GROUNDWATER MODEL AND BACKGROUND DATA WEST BILLINGS FLOOD MITIGATION AND GROUNDWATER RECHARGE STUDY

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November 2010

Project No. 100013850

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1.0 INTRODUCTION

This document presents data and analyses designed to facilitate groundwater modeling efforts, along with a preliminary groundwater flow model for the West Billings Flood Mitigation and Groundwater Recharge Study. The project is intended to identify and evaluate the feasibility of alternatives to mitigate flooding impacts in the project Study Area, shown on **Figure 1-1**, and to assess the potential of using those mitigation measures to provide recharge to groundwater in the West Billings area. This document includes modeling results of potential benefits from groundwater recharge of flood water.

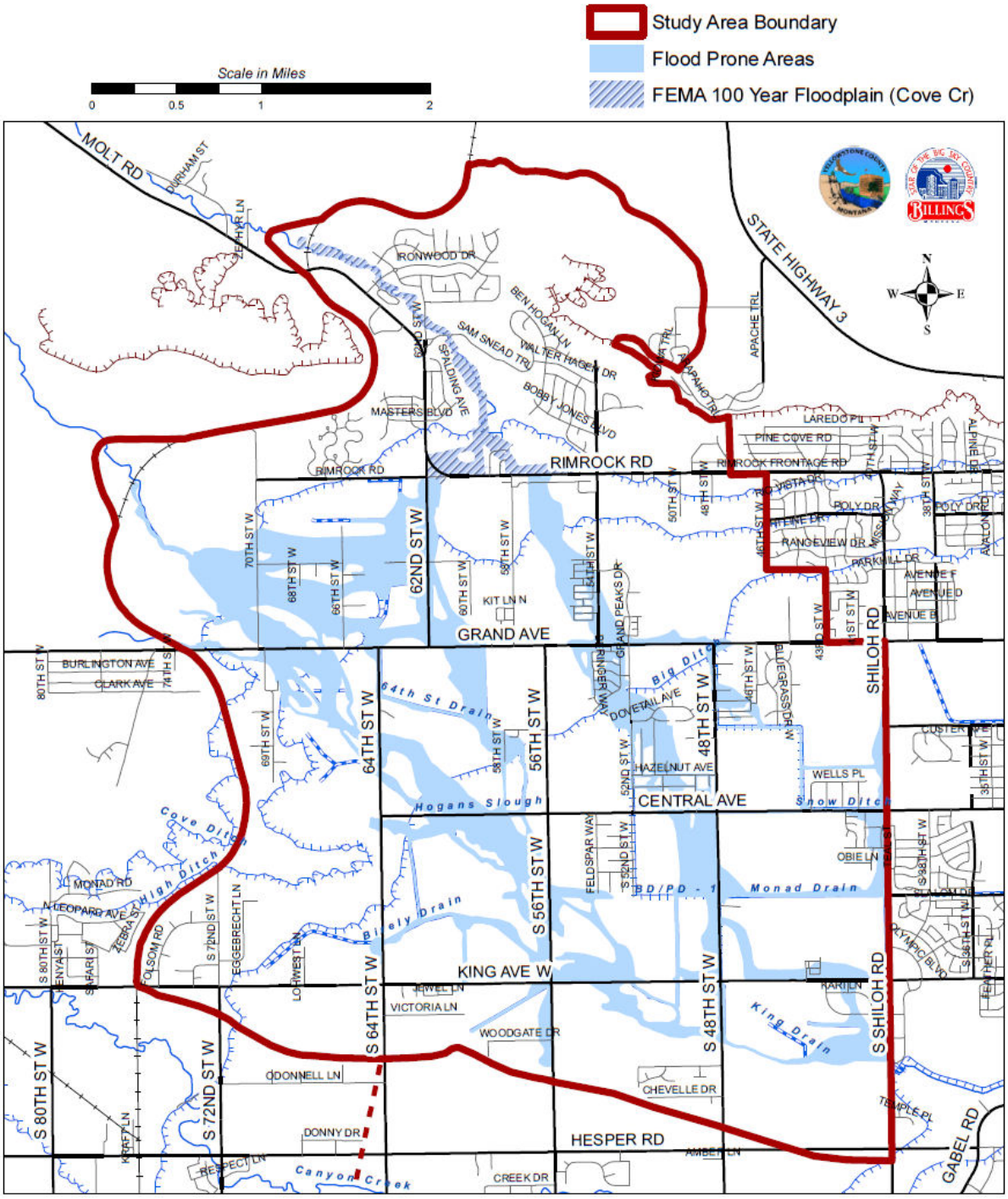


Figure 1-1. West Billings Study Area

The focus of efforts described in this document has been the northern portion of the Study Area because ongoing efforts by the Montana Bureau of Mines and Geology (MBMG) have already addressed the southern portion (see **Appendix B**). The MBMG has agreed to cooperate on this study by providing data and information from their model areas, and allow the use of their models to simulate potential groundwater recharge impacts from flood mitigation alternatives. In exchange, the detailed analyses developed north of the MBMG model areas and described in this document will be provided to the MBMG to facilitate possible expansion of their modeling efforts to the north.

To date, a series of documents and meetings have been completed for the West Billings Flood Mitigation and Groundwater Recharge Study that include the following:

- *Steering Committee Meeting*. Initial Steering Committee meeting to discuss goals and objectives of the study;
- *Problem Statement Report* (PBS&J, 2010a). Report outlining project goals and objectives;
- *Public Meeting*. Public meeting held on April 22, 2010 in Billings to present the Study and solicit input;
- *Existing Data Review Report* (PBS&J, 2010b). Report summarizing known data and analyses, along with data gaps identified as important for this study;
- *Additional Data Gathering Work Plan* (PBS&J, 2010c). Document outlining additional data gathering tasks;
- *Additional Data Gathering Report* (PBS&J, 2010d). Report summarizing additional data gathered, ongoing analyses, and site visits; and
- *Feasibility Study Draft Methodology and Preliminary Alternatives List* (PBS&J, 2010e). Technical Memorandum outlining proposed methodology for this feasibility study and including a list of potential alternatives. The memo was discussed in a subsequent meeting with the Steering Committee and modified into what is presented in this report.

This report has been organized into the following sections:

- 1.0 Introduction. This section listing document purpose and study milestones completed to date;
- 2.0 Data and Analyses. Results of detailed analyses of stratigraphy, changes in land use, and groundwater levels and well information;
- 3.0 Preliminary Model. Presentation of a preliminary groundwater flow model incorporating information from the data and analysis section. Also included are some example simulations of potential flood mitigation-groundwater recharge scenarios;
- 4.0 Conclusions. Summary of the results;
- 5.0 References. List of references cited in the report;
- Appendix A. A detailed summary of the methodology used and results from the stratigraphic analysis; and
- Appendix B. A summary of the MBMG ongoing modeling efforts in the area along with results from groundwater recharge simulations completed for this flood mitigation study.

2.0 DATA AND ANALYSES

This section presents a summary of data and analyses focused on the West Billings area lying to the north of the MBMG model areas. The focus on the northern area is because MBMG has already developed an adequate understanding of the areas covered by their models and the analyses presented below will better facilitate the expansion of modeling to the north.

2.1 Stratigraphy

Well logs obtained from MBMG's GWIC database for the West Billings area were reviewed to identify the subsurface stratigraphy of the area. A detailed summary of the methodology is provided in **Appendix A**. The list of well logs presented in previous documents for this study was reduced to include only those logs located north of the MBMG model areas, which includes a total of 824 borings at the locations as shown on **Figure 2-1**.

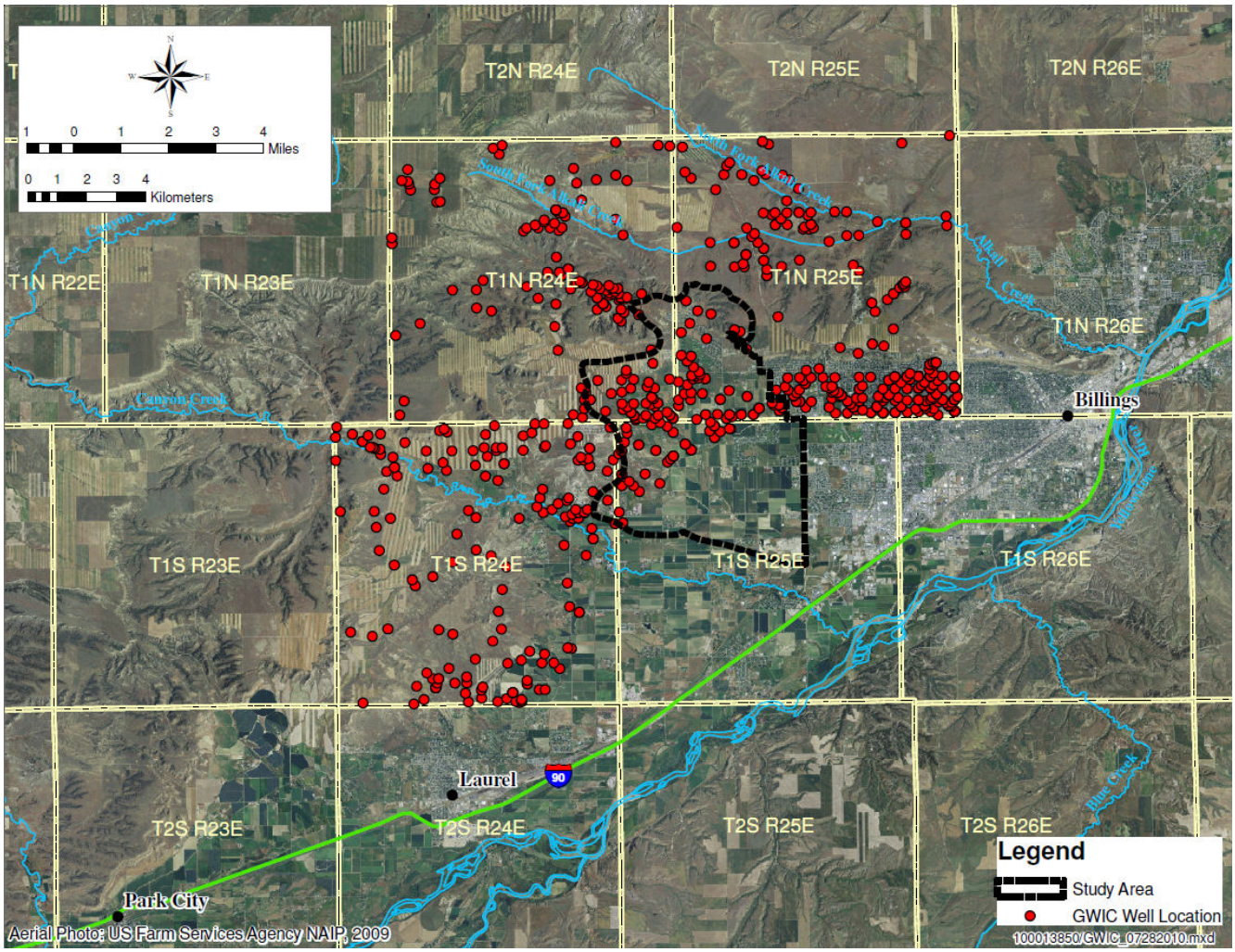


Figure 2-1. Location of MBMG GWIC Well Logs Reviewed

The information from the well log interpretation was compiled into a spreadsheet and was incorporated into GIS coverages shown on maps in this document. Each GWIC entry in the MBMG database was evaluated, and if a well log existed it was reviewed for the information noted below. Of the 824 GWIC en-

tries a total of 136 did not have well logs, leaving 688 to review for stratigraphic information. Information noted in the spreadsheet during review of the well logs included:

- Ground Elevation
- Fine-Grained Cap (FGC) bottom depth, bottom elevation, and thickness
- Aquifer (unconsolidated) thickness, type, and hydraulic conductivity values
- Bedrock/Bottom Clay depth and elevation
- Data Qualifiers and Comments

Data for the stratigraphy in the area were contoured and imported into GIS to develop maps of the fine-grained cap thickness, aquifer thickness, aquifer hydraulic conductivity, and depth to bedrock. The fine-grained cap thickness map is shown on **Figure 2-2**, and maps of the other properties are included in **Appendix A**. Well logs with information on the particular property were filtered to only include logs of good quality and reasonable accuracy for location, although some poorer quality points were added back in to have adequate spatial coverage. Data points clearly outside of the spatial extent of the unconsolidated aquifer were not included.

A series of wells were used to develop cross-sections along the lines shown on **Figure 2-2**. A north-south section (A-A' on **Figure 2-2**) is shown on **Figure 2-3**. A west-east cross-section (B-B' on **Figure 2-2**) is shown on **Figure 2-4**.

The stratigraphy in the area reviewed appears more complex than and not as uniform as it is to the south. In general the fine-grained cap thickens to the north and to the east, while the unconsolidated aquifer thins toward the north but maintains a consistent thickness east to west (**Figure 2-3 and 2-4**). ,

Hydraulic conductivity was estimated based on well log descriptions of the material. These should only be considered estimates because many of the descriptions do not clearly identify the relative amounts of coarse material. Water level and pumping information on the logs were used to get a more accurate estimates at select locations. The northern termination of the unconsolidated aquifer is not clear because as the aquifer thins the wells are commonly drilled into deeper units and as a result the shallower units are not described with much accuracy.

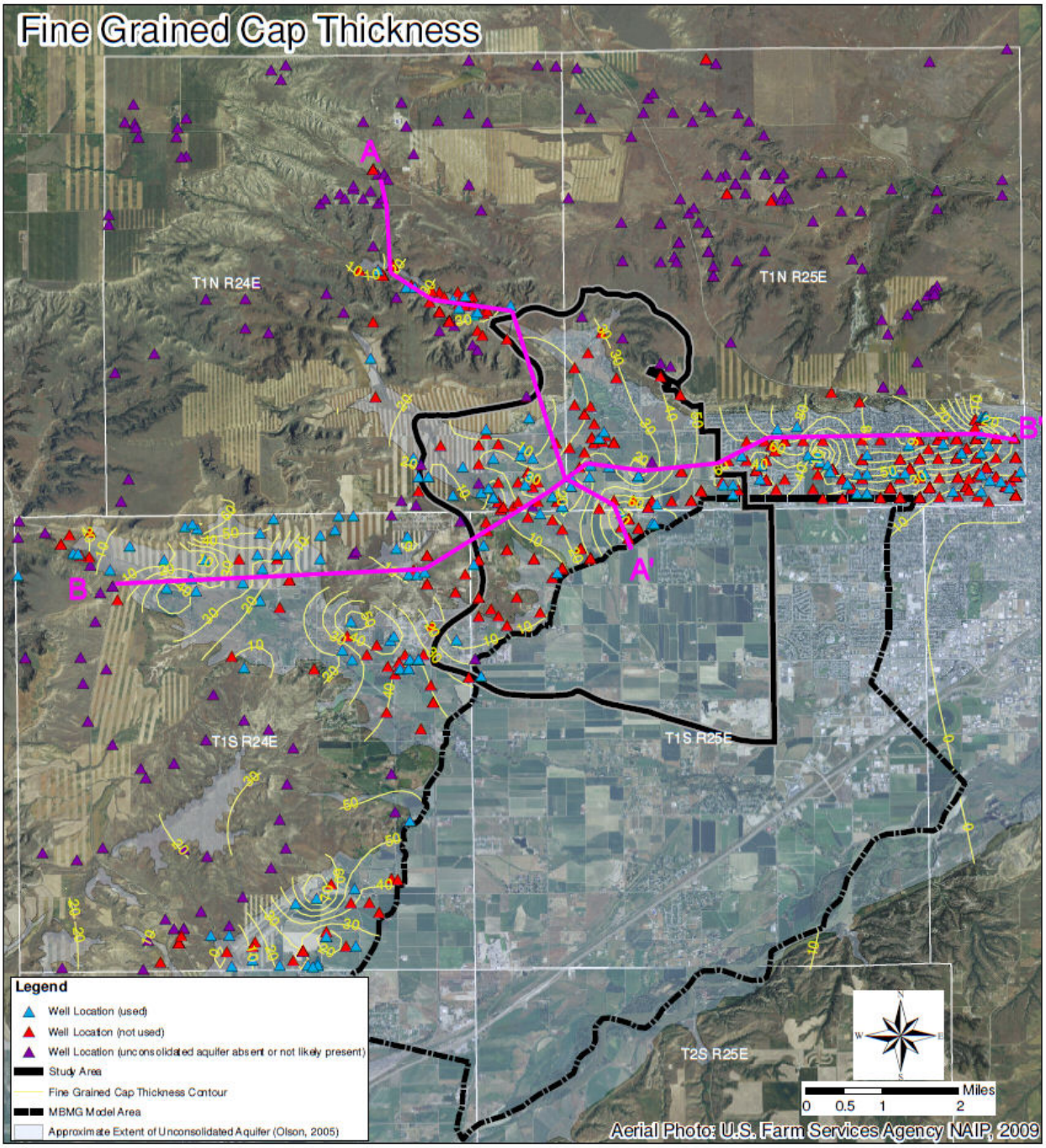
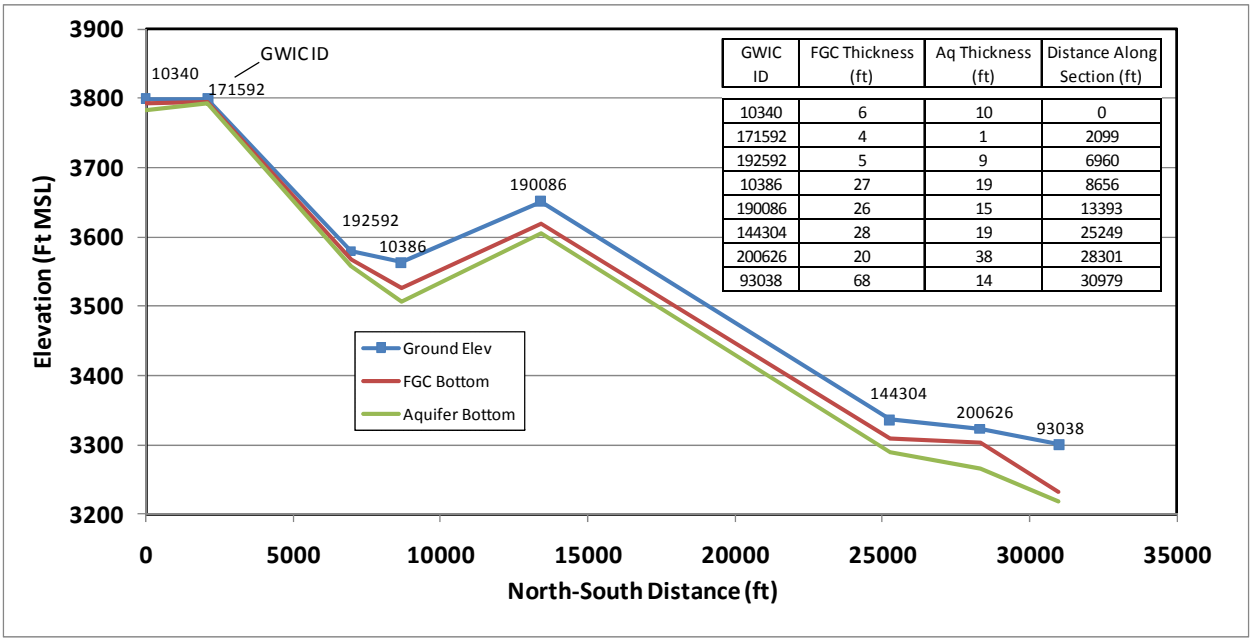
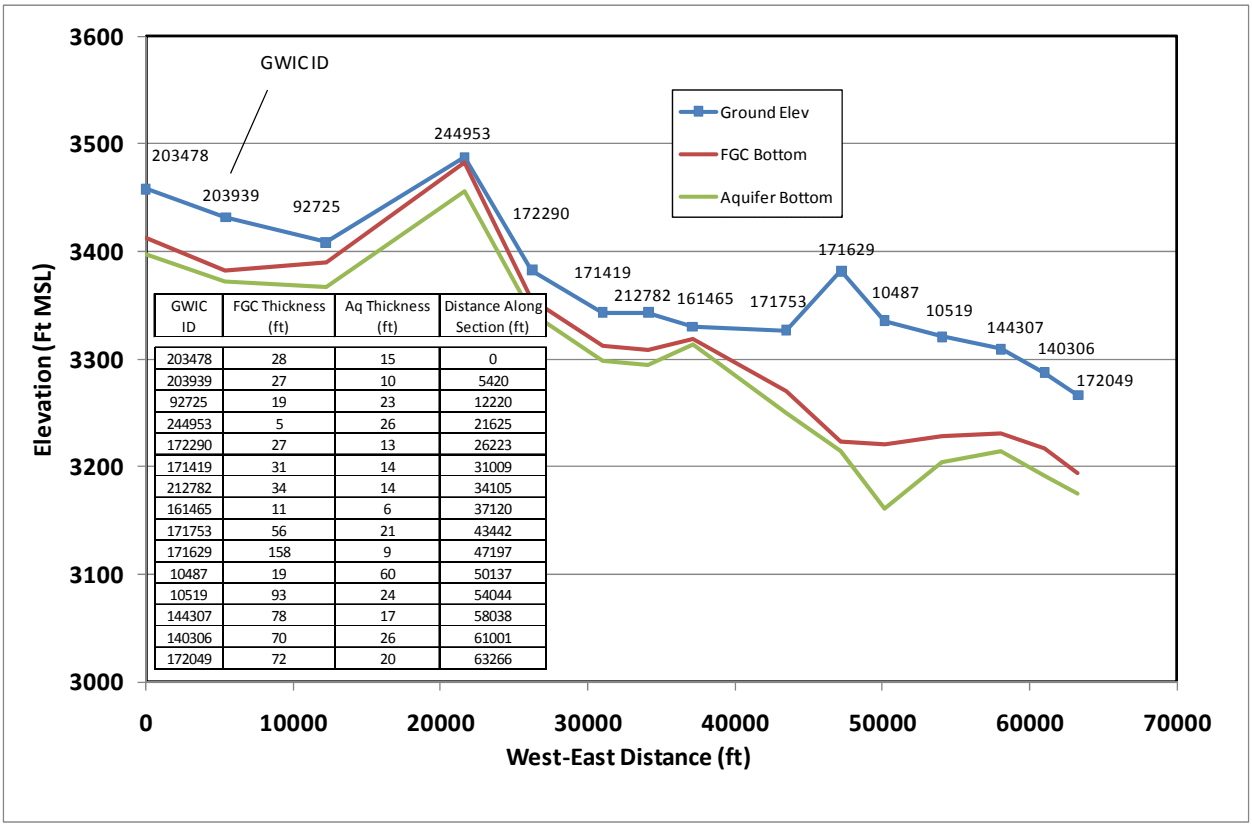


Figure 2-2. Map of Fine-Grained Cap Thickness and Cross-Section Lines



GWIC ID	FGC Thickness (ft)	Aq Thickness (ft)	Distance Along Section (ft)
10340	6	10	0
171592	4	1	2099
192592	5	9	6960
10386	27	19	8656
190086	26	15	13393
144304	28	19	25249
200626	20	38	28301
93038	68	14	30979

Figure 2-3. North-South Cross-Section



GWIC ID	FGC Thickness (ft)	Aq Thickness (ft)	Distance Along Section (ft)
203478	28	15	0
203939	27	10	5420
92725	19	23	12220
244953	5	26	21625
172290	27	13	26223
171419	31	14	31009
212782	34	14	34105
161465	11	6	37120
171753	56	21	43442
171629	158	9	47197
10487	19	60	50137
10519	93	24	54044
144307	78	17	58038
140306	70	26	61001
172049	72	20	63266

Figure 2-4. West-East Cross Section

2.2 Land Use and Recharge

Land use designations were developed for the West Billings area. The designations were specified for years 2000 and 2009 to match the dates being used in the MBMG modeling efforts. Current land use designations were previously presented in the *Existing Data Review* report (PBS&J, 2010b), but those designations were based on tax terminology, so for this evaluation an approach used by the MBMG was adopted which incorporates aerial photo interpretation.

Previously specified land use designations for 2000, shown below on **Figure 2-5**, were provided by MBMG and used as a starting point. The MBMG designations extend into a portion of the flood mitigation Study Area but do not cover the entire area. The MBMG designations were extended to the north by reviewing a 1996 aerial photograph of the area and specifying land use categories consistent with the MBMG designations. An aerial photograph for 2000 could not be found so it is assumed the 1996 conditions are close enough to those in 2000. Resulting land use designations are shown on **Figure 2-6**.

