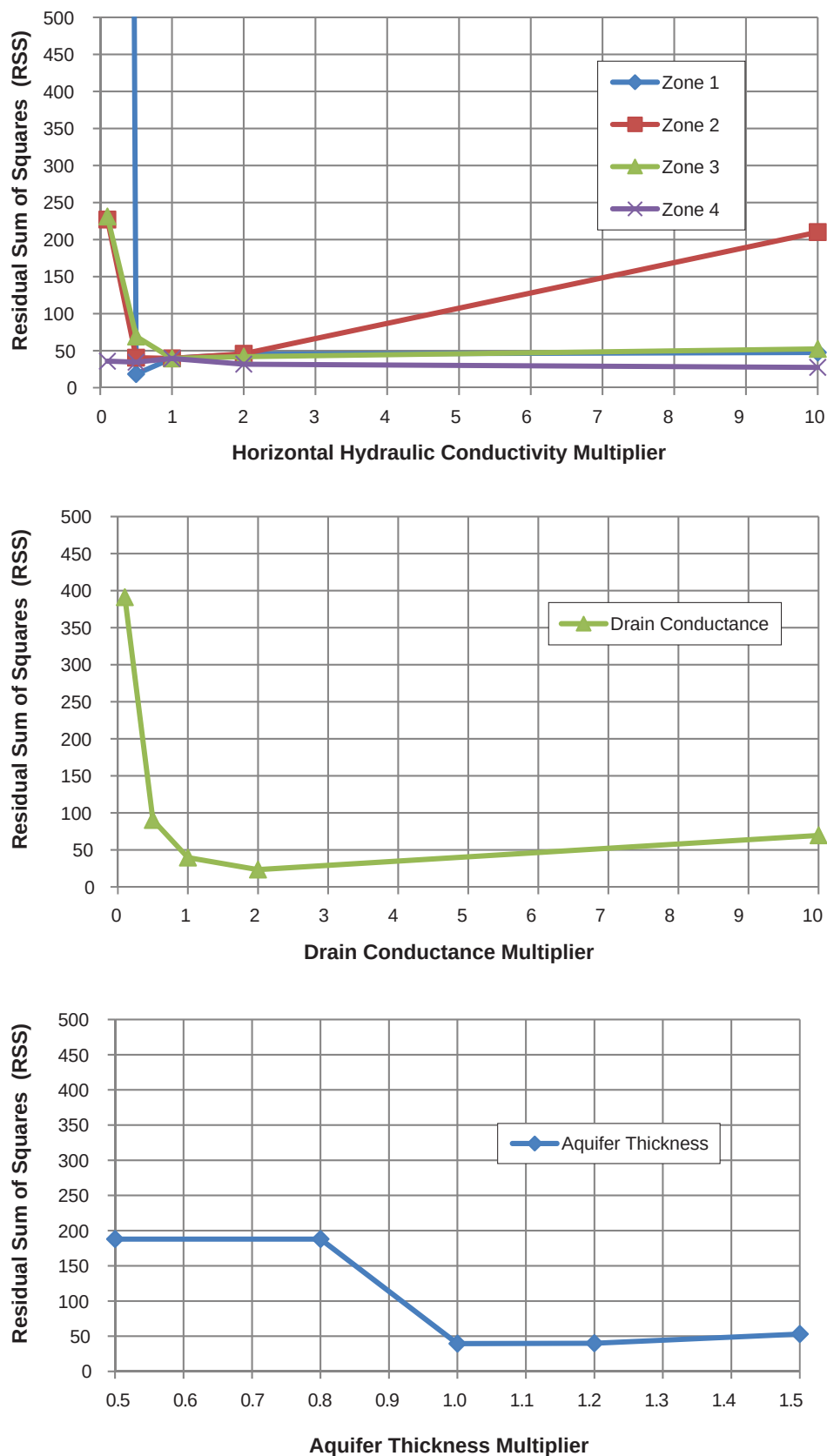


Figure 34. The model sensitivity analysis shows that calibration statistic RSS is most sensitive to hydraulic conductivity (zones 1, 2), drain bed conductance at Parson's Slough and Willow Springs, and aquifer thickness.

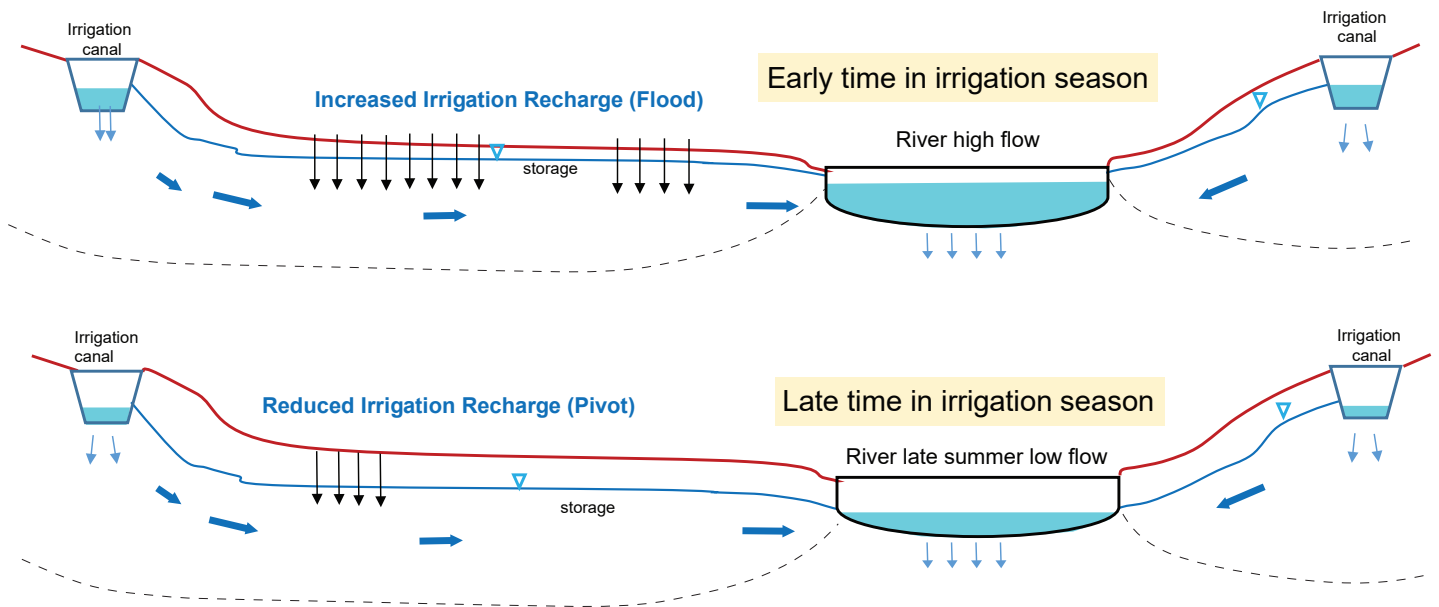


Figure 35. Schematic of groundwater and surface-water interactions in the Upper Jefferson River area during split-season irrigation. This includes flood irrigation during the first half of the season, and center pivot through the rest of the irrigation season.

Table 9. Summary of extreme predictive scenarios for July and August 2024.

Simulated Flow—July 2024							
Scenario	Parson's Slough (cfs)	Willow Springs (cfs)	Total (cfs)	Flow Reduction		Jefferson River Flow Reduction	
				cfs	%	cfs	%
Base run	24.6	40.8	65.5				
C1	23.7	38.4	62.1	3.4	6%	11.9	0.5%
F1	24.2	36.1	60.3	5.2	9%	10.2	0.5%
CF	23.2	33.7	57.0	8.5	15%	22.0	1.0%
SS1	24.5	36.7	61.2	4.3	7%	7.4	0.3%
SS2	25.5	37.7	63.2	2.3	4%	0.6	0.0%

Simulated Flow—August 2024							
Scenario	Parson's Slough (cfs)	Willow Springs (cfs)	Total (cfs)	Flow Reduction		Jefferson River Flow Reduction	
				cfs	%	cfs	%
Base run	18.85	38.69	57.53				
C1	17.24	34.54	51.78	5.8	10%	17.02	2.4%
F1	18.58	32.24	50.82	6.7	12%	12.80	1.8%
CF	16.98	28.29	45.27	12.3	21%	29.70	4.3%
SS1	18.61	32.39	51.00	6.5	11%	12.15	1.7%
SS2	18.76	32.59	51.35	6.2	11%	10.29	1.5%

Table 10. Summary of predictive scenarios for July and August 2024.

Scenario	Modeled Groundwater Discharge to Parson's Slough Flow				Modeled Groundwater Discharge to Willow Springs				Modeled Jefferson River Flow (Corbett Station)*				Corbett Station River Mean Annual Flow (without drain flow) (cfs)		Flow Reduction (Aug 2024)	
	Annual Volume (acre-ft)		August Flow (cfs)		Annual Volume (acre-ft)		August Flow (cfs)		Annual Volume (acre-ft)		August Flow (cfs)		Annual Volume (acre-ft)		Parson's Slough	Jefferson River
	(Year 2024)	(Aug 2024)	(Jul. 2024)	(Aug. 2024)	(Year 2024)	(Aug 2024)	(Jul. 2024)	(Aug. 2024)	(Year 2024)	(Aug 2024)	(Jul. 2024)	(Aug. 2024)	(Year 2024)	(Aug 2024)		
	1.42E+04	19.3	1.35E+03	24.65	18.8	2.42E+04	32.8	2.78E+03	40.85	38.7	1.24E+06	1690.2	5.00E+04	2205.68	696.3	1638.1
C1	1.35E+04	18.6	1.24E+03	23.68	17.2	2.24E+04	30.8	2.48E+03	38.42	34.5	1.23E+06	1682.0	4.87E+04	2193.77	679.3	1632.6
C2	1.40E+04	19.3	1.34E+03	24.59	18.7	2.39E+04	32.8	2.77E+03	40.82	38.6	1.23E+06	1689.1	4.98E+04	2204.58	694.6	1637.1
C3	1.39E+04	19.1	1.31E+03	24.28	18.2	2.38E+04	32.6	2.75E+03	40.63	38.3	1.23E+06	1688.1	4.97E+04	2203.18	692.2	1636.4
C4	1.39E+04	19.1	1.32E+03	24.41	18.4	2.37E+04	32.6	2.74E+03	40.63	38.2	1.23E+06	1688.5	4.98E+04	2204.20	693.6	1636.8
C5	1.39E+04	19.1	1.33E+03	24.43	18.5	2.34E+04	32.2	2.68E+03	40.16	37.4	1.23E+06	1688.2	4.97E+04	2203.69	693.0	1636.8
C6	1.39E+04	19.1	1.32E+03	24.35	18.4	2.28E+04	31.3	2.54E+03	38.87	35.4	1.23E+06	1686.6	4.95E+04	2201.79	690.0	1636.2
C7	1.39E+04	19.1	1.33E+03	24.43	18.5	2.34E+04	32.2	2.68E+03	40.15	37.4	1.23E+06	1687.5	4.96E+04	2202.21	691.4	1636.1
C8	1.39E+04	19.1	1.33E+03	24.43	18.5	2.34E+04	32.2	2.68E+03	40.15	37.4	1.23E+06	1687.3	4.96E+04	2201.65	690.9	1636.0
C9	1.39E+04	19.1	1.33E+03	24.43	18.5	2.34E+04	32.2	2.68E+03	40.15	37.4	1.23E+06	1687.2	4.96E+04	2202.21	691.5	1635.9
F1	1.39E+04	19.1	1.33E+03	24.21	18.6	2.19E+04	30.1	2.31E+03	36.08	32.2	1.23E+06	1683.8	4.90E+04	2195.52	683.5	1634.6
F2	1.39E+04	19.1	1.32E+03	24.37	18.4	2.34E+04	32.2	2.68E+03	40.14	37.4	1.23E+06	1687.5	4.96E+04	2202.90	692.1	1636.2
F3	1.39E+04	19.1	1.33E+03	24.37	18.5	2.34E+04	32.2	2.68E+03	40.15	37.4	1.23E+06	1688.0	4.97E+04	2203.40	692.7	1636.7
F4	1.39E+04	19.1	1.33E+03	24.39	18.5	2.34E+04	32.1	2.68E+03	40.02	37.3	1.23E+06	1688.3	4.97E+04	2203.51	693.0	1637.1
F5	1.41E+04	19.3	1.35E+03	24.58	18.8	2.21E+04	30.3	2.33E+03	36.40	32.5	1.23E+06	1686.3	4.93E+04	2198.90	686.9	1636.7
F6	1.39E+04	19.1	1.33E+03	24.43	18.5	2.34E+04	32.1	2.67E+03	40.01	37.3	1.23E+06	1687.9	4.97E+04	2203.33	692.7	1636.7
CF	1.33E+04	18.3	1.22E+03	23.24	17.0	2.05E+04	28.2	2.03E+03	33.72	28.3	1.22E+06	1675.5	4.78E+04	2183.65	666.6	1629.0
SS1	1.40E+04	19.28	1.34E+03	24.51	18.61	2.22E+04	3.04E+01	2323.23	36.74	32.39	1.23E+06	1685.53	1.56E+05	2198.27	684.17	1635.81
SS2	1.44E+04	19.80	1.35E+03	25.49	18.76	2.24E+04	3.08E+01	2337.84	37.68	32.59	1.23E+06	1688.59	1.57E+05	2205.11	686.04	1638.00

*Modeled Jefferson River Flow at Corbett Station is the sum of simulated drains and streamflows.

Note. F1, Flood to Pivot—All Areas; F2, Change Flood to Pivot—Area 1; F3, Change Flood to Pivot—Area 4; F4, Change Flood to Pivot—Area 2; F5, Change Flood to Pivot—Area 3; F6, Change Flood to Pivot—Area 5; CF, No seepage—Flood to Pivot (All); SS1, Split Season—flood-irrigated areas (1-5); SS2, Split Season—flood-irrigated (all areas); C1, No seepage—All Canals; C2, No seepage—Parrot Reach 1; C3, No seepage—Parrot Reach 2; C4, No seepage—Parrot Reach 3; C5, No seepage—Parrot Reach 4; C6, No seepage—Parrot Reach 5; C7, No seepage—Creeklyn Reach 6; C8, No seepage—Creeklyn Reach 7; C9, No seepage—Creeklyn Reach 8.

- Thirteen scenarios test limited changes in irrigation practices, e.g., lining individual canal segments or converting a single flood-irrigated area to a pivot system.
- Two scenarios test the concept of split season irrigation. The first scenario (SS1) applies changes to five areas (same as scenario F1). Scenario SS2 converts all the flood-irrigated fields (fig. 20) to pivot irrigation from July through September.

We selected August as the most critical late summer month to evaluate the scenarios, because it is typically characterized by low surface-water flows, elevated stream temperatures, high evapotranspiration, and more water consumption. July was also considered when we tested the split season irrigation scenarios. All 18 simulations ran from January 2005 through December 2024 (20 yr), giving the model enough time to achieve stable groundwater–surface-water interactions. The simulations applied changes in irrigation practices starting in April 2015; we documented results for July and August in the years 2005 through 2024.

Before running the scenarios, a base run was executed in which the transient model simulation was extended to 20 yr (2005 to 2024) while keeping all stresses the same throughout the simulation (e.g.,

canal leakage rates, irrigation recharge rates, etc.). The base run average surface-water flows in August 2024 (most critical late summer month) became the reference flow to evaluate results from all scenarios.

Canal Lining Scenarios

Scenario C1 stops canal leakage by lining both Parrot and Creeklyn Canals (fig. 20), which reduces recharge to the underlying aquifer. Lining was simulated by setting the leakage rate to zero along the canals. Results from this scenario show that it takes more than 1 yr (~16 mo) to develop the full effect on streams and the Jefferson River (figs. 36, 37). Relative to the base run, this resulted in about 6 cfs less groundwater discharge to Parson's Slough and Willow Springs, which is a 10% reduction in late summer flow. Flow in the Jefferson River at Corbett station was reduced by about 17 cfs, a 2.4% reduction in late summer flow (tables 9, 10).

Other canal lining scenarios tested lining individual canal segments. The Parrot Canal was divided into five sections, segments 1 to 5, and the Creeklyn Canal was divided to three sections, segments 6 to 8 (fig. 11). As shown in table 10, Scenarios C2 to C6 simulated lining only one of the individual segments in the Parrot Canal (e.g., C2 lines segment 1; C3 lines segment

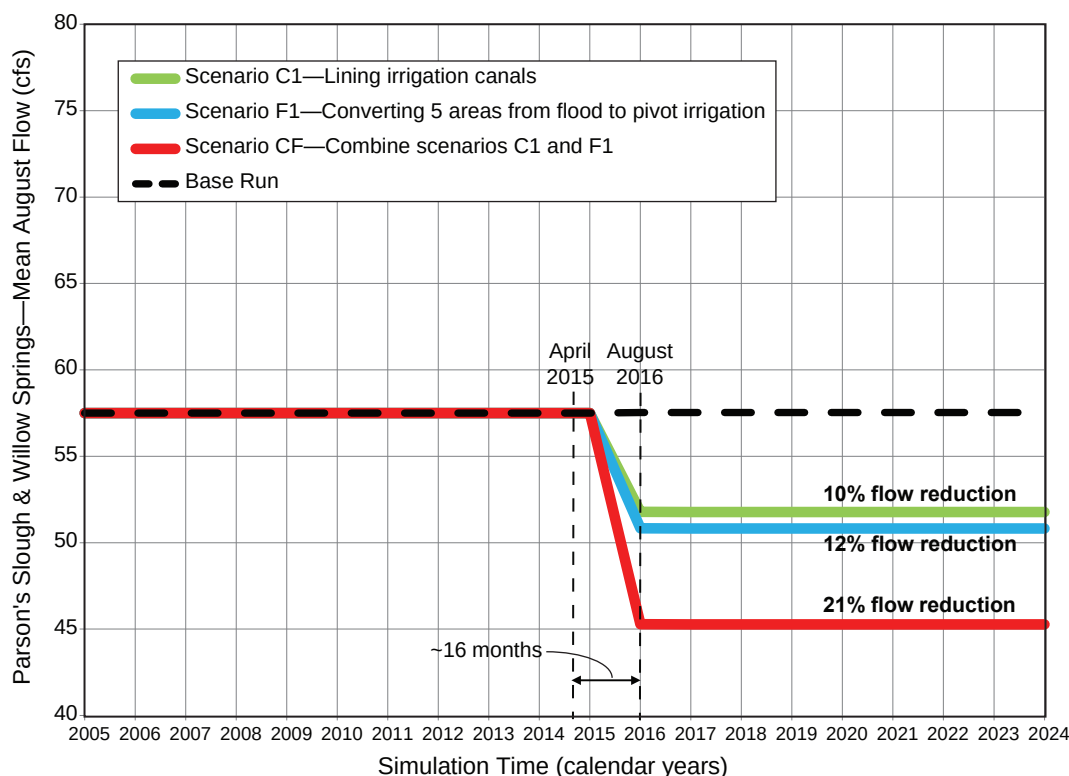


Figure 36. Predictive scenario results show that the greatest flow reduction in groundwater-fed streams discharge occurs with scenario CF. Scenario CF includes lining all irrigation canals (scenario C1) and converting five areas from flood to pivot irrigation (scenario F1).

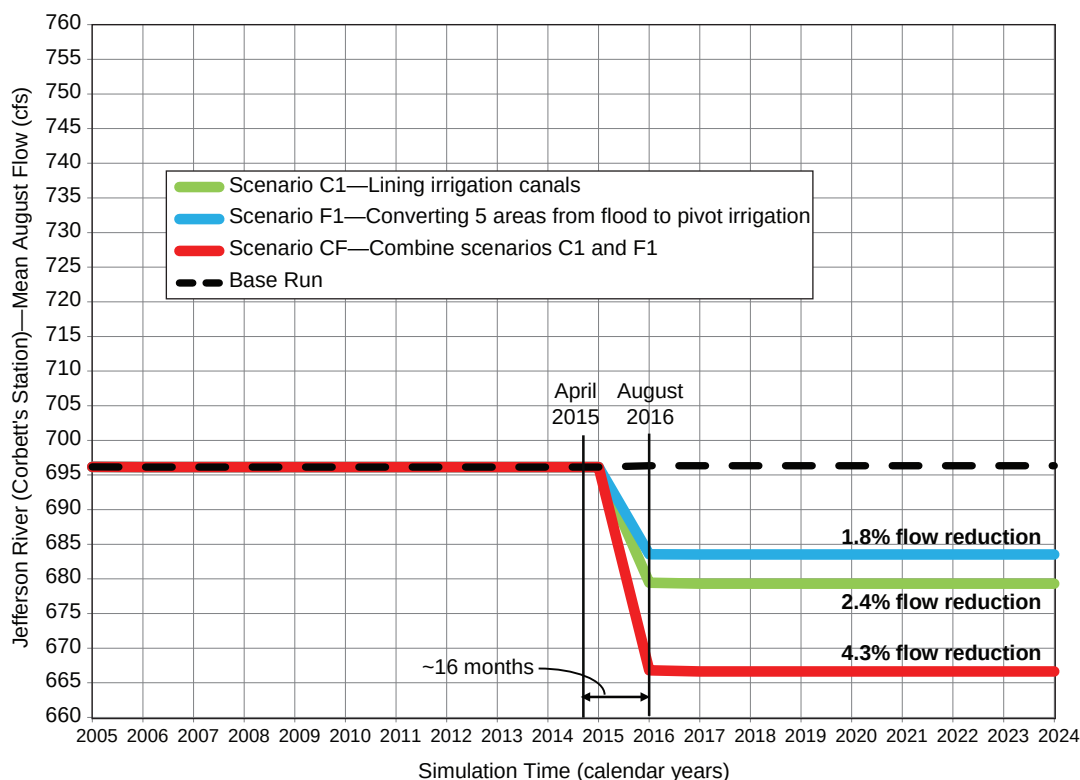


Figure 37. Predictive scenario results show the effect on Jefferson River flow at Corbett's station. The largest reduction in river flow occurs with scenario CF, with lining all irrigation canals and converting five flood-irrigated areas to pivot irrigation.

2). The Creeklyn Canal scenarios C7, C8, and C9 simulate the individual lining of canal segments 6, 7, and 8, respectively. Compared to lining all the canals, lining individual canal segments has a lesser effect on Jefferson River August flow, with flow reductions less than 1% in scenarios C2 to C8 compared to 10% in scenario C1 (table 10).

Flood to Pivot Irrigation Scenarios

Scenario F1 consisted of converting five major flood-irrigated areas (areas 1–5, fig. 20) to center pivot. This would reduce irrigation recharge to the underlying aquifer because center pivot systems are more efficient than flood irrigation. This is simulated by changing the recharge rate applied to the five zones to the lower rate used for pivot areas. The model response to this change occurs over more than 1 yr (~16 mo), the time needed for maximum flow reduction in groundwater-fed streams and rivers (figs. 36, 37). Relative to the base run, the conversion to pivot irrigation reduced the groundwater discharge to Parson's Slough and Willow Springs by 7 cfs in August 2024, a 13% reduction in late summer flow. The change to pivot irrigation also reduced flow in the Jefferson River at Corbett station by 13 cfs in August 2024, a 1.8% reduction in late summer flow (tables 9,

10). Parson's Slough and Willow Springs are relatively more sensitive to changes in irrigation recharge than to canal leakage, because irrigation recharge makes a larger portion of the water budget than canal leakage, and because of the proximity of the irrigated fields to the streams (fig. 20).

Five other scenarios (F2–F6) also tested converting individual flood irrigation areas to center pivot irrigation. In general, results from these scenarios showed less reduction in late summer flows to Parson's Slough, Willow Springs, and the Jefferson River compared to that of extreme scenario F1 (table 10); with the exception of scenarios F2, F3, F4, and F6, the reduction in Parson's Slough flow was more than that of F1 (table 10). Scenario F5 produced comparable flow reductions to that of scenario F1 for Willow Springs and the Jefferson River (table 10). Since the Willow Springs stream flows through the middle of irrigation area 4 (fig. 20), the proximity of the spring to the irrigated field results in a direct effect of changes in irrigation to the amount of groundwater discharge to Willow Springs, consequently affecting discharge to the Jefferson River.

Canal Lining and Conversion to Pivot Scenario (CF)

Scenario CF combines scenarios C1 and F1 to produce an extreme change in irrigation practices. This simulation includes lining all of the Parrot and Creeklyn Canals and converting all major flood-irrigated areas (1 to 5, fig. 20) to center pivot irrigation, creating a pronounced reduction in recharge to the underlying aquifer. It takes about 16 mo to develop the full effect on groundwater-fed streams and river flows (figs. 36, 37). In comparison to the base run, the combined late summer flow in Parson's Slough and Willow Springs was reduced by 12 cfs, a 21% reduction. For the Jefferson River, the changes reduced flows at Corbett station by 30 cfs, a 4.3% reduction in late summer flow (tables 9, 10).

Split Season Irrigation Scenarios

Split season irrigation scenario SS1 adopts the changes from scenario F1, converting five major flood-irrigated areas (1–5, fig. 20) to center pivot irrigation. Scenario SS1 limits center pivot rates to the second half of the irrigation season, July to September, and maintains flood irrigation recharge rates in the first half of the season, April to June. This scenario tested mitigating the reduction of flow in Parson's Slough, Willow Springs, and the Jefferson River caused by converting to pivot irrigation in scenario F1. As shown in table 10, during the summer of 2024, the SS1 scenario lowered the Jefferson River's flow by 7 cfs (0.34% reduction) in July relative to baseline, not much different than the effect of scenario F1 (10.2 cfs, 0.5% reduction). In August 2024, the reduction was about 12 cfs (1.7% reduction), which is also similar to that of scenario F1 (13 cfs, 1.8% reduction).

Split season irrigation scenario SS2 expands scenario SS1 to include all seven flood-irrigated areas in the model (fig. 20). As shown in table 10, for the Jefferson River, the SS2 scenario showed insignificant flow reduction in July 2024 (<1 cfs), a favorable result compared to that of scenario F1 (10.2 cfs, 0.5% reduction). In August 2024, the SS2 reduction was 10.3 cfs (1.5% reduction), similar to that of scenario F1 (13 cfs, 1.8% reduction).

In the split season scenarios, the July reduction in Jefferson River flow was less than in scenario F1; however, the August flow reduction was similar to that of scenario F1. Thus, the desired effect did not last long into the second half of the irrigation season.

Recharge to the alluvial aquifer and the increase in groundwater storage during the flood irrigation months was offset by relatively fast groundwater discharge to surface-water bodies, and therefore did not fully mitigate August low-flow conditions. We attribute this result to (a) the high transmissivity aquifer, and (b) the close proximity of the irrigated fields to Parson's Slough, Willow Springs, and the Jefferson River. As shown in figure 38, field data from Willow well 9 (GWIC276285), located about 1,630 ft from the Parrot Canal, indicates fast water table response to irrigation recharge.

Model Prediction Results

The three extreme hypothetical irrigation scenarios, C1 (lining all irrigation canals), F1 (converting five areas from flood to pivot irrigation), and CF (lining all irrigation canals and converting five areas from flood to pivot irrigation) show that maximum flow reduction occurs during the critical low-flow, late summer month of August. The combined scenario CF produced the largest effect.

In August 2024, the reduction in flow on the combined flow coming from Parson's Slough and Willow Springs was 6 cfs (a 10% reduction) in scenario C1, 7 cfs (12% reduction) in scenario F1, and 12 cfs (21% reduction) in scenario CF (fig. 36).

The transient model base run produced about 700 cfs flow in the Jefferson River near Corbett's station in August 2024. For the same period, the effects were 17 cfs (2.4% reduction) in scenario C1, 13 cfs (1.8% reduction) in scenario F1, and 30 cfs (4.3% reduction) in scenario CF (fig. 37). The drought management plan includes a goal to maintain at least 50 cfs at the USGS station at Parson's Bridge (JRWCV, 2013). The 50 cfs target is the minimum flow needed to maintain pool connectivity and buffer stream temperatures. Therefore, in drought years, these reductions (13 to 30 cfs) would approach the 50 cfs goal.

In general, Willow Springs is more sensitive to changes in irrigation recharge than Parson's Slough. Flow reduction in Willow Springs was 11%, 17%, and 27% in the three scenarios C1, F1, and CF, respectively. Flow reduction in Parson's Slough for these scenarios were 9%, 1%, and 10% (table 10).

Similarly, Willow Springs was more sensitive than Parson's Slough to conversion from flood irrigation

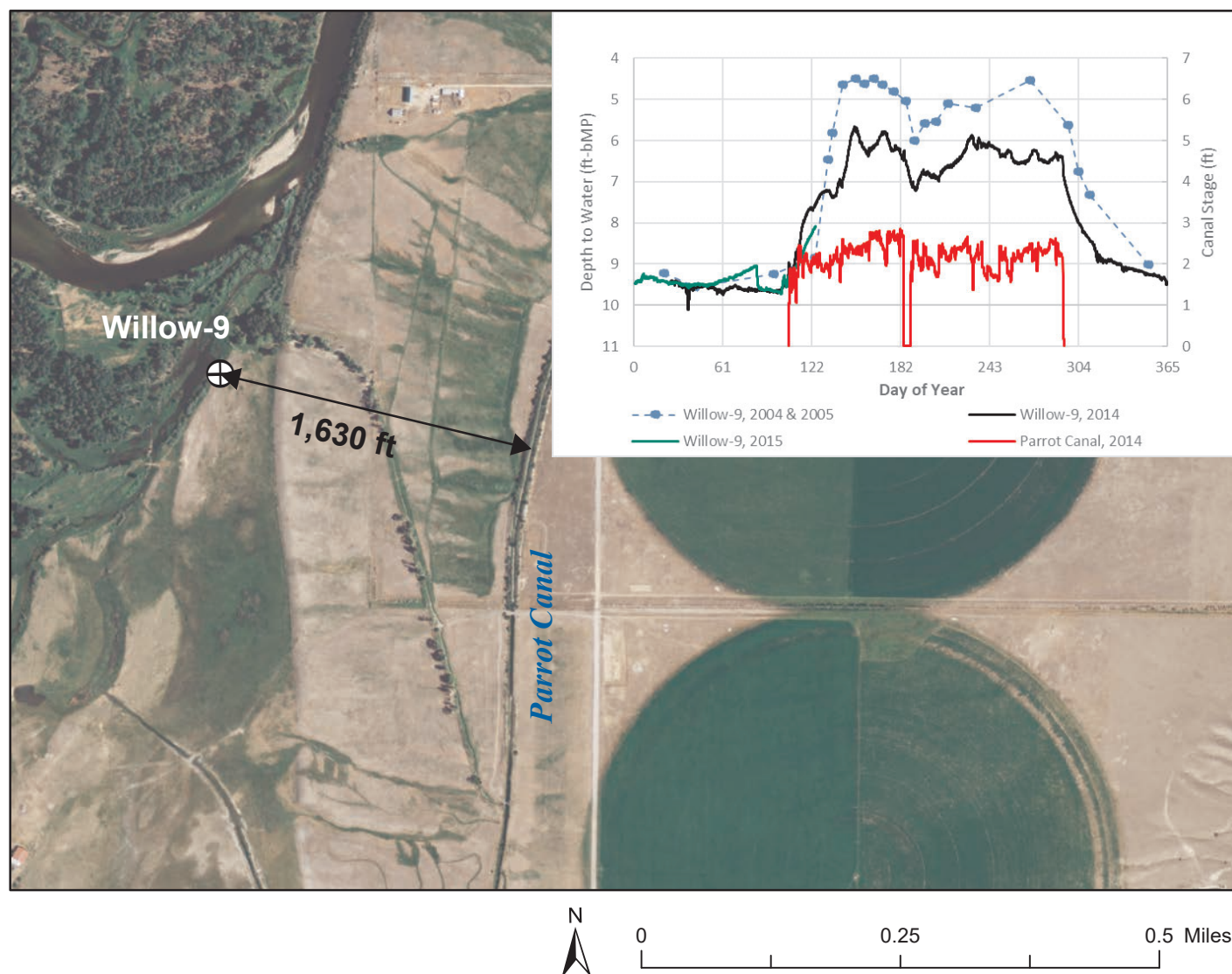


Figure 38. Field data from Willow well 9 (GWIC 276285), located about 1,630 ft from Parrot Canal, shows a fast response to canal stage changes, due to high transmissivity and close proximity to the recharge source. Note that the canal is turned off annually each 4th of July week (Julian day 182), corresponding to a rapid response in the water table elevation at Willow 9.

to center pivot systems (scenarios F1– F6, table 10). In the model, Willow Spring’s branches flow through flood-irrigated areas, while Parson’s Slough has less contact with flood-irrigated zones (fig. 20). Results from scenario F5 (converting flood area 4 to pivot) is a clear example of how the location and branching of drains (model cells that represent the spring) with respect to recharge zones can produce notable effects; there was a 16% reduction in Willow Springs flows compared to a 0.4% decrease in Parsons’s Slough (table 10).

Scenario results showed that lining Creeklyn Canal (scenarios C7 to C9) did not have a large effect on Parson’s Slough or Willow Springs (table 10), most likely due to the Jefferson River forming a hydrologic boundary between Creeklyn Canal and these streams.

In contrast, lining Creeklyn Canal had a noticeable effect on Jefferson River flows at Corbett station.

These simulations demonstrate that split season irrigation can provide a source of delayed discharge to surface water by supplementing aquifer storage early in the irrigation season. However, it is important to evaluate the rate at which the early season groundwater mound will dissipate. In the Waterloo area, the fields modeled with split season irrigation were too close to the surface-water features to allow for a sufficient time lag given the relatively high transmissivity of the alluvial aquifer.

UNCERTAINTY ANALYSIS

For any model predictions, there are two broad sources of uncertainty: (1) uncertainty linked to the

model itself, and (2) uncertainty associated with accurate specifications of future conditions (Anderson and others, 2015).

The first type of uncertainty originates from the following:

- (a) Error in field measurements of certain parameters. Thus, uncertainty in predictions stemming from error in calibration of these parameters can be reduced but not eliminated.
- (b) Failure to capture the complexity of the natural setting relevant to the prediction. This error results from the conceptual model or from the spatial and temporal simplifications made during model construction and calibration.

The second source of uncertainty occurs when predictions require estimating future stresses and properties (e.g., recharge rates affected by changes in climate), and future non-hydrogeological conditions, such as political, economic, and societal actions that may affect hydrologic stresses (e.g., conversion from agricultural land use to residential development).

In this study, we focused on the first type—uncertainty caused by errors in field parameter estimation and the simplifications of spatial and temporal parameters during model construction and calibration. We employed a basic uncertainty analysis that is similar to the *scenario modeling method* presented by Anderson and others (2015). Model parameters selected for uncertainty analysis are based on the sensitivity analysis, and on the uncertainty associated with the method of estimating some model parameters (e.g., leakage rates from irrigation canals). We investigated six parameters that were the most likely to affect predictions:

1. aquifer thickness,
2. horizontal hydraulic conductivity (K_h) in areas initially assigned as zones 1 and 2,
3. lateral groundwater influx (GW_{in-lat}) in Parrot and Creeklyn boundaries,
4. canal leakage (CL) in the three irrigation canals,
5. aquifer storage coefficients (4 zones), and
6. groundwater influx and outflux to the alluvial aquifer across the southern and northern model boundaries.

The uncertainty analysis involved completing the *base run* simulation and the three extreme scenario simulations (C1, F1, and CF) while changing one of the six parameters (e.g., aquifer thickness). Each parameter was varied by applying a low and a high multiplier, creating multiple versions of each model (table 11). The only exception was for changes to the zone 1 alluvium hydraulic conductivity, which was executed once with a low multiplier. A total of 100 models included 27 versions of the base run, 23 versions of scenario C1, 27 versions of scenario F1, and 23 versions of scenario CF (table 12). Each of the six parameters was considered to be independent, so that changing one parameter did not require changing any other parameters.

The uncertainty assessment focused on simulating August surface-water flows in Parson's Slough, Willow Springs, and the Jefferson River. The error in model prediction is the difference between each scenario model's August 2024 flows and that calculated by the base run, with changes to one parameter at a time. The assessment required running all 100 simulations (table 12) and calculating the "error" between the base run and the scenarios for August 2024 flows. This collection (or "ensemble") of errors define an envelope of uncertainty limits around the prediction (Anderson and others, 2015).

Table 11. Uncertainty analysis parameters.

Uncertainty Parameter	Multipliers
Aquifer Thickness	0.5 & 1.5
Hydraulic Conductivity (K_x , K_y) Zone 1	0.1
Hydraulic Conductivity (K_x , K_y) Zone 2	0.1 & 2.0
Parrot Canal—Lateral Groundwater Flux	0.75 & 1.25
Parrot Canal—Leakage	0.75 & 1.25
Creeklyn Canal—Lateral Groundwater Flux	0.75 & 1.25
Creeklyn Canal—Leakage	0.75 & 1.25
Jefferson Canal—Leakage	0.75 & 1.25
South Boundary GW Flux	0.75 & 1.25
North Boundary GW Flux	0.75 & 1.25
Storage Coefficient Zone 1	0.1 & 10
Storage Coefficient Zone 2	0.1 & 10
Storage Coefficient Zone 3	0.1 & 10
Storage Coefficient Zone 4	0.1 & 10

Table 12. Uncertainty analysis for scenarios C1, F1, and CF.