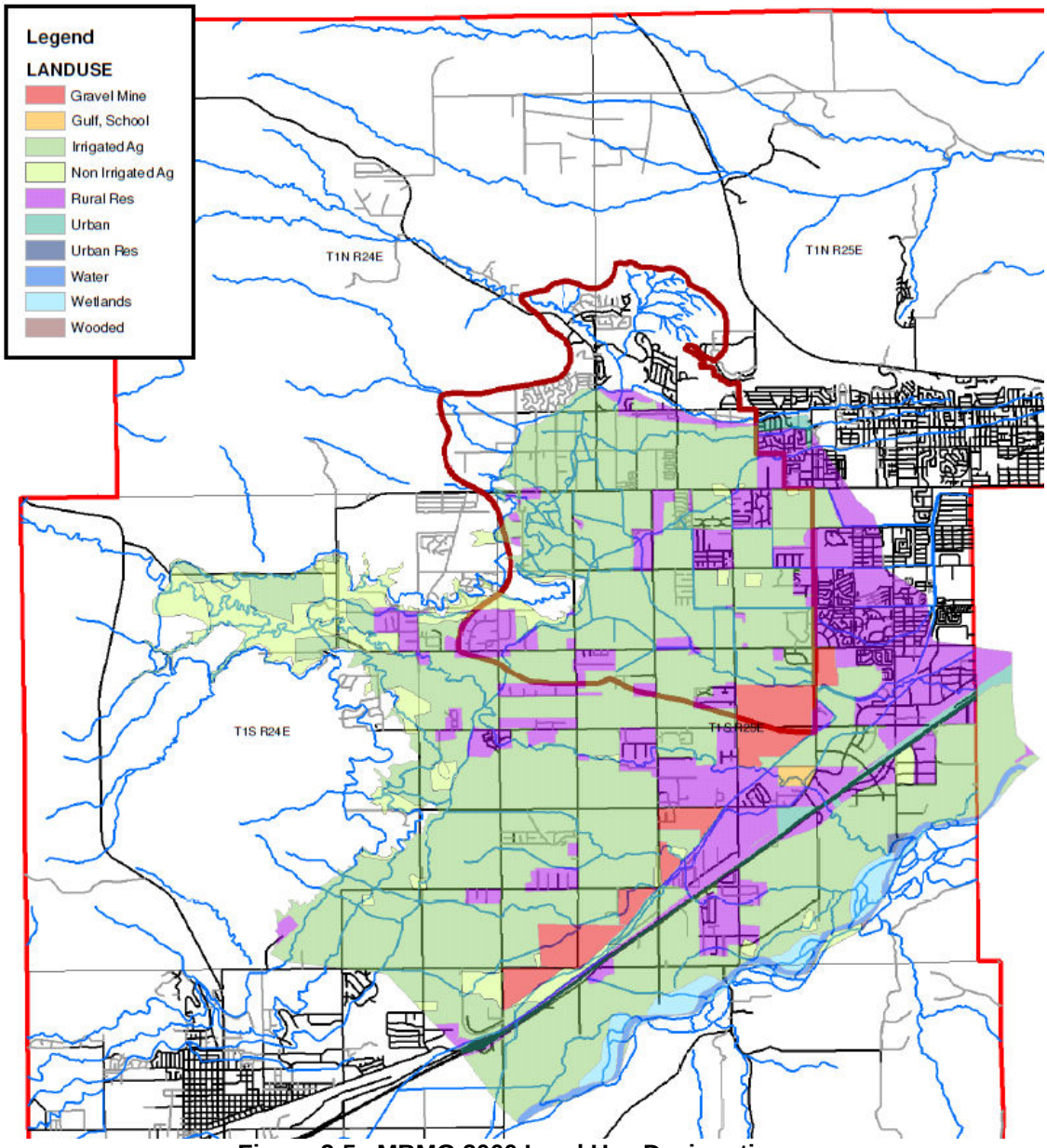


Figure 2-5. MBMG 2000 Land Use Designations

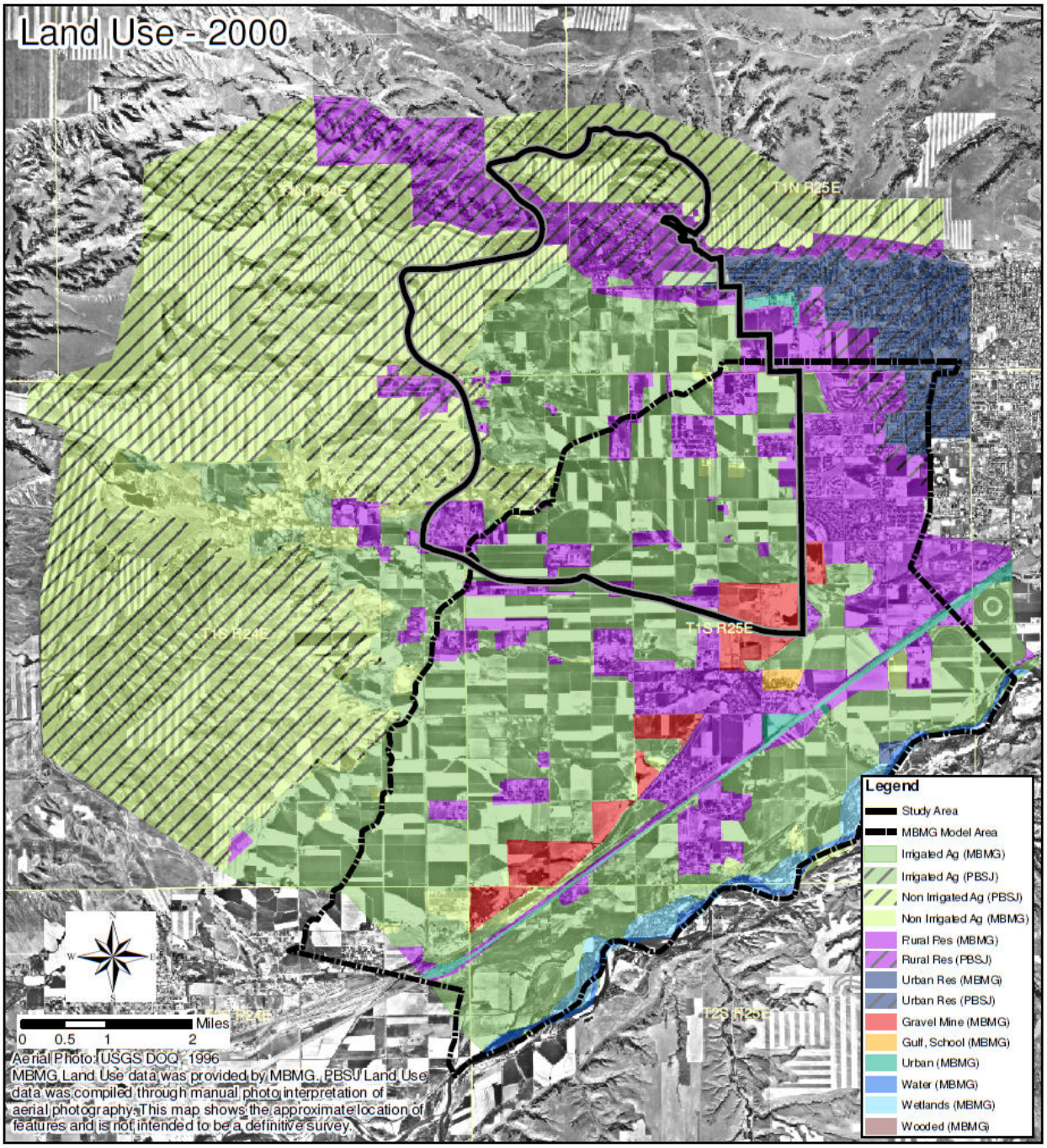


Figure 2-6. Land Use Designations for 2000

For 2009, the designated land uses identified for 2000 were overlain on an aerial photograph from 2009. The 2000 land uses were then reassessed and modified where changes in land use were evident. The results of the 2009 land use evaluation are shown on **Figure 2-7**.

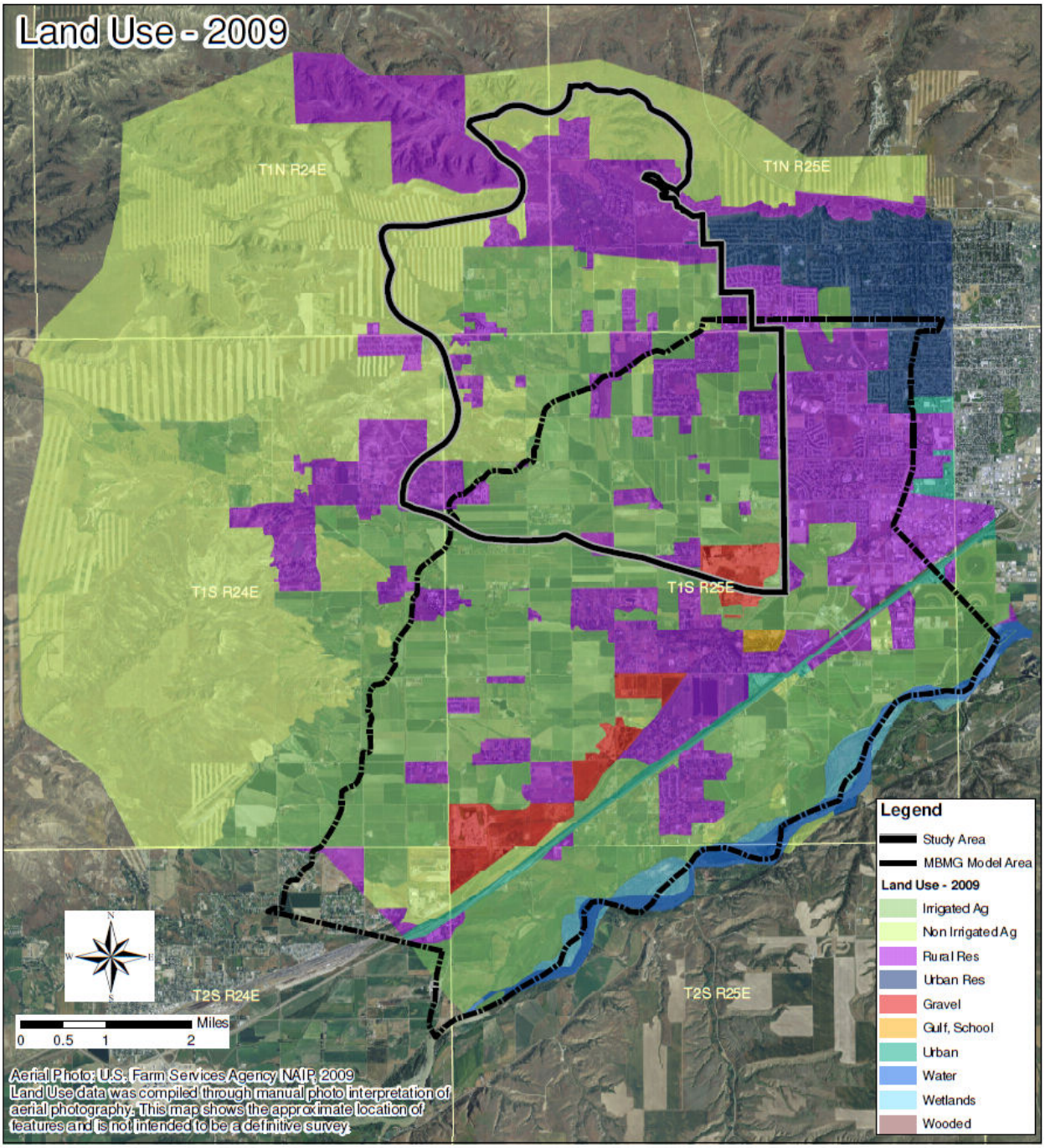


Figure 2-7. Land Use Designations for 2009

Land use changes in the West Billings area have a significant impact upon groundwater and surface-water conditions. Land use changes affect volume of water the land surface is capable of transmitting to the subsurface and the volume of runoff. Spatially quantifying these changes is critical for calibration of modeling efforts, and allows prediction of additional impacts under various future land use scenarios.

The *Existing Data Review* report presented a map showing land use change from irrigation to development for the period 1966-1999 from an MBMG study (Olson & Reiten, 2002), and is reproduced below on **Figure 2-8**.

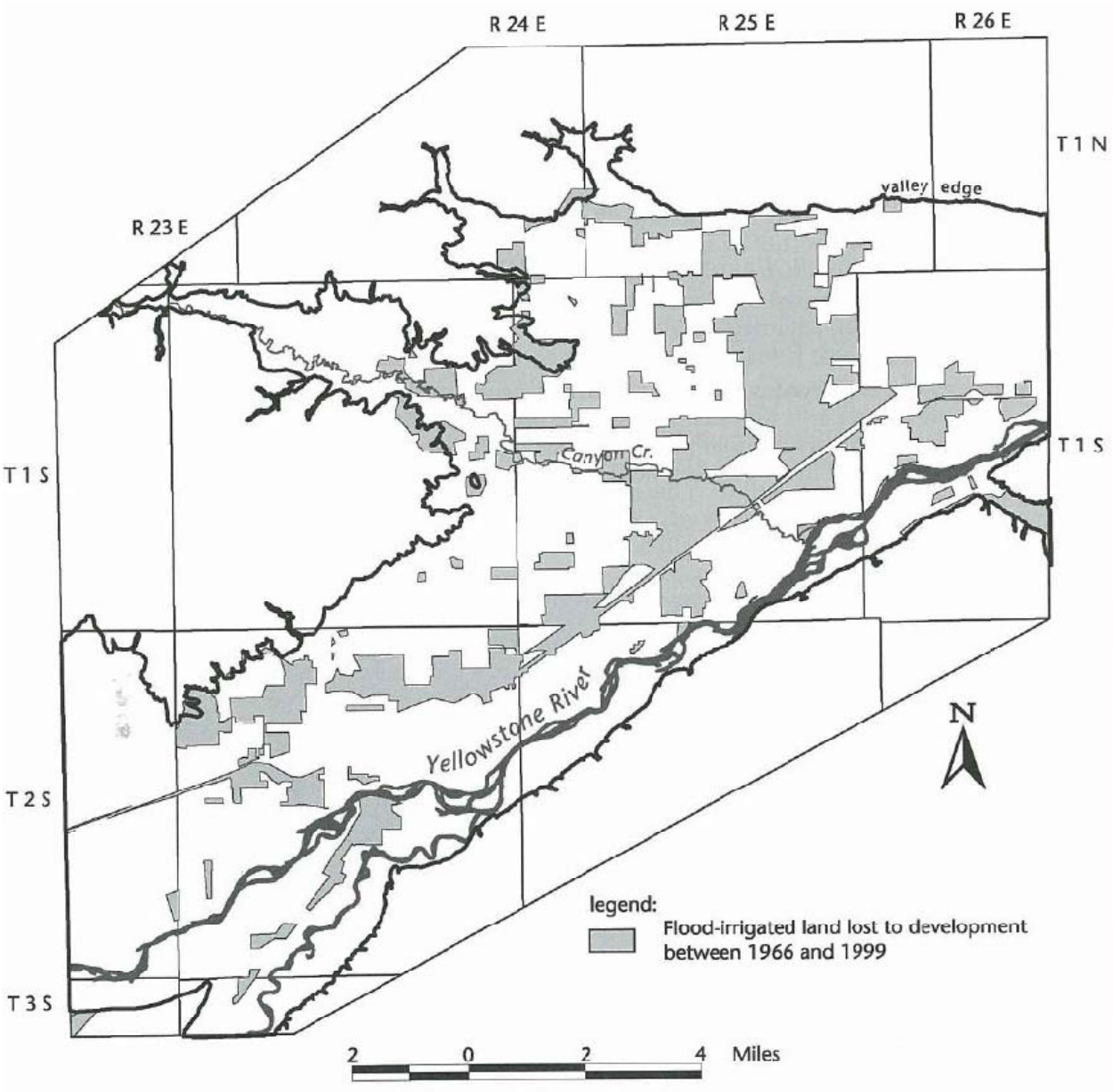


Figure 2-8. Loss of Agricultural Land 1966-1999 (from Olson & Reiten, 2002)

Land use changes for the period 2000-2009 were identified by comparing the land use coverages presented above and identifying areas where agricultural land has been lost to other uses. The results of this comparison are shown on the land use change map presented as **Figure 2-9**.

The comparison reveals that a total of 1,787.6 acres of agricultural land was lost to rural residential use between 2000 and 2009. About a quarter of the lost agricultural land falls within the Study Area for the flood mitigation and groundwater recharge study. A small amount (167.75 acres) of agricultural land was gained during that same period, most coming from former gravel mining areas.

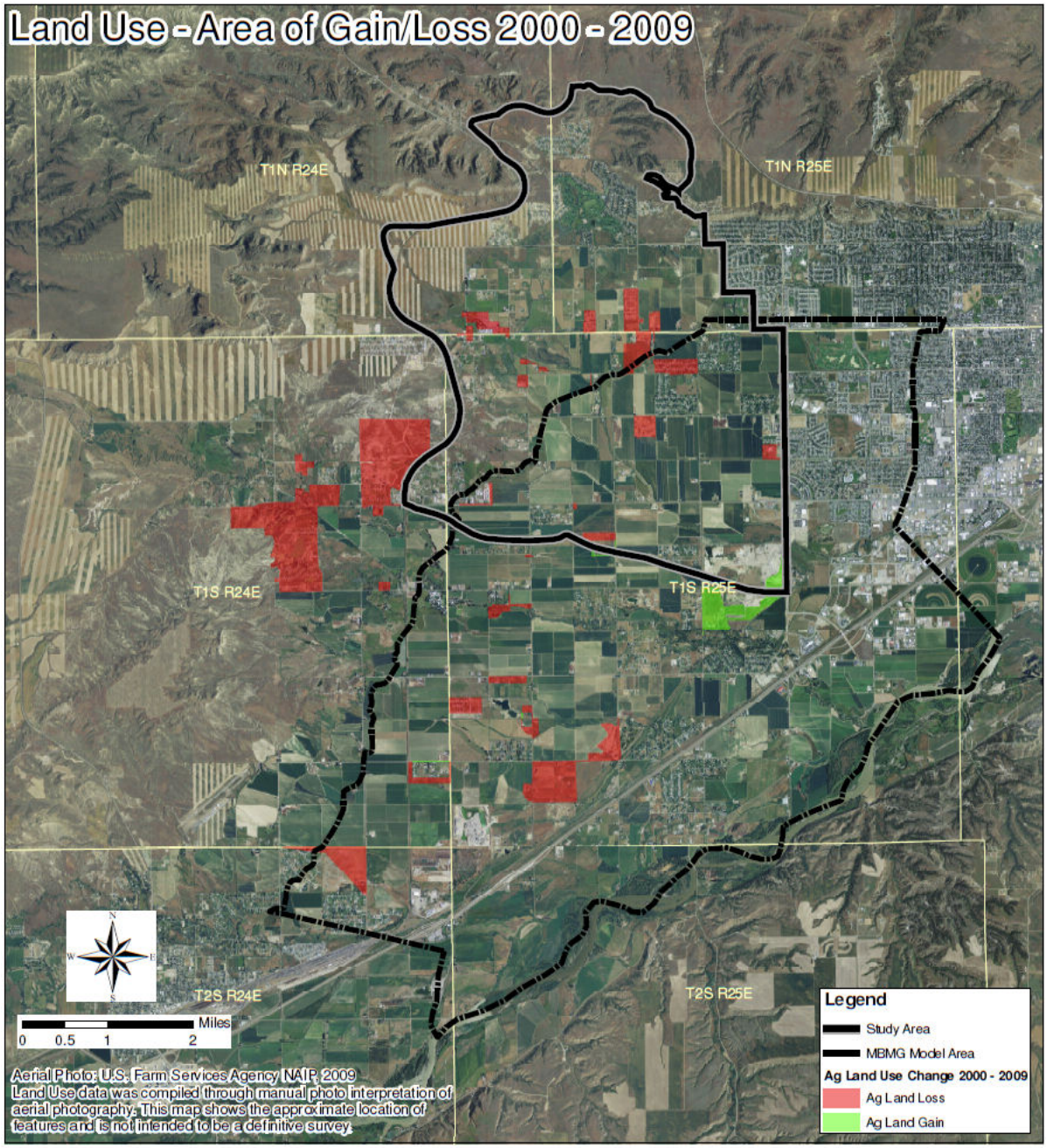


Figure 2-9. Loss of Agricultural Land 2000-2009

2.3 Groundwater Levels and Wells

A search was completed to identify wells with water level data for 2000 and 2009 in the West Billings area north of the MBMG models. In addition, pumping wells were identified from available water rights information. Results are presented below.

2.3.1 Wells and Available Data

Wells in the area north of the MBMG models with water level data were identified and are summarized in **Table 2-1**. The wells listed are those from the GWIC database that are shown above on **Figure 2-1**, and also from the USGS database. The USGS database included a number of additional wells that only had a single water level measurement from long before 2000 so those were not included in the list.

Table 2-1. Wells With Water Level Data: Northern Portion of West Billings Area

GWIC No.	Data Source	Name	Location				Coordinates NAD83		Well Depth (ft)	Ground Elev. (ft MSL)		Water Levels			Aq Code	Target Water Level Period	
			T	R	S	QS	X	Y		Log	Map	Start Date	End Date	No. Rdgs		2000	2009
10615	GWIC	EVERGREEN PARK (BILLINGS)	01N	25E	36	DDBB	2209983.2	561989.4	21	3205	3209	04/08/97	07/27/10	59	111ALVM	x	x
92757	GWIC	Walter Virgil	01S	24E	25	BABA	2169393.9	539130.6	50	3325		03/23/97	07/27/10	46	111TRRC	x	x
10457	GWIC	CARAWAY HERB	01N	25E	31	BABA	2181048.0	565450.8	19	3370	3366	11/08/99	10/09/00	12	111ALVM	x	
10471	GWIC	HANSON CLARENCE	01N	25E	33	ABDD	2193450.2	564893.1	138	3342	3345	11/08/99	10/09/00	12	111ALVM	x	
158556	GWIC	NORTHERN SKIES AVIATION	01S	24E	34	CBCB	2157588.9	530291.6	90	3475	3469	03/25/97	10/16/00	20	112TRRC	x	
158590	GWIC	CDP CONSTRUCTION	01S	25E	7	ADAC	2177504.6	553383.3	38	3320	3327	03/06/97	10/10/00	18	111ALVM	x	
158591	GWIC	DALTON JESSIE	01N	24E	35	CCCB	2168855.8	560765.6	28	3435	3435	03/06/97	10/09/00	21	111CLVM	x	
158941	GWIC	YELLOWSTONE COUNTRY CLUB	01N	25E	30	BBCA	2179876.7	570250.9	18	3415	3409	05/06/97	04/04/03	44	111ALVM	x	
171256	GWIC	WEBER-1	01S	26E	18	DDCC	2208575.6	562481.5	19	3169	3216	08/18/99	04/04/01	361	112YRT2	x	
705285	GWIC	SCHLAEPPI NEIL	01S	25E	6	AABB	2176592.4	559935.5	16	3355	3350	03/06/97	11/21/00	38	111ALVM	x	
92730	GWIC	OLSEN PETER	01S	24E	6	DABA	2145495.1	557412.4	50	3440	3438	03/21/97	03/21/97	1	111CLVM		
92738	GWIC	GRICE PAUL	01S	24E	12	CCCC	2167687.8	549928.4	50	3325	3323	03/24/97	07/11/97	2	111ALVM		
158552	GWIC	Ownwer Unknown From GWCP03	01N	25E	31	BAAD	2181766.6	565168.7	8	3360	3363	03/23/97	03/23/97	1	111ALVM		
158555	GWIC	OLSEN PETE	01S	24E	6	DAAB	2145701.8	557304.1	18	3440	3428	03/21/97	03/21/97	1	111CLVM		
158940	GWIC	YELLOWSTONE COUNTRY CLUB	01N	25E	30	CACB	2180975.8	567599.9	19	3390	3392	05/06/97	05/06/97	1	111ALVM		
705256	GWIC	USGS	01N	25E	25	CD	2207535.5	566153.0	119	3310	3309	10/01/68	08/01/69	14	???		
	USGS	454721108335001	01N	25E	36	CBDA	2207213.8	562628.0	12.5	3222		12/05/66	04/13/92	57	110ALVM		
	USGS	454611108400901	01S	25E	5	CD	2180438.1	555235.6	62	3294		10/22/68	04/06/88	21	110ALVM		
	USGS	454705108333101	01N	25E	36	CDDD	2208584.8	561022.3	17.2	3215		08/04/78	03/27/85	18	110ALVM		
	USGS	454721108335001	01N	25E	36	CBDA	2207213.8	562628.0	12.5	3222		12/05/66	04/13/92	62	110ALVM		

In order to be consistent with the MBMG modeling approach, the wells with water level data for 2000 or 2009 were identified and the location of these wells is shown on **Figure 2-10**. Only two wells could be found in the area searched that have water level data for both 2000 and 2009. There are eight additional wells that have water level data for 2000. The eight wells with only 2000 data could be visited to measure water levels in the future and the data used as an approximation of 2009 conditions.

A list of additional wells with water level data was received from MBMG and is included as **Table 2-2**. The list was received after completion of the search for wells with water level data and development of the groundwater model presented below and the data available were not pursued.