Base Run			SCENARIO C1		SCENARIO F1		SCENARIO CF	
No changes in irrigation methods			Lining all irrigation canals		Change flood-irrigated areas to pivot irrigation system (5 areas)		Combine scenarios C1& F1	
Run #	Uncertainty Parameter	Run #	Uncertainty Parameter	Run #	Uncertainty Parameter	Run #	Uncertainty Parameter	Run #
0	None							
1	Aquifer Thickness x 0.5	28	Aquifer Thickness x 0.5	51	Aquifer Thickness x 0.5	78	Aquifer Thickness x 0.5	
2	Aquifer Thickness x 1.5	29	Aquifer Thickness x 1.5	52	Aquifer Thickness x 1.5	79	Aquifer Thickness x 1.5	
3	K _x zone 1 x 0.1	30	K _x zone 1 x 0.1	53	K _x zone 1 x 0.1	80	K _x zone 1 x 0.1	
4	K _x zone 2 x 0.1	31	K _x zone 2 x 0.1	54	K _x zone 2 x 0.1	81	K _x zone 2 x 0.1	
5	K _x zone 2 x 2	32	K _x zone 2 x 2	55	K _x zone 2 x 2	82	K _x zone 2 x 2	
6	Parrot MFR x 0.75	33	Parrot MFR x 0.75	56	Parrot MFR x 0.75	83	Parrot MFR x 0.75	
7	Parrot MFR x 1.25	34	Parrot MFR x 1.25	57	Parrot MFR x 1.25	84	Parrot MFR x 1.25	
8	Parrot Seepage x 0.75		NA	58	Parrot Seepage x 0.75		NA	
9	Parrot Seepage x 1.25		NA	59	Parrot Seepage x 1.25		NA	
10	Creeklyn MFR x 0.75	35	Creeklyn MFR x 0.75	60	Creeklyn MFR x 0.75	85	Creeklyn MFR x 0.75	
11	Creeklyn MFR x 1.25	36	Creeklyn MFR x 1.25	61	Creeklyn MFR x 1.25	86	Creeklyn MFR x 1.25	
12	Creeklyn Seepage x 0.75		NA	62	Creeklyn Seepage x 0.75		NA	
13	Creeklyn Seepage x 1.25		NA	63	Creeklyn Seepage x 1.25		NA	
14	Jefferson seepage x 0.75	37	Jefferson seepage x 0.75	64	Jefferson seepage x 0.75	87	Jefferson seepage x 0.75	
15	Jefferson seepage x 1.25	38	Jefferson seepage x 1.25	65	Jefferson seepage x 1.25	88	Jefferson seepage x 1.25	
16	South GW Flux x 0.75	39	South GW Flux x 0.75	66	South GW Flux x 0.75	89	South GW Flux x 0.75	
17	South GW Flux x 1.25	40	South GW Flux x 1.25	67	South GW Flux x 1.25	90	South GW Flux x 1.25	
18	North GW Flux x 0.75	41	North GW Flux x 0.75	68	North GW Flux x 0.75	91	North GW Flux x 0.75	
19	North GW Flux x 1.25	42	North GW Flux x 1.25	69	North GW Flux x 1.25	92	North GW Flux x 1.25	
20	Storage Zone 1 x 0.1	43	Storage Zone 1 x 0.1	70	Storage Zone 1 x 0.1	93	Storage Zone 1 x 0.1	
21	Storage Zone 1 x 10	44	Storage Zone 1 x 10	71	Storage Zone 1 x 10	94	Storage Zone 1 x 10	
22	Storage Zone 2 x 0.1	45	Storage Zone 2 x 0.1	72	Storage Zone 2 x 0.1	95	Storage Zone 2 x 0.1	
23	Storage Zone 2 x 10	46	Storage Zone 2 x 10	73	Storage Zone 2 x 10	96	Storage Zone 2 x 10	
24	Storage Zone 3 x 0.1	47	Storage Zone 3 x 0.1	74	Storage Zone 3 x 0.1	97	Storage Zone 3 x 0.1	
25	Storage Zone 3 x 10	48	Storage Zone 3 x 10	75	Storage Zone 3 x 10	98	Storage Zone 3 x 10	
26	Storage Zone 4 x 0.1	49	Storage Zone 4 x 0.1	76	Storage Zone 4 x 0.1	99	Storage Zone 4 x 0.1	
27	Storage Zone 4 x 10	50	Storage Zone 4 x 10	77	Storage Zone 4 x 10	100	Storage Zone 4 x 10	

Note. NA, Not applicable.

The model uncertainty analysis indicated that the greatest uncertainty is associated with the extreme scenario CF (all canals lined and all flood irrigation converted to center pivot systems). This simulation had a maximum error in predicting August flow in Parson's Slough and Willow Springs of about 40% (fig. 39), but remained at less than 10% for most tested parameters. Note that there are two groups of prediction errors that exceeded 10% error (fig. 39). These were due to sharp reductions in the transmissivity of the aquifer, consistent with the sensitivity analysis. For Jefferson River flows, the prediction error remained within 3% for the majority of scenarios using uncertainty parameters. The maximum error is less than 5% under conditions of low hydraulic conductivity (fig. 40).

MODEL LIMITATIONS

The Waterloo groundwater flow model is a useful tool for refining the conceptual model and evaluating the effects of changes in water management practices on groundwater and surface-water flows. However, the model has limitations, mainly due to scale, parameter uncertainty, and lack of precision of the calibrated

river gains and losses. The modeling scale is limited to the Waterloo area and is not designed to account for flow calculations across the entire Jefferson River basin, beyond the model area. On the other hand, the model grid size (178 ft x 188 ft) may not be suitable to accurately simulate groundwater/surface-water interactions at a finer scale. The one-layer model grid cannot simulate vertical flow components in groundwater/surface-water interactions; this limits the model to simulate heat exchange or contaminant transport within the alluvial aquifer only, not between the alluvium and the lower Tertiary sediments (fig. 6).

Predictive sensitivity (uncertainty) analysis showed that parameter uncertainty is also a limitation on model results. In particular, the model predictions are sensitive to aquifer thickness, hydraulic conductivity, estimated inflow to the alluvial aquifer, and rates of canal leakage.

The lack of calibration targets (water levels in wells) in the west and northwest areas of the model limits modeling losses and gains in some reaches along the Jefferson River. The calibration focused on

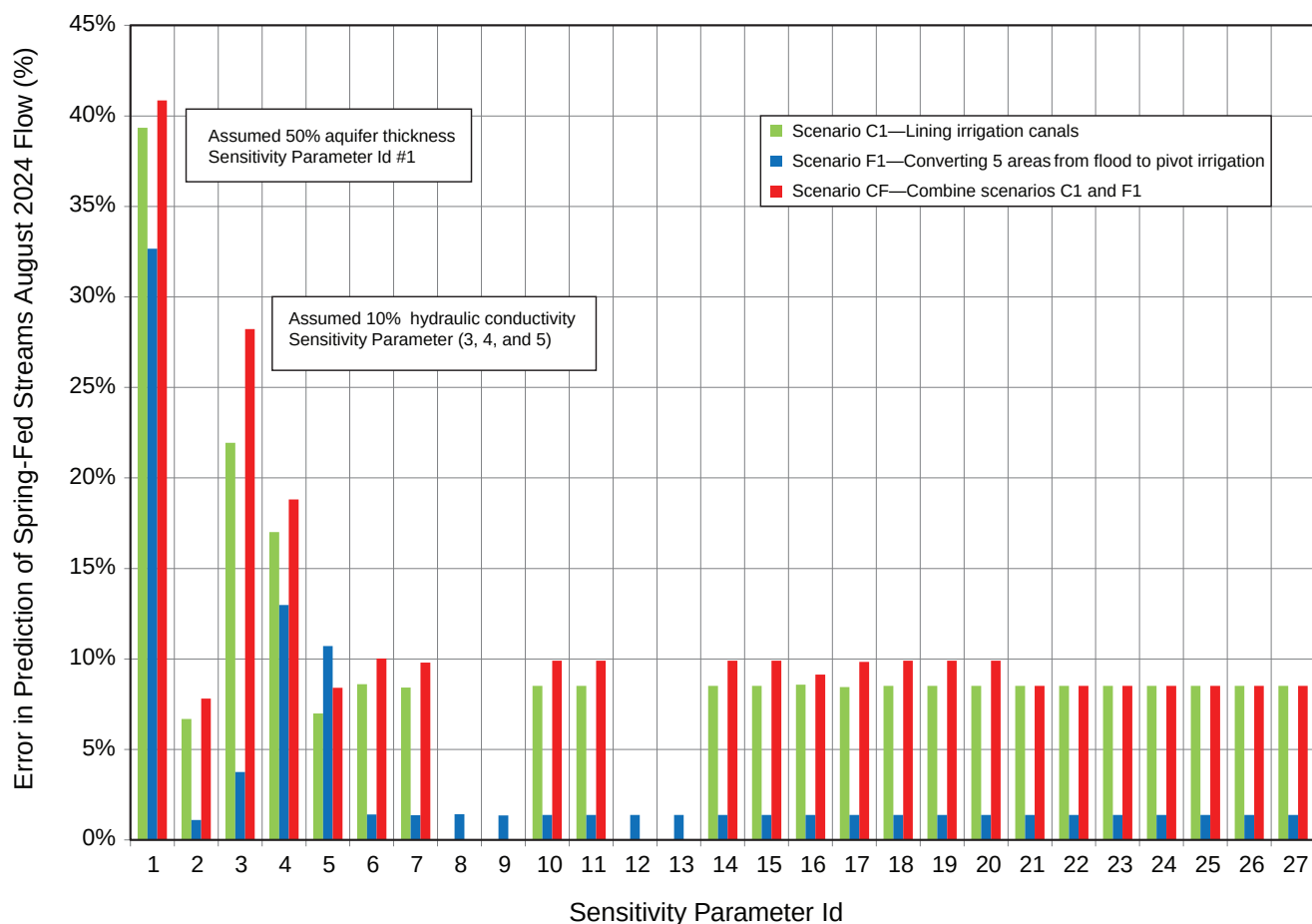


Figure 39. Model uncertainty analysis focused on the prediction error of the combined groundwater discharge to Parson's Slough and Willow Springs. The figure shows the ensemble of prediction errors produced by the model.

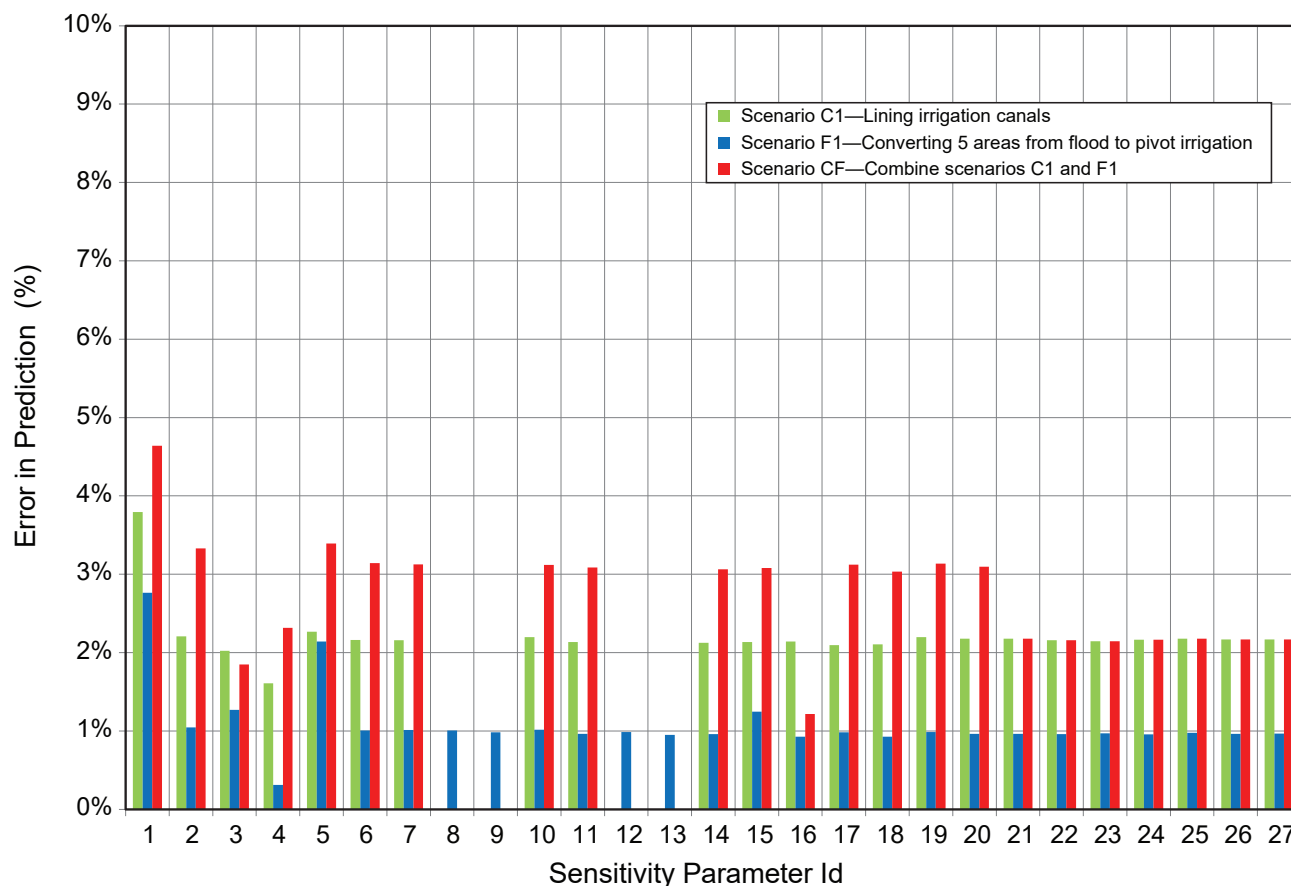


Figure 40. Model uncertainty analysis focused on the prediction error of Jefferson River flow at Corbett's station. The figure shows the ensemble of the prediction errors produced by the model.

simulating Jefferson River flow at the downstream point at Corbett's station and on estimating combined flows from Parson's Slough and Willow Springs.

Additional field information would improve the current model. For example, more groundwater-level measurements and longer monitoring periods from existing or new wells in the northwest region of the model would yield better estimates of river conductance and improve the model calibration and predictive power. Additional aquifer tests could improve the estimate of aquifer parameters, or confirm the calibrated ones. In addition, field measurements of Jefferson Canal leakage could provide a better leakage estimation.

More survey data and DEM information would help better develop the simulation of groundwater/surface-water interactions that are naturally sensitive to elevation differences. With respect to streambed elevations, LiDAR is recommended as the most cost-effective and efficient source of high-accuracy data. Also, additional lithological information can enhance the delineation of the alluvial aquifer thickness. This

would increase the accuracy of estimating groundwater flow into the aquifer and the water budget calculations.

The current model scenarios operate under the assumption that there is no reduction in diversions from the Jefferson River to the canals if the canals were lined or center pivot irrigation was used, i.e., the extra water is not accounted for. That requires more information to correlate leakage from irrigation canals to diversions, but this can be tested in a post audit study, where the decrease in diversions to the canals results in an increase in flows in the Jefferson River and groundwater, which would ultimately flow into the current model domain and offset the loss from the canal leakages.

SUMMARY AND CONCLUSIONS

As development of land and water resources increase, it is apparent that use of either resource affects the quantity and quality of the other (Hirsch, 1999). The objectives of this modeling study were to: (a) simulate the interactions between groundwater and

surface-water components of the flow system in the Waterloo area of the Jefferson River Valley, and (b) forecast the changes in surface-water discharge in Parson's Slough, Willow Springs, and the Jefferson River due to changes in irrigation practices.

The steady-state calibrated model simulated—within specified error limits—the groundwater levels, the groundwater discharge to Parson's Slough and Willow Spring, and the Jefferson River flows at Corbett station. The model generated a balanced water budget that generally agreed with preliminary estimates of model area inflows and outflows. The transient model displayed a reasonable match to changes in heads, and captured the seasonality of water-level changes. The transient model also matched the Jefferson River monthly average flows measured at Corbett station. Eighteen future scenarios were tested to evaluate the effects of changing irrigation practices (lining canals and/or converting flood irrigation to center pivot) on surface-water flows during the August flow period. Results from the simulations indicated a reduction in groundwater discharge to Parson's Slough, Willow Spring, and the Jefferson River. The overall result suggests lower late summer stream flows, and possible warmer stream temperatures, a condition that may affect fish species in the area.

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APPENDIX A
WATERLOO AREA CONCEPTUAL
WATER BUDGET

APPENDIX A— WATERLOO AREA CONCEPTUAL WATER BUDGET

A conceptual water budget was developed for the Waterloo area to aid in model construction and ensure that the amount of water entering and leaving the model through the boundaries was reasonable. This budget was largely based on the budget developed by Brancheau (2015) for the Waterloo area. The preliminary budget was modified during the model calibration process.

1. Alluvial Groundwater Inflow (GW_{in-al})

Groundwater flowed into the model area at the upstream end of the model domain (fig. A1). The inflow at this boundary was calculated using the Darcy Flux Equation:

$$Q = KAI,$$

where Q is groundwater inflow (ft^3/d); K is hydraulic conductivity of the aquifer (ft/d); A is cross-sectional area of the saturated alluvial aquifer at the boundary (ft^2); and I is hydraulic gradient across the boundary (ft/ft or unitless).

Brancheau (2015) estimated the aquifer thickness in this area to be 100 ft; however, further review of well logs showed that the deepest well was 159 ft, so we used a thickness of 200 ft. The alluvial width is estimated to be 10,600 ft based on geologic maps. The hydraulic conductivity was estimated to be 1,100 ft/d based on an aquifer test conducted in the alluvium near Waterloo, and lithologic descriptions from well logs. A gradient of 0.00235 was based on monitoring data.

Table A1. Flow into the model area through the alluvium was estimated using the Darcy Flux Equation.

	K(ft/d)			Width (ft)	Sat Tk (ft)	Area (ft^2)	I (ft/ft)	BE Q (ft^3/d)	Q (acre-ft/yr)		
	BE	MinE	MaxE						BE	MinE	MaxE
Jefferson River	1,100	825	1,375	10,600	200	2,120,000	0.00235	5,480,200	45,947	34,460	57,433

Note. K, range based on aquifer tests, sediment descriptions, and literature values (Heath, 1983; Fetter, 1994). The likely range was based on a range of K values, which is the most variable, and uncertain, component of the calculation. BE, best estimate; MinE, minimum estimate; MaxE, maximum estimate. Width-based geologic maps: Sat Tk, saturated thickness, based on well logs; Area, width x Sat Tk; I, calculated using observed water levels from April 2015.

Table A2. Monthly alluvial inflow (acre-ft).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
BE	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	45,947
MinE	2,872	2,872	2,872	2,872	2,872	2,872	2,872	2,872	2,872	2,872	2,872	2,872	34,460
MaxE	4,786	4,786	4,786	4,786	4,786	4,786	4,786	4,786	4,786	4,786	4,786	4,786	57,433

Note. The estimates for total annual inflow (table A1) were divided by 12 to estimate inflow in each month.

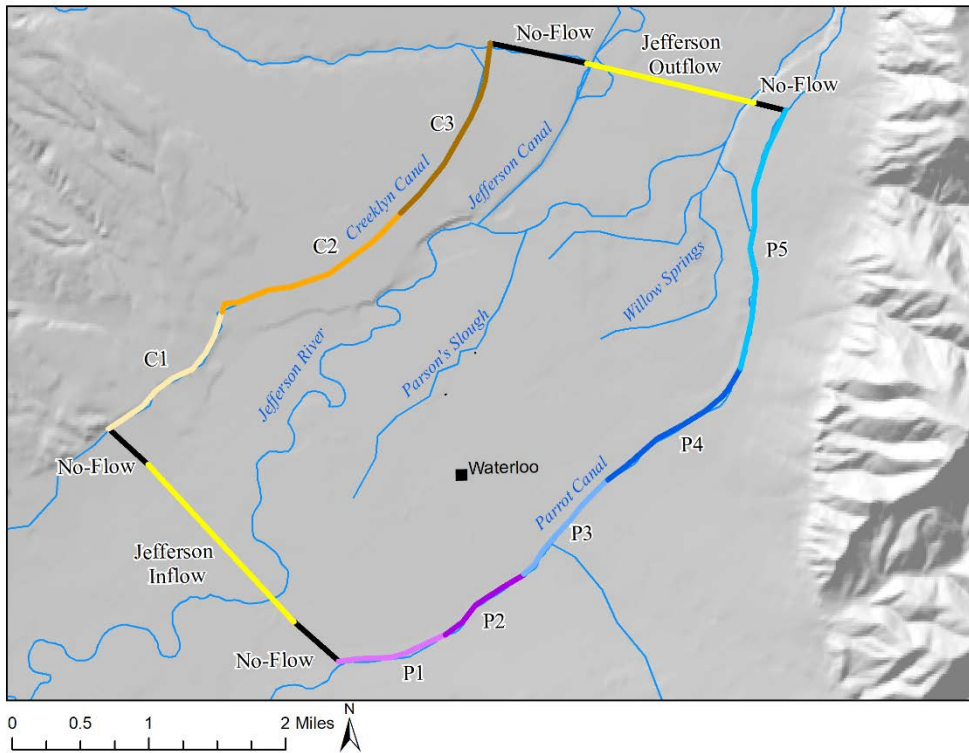


Figure A1. Groundwater inflow and outflow occur along the edges of the model domain. Alluvial inflow occurs along the yellow segment at the southern end. Alluvial outflow occurs along the yellow segment on the northern end. Lateral groundwater inflow occurs along the numbered segments (table A3).

2. Lateral Groundwater Inflow (GW_{in-lat})

Groundwater inflow along the lateral edges of the model (fig. A1). The groundwater inflow was calculated by subtracting estimated evapotranspiration (based on plant types) from precipitation (PRISM 30-yr normal; PRISM, 2018) in the areas upgradient from each lateral edge, and assuming that half of the remaining water would run off and half would recharge the groundwater system.

Table A3. Estimated evapotranspiration—Highland Mountains.

Vegetation Group	Area (acres)	ET Rate (ft/yr)	ET (acre-ft/yr)
Upland Sagebrush	5,350	1.1	5,885
Douglas Fir	8,477	1.4	11,868
Shrub/Grass Lowlands	9,765	1.0	9,765
Mixed Evergreen	8,290	1.8	14,923
High Xeric Grasses	2,472	1.2	2,967
Ag Lands	309	2.1	650
Mesic Meadow	1,216	1.7	2,067
Whitebark Pine	2,838	2.2	6,244
Alpine Rangeland, Deciduous Shrubs	864	2.0	1,728
Developed	186	1.0	186
Riparian	170	2.3	392
TOTAL	39,939	—	56,674

Table A4. Estimated evapotranspiration—Tobacco Root Mountains.

Vegetation Group	Area (acres)	ET Rate (ft/yr)	ET (acre-ft/yr)
Upland Sagebrush	4,593	1.1	5,053
Douglas Fir	12,942	1.4	18,118
Shrub/Grass Lowlands	2,046	1.0	2,046
Mixed Evergreen	3,215	1.8	5,787
High Xeric Grasses	343	1.2	412
Ag Lands	1,995	2.1	4,190
Mesic Meadow	757	1.7	1,287
Whitebark Pine	1,492	2.2	3,283
Alpine Rangeland, Deciduous Shrubs	181	2.0	361
Developed	206	1.0	206
Riparian	422	2.3	971
TOTAL	28,193	---	41,715

Table A5. Lateral groundwater inflow calculated based on precipitation and vegetation types.

	Area (acres)	Average PCP (in/yr)	Annual PCP (acre-ft/yr)	Estimated ET (acre-ft/yr)			Excess Water (acre-ft/yr)			GW _{lat} (acre-ft/yr) [#]		
				BE	MinE ⁺	MaxE ⁺	BE	MinE	MaxE	BE	MinE	MaxE
Highlands	39,939	18.36	61,116	56,674	53,840	59,508	4,442	1,608	7,276	2,221	804	3,638
Tobacco Root	28,193	19.02	44,676	41,715	39,629	43,801	2,961	875	5,047	1,480	438	2,523
TOTAL*										3,701	1,942	5,461

*ET values were considered to be the most uncertain element of the calculation, and their range was estimated based on 5% error.

[#]GW_{lat} was estimated by assuming that half of the excess water infiltrates to groundwater.

*Total range was based on root sum of squares error propagation.

Note. Lateral groundwater inflow was applied to the edges based on the side of the model (Highlands vs. Tobacco Root), and the length of each segment (fig. A1). Values were distributed by month by dividing the total by 12.

Table A6. Monthly lateral groundwater inflow (acre-ft).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
BE	308	308	308	308	308	308	308	308	308	308	308	308	3,701
MinE	162	162	162	162	162	162	162	162	162	162	162	162	1,942
MaxE	455	455	455	455	455	455	455	455	455	455	455	455	5,461

3. Canal Leakage (CL)

The Parrot, Creeklyn, and Jefferson Canals leak water to the underlying aquifer from mid-April to mid-October (fig. A1). Monitoring data was used to estimate overall average leakage rates of 1.31 and 1.36 cfs/mi on the Parrot and Creeklyn Canals, respectively. The average of these rates (1.34 cfs/mi) was assigned to the Jefferson Canal. The total amount of leakage was based on multiplying canals were separated into the same segments used to calculate lateral groundwater inflow (fig. A1).

Table A7. Annual canal leakage amounts.

Canal	Leakage Rate (cfs/mi)			Miles	BE cfs	BE ft ³ /d	Days on per year	BE Leakage (ft ³ /yr)	Leakage (acre-ft/yr)		
	BE	MinE	MaxE						BE	MinE	MaxE
Parrot	1.31	1.18	1.44	5.70	7.46	644,973	183.5	118,352,520	2,717	2,445	2,989
Creeklyn	1.36	1.22	1.50	4.44	6.04	521,533	183.5	95,701,320	2,197	1,977	2,417
Jefferson	1.34	1.21	1.47	1.41	1.88	162,846	183.5	29,882,160	686	617	755
								TOTAL	5,600	5,244	5,956

Note. The likely range was based on a 10% error for the range of leakage rates, which is the most variable, and uncertain, component of the calculation.

Table A8. Monthly canal leakage amounts.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Days on	0	0	0	15	31	30	31	31	30	15.5	0	0	183.5
BE	0	0	0	458	946	916	946	946	916	473	0	0	5,600
MinE	0	0	0	429	886	857	886	886	857	443	0	0	5,244
MaxE	0	0	0	487	1006	974	1006	1006	974	503	0	0	5,956

Note. The estimates for total annual inflow (table A-7) were divided by the days the canal is on (183.5 d), and multiplied by the days on in each month.

4. Irrigation Recharge (IR)

When more water is applied to fields than the crops can use, the excess may evaporate, run off, infiltrate and be stored within the root zone, or infiltrate through the root zone to create groundwater recharge (i.e., irrigation recharge). The Waterloo model area is affected by irrigation recharge within the model domain, and by irrigation recharge occurring immediately upgradient from the model boundaries. Irrigation recharge within the model domain was assigned as groundwater recharge. Upgradient irrigation recharge was applied at the segmented specified flux boundaries at the edges of the model domain (fig. A1).

The NRCS's Irrigation Water Requirements (IWR) program was used to calculate the amount of irrigation recharge (NRCS, 2003, 2019a; Brancheau, 2015; Butler and Bobst, 2017). This analysis considers soil types, crop type, irrigation method, and climate. Sandy loam is the predominant soil type within the study area (NRCS, 2019b). Field observations and landowner interviews indicated that in 2014 crop types included native grass, 50/50 alfalfa-grass mix, alfalfa, barley, peas, potatoes, corn, sod, and conifer trees. This was simplified into four classes of grass, 50/50 mix, alfalfa, and other. The "other" crops compose a small percentage of the crop land, and have similar irrigation requirements. The irrigated acres and irrigation types were based on the MT Department of Revenue's Final Land Units (FLU) Classification coverage (obtained from <http://geoinfo.msl.mt.gov/>), MDOR, 2013), with modifications based on aerial photographs and field observations. Irrigation efficiency was set at 25% for flood, 65% for sprinkler, and 80% for pivot (NRCS, 1993; Sterling and Neibling, 1994).

Table A9. Monthly IWR calculated irrigation recharge rates.

Irrigation & Vegetation Type	Area (acres)	Monthly IR (acre-ft/mo)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pivot (Pasture Grass, Alfalfa Hay, 50/50, other)	1,498	0	0	0	0	0	124	171	144	6	0	0	0
Sprinkler (Pasture Grass, 50/50, other)	810	0	0	0	0	10	146	202	169	42	0	0	0
Sprinkler (Alfalfa Hay)	214	0	0	0	0	5	92	119	99	40	0	0	0
Flood (Pasture Grass, other)	1,333	0	0	0	0	398	1,450	1,993	1,690	693	0	0	0
Flood (50/50)	602	0	0	0	0	220	738	997	833	346	0	0	0
Flood (Alfalfa Hay)	64	0	0	0	0	28	87	116	96	40	0	0	0
TOTAL		0	0	0	0	660	2,638	3,599	3,031	1,168	0	0	0

Table A10. Annual IWR calculated irrigation recharge rates.

Irrigation & Vegetation Type	Area (acres)	Annual Totals (acre-ft/yr)		
		BE	MinE	MaxE
Pivot (Pasture Grass, Alfalfa Hay, 50/50, other)	1,498	446	401	491
Sprinkler (Pasture Grass, 50/50, other)	810	568	512	625
Sprinkler (Alfalfa Hay)	214	356	320	392
Flood (Pasture Grass, other)	1,333	6,223	5,601	6,845
Flood (50/50)	602	3,135	2,821	3,448
Flood (Alfalfa Hay)	64	368	331	405
TOTAL		11,096	10,394	11,798

Note. Ranges were based on 10% error.

5. Alluvial Groundwater Outflow (GW_{out-ai})

Groundwater outflow occurs through the alluvium on the northern side of the model domain (fig. A1). The groundwater outflow was calculated using the Darcy Flux Equation (see Alluvial Groundwater Inflow section).

Table A11. Groundwater flow out of the model area through the Jefferson River alluvium was estimated using the Darcy Flux Equation.

	K (ft/d)			Width (ft)	Sat Tk (ft)	Area (ft ²)	I (ft/ft)	BE Q (ft ³ /d)	Q (acre-ft/yr)		
	BE	MinE	MaxE						BE	MinE	MaxE
Jefferson River	1,100	825	1,375	6,400	200	1,280,000	0.0023	3,238,400	27,154	20,365	33,942

Note. K, range based on aquifer tests, sediment descriptions, and literature values (Heath, 1983; Fetter, 1994). The likely range was based on a range of K values, which is the most variable, and uncertain, component of the calculation. BE, best estimate; MinE, minimum estimate; MaxE, maximum estimate. Width-based geologic maps: Sat Tk, saturated thickness, based on well logs; Area, width x Sat Tk; I, calculated using observed water levels from April 2015.

Table A12. Monthly alluvial outflow (acre-ft).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
BE	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	27,154
MinE	1,697	1,697	1,697	1,697	1,697	1,697	1,697	1,697	1,697	1,697	1,697	1,697	20,365
MaxE	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	2,829	33,942

Note. The estimates for total annual outflow (table A-9) were divided by 12 to get monthly values.

6. Riparian Evapotranspiration (ET_r)

Where groundwater is close to the ground surface, some plants, such as willow, cottonwood, and riparian grasses, can directly remove (transpire) groundwater from the saturated zone.

LANDFIRE data (USGS, 2010) showed that 547 acres have riparian plant coverage in the Waterloo area. Using a potential ET (PET) rate of 1.83 ft/yr (Hackett and others, 1960; Lautz, 2008), an upper bound estimate of 1,002 acre-ft/yr is calculated. Since the depth to groundwater in this area averages about 5 ft, and a 10 ft extinction depth is often used for riparian vegetation, the ET_r value for this area is likely about 50% of the upper bound. The range of values is based on 25% to 75% of the upper bound. The total values were distributed through the growing season (May–Sep) based on average monthly temperatures.

Table A13. Summary of annual actual riparian evapotranspiration.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
BE	0	0	0	0	47	103	149	133	69	0	0	0	501
MinE	0	0	0	0	24	51	74	67	35	0	0	0	251
MaxE	0	0	0	0	71	154	223	200	104	0	0	0	752

Note. BE is based on 50% of PET. MinE and MaxE are based on 25% and 75% of PET.

7. Well Pumping (WEL)

Well pumping amounts are based on the number and type of pumping wells (GWIC, 2016; DNRC, 2016):

Table A14. Summary of types of wells.

Livestock	15
Irrigation	3
Domestic	61

Livestock Wells

Water used by livestock is assumed to be 100% consumed. The total amount of water used for livestock was based on the acreage of the Waterloo area relative to the area of Madison County, and the estimated water use for livestock in Madison County (770,000 gpd; Cannon and Johnson, 2004). This resulted in a usage of 2,646 gpd from the 15 wells, or 176 gpd per well. This is equivalent to pumping each of the wells for 35 min per day at 5 gpm. The calculated consumptive use was 2.97 acre-ft/yr. The distribution of livestock water use was split among months using a time-weighted distribution.

Table A15. Livestock water use (acre-ft).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Days	31	28.25	31	30	31	30	31	31	30	31	30	31	365.25
BE	0.25	0.23	0.25	0.24	0.25	0.24	0.25	0.25	0.24	0.25	0.24	0.25	2.97
MinE	0.23	0.21	0.23	0.22	0.23	0.22	0.23	0.23	0.22	0.23	0.22	0.23	2.67
MaxE	0.28	0.25	0.28	0.27	0.28	0.27	0.28	0.28	0.27	0.28	0.27	0.28	3.27

Note. The range of likely values was based on an estimated uncertainty of $\pm 10\%$.

Irrigation Wells

The use of water by the three irrigation wells was based on water rights, air photos, and calculations using DNRC's IWR program.

Table A16. Summary of irrigation well annual total pumping.

GWIC ID or Water Right	Acres Irrigated ¹	Annual Use ² (acre-ft)		
		BE	MinE	MaxE
107066	18	48	43	53
107064	12	27	25	30
130437	17	26	23	28
TOTAL	47	101	91	111

¹Acres irrigated based on DNRC water rights information and NAIP areal imagery.

²Annual rates based on DNRC's Water Use Standards (ARM 36.12.115; 2.5 ft/yr for hay) and water right information.

³The range of likely values was based on an estimated uncertainty of $\pm 10\%$.

Table A17. Monthly distribution of BE irrigation well pumping (acre-ft).

GWIC ID	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
107066	0.0	0.0	0.0	0.0	3.6	10.7	15.0	13.5	5.0	0.2	0.0	0.0	48
107064	0.0	0.0	0.0	0.0	0.0	6.6	9.3	8.4	3.1	0.0	0.0	0.0	27
130437	0.0	0.0	0.0	0.0	1.9	5.7	8.0	7.2	2.6	0.1	0.0	0.0	26

¹Monthly values are annual rates distributed based on monthly crop requirements from NRCS's IWR program, and water rights dates.

²The range of likely values was based on an estimated uncertainty of $\pm 10\%$.

Domestic Wells

The consumptive use for the 61 domestic wells was based on a previous GWIP study (Waren and others, 2012) which used 15 yr of subdivision water-use records near Helena, MT, to calculate an average annual usage rate of 0.49 acre-ft/yr per home.

Table A18. Domestic well pumping rates (61 wells; acre-ft).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
BE	0.09	0.09	0.12	0.18	3.03	5.41	7.79	7.85	4.22	0.71	0.15	0.06	29.7
MinE	0.08	0.08	0.11	0.16	2.73	4.87	7.01	7.07	3.80	0.64	0.13	0.05	26.7
MaxE	0.10	0.10	0.13	0.20	3.34	5.95	8.57	8.64	4.65	0.79	0.16	0.07	32.7

Note. Total annual rate and distribution by month based on Waren and others, 2012. The range of likely values was based on an estimated uncertainty of $\pm 10\%$.

Total Well Pumping

Table A19. Summary of well pumping rates by month (acre-ft).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	BE	MinE	MaxE
Livestock	0.25	0.23	0.25	0.24	0.25	0.24	0.25	0.25	0.24	0.25	0.24	0.25	3.0	2.7	3.3
Irrigation	0.00	0.00	0.00	0.03	5.57	23.03	32.28	29.04	10.70	0.26	0.00	0.00	100.9	91.0	111.0
Domestic	0.09	0.09	0.12	0.18	3.03	5.41	7.79	7.85	4.22	0.71	0.15	0.06	29.7	26.7	32.7
TOTAL	0.34	0.32	0.37	0.45	8.85	28.68	40.32	37.14	15.16	1.22	0.39	0.31	133.6	120.4	147.0

8. Net Outflow from Groundwater to Surface-Water (SW_{net})

The net discharge from groundwater to surface waters was based on the difference between the calculated inflows and outflows (table A21). Monthly values were estimated based on monitoring data from groundwater-fed streams (Parson's Slough and Willow Springs). Note that these gains occur along Parson's Slough, Willow Springs, and the mainstem of the Jefferson River.

Using best estimate (BE) values, calculated inflows totaled 66,345 acre-ft/yr (table A22), and calculated outflows other than surface water totaled 27,789 acre-ft/yr. Therefore, it is estimated that the average net groundwater discharge to surface waters is about 38,556 acre-ft/yr (53 cfs, on average). Using the likely range of inflow and outflow values based on root sum of squares error propagation (MinE and MaxE), the likely range of net surface water gain was estimated to be from 25,073 to 52,040 acre-ft/yr (35–72 cfs). The best estimate value also correlates well with the monitoring-based estimate of surface-water gains in this area developed by Brancheau (2015) of 39,974 acre-ft/yr (55 cfs).

Table A20. Estimated net flow from groundwater to surface waters (acre-ft).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
BE	3,071	2,537	2,497	2,418	3,090	3,248	3,624	4,361	3,677	3,403	3,272	3,359	38,556
MinE	1,997	1,650	1,623	1,572	2,009	2,112	2,356	2,836	2,391	2,213	2,128	2,184	25,073
MaxE	4,145	3,424	3,370	3,264	4,170	4,384	4,891	5,887	4,963	4,593	4,416	4,533	52,040

9. Overall Budget

Table A21. Waterloo preliminary groundwater budget (acre-ft).

Inflows	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual		
													BE	MinE	MaxE
GW_{in-al}	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	3,829	45,947	34,460	57,433
GW_{in-lat}	309	309	309	309	309	309	309	309	309	309	309	309	3,702	1,942	5,461
CL	0	0	0	458	946	916	946	946	916	473	0	0	5,600	5,244	5,956
IR	0	0	0	0	660	2,638	3,599	3,031	1,168	0	0	0	11,096	10,394	11,798
Total Inflow	4,137	4,137	4,137	4,595	5,744	7,691	8,682	8,114	6,221	4,610	4,137	4,137	66,345	54,697	77,992
Outflows															
GW_{out-al}	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	2,263	27,154	20,365	33,942
ET_r	0	0	0	0	47	103	149	133	69	0	0	0	501	251	752
WEL	0.3	0.3	0.4	0.4	8.9	28.7	40.3	37.1	15.2	1.2	0.4	0.3	134	120	147
SW_{net}^*	3,071	2,537	2,497	2,418	3,090	3,248	3,624	4,361	3,677	3,403	3,272	3,359	38,556	25,073	52,040
Total Outflow	5,334	4,880	4,760	4,681	5,409	5,643	6,075	6,794	6,024	5,667	5,535	5,622	66,345	51,247	81,443
ΔS	-1,179	-663	-622	-86	335	2,048	2,607	1,320	197	-1,057	-1,398	-1,484	0	0	0

Note. Change in storage (ΔS) is calculated as the difference between monthly inflows and outflows. GW_{in-al} , alluvial groundwater inflow; GW_{in-lat} , lateral groundwater inflow; CL , canal leakage; IR , irrigation recharge; GW_{out-al} , alluvial groundwater outflow; ET_r , riparian evapotranspiration; WEL , well pumping; SW_{net} , net outflow from groundwater to surface waters.

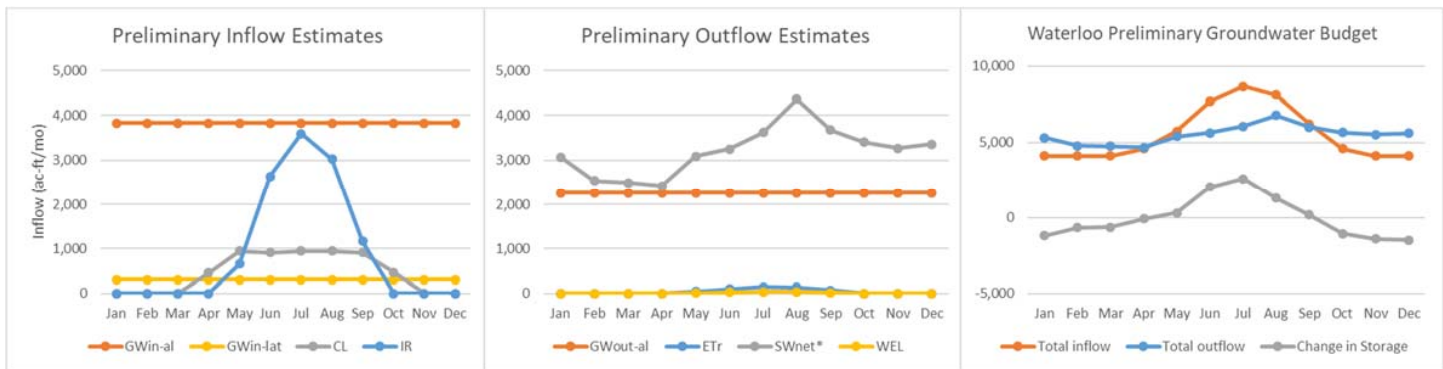


Table A22: Groundwater budget developed by Brancheau (2015).

GW _{in}	Initial Estimate (acre-ft/yr)	Uncertainty (%)	Range (are-ft/yr)		Adjusted Estimate (acre-ft/yr)
			low	high	
Darcy Influx	22,364	10%	20,128	24,601	23,371
Lateral Groundwater Influx	3,702	10%	3,332	4,072	3,869
Canal Leakage	12,829	5%	12,187	13,470	13,406
Irrigation Recharge	11,096	5%	10,541	11,651	11,595
<i>TOTAL IN</i>	49,991				52,241
GW_{out}					
Darcy Flux _{out}	13,503	10%	12,153	14,853	12,963
Spring-fed Streams	16,365	5%	15,547	17,183	15,670
Evapotranspiration	1,002	10%	902	1,102	957
Jefferson River Recharge	23,609	10%	21,248	25,970	22,653
<i>TOTAL OUT</i>	54,479				52,243

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APPENDIX B
JEFFERSON RIVER SLOPE
CALCULATIONS

From Survey data:

Elevation of 0.00 on Staff Gage at Corbett's (downstream end) = 4405.081 ft-amsl

Elevation of Rebar at Funston's = 4469.951 ft-amsl (~3 ft above 0.00 on gage) ~ 4466.951

Elevation of Rebar at Silver Star = 4516.52 ft-amsl (per our survey 0.00 is 5.28 ft lower) = 4511.24

From Google:

River miles from Silver Star to Corbett's = 12.9 miles – Overall Slope = $106/68,112 = 0.001556$ ft/ft

River miles from Silver Star to Funston's = 6.12 miles – Slope = $44/32,314 = 0.001362$

River miles from Funston's to Corbett's = 6.78 miles – Slope = $62/35,798 = 0.001732$

Source:

Andrew L Bobst

Hydrogeologist/Project Manager

Groundwater Investigations Program

Montana Bureau of Mines and Geology

1300 W. Park

Butte, MT 59701

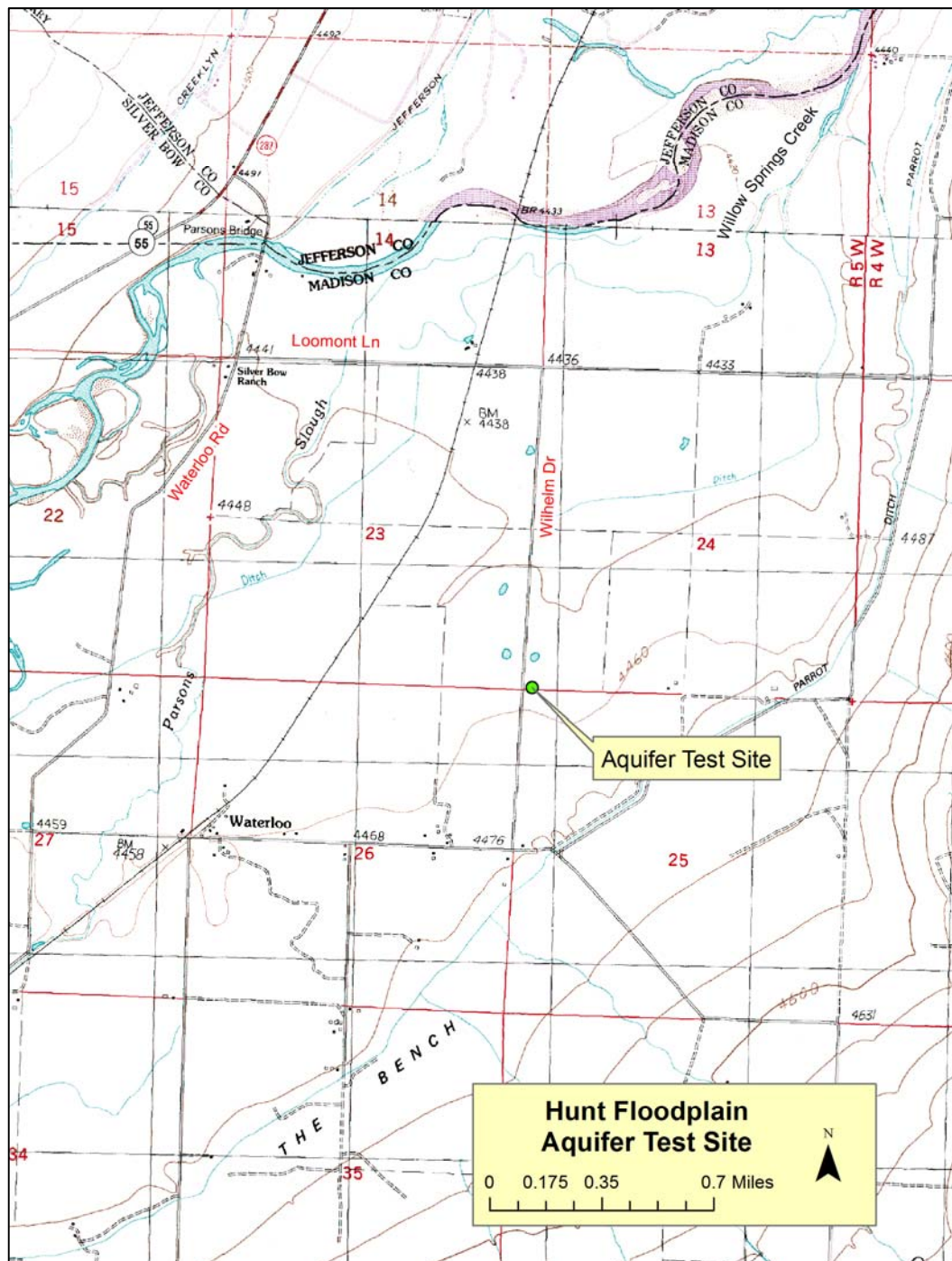
abobst@mtech.edu

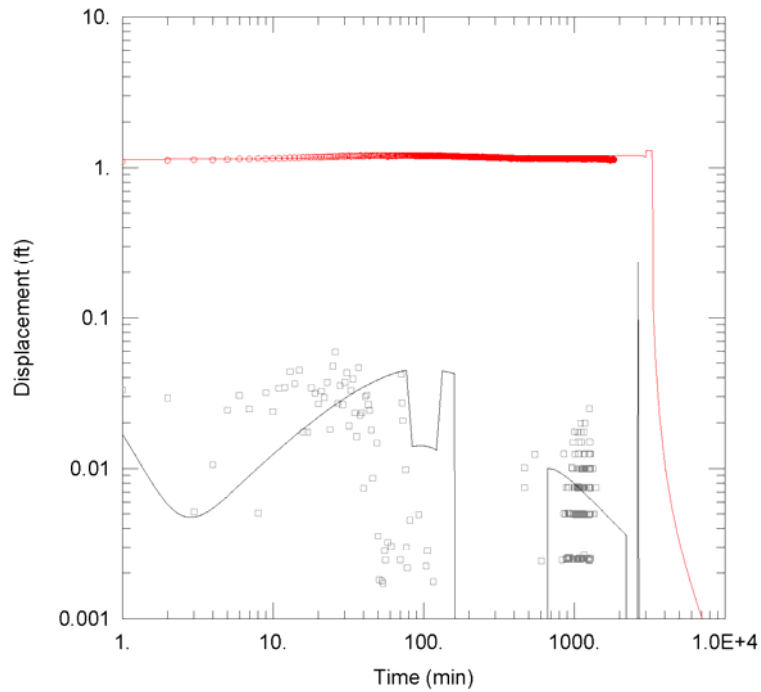
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APPENDIX C

HUNT AQUIFER TEST RESULTS

APPENDIX C Hunt Aquifer Test Results (Hunt, 2015)





HUNTA AQUIFER TEST

Data Set: M:\...HuntA_CR_OW1_UC_CHB.aqt

Date: 11/19/19

Time: 09:11:05

PROJECT INFORMATION

Company: MBMG

Client: HuntA

Project: BWIPUJ

Location: Upper Jefferson

Test Well: PW

Test Date: 2/24/15

AQUIFER DATA

Saturated Thickness: 100. ft

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
PW	0	0	OW1	-1.112	22.767

SOLUTION

Aquifer Model: Unconfined

Solution Method: Neuman

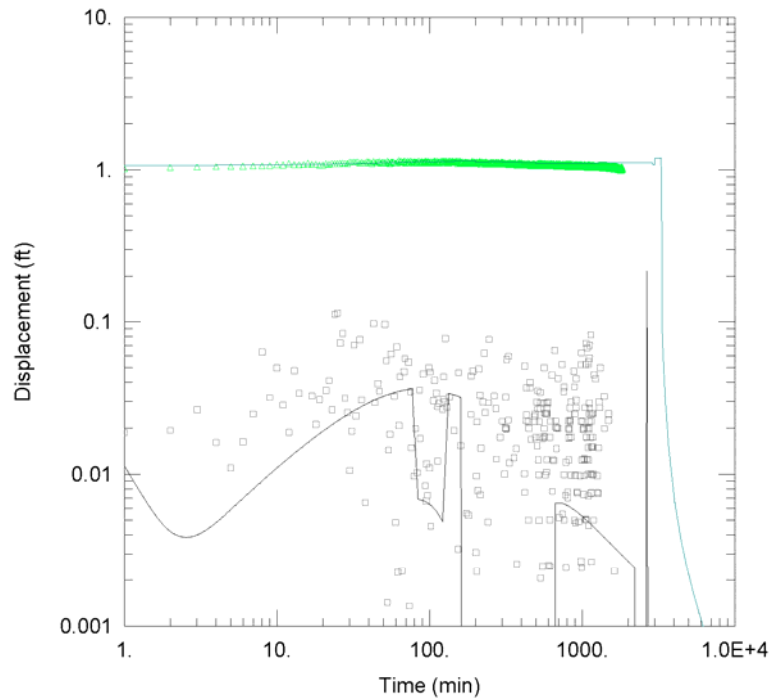
T = 4.1E+4 ft²/day

S = 0.0013

Sy = 0.14

Kz/Kr = 0.2

Figure C2. Observation well (OW1) analysis (Neuman method)



HUNTA AQUIFER TEST

Data Set: M:\...\HuntA_CR_OW2_UC_CHB.aqt

Date: 11/19/19

Time: 09:11:16

PROJECT INFORMATION

Company: MBMG

Client: HuntA

Project: BWIPUJ

Location: Upper Jefferson

Test Well: PW

Test Date: 2/24/15

AQUIFER DATA

Saturated Thickness: 100. ft

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
PW	0	0	OW2	-21.792	2.695

SOLUTION

Aquifer Model: Unconfined

Solution Method: Neuman

T = 4.45E+4 ft²/day

S = 0.0013

Sy = 0.14

Kz/Kr = 0.2

Figure C3. Observation well (OW2) analysis (Neuman method)

APPENDIX D

MODEL CONSTRUCTION

Table D1. Summary of model grid construction.

Grid construction item	Value
Rows	150
Columns	150
Layers	1
Total area	27.13 sq mi
Active area	12.31 sq mi
Row spacing	178.18 ft
Column spacing	188.66 ft
Number of active cells	10,212
No. Inactive/no-flow cells	12,288
Vertical datum	NAVD 88
Spatial units	feet
Temporal units	days
Max thickness	215 ft
Min thickness	199 ft
Max saturated thickness*	208 ft
Min saturated thickness*	109 ft
No. STR cells ^a	795
No. DRN cells ^b	285
No. WELL cells ^c	578
Coordinate system	State Plane MT FIPS 2500, International Ft

*Steady-state simulation results

^aMODFLOW STR Package cells represent Jefferson River^bMODFLOW DRN Package cells represent Parson's Slough and Willow Spring^cMODFLOW WELL Package cells represent pumping wells, canal leakage, alluvial Darcy flow, and lateral groundwater

Table D2. Stress periods and time steps applied to the Waterloo model.

Start Date	Stress Period #	Stress period length (days)	No. of time steps	Time step length (days)	Simulation Type	Remarks
Mar-04	1	1	1	1	Steady-State	
Apr-04	2	30	6	5.0	Transient	Skipped during calibration
May-04	3	31	6	5.2	Transient	""
Jun-04	4	30	6	5.0	Transient	""
Jul-04	5	31	6	5.2	Transient	""
Aug-04	6	31	6	5.2	Transient	""
Sep-04	7	30	6	5.0	Transient	""
Oct-04	8	31	6	5.2	Transient	""
Nov-04	9	30	6	5.0	Transient	""
Dec-04	10	31	6	5.2	Transient	""
Jan-05	11	31	6	5.2	Transient	""
Feb-05	12	28	6	4.7	Transient	""
Mar-05	13	31	6	5.2	Transient	""
Apr-05	14	30	6	5.0	Transient	""
May-05	15	31	6	5.2	Transient	""
Jun-05	16	30	6	5.0	Transient	""
Jul-05	17	31	6	5.2	Transient	""
Aug-05	18	31	6	5.2	Transient	""
Sep-05	19	30	6	5.0	Transient	""
Oct-05	20	31	6	5.2	Transient	""
Nov-05	21	30	6	5.0	Transient	""
Dec-05	22	31	6	5.2	Transient	""
Jan-06	23	31	6	5.2	Transient	""
Feb-06	24	28	6	4.7	Transient	""
Mar-06	25	31	6	5.2	Transient	""
Apr-06	26	30	6	5.0	Transient	""
May-06	27	31	6	5.2	Transient	""
Jun-06	28	30	6	5.0	Transient	""
Jul-06	29	31	6	5.2	Transient	""
Aug-06	30	31	6	5.2	Transient	""
Sep-06	31	30	6	5.0	Transient	""
Oct-06	32	31	6	5.2	Transient	""
Nov-06	33	30	6	5.0	Transient	""
Dec-06	34	31	6	5.2	Transient	""
Jan-07	35	31	6	5.2	Transient	""
Feb-07	36	28	6	4.7	Transient	""
Mar-07	37	31	6	5.2	Transient	""
Apr-07	38	30	6	5.0	Transient	""
May-07	39	31	6	5.2	Transient	""
Jun-07	40	30	6	5.0	Transient	""
Jul-07	41	31	6	5.2	Transient	""

Table D2 (Continued). Stress periods and time steps applied to the Waterloo model.						
Start Date	Stress Period #	Stress period length (days)	No. of time steps	Time step length (days)	Simulation Type	Remarks
Aug-07	42	31	6	5.2	Transient	Skipped during calibration
Sep-07	43	30	6	5.0	Transient	""
Oct-07	44	31	6	5.2	Transient	""
Nov-07	45	30	6	5.0	Transient	""
Dec-07	46	31	6	5.2	Transient	""
Jan-08	47	31	6	5.2	Transient	""
Feb-08	48	29	6	4.8	Transient	""
Mar-08	49	31	6	5.2	Transient	""
Apr-08	50	30	6	5.0	Transient	""
May-08	51	31	6	5.2	Transient	""
Jun-08	52	30	6	5.0	Transient	""
Jul-08	53	31	6	5.2	Transient	""
Aug-08	54	31	6	5.2	Transient	""
Sep-08	55	30	6	5.0	Transient	""
Oct-08	56	31	6	5.2	Transient	""
Nov-08	57	30	6	5.0	Transient	""
Dec-08	58	31	6	5.2	Transient	""
Jan-09	59	31	6	5.2	Transient	""
Feb-09	60	28	6	4.7	Transient	""
Mar-09	61	31	6	5.2	Transient	""
Apr-09	62	30	6	5.0	Transient	""
May-09	63	31	6	5.2	Transient	""
Jun-09	64	30	6	5.0	Transient	""
Jul-09	65	31	6	5.2	Transient	""
Aug-09	66	31	6	5.2	Transient	""
Sep-09	67	30	6	5.0	Transient	""
Oct-09	68	31	6	5.2	Transient	""
Nov-09	69	30	6	5.0	Transient	""
Dec-09	70	31	6	5.2	Transient	""
Jan-10	71	31	6	5.2	Transient	""
Feb-10	72	28	6	4.7	Transient	""
Mar-10	73	31	6	5.2	Transient	""
Apr-10	74	30	6	5.0	Transient	""
May-10	75	31	6	5.2	Transient	""
Jun-10	76	30	6	5.0	Transient	""
Jul-10	77	31	6	5.2	Transient	""
Aug-10	78	31	6	5.2	Transient	""
Sep-10	79	30	6	5.0	Transient	""
Oct-10	80	31	6	5.2	Transient	""
Nov-10	81	30	6	5.0	Transient	""
Dec-10	82	31	6	5.2	Transient	""

Table D2 (Continued). Stress periods and time steps applied to the Waterloo model.						
Start Date	Stress Period #	Stress period length (days)	No. of time steps	Time step length (days)	Simulation Type	Remarks
Jan-11	83	31	6	5.2	Transient	Skipped during calibration
Feb-11	84	28	6	4.7	Transient	""
Mar-11	85	31	6	5.2	Transient	""
Apr-11	86	30	6	5.0	Transient	""
May-11	87	31	6	5.2	Transient	""
Jun-11	88	30	6	5.0	Transient	""
Jul-11	89	31	6	5.2	Transient	""
Aug-11	90	31	6	5.2	Transient	""
Sep-11	91	30	6	5.0	Transient	""
Oct-11	92	31	6	5.2	Transient	""
Nov-11	93	30	6	5.0	Transient	""
Dec-11	94	31	6	5.2	Transient	""
Jan-12	95	31	6	5.2	Transient	""
Feb-12	96	29	6	4.8	Transient	""
Mar-12	97	31	6	5.2	Transient	""
Apr-12	98	30	6	5.0	Transient	""
May-12	99	31	6	5.2	Transient	""
Jun-12	100	30	6	5.0	Transient	""
Jul-12	101	31	6	5.2	Transient	""
Aug-12	102	31	6	5.2	Transient	""
Sep-12	103	30	6	5.0	Transient	""
Oct-12	104	31	6	5.2	Transient	""
Nov-12	105	30	6	5.0	Transient	""
Dec-12	106	31	6	5.2	Transient	""
Jan-13	107	31	6	5.2	Transient	""
Feb-13	108	28	6	4.7	Transient	""
Mar-13	109	31	6	5.2	Transient	""
Apr-13	110	30	6	5.0	Transient	Start calibration simulation
May-13	111	31	6	5.2	Transient	Calibration simulation
Jun-13	112	30	6	5.0	Transient	""
Jul-13	113	31	6	5.2	Transient	""
Aug-13	114	31	6	5.2	Transient	""
Sep-13	115	30	6	5.0	Transient	""
Oct-13	116	31	6	5.2	Transient	""
Nov-13	117	30	6	5.0	Transient	""
Dec-13	118	31	6	5.2	Transient	""
Jan-14	119	31	6	5.2	Transient	""
Feb-14	120	28	6	4.7	Transient	""
Mar-14	121	31	6	5.2	Transient	""
Apr-14	122	30	6	5.0	Transient	""
May-14	123	31	6	5.2	Transient	""

Start Date	Stress Period #	Stress period length (days)	No. of time steps	Time step length (days)	Simulation Type	Remarks
Jun-14	124	30	6	5.0	Transient	Calibration simulation
Jul-14	125	31	6	5.2	Transient	""
Aug-14	126	31	6	5.2	Transient	""
Sep-14	127	30	6	5.0	Transient	""
Oct-14	128	31	6	5.2	Transient	""
Nov-14	129	30	6	5.0	Transient	""
Dec-14	130	31	6	5.2	Transient	""
Jan-15	131	31	6	5.2	Transient	""
Feb-15	132	28	6	4.7	Transient	""
Mar-15	133	31	6	5.2	Transient	""
Apr-15	134	30	6	5.0	Transient	""
May-15	135	31	6	5.2	Transient	""
Jun-15	136	30	6	5.0	Transient	""
Jul-15	137	31	6	5.2	Transient	""
Aug-15	138	31	6	5.2	Transient	""
Sep-15	139	30	6	5.0	Transient	""
Oct-15	140	31	6	5.2	Transient	""

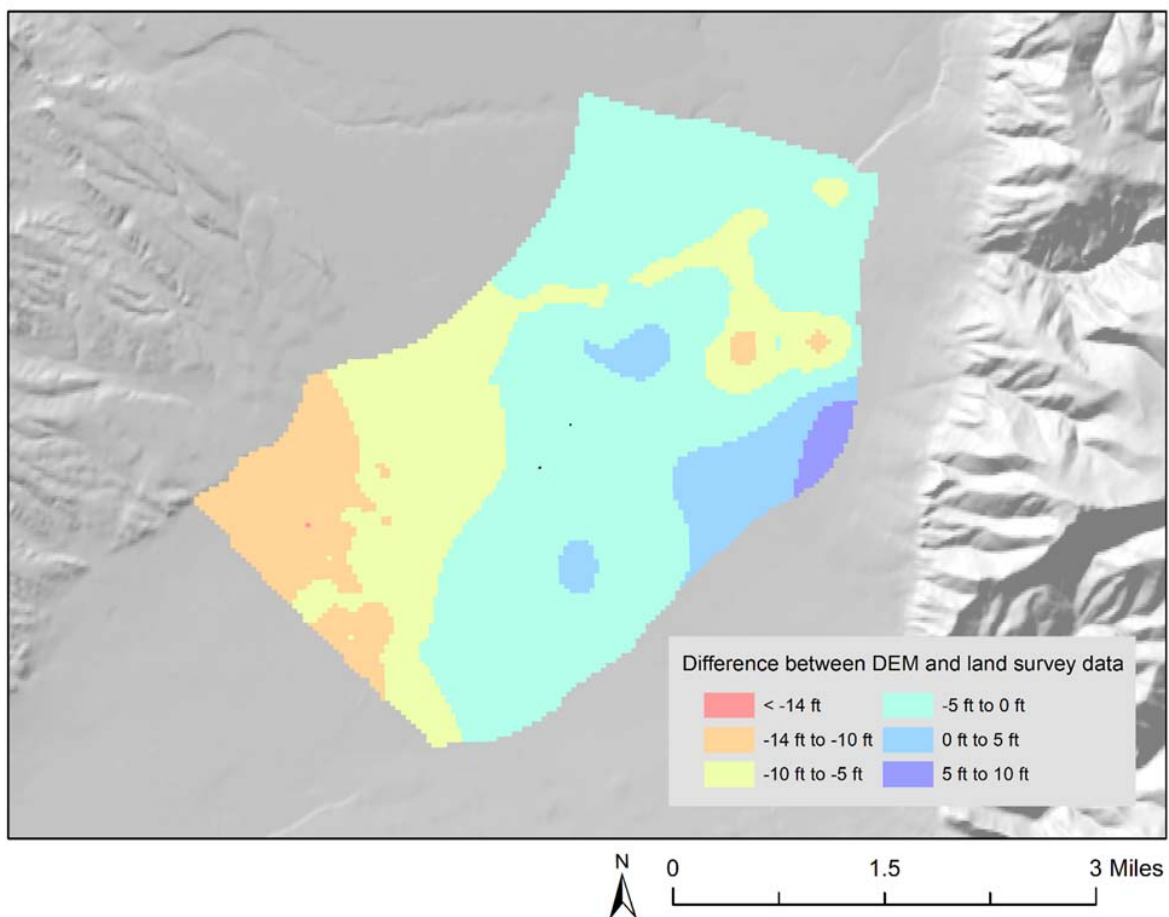


Figure D1. The distribution of the difference between DEM and land surveyed points (Sept 2016).

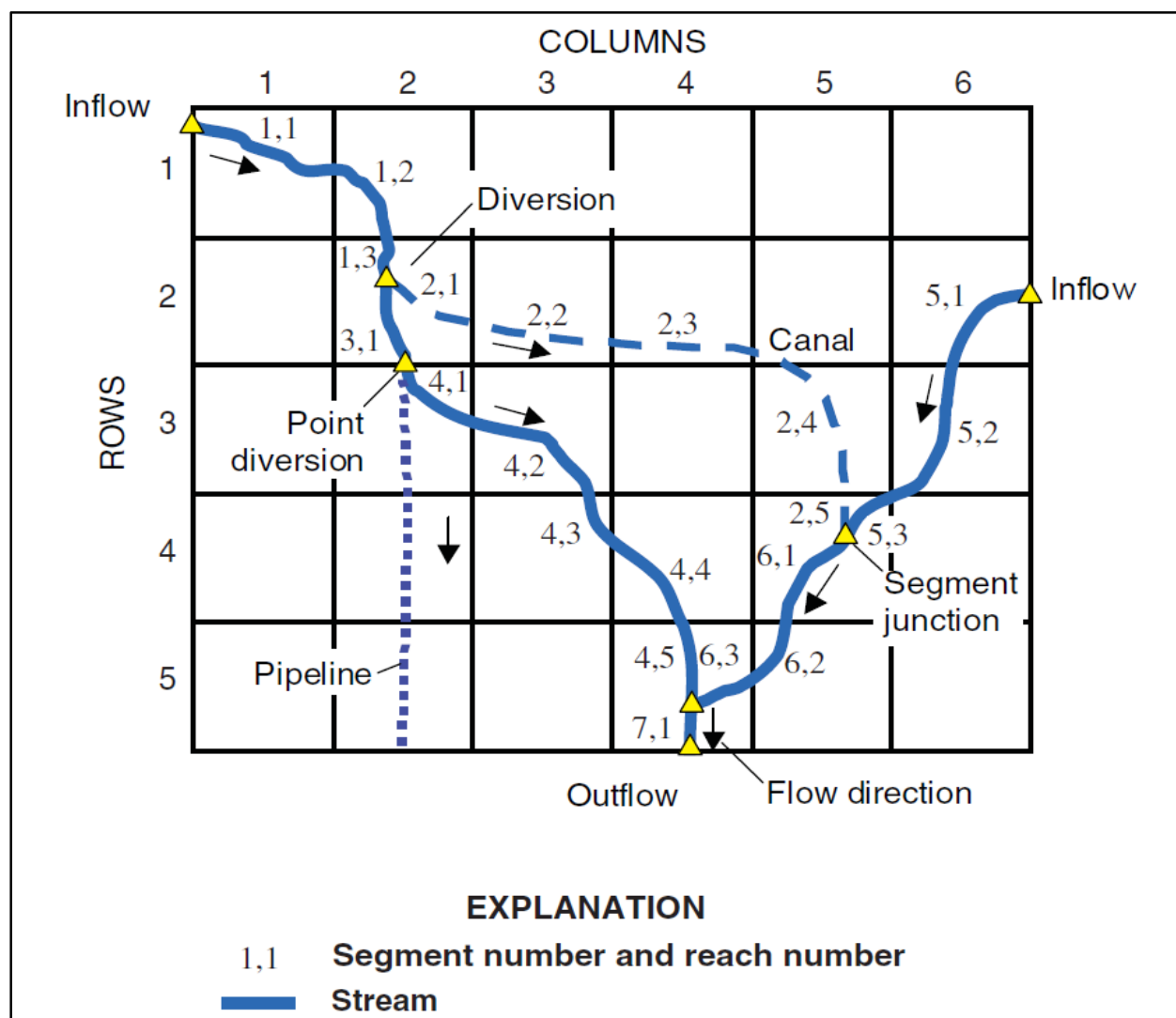


Figure D2. Schematic of the stream package (STR) shows the network of segments and reaches (from Prudic and others, 2004). The stream is divided into segments (arches between yellow triangles) in a sequential order indicated by the first number. A stream segment can extend over multiple model grid cells. Within each grid cell, the segment is defined by a reach number (second number), only one reach number per cell. The number of reaches represent the number of cells a segment passes through (e.g., the first segment passes through three cells, it has three reaches designated as 1.1, 1.2, and 1.3). Diversions and junctions can also be incorporated into the network.

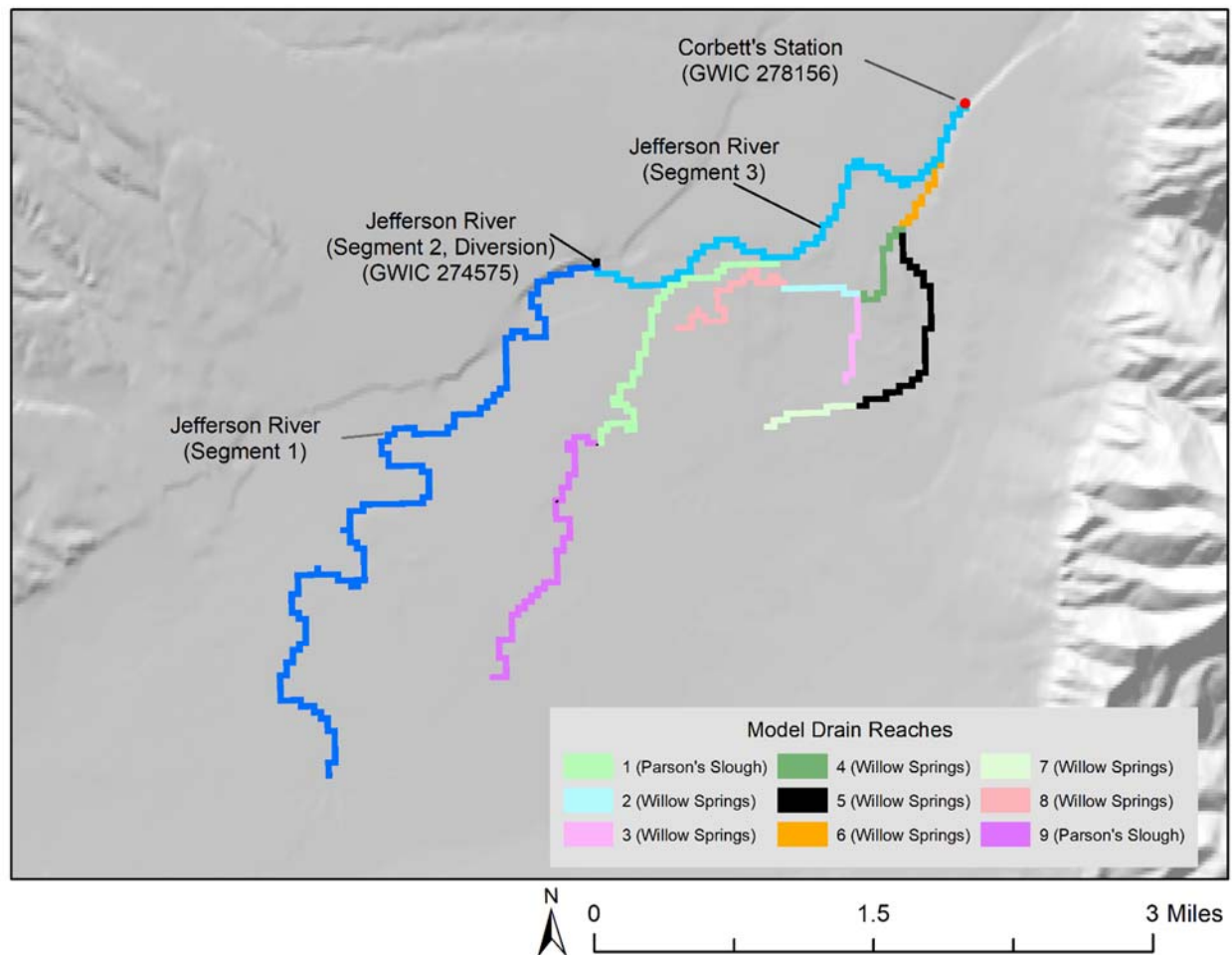


Figure D3. Three segments of the stream package (STR) represent the Jefferson River within the model area [GM1]. Stream segment 2 consists of one cell to simulate water diverted from the river. The diverted water flows through the Jefferson Canal and part of the flow returns to the simulated aquifer as canal leakage.