Table 2-2. MBMG List of Additional Wells With Water Level Data

92777	DAUGHERTY THOMAS	01S	24E	36	AABA	111TRRC
147423	SCOTT	01S	25E	3	BAD	111TRRC
151382	CHURCH OF CHRIST	01S	25E	4	DDDC	111TRRC
171246	BELL-1 HOFMAN	01S	25E	10	AABC	112TRRC
93073	EMMANUEL BAPTIST CHURCH	01S	25E	10	ADDC	111TRRC
156654	MACDONALD GREGORY	01S	25E	14	ABCA	111TRRC
171243	SLOUGH-1	01S	25E	15	ACCC	112TRRC
705291	USGS	01S	25E	17	AAAA	111TRRC
93305	ELDERGROVE SCHOOL	01S	25E	18	DDDC	111TRRC
93316	Yellowstone Treatment Ctr - Yellowstone Boys Ranch Well 2	01S	25E	19	BBAB	111TRRC
93329	BERGER, DON	01S	25E	20	A	111TRRC
93351	A-1 LANDSCAPING	01S	25E	21	AADD	111TRRC
171251	SAUNDERS-1	01S	25E	21	DAAA	112YRT2
171252	SAUNDERS-2	01S	25E	21	DAAA	112YRT2
171250	JONES-2	01S	25E	21	DDAD	112YRT3
171249	JONES-1	01S	25E	21	DDDB	211CLRD
93417	ZOO MONTANA INC	01S	25E	22	DADA	111TRRC
144832	ZOO MONTANA	01S	25E	22	DBAB	111TRRC
93432	ELYSIAN ELEMENTARY SCHOOL	01S	25E	24	AAAA	112TRRC
166073	ZEILER HAROLD	01S	25E	25	AABA	
171258	GOODMAN-1	01S	25E	25	BCBC	112YRT2
154210	GABEL EVERETT	01S	25E	26	AADD	111TRRC
162752	JONES ELLEN	01S	25E	28	CDCD	111TRRC
171248	THOMAS-1	01S	25E	29	BCCC	112YRT3
93528	SWANSON CLARENCE L.	01S	25E	30	DDDC	111TRRC
158589	CRYSTAL SPRINGS	01S	25E	33	ACDA	111ALVM
162779	LIMPP RICK AND MARCIE	01S	25E	34	ADDD	111TRRC
158946	REITEN PALMER	01S	25E	34	BBBB	111TRRC
158606	HICKS AL	02S	24E	2	DCAA	111TRRC

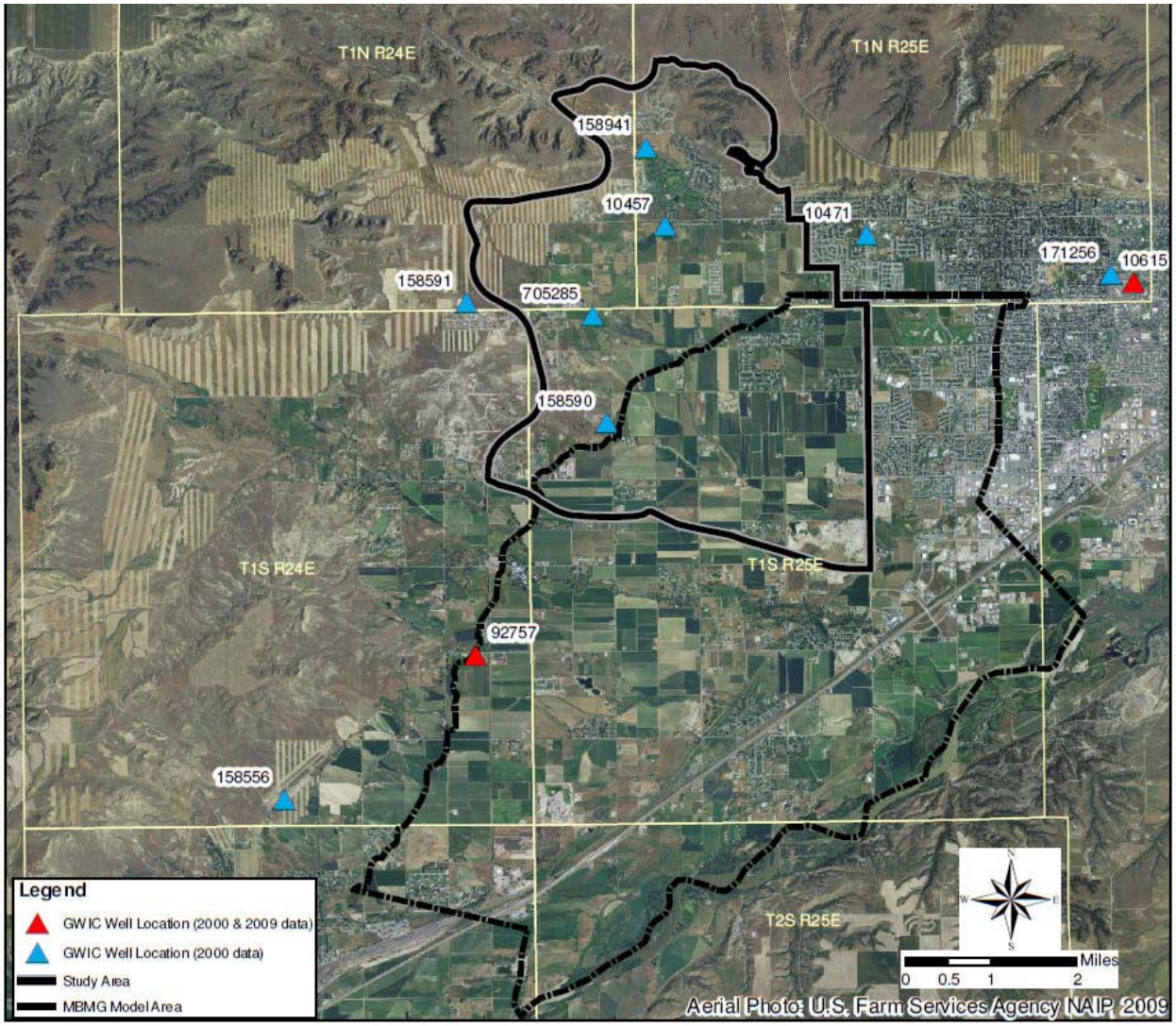


Figure 2-10. Wells With Water Level Data for 2000 and 2009

2.3.2 Pumping Wells

The Montana Department of Natural Resources and Conservation (DNRC) database was queried for wells with water rights that are located in the area north of the MBMG models. The resulting list of wells was further reduced to wells with pumping rates of 50 gpm or greater, with the results shown in **Table 2-3**. The location of these wells is shown on **Figure 2-11**.

The 50 gpm is an arbitrary cut-off and is used to identify wells that have what is considered a "significant" pumping rate and therefore should potentially be included in a groundwater model. The rates and volumes listed are what have been appropriated and may not reflect actual pumping rates. It is also important to point out that the DNRC listings only include wells that have acquired a water right. There are an unknown number of wells in the project area that are low yield wells and thus exempt from the water rights process. In many cases these wells aren't important to model, but in some cases such as developments that use a number of exempt wells instead of a single public water supply well it may be appropriate to include in a model.

Table 2-3. Select DNRC Water Right Listings-Area Not Modeled By MBMG

Map Key	WR Number	Name	TR	Sec	Q Sec	Well Dpth	Coordinates X	Coordinates Y	Purpose	Max Flow Rate	Max Flow Unit	Max Vol
203213-1	43Q 115422 00	REHBERG RANCH LLC	1N25E	15	SWNENE	120	580769.36	2200051.84	Commercial	500	GPM	333
						100	580077.10	2198083.33				
335061-1	43Q 107106 00	YELLOWSTONE VALLEY MEMORIAL PARK	1N25E	34	SESWSW	51	560902.23	2196171.26	Irrigation	150	GPM	50
320867-1	43Q 10441 00	PARKER DORIS E	1N24E	11	SWSW		582040.68	2169169.95	Stock Irrigation Domestic	90	GPM	27
188954-1	43Q 107159 00	ROCKY MOUNTAIN COLLEGE	1N25E	36	SWNENE	75	565065.62	2210022.97	Irrigation	110	GPM	25
137911-1	43Q 74729 00	YELLOWSTONE COUNTY SCHOOL DIST #2	1N25E	33	NENE	125	565200.13	2194452.10	Lawn & Garden	85	GPM	25
179119-1	43Q 101478 00	ROCKY MOUNTAIN COLLEGE	1N25E	36	SENWNE	77	565052.49	2209363.52	Irrigation	85	GPM	22.5
331358-1	43Q 80822 00	ASPEN MEADOWS PARTNERSHIP	1N25E	34	NWSESE		561614.17	2199458.66	Lawn & Garden	80	GPM	22.16
8038-1	43Q 2968 00	HALLBERG FAMILY TRUST	1N25E	11	SESESW		582158.79	2202673.88	Irrigation	102	GPM	21.4
285294-1	43Q 208170 00	WOODS EDITH J	1S25E	6	NWSENE		558704.07	2176847.11	Irrigation	100	GPM	21.4
157319-1	43Q 88845 00	YELLOWSTONE COUNTY SCHOOL DIST #2	1N25E	33	NESENE	188	564215.88	2194799.87	Irrigation	90	GPM	17.5
146679-1	43Q 79837 00	GREYSTONE CONDOMINIUM ASSN	1N25E	34	SENWSE	65	562263.78	2198789.37	Lawn & Garden	80	GPM	10
188951-1	43Q 107157 00	ROCKY MOUNTAIN COLLEGE	1N25E	36	NENWNE	92	565711.94	2209353.67	Irrigation	70	GPM	10
131213-1	43Q 70861 00	ROCKY MOUNTAIN COLLEGE	1N25E	36	SWNWNE	76	565042.65	2208704.07	Lawn & Garden	60	GPM	10
330075-1	43Q 72289 00	SHILOH UNITED METHODIST CHURCH	1N25E	33	NWSE	58	562539.37	2193175.85	Lawn & Garden	55	GPM	10
188953-1	43Q 107158 00	ROCKY MOUNTAIN COLLEGE	1N25E	36	SWNENE	85	565065.62	2210022.97	Irrigation	50	GPM	10

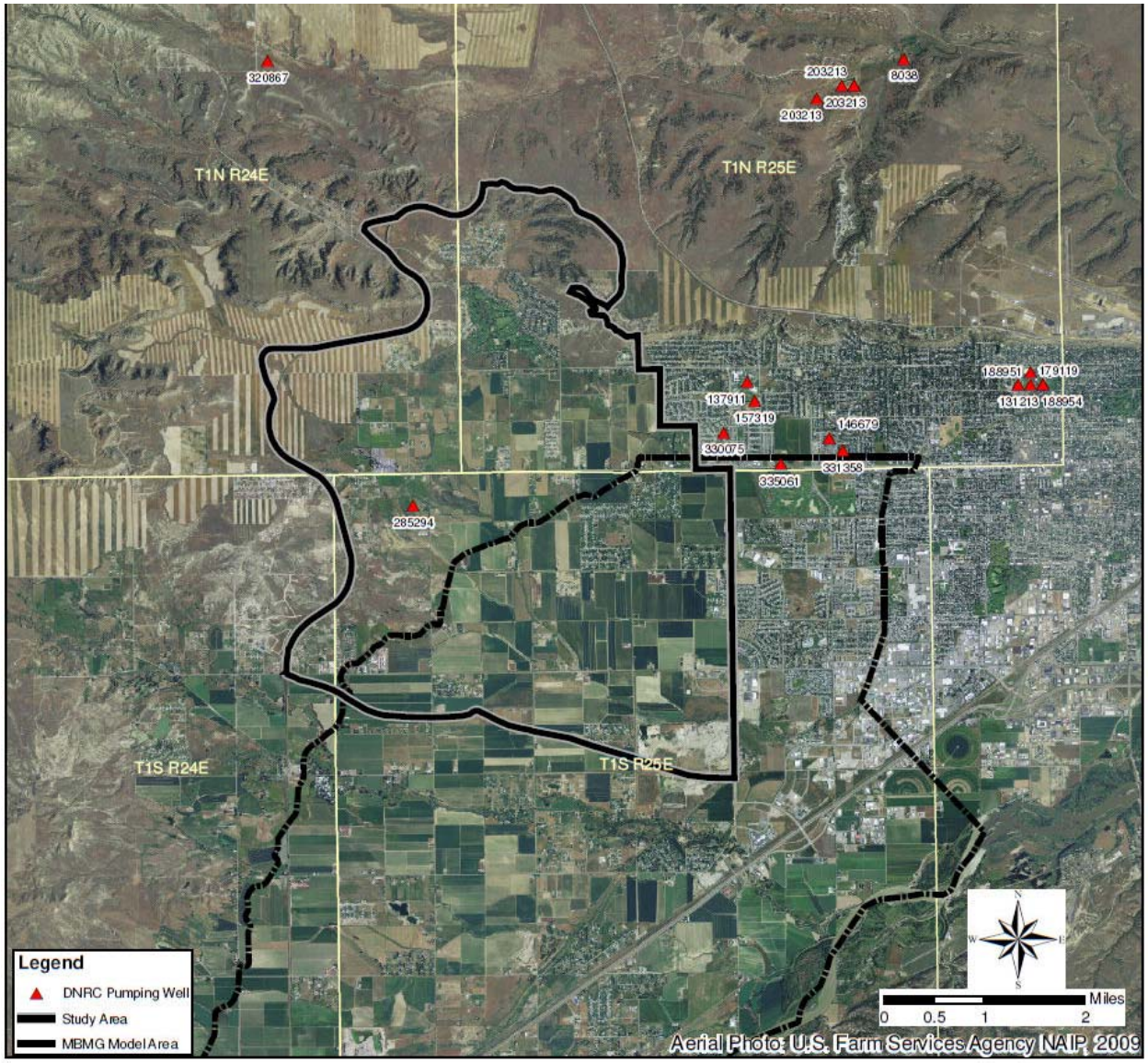


Figure 2-11. Wells in DNRC Database: 50 gpm or Greater

3.0 PRELIMINARY GROUNDWATER FLOW MODEL

The MBMG modeling areas extend northward as far as Big Ditch. The unconsolidated aquifer extends beyond Big Ditch to the northwest, and also to the north of the eastern portion of the MBMG models. A map showing the MBMG model areas and the previously mapped extent of the unconsolidated aquifer is shown on **Figure 3-1**. The boring log review presented in **Section 2.1** above suggests that the aquifer may extend beyond the area mapped.

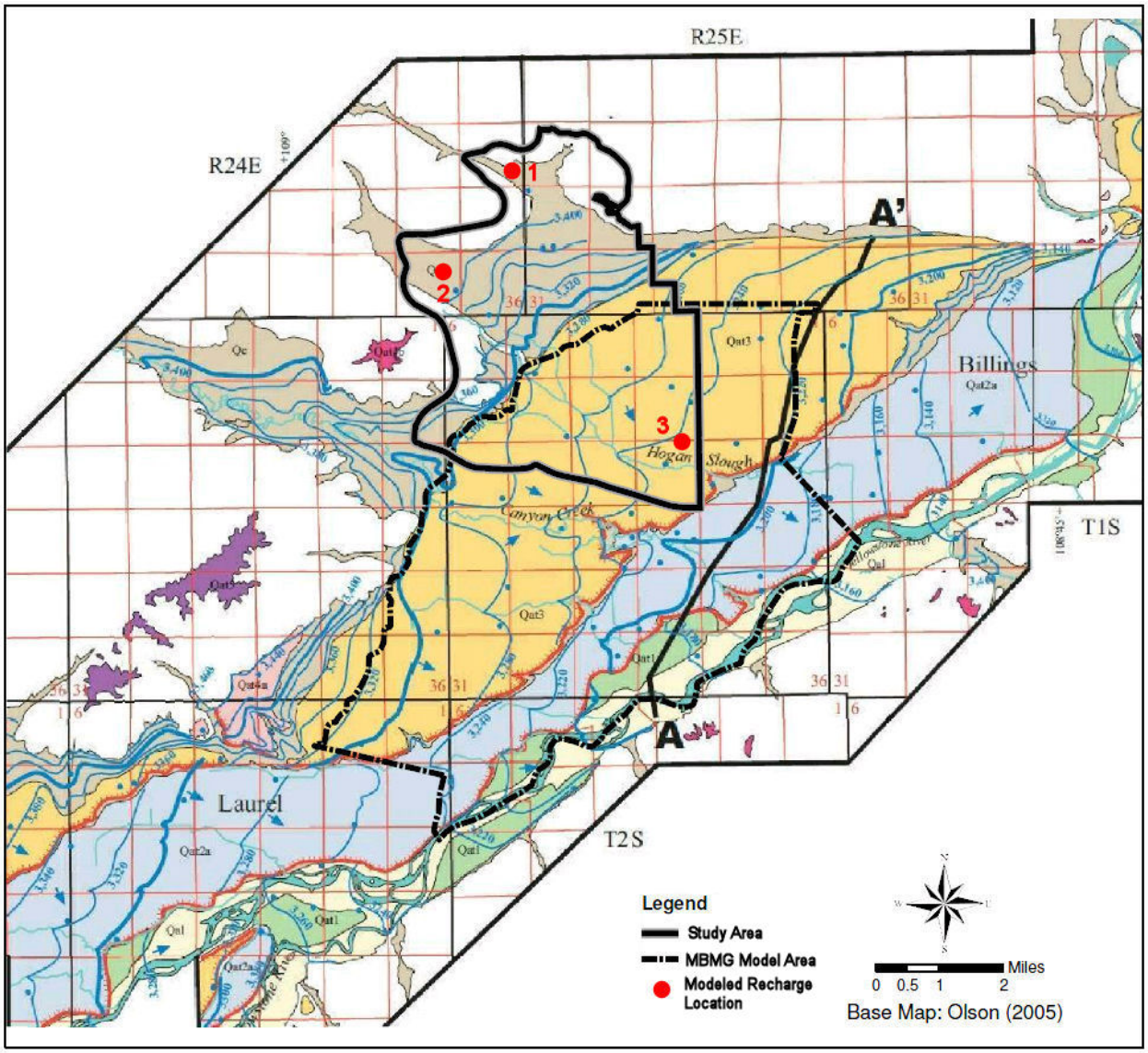


Figure 3-1. MBMG Model Area and Mapped Extent of Unconsolidated Aquifer

A preliminary groundwater flow model was created for this study that covers the area occupied by the unconsolidated aquifer to the north of the MBMG modeled areas. The model is considered preliminary because it has not been aggressively calibrated, is currently steady-state (pre-irrigation conditions), and will require some additional modifications to represent additional spatial features (see **Section 4**).

The model is presented below and was developed primarily to allow simulation of potential groundwater recharge effects from flood mitigation alternatives. Model construction was developed in a manner similar to the MBMG models and is designed to facilitate the potential extension of their modeling to the north.

3.1 Preliminary Model Construction

The preliminary model was constructed using the stratigraphic and land use information presented in **Section 2**, along with groundwater level and stratigraphic information from the MBMG models. Layer elevations and recharge information is detailed but some other aspects of the model have been simplified to facilitate development of a functional model for the purpose of simulating potential groundwater recharge from flood mitigation alternatives. Specifics of model construction are included below.

The model uses the code MODFLOW (McDonald and Harbaugh, 1988) and is housed in the user interface Groundwater Vistas, version 5.32 (ESI, 2007). Groundwater Vistas houses the properties and boundary condition information detailed below and uses that information to generate model files for MODFLOW simulations. Separate spreadsheets have also been developed that include all of this information to facilitate easier import into other user interfaces.

3.1.1 Grid and Domain

The model domain is shown on **Figure 3-2**. The southern extent of the model ends where the MBMG model areas begin. To the northwest the model domain includes the unconsolidated aquifer where it is believed to be present along Canyon Creek, Little Cove Creek, and Cove Creek. The eastern portion of the model extends to the bluffs north of Billings.

The model grid cells are not presented on **Figure 3-2** for clarity, but consists of 180 rows and 280 columns with each cell 200 ft by 200 ft. The model is made up of three layers, similar to the MBMG models, and includes a total of 41,433 active cells. Boundary conditions are also shown on **Figure 3-2** and are discussed further below.

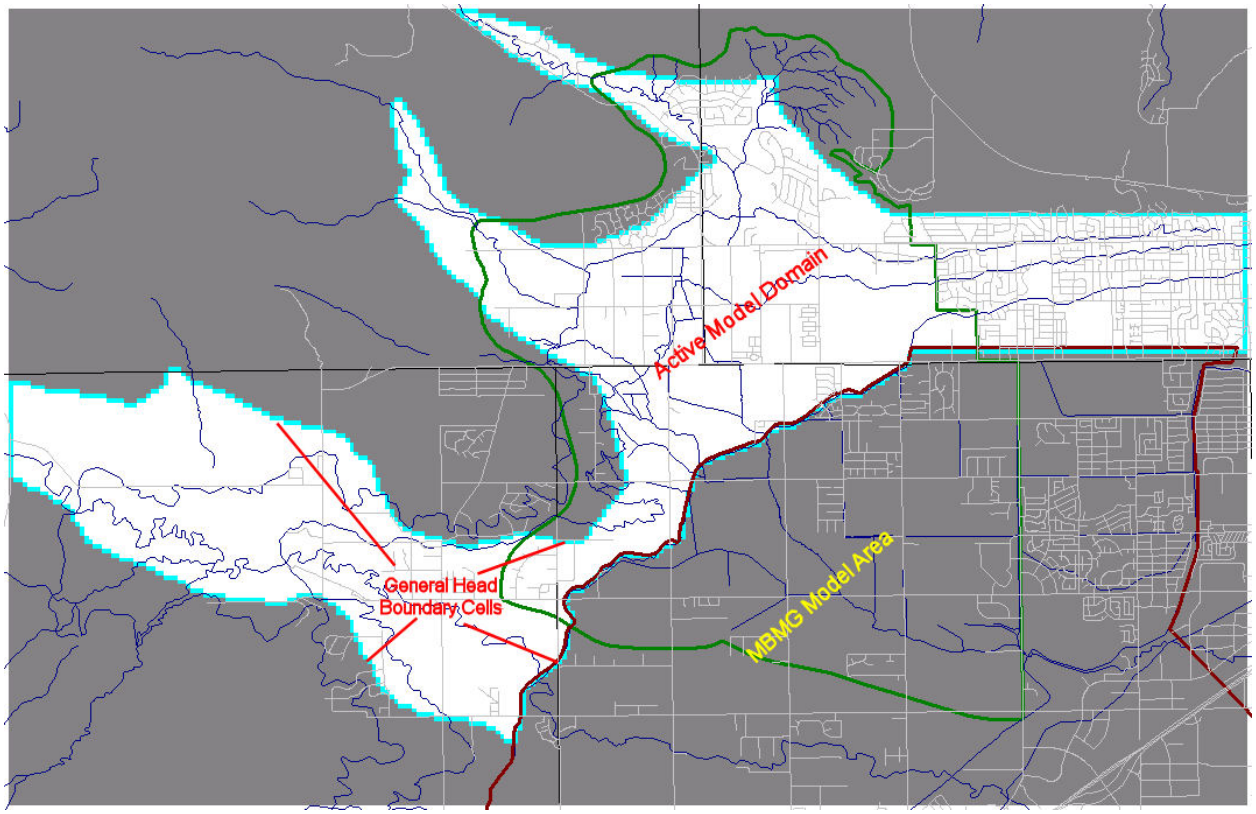


Figure 3-2. Preliminary Model Domain and Boundary Conditions

3.1.2 Properties

Model properties include layer elevations, hydraulic conductivity, and recharge. Layer elevations were specified by importing Surfer grids. The grids were developed to cover the area of the model domain and contoured using 200 ft centers to eliminate interpolation upon import into Groundwater Vistas. Imported fields include ground surface elevation, developed from DEM coverage, plus bottom elevations for the fine-grained cap, unconsolidated aquifer, and bedrock base. Bottom elevations for the fine-grained cap and unconsolidated aquifer were developed from the stratigraphic maps included in **Appendix A**, with a minimum thickness set at 5 ft. The bedrock thickness was set at 20 ft, consistent with the MBMG approach. In some cases, elevations were manually modified to address anomalies. A map of the top elevation assigned to layer 2 is presented on **Figure 3-3**.

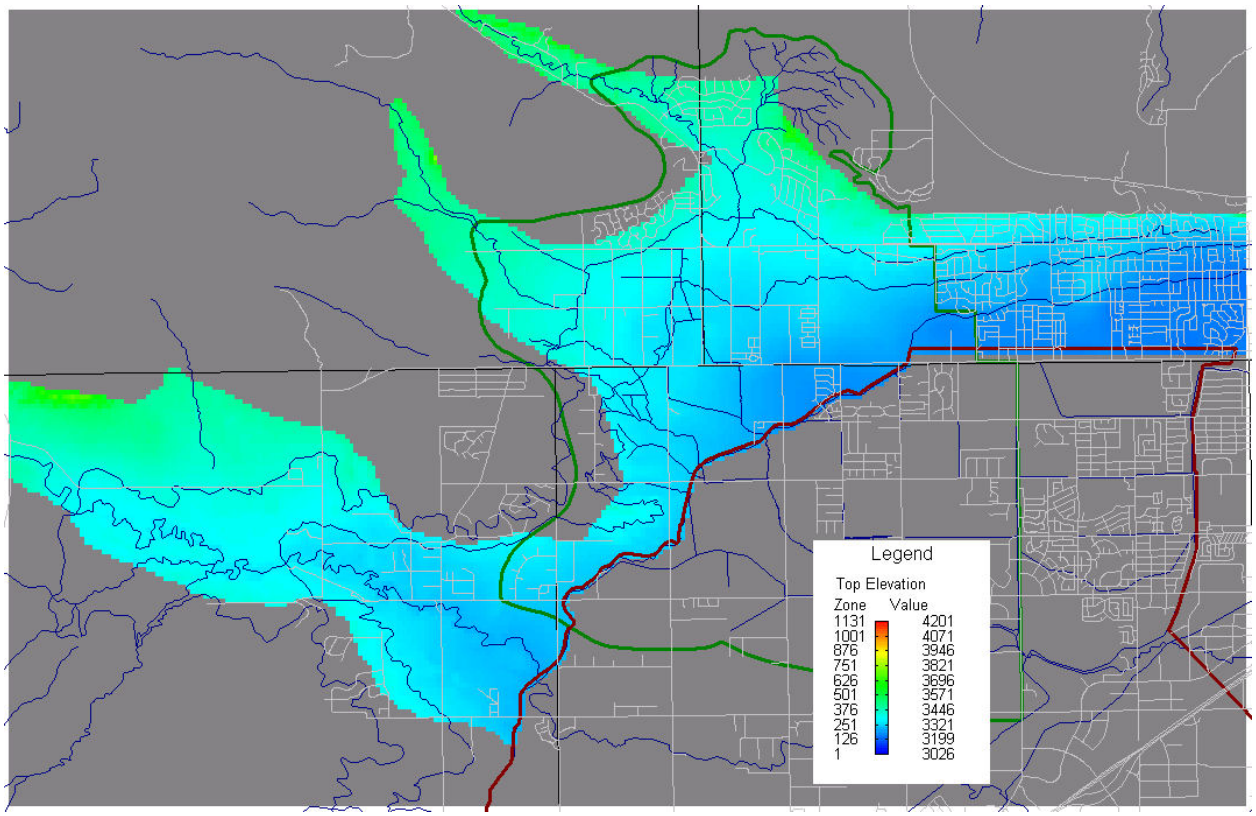


Figure 3-3. Model Layer 2 Top Elevation

Hydraulic conductivity values were assigned by importing a Surfer grid contoured in a similar fashion to those for layer elevations (see **Appendix A** for initial field of values). Prior to import, a total of 11 specific values were set such that the imported cells were assigned one of the specific values. Two of the set values were for model layer 1 and layer 3 consistent with the values in the MBMG model (see **Appendix B**). The other values are for the unconsolidated aquifer and range from 5-140 ft/d. The resulting hydraulic conductivity field for layer 2 is shown on **Figure 3-4**.