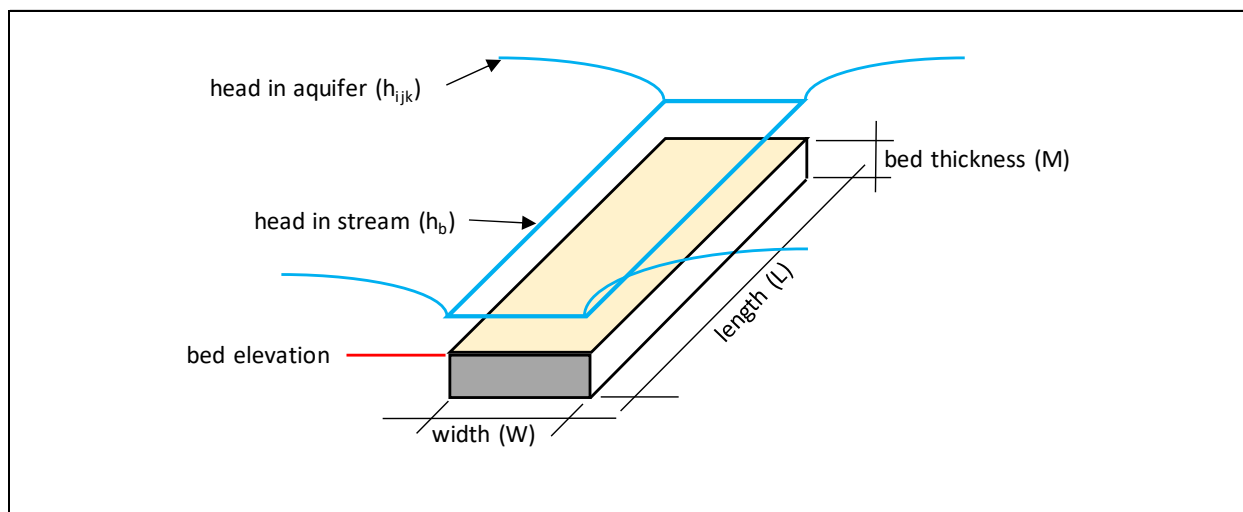


Figure D4. A schematic of the stream package (STR) shows that when the head in the aquifer exceeds the stream's head (e.g., Jefferson River stage), water discharges from the aquifer to the stream (gaining stream). But when head in the stream exceeds the head in the aquifer, water infiltrates from the stream to the aquifer (losing stream). The rate of exchange is also controlled by the streambed conductance, a function of streambed vertical hydraulic conductivity and streambed geometry (W , L , and M).

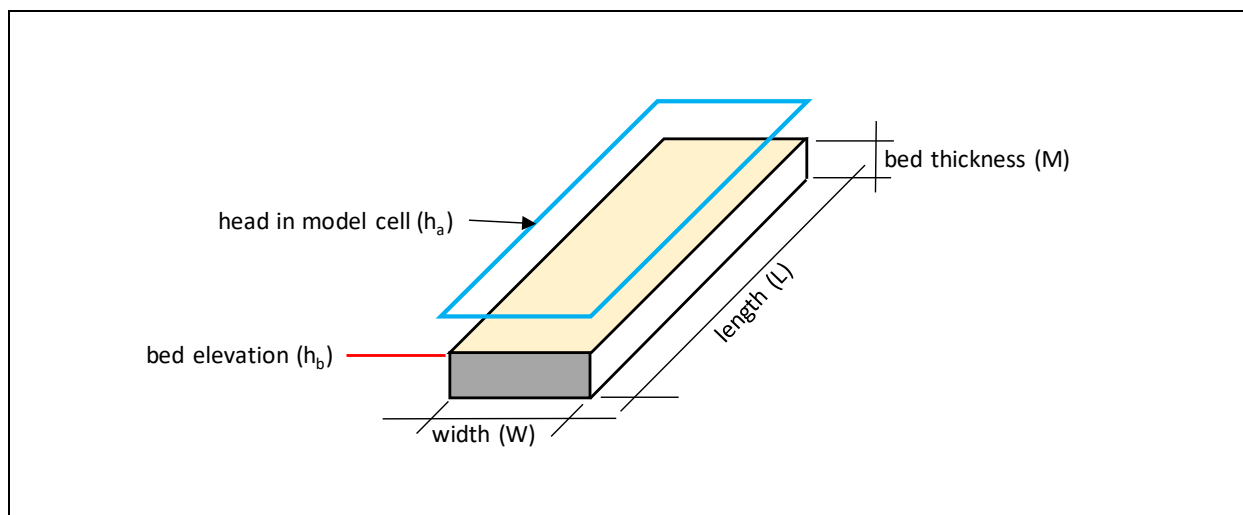


Figure D5. Schematic of the drain package (DRN) shows that when the head in the aquifer exceeds the drain's bed elevation (e.g., Willow Springs bed elevation), groundwater discharges from the aquifer to the drain, and the drain collects water. When the head in the aquifer is equal to or less than the drain's bed elevation, there is no exchange of groundwater between the aquifer and the drain. The drain boundary condition only allows groundwater to flow in one direction, from the aquifer to the drain. The flow rate is also controlled by the drain's bed conductance, a function of drain bed vertical hydraulic conductivity and drain bed geometry (W , L , and M).

APPENDIX E

MODEL RESULTS

Table E1. Steady-state calibration results comparing observed and modeled groundwater elevations.

GWIC Id	Observed Average (GWE ft-amsl)	Modeled GWE* (ft-amsl)	Residual (ft) (observed - modeled)
107080	4453.35	4454.32	-0.97
195941	4458.34	4461.31	-2.97
209718	4439.01	4439.06	-0.05
259547	4461.78	4463.03	-1.25
261912	4464.04	4466.72	-2.68
276038	4451.55	4453.14	-1.59
276041	4455.34	4456.37	-1.03
276103	4434.22	4435.14	-0.92
276106	4432.59	4433.98	-1.39
276107	4435.52	4436.02	-0.50
276108	4438.29	4438.40	-0.11
276109	4437.99	4438.66	-0.67
276111	4441.15	4442.80	-1.65
276112	4427.96	4428.13	-0.17
276285	4414.40	4413.54	0.86
276287	4445.83	4446.28	-0.45
277329	4443.63	4444.15	-0.52
277868	4426.41	4428.32	-1.91
279258	4449.30	4450.97	-1.67
279259	4449.37	4450.99	-1.62
279260	4449.89	4451.00	-1.11

*GWE, Groundwater elevation

Nash efficiency coefficient analysis (Targets group 1)

Well (259547)					276111				
Date	Obs head (ft)	$F_o = \sum[\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum(\text{obs-sim})^2$	Date	Obs head (ft)	$F_o = \sum[\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum(\text{obs-sim})^2$
7/19/2013	4467.63	6.16	4468.591	0.92	9/19/2013	4447.25	16.56	4444.757	6.22
8/14/2013	4467.33	4.76	4468.953	2.63	10/17/2013	4445.1	3.69	4443.934	1.36
9/19/2013	4467.04	3.58	4468.831	3.21	11/21/2013	4443.29	0.01	4442.595	0.48
10/17/2013	4466.92	3.14	4466.063	0.73	12/17/2013	4442.44	0.55	4442.192	0.06
11/21/2013	4464.83	0.10	4462.514	5.36	1/25/2014	4441.69	2.22	4441.972	0.08
12/17/2013	4463.11	4.15	4462.031	1.16	2/21/2014	4441.3	3.53	4441.928	0.39
1/25/2014	4462.14	9.05	4461.680	0.21	3/19/2014	4441.2	3.92	4441.901	0.49
2/21/2014	4461.53	13.09	4461.429	0.01	5/14/2014	4442.32	0.74	4443.602	1.64
3/19/2014	4461.22	15.43	4461.358	0.02	6/12/2014	4443.4	0.05	4444.755	1.84
4/18/2014	4461.45	13.67	4463.363	3.66	7/9/2014	4443.99	0.66	4444.946	0.91
5/14/2014	4464.25	0.81	4466.580	5.43	8/8/2014	4446.31	9.80	4444.622	2.85
6/12/2014	4467.89	7.52	4467.781	0.01	10/7/2014	4445.45	5.15	4444.420	1.06
7/9/2014	4468.3	9.94	4468.859	0.31	11/11/2014	4444.01	0.69	4442.939	1.15
8/8/2014	4468.64	12.20	4468.887	0.06	12/9/2014	4443.16	0.00	4442.316	0.71
9/9/2014	4468.57	11.71	4468.705	0.02	1/14/2015	4442.32	0.74	4442.015	0.09
10/7/2014	4468.19	9.26	4466.988	1.44	2/11/2015	4442	1.39	4441.934	0.00
11/11/2014	4466.35	1.45	4463.002	11.21	3/9/2015	4441.65	2.34	4441.908	0.07
12/9/2014	4464.31	0.70	4462.228	4.33	4/13/2015	4441.15	4.12	4442.390	1.54
1/14/2015	4463.3	3.41	4461.747	2.41	5/4/2015	4442.39	0.62	4442.926	0.29
2/11/2015	4462.76	5.70	4461.450	1.72					
3/9/2015	4462.34	7.88	4461.345	0.99					
4/13/2015	4461.78	11.34	4463.000	1.49					
5/4/2015	4463.79	1.84	4463.875	0.01					
Average =		4465.1	156.89	47.36	Average =		4443.2	56.79	21.24
NS = 1-(F/Fo) =		0.70			NS = 1-(F/Fo) =		0.63		

209718				
Date	Obs head (ft)	$F_o = \sum[\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum(\text{obs-sim})^2$
7/19/2013	4443.0	11.67	4444.809	3.13
7/25/2013	4442.6	8.62	4444.775	4.91
9/19/2013	4443.0	11.67	4442.520	0.27
10/17/2013	4440.1	0.26	4440.738	0.37
11/21/2013	4437.8	3.36	4439.061	1.62
12/17/2013	4437.0	6.73	4438.116	1.18
1/25/2014	4436.9	7.26	4437.583	0.43
1/29/2014	4436.9	7.42	4437.526	0.39
2/3/2014	4436.9	7.53	4437.466	0.34
2/8/2014	4436.9	7.70	4437.479	0.40
2/13/2014	4436.8	7.75	4437.479	0.41
2/18/2014	4436.8	7.81	4437.467	0.41
2/21/2014	4436.9	7.70	4437.448	0.36
3/19/2014	4437.0	6.89	4437.292	0.09
4/18/2014	4437.9	2.87	4438.236	0.09
5/14/2014	4442.3	7.16	4440.366	3.74
6/12/2014	4444.6	24.56	4442.958	2.63
7/9/2014	4444.6	24.26	4444.187	0.13
8/8/2014	4444.2	20.48	4443.709	0.19
9/9/2014	4443.1	12.29	4442.360	0.59
11/11/2014	4439.7	0.00	4439.151	0.28
12/9/2014	4438.7	0.95	4438.238	0.17
1/14/2015	4439.1	0.31	4437.456	2.60
2/11/2015	4438.9	0.47	4437.310	2.66
3/9/2015	4438.9	0.55	4437.210	2.79
4/13/2015	4439.0	0.38	4437.834	1.38
5/4/2015	4440.3	0.47	4438.741	2.46
Average =		4439.6	197.11	34.01
NS = 1-(F/Fo) =		0.83		

Nash efficiency coefficient analysis (Targets group 2)

276103					276106				
Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$	Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$
10/8/2004	4436.66	1.07			10/8/2004	4434.01	0.58		
12/17/2004	4434.8	0.68			12/17/2004	4432.95	0.09		
1/21/2005	4434.36	1.60			1/21/2005	4432.57	0.46		
2/11/2005	4434.26	1.87			2/11/2005	4432.55	0.49		
4/6/2005	4434.12	2.27			4/6/2005	4432.46	0.62		
5/4/2005	4434.45	1.38			5/4/2005	4432.55	0.49		
5/13/2005	4435.84	0.05			5/13/2005	4433.46	0.04		
5/16/2005	4435.91	0.08			5/16/2005	4433.34	0.01		
5/23/2005	4435.94	0.10			5/23/2005	4433.38	0.02		
5/31/2005	4435.83	0.04			5/31/2005	4433.29	0.00		
6/6/2005	4436.01	0.15			6/6/2005	4433.57	0.10		
6/13/2005	4436.01	0.15			6/13/2005	4433.76	0.26		
6/20/2005	4435.92	0.09			6/20/2005	4433.58	0.11		
6/27/2005	4435.83	0.04			6/27/2005	4433.57	0.10		
7/5/2005	4435.69	0.00			7/5/2005	4433.31	0.00		
7/11/2005	4435.76	0.02			7/11/2005	4433.34	0.01		
7/18/2005	4435.83	0.04			7/18/2005	4433.13	0.01		
7/26/2005	4435.92	0.09			7/26/2005	4433.12	0.02		
8/2/2005	4435.95	0.10			8/2/2005	4433.01	0.06		
8/22/2005	4436.07	0.20			8/22/2005	4433.18	0.00		
9/28/2005	4436.26	0.40			9/28/2005	4433.65	0.16		
10/13/2005	4436.37	0.55			10/13/2005	4433.73	0.23		
10/24/2005	4435.9	0.07			10/24/2005	4433.55	0.09		
10/31/2005	4435.59	0.00			10/31/2005	4433.43	0.03		
11/8/2005	4435.42	0.04			11/8/2005	4433.37	0.01		
8/13/2013	4435.92	0.09	4436.272	0.12	8/13/2013	4433.17	0.01		
9/19/2013	4436.63	1.01	4436.293	0.11	9/19/2013	4433.53	0.08	4434.395	0.75
10/17/2013	4435.83	0.04	4435.765	0.00	10/17/2013	4433.49	0.06	4434.222	0.54
11/21/2013	4435.05	0.33	4434.937	0.01	11/21/2013	4433.04	0.04	4433.837	0.64
12/17/2013	4434.63	0.99	4434.631	0.00	12/17/2013	4432.69	0.31	4433.625	0.87
1/25/2014	4434.38	1.55	4434.472	0.01	1/25/2014	4432.57	0.46	4433.496	0.86
2/21/2014	4434.23	1.95	4434.442	0.04	2/21/2014	4432.47	0.61	4433.476	1.01
3/19/2014	4434.24	1.92	4434.425	0.03	3/19/2014	4432.61	0.41	4433.496	0.78
4/18/2014	4434.13	2.24	4434.986	0.73	4/18/2014	4432.58	0.45	4433.863	1.65
5/14/2014	4434.77	0.73	4435.744	0.95	5/14/2014	4432.86	0.15	4434.426	2.45
6/12/2014	4435.51	0.01	4436.459	0.90	6/12/2014	4433.37	0.01	4434.885	2.30
7/9/2014	4435.32	0.09	4436.539	1.49	7/9/2014	4433.38	0.02	4434.899	2.31
8/8/2014	4435.85	0.05	4436.254	0.16	8/8/2014	4433.58	0.11	4434.496	0.84
9/9/2014	4436.35	0.52	4436.262	0.01	9/9/2014	4433.5	0.06	4434.350	0.72
10/7/2014	4435.88	0.06	4436.063	0.03	10/7/2014	4433.56	0.10	4434.349	0.62
11/11/2014	4435.3	0.11	4435.174	0.02	11/11/2014	4433.24	0.00	4433.964	0.52
12/9/2014	4435.01	0.38	4434.727	0.08	12/9/2014	4433.13	0.01	4433.707	0.33
1/14/2015	4434.63	0.99	4434.503	0.02	1/14/2015	4432.82	0.19	4433.522	0.49
2/11/2015	4434.53	1.20	4434.446	0.01	2/11/2015	4432.8	0.20	4433.476	0.46
3/9/2015	4434.36	1.60	4434.431	0.01	3/9/2015	4432.6	0.42	4433.481	0.78
4/13/2015	4434.22	1.98	4434.837	0.38	4/13/2015	4432.59	0.44	4433.749	1.34
5/4/2015	4434.86	0.59	4435.230	0.14	5/4/2015	4432.78	0.22	4434.063	1.65
Average =	4435.6	29.55		5.26	Average =	4433.3	8.38		21.91
NS = 1 - (F/F _o) =	0.82				NS = 1 - (F/F _o) =	-1.62			

276109					276112				
Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$	Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$
12/17/2004	4439.9	0.09			38338	4429.82	2.40		
1/21/2005	4439.1	1.17			38373	4429.16	4.87		
2/11/2005	4438.9	1.59			38394	4429.06	5.33		
4/6/2005	4438.6	2.60			38448	4428.88	6.19		
5/4/2005	4439.1	1.26			38476	4430.92	0.20		
5/13/2005	4440.8	0.30			38485	4434.21	8.08		
5/16/2005	4441.0	0.59			38488	4434.98	13.05		
5/23/2005	4441.2	1.08			38495	4435.2	14.69		
5/31/2005	4441.3	1.21			38504	4434.89	12.41		
6/6/2005	4441.5	1.74			38509	4434.81	11.85		
6/13/2005	4441.5	1.76			38516	4434.88	12.34		
6/20/2005	4441.4	1.46			38523	4434.79	11.71		
6/27/2005	4441.3	1.16			38530	4434.07	7.30		
7/5/2005	4441.3	1.27			38538	4433.14	3.14		
7/11/2005	4441.4	1.36			38544	4432.89	2.32		
7/18/2005	4441.5	1.58			38551	4433.33	3.85		
7/26/2005	4441.6	1.93			38559	4434.12	7.57		
8/2/2005	4441.5	1.71			38566	4434.37	9.01		
8/22/2005	4441.7	2.33			38623	4434.34	8.83		
9/28/2005	4442.2	3.95			38649	4432.73	1.86		
10/13/2005	4442.2	3.95			38656	4431.7	0.11		
10/24/2005	4441.7	2.30			38664	4431.17	0.04		
10/31/2005	4441.3	1.12			41536	4433.81	5.96	4429.663	17.20
11/8/2005	4441.0	0.69			41564	4431.17	0.04	4428.853	5.37
9/19/2013	4441.3	1.18	4440.067	1.50	41599	4429.23	4.57	4427.870	1.85
10/17/2013	4440.7	0.20	4439.483	1.36	41625	4428.65	7.39	4427.557	1.19
11/21/2013	4439.5	0.55	4438.502	0.92	41664	4428.33	9.23	4427.397	0.87
12/17/2013	4438.8	1.91	4438.180	0.41	41691	4428.05	11.01	4427.368	0.47
1/25/2014	4438.3	3.47	4438.008	0.11	41717	4428.03	11.14	4427.354	0.46
2/21/2014	4438.1	4.50	4437.974	0.01	41747	4427.94	11.75	4428.012	0.01
3/19/2014	4438.1	4.63	4437.951	0.01	41773	4429.83	2.37	4429.010	0.67
4/18/2014	4437.8	5.63	4438.487	0.43	41802	4431.82	0.20	4429.948	3.50
5/14/2014	4438.8	1.97	4439.283	0.23	41829	4430.43	0.88	4430.039	0.15
6/12/2014	4439.9	0.09	4440.149	0.06	41859	4430.91	0.21	4429.627	1.65
7/9/2014	4439.9	0.10	4440.264	0.14	41891	4432.28	0.83	4429.642	6.96
8/8/2014	4441.0	0.69	4439.989	1.08	41919	4430.92	0.20	4429.245	2.81
9/9/2014	4441.4	1.48	4440.013	1.98	41954	4429.5	3.49	4428.122	1.90
10/7/2014	4440.8	0.39	4439.839	0.98	42018	4428.45	8.51	4427.426	1.05
11/11/2014	4439.9	0.12	4438.772	1.18	42046	4428.39	8.87	4427.371	1.04
12/9/2014	4439.4	0.69	4438.279	1.19	42072	4428.19	10.10	4427.359	0.69
1/14/2015	4438.8	2.02	4438.041	0.55	42107	4427.96	11.61	4427.851	0.01
2/11/2015	4438.6	2.73	4437.978	0.33	42128	4430.1	1.61	4428.265	3.37
3/9/2015	4438.3	3.66	4437.958	0.11					
4/13/2015	4438.0	4.89	4438.342	0.12					
5/4/2015	4438.8	1.86	4438.773	0.00					
Average =	4440.2	80.96		12.71	Average =	4431.4	257.10		51.20
NS = 1 - (F/Fo) =	0.84				NS = 1 - (F/Fo) =	0.80			

276285					276285 (continued)					
Date	Obs head (ft)	F _o =Σ[obs-(avg. obs)]^2		sim head (ft)	F=Σ (obs-sim)^2	Date	Obs head (ft)	Σ[obs-(avg. obs	Sim head (ft)	F=Σ (obs-sim)^2
12/17/2004	4414.76			1.41		5/18/2014	4416.54	0.35	4414.40	4.57
1/21/2005	4414.56			1.93		5/23/2014	4416.90	0.90	4414.46	5.95
2/11/2005	4414.23			2.96		5/29/2014	4417.81	3.46	4414.50	10.94
4/6/2005	4414.54			1.99		6/3/2014	4417.84	3.58	4414.54	10.92
5/4/2005	4414.94			1.02		6/8/2014	4417.53	2.50	4414.74	7.79
5/13/2005	4417.32			1.88		6/13/2014	4417.64	2.86	4414.83	7.89
5/16/2005	4417.96			4.04		6/18/2014	4417.90	3.81	4414.89	9.07
5/23/2005	4419.14			10.18		6/23/2014	4417.76	3.28	4414.93	8.00
6/1/2005	4419.29			11.16		6/28/2014	4417.58	2.66	4414.97	6.83
6/7/2005	4419.17			10.37		7/3/2014	4417.37	2.02	4415.00	5.64
6/13/2005	4419.29			11.16		7/8/2014	4416.85	0.81	4414.53	5.39
6/19/2005	4419.14			10.18		7/13/2014	4416.74	0.63	4414.37	5.61
6/27/2005	4418.97			9.13		7/18/2014	4416.99	1.08	4414.31	7.17
7/5/2005	4418.75			7.84		7/23/2014	4416.92	0.94	4414.28	6.95
7/11/2005	4417.78			3.35		7/29/2014	4416.97	1.04	4414.27	7.31
7/18/2005	4418.2			5.07		8/3/2014	4417.15	1.44	4414.25	8.39
7/26/2005	4418.25			5.29		8/8/2014	4417.26	1.72	4414.13	9.77
8/3/2005	4418.67			7.40		8/13/2014	4417.47	2.31	4414.08	11.51
8/22/2005	4418.57			6.87		8/18/2014	4417.81	3.46	4414.06	14.03
9/28/2005	4419.24			10.83		8/23/2014	4417.69	3.03	4414.06	13.17
10/24/2005	4418.16			4.89		8/29/2014	4417.67	2.96	4414.06	13.02
10/31/2005	4417.03			1.17		9/3/2014	4417.62	2.79	4414.07	12.64
11/8/2005	4416.46			0.26		9/8/2014	4417.45	2.25	4414.12	11.08
12/17/2013	4414.87	1.16	4413.173	2.88		9/13/2014	4417.47	2.31	4414.15	11.05
1/23/2014	4414.38	2.46	4413.026	1.83		9/18/2014	4417.26	1.72	4414.16	9.64
1/29/2014	4414.32	2.65	4413.016	1.70		9/23/2014	4417.26	1.72	4414.16	9.62
2/3/2014	4414.22	2.99	4413.009	1.47		9/28/2014	4417.41	2.13	4414.16	10.54
2/8/2014	4414.12	3.35	4413.013	1.23		10/3/2014	4417.42	2.16	4414.17	10.60
2/13/2014	4414.23	2.96	4413.011	1.49		10/8/2014	4417.26	1.72	4413.99	10.73
2/18/2014	4414.24	2.92	4413.008	1.52		10/13/2014	4417.35	1.96	4413.91	11.86
2/23/2014	4414.19	3.09	4413.004	1.41		10/18/2014	4417.36	1.99	4413.85	12.33
2/27/2014	4414.13	3.31	4413.000	1.28		10/23/2014	4416.57	0.39	4413.81	7.64
3/3/2014	4414.12	3.35	4412.997	1.26		10/29/2014	4415.98	0.00	4413.77	4.88
3/8/2014	4414.22	2.99	4413.035	1.40		11/3/2014	4415.59	0.13	4413.74	3.41
3/13/2014	4414.19	3.09	4413.044	1.31		11/8/2014	4415.34	0.37	4413.61	3.00
3/18/2014	4414.16	3.20	4413.045	1.24		11/13/2014	4415.00	0.90	4413.53	2.15
3/23/2014	4414.15	3.24	4413.043	1.23		11/18/2014	4414.86	1.19	4413.48	1.91
3/29/2014	4414.15	3.24	4413.040	1.23		11/23/2014	4414.84	1.23	4413.43	1.98
4/3/2014	4414.12	3.35	4413.037	1.17		11/28/2014	4414.75	1.44	4413.40	1.83
4/8/2014	4414.12	3.35	4413.406	0.51		12/3/2014	4414.67	1.64	4413.37	1.70
4/13/2014	4414.28	2.79	4413.555	0.53		12/8/2014	4414.64	1.71	4413.25	1.92
4/18/2014	4414.71	1.54	4413.625	1.18		12/13/2014	4414.59	1.85	4413.20	1.93
4/23/2014	4415.33	0.38	4413.669	2.76		12/18/2014	4414.53	2.01	4413.17	1.85
4/28/2014	4415.99	0.00	4413.700	5.24		12/23/2014	4414.49	2.13	4413.15	1.80
5/3/2014	4416.19	0.06	4413.724	6.08		12/29/2014	4414.39	2.43	4413.13	1.59
5/8/2014	4416.48	0.28	4414.153	5.41		1/3/2015	4414.36	2.53	4413.12	1.55
5/13/2014	4416.52	0.33	4414.318	4.85		1/8/2015	4414.46	2.22	4413.07	1.93

276285 (continued)					277868				
Date	Obs head (ft)	$\Sigma[\text{obs}-(\text{avg. obs})]$	Sim head (ft)	$F = \Sigma(\text{obs-sim})^2$	Date	Obs head (ft)	$F_o = \Sigma[\text{obs}-(\text{avg. obs})]^2$	Sim head (ft)	$F = \Sigma(\text{obs-sim})^2$
1/13/2015	4414.44	2.28	4413.05	1.94	5/14/2014	4426.66	0.03	4429.178	6.34
1/18/2015	4414.37	2.49	4413.03	1.78	6/12/2014	4426.98	0.02	4429.793	7.91
1/23/2015	4414.33	2.62	4413.02	1.71	7/9/2014	4426.97	0.02	4429.680	7.34
1/29/2015	4414.32	2.65	4413.02	1.70	8/8/2014	4427.18	0.12	4429.056	3.52
2/3/2015	4414.28	2.79	4413.01	1.62	8/19/2014	4427.27	0.20	4428.929	2.75
2/8/2015	4414.26	2.85	4413.01	1.56	9/9/2014	4427.27	0.20	4428.935	2.77
2/13/2015	4414.28	2.79	4413.01	1.61	10/7/2014	4427.31	0.23	4428.776	2.15
2/18/2015	4414.27	2.82	4413.01	1.60	11/11/2014	4427.05	0.05	4428.150	1.21
2/23/2015	4414.29	2.75	4413.00	1.66	11/18/2014	4426.91	0.01	4428.060	1.32
2/27/2015	4414.35	2.56	4413.00	1.83	12/9/2014	4426.84	0.00	4427.822	0.96
3/3/2015	4414.39	2.43	4413.00	1.94	1/14/2015	4426.59	0.06	4427.607	1.03
3/8/2015	4414.46	2.22	4413.03	2.04	1/30/2015	4426.58	0.06	4427.573	0.99
3/13/2015	4414.53	2.01	4413.04	2.21	2/11/2015	4426.57	0.07	4427.569	1.00
3/18/2015	4414.62	1.77	4413.04	2.48	3/9/2015	4426.45	0.14	4427.587	1.29
3/23/2015	4414.67	1.64	4413.04	2.65	3/30/2015	4426.44	0.15	4427.610	1.37
3/29/2015	4414.17	3.17	4413.04	1.28	4/13/2015	4426.41	0.17	4428.120	2.92
4/3/2015	4414.15	3.24	4413.04	1.24	5/4/2015	4426.6	0.05	4428.454	3.44
4/8/2015	4414.10	3.42	4413.41	0.48	Average =	4426.8	1.58		48.33
4/13/2015	4414.33	2.62	4413.55	0.60	NS = 1-(F/Fo) =	-29.60			
4/18/2015	4414.56	1.93	4413.62	0.88					
4/23/2015	4414.85	1.21	4413.67	1.40					
42122.00	4415.29	0.43	4413.70	2.53					
42127.00	4415.58	0.14	4413.72	3.44					
Average =	4415.95	327.04		421.45					
NS = 1-(F/Fo) =	-0.29								

Nash efficiency coefficient analysis (Targets group 3)

107080					107080 (continue..)				
Date	Obs head (ft)	$F_o = \sum [obs - (avg. obs)]^2$	Sim head (ft)	$F = \sum (obs - sim)^2$					
6/2/2004	4455.06	0.07			3/3/2011	4455.05	0.07		
11/30/2004	4456.04	0.52			4/6/2011	4454.93	0.15		
3/7/2005	4453.63	2.85			5/6/2011	4454.94	0.14		
6/1/2005	4454.86	0.21			6/6/2011	4455.52	0.04		
8/29/2005	4453.4	3.68			9/7/2011	4458.05	7.46		
12/5/2005	4456.07	0.57			12/20/2011	4456.44	1.26		
8/30/2006	4456.94	2.63			3/12/2012	4454.90	0.17		
11/30/2006	4456.13	0.66			9/27/2012	4458.20	8.31		
3/26/2007	4454.02	1.69			12/6/2012	4455.75	0.19		
8/27/2007	4453.97	1.82			3/13/2013	4453.76	2.43		
12/4/2007	4455.85	0.28			6/18/2013	4453.88	2.07	4456.60	7.38
3/4/2008	4454.02	1.69			7/15/2013	4454.18	1.30	4456.63	6.00
5/8/2008	4453.91	1.98			8/14/2013	4456.39	1.15	4456.16	0.05
6/5/2008	4456.45	1.28			9/19/2013	4456.43	1.24	4456.24	0.04
9/4/2008	4457.84	6.36			10/17/2013	4456.39	1.15	4455.35	1.08
10/23/2008	4457.76	5.96			11/21/2013	4455.05	0.07	4454.11	0.88
11/3/2008	4457.17	3.43			12/17/2013	4454.26	1.12	4453.66	0.36
12/3/2008	4456.06	0.55			1/25/2014	4453.60	2.95	4453.38	0.05
1/7/2009	4455.16	0.02			2/21/2014	4453.21	4.44	4453.33	0.01
2/12/2009	4454.64	0.46			3/19/2014	4453.07	5.05	4453.35	0.08
3/8/2009	4454.37	0.90			4/18/2014	4452.36	8.75	4454.09	2.99
4/7/2009	4454.33	0.98			5/14/2014	4451.77	12.59	4455.27	12.22
5/7/2009	4454.7	0.38			7/9/2014	4455.32	0.00	4456.79	2.16
6/7/2009	4456.16	0.71			8/8/2014	4455.03	0.08	4456.20	1.37
8/6/2009	4458.01	7.25			9/9/2014	4457.37	4.21	4456.08	1.66
9/3/2009	4456.48	1.35			10/7/2014	4457.31	3.97	4455.86	2.11
10/8/2009	4458.56	10.51			11/11/2014	4456.13	0.66	4454.44	2.85
11/3/2009	4457.49	4.72			12/9/2014	4450.31	25.08	4453.82	12.34
12/3/2009	4456.46	1.30			1/14/2015	4454.49	0.69	4453.44	1.11
1/7/2010	4455.44	0.01			2/11/2015	4454.08	1.53	4453.33	0.56
2/2/2010	4455.07	0.06			3/9/2015	4453.76	2.43	4453.33	0.19
3/2/2010	4454.68	0.41			4/13/2015	4453.35	3.87	4453.87	0.27
4/2/2010	4454.36	0.92			5/4/2015	4453.95	1.87	4454.51	0.32
5/5/2010	4454.53	0.62			6/30/2015	4455.18	0.02	4456.78	2.56
10/7/2010	4458.43	9.68			12/23/2015	4454.72	0.36	4455.02	0.09
11/4/2010	4457.89	6.61							
12/7/2010	4456.84	2.32							
1/6/2011	4456.04	0.52							
Average =					4455.32	192.90		58.72	
NS = 1 - (F/Fo) =					0.70				

261912					276041					279258				
Date	Obs head (ft)	$F_o = \sum [obs - (avg. obs)]^2$	Sim head (ft)	$F = \sum (obs - sim)^2$	Date	Obs head (ft)	$F_o = \sum [obs - (avg. obs)]^2$	Sim head (ft)	$F = \sum (obs - sim)^2$	Date	Obs head (ft)	$F_o = \sum [obs - (avg. obs)]^2$	Sim head (ft)	$F = \sum (obs - sim)^2$
7/23/2013	4468.36	4.84	4467.417	0.89	10/25/2013	4457.53	1.00	4457.056	0.22	9/9/2014	4452.89	4452.883	7.07	0.00
9/19/2013	4467.83	2.79	4466.563	1.61	11/21/2013	4456.63	0.01	4456.116	0.26	10/7/2014	4452.79	4452.634	6.55	0.02
10/17/2013	4467.32	1.34	4466.638	0.47	12/17/2013	4455.88	0.43	4455.687	0.04	11/11/2014	4451.74	4451.162	2.28	0.33
11/21/2013	4465.75	0.17	4466.223	0.22	1/25/2014	4455.26	1.62	4455.428	0.03	12/9/2014	4451.08	4450.502	0.72	0.33
12/17/2013	4465.13	1.06	4465.810	0.46	3/19/2014	4454.74	3.21	4455.423	0.47	1/14/2015	4450.3	4450.126	0.00	0.03
1/25/2014	4464.44	2.96	4465.598	1.34	4/18/2014	4454.75	3.18	4456.225	2.18	2/13/2015	4449.94	4450.020	0.08	0.01
2/21/2014	4464.15	4.04	4465.606	2.12	5/14/2014	4455.43	1.21	4457.377	3.79	2/18/2015	4449.903	4450.016	0.11	0.01
3/19/2014	4463.91	5.07	4465.748	3.38	7/9/2014	4457.63	1.21	4458.663	1.07	2/23/2015	4449.863	4450.013	0.14	0.02
4/18/2014	4464.05	4.46	4466.989	8.64	8/8/2014	4458.29	3.09	4457.937	0.12	2/27/2015	4449.757	4450.011	0.23	0.06
5/14/2014	4466.12	0.00	4468.203	4.34	9/9/2014	4459.03	6.24	4457.754	1.63	3/3/2015	4449.71	4450.009	0.27	0.09
6/12/2014	4468.75	6.70	4469.082	0.11	10/7/2014	4459.02	6.19	4457.599	2.02	3/8/2015	4449.627	4450.006	0.37	0.14
7/9/2014	4468.65	6.20	4468.174	0.23	11/11/2014	4457.89	1.84	4456.402	2.21	3/13/2015	4449.58	4450.010	0.42	0.18
8/8/2014	4468.14	3.92	4466.730	1.99	12/9/2014	4457.13	0.36	4455.851	1.64	3/18/2015	4449.542	4450.017	0.47	0.23
9/9/2014	4468.31	4.62	4466.441	3.49	1/14/2015	4456.36	0.03	4455.480	0.77	3/23/2015	4449.508	4450.025	0.52	0.27
10/7/2014	4468.18	4.08	4466.700	2.19	2/11/2015	4455.64	0.80	4455.388	0.06	3/29/2015	4449.443	4450.032	0.62	0.35
11/11/2014	4466.71	0.30	4466.344	0.13	3/9/2015	4455.34	1.42	4455.393	0.00	4/3/2015	4449.386	4450.038	0.71	0.42
12/9/2014	4465.85	0.10	4465.957	0.01	4/13/2015	4455.34	1.42	4456.006	0.44	4/8/2015	4449.337	4450.233	0.80	0.80
1/14/2015	4465.27	0.79	4465.631	0.13	5/4/2015	4455.69	0.71	4456.608	0.84	4/13/2015	4449.305	4450.453	0.86	1.32
2/11/2015	4464.73	2.05	4465.604	0.76						4/18/2015	4449.345	4450.660	0.79	1.73
3/9/2015	4464.21	3.81	4465.694	2.20						4/23/2015	4449.459	4450.836	0.60	1.90
4/13/2015	4464.04	4.50	4466.812	7.68						4/28/2015	4449.684	4450.979	0.30	1.68
5/4/2015	4465.64	0.27	4467.205	2.45						5/3/2015	4449.804	4451.092	0.18	1.66
Average =					4456.5	34.0	17.80			Average =				
NS = 1 - (F/Fo) =					0.48					NS = 1 - (F/Fo) =				

Nash efficiency coefficient analysis (Targets group 4)

195941					276038				
Date	Obs head (ft)	$\sum [\text{obs} - (\text{avg. obs})]$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$	Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$
6/16/2011	4462.78	6.55			11/21/2013	4451.69	0.00	4452.684	0.99
7/19/2013	4461.58	1.85	4462.328	0.56	12/17/2013	4451.53	0.03	4452.343	0.66
8/14/2013	4461.45	1.51	4461.481	0.00	1/25/2014	4451.34	0.13	4452.182	0.71
9/19/2013	4461.61	1.93	4461.539	0.01	2/21/2014	4451.23	0.22	4452.208	0.96
10/17/2013	4461.43	1.46	4461.432	0.00	4/18/2014	4451.31	0.15	4453.497	4.78
11/21/2013	4460.1	0.01	4460.896	0.63	5/14/2014	4451.68	0.00	4454.505	7.98
12/17/2013	4459.37	0.72	4460.496	1.27	7/9/2014	4452.25	0.30	4454.183	3.74
1/25/2014	4458.72	2.25	4460.281	2.44	9/9/2014	4452.25	0.30	4452.551	0.09
2/21/2014	4458.35	3.50	4460.278	3.72	10/7/2014	4452.37	0.45	4452.814	0.20
3/19/2014	4458.17	4.21	4460.392	4.94	11/11/2014	4452	0.09	4452.730	0.53
4/18/2014	4458.23	3.96	4461.477	10.54	12/9/2014	4451.76	0.00	4452.472	0.51
5/14/2014	4459.41	0.66	4462.618	10.29	1/14/2015	4451.57	0.02	4452.204	0.40
6/12/2014	4461.34	1.25	4463.519	4.75	2/11/2015	4451.49	0.04	4452.203	0.51
7/9/2014	4461.75	2.34	4462.948	1.44	3/9/2015	4451.34	0.13	4452.297	0.92
9/9/2014	4462.28	4.24	4461.405	0.77					
10/7/2014	4462.28	4.24	4461.568	0.51					
11/11/2014	4461.04	0.67	4461.048	0.00					
12/9/2014	4460.23	0.00	4460.649	0.18					
1/14/2015	4459.5	0.52	4460.318	0.67					
2/11/2015	4459.04	1.39	4460.277	1.53					
3/9/2015	4458.67	2.41	4460.341	2.79					
4/13/2015	4458.34	3.54	4461.291	8.71					
5/4/2015	4459.41	0.66	4461.721	5.34					
Average =	4460.2	49.87		61.06	Average =	4451.7	1.87		22.97
NS = $1 - (F/F_o) =$	-0.22				NS = $1 - (F/F_o) =$	-11.28			

276107					276108				
Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$	Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$
10/8/2004	4436.65	1.92			10/8/2004	4438.67	0.17		
12/17/2004	4434.63	0.40			12/17/2004	4437.57	0.47		
1/21/2005	4434.41	0.73			1/21/2005	4437.44	0.67		
2/11/2005	4434.33	0.87			2/11/2005	4437.15	1.23		
4/5/2005	4434.24	1.05			4/6/2005	4437.17	1.18		
5/4/2005	4437.29	4.11			5/4/2005	4437.46	0.64		
5/13/2005	4435.53	0.07			5/13/2005	4439.8	2.38		
5/16/2005	4435.36	0.01			5/16/2005	4439.8	2.38		
5/23/2005	4435.48	0.05			5/23/2005	4439.85	2.53		
5/31/2005	4435.28	0.00			5/31/2005	4439.49	1.52		
6/6/2005	4435.61	0.12			6/6/2005	4439.7	2.08		
6/13/2005	4436.08	0.67			6/13/2005	4439.76	2.26		
6/20/2005	4435.84	0.33			6/20/2005	4439.55	1.67		
6/27/2005	4436.07	0.65			6/27/2005	4439.32	1.13		
7/5/2005	4436.32	1.12			7/5/2005	4438.34	0.01		
7/11/2005	4435.2	0.00			7/11/2005	4438.21	0.00		
7/18/2005	4435	0.07			7/18/2005	4437.9	0.13		
7/26/2005	4434.7	0.32			7/26/2005	4437.67	0.35		
8/2/2005	4434.53	0.54			8/2/2005	4437.52	0.54		
8/22/2005	4434.48	0.61			8/22/2005	4437.45	0.65		
9/28/2005	4435.49	0.05			9/28/2005	4438.11	0.02		
10/13/2005	4435.5	0.06			10/13/2005	4439.49	1.52		
10/24/2005	4435.27	0.00			10/24/2005	4438.07	0.04		
10/31/2005	4435.08	0.03			10/31/2005	4437.89	0.14		
11/8/2005	4435.02	0.06			11/8/2005	4437.85	0.17		
8/13/2013	4435.21	0.00	4436.091	0.78	8/13/2013	4437.65	0.37	4437.697	0.00
9/19/2013	4435.51	0.06	4435.935	0.18	9/19/2013	4438.81	0.30	4437.782	1.06
10/17/2013	4435.19	0.01	4435.897	0.50	10/17/2013	4437.9	0.13	4438.000	0.01
11/21/2013	4434.9	0.13	4435.648	0.56	11/21/2013	4437.7	0.31	4437.876	0.03
12/17/2013	4434.69	0.33	4435.375	0.47	12/17/2013	4437.96	0.09	4437.532	0.18
1/24/2014	4434.58	0.47	4435.179	0.36	1/25/2014	4438.05	0.04	4437.358	0.48
2/21/2014	4434.52	0.55	4435.171	0.42	2/21/2014	4437.69	0.32	4437.389	0.09
3/19/2014	4434.65	0.38	4435.261	0.37	3/19/2014	4437.61	0.42	4437.551	0.00
4/18/2014	4434.87	0.15	4435.985	1.24	4/18/2014	4437.88	0.14	4438.772	0.80
5/14/2014	4435.24	0.00	4436.777	2.36	5/14/2014	4438.24	0.00	4439.787	2.39
6/12/2014	4436.2	0.88	4437.278	1.16	6/12/2014	4438.64	0.15	4440.345	2.91
7/9/2014	4436.48	1.48	4437.107	0.39	7/9/2014	4438.86	0.36	4439.334	0.22
8/8/2014	4435.8	0.29	4436.282	0.23	8/8/2014	4438.35	0.01	4437.999	0.12
9/9/2014	4435.27	0.00	4435.848	0.33	9/9/2014	4437.89	0.14	4437.657	0.05
10/7/2014	4435.52	0.07	4435.930	0.17	10/7/2014	4438.08	0.03	4437.922	0.02
11/11/2014	4435.16	0.01	4435.725	0.32	11/11/2014	4437.94	0.10	4437.904	0.00
12/9/2014	4435.1	0.03	4435.509	0.17	12/9/2014	4437.84	0.17	4437.670	0.03
1/14/2015	4434.89	0.14	4435.219	0.11	1/14/2015	4437.93	0.11	4437.383	0.30
2/11/2015	4434.87	0.15	4435.167	0.09	2/11/2015	4437.77	0.24	4437.382	0.15
3/9/2015	4434.67	0.35	4435.207	0.29	3/9/2015	4437.59	0.45	4437.484	0.01
4/13/2015	4435.52	0.07	4435.820	0.09	4/13/2015	4438.29	0.00	4438.634	0.12
5/4/2015	4435.16	0.01	4436.210	1.10	5/4/2015	4438.23	0.00	4438.871	0.41
Average =	4435.3	19.39		11.70	Average =	4438.3	27.74		9.40
NS = $1 - (F/F_o) =$	0.40				NS = $1 - (F/F_o) =$	0.66			

276287					276287 (continued)				
Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$	Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$
4/6/2005	4445.1	0.51			8/3/2014	4445.78	0.00	4446.42	0.41
5/4/2005	4445.28	0.29			8/8/2014	4445.65	0.03	4445.54	0.01
5/13/2005	4446.65	0.69			8/13/2014	4445.59	0.05	4445.32	0.07
5/16/2005	4446.6	0.61			8/18/2014	4445.71	0.01	4445.25	0.22
5/23/2005	4446.64	0.68			8/23/2014	4445.95	0.02	4445.22	0.53
5/31/2005	4446.09	0.07			8/29/2014	4445.93	0.01	4445.21	0.53
6/6/2005	4446.36	0.30			9/3/2014	4445.80	0.00	4445.20	0.36
6/13/2005	4446.49	0.45			9/8/2014	4445.63	0.03	4445.45	0.03
6/20/2005	4446.38	0.32			9/13/2014	4445.63	0.04	4445.51	0.01
6/27/2005	4446.37	0.31			9/18/2014	4445.62	0.04	4445.54	0.01
7/5/2005	4445.97	0.02			9/23/2014	4445.61	0.04	4445.55	0.00
7/12/2005	4445.91	0.01			9/28/2014	4445.75	0.00	4445.55	0.04
7/19/2005	4445.62	0.04			10/3/2014	4445.85	0.00	4445.55	0.09
7/27/2005	4445.35	0.22			10/8/2014	4445.83	0.00	4445.79	0.00
8/2/2005	4445.21	0.37			10/13/2014	4445.81	0.00	4445.84	0.00
8/22/2005	4445.39	0.18			10/18/2014	4445.79	0.00	4445.85	0.00
9/9/2005	4445.33	0.24			10/23/2014	4445.85	0.00	4445.85	0.00
9/28/2005	4446.13	0.10			10/29/2014	4445.87	0.00	4445.84	0.00
10/13/2005	4446.64	0.68			11/3/2014	4445.85	0.00	4445.84	0.00
10/24/2005	4446.01	0.04			11/8/2014	4445.82	0.00	4445.78	0.00
10/31/2005	4445.95	0.02			11/13/2014	4445.59	0.05	4445.76	0.03
11/8/2005	4446	0.03			11/18/2014	4445.60	0.05	4445.75	0.02
12/17/2013	4446.64	0.68	4445.357	1.65	11/23/2014	4445.74	0.01	4445.74	0.00
1/23/2014	4445.471667	0.12	4445.190	0.08	11/28/2014	4445.77	0.00	4445.74	0.00
1/29/2014	4445.423056	0.16	4445.188	0.06	12/3/2014	4445.64	0.03	4445.73	0.01
2/3/2014	4445.300333	0.27	4445.187	0.01	12/8/2014	4445.64	0.03	4445.45	0.03
2/8/2014	4445.26	0.31	4445.219	0.00	12/13/2014	4445.63	0.03	4445.38	0.06
2/13/2014	4445.485167	0.11	4445.227	0.07	12/18/2014	4445.57	0.06	4445.36	0.05
2/18/2014	4445.486917	0.11	4445.229	0.07	12/23/2014	4445.56	0.06	4445.35	0.05
2/23/2014	4445.450714	0.13	4445.230	0.05	12/29/2014	4445.43	0.15	4445.34	0.01
3/18/2014	4445.424286	0.15	4445.413	0.00	1/3/2015	4445.48	0.11	4445.34	0.02
3/23/2014	4445.253417	0.32	4445.417	0.03	1/8/2015	4445.66	0.02	4445.23	0.19
3/29/2014	4445.244931	0.33	4445.420	0.03	1/13/2015	4445.63	0.03	4445.21	0.18
4/3/2014	4445.228333	0.35	4445.421	0.04	1/18/2015	4445.53	0.08	4445.20	0.11
4/8/2014	4445.2815	0.29	4446.455	1.38	1/23/2015	4445.48	0.12	4445.19	0.08
4/13/2014	4445.828333	0.00	4446.699	0.76	1/29/2015	4445.48	0.11	4445.19	0.09
4/18/2014	4445.650917	0.03	4446.778	1.27	2/3/2015	4445.40	0.17	4445.19	0.05
4/23/2014	4445.7185	0.01	4446.811	1.19	2/8/2015	4445.44	0.14	4445.22	0.05
4/28/2014	4445.74025	0.01	4446.827	1.18	2/13/2015	4445.62	0.04	4445.23	0.15
5/3/2014	4445.699583	0.01	4446.836	1.29	2/18/2015	4445.57	0.06	4445.23	0.11
5/8/2014	4445.952333	0.02	4447.717	3.11	2/23/2015	4445.49	0.11	4445.23	0.07
5/13/2014	4445.951	0.02	4447.903	3.81	2/27/2015	4445.43	0.15	4445.23	0.04
5/18/2014	4446.046167	0.05	4447.958	3.66	3/3/2015	4445.37	0.20	4445.23	0.02
5/23/2014	4446.320667	0.25	4447.979	2.75	3/8/2015	4445.35	0.22	4445.37	0.00
5/29/2014	4447.387153	2.47	4447.989	0.36	3/13/2015	4445.43	0.15	4445.40	0.00
6/3/2014	4447.165417	1.82	4447.995	0.69	3/18/2015	4445.63	0.04	4445.41	0.05
6/8/2014	4446.527	0.50	4448.451	3.70	3/23/2015	4445.60	0.05	4445.42	0.03
6/13/2014	4446.301333	0.23	4448.543	5.03	3/29/2015	4445.53	0.08	4445.42	0.01
6/18/2014	4446.6	0.61	4448.570	3.88	4/3/2015	4445.73	0.01	4445.42	0.10
6/23/2014	4446.489583	0.45	4448.580	4.37	4/8/2015	4445.80	0.00	4446.46	0.43
6/28/2014	4446.57275	0.57	4448.585	4.05	4/13/2015	4445.85	0.00	4446.70	0.72
7/3/2014	4446.461417	0.42	4448.587	4.52	4/18/2015	4445.84	0.00	4446.78	0.88
7/8/2014	4446.37125	0.31	4446.919	0.30	4/23/2015	4445.85	0.00	4446.81	0.92
7/13/2014	4446.415167	0.36	4446.576	0.03	4/28/2015	4445.90	0.01	4446.83	0.86
7/18/2014	4446.303917	0.24	4446.478	0.03	5/3/2015	4445.95	0.02	4446.84	0.78
7/23/2014	4446.103417	0.08	4446.442	0.11	Average =	4445.82	20.65		58.32
7/29/2014	4445.93125	0.01	4446.426	0.24	NS =1-(F/Fo) =	-1.82			

277329				
Date	Obs head (ft)	$F_o = \sum [\text{obs} - (\text{avg. obs})]^2$	Sim head (ft)	$F = \sum (\text{obs} - \text{sim})^2$
4/6/2005	4442.84		1.00	
5/4/2005	4442.89		0.90	
5/13/2005	4443.86		0.00	
5/16/2005	4443.74		0.01	
5/23/2005	4443.71		0.02	
5/31/2005	4443.46		0.15	
6/6/2005	4443.74		0.01	
6/13/2005	4444.1		0.07	
6/20/2005	4443.91		0.00	
6/27/2005	4444.07		0.05	
7/5/2005	4443.69		0.02	
7/12/2005	4443.71		0.02	
7/18/2005	4443.54		0.09	
7/26/2005	4443.45		0.15	
8/2/2005	4443.39		0.20	
8/22/2005	4443.6		0.06	
9/9/2005	4443.66		0.03	
9/28/2005	4444.19		0.12	
10/13/2005	4444.43		0.35	
10/24/2005	4444.21		0.14	
10/31/2005	4444.08		0.06	
11/8/2005	4444.03		0.04	
4/18/2014	4443.36		0.23	4444.210
5/14/2014	4443.75		0.01	4444.895
6/12/2014	4444.33		0.24	4445.310
7/9/2014	4444.53		0.47	4445.174
8/8/2014	4444.32		0.23	4444.342
9/9/2014	4444.44		0.36	4443.819
10/7/2014	4444.55		0.50	4444.033
11/11/2014	4444.21		0.14	4443.846
12/9/2014	4444.05		0.04	4443.573
1/14/2015	4443.73		0.01	4443.228
2/11/2015	4443.71		0.02	4443.176
3/9/2015	4443.5		0.12	4443.230
4/13/2015	4443.63		0.04	4444.013
5/4/2015	4443.87		0.00	4444.445
Average =	4443.8		5.90	5.51
NS = 1-(F/Fo)	0.07			

APPENDIX F

MODEL SENSITIVITY ANALYSIS

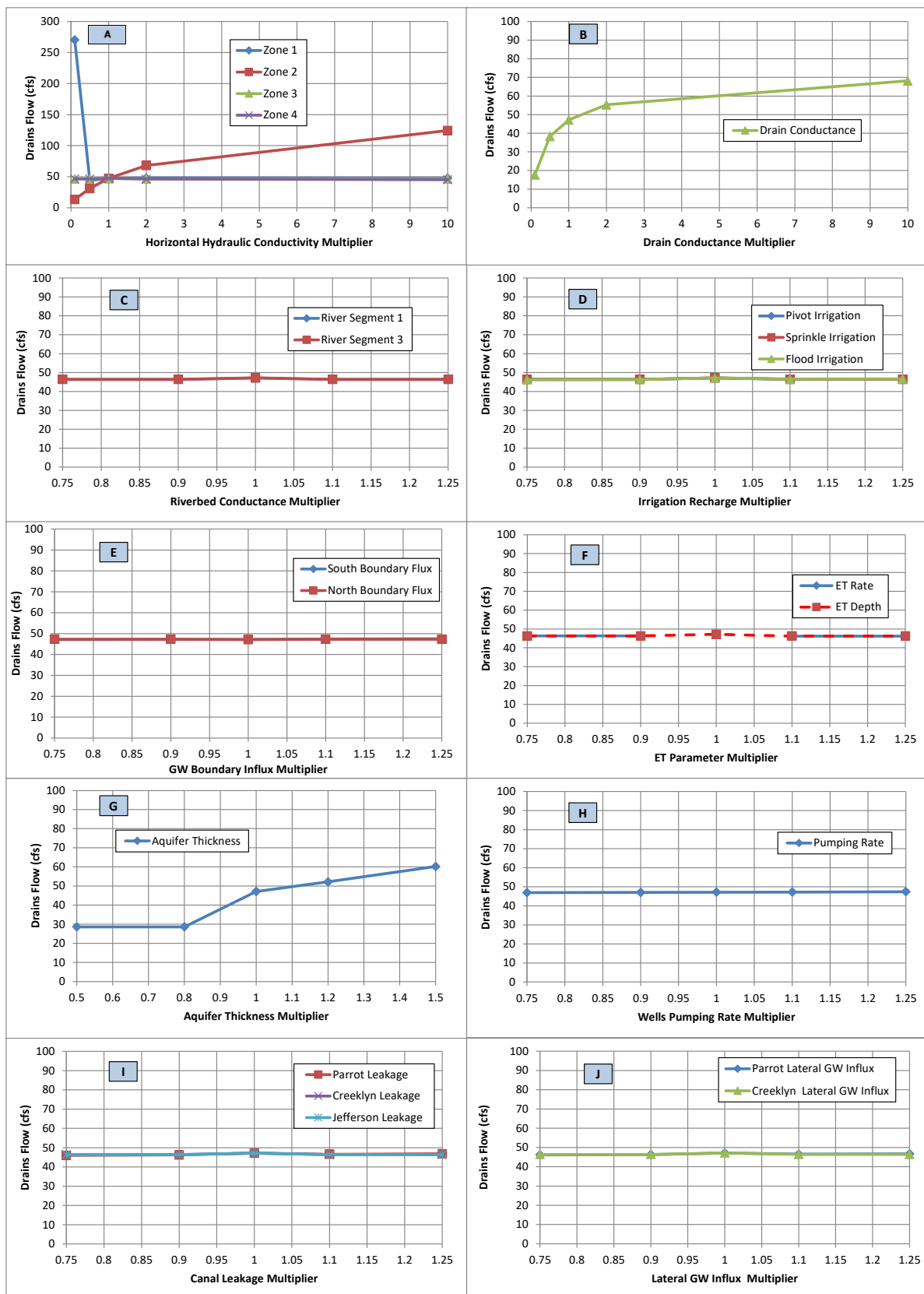


Figure F1. The sensitivity analysis done for the groundwater-fed streams (drains) indicates that the discharge is most sensitive to zone 2 hydraulic conductivity, drain bed conductance, and aquifer thickness.

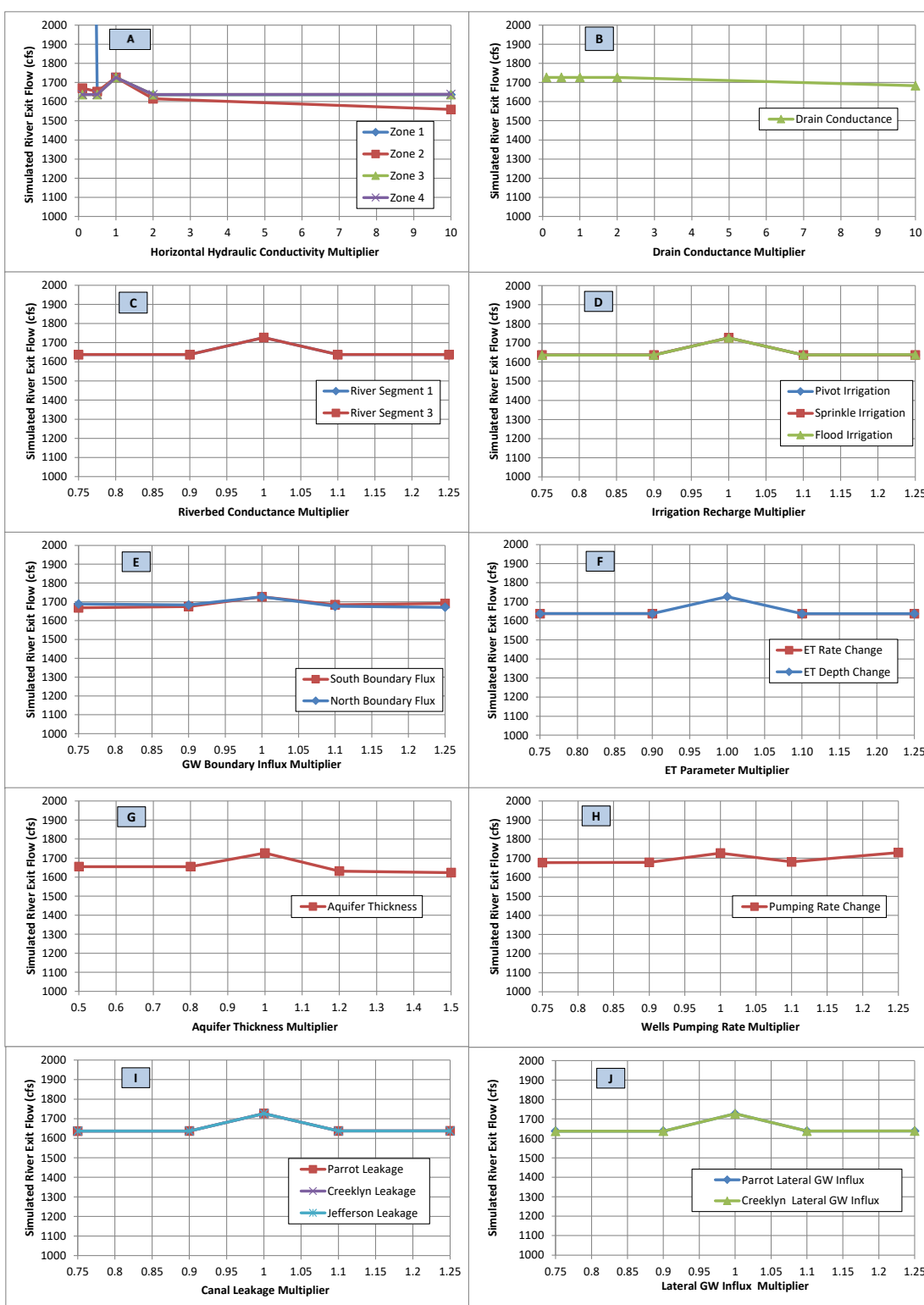


Figure F2. The Jefferson River flow at Corbett's station is sensitive to zone 1 hydraulic conductivity.

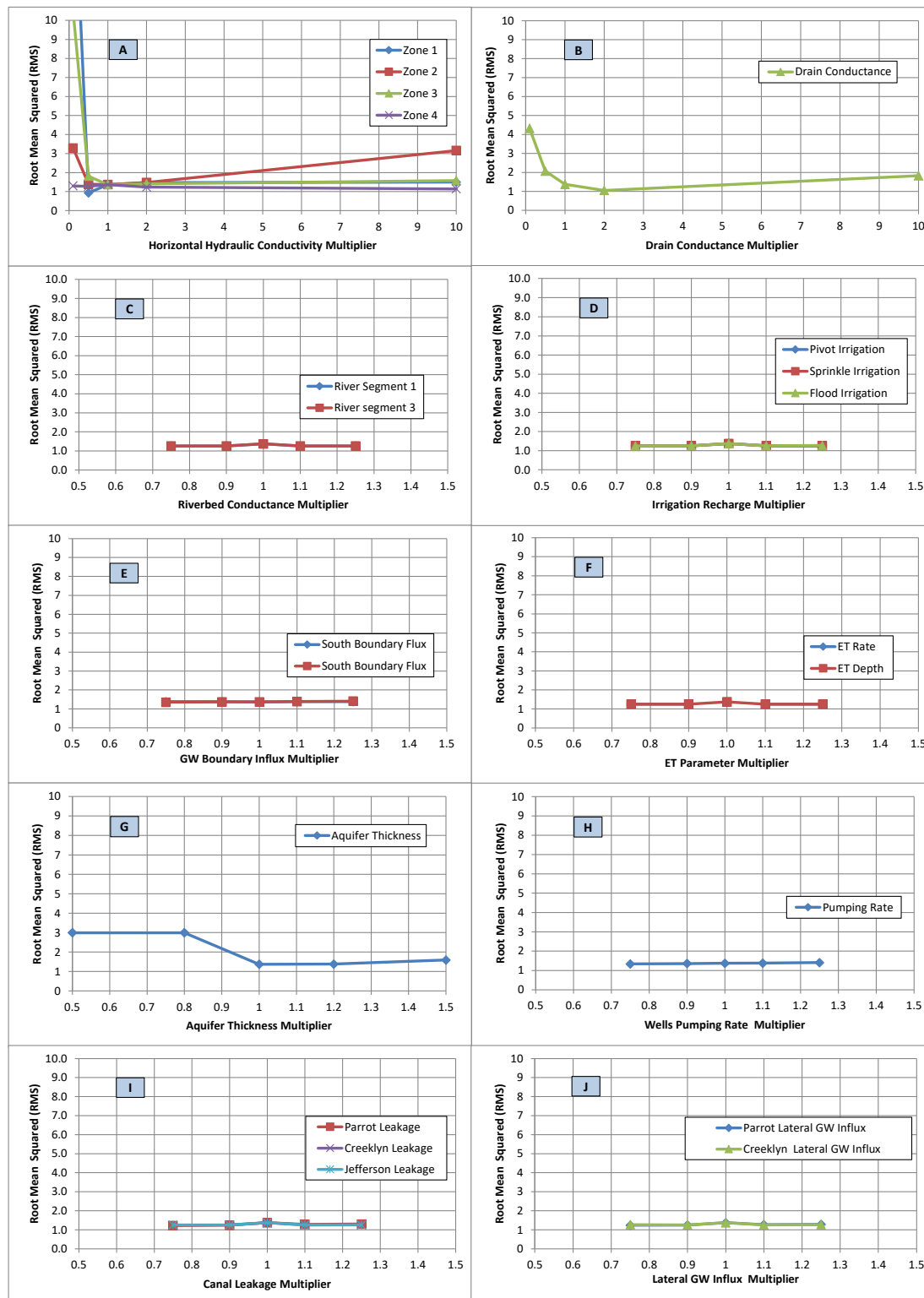


Figure F3. The model sensitivity analysis show that the calibration statistic RMS is most sensitive to hydraulic conductivity in zones 1, 2, and 3, drain bed conductance for Parson's Slough and Willow Spring, and aquifer thickness.

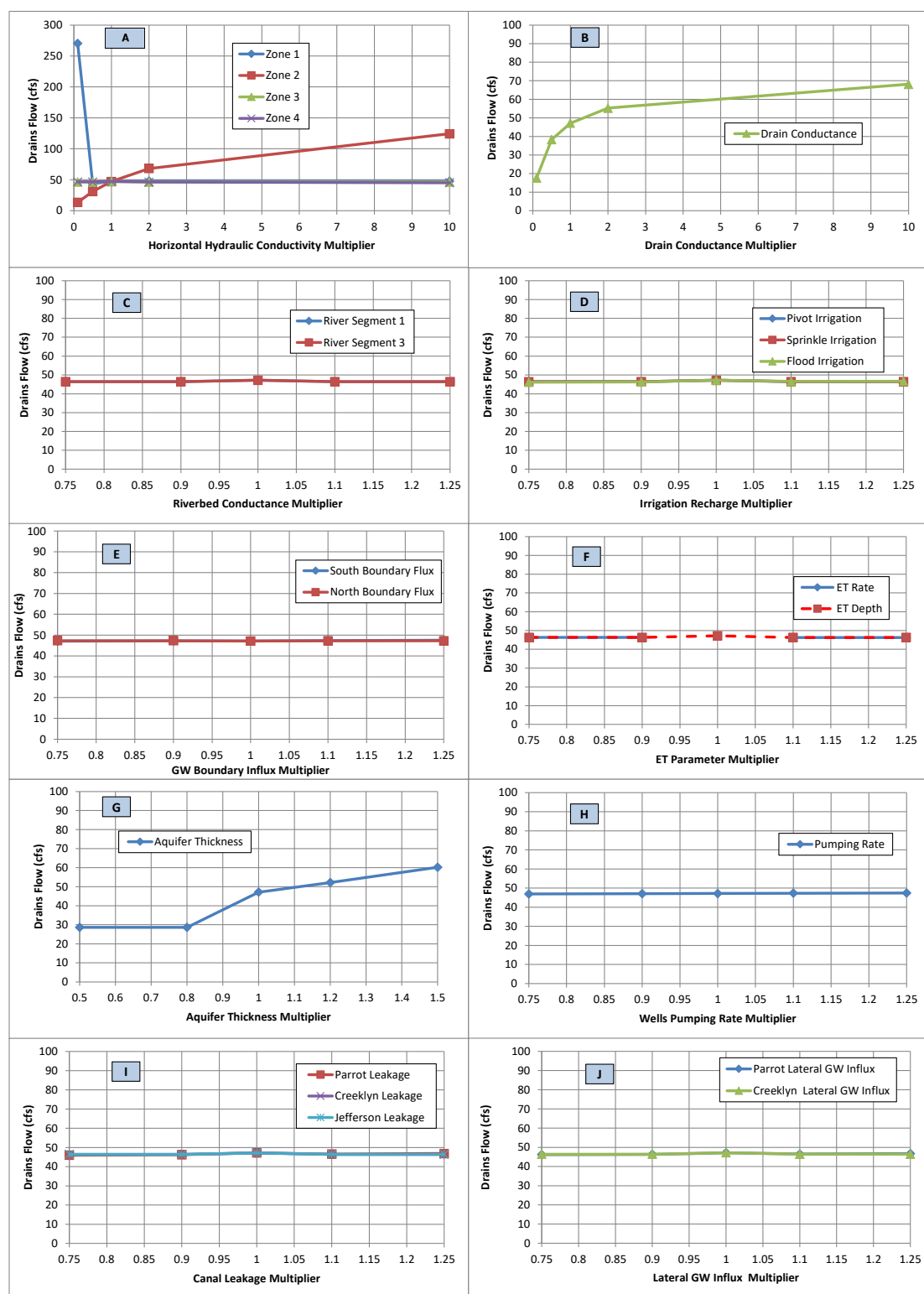


Figure F4. The model sensitivity analysis show that calibration statistics RSS is most sensitive to hydraulic conductivity (zones 1 & 2), drain bed conductance at Parson's Slough and Willow Springs, and aquifer thickness.

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EXECUTIVE SUMMARY

This hydrogeologic study was performed in order to define the ground water/surface water interaction in the Waterloo area of the Jefferson River. Three major irrigation ditches are located in this reach of the river, and water shortages regularly occur during low flow summer conditions when irrigation needs are high. The project study area consists of the area between the Jefferson River and the Tobacco Root Mountain Range, from the Parrot Ditch diversion to the confluence of Willow Springs. Parson's Slough and Willow Springs, two important spawning tributaries, are located in the study area. Specific goals of the project were to define the nature of water movement through the study area, and broadly define the interaction between the Jefferson River, spawning tributaries, the Parrot Ditch, mountain recharge, and ground water flow. The project was completed using a combination of historical data review, ground water and surface water monitoring, aquifer testing, and interviews with landowners and agency personnel. Data was collected during the second half of the 2004 irrigation season and the entire 2005 season.

A monitoring network was developed using a combination of 13 existing landowner wells and 22 shallow piezometers installed throughout the study area. Surface water measurements were also collected at four locations on the Jefferson River, the Parrot Ditch, several smaller irrigation ditches and blowoffs, Parson's Slough, and Willow Springs. Water level data, streamflow, and water quality parameters were collected from monitoring points under both irrigation and non-irrigation conditions. An aquifer test was also conducted on an irrigation well in the study area to determine aquifer parameters in the upper saturated zone. Data was collected on a monthly basis during the winter months (November – March) and weekly or bi-weekly during the irrigation season (April – October). Evaluation of monitoring data was focused on determining the differences between pre-irrigation conditions (April), mid-irrigation season (July-August), and late irrigation season (September/October).

Irrigation in the Waterloo area generally begins in mid April when the Parrot Ditch is opened and runs through early July, when the first cutting takes place. During this time period, spring precipitation and snowmelt results in high river flows and there is an excess of water for both irrigation and fishery needs. The ditch is generally shut down for a week over the 4th of July weekend, and reopened in mid-July through late October. During the period from mid-July through mid-September, irrigation needs are greatest at a time when river flows are at their lowest and water temperatures are at their highest. This two-month time period is when frequent water shortages have occurred in the Jefferson River, creating a strain on both the fishery and agricultural operations; and the potential exists to dry up the river.

A detailed evaluation of monitoring results show a complex connection between ground water, surface water, and irrigation practices throughout the study area. In the first part of the irrigation season, ground water and surface water exhibit distinct characteristics that would generally be expected in a system with no ground water/surface water

interaction: warmer ground water temperatures, stable water quality parameters, and rising ground water elevations and surface flows in response to spring precipitation and snowmelt. A component of ground water inflow from the Tobacco Root Mountains is also visible in water quality results. The Parrot ditch is shutoff in early July and there is a brief stop in irrigation, while ranchers harvest their first cutting. The impacts of this shutdown can be seen in ground water elevations across the Parson-Willow area, which indicates a connection between irrigation practices and ground water. Ground water quality begins to show impacts from surface water, specifically in the Parson-Willow area.

During the peak irrigation season (mid-July through mid-September), ground water elevations continue to rise due to irrigation impacts, and surface water temperature and conductivity values show strong correlations with ground water. During this critical time, ground water and irrigation return flow provide the majority of water to the Jefferson River in the study area. Ground water inflow enters the river as discharge through various slough channels, Parson's Slough, Willow Springs, and direct flux into the river. Irrigation return flow appears to be the primary component of ground water inflow, and enters the aquifer by ditch seepage, crop return flow, and flood irrigation returns.

Late in the irrigation season (September-October), ground water elevations reach their seasonal highs, most notably in the lower project area, as the ditch continues to flow but the majority of late season irrigation is flood irrigation. Surface flows in Parson's Slough and Willow Springs are also at their peak levels, which is consistent with a strong ground water/surface water interaction. Ground water and surface water are very well mixed based on uniform water quality parameters throughout the valley. During the off-season (November-March), data show ground water and surface water slowly returning to base flow conditions.

During periods of low stream flow and high irrigation needs, the river flows remain only due to conservation efforts by irrigators, and a significant amount of ground water and irrigation return flow. The first reaction to remedy this situation is to decrease ditch diversions and increase on-farm efficiency by converting from flood to sprinkler irrigation methods. Although some water savings can be achieved by more closely managing diversions and irrigation needs, and an increase in the minimum baseflow in the river is needed, caution should be taken before making widespread changes to the current irrigation regime.

Irrigation return flow supplies water to the alluvial aquifer, which in turn discharges to surface water bodies and helps maintain river flows during late season water shortages. If this important ground water recharge source is reduced too drastically, it could change the hydrologic system and reduce or eliminate historical return flow that helps support the river during critically low flows. A certain percentage of baseflow during the off-season exists due to irrigation return flow from the previous season; however, it is unknown what that amount is. That said, there are a number of improvements and water

savings that can be achieved, but the majority of these savings are aimed at water delivery and reduction of blowoff water instead of on-farm efficiency. At the end of the day, stakeholders must walk a fine line between finding available water savings without significantly altering the hydrology of the valley.

WET has developed a series of recommendations that can be used by project stakeholders and decision-makers to better understand the Jefferson River hydrologic system and aid in future land management decisions. Surface water recommendations consist of increasing ditch oversight and management by the ditch walker, as it is documented that 45 cfs of excess water is diverted on the Parrot Ditch. Other recommendations are to find a long-term funding source to continue the JRWC Drought Management Plan, and to conduct a return flow study between USGS station near Twin Bridges to the mouth of Willow Springs. Results from this study will quantify major areas of irrigation return flow in this critically dewatered reach. New canal structures with continuous flow monitoring equipment should also be installed on the three major irrigation ditches.

Ground water recommendations include the selection of a scaled back ground water monitoring network to be implemented annually in conjunction with the Drought Management Plan monitoring. The network will include wells at critical locations in the Waterloo area, and should also include locations on the west side of the river. This study was a short snapshot of the hydrologic cycle of the study area. Valuable information can be obtained by monitoring the system over several seasons.

It is also recommended that irrigation practices in the Willow Springs area be maintained in their current configuration, as any significant changes could lead to a different flow and temperature regime in the stream, which could impact this valuable Rainbow trout spawning tributary. A pilot study could be conducted in the Parson's Slough area that would consist of temporarily stopping flood irrigation in the immediate area, and closely monitoring impacts to the slough.

1.0 INTRODUCTION

On behalf of the Jefferson River Watershed Council (JRWC) and Trout Unlimited (TU), Water & Environmental Technologies (WET) has prepared this study report of ground water/surface water interaction in the Waterloo area of the upper Jefferson River (**Figure 1**). The project consisted of: existing data compilation and analysis; data collection and field testing; and, project communication and reporting. The goal of the project was to define the complex hydrologic relationship between surface water and ground water in the Waterloo area, and the impacts of irrigation on Willow Springs, Parson's Slough, and the Jefferson River. WET began work on the project in July of 2004, and data was collected through December 2005.