Model recharge values (**Figure 3-5**) were assigned to one of three values representing irrigated agriculture, non-irrigated agriculture, and housing. Land use designations shown on **Figure 2-7** were used to assign cell values. The model values specified are as follows:

- Housing, Zone 2, 0.00097 ft/d (MBMG value for April);
- Non-Irrigated Agriculture, Zone 3, 0.002 (estimated value)
- Gravel Pit, Zone 43 (not currently used)
- Irrigated Agriculture, Zone 5, 0.003 ft/d (modified from MBMG value for April of 0.0046 ft/d.

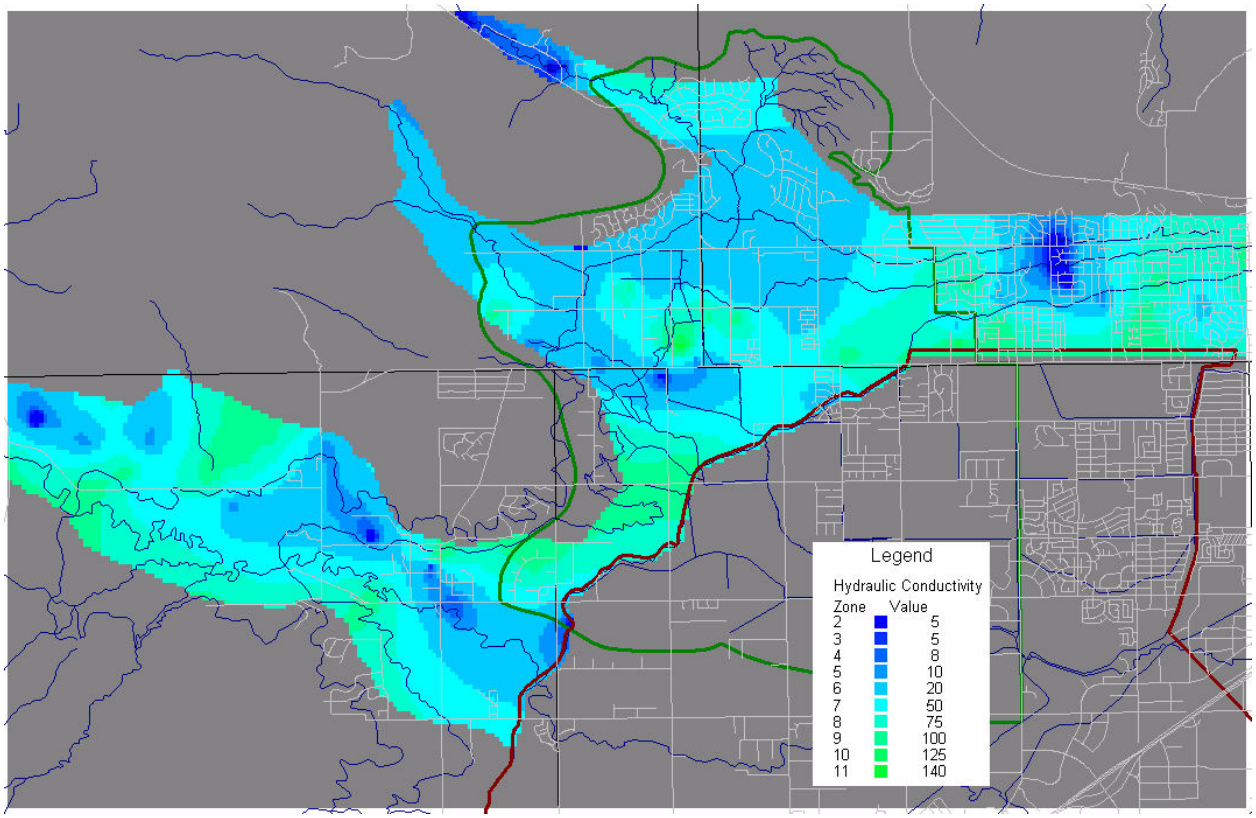


Figure 3-4. Model Layer 2 Hydraulic Conductivity Values

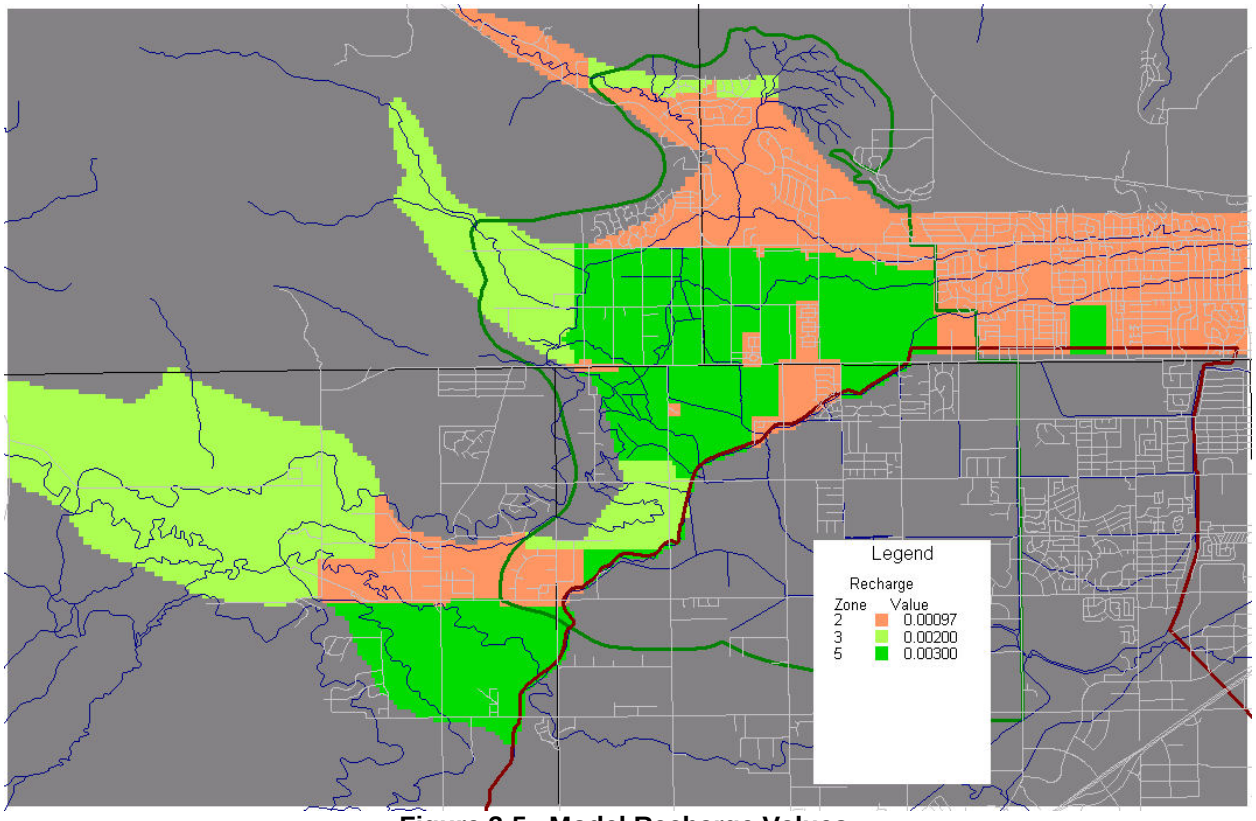


Figure 3-5. Model Recharge Values

3.1.3 Boundary Conditions

Other than no-flow cells (gray area on the model figures) the only boundary condition currently specified in the model are general head boundary cells (GHB's). The GHB cells are located along the perimeter of the active model area in layer 2, as shown on **Figure 3-3** above. GHB cells use an assigned value of water level, or head, and a calculated conductance term to let water in or take it out of the model.

The head values assigned to the GHB cells along the perimeter of the MBMG model area and the easternmost boundary were calibrated values for April from the MBMG model. Heads for the other GHB cells were initially set to the top elevation for layer 1 and subsequently lowered in places.

The conductance term for all GHB cells is based on assigned values of hydraulic conductivity (10 ft/d), saturated thickness (10 ft) and cell width (200 ft). This is a simplified approach and future versions of the model may incorporate the actual hydraulic conductivity and saturated thickness in each cell rather than common values.

3.2 Base Simulation

Model calibration consisted of a qualitative review of the simulated groundwater contours rather than the typical aggressive approach using observed heads at specific points. This simplified assessment of the model was done in part due to time constraints and also because a thoroughly calibrated model was not necessary to meet the modeling goals for this study. The review included using two points with measured water levels and also a visual comparison to previously developed groundwater contour maps (**Figure 3-1**). Resulting groundwater elevation contours for model layer 2 for the "base case" simulation are shown on **Figure 3-6**. The contours match the general pattern of those on **Figure 3-1**, but because the model represents more current conditions an exact match to the older contours was not attempted. Simulated groundwater levels were within 2 ft of measured values at two points within the model domain. Additional observed water level points will be needed for future calibration efforts.

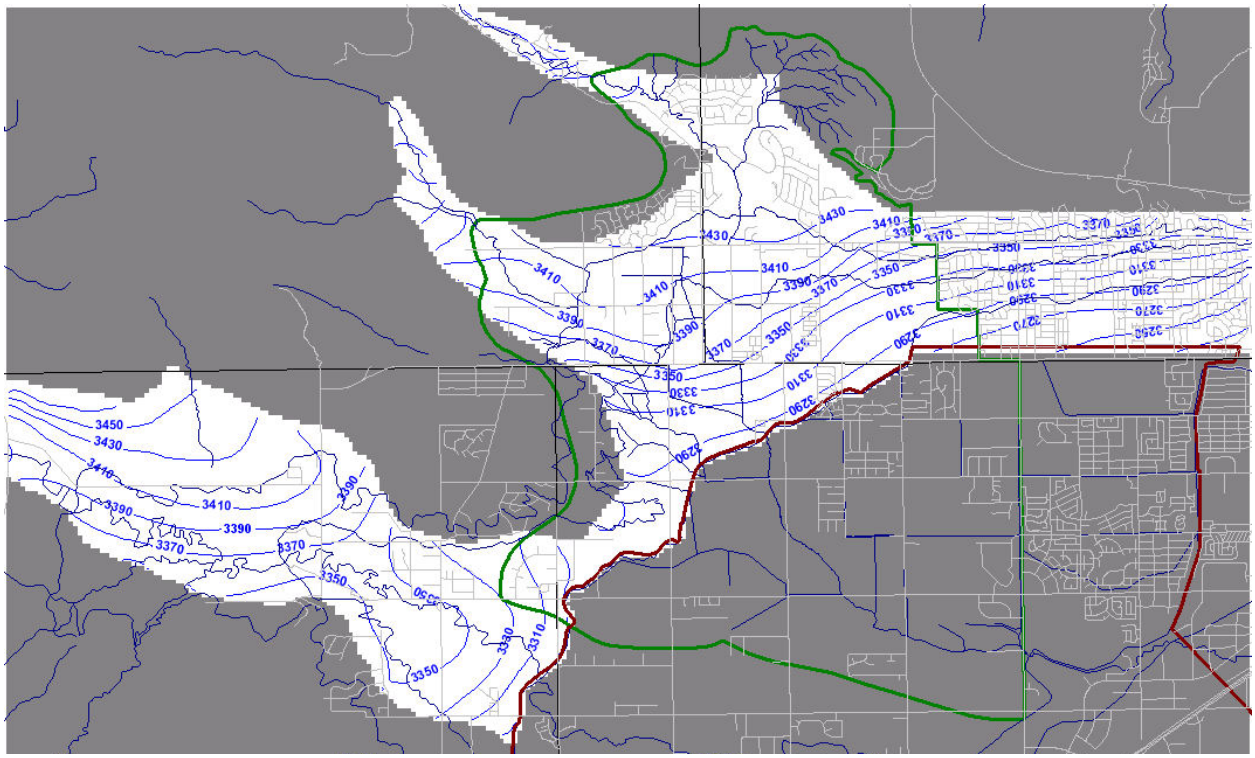


Figure 3-6. Base Case Groundwater Elevation Contours: Model Layer 2

3.3 Groundwater Recharge Simulations

Potential groundwater recharge simulations were completed for three locations, as shown on **Figure 3-1**. Two locations, Cove Creek and Little Cove Creek, are in the domain of the preliminary model presented in this section. The third location, Sharptail Pond, is located in the northern MBMG model domain. The MBMG model and recharge simulation results are included as **Appendix B**.

Two simulations were completed for each location. The simulations consisted of applying additional water for a month at the rates shown in **Table 3-1** for a 10-year and 100-year flood event. Surface water modeling provided the total volume of water expected for each of these events, and the total volume was subsequently reduced based on assumed losses due to evaporation and drainage through surface water.

Points were identified in the models at various distances downstream from the potential reservoirs to evaluate changes in water levels on a monthly basis resulting from the additional recharge. The preliminary model was converted to transient with monthly time steps, although the conditions were held at those of the steady-state model for each month with the exception of the additional groundwater recharge.

Table 3-1. Groundwater Recharge Rates and Volume for Modeling Scenarios

100-year

Site	Location	Area			Available Water				Rate (ft^3/d)	
		acres	ft^2	# cells	Ttl (af)	Lost (af)[1]	Rech (af)	Rech (ft^3)	Total	Per Cell
1	Cove Creek	55	2,395,800	59	550	275	275	11,979,000	386,419	6,549
2	Little Cove Crk	48	2,090,880	52	484	242	242	10,541,520	340,049	6,539
3	Sharptail Pond	30	1,306,800	32.67	120	19.5	100.5	4,375,166	141,134	4,320

10-year

Site	Location	Area			Available Water				Rate (ft^3/d)	
		acres	ft^2	# cells	Ttl (af)	Lost (af)[1]	Rech (af)	Rech (ft^3)	Total	Per Cell
1	Cove Creek	55	2,395,800	59	350	175	175	7,623,000	245,903	4,168
2	Little Cove Crk	48	2,090,880	52	300	150	150	6,534,000	210,774	4,053
3	Sharptail Pond	30	1,306,800	32.67	75	19.5	55.5	2,418,495	78,016	2,388

1 Water lost to evaporation & downstream surface flow (Site 1 and 2) or just evaporation (Site 3)

3.3.1 Cove Creek Simulations

The potential reservoir site for groundwater recharge of flood water at Cove Creek is shown as Site 1 on **Figure 3-1**. The site would cover an area of approximately 55 acres, but the exact location has not yet been specified. An approximation of the Cove Creek reservoir area was developed in the preliminary model and is shown on **Figure 3-7**. Also shown on the figure are the location of four model/monitoring points located at distances of 100, 1000, 2000, and 5000 ft from the downgradient end of the potential reservoir.

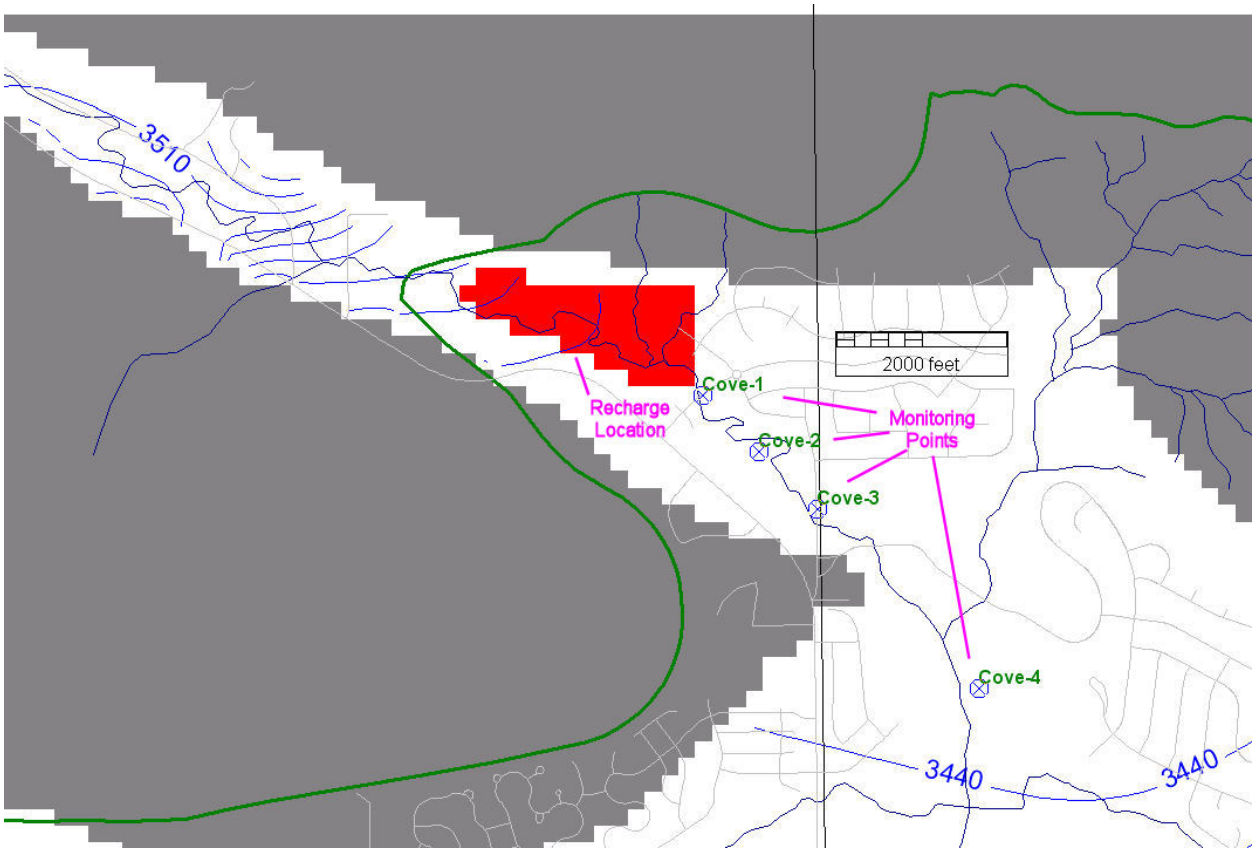


Figure 3-7. Model Setup for Cove Creek Groundwater Recharge Simulation

The reservoir was represented in the model as injection wells in layer 2. Rates used are shown in **Table 3-1** and are 6,549 ft^3/d for the 100-year event and 4,168 ft^3/d for the 10-year event for each cell. A total of 59 wells were used to represent the reservoir.

Results of the 100-year and 10-year recharge events are shown on **Figure 3-8** and **Figure 3-9**, respectively. The results show that, given the model limitations and the assumptions of a 55-acre reservoir that can route 50% of the water from a 100-year or 10-year flood event into the groundwater, that water levels might be expected to rise 1-2 ft immediately downgradient of the reservoir, with the effect decreasing to almost nothing a distance of 5,000 ft away. The water level rise will be realized for some period of time after the recharge event though, with a rise of less than 0.5 ft still present near the reservoir after 4 years. At a distance of 1,000 ft from the reservoir the maximum water level rise of 0.3-0.5 ft isn't realized until about two years after the recharge event.

These results suggest that routing flood water into the shallow aquifer may not have a significant effect and the effect will be localized to within a mile or so of the point of recharge. However, the effect appears to be longer lasting and if more frequent flood events can be utilized and even with some regular input of water, a greater impact could result.

To evaluate the effect of multiple recharge events a third simulation was performed combining flood events along with an annual input of water. The simulation assumes the 100-year flood event in the first year, the 10-year flood event in the third year, and an annual input of water of roughly 10% of the 10-year event volume (17.5 af) used as recharge during June, July, and August of each year. The resulting hydrographs are shown on **Figure 3-10**.

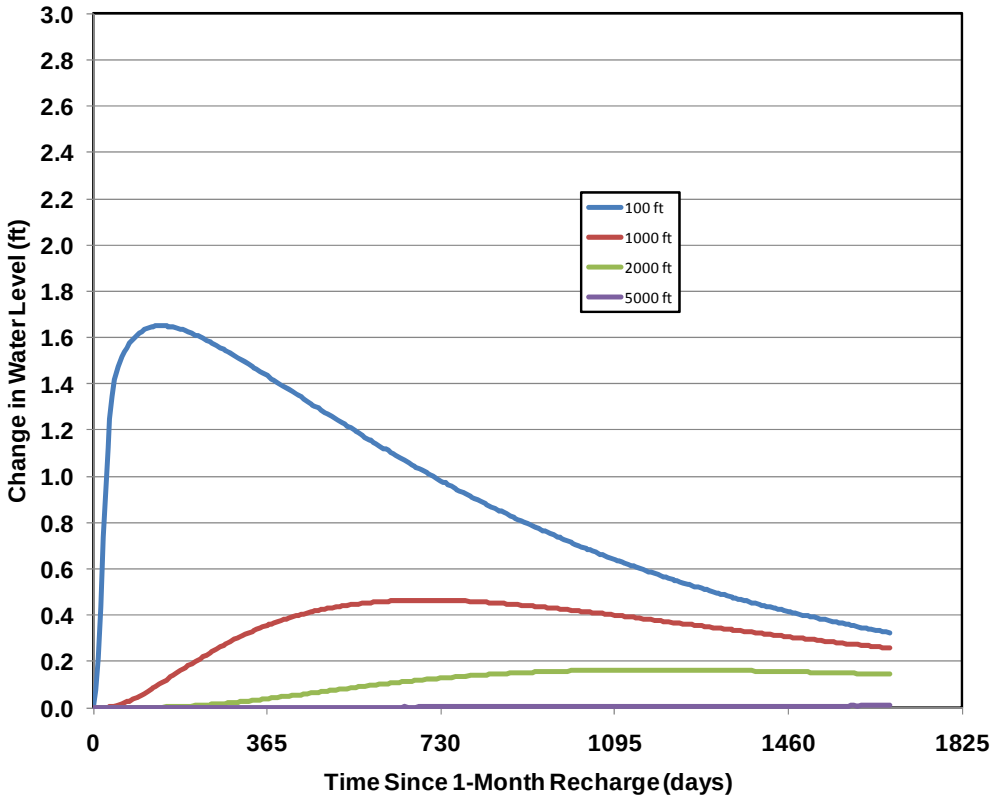


Figure 3-8. Monitoring Point Hydrographs: Cove Creek Reservoir 100-year Flood Event

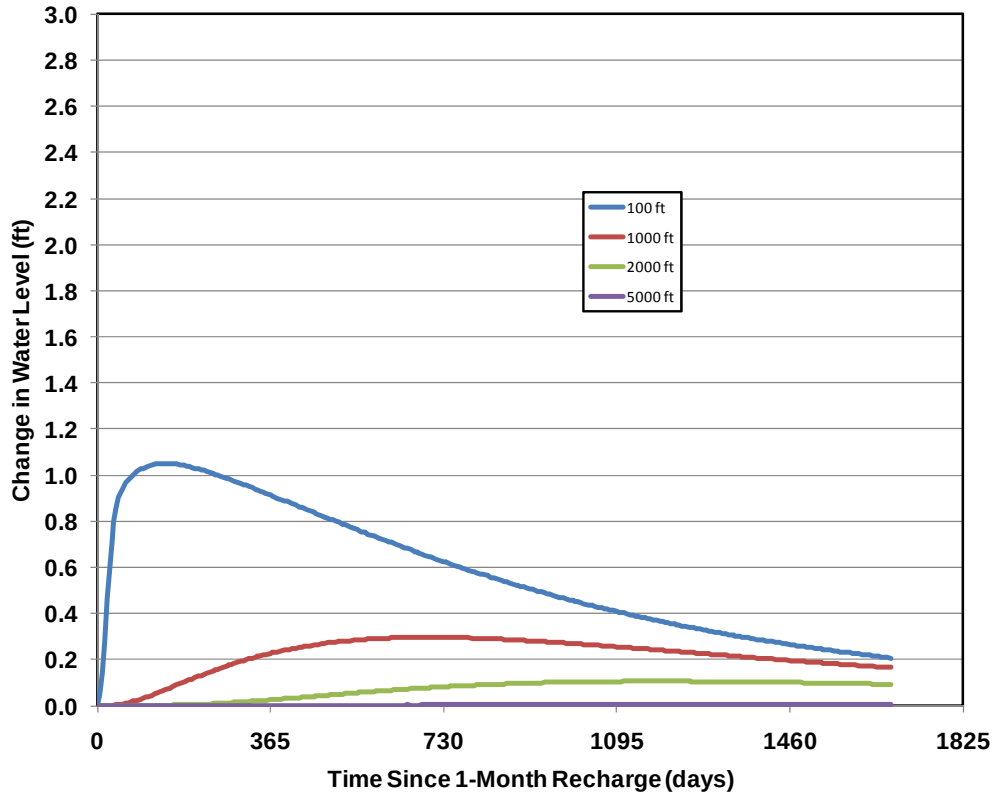


Figure 3-9. Monitoring Point Hydrographs: Cove Creek Reservoir 10-year Flood Event