WET completed three primary phases of the project as stated in its proposal and requested by the JRWC and TU, with many tasks completed concurrently throughout the life of the project. A brief description of the work entailed in each phase is provided below:

Phase I – Data Compilation & Analysis

WET performed a comprehensive data search of existing natural resource data that was available within the project area. Data was gathered from the following sources: MBMG (water well data, geologic reports), DNRC (water rights, irrigation data, flow data); FWP (fisheries data); and various private sources (TMDL documents, riparian studies, irrigation delivery data, etc). These data were evaluated and used to develop field sampling networks, and to aid in understanding the complex nature of the Waterloo hydrologic system. WET also attended several JRWC meetings and met with several project stakeholders in the area (landowners, agencies, etc). These interviews provided critical insight into both past and present land use practices in the area. The final task included in Phase I was the development of a database with all relevant data used as part of this project. Database entry and management have been conducted throughout the project, with files provided in GIS and spreadsheet formats.

Phase II – Data Collection and Field Testing

Based on WET's initial field visits, review of historical existing data, and discussions with landowners, surface water and ground water monitoring networks were designed to provide data from critical areas to define ground water/surface water interaction. In addition, an aquifer test was conducted on an existing irrigation well in the project study area. The test was performed in conjunction with the landowner as part of an aquifer evaluation to determine if surface water in the project area will be adversely impacted by this ground water withdrawal or additional ground water usage. More detailed information on project monitoring activities is included in Sections 3.0 and 4.0.

Phase III – Project Communication & Reporting

WET personnel regularly attended JRWC meetings throughout the life of the project, and provided monthly updates on project activities. In addition, several formal presentations were conducted to keep watershed members informed as to our activities and findings.

2.0 WATERLOO STUDY AREA

The Jefferson River in southwest Montana has historically provided both high quality trout habitat, as well as the primary source of irrigation water for the valley's agricultural economy. Recent drought conditions have led to severe de-watering of the river, which has put a strain on both agricultural and fishery needs. Within the Waterloo area of the Jefferson watershed, there are three major irrigation ditches (Creeoklyn, Parrot, and Fish Creek), two spring creeks (Willow Springs and Parson's Slough) with high spawning potential, and numerous private residential, stock water, and irrigation wells; as a result, this is one of the most critical areas on the river. The approximate study area boundary, as defined in the JRWC proposal, as well as all major tributaries and ditches within the study area, are shown in **Figure 2**. The current Drought Management Plan has set the critically low water level at the Waterloo Bridge, which is in the middle of the study area, at 50 cfs. Willow Springs is one of only two known tributaries in the Jefferson drainage that supports rainbow trout spawning, and Parson's Slough is currently being developed as a potential spawning tributary as well. Due to the importance of these tributaries to the Jefferson River fishery, this project was developed to understand the hydrologic interaction between irrigation water use and delivery, ground water, spring creeks, and the Jefferson River. An irrigation delivery study of all the major ditches was also completed to evaluate potential improvements to the systems.

2.1 Site Geology

Alt and Hyndman, (1991), describe the Jefferson Valley as bound on the east by the Tobacco Root Mountains and to the west by the Highland Mountains. Both mountain ranges consist mainly of Precambrian basement rocks with a core of granite emplaced about 70 million years ago. The west flank of the Tobacco Root Mountains has thick deposits of Paleozoic and Mesozoic sedimentary rocks. Similar deposits are observed along the east flank of the Highland Mountains with a tightly folded sedimentary formation in the Silver Star area.

The west flank of the Tobacco Root Mountains has a large terrace surface known as the Parrot Bench that slopes gently westward toward the valley. It is believed the Parrot Bench is an older desert erosional surface developed during the Pliocene time, when the region had an extremely arid climate.

The east side of the upper Jefferson Valley, as described by Vuke et al (2004), is almost entirely covered by alluvial fan deposits mainly of middle Pleistocene age or younger (1.6 million years or younger). A larger alluvial fan is present at the mouth of Fish Creek on the west side of the valley and differs from those on the

east side of the valley. The alluvial fan contains large boulders believed to have resulted from glacial outbursts of melt waters derived from either a glacier or a glacier dammed lake.

Seismic and gravity data indicate that the southern (uppermost) Jefferson Valley is divided by a structural arch interpreted as a basement high, (Vuke, et al, 2004). Varying thicknesses of the basin fill over the basement high have been interpreted ranging from 600 m to 3,000 m. The basement high has been mapped at the surface as a horst between the Silver Star and Twin Bridges faults (**Figure 3**). The uplift of the horst is interpreted from observed changes of channel pattern, dimension, and shape, and associated hydraulic conditions of the Jefferson River across the area of the horst.

Gravity data collected on the east side of the valley indicate that the depth to the bottom of the Jefferson Basin changes from sea level near Dry Boulder Canyon over the basement high, to 3,000 feet near Hellroaring Canyon. This sudden change is believed to have resulted from the Silver Star fault, a northwest-striking fault that is down-dropped to the northeast. Another fault in this area is the Waterloo fault which also shows a similar offset of deposits, and a northwest trend.

Vuke et al (2004) described the upper Jefferson Valley as an asymmetrical valley with large, steep, west-dipping faults on the east flank, and east dipping faults of smaller magnitude on the west flank. Several smaller faults are described in the area, and their orientation is perpendicular to the major faults.

Using completion logs from selected wells in the study area, a geologic cross section of the upper valley is shown in **Figure 4**. This cross section shows the geology of the upper saturated zone running from east to west across the project area, from the Parrot Bench to the Jefferson River. The cross section location is shown on Figure 3. A review of soil data in the project area also showed that a narrow alluvial channel is present in the Mill/Beall Creek drainage, which runs from the base of the Tobacco Root Mountains to the Jefferson River Valley bottom.

2.2 Site Hydrology

The Upper Jefferson River encompasses a geographic area of approximately 469,994 acres. The average annual rainfall in the Jefferson River Valley is 9.65 inches with May and June typically the wettest months. Average annual snowfall is 11 inches with the majority occurring during January through March. The study area has four ephemeral streams, two perennial streams, and is drained by the Jefferson River. The ephemeral streams are located along the west slope of the Tobacco Root Mountains, consisting of Dry Boulder Creek, Beall Creek, Spring Creek, and Mill Creek. These streams flow west-northwest toward the

Jefferson River, but are either diverted for irrigation, intercepted by the Parrot Ditch, or dry by the time they reach the valley floor.

Two perennial streams located in the north-central portion of the study area are Parsons Slough and Willow Springs Creek. Water from these streams is supplied by a combination of natural and developed springs in the area, and near-surface ground water inflow. Both of these waters flow to the north, draining into the Jefferson River. Willow Springs Creek has an annual average flow of 22.0 cfs, and Parson Slough has an annual average flow of 9.5 cfs. The Jefferson River comprises the west border of the study area, with an average flow at the Waterloo Bridge of 236 cfs based on aquarod data from July 10th through September 30th, 2005.

The principal water-bearing formation in the study area is unconsolidated alluvium. The alluvial deposits include valley fill, alluvial fan gravels and glacial deposits resulting from outwash derived from either a glacier or glacier dammed lakes. The full alluvium thickness is not well known as wells drilled in the area are generally completed when sufficient water is encountered, well above the alluvial bottom. Information reviewed from driller logs show a coarsening downward sequence consisting of silty clay, sand and coarse gravels.

The water bearing material is characterized as an unconfined aquifer with the water table depth varying throughout the valley. The greatest water table depth within the study area is on the Parrot Bench and ranges from 80 to 180 feet below ground surface (bgs), shallowing westward toward the valley center to depths of 1 to 10 feet bgs. Ground water flows to the north at an average gradient of 11.7 feet per mile (0.002%).

2.3 Land Use/Irrigation Practices

The upper Jefferson River watershed, from the headwaters near Twin Bridges to Cardwell, encompasses 469,994 acres. Ownership in the watershed is 57% private, 28% Forest Service, and 15% State Lands and Bureau of Land Management combined. The primary land use is rangeland and forested areas, with 15% classified as agricultural use. The majority of agricultural production in the valley is irrigated hayland (**Figure 5**).

The majority of agricultural lands within the project study area are irrigated through shares from the Parrot Ditch, with a small percentage of lands irrigated by smaller diversions along the Jefferson River or through ground water irrigation wells. The Parrot ditch is the largest delivery canal on the Jefferson River, flowing along the Parrot Bench, at the eastern edge of the study area. The Parrot Ditch is 26 miles long, serves approximately 9,000 irrigated acres, and carries over 200 cfs during the irrigation season.

Past irrigation practices were primarily flood irrigation, but over time the majority of land is now irrigated by sprinkler methods in an attempt to increase production and efficiency, and reduce water usage and labor. Over 70% of the irrigated lands in the Jefferson Valley are now irrigated with sprinkler systems. Where flood irrigation systems rarely applied water with greater than 50% efficiency, the application efficiency for center pivot systems is commonly 70 to 75% (Van Mullem, 2005). There are a number of smaller ditches throughout the project area that still provide flood irrigation to pasture and hay ground. These ditches generally flow from smaller diversions on the Jefferson River downstream of the Parrot Ditch, or from lateral ditches off the Parrot. There are also several old river channels or slough channels along the river bottom, some of which are used for irrigation or serve as return flow conduits.

3.0 FIELD DATA COLLECTION

Various industry-accepted field methods and instruments were used to measure, collect and sample ground water and surface water parameters. All monitoring locations and elevations were surveyed by a licensed surveyor. Detailed descriptions of field methods and QA/QC procedures are included in this section.

3.1 Ground Water Monitoring

The ground water monitoring program was designed to characterize aquifer conditions in the study area and the interaction with surface water. Data collection consisted of ground water depths, ground water elevations, and field and laboratory water quality. Field water quality data consisted of temperature, dissolved oxygen, specific conductivity, pH, and total dissolved solids. Water samples collected for laboratory analysis consisted of pH, conductivity, total dissolved solids, anion-cation balance, sulfate, alkalinity, bicarbonate, carbonate, chloride, hardness, nitrogen, calcium, magnesium, potassium, sodium, and iron. These data were used to help determine any detectable interaction between ground water and surface water.

Depths to ground water were measured from a designated surveyed point at each monitoring location using a Heron water level meter capable of measuring to 0.01 foot accuracy. Ground water quality parameters were collected utilizing a portable peristaltic pump and flow through cell to minimize contact with the atmosphere. Water was continuously pumped through the cell and measured with a YSI 556 MPS meter until parameter concentrations stabilized. Ground water data measured was recorded in a field notebook and transferred to electronic data files. Water quality parameter results are presented in Section 4.0.

Ground water monitoring data were collected at 13 private wells and 22 piezometers located throughout the study area, as shown in **Figure 6**. Piezometers were installed using a GeoProbe hydraulic drill rig, with 1-inch PVC

casing and slotted screened interval. Piezometers were sited in critical areas along the ditch and valley bottom, where no landowner wells were present or available. Well completion logs from landowner wells and piezometer completion information is included in **Appendix D**. A summary of the ground water monitoring network is shown in **Table I** below.

**Table I. Ground Water Monitoring Network
Waterloo Ground Water Study**

Monitoring Well ID	TOC Elevation (Ft)	Total Depth (Ft)	Screen Interval (Ft)
Willow-1	4435.83	12	7 - 12
Willow-2	4481.22	12	7 - 12
Willow-3	4432.09	13	8 - 13
Willow-4	4436.71	14	9 - 14
Willow-5	4439.02	14	9 - 14
Willow-6	4440.83	12 (est)	Fully Perforated
Willow-7	4439.07	9	4 - 9
Willow-8	4451.69	14	9 - 14
Willow-9	4420.00	14	9 - 14
Willow-10	4431.07	9	4 - 9
Bench - 1	4490.91	20	15 - 20
Bench - 3	4501.33	22	14.5 - 22
Bench - 4	4506.03	12	9.5 - 12
Parson - 1	4465.18	19	14 - 19
Parson - 2	4444.53	19	14 - 19
Parson - 3	4446.11	20	15 - 20
Parson - 4	4450.70	16	11 - 16
Prim - 1	4502.25	12	7 - 12
Prim - 2	4504.25	12	7 - 12
Point Rock - 1	Dry Well	22	17 - 22
Point Rock - 2	Dry Well	16	11 - 16
Hunt-1	4583.97	200 (est)	unknown
Hunt-2	4542.79	110	unknown
Wind Mill	4679.87	56 (est)	unknown
Sams	4540.58	120	118 - 120 open
Schmidt	4461.34	31	unknown
Schlabach	4462.82	85	12 - 72
Harrie	4486.97	40	33 - 38
Schelhammer	4454.09	30	unknown
Kuehel	4438.17	38	unknown
Konen	4467.28	30	23 - 30

Lund	4463.63	unknown	unknown
Holman	4504.61	50	unknown

3.2 Surface Water Monitoring

Surface water monitoring was conducted in conjunction with the ground water monitoring program. Surface water monitoring parameters consisted of measuring stream flow and water quality. Field methods utilized to collect surface water data consisted of staff gauge readings, flow meters, and stilling wells equipped with Aquarods. Water quality parameters were collected and measured in the same manner as the ground water utilizing the peristaltic pump, flow-through cell and YSI 556MPS meter. Surface water levels were measured using permanent staff gauges at monitoring stations throughout the study area, and readings were recorded on a weekly or monthly basis during the study period. Manual flows were measured at or near the staff gauge stations periodically in order to calibrate the staff gauges to read accurate flows. The surface water velocities were measured using a Marsh-McBirney Flo-Mate Model 2000 portable flow meter in accordance with standard USGS methods. Staff gauges were either attached to a post or a stilling well. Each staff gauge was graduated to hundredths of a foot and marked every foot and tenth of a foot.

Aquarods were installed in six stilling wells to measure and collect detailed water level, air and water temperature changes on 30 minute intervals. Aquarod data was downloaded on a bi-monthly or monthly schedule. These data were also correlated with the velocity and staff gauge readings to provide daily average flows at that particular location. Surface water monitoring was conducted at eleven permanent monitoring stations consisting of six aquarods and five staff gauges. Each aquarod location had a staff gauge attached to the stilling well and the water level was manually read and recorded during monitoring events. Surface water monitoring locations are shown on **Figure 7**.

Additional surface water monitoring locations were monitored periodically throughout the study period, based on field inspections by WET personnel, or information provided by project stakeholders and landowners. These locations included manual flow measurements in various Tobacco Root tributaries where flow was noted as reaching the Parrot Ditch, as well as various locations on the three forks of Willow Springs, where a focused flow study was performed (Section 4.4). A summary of the surface water monitoring network is shown in **Table II**.

**Table II. Surface Water Monitoring Network
Waterloo Ground Water Study**

Surface Water ID	Monitoring Method	Monitoring Frequency
Parson's Slough	Aquarod	30 minutes-Annual
Willow Springs	Aquarod	30 minutes-Annual
Jefferson River @ Waterloo	Aquarod	30 minutes-Seasonal
Jefferson River ab Parrot Diversion	Aquarod	30 minutes-Seasonal
Jefferson River @ Reising Property	Aquarod	30 minutes-Seasonal
Big Hole River @ High Road	Aquarod	30 minutes-Seasonal
Creeoklyn Ditch	Staff Gauge	Weekly-Seasonal
Parrot Ditch (3)	Staff Gauge	Weekly-Seasonal
Fish Creek Ditch	Staff Gauge	Weekly-Seasonal
Andren Ditch	Staff Gauge	Monthly-Seasonal
Hunt Ditch	Staff Gauge	Monthly-Seasonal
Kurnow Blowoff	Staff Gauge	Monthly-Seasonal
Mill Creek	Manual	Individual
Dry Boulder Creek	Manual	Individual
Willow Springs	Manual	Individual

3.3 Aquifer Test

An aquifer test was conducted on an irrigation well located near the town of Waterloo within the project study area, located in the NE ¼, SW ¼, NE ¼, of Section 26, Township 1 South, Range 5 West. This well is located near the center of the project study area, and the owners of the well have requested a permit from the DNRC to increase the water right from the 543 gallons per minute (gpm) water right to 1,200 gpm. WET agreed to perform an independent aquifer test that would serve the needs of both the landowner and the ground water/surface water interaction study.

DNRC groundwater permit application requirements (MCA 85-2-311) require that a 72-hour pump test be performed while monitoring the influence on the surrounding aquifer and surface water bodies through a series of test wells. The purpose of this test was to determine the availability of groundwater at the requested flow rate and volume. Results of the test were used to calculate whether water is physically available at the well location, and whether pumping the well at the requested rate and duration will induce surface water infiltration, reduce streamflows, or adversely affect senior water users. Detailed results of the aquifer test are included in Section 4.3.

3.4 Monitoring Procedures & QA/QC

WET personnel conducted field activities according to applicable American Society of Testing and Materials (ASTM) standards for environmental sampling. Stream flows were calculated with field velocities and area calculations according to United States Geological Survey (USGS) procedures. Water quality meters were properly calibrated before each monitoring event according to manufacturer specifications. WET collected laboratory samples on three occasions, to perform a cation-anion analysis and confirm the variability and accuracy of the field sampling results. Complete analytical results are presented in Appendix G of this report.

The field and laboratory parameters collected from locations throughout the surface water and ground water monitoring networks are listed in **Table III** on the following page. Laboratory samples were analyzed by Energy Laboratories in Helena, MT.

**Table III. Field & Laboratory Parameters
Waterloo Ground Water Study**

Field Parameters	Units	
Depth to Water	Feet	
Temperature	Degrees Celsius	
pH	SU	
Conductivity	mS/cm	
Dissolved Oxygen	mg/l	
ORP		
Laboratory Parameters	Units	Analytical Method
Conductivity	mS/cm	A 2510 B
pH	S.U.	EPA 150.1
Total Dissolved Solids	@ 180 C (mg/l)	A2540 C
A/C Balance	Sigma	A1030 E
Sulfate	mg/l	A4500-SO4 E
Alkalinity	CaCO ₃ (mg/l)	A2320 B
Bicarbonate	HCO ₃ (mg/l)	A2320 B
Carbonate, CO ₃	mg/l	A2320 B
Chloride	mg/l	A4500-Cl B
Hardness	mg/l	A2340 B
Nitrogen	mg/l	E353.2
Calcium	mg/l	E200.7
Magnesium	mg/l	E200.7
Potassium	mg/l	E200.7
Sodium	mg/l	E200.7
Iron	mg/l	E200.7

4.0 MONITORING RESULTS

WET personnel collected monitoring data from October 2004 through January 2006 throughout the study area. Ground water data was collected on a monthly basis during the winter months (November – March) and weekly or bi-weekly during the irrigation season (April – October). WET combined monitoring for the ground water study with the drought monitoring plan associated with the Jefferson River Drought Management Plan. Drought monitoring was conducted on the three major irrigation ditches, and several locations on the Big Hole and Jefferson Rivers. An aquifer test was performed on an irrigation well in the study area on November 9th-11th, 2004. Various additional ground water and surface water measurements were performed based on preliminary review of monitoring results, including more detailed surface water measurements on the Willow Springs headwaters in the fall of 2005.

Due to the multi-year study timeframe and large monitoring network, a tremendous amount of data was collected and recorded throughout the life of the project. In an effort to streamline the report for use by various groups, data summary reporting (Section 4.0), data evaluation (Section 5.0), and project conclusions (Section 6.0) are located in separate sections of the report. Data summary of monitoring results is included in this section. Detailed supporting tables, charts, and figures associated with the monitoring information are included in **Appendices A through C, and Figures 3 through 9**. Specific data references are also made in the following subsections.

4.1 Field Parameters Results

Ground water monitoring results varied throughout the study area, depending on the season and location. In order to assist in data evaluation, ground water contour maps were developed for the following field parameters: ground water elevations, temperature, pH, and specific conductivity. These parameters provided insight into significant areas of ground water/surface water interaction. Each parameter was contoured during three monitoring events that were expected to represent different water conditions: April (pre-irrigation), July (mid-season irrigation), and September/October (late season irrigation). Brief descriptions of results for each parameter are included in the following paragraphs. Contour maps for field parameters are located in **Appendix C, Figures A through L**.

Ground Water Elevations

Spatially, ground water elevations are highest at the southwest (upstream) portion of the project area and decrease moving to the northeast (downstream). Depth to ground water measurements also decrease from south to north and east to west through the project area, with wells above the Parrot ditch having the greatest depths to ground water. Wells in the Willow Springs area have the shallowest depths to water, with some water levels rising to within one foot of the ground surface.

Ground water in the study area flows to the northwest through the project area at an average gradient of 1.2%, with flow direction remaining consistent throughout the irrigation season. Flow through the study area is generally parallel to the Jefferson River, turning more northerly toward the river in the Parsons Slough/Willow Springs area. Seasonal ground water fluctuations varied significantly depending on location, ranging from 21 feet at the Hunt-1 well to less than one foot at the PRIM-1 well. The majority of wells in the valley bottom exhibited smaller elevation changes compared to wells on or near the Parrot bench. Ground water contour maps were developed for the April, July, and October monitoring events, and are located in **Appendix C, Figures A, B, and C**. Well hydrographs are located in **Appendix A**.

Temperature

Water temperature can assist in the evaluation of ground water/surface water interaction, since ground water temperatures are generally significantly cooler than surface water temperatures during the summer months. Temperature trends consisted of warmer temperatures along the east valley edge, cooling towards the center of the valley. Temperatures in the center of the study area consistently stayed cooler than the valley perimeter early in the season, with the coolest portion of the valley bottom consistently being the area between Parson's Slough and Willow Springs in the north-central portion of the study area. As the monitoring season progressed, ground water temperatures increased throughout the study area and a more uniform temperature gradient was noted. Temperature values ranged from 41 to 59 degrees during the April event, from 50 to 59 degrees in July, and from 50 to 56 degrees in October.

Ground water temperatures in April demonstrated cooler zones near the river, and warmer temperatures near the base of the Parrot Bench. Cooler temperature intrusions are noted in alluvial fan areas coming from the Tobacco Root range, as ground water is not mixed in the valley bottom and there are little or no irrigation impacts (**Appendix C, Figure D**). In the July event, temperatures warm significantly in wells near the river or other surface water bodies, and start to demonstrate a more uniform temperature gradient in the valley, which indicates some mixing of surface water and ground water. Parrot Ditch water and river water in the upper study area are warmer than ground water at this point in the season; however, river water at the lower end of the study area is 5 degrees cooler than at the upper end. A noticeable shift in the temperature gradient occurs as the valley center temperatures increase, but are still cooler than the perimeter temperatures (**Appendix C, Figure E**). In October, surface water and ground water are well mixed, which is indicated in the easily contoured temperature gradients throughout the valley. These three monitoring events show that ground water is impacted significantly by surface water and irrigation practices throughout the season (**Appendix C, Figure F**).

Cooler ground water temperatures are consistently present in the center of the valley, with cold ground water (approximately 50° F) shown coming from the Tobacco Root range throughout the year. Wells near the center of the valley show peak temperature values in the October, while wells located near surface water bodies show peak temperatures in July, with cooler temps in October.

River water temperatures during the monitoring season ranged from a high of 70 degrees in July to 56 degrees in October. Parrot Ditch water temperatures during the monitoring season ranged from 46 to 69 degrees F.

pH

Normal pH values for ground water and surface water are somewhat dependent upon the specific geology of an area, but generally fall in the 6-9 range. pH values ranged from 4.0 to 8.6 throughout the valley, but the majority of values were in the 5.5 to 8.0 range. Higher pH values were present in the middle of the valley, with lower values near the edges of the study area. Higher pH water is also noted coming off the Parrot Bench wells (Hunt-1 and Sams). The ground water network exhibited the highest pH values (7 - 8.5) in April or May, and the lowest values (4 - 6.5) later in the year (late July – October). Private wells exhibited their highest levels slightly later (May) than the shallow piezometers installed by WET.

pH values at some locations were measured at their lowest levels when ground water levels were at or near their highest elevation. Many wells in the study area had ground water elevations rise to within a few feet of the surface; as a result, ground water comes into contact with the organic and vegetation producing soil horizons. Tannic and humic acids present in this layer naturally leach into the ground water and lower the pH levels. Wells located near wetland areas in the Willow Springs and Primrose Lane area also exhibited lower pH levels. pH values dropped significantly in the bench wells later in the year, which suggests that early season values are being impacted by surface water runoff and infiltration into ground water. April and July 2005 contour maps are included in **Appendix C, Figures G and H**; but, the October event was not included due to data anomalies that prevented contour interpretation.

Surface water locations showed the highest pH values in June and the lowest values later in the year (July – September), depending on location and magnitude of flow.

Specific Conductivity

Conductivity values showed distinct differences between ground water and surface water monitoring locations. Conductivity values during the monitoring period ranged from 0.114 mS/cm to 1.106 mS/cm. Ground water conductivity values reached their peak during mid-season (June-July) and decreased, reaching their lowest levels during the off-season (November). Ground water

conductivities were higher in shallow wells completed in the upper portion of the aquifer, and lower in wells completed to deeper parts of the aquifer or outside of the valley bottom. These values are typical, as the wells completed on the Parrot Bench are likely both completed deeper and recharged by precipitation and runoff, which generally have low conductivity values.

The highest average conductivity values were noted in Willow-6, 8, and 10 monitoring wells, and the lowest average values were measured in the Keuhel, Sams, and Konen wells. Contour maps show higher conductivity values in the valley center in April, with lower values present in wells on or near the Parrot Bench (**Appendix C, Figure J**). The July event shows high levels in the Willow Springs area, and low values in wells near the river (**Appendix C, Figure K**), while the October event shows lower conductivity levels in the Willow Springs area in comparison to levels throughout the rest of the valley (**Appendix C, Figure L**).

Surface water locations on the Jefferson River and irrigation ditches showed strongly increasing conductivity trends, with the lowest values being the first event recorded (May), and values steadily increasing until the end of the irrigation season. The exception to this increasing trend is Willow Springs and Parsons Slough, which show trends with more similarities to ground water monitoring locations.

Generally, precipitation and spring snowmelt have low conductivity values. This water shows up in the river during the spring, with conductivities increasing through the year as snowmelt ends and precipitation decreases during the summer months. Low conductivity precipitation and runoff can also be seen entering the valley through wells on the Parrot Bench. Rising conductivity levels throughout the season are indicative of an increasing ground water contribution to surface water, as ground water conductivity is generally higher than surface water. Irrigation return flow also generally exhibits higher conductivity.

Dissolved Oxygen

Dissolved oxygen concentrations in ground water were generally very low (less than 3 mg/l) in shallow piezometers in the valley bottom, with some deeper landowner wells and wells near surface water bodies exhibiting higher concentrations. Wells above the Parrot Ditch also showed higher DO concentrations. Most wells also exhibited their lowest DO concentration during the June/July timeframe, and their highest concentrations during the off-season. These data are similar to what would be expected with high temperature irrigation water in mid-season and colder water during the off-season, as temperature is inversely correlated with DO. An attempt was made to contour seasonal dissolved oxygen concentrations in the study area; however, data did not show any significant trends or patterns and were not contoured in the report.

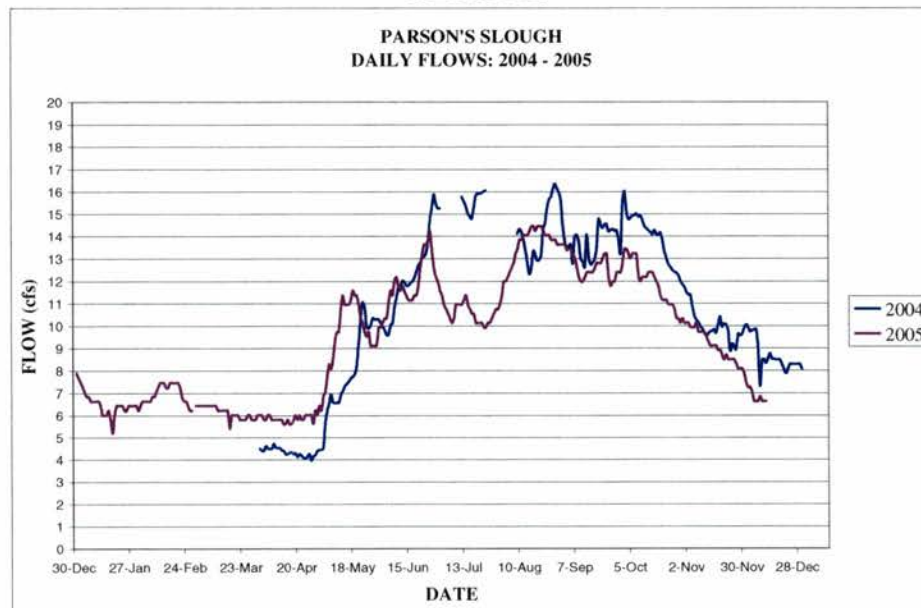
4.2 Surface Water Results

The majority of surface water data was collected during the 2005 irrigation season (April – October 2005), with continuous data collected from the Willow Springs and Parsons Slough aquarods during the 2004 and 2005 seasons. Between the 2004 and 2005 irrigation seasons, WET made several additions to the monitoring network in order to gather the most efficient data. Staff gauges were added to two small ditches off the Jefferson River (Andren Ditch and Hunt Ditch), as well as the Kurnow blowoff. In addition to the Waterloo aquarod, two aquarods were added at other locations on the Jefferson River: upstream from the Parrot Ditch (Jefferson-Parrot), and downstream from the Willow Springs outlet (Jefferson – Reising). A staff gauge was also maintained just downstream from the Parrot Ditch headgate as part of the JRWC Drought Management Plan. Manual flows were collected from Mill Creek, Dry Boulder Creek, and two small headgates on the Willow Springs Ranch (H-1 and H-2).

Parsons Slough

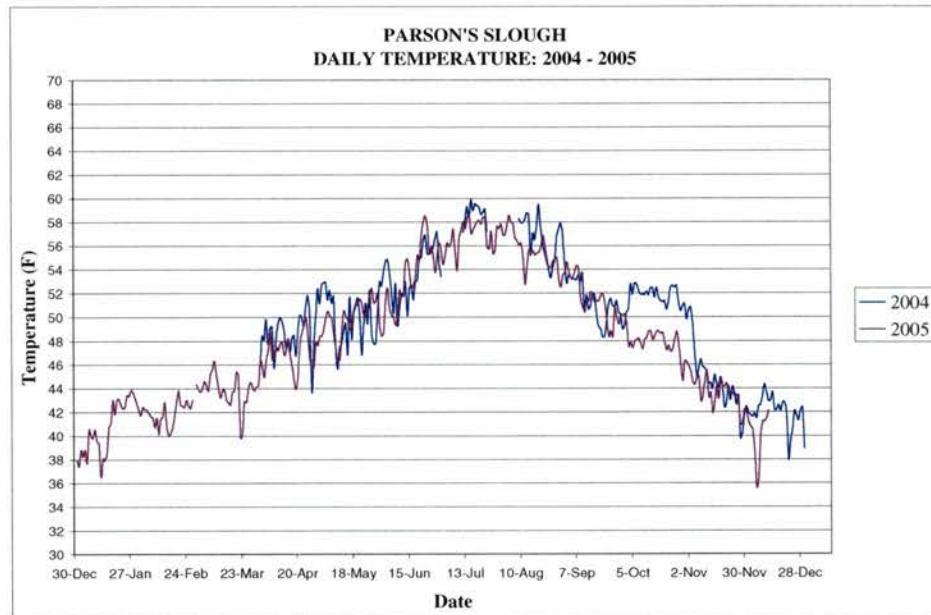
Detailed flow and temperature data are available for Parsons Slough from March of 2004 through the 2005 irrigation season. Data show slightly higher flows (2-3 cfs) were noted during the irrigation season in 2004 compared with 2005; however, base flow appeared to be higher in 2005 (December – March) coming into the irrigation season at approximately 6 cfs. Flow differences may be due to yearly precipitation differences, or some channel restoration work performed by the landowner in 2004. **CHART 1** shows a comparison of 2004 versus 2005 flow data.

CHART 1.



Temperature data remained very similar between the 2004 and 2005 seasons, with a few higher peaks in the 2004 data (April & October). Temperatures in Parson's Slough increase more than 20 degrees (38° to 58° F) throughout the year, and 14 degrees during the irrigation season. **CHART 2** shows 2004 and 2005 temperature comparisons.

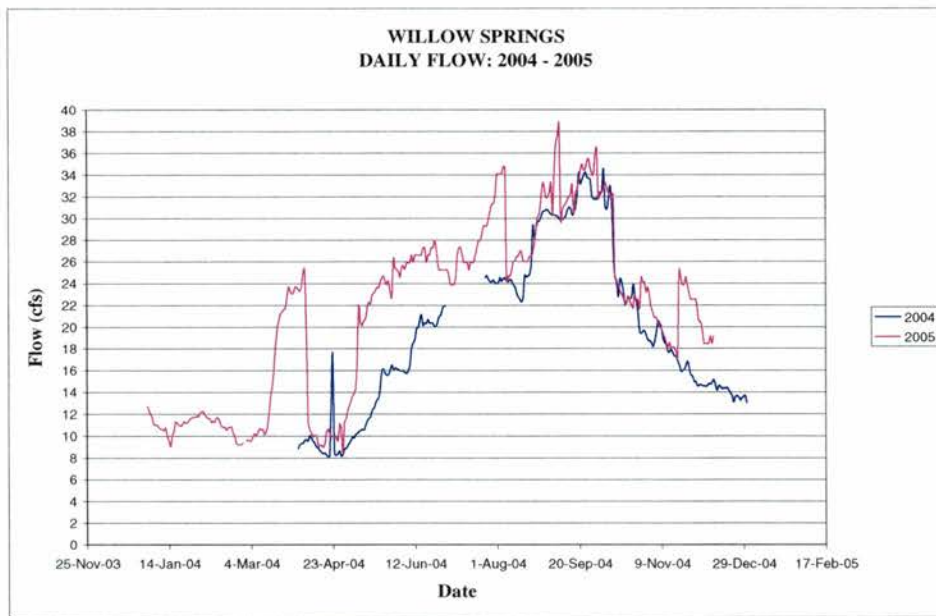
CHART 2.



Willow Springs

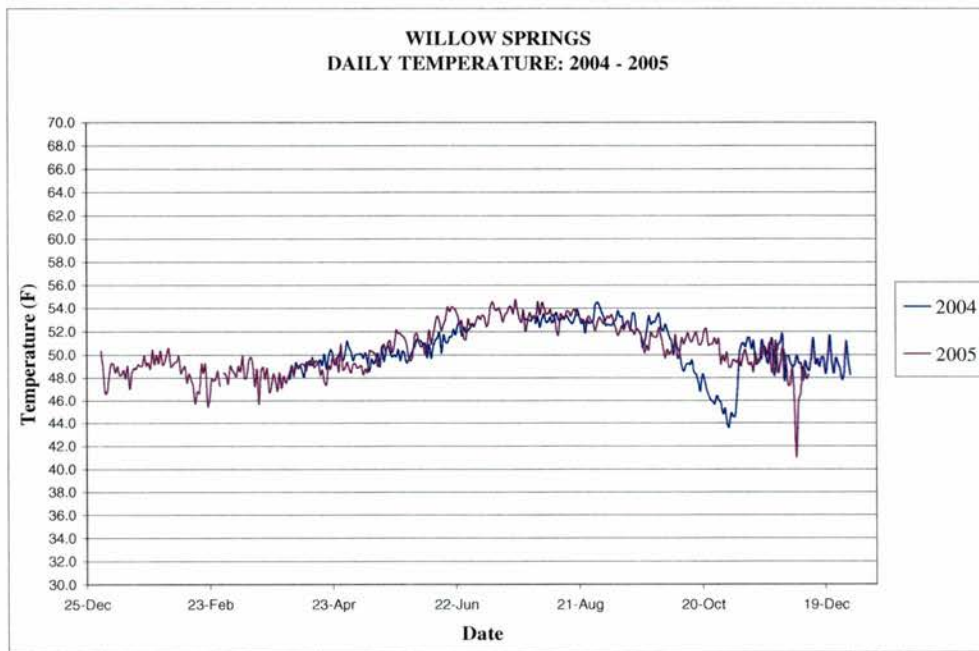
Willow Springs flows showed a similar pattern between the 2004 and 2005 season. Peak flows were similar in time and magnitude; however, 2005 flows were higher earlier in the year. This is likely due to annual precipitation and climate differences between seasons. **CHART 3** on the following page shows the differences between 2004 and 2005 flows on Willow Springs.

CHART 3.



Daily temperature values were very consistent between 2004 and 2005, with some minor late season variations noted. Temperatures displayed much smaller fluctuations than Parson's Slough, ranging from 46 to 54 degrees throughout the year, and 5 degrees during the irrigation season. **CHART 4** shows the temperature comparisons between 2004 and 2005.

CHART 4.

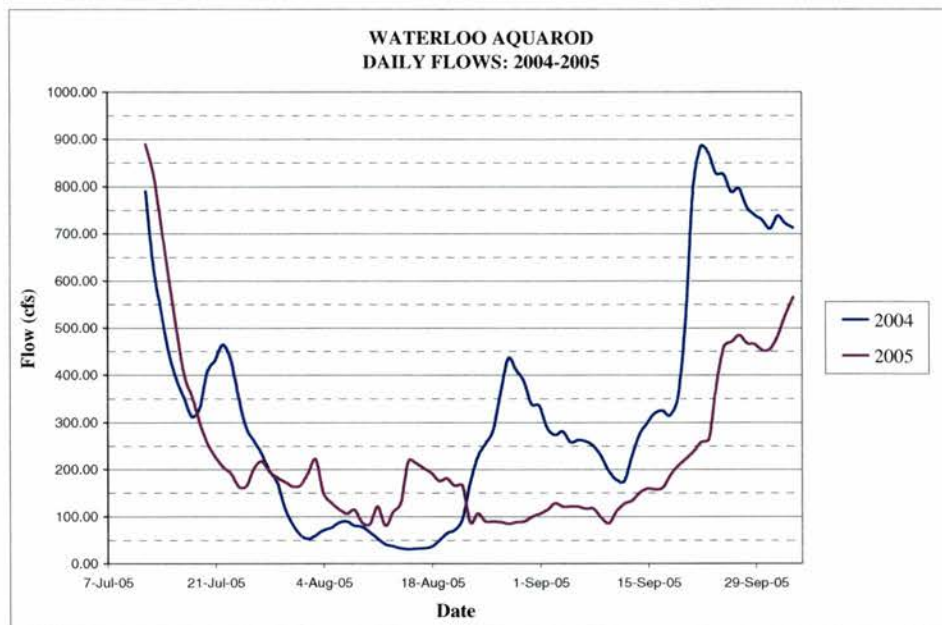


Jefferson River Flows

An aquarod was maintained below the Waterloo Bridge during the 2004 and 2005 irrigation seasons as part of the JRWC Drought Management Plan. The following additional monitoring points on the Jefferson River were added for the 2005 season: aquarod above the Parrot diversion (Jefferson-Parrot), and an aquarod below the confluence with Willow Springs on the Reising property (Jefferson-Reising).

Data from the Waterloo aquarod show that although flows were lower in 2005 than in 2004 for a better portion of the irrigation season, 2005 flows were actually higher during the critical low-flow period in July and August. The lowest recorded flow in 2005 was 87.90 cfs compared with 30.9 cfs in 2004. In 2004, flows dropped below 100 cfs for 23 days and below 50 cfs for 8 days. In 2005, flows dropped below 100 cfs for only 13 days, and did not drop below 50 cfs all season. **CHART 5** shows a comparison of 2004 and 2005 flows.

CHART 5.



For a majority of the year, the primary determining factor for river flows is precipitation events. Periods of critically low flow generally occur from late July through early September. During these times the river depends greatly on water conservation efforts by the ditch companies, ground water inflow from the valley alluvium, and irrigation return flows.

CHART 6.

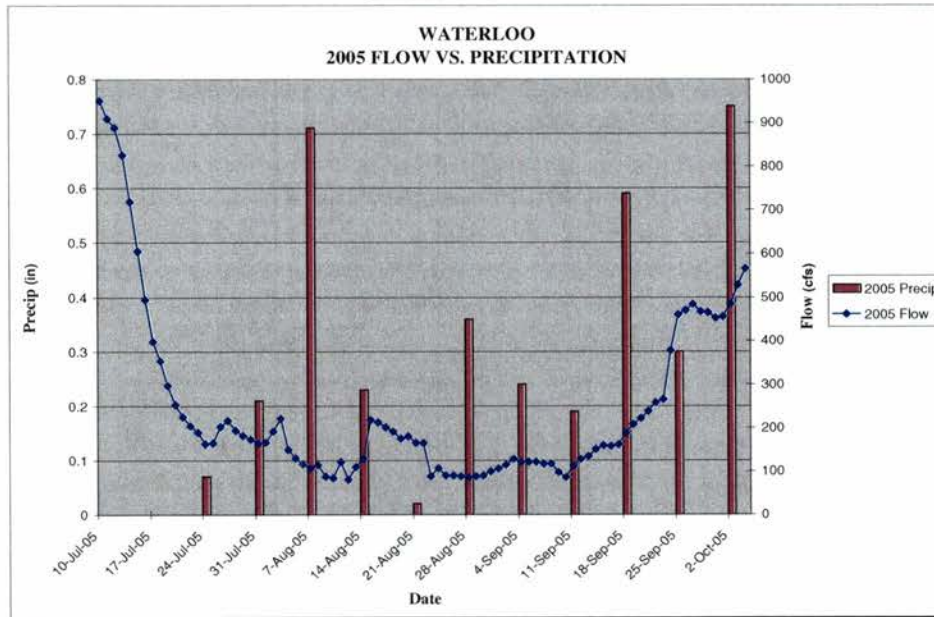


CHART 6 shows a comparison of weekly precipitation data and flow data, with precipitation data obtained from the National Climate Data Center (NCDC) for the Twin Bridges location, as well as local rain gauge data collected by WET. Generally a precipitation event will result in a flow increase in river systems; however, a close look at CHART 6 shows that during many of the critical low flow periods (August 7th through 14th and August 28th through September 11th), river flows do not increase in relation to precipitation events. These periods most likely represent periods where irrigation use was heaviest, with precipitation offsetting increases in irrigation withdrawal.

Irrigation Ditch Flows

Staff gauges were maintained on the Creeklyn, Parrot and Fish Creek/Jefferson Canals for the 2004 and 2005 irrigation seasons as part of the JRWC Drought Management Plan. Additional monitoring locations were added by WET on two smaller ditches that flood irrigate lands in the Parson's Slough area (Andren Ditch and Hunt Ditch), and the Kurnow blowoff (Kurnow) before it flows into Willow Springs. Also, four staff gauge locations were installed and maintained on the Parrot Ditch by Joe Van Mullem as part of the irrigation efficiency study.

WET maintained data on the major canal flows throughout the 2005 irrigation season. Diversions peaked from mid-July through late September, with a total diverted flow average of 344 cfs from July 12th through September 26th. This compares to an average flow of 333 cfs during a similar period in 2004. **TABLE IV** on the following page contains a summary of all ditch flows monitored during the 2005 season.

**TABLE IV. 2005 Irrigation Ditch Flows
Waterloo Ground Water Study**

Date	Creekslyn	Parrot	Andren	Hunt	Fish Creek	Total (cfs)
4-May-05	56.88	73.31			67.43	197.6
13-May-05		145.49	2.32			147.8
16-May-05	64.43	143.08	0.7	10.96	76.23	295.4
23-May-05	75.32	155.11	0.3	8.22		239.0
1-Jun-05	61.07	188.79	0	6.16	76.23	332.3
6-Jun-05	70.71	114.21	0.1	4.24	61.14	250.4
13-Jun-05	75.32	114.21	11.83	2.32	57.36	261.0
20-Jun-05	67.78	116.61	12.23	3.97	52.33	252.9
27-Jun-05	73.62	147.89	13.8	1.98	91.33	328.6
5-Jul-05			10.1			10.10
12-Jul-05	52.28	171.95	4.19		59.88	288.3
19-Jul-05	67.36	188.79	1.66		105.79	363.6
25-Jul-05	61.07	191.2	1.31		108.94	362.5
2-Aug-05	68.62	181.58	1.61		107.68	359.5
8-Aug-05	72.81	174.36			98.88	346.0
15-Aug-05	76.16	191.2			108.94	376.3
22-Aug-05	72.81	185.18			100.13	358.1
25-Aug-05	67.1	179.2			82.92	329.2
29-Aug-05	67.1	180.4			81.25	328.8
5-Sep-05	67.1	188.8			85.88	341.8
12-Sep-05	68.8	200.8			85.33	354.9
19-Sep-05	62.1	220			94.03	376.1
26-Sep-05	68.8	165.9		5.07	46.42	286.2

Blank Space = No Data for Specific Location and Time

4.3 Aquifer Test Results

As part of the ground water study, WET performed an independent pilot test on an irrigation well in the Waterloo area. The test was performed both as a part of this study, and to determine if the owner of the well could receive a permit from the DNRC double the pumping rate of a well to 1,200 gpm. In order to determine the effects of well pumping on the aquifer, WET conducted a 72-hour pump test in the proposed well while observing aquifer influence in one adjacent monitoring well and five piezometers. This test allows the determination of aquifer properties and the pumping well's effective radius of influence. The test was performed on November 9th–11th, 2004, and was stopped following approximately 55.3 hours of pumping, due to a failed riser cap causing discharged water to flood

a nearby haystack. With input from DNRC officials, the test was determined to be successful due to sufficient data collection to determine aquifer parameters and stable aquifer conditions.

The test was conducted using a steady flow rate of 1,425 gallons per minute (gpm). Flows were monitored using a magnetic resonance flow meter attached to the outside of the discharge pipe. The flow rate exhibited minor fluctuations of less than 10 gpm throughout the test period. Pressure transducers were placed in the observation well and each piezometer one day prior to the start of pumping. Manual depth to groundwater measurements were collected throughout the testing period.

Data collected during the test were modeled using Aqtesolv aquifer testing software to determine aquifer properties. The aquifer reacts initially as a confined aquifer due to a silt and clay layer extending from the surface to a depth of approximately 12 feet below ground surface (static water levels are approximately 10 feet bgs), but immediately becomes an unconfined aquifer as pumping decreases the static water level to greater than 12 feet bgs. Therefore, for the purposes of the analysis, it is considered an unconfined aquifer consisting of interbedded gravel, sand, silt and clay.

Aquifer test results identified a maximum drawdown of 4.5 feet in OW-1, eight feet from the test well, and 0.13 feet in piezometer PZ-4, 2,400 feet away. Both the Theis and Moench analytical solutions were incorporated to verify aquifer properties, with results from the two procedures falling within two percent of each other for each parameter. Principle aquifer parameters determined using the data collected during the test included a transmissivity (T) of 55,750 ft²/day, a specific yield of 0.12, and an anisotropy ratio of 0.00024.

The above-listed parameters were used in the Aqtesolv program to project total drawdown at the pumping well and the zone of influence to an accuracy of 0.01 feet of drawdown at the end of a season of pumping. The total drawdown in the pumping well (based on a cyclical pumping schedule of 12 hours on / 12 hours off at the maximum requested flow of 1,200 gpm and a maximum volume of 438.7 ac-ft) is estimated at 4.75 feet with a projected radius of influence of 10,800 feet. The cycle schedule is based on the requested appropriation volume and observations of pumping schedules during the 2005 monitoring season. This analysis, which is required by the DNRC, does not account for infiltration of irrigation water, infiltration of precipitation, or ground water flow.

The calculated zone of influence does encompass the Jefferson River and other nearby surface water bodies. Ground water elevation data for several nearby study wells identify a difference in elevation of greater than 12 feet between the test well and the Jefferson River, and a review of monitoring data for the 2005 irrigation season do not show noticeable effects on piezometers located between the pumping well and the surface water bodies. Piezometers within the projected

cone of depression actually show increasing ground water elevations during the time period that the well is operating, due to aquifer recharge not accounted for by the modeling software.

Based on the elevation difference between the maximum drawdown at the pumping well and the surface water bodies, and the lack of any affect on observation points, it appears that induced infiltration from surface water bodies in the area will not occur due to increased pumping from this well. However, a recent ruling by the Montana Supreme Court (Montana Trout Unlimited, et al. vs. Montana DNRC, et al) has determined that DNRC must change the way it interprets the relationship between surface water and ground water. As of the date of this report, the DNRC has temporarily stopped accepting ground water use permits until such time as an acceptable solution can be reached, which will likely require legislative action. As a result, it is unknown whether this well will receive a ground water appropriation permit.

4.4 Additional Testing

During the end of the 2004 irrigation season, flow increases were noted in the east fork of Willow Springs, along the base of the Parrot Bench. As a result, WET installed additional piezometers to track ground water levels in this area during 2005. When flows showed similar increases in 2005, a surface water pilot study was performed on the headwaters of Willow Springs to further define the source of these increased flows. The pilot test consisted of collecting a series of synoptic flows and field water quality parameters at various locations on the upper reaches of Willow Springs. Three distinct tributaries or forks of Willow Springs were evaluated, as well as ditches in the area adding flow from the Parrot Ditch. Locations of these additional monitoring points are shown on **Figure 8**.

Synoptic flow results showed that the East Fork of Willow Springs exhibits large increases in flow (5-8 cfs) during the late summer/fall when compared with baseflow conditions, which were observed during the January event (<1 cfs). Flows also tended to increase moving downstream. The East Fork of Willow Springs is actually a man-made ditch, which was installed decades ago to drain wetland areas for agricultural use. As a result, this channel is already a ground water drain for the area, with base flow increases proportional to rising ground water elevations.

However, two small ditches (H1 and H2) coming off the Parrot ditch located just east on the bench (**Figure 8**) are a primary source of inflow into the East Fork wetlands complex. These ditches are used to flood irrigate the bench directly east of Willow Springs, and the ditches drain into the wetlands complex, and eventually, the East Fork of Willow Springs. The Middle and West Forks of Willow Springs also showed flow increases; however, they were relatively steady compared with the East Fork.

Flows from the three forks were summed and compared with the flow at the Willow Springs aquarod. The aquarod contained almost 20 cfs more water than the sum of the three tributary flows in August and September, which indicates large amounts of inflow into the stream in a very short reach. The inflow source is primarily a combination of return flow from the two flood irrigation ditches on the Parrot bench, and drainage of the wetlands complex between the pilot flow locations and the aquarod.

Temperatures in the East Fork are generally the warmest of the three tributaries, with a warming trend moving downstream. The Middle and West Forks are spring fed (ground water); therefore, their temperatures are cooler and less variable. Specific conductivity values are higher in the East Fork as well. Higher temperature and conductivity values on the East Fork indicate that this tributary is significantly impacted by irrigation return flows in the area.

A major precipitation event was monitored between the August 29th and September 2nd, 2005 pilot test events; as a result, all monitoring locations showed significant temperature decreases and pH increases between the two events. This is indicative of the impacts from precipitation runoff, which is of higher quality than irrigation return flows.

5.0 DATA EVALUATION

Many types of ground water and surface water data were collected from the study area during the 2004 and 2005 irrigation seasons, resulting in a number of different evaluation techniques which were used to better understand the system. Water levels, stream and irrigation ditch flows, field parameters, laboratory samples, historical data review, and landowner interviews were all used in various capacities to draw conclusions about ground water interaction with surface water.

5.1 Spatial & Temporal Trends

WET performed an evaluation of depth to water and water quality ground water data, in order to identify spatial and temporal trends across the project study area. Surface water flow and water quality data was evaluated and compared for any correlation with ground water data. WET used a number of methods to evaluate the data: water level and field parameter contour mapping; seasonal precipitation/irrigation timing comparisons; and, detailed water quality evaluation using computer analysis.

5.2 Water Quality Analysis

Both field and laboratory water quality parameters were collected as indicators of ground water/surface water interaction. WET collected field pH, temperature,

dissolved oxygen, specific conductivity, and oxygen reduction potential (ORP) information on a monthly basis during the 2005 irrigation season. The results of the field sampling data are reviewed in Sections 4.1 and 4.2 of this report. The following subset of monitoring locations were selected and sampled for a full laboratory water quality analysis in April, August and October of 2005 (**Table V**).

**TABLE V. Laboratory Water Quality Locations
Waterloo Ground Water Study**

Well ID	Location	Total Depth (ft)	Screened Interval (ft)	SWL Range (ft)
Bench-4:	Above Ditch	12	9.5-12	5.0 – 6.8
Holman Well:	Above Ditch	50	Unknown	30.5 – 35.5
Hunt-1:	Above Ditch	200 (est)	Unknown	149 – 172
Parson-1:	Below Ditch	19	14-19	4.9 – 8.3
Parson-2:	Below Ditch	19	14-19	4.3 – 5.5
Sams Well:	Above Ditch	120	118-120	75.0 – 81.7
Willow-7:	Below Ditch	9	4-9	1.7 – 4.7
Willow-10:	Below Ditch	9	4-9	0.6 – 6.9
Parrot Ditch	Loomont Road	N/A	N/A	N/A

The subset of monitoring points included wells above the ditch, below the ditch, and a sample from surface water in the ditch. The subset also included samples from both shallow and deep wells. The sample events were selected to show pre-season, mid-season, and late season irrigation effects. A summary table of field water quality results is shown in **Appendix B**, along with the analytical laboratory data sheets in **Appendix F**.

Total dissolved concentrations (TDS) in the sampled wells ranged from 148 mg/L to 406 mg/L, with the highest concentrations in Willow-10 (357 mg/l to 406 mg/l) and the lowest in Sams (156 mg/L to 168 mg/L). TDS concentrations indicate the amount of dissolved constituents in the ground water. It can be an indication of how much time water has been in contact with aquifer material (retention time). Generally with longer aquifer retention time, TDS concentrations are higher. Higher concentrations in the Willow series wells may indicate a longer residence time for ground water surfacing in the Willow Springs area, while Sams with its lower concentration may represent ground water which has not been in the ground as long, possibly runoff from the upgradient benches and valley alluvium (**Figure 6**).

Conductivity measures the amount of electricity the water can conduct and gives a similar indication of the amount of dissolved minerals in the water. Conductivity values in the sampled wells closely follow the TDS trends.

The major cations (calcium, magnesium, potassium and sodium) in the sampled wells have similar trends. Calcium, magnesium and potassium concentrations are highest in Willow-10 and lowest in Sams. Again, these data give an indication of ground water retention time. Sodium concentrations differ from the other cations with the highest values (17 mg/l to 23 mg/l) occurring in the Parson-1 and Parson-2, while lowest concentrations (3 mg/l to 4 mg/l) occur in Sams. These data may indicate slightly higher levels of evaporative salts in the valley middle due to irrigation practices, or ground water levels in close proximity to the ground surface.

The major anions (bicarbonate, chloride and sulfate) have the lowest concentrations in Sams, but their high concentrations occur at different sampling points. The highest bicarbonate concentrations (320 mg/l to 380 mg/l) occur in Willow-10, another indication of longer residence time. The highest chloride concentrations (14 mg/l to 30 mg/l) occur in Hunt-1 and Parson-2. The Parson-2 chloride concentration high correlates with the sodium concentration high and indicates slightly higher levels of evaporative salts in this area. The Hunt-1 well chloride high does not correlate with a sodium high and probably represents a slight difference in natural aquifer chemistry. The highest sulfate concentration (320 mg/l to 380 mg/l) occurs in Parson-1 and again may indicate slightly higher evaporative salt content in this area.

Nitrate concentrations within the study wells are low, with most wells below 1 mg/l. The Willow wells have very low nitrate concentrations, below or at the method detection limit of 0.05 mg/l over the monitoring period. This indicates little surface contact with these waters. The highest concentrations (2.09 mg/l to 4.21 mg/l) occur in Hunt-1, and may be due to the thinner aquifer along the valley margin which has less dilution potential.

Overall, iron concentrations in the study area wells are low (less than 0.30 mg/l). Higher concentrations (12 mg/l in Willow-10 and 1.7 mg/l in Willow 7) occurred in the Willow wells in October 2005. The higher concentrations correlate with lower pH at this time of the year.

The cation/anion (A/C) balance gives an indication of data quality. Generally, A/C ratios less than 10 indicate good data quality. All of the ratios, except for the April 2004 data from Willow-7, are below 10. The April Willow-7 data are suspect, especially the bicarbonate concentration; therefore these data were not used in the analysis.

A geochemical analysis of the water chemistry was also completed for the sampling locations with water chemistry data using Trilinear and Stiff diagrams (**Appendix F**). Stiff and Trilinear diagrams indicate that the predominant water type in all locations can be classified as a calcium bicarbonate. Wells located

above the ditch (Sams and Hunt-1) have a different chemical signature than the ditch water or wells located below the ditch.

Water chemistry in Sams and Hunt-1 shows little change throughout the season and remains consistently different than the other sampling points. With the exception of Willow-7 and Willow-10, the rest of the wells have a relatively consistent shape to their stiff diagrams and plot on in a small group on the Trilinear diagrams, indicating similar water quality. Wells Willow-7 and Willow-10 plot below the grouped wells on the April Trilinear diagram, but in July their chemistry is similar to the water chemistry of the ditch water and other alluvial wells. This change shows that Willow-7 and Willow-10, located between the Parrot Ditch and the East Fork of Willow Springs, are influenced by surface water during the irrigation season. In October, the water chemistry in Willow-7 and Willow-10 moves back towards the April data, indicating the waning effects of ditch water in the late fall.

5.3 Conceptual Surface Water Balance – Waterloo Study Area

WET used selected data to develop a conceptual surface water balance for the Waterloo Study area throughout the 2005 irrigation season. This surface water balance was developed recognizing that there were several unknown variables that may impact its accuracy; and as a result, care should be taken before using the actual final flow values to make critical decisions. However, the water balance does identify gaining and losing reaches of the river, critical areas of ground water recharge and discharge that can be used in future land management decisions.

The Jefferson River was divided into three primary reaches based on the location of four surface water monitoring locations in the study area (**Figure 7**). The reaches are listed below along with reach break locations and station names in quotes:

- Twin Bridges (USGS Station) - Above Parrot Ditch (Parrot AR)
- Above Parrot Ditch (Parrot AR) - Waterloo Bridge (Waterloo AR)
- Waterloo Bridge (Waterloo AR) – Below Willow Springs (Reising AR)

The surface water balance for each reach was calculated by subtracting the upstream flow from the downstream flow while making necessary adjustments accounting for any significant inflows and/or diversions in that reach:

$$\text{Flow (down)} - [\text{Flow(up)} + \text{Inflows} - \text{Outflows}] = \text{Gain (Loss)}$$

Using this equation, a negative number indicates a losing reach of river and a positive number indicates a gaining reach. **Table II** located in **Appendix B**

shows a detailed summary of the river flows, known diversions and inflows, and the resulting water balance.

Generally, the upper reach of river (Twin Bridges to Above Parrot) is a slightly losing reach, the middle reach (Above Parrot to Waterloo AR) is a gaining reach, and the lower reach (Waterloo AR to Reising AR) is also a gaining reach. The Parrot Ditch to Waterloo AR reach shows the most significant gains. There are some variations in the data; however, these trends are shown very clearly in **Table VI**. Limited early season data shows that the lower reaches may be losing to the surrounding aquifer during spring runoff, but conditions change to gaining as surface water flows decrease and irrigation increases.

TABLE VI. Jefferson River Surface Water Gain/Loss by Reach (cfs)
Waterloo Ground Water Study

Date of Data Collection	Upper Reach (USGS Station–Parrot)	Middle Reach (Parrot–Waterloo)	Lower Reach (Waterloo–Reising)
River Miles	3.1 Miles	13.3 Miles	2.3 Miles
7/11/2005		83.51	
7/12/2005	(1.34)	15.23	
7/14/2005			10.51
7/19/2005		132.27	(34.60)
7/25/2005	(1.14)	116.30	(5.86)
8/1/2005	(25.54)	101.88	7.59
8/2/2005		88.68	
8/8/2005	4.22	52.53	
8/11/2005			19.63
8/15/2005	(20.74)	40.80	
8/22/2005	(24.41)	74.43	
8/25/2005	(58.90)	62.92	
8/26/2005	(4.90)	96.12	
8/29/2005	(89.20)	46.65	
9/5/2005	20.35	65.63	25.25
9/12/2005	42.80	59.83	27.96
9/19/2005	62.86	5.57	31.00
9/26/2005	(0.60)	87.72	53.00
Average Gain(Loss)	(6.7)	70.6	14.94
Gain(Loss)/Mile	(2.2)	5.31	6.50

Red Value = Negative value (Losing Reach)

Green Value = Positive Value (Gaining Reach)

Blank = No Data for Specific Location & Time

Data show that during critical periods of low flow (mid-July through mid – September), ground water inflow and other inflows account for a significant

portion of the Jefferson River flow near Waterloo; in fact, data collected on August 26th show inflows making up the entire flow in the Jefferson River at the Waterloo Aquarod. This was evidenced by the total irrigation withdrawals exceeding available river flow. In addition to ground water, other inflows that are contributing to the river are irrigation return flow channels and side/slough channel inflows.

The geologic makeup of the Waterloo area also suggests that there are additional sources of ground water inflow to the study area. Two primary faults, the Waterloo and Silver Star faults, cross the project study area striking northwest, and several other minor faults are noted as well. In fact, the study area lies within a seismically active part of Montana called the Intermountain Seismic Belt, and although modern surface-rupturing faults are rare, the area continues to experience numerous small and moderate-magnitude earthquakes (Stickney and others, 2000; Vuke, 2004). The recent earthquake activity in the Dillon area is evidence of this seismic activity. Water chemistry shows that there may be a source of ground water inflow from the Tobacco Roots in the area of the Waterloo fault, which coincides with the Mill Creek alluvial fan. Water quality from the Sams well suggests this potential connection, as temperatures remain cooler throughout the year, and trilinear diagrams indicate a unique water quality signature (**Appendix F**). Seismic activity can have impacts on the hydrogeologic conditions in the study area. There are many fault-related hot springs in the area, and the Golden Sunlight ore body is a hydrothermal deposit. A structural arch or horst is also noted in the area between the Twin Bridges and Waterloo faults. This high has been interpreted from observed channel shape and hydrologic conditions of the Jefferson River. This uplifted section of the alluvial aquifer may explain the upper portion of the study area being a losing reach of river, as these areas coincide geographically.

There were several limitations that must be noted in these water balance calculations: the most notable being the fact that only one side of the river valley was evaluated in detail. The water system on the west side of the river has not been quantified. Other limitations include the number of monitoring points, which was somewhat limited due to timeframes, access, and budget; and the exact usage and timing of irrigation along the Parrot Ditch.

5.4 Ground Water-Surface Water Interaction

The conceptual water balance identified gaining and losing reaches of the study area, both by river reach and time of year. An additional step was taken to attempt to identify and quantify the source of the inflow on the middle and lower reaches of the study area, both consistently gaining reaches. Since all major surface water flows were accounted for in the water balance described above, the following additional sources of inflow were identified in **Table VII**.

**TABLE VII. Total Water Inflows – Middle and Lower Reach (cfs)
Waterloo Ground Water Study**

Middle Reach: Above Parrot – Waterloo AR	
<i>Inflow Description</i>	<i>Flow (cfs)</i>
Irrigation Return Channel (10.5) – Creeklyn Blowoff	5
Slough Channel/Parrot Blowoff (14.07)	5-10
Irrigation Return Channel (15.08)	5
Irrigation Return Channel (16.2)	5
Slough Channel – Creeklyn Blowoff (19.5)	5
Small Slough Channel (20.2)	5
Ground Water Inflow: East Side - Parallel to River	3
Ground Water Inflow: West Side	6
Parrot Ditch Blowoff	5-10
Creeklyn Ditch Leakage – (2.42 cfs/mi x 4.4 miles)	10.6
Total Inflows:	54.6 – 64.6 cfs
Lower Reach: Waterloo AR – Reising AR	
<i>Inflow Description</i>	<i>Flow (cfs)</i>
Fish Creek Ditch Leakage (20.45)	2
Irrigation Return Flow, Hunt Ditch (20.75)	2
Parsons Slough Confluence, Seasonal (21.36)	1
Irrigation Return, Reising ditch (22.85)	3-5
Ground Water Inflow: East Side	10.3
Ground Water Inflow: West Side	2
Total Inflows:	20.3 – 22.3 cfs

Slough channels and irrigation return channel locations were identified using 2003 field riparian maps developed by Hoitsma Ecological, Inc and EMC². Return flow estimates were identified using visual or anecdotal evidence from on-site visits and area landowners. Identified mileage locations were included above where present on the Hoitsma/EMC project maps. Values for canal seepage were calculated using average ditch seepage losses calculated by DNRC (Amman 2004), and identifying reaches of ditch that are very near the Jefferson River, where seepage likely reaches the river in short order. Parrot ditch seepage was not included in the inflow calculations, as any leakage from the Parrot will discharge as ground water flux, Willow Springs flow, or various slough/irrigation return channel flows.

Determination of the ground water inflow (flux) was calculated using the Ground Water Flux equation:

$$Q = KIA, \text{ where:}$$

Q	= Volumetric Flow Rate/Discharge
K	= Hydraulic Conductivity
I	= Hydraulic Gradient
A	= Cross-Sectional Area

Site specific ground water flow paths, conductivities, and gradients were developed from monitoring data. Flow paths show that ground water generally flows parallel to the river through the middle reach, and the majority of ground water discharge happens in the lower reach where the valley width decreases. Ground water inflows from the west side of the valley were not calculated; however, estimates were made based on similarities with valley conditions on the east side.

Ground water flux values were developed for both valley and mountain ground water conditions. Using data from site monitoring wells and pump test results from the Schlabach well, a hydraulic conductivity (k) of 633.6 ft/day was estimated for the valley alluvium. Using well data from the Hunt-1 and Sams wells, a hydraulic conductivity (k) of 4.53 ft/day was estimated for the mountain recharge component. These conductivities were used to develop the ground water inflow values located in **Table VII**.

The sum of the total estimated inflow in each reach was then compared with the amount of flow gain in each reach shown by the surface water balance (**Table VI**). Although the surface water flows varied with each monitoring event, the estimated inflow amounts on the previous page are well within the range of values in the water balance table. The average water balance flow gains in the middle reach (70.6 cfs) and the lower reach (14.9 cfs) compare very well with the estimated inflows. Ground water inflow accounts for approximately 15% of total inflows within the middle reach and 48% of total inflows in the lower reach.

Ground water/surface water interaction in the Waterloo area is complex, with a very close relationship between the Jefferson River and the surrounding alluvial aquifer. Hydrogeologic features of the valley in this area, in combination with existing land use and irrigation practices, have created an intricate water system that results in water shortages under severe drought conditions, but also results in excess water in certain parts of the system. WET has taken this intricate comingled system and created a simple, conceptual view of the ground water/surface water interaction in the study area, which is shown in **Figure 9**.

Figure 9 shows the existing surface water and ditch network throughout the study area, and then shows the different water inflow sources (both ground water and surface water) into the Jefferson River. It is very difficult to develop accurate inflow numbers for each source, as irrigation and river conditions change on a daily basis throughout the season. The figure is meant as a visual aid in understanding the Waterloo area system.

6.0 PROJECT CONCLUSIONS

Irrigation of the Jefferson River Valley dates back well before 1900, and has permanently changed the hydrogeologic system within the Jefferson watershed. Decades of irrigation have artificially increased ground water elevations throughout the valley. Every time irrigation practices are changed, there is an impact to both ground water and surface water, whether it is a diversion, delivery, or efficiency issue. Study results have shown that there is a significant amount of ground water/surface water interaction throughout the study area, with strong relationships between shallow ground water, irrigation practices, tributary flows, and river flows.

A large number of ranches have converted from flood to sprinkler irrigation, which has likely reduced irrigation return flow and lowered ground water elevations in the upper alluvium. Although improving irrigation efficiency can lead to on-farm benefits, less water use, and higher river flows, continued widespread use of these methods may eventually change to hydrologic system and reduce or eliminate historical return flow that helps support the river during critically low flows. That said, there are a number of improvements and water savings that can be achieved, but the majority of these savings are aimed at water delivery instead of on-farm efficiency. At the end of the day, stakeholders must walk a fine line between finding available water savings without significantly altering the hydrology of the valley.

Parson's Slough shows surface water impacts throughout the year, as baseflow has very low temperatures, indicative of a surface water component from the Jefferson River. Ground water contour maps show flow paths between the river and Parson's Slough. During the irrigation season, two small irrigation ditches off the Jefferson River flood irrigate surrounding property, which creates a large component of higher temperature irrigation return flow. These return flows result in a greater surface water component of flow to the slough and higher temperatures during the summer months. The majority of Parson's Slough water is diverted below Loomont Road for a good portion of the irrigation season and is used to flood irrigate land to the east near Willow Springs.

Willow Springs is primarily fed by ground water, with two ground water springs and a man-made drainage ditch accounting for the majority of base flow. However, Willow Springs does show significant impacts from irrigation return flow later in the irrigation season, as small lateral flood irrigation ditches from the Parrot Ditch drain into the East Fork of Willow Springs. Other irrigation return flow and ditch seepage in the area infiltrates into the surrounding aquifer, increasing ground water elevations and its resulting discharge to surface water. This results in a large increase in Willow Springs flow.

Ground water shows irrigation season impacts from surface water throughout the study area. These surface water impacts are due primarily to irrigation return flow, with some ditch seepage effects, and a component of ground water recharge from the Tobacco Root Mountains. Ground water in the upper zone of the valley alluvium generally flows from

south to north through the study area, and discharges to area surface water tributaries or directly to the river.

In the upper portion of the study area (USGS Station to Parrot Ditch), ditch seepage, blowoffs, and irrigation return flow recharge the river through slough channels, wetlands, or direct discharge to the river. On the middle reach of the study area, a major component of river flow is due to irrigation return flow. Ground water through this reach generally parallels the river; as a result, ground water flux on the east side of the river appears minimal. Although data was not collected from the west side of the river, it is reported that there is large amounts of flood irrigation, and the valley suggests that there is significant ground water flux into the river, where the river reaches the west side of the alluvial valley just upstream from the Waterloo Bridge. The majority of ground water flux from the Waterloo study area discharges to the Jefferson River on the lower reach, between Waterloo Bridge and the Reising aquarod. A large portion of this ground water inflow discharges via Willow Springs.

Data collected between the 2004-2005 and 2005-2006 irrigation seasons (November–April) document the surface water and ground water systems returning to baseline conditions, both in flow and water quality. These baseline conditions were used quantify the magnitude and extent of irrigation season impacts.

Vital scientific data was collected during this study that supports the conclusion that there is a serious water shortage in the upper Jefferson River during late summer flow conditions, which has been exacerbated by drought conditions over the past several years. The most critically dewatered reach is from the Twin Bridges USGS Gauging Station to below the confluence of the Jefferson River with Willow Springs. The critical timeframe when water shortages occur runs from mid-July through mid-September. This water shortage coincides with the highest needs for irrigation (2nd crop) and also the highest water temperatures, which further stresses the fishery. During periods of low stream flow and high irrigation needs, the river flows remain only due to conservation efforts by irrigators, and a significant amount of ground water and irrigation return flow. Current irrigation systems and application methods contain many opportunities for continued improvement; and continued efforts and cooperation by area landowners and irrigators will be the most critical part of any future water savings.

7.0 MANAGEMENT RECOMMENDATIONS

WET has spent a great deal of time studying the Waterloo area over the past two years, using a combination of existing data review, stakeholder interviews, agency consultation, and data analysis. At the end of the project we have answered some questions and raised several more; however, we have reached a better understanding of the Jefferson River water system. The study documents baseline conditions in the valley during the off-season and current irrigation regime; as a result, future conservation efforts can be quantitatively measured.

WET has developed a series of recommendations that can be used by project stakeholders and decision-makers to better understand the Jefferson River hydrologic system and aid in future land management decisions. Recommendations are aimed at two goals: 1.) continue to improve understanding and management of agriculture and irrigation operations that result in fewer water shortages on the Jefferson River; and, 2.) prevent a significant upset to the water balance in the area, which could result in major damage to the Jefferson River fishery and/or existing ranch operations.

Surface Water Administrative Efforts

Surface water recommendations are very broad and twofold in composition. The first part of this recommendation is to continue current administrative water management activities, and develop new practices that may lead to diverting less water without sacrificing supply. First off, the current JRWC Drought Management Plan is a proven success in maintaining minimum flows in the Jefferson River, and the three major canals have made significant efforts to balance irrigation and fishery needs. These efforts have likely been the primary reason that the fishery has been sustained during this prolonged period of drought. The primary focus of any further administrative efforts should be the two month period from mid-July through mid-September, which has been identified as having the lowest flows and highest irrigation need of the season.

- **Increase Day-to-Day Ditch Oversight:** The amount of “ditch spill” water (i.e. – unused diverted water) was estimated at 45 cfs in the Irrigation Delivery Improvement Project report (Van Mullem, 2006). This number was corroborated by the consistent measurement of significant flows at the Kurnow blow off, in addition to other blow offs that were not measured or not in the study area. River flows and irrigation needs change on a constant basis, and it is a difficult job to satisfy both conservation efforts and ditch shareholders. With limited time in the field, the ditch manager must be conservative and divert more water to ensure that water is provided. This also leads to a lag time between when the ditch flow needs to be adjusted (up or down) and when the adjustment actually happens. This practice sometimes results in the need to blow off excess water or have unused water at the end of the ditch.

Additional funding should be sought through various grant programs to increase the on-site ditch oversight time during the mid-July to mid September time period. The goal of a greater on-site presence would be to shorten the reaction time on canal flow adjustments, and reducing the amount of excess diverted water. More on-site time could also be used to improve communication between water users and the ditch manager.

- **Continue Drought Monitoring:** Implementation of the Drought Management Plan (DMP) over the past five years is likely the main reason why a trout fishery still exists in the Jefferson River. Seeing the proven success that across-the-board stakeholder cooperation has achieved makes it easier to bring more ideas to the table; however, funding to implement the water monitoring tasks during the

season seems to be difficult to find. It is recommended that efforts to secure a long term source of funding for implementation of the DMP.

- Conduct Return Flow Study on Jefferson River: There is relatively good monitoring data and knowledge on the major diversions within the project study area; however, very little is known about the various return flow channels and slough channels that are present. A major percentage of water that recharges the Jefferson River in this area comes from these return flow channels, which also contain ground water discharge as well as irrigation water.

It is recommended that a flow study be conducted to measure all inflow channels into the Jefferson River between the Creeklyn Ditch and the mouth of Willow Springs. The study should be conducted between mid-July and mid-September. Results from this study will quantify major areas of irrigation return flow in this critically dewatered reach. Channels with significant inflows can then be evaluated on a case-by-case basis to determine their source, and whether there is a need to change or maintain current irrigation practices.