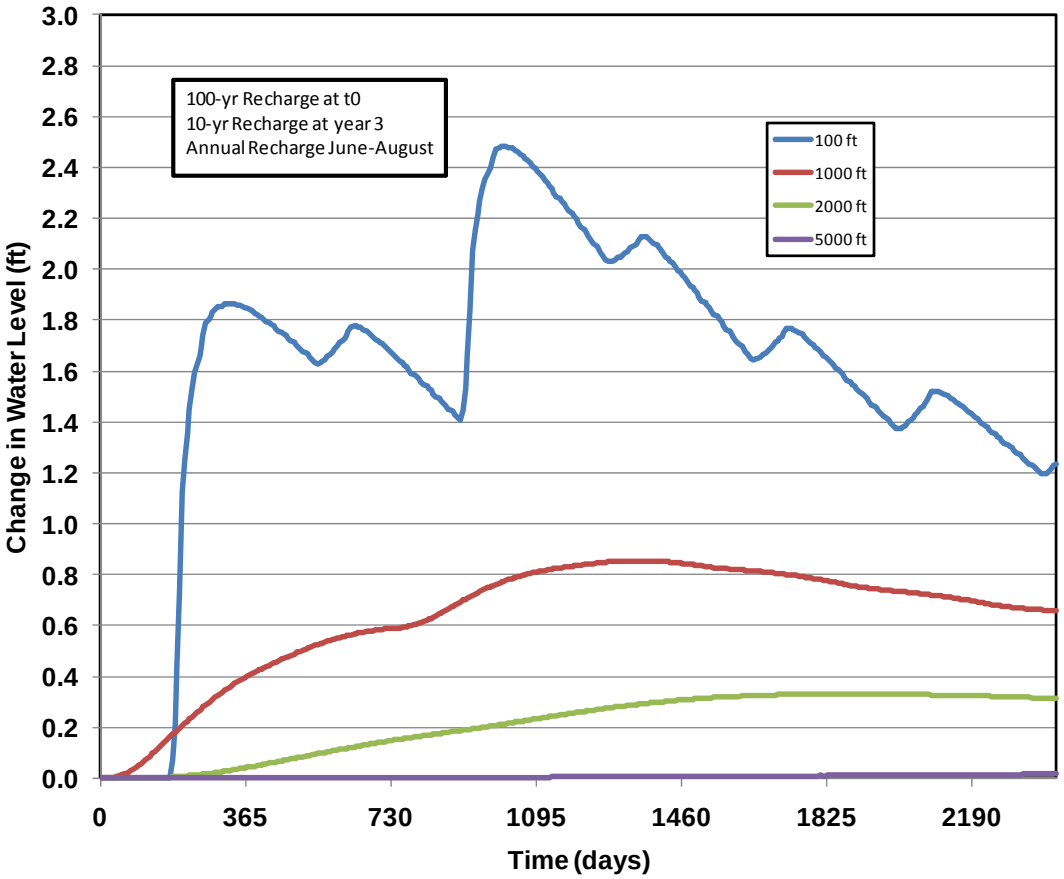


Figure 3-10. Monitoring Point Hydrographs: Cove Creek Reservoir Combined Recharge Events

The combined recharge events have a greater impact than either of the single events in the first two simulations, although the distance away that the impact is realized is still less than a mile. Six years after the 100-year event water levels remain over a foot higher at a distance of 100 ft from the reservoir. At a distance of 2,000 ft from the reservoir groundwater levels exhibit a small increase of about 0.3 ft but the rise is delayed several years after the 100-year flood event. Like in the previous simulations, there is essentially no change at a distance of 5,000 ft but water levels were rising slightly at the end of the time modeled.

The regular annual input is evident as small rises on the curve for the 100 ft monitoring point. These inputs could represent recharge from smaller and more frequent flood events or they could be other regular inputs such as purchased water rights from land use changes. The regular inputs were included to illustrate how they might benefit groundwater conditions and could be considered as a means to keep water in the reservoir rather than have long periods where it is dry.

Clearly there are an infinite number of ways to combine flood events and arranging the sequence of events, or even adding in other potential flood events. Rearranging the sequence of events would likely change the appearance of the hydrographs, and some additional patterns of recharge may need to be evaluated in the event groundwater recharge from flood events is considered further.

3.3.2 Little Cove Creek Simulations

The potential reservoir site for groundwater recharge of flood water at Little Cove Creek is shown as Site 2 on **Figure 3-1**. The site would cover an area of approximately 48 acres, but the exact location has not

yet been specified. An approximation of the Little Cove Creek reservoir area was developed in the preliminary model and is shown on **Figure 3-11**. Also shown on the figure are the location of four model/monitoring points located at distances of 100, 1000, 2000, and 5000 ft from the downgradient end of the potential reservoir.

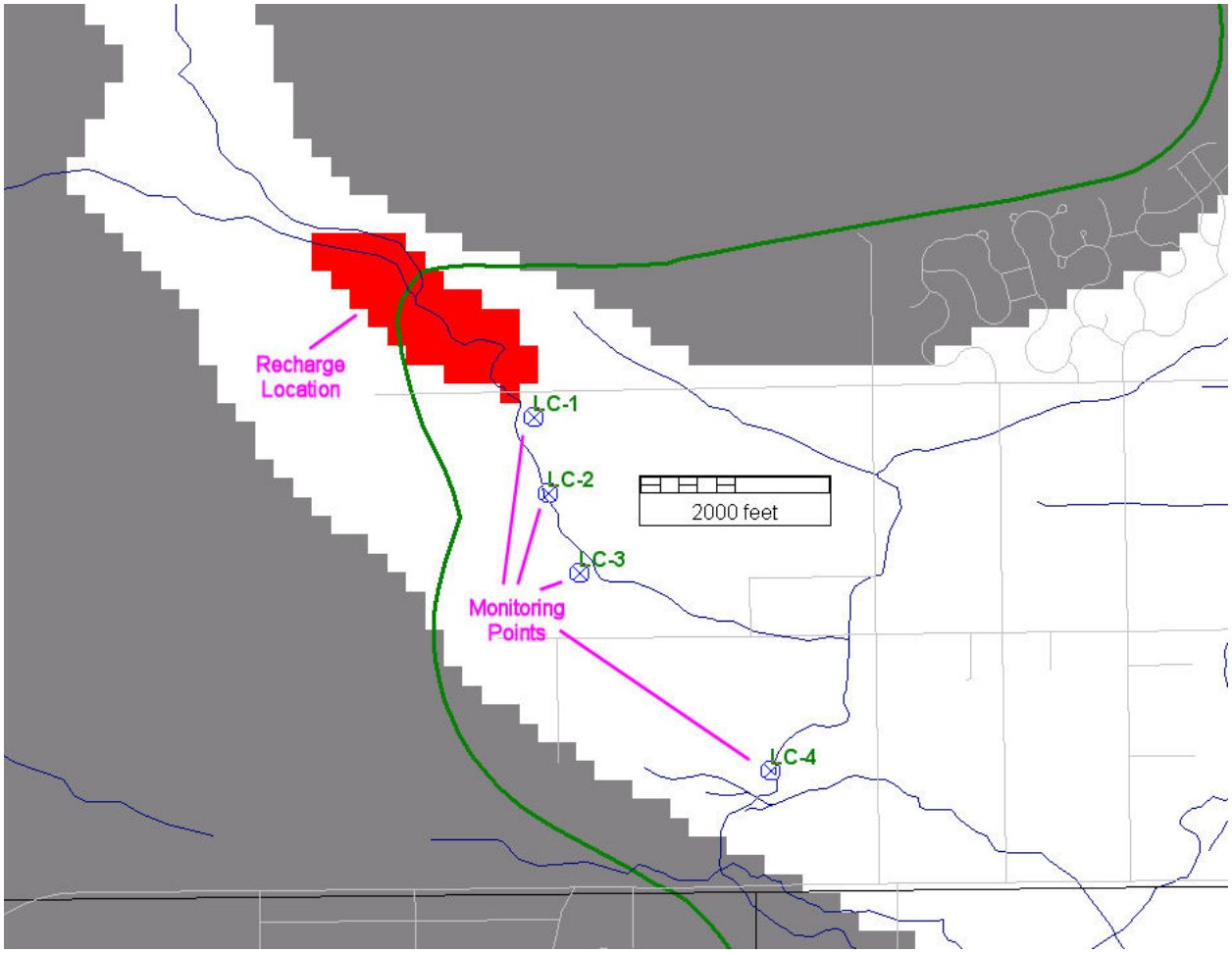


Figure 3-11. Model Setup for Little Cove Creek Groundwater Recharge Simulation

The reservoir was represented in the model as injection wells in layer 2. Rates used are shown in **Table 3-1** and are 6,539 ft^3/d for the 100-year event and 4,053 ft^3/d for the 10-year event for each cell. A total of 52 wells were used to represent the reservoir.

Results of the 100-year and 10-year recharge events are shown on **Figure 3-12** and **Figure 3-13**, respectively. The results show that, given the model limitations and the assumptions of a 48-acre reservoir that can route 50% of the water from a 100-year or 10-year flood event into the groundwater, that water levels might be expected to rise 1-1.5 ft immediately downgradient of the reservoir, with the effect decreasing to almost nothing a distance of 5,000 ft away. The water level rise will be realized for some period of time after the recharge event though, with a rise of less than 0.4-0.6 ft still present near the reservoir after 4 years. At a distance of 1,000 ft from the reservoir the maximum water level rise of 0.3-0.4 ft isn't realized until about two years after the recharge event.

Like the results from the Cove Creek simulations, these results suggest that routing flood water into the shallow aquifer may not have a significant effect and the effect will be localized to within a mile or so of the point of recharge.

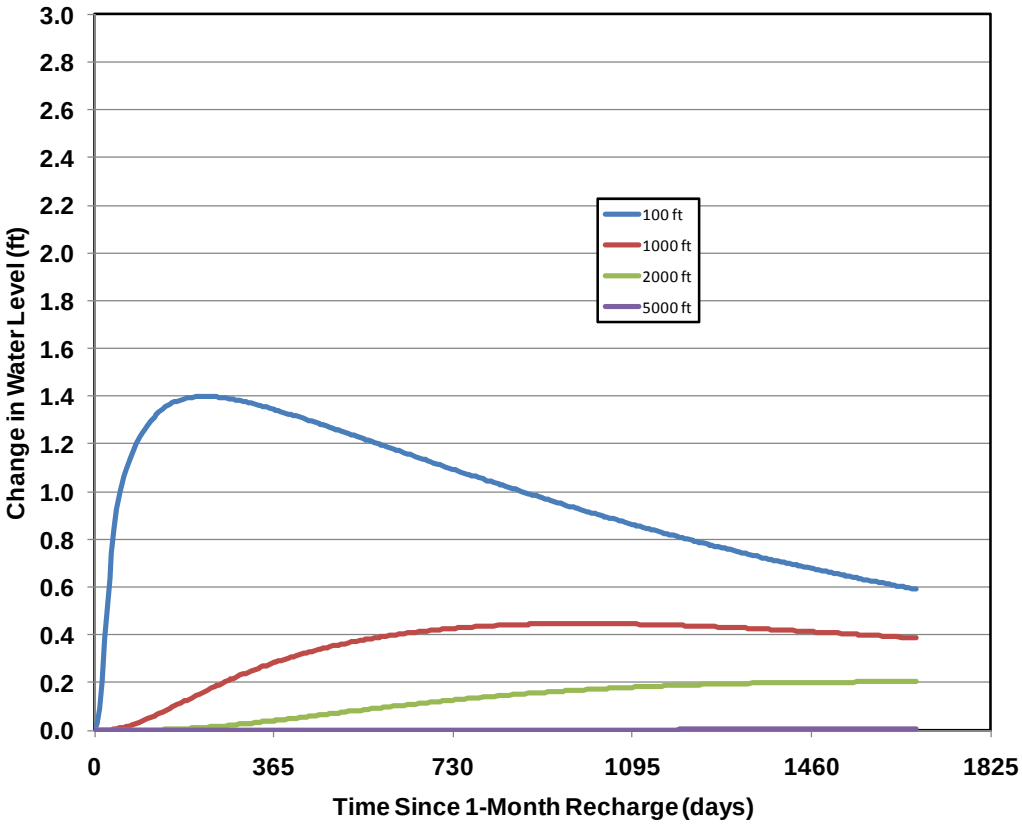


Figure 3-12. Monitoring Point Hydrographs: Little Cove Creek Reservoir 100-year Flood Event

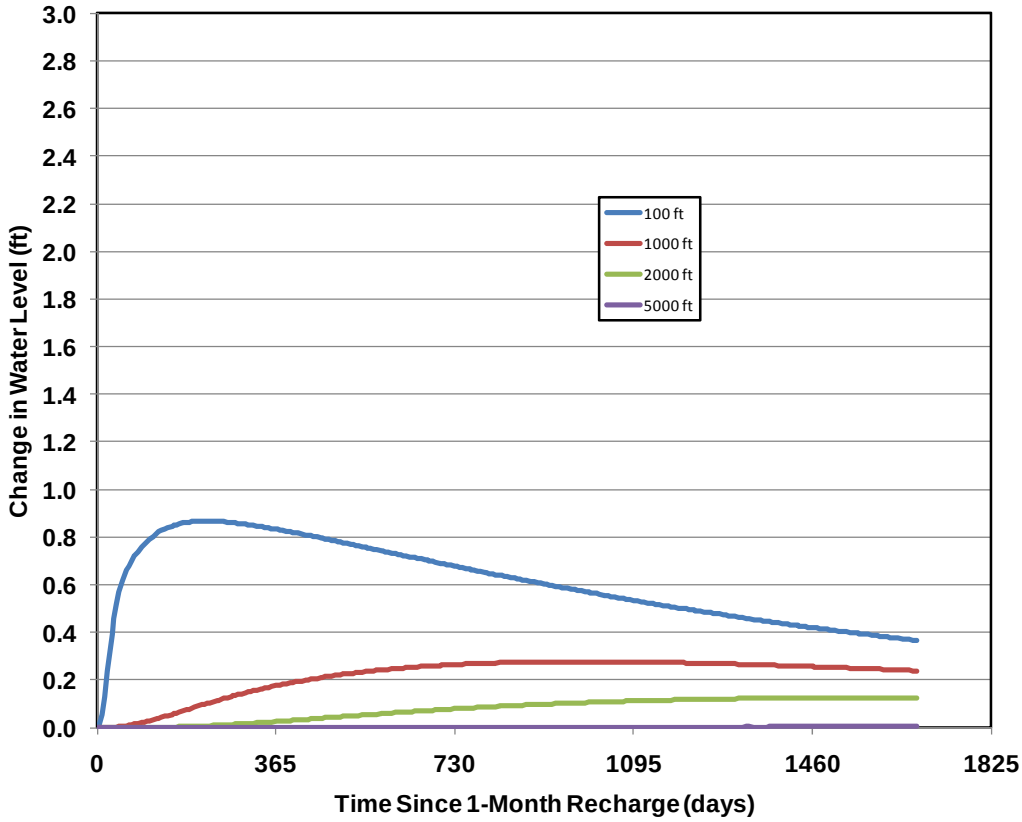


Figure 3-13. Monitoring Point Hydrographs: Little Cove Creek Reservoir 10-year Flood Event

A third simulation was performed combining flood events along with an annual input of water. The simulation assumes the 100-year flood event in the first year, the 10-year flood event in the fourth year, and an annual input of water of roughly 10% of the 10-year event volume (15.0 af) used as recharge during June, July, and August of each year. Note that the timing for the 10-year flood event is a year later than was simulated for Cove Creek to illustrate the effect of a difference in timing. The resulting hydrographs are shown on **Figure 3-14**.

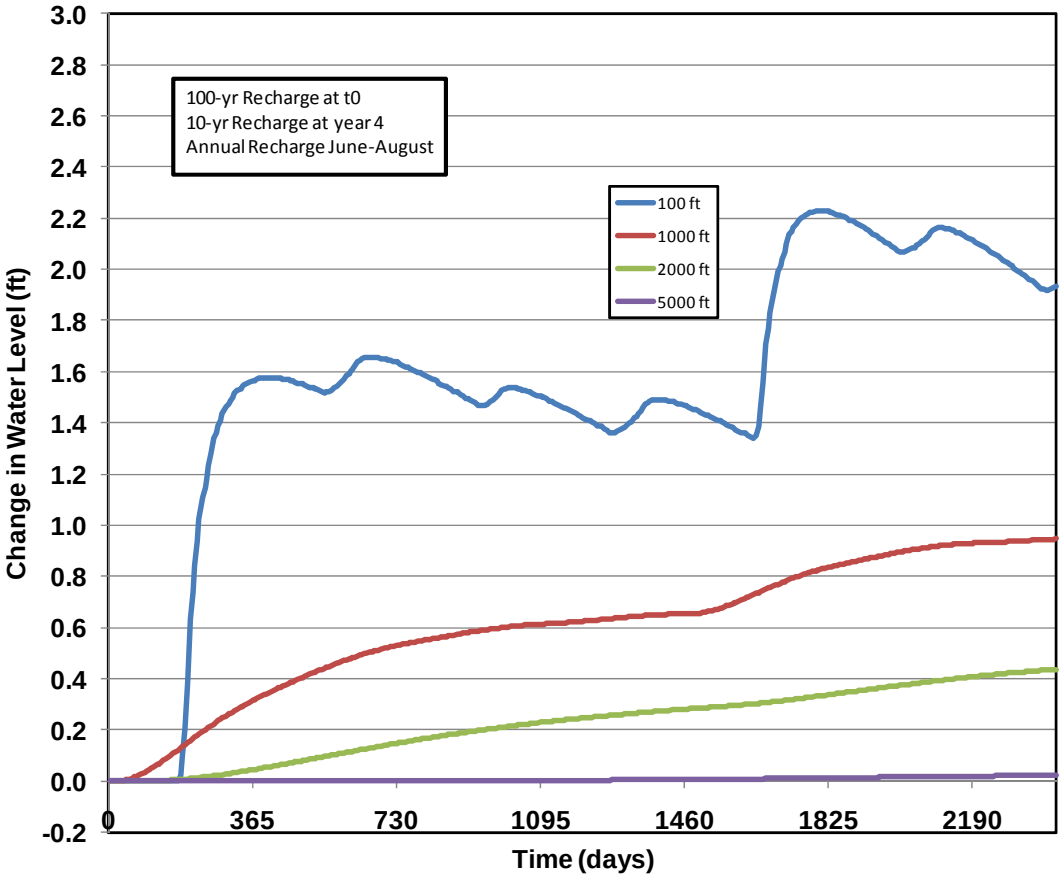


Figure 3-14. Monitoring Point Hydrographs: Little Cove Creek Reservoir Combined Recharge Events

Like for the Cove Creek simulations, the combined recharge events have a greater impact than either of the single events in the first two simulations, although the distance away that the impact is realized is still less than a mile. This combined simulation differs from that for Cove Creek however in that with the regular annual input the decline in water levels 100 ft from the reservoir is slower and when the 10-year event happens the water level rise jumps to over 2 ft. At a distance of 1,000 ft the water level rise is just starting to peak four years into the simulation when the effects of the 10-year event increase the water level change to nearly 1.0 ft. There still is essentially no change at a distance of 5,000 ft but water levels were rising slightly at the end of the time modeled. These results suggest that groundwater recharge in the Little Cove Creek drainage may have a greater impact than along Cove Creek, but the effects would still be limited to less than a mile.

3.3.3 Sharptail Pond Simulations

The potential groundwater impacts from recharging water at a reservoir site located at Sharptail Pond was simulated by the MBMG using their model covering the southern portion of the Study Area. Their modeling efforts and results are covered in **Appendix B**.

The magnitude of the water level rise in the Sharptail Pond simulations is similar to the results from the simulations in the northern portion of the Study Area near the point of recharge. However, the Sharptail Pond simulations indicate much less of a rise downgradient, with a maximum rise of 0.003 ft predicted at a distance of roughly 1,000 ft. Water level rise for the Sharptail Pond simulations are also much briefer, lasting only about three months after the recharge event.

The differences from the Sharptail Pond simulations may be due to the fact that recharge was simulating by increasing recharge rates at the model surface instead of using injection wells, or it may be because hydraulic conductivity values or other model specifications are different in that area. Regardless, the results from all the simulations show a very localized and short-lived groundwater impact from flood water recharge.

4.0 CONCLUSIONS

Detailed analyses have been completed of the shallow stratigraphy and land use changes in the West Billings area. These analyses have been used to develop a preliminary groundwater flow model for the northern portion of the Flood Mitigation and Groundwater Recharge Study Area. The model represents an extension of areas already being modeled by MBMG, and, in combination, are means to simulate potential groundwater recharge alternatives in the entire West Billings area.

Simulations of potential groundwater recharge events have been completed for locations on Cove Creek and Little Cove Creek using the preliminary model. Modeling included simulating recharge from a 100-year flood event, a 10-year flood event, and a combination of the two flood events with regular annual recharge. A third location at Sharptail Pond was simulated by MBMG using their model. The Sharptail Pond modeling included simulating recharge from a 100-year flood event and a 10-year flood event.

The modeling results suggest that recharging groundwater from flood events will cause a modest rise in groundwater levels near the point of recharge but the effect may not be noticeable more than one mile away. Water level rises of roughly 1-2 feet are evident 100 ft away from the recharge and could be even greater depending upon the timing of flood events. Further away the degree of rise is less but for simulations in the northern part of the drainage it is delayed by a year or more, with a rise of up to one foot occurring 1,000 ft from the point of recharge for one of the combined flood recharge simulations.

Modeling simulates a 10 year flood, which represents a 10% annual occurrence per year, and a 100 year flood, which represents a 1% occurrence. Relying on these infrequent events suggest recharging groundwater through flood flows alone is insignificant. The only way to have appreciable impact is by supplementing the flood water with a diversion of water on a regular basis.

These modeling results should be viewed as general indicators of the potential impact upon groundwater from routing flood water into the subsurface because there are a number of limitations that affect the results. The volume of water from flood events that recharges the groundwater is only an estimate at this point and may be greater or less than modeled, and which events can be used for groundwater recharge is uncertain at this level of the feasibility evaluation. In addition, the sequence of various flood events cannot be predicted and the model results show that varying the timing of flood events changes the downgradient groundwater response over time. Additional modeling may be necessary if groundwater recharge alternatives are considered further in the flood mitigation study.

The preliminary model developed for the northern portion of the Study Area is considered adequate for simulating general impacts from groundwater recharge events. It is considered to be preliminary because it has not been aggressively calibrated and some modifications will likely be necessary if greater accuracy of simulations is needed and if it is to become part of the MBMG model network in the area. Modifications might include representing creeks, ditches, and drains in the model domain with boundary conditions, including pumping wells, and varying boundary conditions seasonally.

5.0 REFERENCES

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Appendix A

Stratigraphic Analysis Methodology and Results

This Appendix provides a detailed summary of the methodology used to review and interpret well logs for the West Billings area to the north of the current MBMG model areas. The information from the well log interpretation was compiled into a spreadsheet and was incorporated into GIS coverages shown on maps in this document.

The list of well logs obtained from MBMG's GWIC database and presented in previous documents for this study was reduced to include only those logs located north of the MBMG model areas. The reduced list includes a total of 824 borings at the locations shown on **Figure A-1**.