- Educate Landowners on Irrigation Timing: This study has documented the magnitude and extent of the critical water shortage that exists from mid-July through mid-September on the upper Jefferson River. During this period, irrigators are generally taking maximum diversions while river flows are at their lowest. Efforts should be made to encourage landowners to irrigate during the “non-critical” time period, when excess water is available. Specifically, during the spring runoff season, irrigation withdrawal is generally low due to cool, wet weather and high flows. However, early season irrigation during this time would help raise ground water elevations throughout the valley, which would help maintain flows during the late season drought conditions.

Surface Water Structural Efforts

The second major water conservation topic is structural measures (both on-farm and canal) that could be taken to improve irrigation delivery and reduce seepage losses. A detailed review of structural and irrigation improvement alternatives was covered in detail in the irrigation efficiency report prepared in concert with this report. Results of the ground water study identify/support the following structural improvements as the highest priority:

- New Canal Structures: Irrigators in the study area and the Creeklyn, Parrot, and Fish Creek ditch companies have been extremely cooperative in water conservation efforts, but they can only do as good of a job as their equipment will allow. Many diversion structures along these major canals, although serviceable, should be replaced with more efficient structures. These new structures should be equipped with flow measuring equipment which will allow for more accurate adjustments by ditch walkers. Structures could also be equipped with telemetry equipment, which would allow remote flow adjustment. Capital costs would vary

depending on project; however, there are various grant programs available at the state and federal level that would likely support this type of water conservation project.

Ground Water Conservation Efforts

Ground water in the Waterloo area is recharged by various sources, both natural and artificial. Natural sources include snowmelt, runoff, precipitation, and potential river losses. Artificial recharge includes irrigation return flow and seepage. Irrigation improvements may lead to the reduction or elimination of these artificial recharge sources, and the resulting impact to the Jefferson River, Parson's Slough, and Willow Springs fisheries are unknown. As a result, care should be taken on any major irrigation projects that have the potential to significantly reduce aquifer recharge.

- **Continue Ground Water Monitoring Program:** Baseline ground water monitoring in the Waterloo area has been established with this project, and has helped define the ground water/surface water interaction. WET recommends that a long term ground water monitoring program be continued throughout the project reach (in coordination with the Drought Management Plan surface water monitoring), and should also include points on the west side of the Jefferson River. In order to keep costs manageable, the number of monitoring sites can be reduced from the current network, and frequency can also be reduced. In addition, a well located within the study area is included in the MBMG's long term monitoring network, and should be included in the monitoring dataset (Well 107080). Ground water monitoring should occur monthly through the irrigation season (May through September), and quarterly (January and April) during the off-season. Results should be submitted to the MBMG for inclusion in their statewide ground water monitoring network. The recommended ground water monitoring network is shown on **Figure 10**.
- **Maintain Irrigation Practices in Willow Springs Area:** Willow Springs is one of the most important spawning tributaries on the Jefferson River, and is critical to the long term preservation and improvement of the Jefferson River fishery. Willow Springs is recharged by a combination of ground water springs, irrigation return flows off the Parrot Bench and seepage from the ditch, and care should be taken before implementing any significant changes to the current irrigation regime. The current temperature and flow regime supports successful rainbow spawning, and ranch irrigation needs are being met. Although flood irrigation may not be highly efficient in this area, it is providing important return flows during the later part of the irrigation season. As a result, it is recommended that flood irrigation continue in the area below the Parrot Ditch between Loomont Road and the Kurnow blowoff. Emphasis should also be placed on early season irrigation to help raise ground water levels early in the year, which will benefit the river system during drought conditions.

Limit Ground Water Withdrawal Within Study Area: Data from the study supports the hypothesis that ground water inflow is a major factor in maintaining Jefferson River flows during late summer drought conditions. Precipitation and early season irrigation helps replenish the alluvial aquifer and raise ground water elevations, which in turn supplements surface flows in late season. Current land use in the area consists of low density residential development and minimal ground water withdrawals for irrigation purposes. An influx of subdivision development, or the installation of additional irrigation wells could potentially alter the ground water flow regime in the area and reduce the amount of ground water available for infiltration to the river system. Conservation tools such as conservation easements and ground water control areas can be used to help maintain the land use similar to its current condition.

8.0 CERTIFICATION/REVIEW

Water & Environmental Technologies, PC hereby certifies that the information and findings in this report are as described in this document. All statements made herein are true to the best of its knowledge. Water & Environmental Technologies assumes all information related to this project supplied by outside sources to be accurate. No expressed or implied warranties, including but not limited to any as to the accuracy of the information obtained, are made. All warranties are expressly disclaimed.

This report represents the professional opinions of Water & Environmental Technologies. Recommendations contained in this document were arrived at in accordance with reasonable and customary practices, which were currently accepted as of the date and at the location at which the work was performed. Water and Environmental Technologies assumes no responsibility for conditions that did not come to its actual knowledge or from conditions not recognized as environmentally unacceptable at the time this report was prepared.

Prepared By:

ITS: _____

Reviewed By:

ITS: _____

9.0 REFERENCES

- Alt, D., and Hyndman, D. W., 1991, Roadside Geology of Montana. (Third Printing). Mountain Press Publishing Company: 237-240.
- Associated Society of Testing and Materials International, 2003. Standards on Disc, Section Eleven, Volumes 11.01 through 11.05, Water & Environmental Technology.
- Hoitsma Ecological, Inc. December 18, 2003. Final Report Jefferson River Riparian Inventory. Report prepared for Jefferson River Watershed Council
- Land & Water Consulting, Inc. 2003. Water Quality Status Report Jefferson River Water Quality Restoration Planning Areas. Report prepared for Jefferson River Watershed Council.
- Land & Water Consulting, Inc. 2003. Watershed Characterization Report Jefferson River Water Quality Restoration Planning Areas. Report prepared for Jefferson River Watershed Council.
- United States Geological Survey, 1989. General Procedure for Gaging Streams (Fourth Printing), Techniques of Water-Resources Investigations of the USGS, Book 3, Chapter A6.
- Van Mullem, J. 2006. Upper Jefferson River Irrigation Delivery Improvement Project. Draft report prepared for Jefferson River Watershed Council and Trout Unlimited.
- Vuke, S. M., Coppinger, W. W., and Cox, B. E., 2006. Geologic map of the Cenozoic deposits of the upper Jefferson Valley. Montana Bureau of Mines and Geology Open File Report 505, 36p.

APPENDIX A.
Ground Water & Surface Water Charts

APPENDIX B.
Data Summary Tables – Ground Water & Surface Water

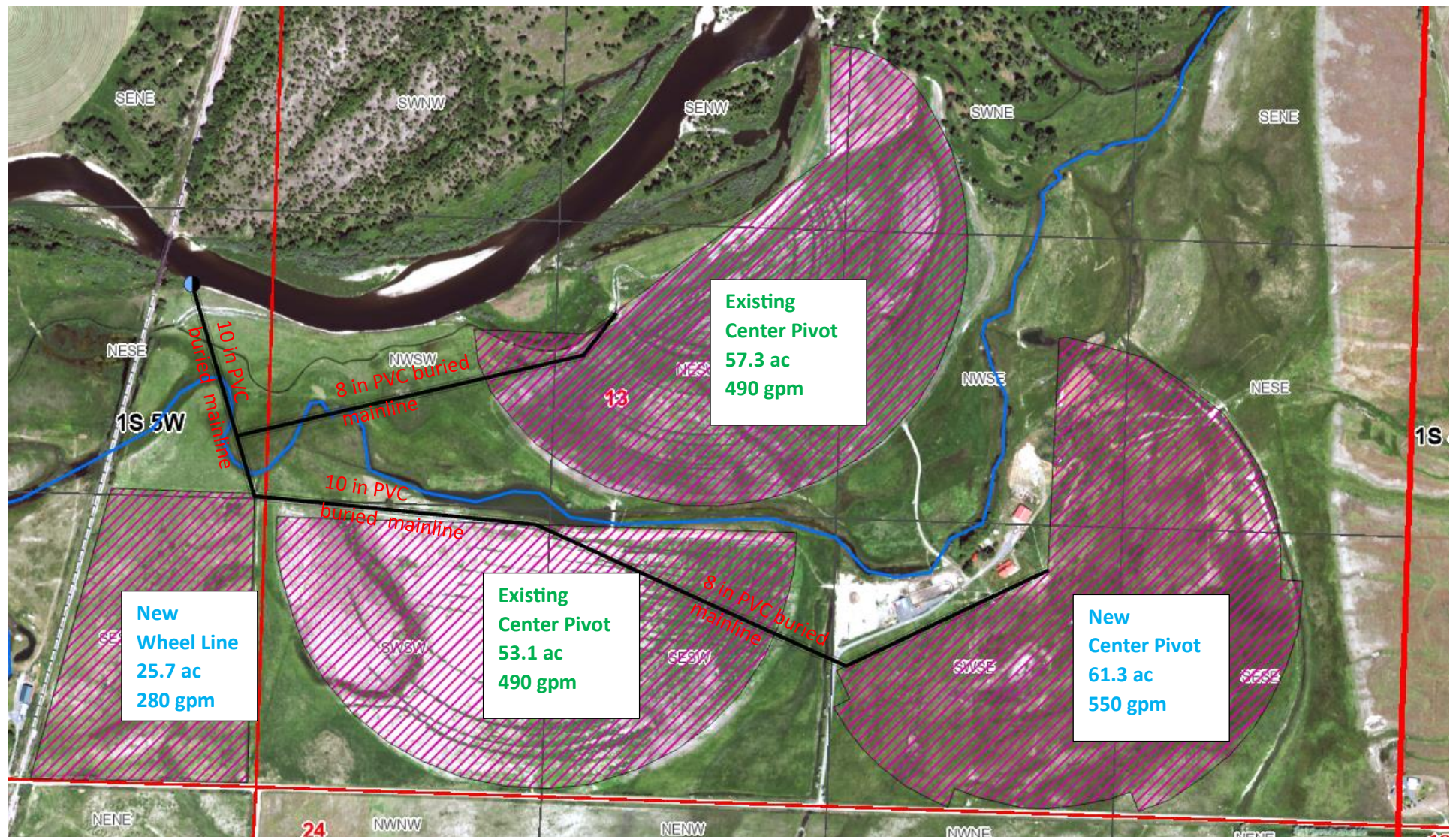
APPENDIX C.
Field Parameter Contour Maps

APPENDIX D.
Well Completion Logs & Piezometer Information

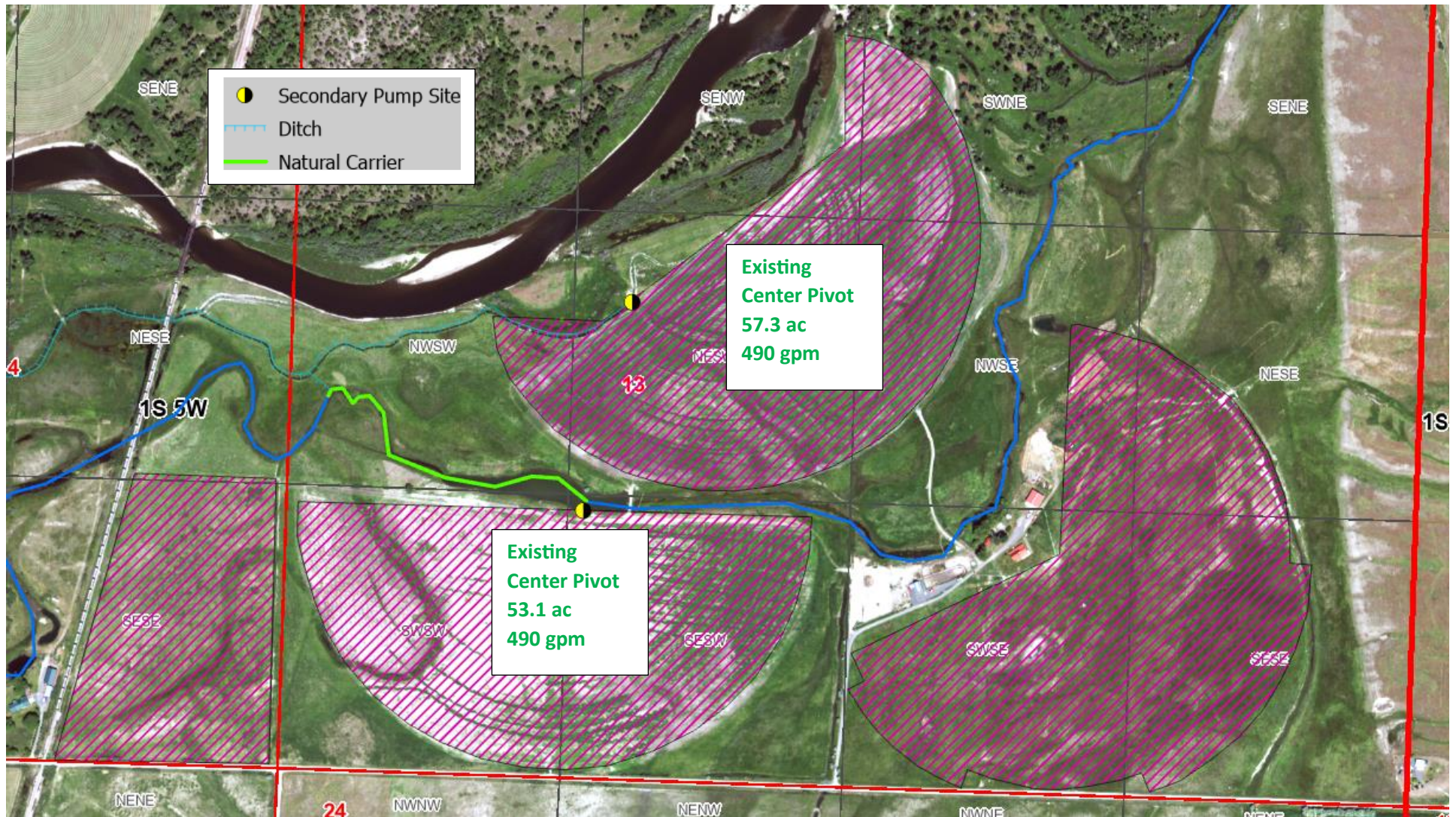
APPENDIX E.
Willow Springs Pilot Test Data

APPENDIX F.
Laboratory Analytical Results & Analysis

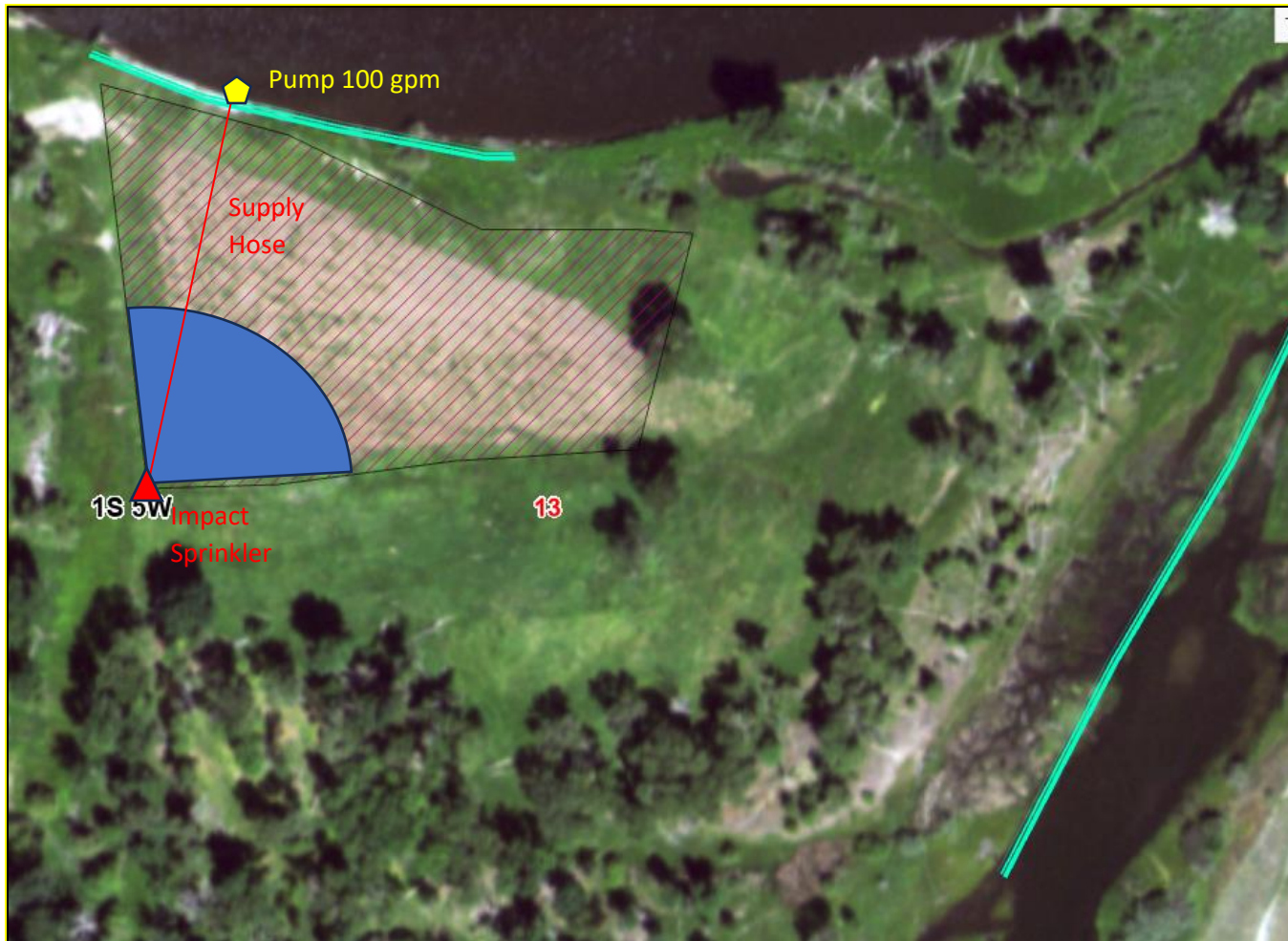
LIST OF FIGURES



System under normal operation.



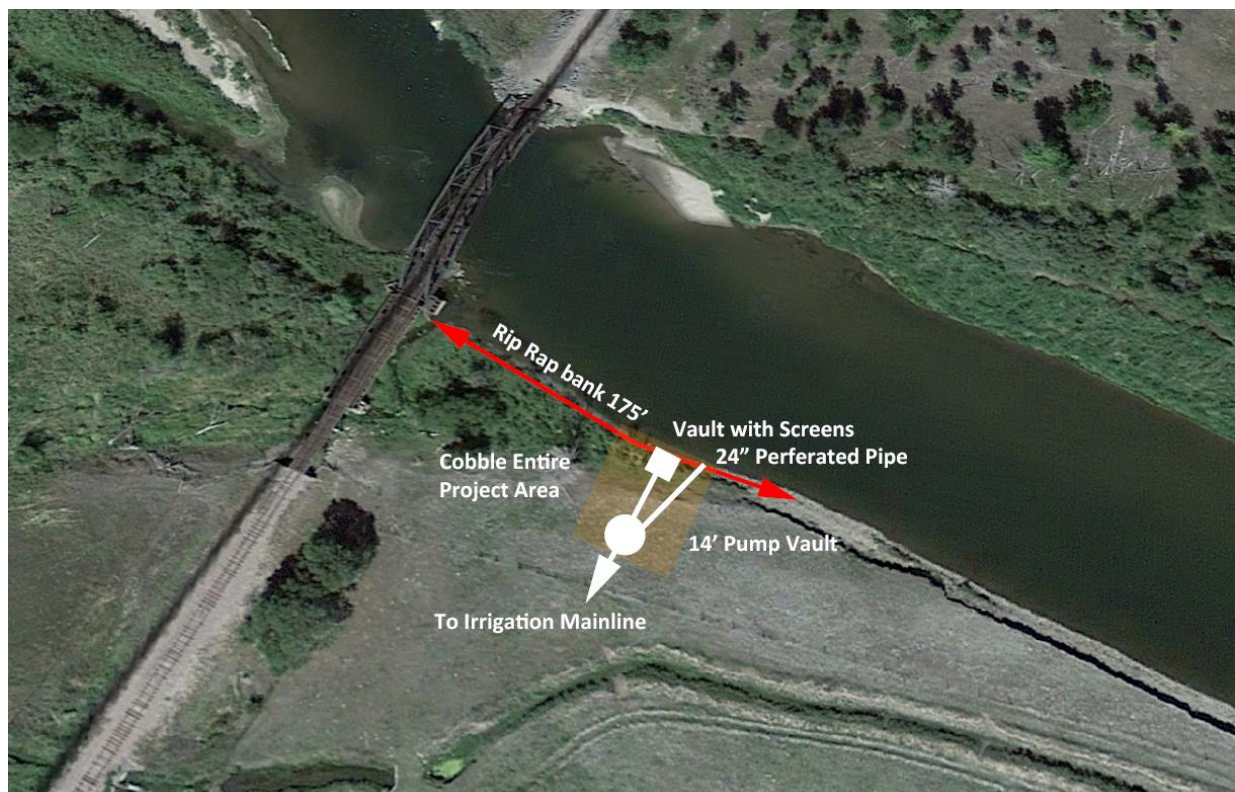
System if Jefferson pump site not operational.

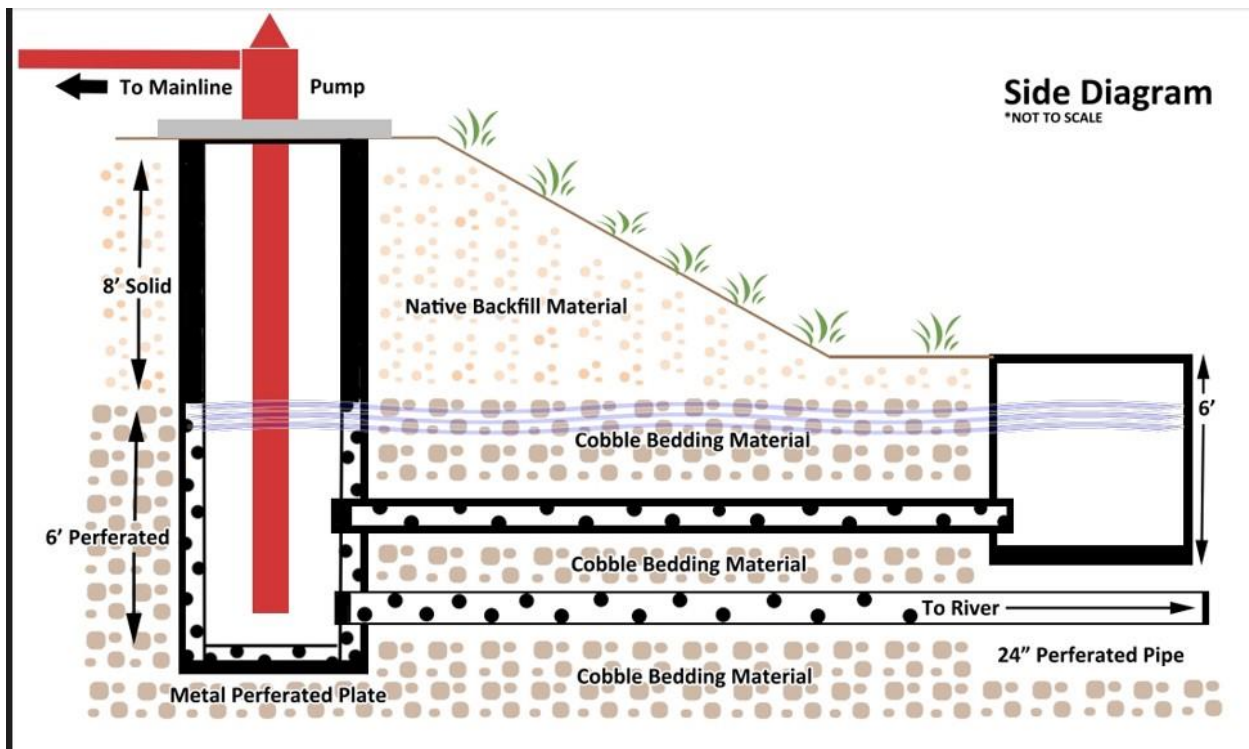


Sample set up for 100 gpm impact sprinkler shown pumping from Jefferson River. Sprinkler will be moved and arc adjusted to irrigate entire 1.6-ac place of use.

Jefferson River Pump Diversion Description

The intent of this project is to have a continuous flow system to be able to pull constant water to provide adequate flow to irrigation pivots. We have created a design that utilizes a screened vault set in the Jefferson riverbed at a 100 CFS. Attached to the screened vault will be a 24" perforated pvc pipe that will draw water from the river and collect ground water from the bedded perforated pvc pipe that will feed the 14' containment sump. This containment sump will be located back on the riverbank shelf and will act as a collection basin to retain enough water to always be available for the pivot pump. This containment sump is in two separated pieces. The lower half consists of a 6' perforated containment chamber that is perforated including a metal plate that it will sit on. This will draw groundwater in through layers of a mixture of oversized and clean bedding material. The upper 8' portion of the containment sump will be solid. Inside the containment pump will be a pipe that will draw out the water to feed the pivot pump. As a secondary backup in case the Jefferson River dips below 100 cfs will be a secondary 24" perforated pipe that will be embedded in the Jefferson riverbed that will always have a consistent water draw. Both 24" perforated pipe shall be bedded in both oversized and smaller cobble to allow not only river water draw, but groundwater saturation draw as well. The screened vault shall have 2' rip rap installed along both sides of the screened vault along the bank line 50' on each side. This will speed up water along the front of the screen, which in return the screens have a less chance of foreign objects sticking or collecting on the screens. As an additional failsafe the screened vault will have a water spray bar that will be fed by the pivot pump that will apply pressurized water to blow anything off the screens from inside out. This should also help reduce foreign objects accumulating on the screens as well. The entire installation area will be embedded with oversized and small clean gravel. This will allow as much groundwater seepage to accumulate inside the perforated pipe as possible.







Example of similar pump site installed on Big Hole River.

Proposed Sprinkler System

The system would consist of a 14 HP gasoline powered centrifugal pump supplying a 2-in flexible hose connected to a single large impact type sprinkler. The suction line would be a 15 ft., 3 in. flexible line with a screen. Based on the pump performance information supplying 100 gpm at 85 psi, a 16 mm sprinkler nozzle would be used. The estimated friction loss is 16.5 psi through 200 ft. of flexible hose, providing just under 70 psi at the sprinkler and about 100 gpm. The radius of sprinkler application of 230 ft. is appropriate as it is approximately the same as the field width. The sprinkler can be set to provide full or partial circle pattern to accommodate the field boundaries.



Performance Chart								
PSI	120	110	104	95	85	70	60	40
GPM	5	25	50	75	100	125	150	180

2.5 in. discharge

3.0 in. suction



14 HP



2000S Sprinkler Cart Performance Chart

Nozzle Size	PSI	GPM	Jet Length/Feet (One Direction)	Wetted Circle (Diameter/Feet)
12 mm (0.47")	22	34.3	62	124
	29	40.2	72	144
	44	48.1	78	156
	56	55	88	176
14 mm (0.55")	29	51.5	75	150
	44	63.2	91	182
	56	73.2	101	202
	70	81.7	111	222
16 mm (0.63")	29	65.3	78	156
	44	80.1	98	196
	56	92.8	111	222
	70	103	118	236
18 mm (0.71")	29	91.7	78	156
	44	100	105	210
	56	115	115	230
	70	128	125	250
20 mm (0.78")	29	99.4	82	164
	44	121	100	200
	56	140	122	244
	70	157	135	270



Solve for:

Energy (Head) Loss (Q known)

Select units:

Use feet and seconds units

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Research, and Software, Ltd.
http://www.LMNOeng.com

Click to Calculate

k = 1.318

Discharge, Q (ft³/s): 223

Velocity, V (ft/s): 10.180803

Pipe Diameter, D (ft): 00.167

Pipe Length, L (ft): 200

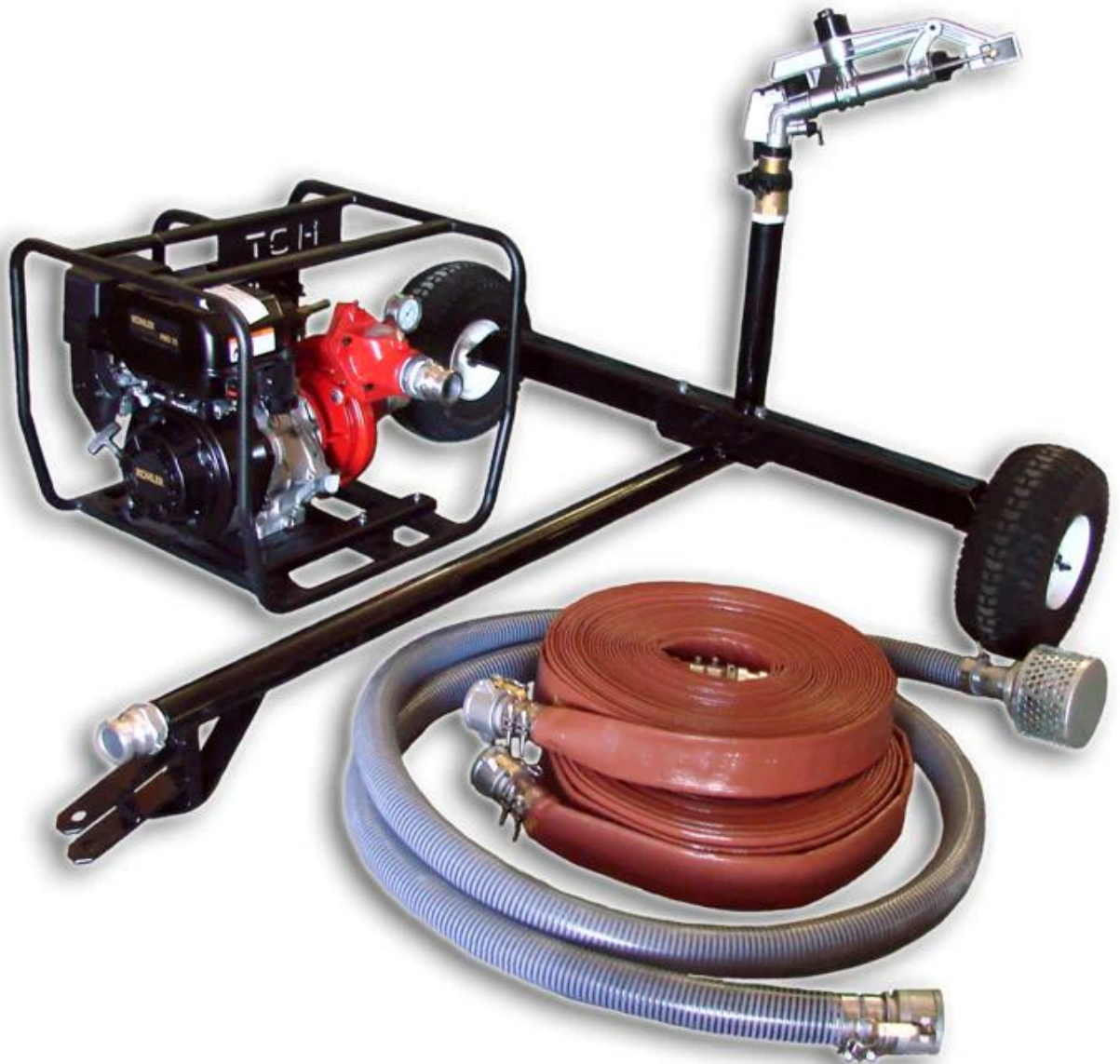
Hazen-Williams C: 140

Head Loss, h_f (ft): 38.032107

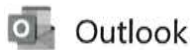
Energy Slope, S (ft/ft): 0.19016054

Units: ft=foot, m=meter, s=second.

Hazen-Williams Equation: $V = k C (D/4)^{0.63} S^{0.54}$ where $S = h_f / L$ and $Q = V \pi D^2 / 4$



<https://bigsprinkler.com/products/2000s-complete-irrigation-kit-w-high-pressure-pump>



RE: Treasured Mountains Holdings Preapplication Meeting Form

From Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>

Date Sun 1/5/2025 10:51 AM

To Brummond, Andy <abrummond@mt.gov>; Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Cc Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Hi Andy,

Sorry for the late follow-up from me. No further measurements on Willow Spring Creek will be needed for this application.

Best,
Kim



Kim Bolhuis | Groundwater Hydrologist

Water Sciences Bureau, Groundwater Studies, Water Resources Division

Montana Department of Natural Resources and Conservation

1424 9th Ave, Helena, MT 59601

MOBILE: 503-547-7789 **EMAIL:** kimberly.bolhuis@mt.gov

Website | **Facebook** | **X (Twitter)** | **Instagram**

How did we do? Let us know here: [Feedback Survey](#)

From: Brummond, Andy <abrummond@mt.gov>

Sent: Thursday, January 2, 2025 1:06 PM

To: Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Subject: RE: Treasured Mountains Holdings Preapplication Meeting Form

Lyra

Any word on the physical availability for Willow Spring Creek?

Thanks

Andy

From: Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Sent: Wednesday, December 18, 2024 9:55 AM

To: Brummond, Andy <abrummond@mt.gov>

Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Subject: RE: Treasured Mountains Holdings Preapplication Meeting Form

Hi Andy-

Thank you for sending these over. Please make sure to include these follow-up items when the form is completed and the fee (\$500) is paid.

When you/the Applicant has completed the Preapplication Meeting Form and follow-up information and are ready to pay the fee, please submit the full form. We can accept the electronic form with a certified electronic signature (DocuSign or Adobe Certified) for the second signature. If you choose to submit electronically, please combine the full Preapplication Meeting Form and follow-up information into one completed PDF. If you choose to mail in a paper copy of the information with the fee, please submit the full Preapplication Meeting Form along with all of the follow-up information.

We hope to get you information regarding the Willow Spring Creek physical availability back by the end of this week. Please let us know if when you anticipate sending in the complete Preapplication Meeting Form, if possible, as we have multiple staff out of the office next week.

Please let me know if you have any other questions.

-Lyra



Lyra Reynolds (they/them/she/her) | Regional Hydrospecialist
Bozeman Water Resources Office
Montana Department of Natural Resources and Conservation
2273 Boot Hill Court, Suite 110; Bozeman, MT 59715
DESK: 406-556-4500 **EMAIL:** lyra.reynolds@mt.gov
[Website](#) | [Facebook](#) | [X \(Twitter\)](#) | [Instagram](#)
How did we do? Let us know here: [Feedback Survey](#)

From: Brummond, Andy <abrummond@mt.gov>

Sent: Wednesday, December 18, 2024 8:50 AM

To: Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Subject: RE: Treasured Mountains Holdings Preapplication Meeting Form

Lyra

I have attached one more supplemental response (#46) that was not identified for follow-up, but I thought it would be helpful in conjunction with the . It provides the breakdown between flood and sprinkler that will be removed from irrigation. I also noticed that the #45 supplemental map incorrectly overlapped the acres remaining irrigated with acres to be removed in the northwest corner of the existing southern pivot. The attached map corrects this.

Thanks

Andy

From: Brummond, Andy

Sent: Tuesday, December 17, 2024 4:15 PM

To: Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Subject: RE: Treasured Mountains Holdings Preapplication Meeting Form

Thanks Lyra. I am following up with Mr. Gould to secure his initial signature.

Attached is the follow up information along with what I believe qualifies as an amended response to question 125.d regarding ditch length.

I have also attached an additional spreadsheet with the MBMG measurements for Willow Creek. Hopefully, this will assist Kim in determining the adequacy of the existing information.

Please let me know if you have questions or need additional information.

Andy

From: Reynolds, Lyra <Lyra.Reynolds@mt.gov>

Sent: Tuesday, December 17, 2024 11:30 AM

To: Brummond, Andy <abrummond@mt.gov>

Cc: Strasheim, Kerri <kstrasheim@mt.gov>; Ellis, Kendrew <Kendrew.Ellis@mt.gov>; Bolhuis, Kimberly <Kimberly.Bolhuis@mt.gov>; Rasmussen, Derek <Derek.Rasmussen@mt.gov>

Subject: Treasured Mountains Holdings Preapplication Meeting Form

Hi Andy-

Attached is a copy of the Preapplication Meeting Form from today's meeting (12/17/2024) for the Preapplication to Change by Treasured Mountains Holdings. I have sent this form to the Applicant via DocuSign to sign Page 57. You will receive a copy of this form from DocuSign.

The DNRC is going to review the suitability of the groundwater information you provided for Willow Spring Creek for a potential physical availability analysis (questions 161 – 163 in Preapp form). We will let you know soon whether this information would work or if any additional information will be needed.

Reminder that the Preapplication Meeting Form, including the \$500 fee, all follow-up information, and any amended responses, must be completed and returned to the Bozeman Office within 180 days (June 15, 2025). Please make sure to submit the Preapplication Meeting Form along with all the required information and the second signature page signed. The Department will review the form upon receipt and determine if the form is complete within 5 days of receipt. If the form is complete, the Department will complete a Technical Analysis within 45 days of receipt. If incomplete, the form will be returned to the Applicant and the remaining time in the 180 days may be used to complete the form.

The Bozeman Office does appreciate a heads-up for when this form may be submitted, so that we may ensure the proper staff will be able to review the form upon receipt.

Please let me know if you have any further questions.

-Lyra



Lyra Reynolds (they/them/she/her) | Regional Hydrospecialist
Bozeman Water Resources Office

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