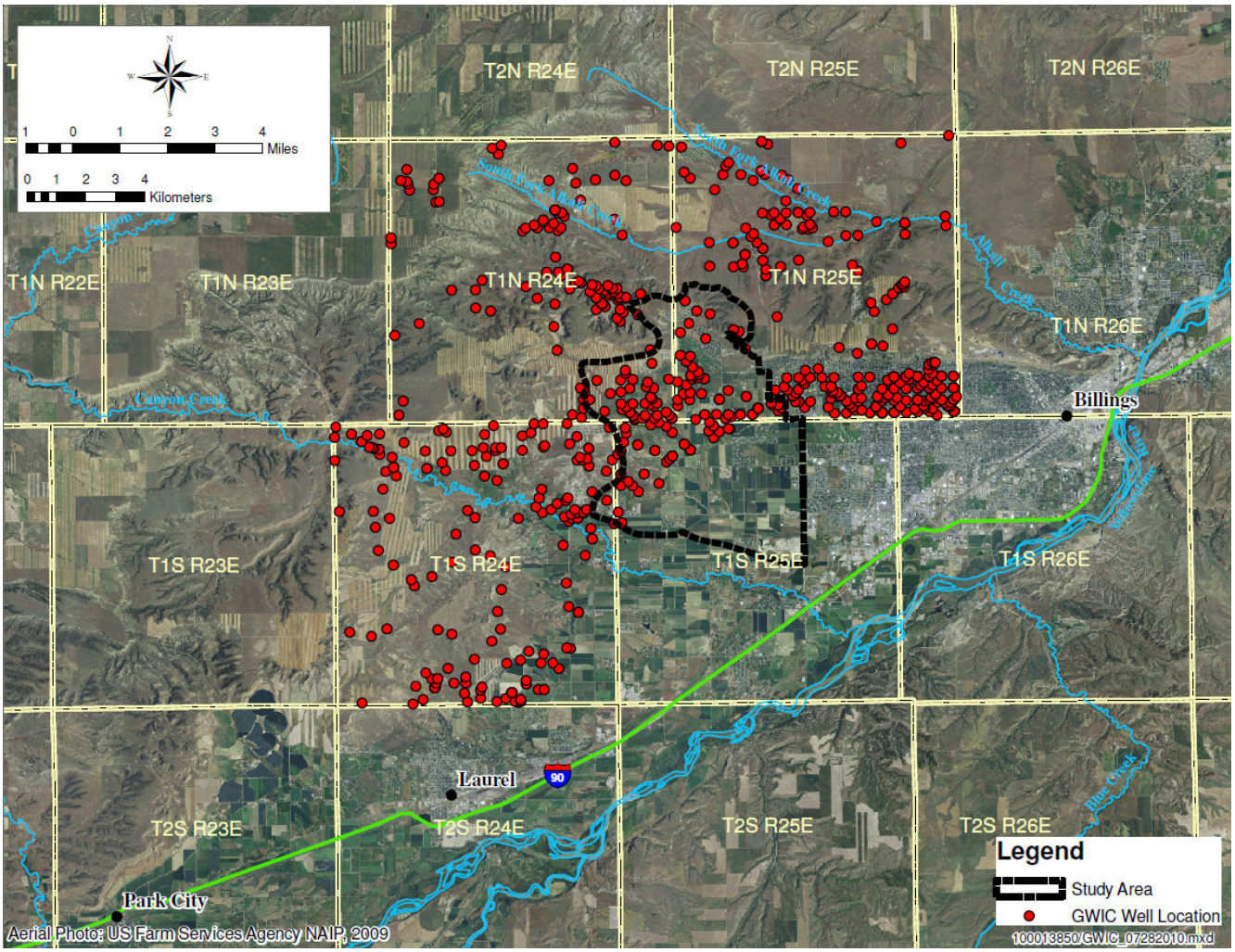

Figure A-1. Location of MBMG GWIC Well Logs Reviewed

The GIS coverage for the wells initially consisted of information provided in the GWIC database including features such as GWIC number, owner name, location information, and others. This information was then imported into an Excel spreadsheet and reduced to relevant information. Additional information columns were added as noted below. Each GWIC entry was visited in the MBMG database, and if a well log existed it was reviewed for the information noted below. Of the 824 GWIC entries a total of 136 did not have well logs, leaving 688 to review for stratigraphic information. Information that was missing or could not be determined was noted with a "---".

Information added to the spreadsheet during review of the well logs included:

- Ground Elevation
- Fine-Grained Cap bottom depth, bottom elevation, and thickness
- Aquifer (unconsolidated) thickness, type, and hydraulic conductivity values
- Bedrock/Bottom Clay depth and elevation
- Data Qualifiers and Comments

Ground Elevation

Ground elevation was specified in two manners. First, the well location was compared to topographic coverage and the elevation at the location specified was noted in the spreadsheet. The topographic coverage used was USGS 24K DEM with a 10 meter resolution. Second, during review of the well logs some of the logs included the ground elevation. These were noted in a separate column. In general, elevation noted on the logs matched closely to elevations obtained from GIS topographic information, but in some cases there was a significant difference.

The ground elevations were used to specify other elevations in the spreadsheet as noted below. Ground elevations from well logs were assumed to be more accurate and were given preference when available. Subsequent elevations deriving from this information were color coded to indicate which of the two ground surface elevations were used.

Fine-Grained Cap Information

Information on the fine-grained material, overlying the unconsolidated aquifer was added at each location. If this cap material was not present in the log a thickness of 0 was assigned. In some cases the material was noted by a single entry such as “clay” or “silt”. In other cases there were interbedded fine and coarse-grained units, and in those cases some of the coarse grained material that was considered to be above the main unconsolidated aquifer was included in the fine-grained cap and the thickness adjusted as noted below.

Bottom Depth

Depth on the log where the fine-grained material transitions to the unconsolidated aquifer, if present, or to bedrock. For logs where drilling did not get through the fine-grained material, the total drilling depth was used with a “greater than” sign.

Bottom Elevation

Bottom elevation where the fine-grained material transitions to the unconsolidated aquifer, if present, or to bedrock. Elevation related to ground elevation and color coded as to whether the reference elevation was a log value of the USGS DEM.

Thickness

Thickness of the fine-grained material. If minor layers of coarse-grained material were included in the interpretation of the cap material their total thickness was subtracted out to allow for future assignment of variable hydraulic conductivity values.

Aquifer Information

Aquifer information was specified for locations where the shallow unconsolidated aquifer was present. For locations where it was absent in the log a thickness of 0 was assigned.

Thickness

Thickness of the aquifer was assigned at the difference between the fine-grained cap bottom depth and the depth to bedrock or bottom clay. For logs where drilling did not get through the aquifer material a “greater than” sign was added.

Type

An aquifer type qualifier was assigned based on the log description. The types used in the spreadsheet are noted below and were used to assign hydraulic conductivity values.

Aquifer Types Assigned

Aq Types:		K (ft/d)
1	mostly gravel	200
2	gvl & sand	100
3	med-crs sand	50
4	fine sand	10
5	sand & fines	1

Hydraulic Conductivity

Hydraulic conductivity (K) values were assigned in two manners. The first approach was to assign K values based on the aquifer types as described above. The second approach was to assign K values based on water level and yield information in the logs. For the second approach, the list of wells was reduced to those with information on static water level, pumping water level, and yield (a total of 301 wells). This information was then used to estimate K in a separate spreadsheet tab using the following empirical formula:

T (gpd/ft) = [Q (gpm) * 2000] / s (ft)

K = T/b

Where:

T = transmissivity
Q = yield
s = drawdown
K = hydraulic conductivity
b = saturated thickness

Bedrock/Bottom Clay Information

The depth to and elevation of bedrock or fine-grained material on top of bedrock was noted in additional columns in the spreadsheet. These columns were filled in with "---" for logs where drilling did not clearly go through the unconsolidated material. Elevation was related to ground elevation and color coded as to whether the reference elevation was a log value of the USGS DEM.

Data Qualifiers

Two types of data qualifiers were assigned to allow for filtering of the data points when developing spatial GIS coverages. The qualifiers ranked log quality, and location quality.

Log Quality

Log quality consisted of two separate components and columns consisting of "contacts" and "description". For each GWIC well these columns were assigned numbers from 1 to 4 based on the table below.

Contacts and Description Quality Assignments

Log Qual:		
	1	V Good (high detail level)
	2	Good (contacts/desc reliable)
	3	Poor (contact/desc questionable)
	4	Unconsol. aquifer absent/outside of probable area

The contact qualifier is a measure of how reasonable the depth information noted on the log appears to be. The description qualifier is a measure of the reliability of the description. For example a log describing 40 feet of "sand & gravel" was not considered reliable for determining aquifer types, but is reliable for the contact depth information.

Location Quality

A location qualifier was added to allow for filtering of data points as needed based on the accuracy of the location. Each GWIC well was assigned a location qualifier from 1 to 3 based on the table below.

Location Quality Assignments

Loc Qual:	1	V Good (GPS or survey)
	2	Good (at least qtr-qtr-qtr)
	3	Poor (less than qtr-qtr-qtr)

Comments

A comment column was added to the spreadsheet and notes were added where appropriate as an aide for future use of the data. The notes vary from ones indicating that there is no log or the log was too poor to use, to more specific notes such as how much coarse material was included or that the description of aquifer material type is limited.

Results

Datasets were created from the final log review spreadsheet, contoured in Surfer and imported into GIS. The datasets included data points with information for a given property from the stratigraphy spreadsheet. In addition, datapoints from the northern extent of the MBMG model area were included so the data would transition smoothly from the modeled areas.

The data points used for contouring were filtered to remove locations where the unconsolidated aquifer is clearly not present, using the previously mapped extent shown on the figures below as a guide. The data were also filtered to only include points with a log and location quality of 1 or 2. After initial contouring some poorer quality data points were added back in for areas where there would otherwise be no coverage, and some points were removed if they appeared anomalous based on other nearby points. Finally, contours were truncated just beyond the perimeter of the unconsolidated area previously mapped by Olson (2005).

Results are shown below for thickness of the fine-grained cap (**Figure A-2**), thickness of the unconsolidated aquifer (**Figure A-3**), hydraulic conductivity of the unconsolidated aquifer (**Figure A-4**), and depth to bedrock (**Figure A-5**). The location of well logs evaluated are shown on the figures with those that were used for the contouring shown as blue, those not used as red, and those that indicate the unit is absent or is in a location that the unconsolidated aquifer is clearly not present as purple. Note that for the "used" well postings the data points from the MBMG model were not included. A printout of the final spreadsheet is included at the end of this Appendix as **Table A-1**.

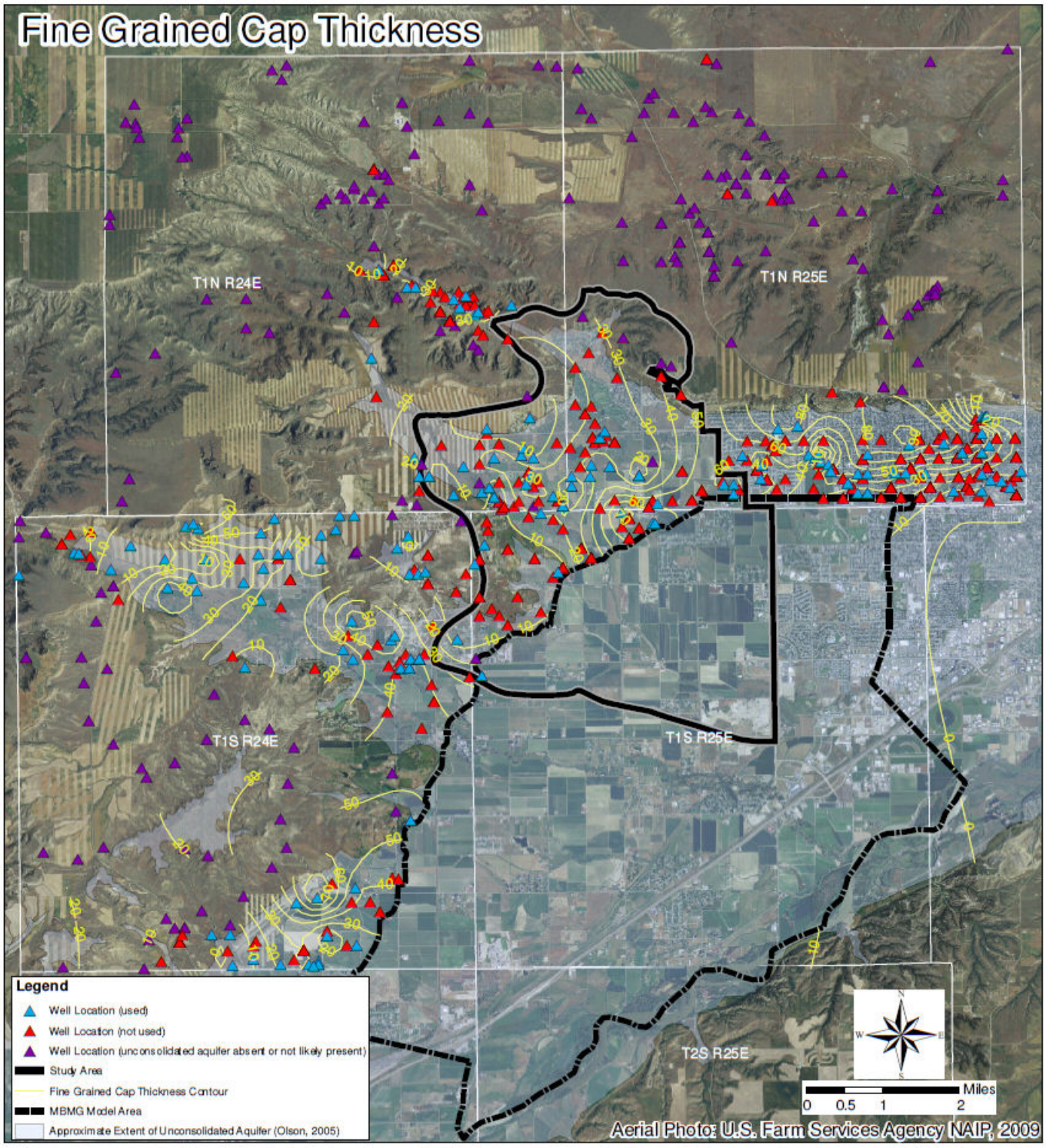

Figure A-2. Thickness of Fine-Grained Cap

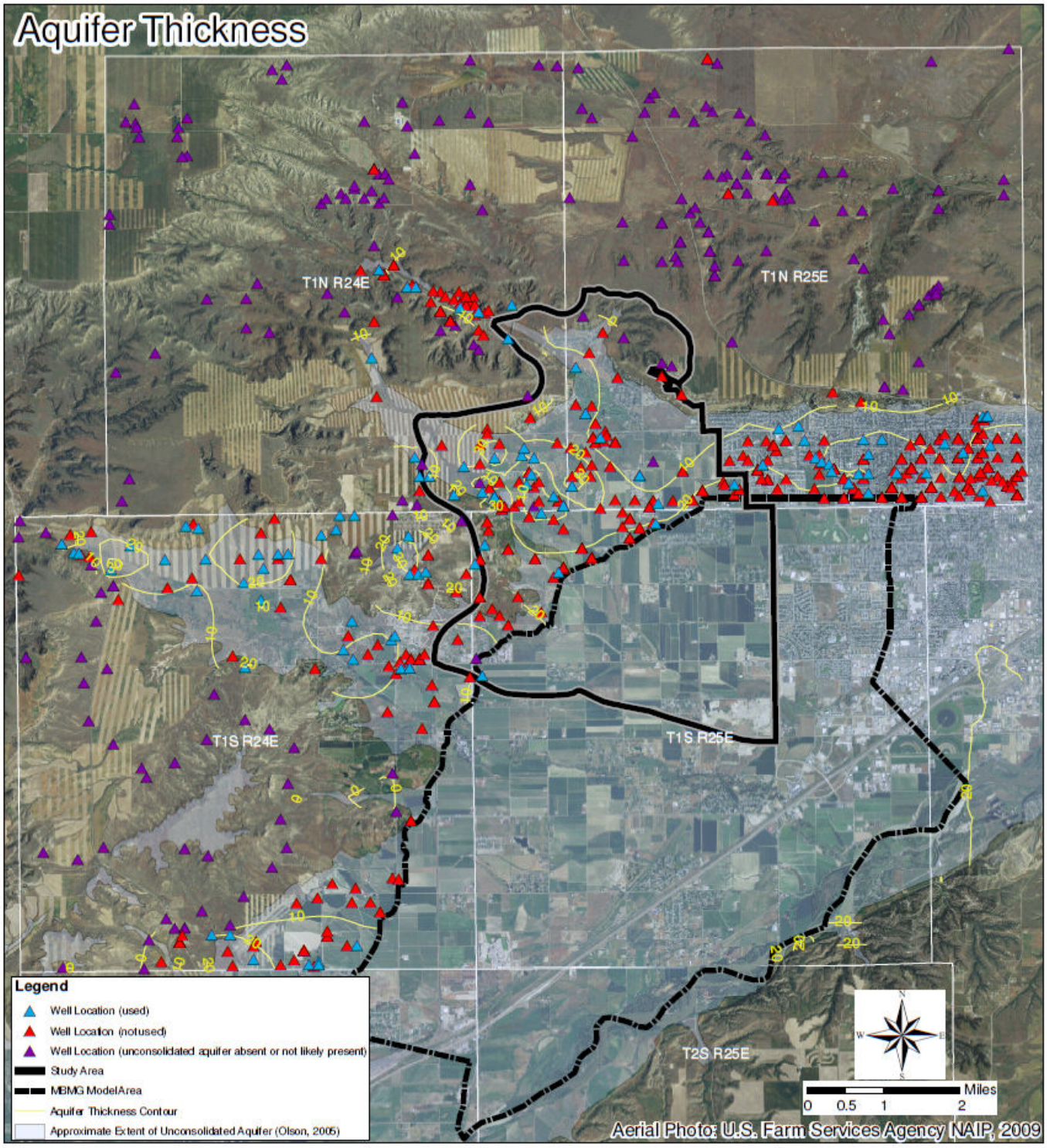

Figure A-3. Thickness of Unconsolidated Aquifer

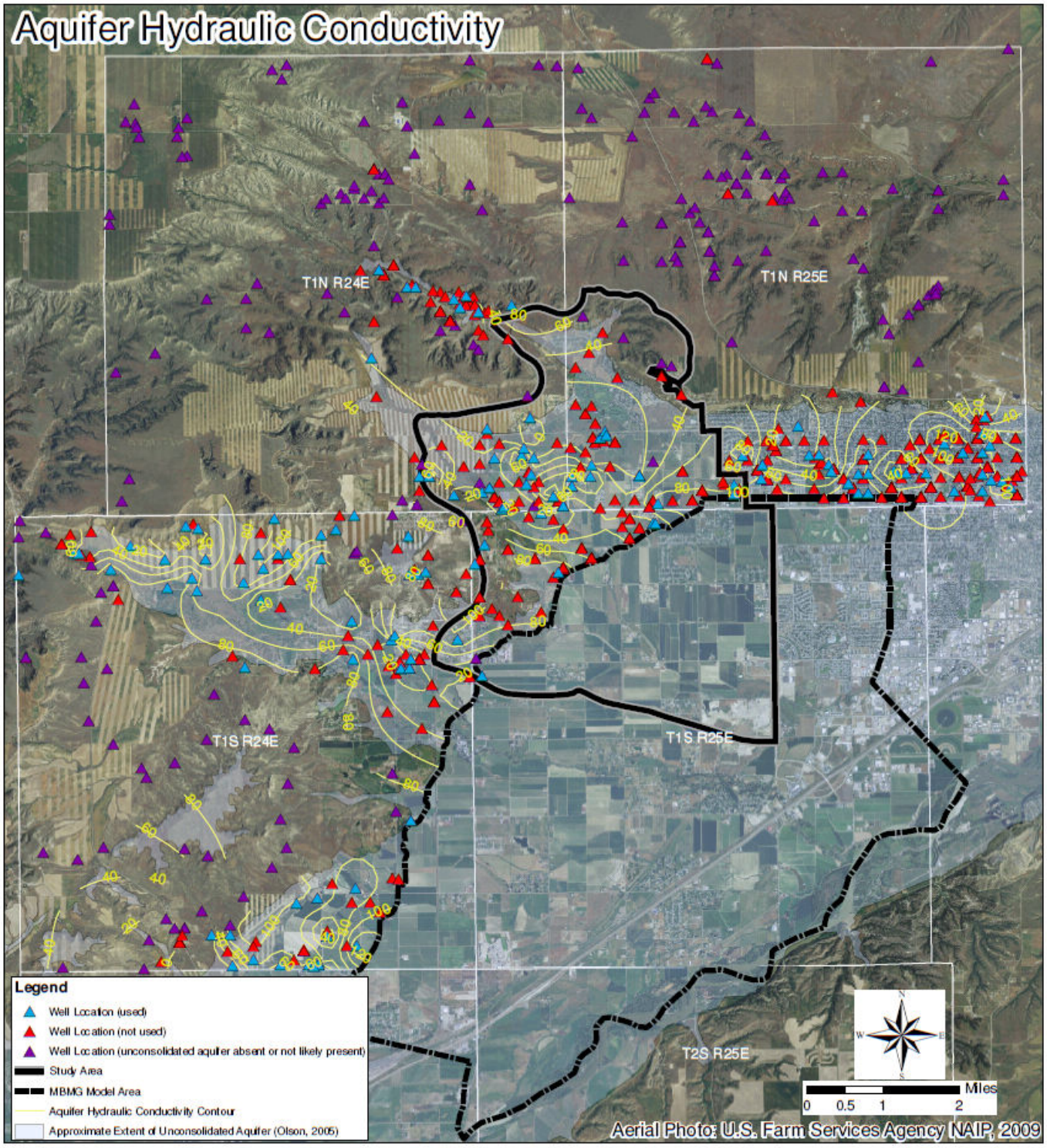

Figure A-4. Hydraulic Conductivity of Unconsolidated Aquifer

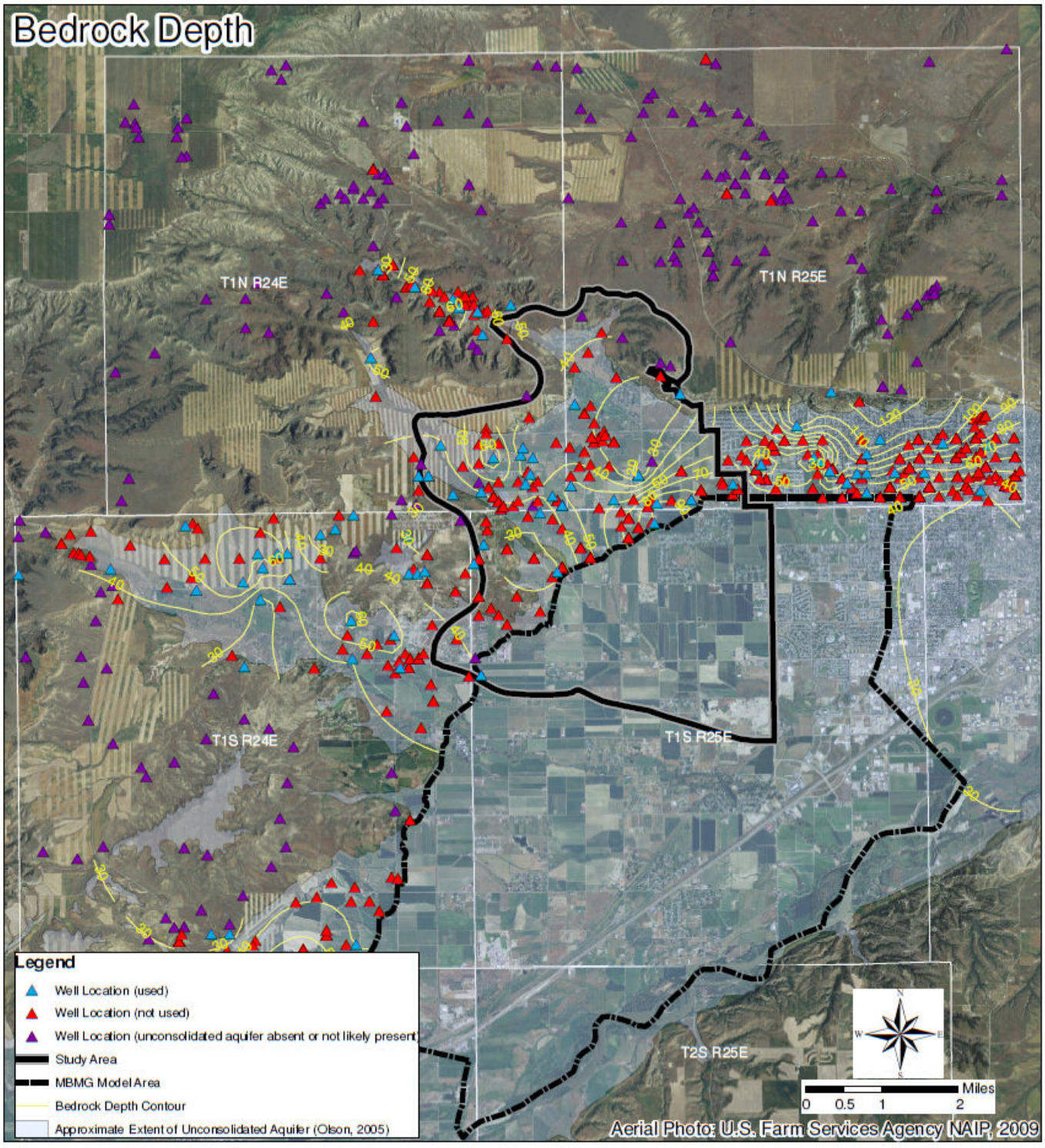

Figure A-5. Depth to Bedrock

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
															K (ft/d)				Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	Btm Dpth (ft)	Btm Elev (ft MSL)	Thkns (ft)	Thkns (ft)	Type	Type	WL/Yld	Depth (ft)	Elev (ft MSL)	Contacts	Descr	Qual	Comment
422	142014	BILLINGS WATER SUPPLY * CALAMITY JANE	TRS-SEC	01S	24E	6	BCBB		3451	0	---	0	>20	5	1	---	---	---	4	4	2	no apparent clay cap
423	142015	BILLINGS WATER * CALAMITY JANE DAMSITE	TRS-SEC	01S	24E	6	CCBB	3708.9	3730	0	---	0	39	5	1	---	39	3670	1	1	2	no clay cap. Landslide debris
425	179873	HUGHES DOUG	TRS-SEC	01S	24E	6	BBB		3484	---	---	---	---	---	---	---	---	---	4	4	3	no log
436	222251	SCARIANO RON *WELL 2	TRS-SEC	01S	24E	7	CC	---	3665	37	3628	37	0	---	---	---	37	3628	4	4	3	no sand?
461	92765	KUKES JAKE	TRS-SEC	01S	24E	30	BDC	---	3788	---	---	---	---	---	---	---	---	---	4	4	3	no log
478	142013	BILLINGS WATER SUPPLY * CALAMITY JANE	TRS-SEC	01S	24E	6	BADC	3474	3481	>25	---	---	---	---	---	---	---	---	4	4	2	19' clayey sand on top of silty shale
518	92767	FRANK ALEX P.	TRS-SEC	01S	24E	31	DCC	---	3740	---	---	---	---	---	---	---	---	---	4	4	2	no log
530	92728	KASEMAN CLAUDE	TRS-SEC	01S	24E	6	AC		3448	---	---	---	---	---	---	7.6	---	---	3	3	3	poor log
531	92729	KASEMAN E.C.	TRS-SEC	01S	24E	6	AC		3448	15	3433	15	33	2	100	---	48	3400	2	2	3	
558	92727	OLSEN PETER	TRS-SEC	01S	24E	6	A		3465	30	3435	30	15	1	200	17.4	45	3420	2	2	3	
573	92766	KUKES JAKE W.	TRS-SEC	01S	24E	30	DABB	---	3645	---	---	---	---	---	---	---	---	---	4	4	3	no log
578	222252	SCARIANO RON *WELL 1	TRS-SEC	01S	24E	7	DD	---	3543	74	3469	73	>10	1	200	---	---	---	4	4	3	general clay description
581	142064	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	18	AADC	3517	3524	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
597	142065	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	18	DADD	3518	3512	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
607	141949	BILLINGS WATER SUPPLY * CALAMITY JANE	TRS-SEC	01S	24E	5	CBBBC	3426	3425	>25	---	---	---	---	---	---	---	---	1	1	2	11 ft clayey sand on clay
610	141948	BILLINGS WATER SUPPLY * CALAMITY JANE	TRS-SEC	01S	24E	5	BBCC	3483	3478	>25	---	---	---	---	---	---	---	---	1	1	2	19' clayey sand on top of silty shale
611	141950	BILLINGS WATER SUPPLY * CALAMITY JANE	TRS-SEC	01S	24E	5	CBCB		3425	0	---	0	>25	4	10	---	---	---	4	4	2	no clay cap
624	142017	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	8	BCCA	3520	3524	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
636	92764	KUKES JAKE W.	TRS-SEC	01S	24E	29	BC	---	3602	---	---	---	---	---	---	---	---	---	4	4	3	no log
642	142016	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	8	BBAB	3519	3530	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
651	248381	MERCHANT LOUIE	TRS-SEC	01S	24E	17	BBAA	---	3465	11	3454	11	28	2	100	---	40	3425	4	4	2	general aquifer description
658	92726	MT DEPT OF HWYS * CANYON CRK BRIDGE	TRS-SEC	01S	24E	5	CACC	3415	3412	0	---	0	41	2	100	---	41	3374	1	1	2	no clay cap
659	142068	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	20	BABB	3520	3502	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
660	10354	DOWNER HAROLD F.	TRS-SEC	01N	24E	18	BBB		4177	---	---	---	---	---	---	---	---	---	4	4	2	no log
661	10355	DOWNER HAROLD F.	TRS-SEC	01N	24E	18	BBC		4190	---	---	---	---	---	---	---	---	---	4	4	2	no log
662	203474	BRENNAN MATT	TRS-SEC	01S	24E	5	CDC		3458	46	3412	18	>14	2	100	---	---	---	4	4	2	28' sand interbedded with clay
663	203478	KLEIN BUTCH	TRS-SEC	01S	24E	5	CDC		3458	45	3413	28	>15	2	100	---	---	---	4	4	2	17' sand interbedded with clay
668	200619	RYAN BILL	TRS-SEC	01N	24E	30	BB		3780	---	---	---	---	---	---	---	---	---	4	4	3	interbedded "sand rock" & shale
669	206373	"WIDUP, HAROLD J & EUNICE E"	TRS-SEC	01S	24E	8	BA		3458	24	3434	24	16	2	100	---	40	3418	2	2	3	
699	10398	KINNEY LAVINA	TRS-SEC	01N	24E	31	CCA		3901	---	---	---	---	---	---	---	---	---	4	4	2	no log
723	192601	HEGER JIRI	TRS-SEC	01N	24E	31	CABB		3885	6	3879	6	34	4	10	26.1	40	3845	4	4	2	
728	141947	BILLINGS WATER SUPPLY * PIPELINE	TRS-SEC	01S	24E	5	ACCB	3465	3465	0	---	0	>20	5	1	---	---	---	1	1	2	no apparent clay cap
748	219895	MCFARLAND CLINT	TRS-SEC	01N	24E	6	CA		4203	---	---	---	---	---	---	---	---	---	4	4	3	callouts unclear
749	183602	MCFARLAND CLINT	TRS-SEC	01N	24E	6	CD		4160	---	---	---	---	---	---	0.2	---	---	4	4	3	Eagle Sandstone
757	142066	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	20	ACAC	3525	3516	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
758	142117	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	32	DCDC	3563	3574	0	---	0	>22	5	1	---	---	---	4	4	2	no apparent cap
760	10337	BERMES ROBERT JR	TRS-SEC	01N	24E	7	BAA		4157	---	---	---	---	---	---	6.5	---	---	4	4	2	sandstone
772	142067	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	20	ACDD	3531	3499	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
773	142116	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	32	DBAD	---	3540	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
803	232021	WEBER ROSEMARIE	TRS-SEC	01N	24E	19	DC		3973	18	3955	18	>22	4	10	---	---	---	4	4	3	
804	92768	FRANK ALEX P.	TRS-SEC	01S	24E	32	DD	---	3499	---	---	---	---	---	---	---	---	---	3	3	3	no log
833	133213	LAUREL LANDFILL * MW-4	TRS-SEC	01S	24E	32	ADA	---	3589	12	3577	12	0	---	---	---	12	3577	4	4	2	no sand, shale unclear
848	141951	BILLINGS WATER SUPPLY * PIPELINE	TRS-SEC	01S	24E	5	DAAD	3465	3458	0	---	0	>20	4	10	---	---	---	1	1	2	no clay cap
852	220060	FONERY LISA & KEN	TRS-SEC	01S	24E	4	CCCC		3409	57	3352	50	>12	2	100	---	---	---	2	2	2	7' sand interbedded with clay
874	133212	LAUREL LANDFILL * MW-3	TRS-SEC	01S	24E	33	BCC	---	3560	35	3525	35	0	---	---	---	35	3525	4	4	2	no sand, shale unclear
882	142069	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	21	BCBA	3540	3538	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
908	166026	CITY OF LAUREL CONTAINER SITE	TRS-SEC	01S	24E	33	CB	---	3537	---	---	---	---	---	---	---	---	---	3	3	3	no log
909	166027	CITY OF LAUREL CONTAINER SITE	TRS-SEC	01S	24E	33	CB	---	3537	---	---	---	---	---	---	---	---	---	3	3	3	no log
910	166028	CITY OF LAUREL CONTAINER SITE	TRS-SEC	01S	24E	33	CB	---	3537	---	---	---	---	---	---	---	---	---	3	3	3	no log
911	166029	CITY OF LAUREL CONTAINER SITE	TRS-SEC	01S	24E	33	CB	---	3537	---	---	---	---	---	---	---	---	---	3	3	3	no log
912	166030	CITY OF LAUREL CONTAINER SITE * MW-2D	TRS-SEC	01S	24E	33	CB	---	3537	---	---	---	---	---	---	---	---	---	3	3	3	no log
913	166031	CITY OF LAUREL CONTAINER SITE * MW-2	TRS-SEC	01S	24E	33	CB	---	3537	---	---	---	---	---	---	---	---	---	3	3	3	no log
927	142121	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	33	CBAB	3534	3537	>25	---	---	---	---	---	---	---	---	1	1	2	didn't go through clay
943	133210	LAUREL LANDFILL * MW-1	TRS-SEC	01S	24E	33	BCD	---	3538	6	3532	6	0	---	---	---	6	3532	4	4	2	no sand, shale unclear
944	133211	LAUREL LANDFILL * MW-2	TRS-SEC	01S	24E	33	BCD	---	3538	10	3528	10	0	---	---	---	10	3528	4	4	2	no sand, shale unclear
951	10335	JOHNSON DAROLD	TRS-SEC	01N	24E	7	AAA		4196	---	---	---	---	---	---	---	---	---	4	4	2	sandstone

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
															K (ft/d)				Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	Btm Dpth (ft)	Btm Elev (ft MSL)	Thkns (ft)	Thkns (ft)	Type	Type	WL/Yld	Depth (ft)	Elev (ft MSL)	Contacts	Descr	Qual	Comment
952	10334	MCFARLAND CLINTON B.	TRS-SEC	01N	24E	6	DDD		4170	---	---	---	---	---	---	---	---	---	4	4	2	no log
1000	235997	"MEYER, DON"	TRS-SEC	01S	24E	4	BACB		3606	48	3558	33	7	2	100	---	55	3551	2	2	2	
1012	10338	DOWNER HAROLD F.	TRS-SEC	01N	24E	8	BCB		4177	---	---	---	---	---	---	---	---	---	4	4	2	no log
1013	219505	JONES STEPHON AND STEPHANIE	TRS-SEC	01N	24E	5	CCB		4183	0	---	0	16	3	50	---	16	4167	4	4	2	
1023	203939	EKLE TIGE AND TERESA	TRS-SEC	01S	24E	4	CDBD		3432	50	3382	27	>10	2	100	---	---	---	2	2	2	23' sand interbedded with clay
1024	204411	BENTSUN ERIC	TRS-SEC	01S	24E	4	BA		3560	62	3498	54	>18	2	100	---	---	---	2	2	3	
1045	142120	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	33	BADC	3537	3540	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1050	176228	KRASKE WILLIAM	TRS-SEC	01S	24E	4	BAD		3540	78	3462	78	14	3	50	12.1	92	3448	2	2	2	
1075	92763	MCLEOD R.C.	TRS-SEC	01S	24E	28		3900	3742	0	---	---	>24	1	200	174.4	---	---	4	4	3	poor log
1115	142063	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	16	DCCC	3526	3523	>15	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1116	141946	BILLINGS WATER SUPPLY * PIPELINE	TRS-SEC	01S	24E	4	DBBC	3465	3465	0	---	0	>20	4	10	---	---	---	1	1	2	no clay cap
1117	228846	PELCHER JAY	TRS-SEC	01S	24E	33	DBBB	---	3505	3	3502	3	21	5	1	---	25	3480	2	2	2	
1124	144294	CELLMER STEVEN	TRS-SEC	01N	24E	20	BAC		3852	11	3841	11	19	5	1	0.5	30	3822	4	4	2	shale on top of Eagle Sandstone
1147	158346	MT DEPT OF HWYS * INT SIGN CL 4-50-96	TRS-SEC	01S	24E	16	AC	---	3463	5	3458	5	>16	5	1	---	---	---	4	4	3	very thin cap?
1185	92769	FELKE FRANK	TRS-SEC	01S	24E	33	D	---	3458	30	3428	30	>60	2	100	17.8	---	---	3	3	3	poor log
1196	142119	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	33	ADCB	3539	3519	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1197	225298	HIMMELSLACH RON L.	TRS-SEC	01S	24E	33	DABB	---	3506	0	---	0	25	2	100	---	25	3481	2	2	2	no apparent clay
1198	171429	WEBER & SONS	TRS-SEC	01S	24E	33	DDC	---	3449	0	---	0	93	4	10	21.2	93	3356	1	1	2	interbedded, variable
1222	243005	INTERCOUNTY LAND BANK	TRS-SEC	01S	24E	9	DD	---	3379	---	---	---	---	---	---	---	---	---	3	3	3	poor log
1258	141945	BILLINGS WATER SUPPLY * PIPELINE	TRS-SEC	01S	24E	4	DAAD	3455	3451	>20	---	---	---	---	---	---	---	---	1	1	2	10 ft clayey sand on clay
1259	142118	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	33	AAAA	3534	3541	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1261	228841	HANN KAREN AND KEITH	TRS-SEC	01S	24E	3	CCCB		3425	48	3377	41	22	2	100	---	70	3355	2	2	2	7' gravel interbedded with clay
1262	217748	WAGNER PAUL & CINDY	TRS-SEC	01S	24E	15	BBBB	---	3425	4	3421	4	22	2	100	---	27	3398	2	2	2	
1263	142061	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	15	CBCC	3528	3541	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1277	10356	ZIMMERMAN CHARLES	TRS-SEC	01N	24E	20	AAC		3730	---	---	---	---	---	---	1.6	---	---	4	4	2	8' clay on top of Eagle Sandstone
1278	185981	PAULSON RANDY	TRS-SEC	01N	24E	20	DAB		3737	0	---	0	24	2	100	---	24	3713	4	4	2	
1298	92770	VISSER MIKE	TRS-SEC	01S	24E	34	CB	---	3468	70	3398	70	>40	5	1	23.4	---	---	3	3	3	poor log
1336	221280	OLSEN JEFF	TRS-SEC	01S	24E	3	CBAA		3458	34	3424	34	27	2	100	---	61	3397	2	2	2	
1337	247497	HAYES MIKE	SUR-GPS	01S	25E	27	BBB		3740	0	---	0	>30	2	100	---	---	---	4	4	1	limited aq description
1339	160913	GILMAN GARY	TRS-SEC	01S	24E	3	B		3507	50	3457	50	9	2	100	74.9	59	3448	2	2	3	
1347	217731	NORTH HILL DEVELOPMENT	TRS-SEC	01S	24E	3	CACC		3445	22	3423	22	30	2	100	---	52	3393	2	2	2	
1366	142062	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	15	CDBD	3536	3537	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1367	142113	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	27	CACA	3543	3552	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1390	10357	ZIMMERMAN CHARLES	TRS-SEC	01N	24E	21	CB		3737	---	---	---	---	---	---	---	1	3736	4	4	3	shale at surface?
1394	127682	KENNEDY MARK	TRS-SEC	01S	24E	3	BAA		3609	55	3554	55	>18	2	100	---	---	---	2	2	2	
1395	92771	FOX HARVEY & MELODYE	TRS-SEC	01S	24E	34	CDD	---	3425	67	3358	22	>15	3	50	---	---	---	2	2	2	40' sand on top of clay
1408	10329	MCFARLAND CLINT	TRS-SEC	01N	24E	4	BBD		3983	---	---	---	---	---	---	0.9	---	---	4	4	2	limited descriptions
1409	237560	CAUDILL CONSTRUCTION CO.	TRS-SEC	01S	24E	3	CAAA		3458	48	3410	41	27	2	100	---	75	3383	2	2	2	7' gravel in with clay
1410	141944	BILLINGS WATER SUPPLY * PIPELINE	TRS-SEC	01S	24E	3	CAAD	3455	3461	>20	---	---	---	---	---	---	---	---	1	1	2	10 ft clayey sand on clay
1411	142115	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	27	BAAA	3526	3531	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1463	142114	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	27	ACCB	3563	3567	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1465	142112	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	22	DBB	3530	3534	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1477	10330	MCFARLAND CLINTON B.	TRS-SEC	01N	24E	4	BDB		4003	---	---	---	---	---	---	---	---	---	4	4	2	no log
1478	208699	MARKEGAND CURT	TRS-SEC	01S	24E	3	DBBA		3451	28	3423	14	22	2	100	92.6	50	3401	2	2	2	14' gravel on top of clay
1480	92725	KLOTOVICH M JOSEPH	TRS-SEC	01S	24E	3	DC		3409	19	3390	19	>23	2	100	118.0	---	---	2	2	3	
1481	143867	ENGEL CONSTRUCTION	TRS-SEC	01S	24E	3	DC		3409	25	3384	25	>16	2	100	34.8	---	---	2	3	3	
1486	160912	FOSSUM SHAWN	TRS-SEC	01S	24E	34	DC	---	3404	55	3349	52	>14	1	200	10.5	---	---	3	3	3	3' gravel on top of clay
1499	10328	MCFARLAND CLINTON	TRS-SEC	01N	24E	4	BA		3937	---	---	---	---	---	---	0.1	---	---	4	4	3	Very limited shallow detail
1500	142111	BILLINGS WATER * CALAMITY JANE CANAL	TRS-SEC	01S	24E	22	ABAC	3537	3513	>25	---	---	---	---	---	---	---	---	4	4	2	didn't go through clay
1513	92772	FRANK JAKE H.	TRS-SEC	01S	24E	34	D	---	3398	50	3348	40	>5	3	50	---	---	---	3	3	3	10' gravel on top of clay
1514	160914	GOODMAN PAUL	TRS-SEC	01S	24E	34	D	---	3398	72	3326	56	8	2	100	35.3	90	3308	2	2	3	16' gravel on top of clay
1515	160916	R & J BUILDERS INC	TRS-SEC	01S	24E	34	D	---	3398	36	3362	28	20	2	100	60.9	56	3342	2	2	3	6' gravel on top of clay
1516	217749	ERLENBUSH GENE & LINDA	TRS-SEC	01S	24E	34	D	---	3398	---	---	---	---	---	---	---	---	---	3	3	3	no log
1551	224605	"CRITELLI, ROD"	TRS-SEC	01S	24E	34	DDC	---	3383	51	3332	37	14	2	100	---	64	3319	2	2	2	14' gravel on top of clay
1576	240089	KLASNA JOHN	NAV-GPS	01S	24E	34	DDDD	---	3377	34	3343	26	21	2	100	---	55	3322	2	2	1	8' gravel on top of clay
1577	224960	REITER RANDY	TRS-SEC	01S	24E	34	AAA	---	3420	88	3332	88	>13	2	100	---	---	---	2	2	2	

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
										Btm Dpth	Btm Elev	Thkns	Thkns		K (ft/d)		Depth	Elev	Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	(ft)	(ft MSL)	(ft)	(ft)	Type	Type	WL/Yld	(ft)	(ft MSL)	Contacts	Descr	Qual	Comment
1578	167982	R AND J BUILDERS INC	TRS-SEC	01S	24E	34	DDD	---	3374	36	3338	31	20	1	200	4.7	56	3318	2	2	2	5' gravel on top of clay
1579	198658	MYRUP RANDY	TRS-SEC	01S	24E	34	DDD	---	3374	31	3343	27	>15	1	200	---	---	---	2	2	2	4' gravel on top of clay
1590	232107	BEARTOOTH HOLDING & CONST*WELL #1	TRS-SEC	01S	24E	2	BCBB		3494	4	3490	4	15	2	100	---	19	3475	2	2	2	
1591	141943	BILLINGS WATER SUPPLY * PIPELINE	TRS-SEC	01S	24E	2	CBBC	3420	3419	0	---	0	>20	4	10	---	---	---	1	1	2	no clay cap
1595	139083	KRAFT BOB	TRS-SEC	01S	24E	35	CBB	---	3384	51	3333	45	>10	2	100	---	---	---	3	3	2	
1596	160917	RUFF DAVID	TRS-SEC	01S	24E	35	CBB	---	3384	8	3376	8	>30	2	100	11.9	---	---	2	2	2	
1600	191011	SPANJIAN KRIS	TRS-SEC	01N	24E	9	DDC		3783	16	3767	16	16	4	10	---	32	3751	4	4	2	limited aq description
1601	176230	RUFF DAN	TRS-SEC	01S	24E	26	CC	---	3414	82	3332	75	>14	1	200	---	---	---	2	2	3	at least 7' sand on/in clay
1642	170121	COVE CANYON RANCHLAND LLC	TRS-SEC	01N	24E	21	AA		3855	---	---	---	---	---	---	2.5	---	---	4	4	3	Eagle Sandstone
1643	212659	GILBERTSON RAY	TRS-SEC	01N	24E	9	DD		3812	16	3796	16	8	4	10	---	24	3788	4	4	3	limited aq description
1647	232104	BEARTOOTH HOLDING & CONST*WELL #2	TRS-SEC	01S	24E	2	BBDD		3471	10	3461	10	10	2	100	---	20	3451	2	2	2	
1655	232105	BEARTOOTH HOLDING & CONST*WELL #3	TRS-SEC	01S	24E	2	BABB		3497	9	3488	8	9	2	100	---	18	3479	2	3	2	general aquifer description
1657	92733	SCHWEHR LEO	TRS-SEC	01S	24E	11	CDB	3180	3337	21	3159	21	9	2	100	---	30	3150	2	3	2	general aquifer description
1658	100347	BAIRD DORIS	TRS-SEC	01S	24E	35	CAC	---	3359	---	---	---	---	---	---	---	---	---	3	3	3	no log
1660	165438	WHITFIELD BRUCE	TRS-SEC	01N	24E	10	CCB		3839	---	---	---	---	---	---	0.2	---	---	4	4	2	sandstone
1661	92732	SCHILD GARY C.	TRS-SEC	01S	24E	11	CA		3360	55	3305	55	13	3	50	0.6	68	3292	2	3	3	general aquifer description
1662	212663	MCEVOY LARRY	TRS-SEC	01N	24E	22	BC		3806	---	---	---	---	---	---	---	---	---	4	4	3	interbedded sand and shale?
1663	216693	PICARD DEVELOPMENT	TRS-SEC	01S	24E	35	BA	---	3382	10	3372	10	>20	2	100	---	---	---	2	2	3	
1671	154999	GRIFFIN BILL	TRS-SEC	01N	24E	10	CC		3786	---	---	---	---	---	---	0.3	---	---	4	4	3	sandstone
1675	143870	DECKER JIM	TRS-SEC	01S	24E	26	CDD	---	3384	41	3343	41	>18	2	100	60.3	---	---	2	2	2	clay mixed with some coarse
1676	92734	SCHWEHR LEO	TRS-SEC	01S	24E	11	CDD	---	3340	23	3317	23	17	2	100	---	40	3300	2	2	2	
1677	171195	FRANK VICTOR	TRS-SEC	01S	24E	35	CAD	---	3349	27	3322	27	12	2	100	145.9	39	3310	2	2	2	
1678	208036	RONAN DEAN	TRS-SEC	01S	24E	2	BAAA		3497	17	3480	17	22	2	100	---	39	3458	2	2	2	
1679	141942	BILLINGS WATER SUPPLY * PIPELINE	TRS-SEC	01S	24E	2	CAAA	3465	3438	>25	---	---	---	---	---	---	---	---	4	4	2	11 ft clayey sand on clay
1681	92724	KINNEY LAVINA	TRS-SEC	01S	24E	2			3442	---	---	---	---	---	---	---	---	---	4	4	3	no log
1719	10343	FORD DAVID	TRS-SEC	01N	24E	10	C		3852	---	---	---	---	---	---	14.3	---	---	4	4	3	sandstone
1732	231869	BROWN BEN	TRS-SEC	01N	24E	15	CDB		3606	---	---	---	---	---	---	---	---	---	3	3	2	interbedded shale and sandstone
1735	92735	MEYER JAMES	TRS-SEC	01S	24E	11	DC	---	3340	37	3303	37	>11	2	100	29.7	---	---	2	2	3	
1736	92774	FRANK HENRY H.	TRS-SEC	01S	24E	35	AB	---	3362	53	3309	53	22	2	100	41.1	65	3297	2	2	3	
1755	171591	SHAWHAN TIM	TRS-SEC	01N	24E	10	CD		3812	---	---	---	---	---	---	---	---	---	4	4	3	sandstone
1756	10327	SCHAAK DAN	TRS-SEC	01N	24E	3	CD		3957	0	---	0	33	2	100	0.02	33	3924	4	4	3	limited aq description
1773	194001	GRAYSON LYLE	TRS-SEC	01N	24E	22	CDDD		3517	30	3487	30	21	3	50	18.2	51	3466	2	2	2	
1774	10344	MCFARLAND CLINTON B.	TRS-SEC	01N	24E	10	CDAA		3802	---	---	---	---	---	---	---	---	---	4	4	2	no log
1775	10358	RICHARDSON A W	TRS-SEC	01N	24E	22			3812	0	---	0	32	2	100	---	32	3780	2	3	3	limited aq description, no clay?
1776	92773	FRANK HENRY H.	TRS-SEC	01S	24E	35	A	---	3342	63	3279	63	6	2	100	---	69	3273	3	3	3	good shale contact
1777	127684	YAGER JIM	TRS-SEC	01S	24E	11	D		3340	39	3301	39	10	4	10	---	41	3299	2	3	3	general aquifer description
1820	10348	LECHTENBERGER ADOLPH	TRS-SEC	01N	24E	15			3694	---	---	---	---	---	---	15.3	---	---	4	4	3	Eagle Sandstone
1821	10339	BRADSHAW GARY	TRS-SEC	01N	24E	10			3799	---	---	---	---	---	---	0.1	---	---	3	3	3	limited descriptions
1822	10340	MURRAY TOM	TRS-SEC	01N	24E	10			3799	6	3793	6	10	5	1	1.9	16	3783	4	4	3	
1823	10341	WARNER ROBERT	TRS-SEC	01N	24E	10			3799	6	3793	6	55	---	---	0.4	---	---	4	4	3	sand/bedrock descriptions unclear
1824	10342	WILLIAMS BERT & LINDA	TRS-SEC	01N	24E	10			3799	---	---	---	---	---	---	2.2	38	3761	4	4	3	poor shallow detail
1825	161458	MEHRER RICHARD	TRS-SEC	01N	24E	10			3799	10	3789	10	0	---	---	3.2	---	---	4	4	3	well in Eagle Sandstone
1826	10396	SALEY WILLIAM	TRS-SEC	01N	24E	27	ACCC		3504	---	---	---	---	---	---	---	---	---	3	3	3	Eagle Sandstone and drift
1841	192592	BROWN BEN	TRS-SEC	01N	24E	15	DCB		3579	12	3567	5	9	4	10	---	21	3558	2	2	2	
1842	192597	BROWN BEN	TRS-SEC	01N	24E	15	DCB		3579	---	---	---	---	---	---	---	---	---	2	2	2	Eagle Sandstone
1843	10346	MCFARLAND CLINTON B.	TRS-SEC	01N	24E	10	DBB		3780	---	---	---	---	---	---	---	---	---	4	4	2	no log
1844	10347	IMLAY JEFF	TRS-SEC	01N	24E	10	DCC		3796	---	---	---	---	---	---	0.2	5	3791	4	4	2	no clay or sand described
1847	176229	HEINS BILL	TRS-SEC	01S	24E	14	DA	---	3365	---	---	---	---	---	---	---	---	---	3	3	3	poor log
1883	10352	LEE ROGER	TRS-SEC	01N	24E	15	DC		3599	---	---	---	---	---	---	---	---	---	1	1	3	thin sand on Eagle Sandstone
1884	10353	LEE ROGER	TRS-SEC	01N	24E	15	DC		3599	---	---	---	---	---	---	0.4	---	---	2	2	3	14' sand on Eagle Sandstone
1885	150051	BROWN BEN	TRS-SEC	01N	24E	15	DC		3599	---	---	---	---	---	---	---	---	---	2	2	3	Eagle Sandstone
1886	171592	THOMPSON KEN	TRS-SEC	01N	24E	10	DC		3799	4	3795	4	1	5	1	0.5	7	3792	4	4	3	
1887	92747	ZEILER W. E.	TRS-SEC	01S	24E	14	AAAB	---	3320	---	---	---	---	---	---	---	---	---	3	3	2	no log
1889	92762	RONAN PAUL & RALPH	TRS-SEC	01S	24E	26	DDA	---	3354	---	---	---	---	---	---	---	---	---	3	3	3	no log
1891	92748	KRAFT EDWARD	TRS-SEC	01S	24E	23	ADD	---	3389	---	---	---	---	---	---	---	---	---	4	4	2	no log
1892	144771	YAGER JIM	TRS-SEC	01S	24E	11	DAD		3350	46	3304	46	13	2	100	4.5	59	3291	2	3	2	general aquifer description

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
										Btm Dpth	Btm Elev	Thkns	Thkns		K (ft/d)		Depth	Elev	Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	(ft)	(ft MSL)	(ft)	(ft)	Type	Type	WL/Yld	(ft)	(ft MSL)	Contacts	Descr	Qual	Comment
1904	141941	BILLINGS WATER SUPPLY * PIPELINE	TRS-SEC	01S	24E	2	AAAA	3460	3458	0	---	0	>20	5	1	---	---	---	4	4	2	no apparent clay cap
1907	10349	REHBERG MARY A.	TRS-SEC	01N	24E	15	D		3583	---	---	---	---	---	---	---	---	---	3	3	3	no log
1908	10350	REBERG JACK	TRS-SEC	01N	24E	15	D		3583	16	3567	16	---	---	---	16.5	---	---	2	3	3	16' clay on top of Eagle Sandstone
1909	10351	ARCHER JAMES	TRS-SEC	01N	24E	15	D		3583	0	---	0	42	3	50	44.6	42	3541	2	2	3	
1910	228838	ENCORE CONSTRUCTION	TRS-SEC	01S	24E	1	BCCC		3501	0	---	0	34	2	100	---	34	3467	2	3	2	
1912	92742	HOLDEN HAROLD	TRS-SEC	01S	24E	13	BBB	---	3317	40	3277	40	10	3	50	7.3	50	3267	2	3	2	general aquifer description
1913	171347	LOVE BRUCE AND BARB	TRS-SEC	01S	24E	13	BBB	---	3317	37	3280	37	12	4	10	4.7	49	3268	2	2	2	"quick sand"
1917	170726	SCHENNAM DEAN	TRS-SEC	01N	24E	22	AAC		3760	---	---	---	---	---	---	---	---	---	4	4	2	difficult to interpret log
1918	190959	GRICE HERB	TRS-SEC	01S	24E	12	CC	---	3333	46	3287	46	>7	2	100	---	---	---	2	3	3	general aquifer description
1941	161457	BEARTOOTH HOLDING	TRS-SEC	01N	24E	3	DA		3862	17	3845	17	17	2	100	102.8	34	3828	4	4	3	
1943	92760	WALTER VIRGIL	TRS-SEC	01S	24E	25	BBA	---	3345	---	---	---	---	---	---	---	---	---	3	3	2	no log
1944	92761	WALTERS VIRGIL	TRS-SEC	01S	24E	25	BBA	---	3345	57	3288	53	>13	2	100	---	---	---	2	2	2	4' gravel on top of clay
1945	197697	LOVE BRUCE AND BARB	TRS-SEC	01S	24E	13	BBA	---	3320	46	3274	46	4	4	10	7.8	50	3270	2	3	2	
1946	209803	SORENSON GORDON	TRS-SEC	01S	24E	13	BBA	---	3320	45	3275	45	>3	4	10	---	---	---	2	3	2	general aquifer description
1947	225283	BAKER ROB	TRS-SEC	01S	24E	1	BCA		3478	0	---	0	29	2	100	---	29	3449	2	2	2	
1948	218248	FRONTIER BUILDERS	TRS-SEC	01S	24E	1	CCA		3537	4	3533	4	31	2	100	---	35	3502	2	2	2	
1949	190943	HARRELL LEO	TRS-SEC	01S	24E	12	CCD	---	3330	30	3300	30	>18	4	10	---	---	---	2	2	2	
1950	209800	BRITTON LEVI * WELL 4	TRS-SEC	01S	24E	12	CCD	---	3330	40	3290	40	>8	2	100	---	---	---	2	3	2	general aquifer description
1951	224207	LEVI BRITTON WELL 4	TRS-SEC	01S	24E	12	CCD	---	3330	---	---	---	---	---	---	---	---	---	3	3	2	no log
1952	10359	REICHERT DAVE	TRS-SEC	01N	24E	22	AAA		3622	40	3582	40	>8	2	100	---	---	---	3	3	2	upper 40" "sand & clay"
1953	165962	CLADIS NICK	TRS-SEC	01N	24E	22	AAA		3622	38	3584	38	19	5	1	0.1	57	3565	2	3	2	limited aq description
1956	236624	"KIRKSEY PROPERTIES, LLC "	TRS-SEC	01N	24E	3	DDD		3871	---	---	---	---	---	---	---	---	---	4	4	2	Poor log
1958	10415	JOVANOVICH GARY L.	TRS-SEC	01S	24E	1	C		3533	---	---	---	---	---	---	---	---	---	3	3	3	no log
1966	218058	BYORTH PAUL	TRS-SEC	01N	24E	35	BCBB		3435	31	3404	13	9	3	50	---	40	3395	2	3	2	18' quick sand in clay layer
1967	10386	JONES JIM	TRS-SEC	01N	24E	23	BBB		3563	37	3526	27	19	4	10	5.5	56	3507	2	2	2	10' coarse material in with clay
1968	144295	JONES JIM	TRS-SEC	01N	24E	23	BBB		3563	---	---	---	---	---	---	0.1	---	---	3	3	2	sandstone and shale, well in Eagle SS
1969	227199	KELLY JAMES AND MARIC	TRS-SEC	01N	24E	23	BBB		3563	---	---	---	---	---	---	---	---	---	2	2	2	sandstone and siltstone
1970	191829	LLEWELLYN ASSOC TRUST	TRS-SEC	01S	24E	1	CDB		3514	3	3511	3	29	3	50	---	32	3482	2	2	2	
1971	209797	BRITTON LEVI * WELL 1	TRS-SEC	01S	24E	12	CDC	---	3330	40	3290	40	>8	2	100	---	---	---	2	3	2	general aquifer description
1972	209798	BRITTON LEVI * WELL 2	TRS-SEC	01S	24E	12	CDC	---	3330	40	3290	40	>8	2	100	---	---	---	2	3	2	general aquifer description
1973	209799	BRITTON LEVI * WELL 3	TRS-SEC	01S	24E	12	CDC	---	3330	40	3290	40	>8	2	100	---	---	---	2	3	2	general aquifer description
1974	224204	LEVI BRITTON WELL 1	TRS-SEC	01S	24E	12	CDC	---	3330	---	---	---	---	---	---	---	---	---	3	3	2	no log
1975	224205	LEVI BRITTON WELL 2	TRS-SEC	01S	24E	12	CDC	---	3330	---	---	---	---	---	---	---	---	---	3	3	2	no log
1976	224206	LEVI BRITTON WELL 3	TRS-SEC	01S	24E	12	CDC	---	3330	---	---	---	---	---	---	---	---	---	3	3	2	no log
1979	195540	CELLMER STEVE	TRS-SEC	01N	24E	11	BCB		3845	0	---	0	42	4	10	---	42	3803	4	4	2	
1981	197900	FETTING DENNIS	TRS-SEC	01N	24E	35	CBBA		3419	30	3389	30	4	2	100	13.4	34	3385	2	2	2	
1982	140466	BILLINGS WATER * BILLINGS PIPELINE	TRS-SEC	01N	24E	35	CBCD	3415	3415	>20	---	---	---	---	---	---	---	---	1	1	2	did not go through clay
1983	92744	LENHARDT ADOLPH	TRS-SEC	01S	24E	13	CDBD	---	3340	---	---	---	---	---	---	---	---	---	3	3	2	no log
1985	221793	EGGART PE QUENTIN *DRY HOLE 2	TRS-SEC	01N	24E	35	BC		3425	47	3378	47	0	---	---	---	47	3378	4	4	3	no sand described
1994	205761	KNAUP ROGER	TRS-SEC	01S	24E	12	CD	---	3333	42	3291	42	>8	3	50	---	---	---	2	3	3	general aquifer description
2000	244953	O'REAN DAVID	TRS-SEC	01S	24E	1	CDAB		3488	5	3483	5	26	2	100	---	31	3457	2	2	2	
2001	191826	LLEWELLYN ASSOC TRUST	TRS-SEC	01S	24E	1	CAA		3468	0	---	0	31	2	100	---	31	3437	3	3	2	no clay cap described
2002	191828	LLEWELLYN ASSOC TRUST	TRS-SEC	01S	24E	1	CAA		3468	0	---	0	32	2	100	---	32	3436	3	3	2	no clay cap described
2003	218102	FRONTIER BUILDERS	TRS-SEC	01S	24E	1	CDD		3445	0	---	0	32	2	100	---	32	3413	3	3	2	may have missed clay cap
2004	218105	RIEDLINGER BRAD	TRS-SEC	01S	24E	1	CDD		3445	0	---	0	35	2	100	---	35	3410	3	3	2	may have missed clay cap
2006	92743	WILLEMS MARTIN	TRS-SEC	01S	24E	13	BDAA	---	3317	---	---	---	---	---	---	---	---	---	3	3	2	no log
2007	227098	OTT STEVE	TRS-SEC	01N	24E	35	CBAA		3415	24	3391	6	7	2	100	---	32	3383	2	2	2	17' quick sand in with clay
2008	227286	OTT STEVE	TRS-SEC	01N	24E	35	CBAA		3415	24	3391	6	7	2	100	---	32	3383	2	2	2	17' quick sand in with clay
2009	92739	ZAHM ROY	TRS-SEC	01S	24E	13		---	3320	40	3280	40	1	4	10	0.5	41	3279	3	3	3	
2010	92740	LENHARDT ADOLPH	TRS-SEC	01S	24E	13		---	3320	---	---	---	---	---	---	---	---	---	3	3	3	no log
2012	92736	HAPPMAN JOAN	TRS-SEC	01S	24E	12			3369	---	---	---	---	---	---	1.7	---	---	3	3	3	very poor log
2015	10383	HERTZ JAMES	TRS-SEC	01N	24E	23	B		3553	---	---	---	---	---	---	---	---	---	3	3	3	interbedded "sand rock" & shale
2024	171349	ANDERSON HERBERT LAURALEE	TRS-SEC	01N	24E	35	BA		3435	16	3419	16	22	5	1	7.0	38	3397	2	2	3	
2029	10385	KNUTSON GEORGE	TRS-SEC	01N	24E	23	BA		3560	30	3530	30	45	4	10	---	75	3485	2	3	3	shale is "sandy"
2030	10387	STRAW PAUL	TRS-SEC	01N	24E	23	BD		3599	0	---	0	40	4	10	---	40	3559	2	3	3	deep well, poor shallow detail
2031	145007	HENDERSON ED	TRS-SEC	01N	24E	23	BD		3599	---	---	---	---	---	---	14.3	---	---	2	2	3	Eagle Sandstone

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
															K (ft/d)				Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	Btm Dpth (ft)	Btm Elev (ft MSL)	Thkns (ft)	Thkns (ft)	Type	Type	WL/Yld	Depth (ft)	Elev (ft MSL)	Contacts	Descr	Qual	Comment
2032	200618	FLOYD JOE	TRS-SEC	01N	24E	23	BD		3599	0	---	0	31	4	10	---	31	3568	2	2	3	
2033	10388	CHAUNCEY JIM	TRS-SEC	01N	24E	23	CA		3652	36	3616	36	---	---	---	---	---	---	4	4	3	sandstone below silt
2039	170993	BERMIS ERVIN	TRS-SEC	01N	24E	2	CD		3848	18	3830	18	102	5	1	0.5	120	3728	4	4	3	limited aq description
2043	217029	FINNICUM CURT	TRS-SEC	01N	24E	23	BAD		3524	---	---	---	---	---	---	---	12	3512	2	3	2	poor shallow detail
2057	10360	KASSAHN JACK	TRS-SEC	01N	24E	23			3694	80	3614	80	>15	4	10	7.6	---	---	2	3	3	sand rock in with clay
2058	10361	KASSAHN JACK	TRS-SEC	01N	24E	23			3694	45	3649	45	>53	4	10	28.7	---	---	2	3	3	limited aq description
2059	10363	THEISEN WILFRED	TRS-SEC	01N	24E	23			3694	---	---	---	---	---	---	3.6	---	---	3	3	3	Eagle Sandstone
2060	10365	KNUTSON GEORGE & LINDA	TRS-SEC	01N	24E	23			3694	0	---	0	60	4	10	9.4	60	3634	2	2	3	
2061	10366	KASSHAW JACK	TRS-SEC	01N	24E	23			3694	45	3649	45	>11	3	50	51.4	---	---	2	2	3	
2062	10367	BLACK JIM	TRS-SEC	01N	24E	23			3694	0	---	0	70	4	10	8.9	70	3624	2	2	3	
2063	10369	RANDASH EDWARD	TRS-SEC	01N	24E	23			3694	0	---	0	55	4	10	2.7	55	3639	2	2	3	
2064	10370	CHAUNCEY JIM	TRS-SEC	01N	24E	23			3694	10	3684	10	35	4	10	0.03	45	3649	2	2	3	well below shale
2065	10371	CHAUNCEY JIM	TRS-SEC	01N	24E	23			3694	---	---	---	---	---	---	5.5	120	3574	2	2	3	Eagle Sandstone on top of shale
2066	10372	CHAUNCEY JIM	TRS-SEC	01N	24E	23			3694	---	---	---	---	---	---	5.3	100	3594	2	2	3	Eagle Sandstone on top of shale
2067	10373	MONGER KEN	TRS-SEC	01N	24E	23			3694	---	---	---	---	---	---	5.9	60	3634	2	2	3	Eagle Sandstone on top of shale
2068	144699	GATZEMEIER PAUL	TRS-SEC	01N	24E	23			3694	---	---	---	---	---	---	1.1	50	3644	2	2	3	sandstone on top of shale
2069	161456	GOLDEN ACRES PARTNERSHIP	TRS-SEC	01N	24E	23			3694	---	---	---	---	---	---	---	---	---	3	3	3	poor shallow detail
2075	218242	MCLELLY ROBERT	TRS-SEC	01N	24E	35	DCBB		3399	0	---	0	25	4	10	---	31	3368	2	2	2	
2079	92737	PELICAN FRANK	TRS-SEC	01S	24E	12	AAB		3409	---	---	---	---	---	---	46.5	---	---	3	3	2	poor log
2080	28367	CHEX-91-076 * BORING MW-3	TRS-SEC	01S	24E	12	DAC		3327	3	3324	3	>17	2	100	---	---	---	1	1	2	
2084	10391	ZIMMERMAN CHAS INC	TRS-SEC	01N	24E	23	DBB		3566	43	3523	43	0	---	---	---	43	3523	4	4	2	shallow detail unclear
2088	160911	TIMBERMAN BOB	TRS-SEC	01S	24E	1	AA		3419	24	3395	24	0	---	---	---	24	3395	4	4	3	
2094	131684	BEIERS G D	TRS-SEC	01N	24E	23	AB		3681	---	---	---	---	---	---	---	---	---	2	2	3	all sandstone
2105	201566	AMES CATHERINE L	TRS-SEC	01N	24E	35	ACDB		3402	18	3384	18	21	3	50	---	39	3363	2	3	2	limited aq description
2106	92723	ORSER E.D.	TRS-SEC	01S	24E	1	DDA	3600	3402	---	---	---	---	---	---	---	---	---	3	3	2	no log
2109	10378	ZIMMERMAN CHARLES	TRS-SEC	01N	24E	23	ABD		3540	---	---	---	---	---	---	---	---	---	3	3	2	limestone?
2118	10375	MARTIN EVERETT	TRS-SEC	01N	24E	23	A		3589	---	---	---	36	4	10	5.8	72	3517	3	3	3	sandstone on top of shale
2121	226681	BRUCKHUNST WILLIAM	TRS-SEC	01N	24E	2	DDBB		3829	0	---	0	36	2	100	---	36	3793	4	4	2	No clay described
2122	219528	DOT *BIG DITCH *3-102-04	TRS-SEC	01S	25E	7	CCC	---	3310	20	3290	20	0	---	---	---	20	3290	4	4	2	no sand?
2123	160921	WOLFF MAGDALENA	TRS-SEC	01S	25E	6	CBC		3415	7	3408	7	25	2	100	111.3	32	3383	2	2	2	
2125	10377	ZIMMERMAN CHARLES	TRS-SEC	01N	24E	23	AAC		3701	---	---	---	---	---	---	---	---	---	3	3	2	Eagle Sandstone
2126	10392	WEEDEN WILLIAM W.	TRS-SEC	01N	24E	23	DDB		3570	---	---	---	---	---	---	---	---	---	4	4	2	no log
2133	221869	CITY OF BILLINGS PUD *MW-05-B	TRS-SEC	01S	25E	7	BB		3376	5	3371	5	17	2	100	---	22	3354	2	2	3	
2134	221870	CITY OF BILLINGS PUD *MW-05-C	TRS-SEC	01S	25E	7	BB		3376	8	3368	8	9	2	100	---	17	3359	2	2	3	
2135	93056	TUCKER F.W. JR.	TRS-SEC	01S	25E	7	BC	3250	3350	---	---	---	---	---	---	---	---	---	3	3	3	poor log
2136	93054	BASTIAN MILTON	TRS-SEC	01S	25E	6	CB		3379	---	---	---	---	---	---	---	---	---	3	3	3	no log
2137	160939	ENGBERG MARLON	TRS-SEC	01S	25E	6	CB		3379	8	3371	8	28	2	100	---	36	3343	2	2	3	
2145	10379	CHAUNCEY JIM	TRS-SEC	01N	24E	23	AD		3510	0	---	0	45	5	1	0.2	45	3465	3	3	3	poor shallow detail, well in bedrock
2146	10380	CHAUNCEY JIM	TRS-SEC	01N	24E	23	AD		3510	---	---	---	---	---	---	1.5	---	---	3	3	3	all sandstone
2147	10381	CHAUNCEY JAMES	TRS-SEC	01N	24E	23	AD		3510	---	---	---	---	---	---	---	---	---	3	3	3	sandstone and shale at about 33'
2148	10389	FLEER ELMER	TRS-SEC	01N	24E	23	DA		3533	15	3518	15	15	4	10	1.6	30	3503	2	2	3	well below shale
2149	237199	OHMAN GARY	TRS-SEC	01N	24E	23	DD		3576	---	---	---	>40	4	10	---	---	---	4	4	3	shale contact unclear
2150	222157	EGGART QUENTIN PE	TRS-SEC	01N	24E	35	AA		3399	---	---	---	---	---	---	---	---	---	3	3	3	difficult to interpret log
2151	221792	EGGART PE QUENTIN *WELL 1	TRS-SEC	01N	24E	35	AD		3396	55	3341	55	>4	1	200	---	---	---	2	2	3	
2152	221794	EGGART PE QUENTIN *DRY HOLE 3	TRS-SEC	01N	24E	35	DA		3399	44	3355	44	0	---	---	---	44	3355	4	4	3	no sand
2155	185980	BRAUN STEVEN	TRS-SEC	01S	25E	6	BCD		3369	4	3365	4	25	2	100	244.1	29	3340	2	2	2	
2157	142497	REHBERG DENNIS	TRS-SEC	01N	24E	14	AAA		3675	---	---	---	---	---	---	0.1	---	---	4	4	2	60' soft sand on top Eagle SS
2158	10390	PENDERGRAFT LARRY & DOROTHY	TRS-SEC	01N	24E	23	DAD		3533	---	---	---	---	---	---	3.7	65	3468	2	2	2	"sand rock" on top of shale
2161	140465	BILLINGS WATER * BILLINGS PIPELINE	TRS-SEC	01N	24E	26	DDDA	3420	3422	0	---	0	>20	5	1	---	---	---	2	1	2	no clay apparent
2162	10395	US GEOLOGICAL SURVEY	TRS-SEC	01N	24E	26	DDDD	3406	3412	>48	---	---	---	---	---	---	---	---	2	2	2	did not get through clay
2168	172290	TOAVS WARREN	TRS-SEC	01S	25E	6	B		3383	27	3356	27	13	5	1	2.9	40	3343	2	2	3	
2176	197015	MURPHY MARJORIE	TRS-SEC	01S	25E	7	BDBB		3383	---	---	---	---	---	---	---	---	---	3	3	2	poor log
2179	227926	RUTH CHARLES	TRS-SEC	01N	24E	1	CCCB		3793	7	3786	7	34	2	100	---	41	3752	4	4	2	9' of quick sand
2186	10403	LUDINGTON EDWIN M	TRS-SEC	01N	24E	36	BCB		3392	28	3364	28	42	3	50	25.5	70	3322	2	2	2	
2187	219187	MCKENZIE CRAIG	TRS-SEC	01N	24E	36	CCB		3369	0	---	0	38	4	10	---	38	3331	2	3	2	no clay. "quick sand"
2188	219188	MCKENZIE CRAIG	TRS-SEC	01N	24E	36	CCB		3369	26	3343	12	17	4	10	---	43	3326	2	3	2	14' quick sand on top of clay

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
															K (ft/d)				Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	Btm Dpth (ft)	Btm Elev (ft MSL)	Thkns (ft)	Thkns (ft)	Type	Type	WL/Yld	Depth (ft)	Elev (ft MSL)	Contacts	Descr	Qual	Comment
2189	219190	MCKENZIE CRAIG	TRS-SEC	01N	24E	36	CCB		3369	0	---	0	41	4	10	---	41	3328	2	3	2	no clay. "quick sand"
2190	219191	MCKENZIE CRAIG	TRS-SEC	01N	24E	36	CCB		3369	48	3321	11	30	4	10	---	78	3291	2	3	2	37' quick sand on top of clay
2193	235588	SCARIANO RON	TRS-SEC	01S	25E	7	BD		3360	75	3285	75	6	2	100	---	81	3279	2	2	3	"quick sand" & gravel
2198	235586	PICARD SHAY	TRS-SEC	01N	24E	36	BB		3396	7	3389	7	>23	2	100	---	---	---	2	3	3	limited aq description
2199	171350	SCHIE DUDLEY	TRS-SEC	01N	24E	36	CB		3383	20	3363	20	>40	3	50	57.3	---	---	2	2	3	34' of quick sand
2200	10404	GRAND AVE TRADING POST	TRS-SEC	01N	24E	36	CC		3360	---	---	---	---	---	---	---	---	---	3	3	3	no log
2201	10405	PESTAL ROSE	TRS-SEC	01N	24E	36	CC		3360	---	---	---	---	---	---	37.1	---	---	3	3	3	no log
2202	235463	COPELAND MIKE AND JOAN	TRS-SEC	01N	24E	36	CC		3360	12	3348	12	>23	2	100	---	---	---	2	3	3	
2206	10408	KINNEY LAVINA	TRS-SEC	01N	24E	36	CCDC		3360	40	3320	40	>12	2	100	7.0	---	---	3	3	2	
2207	10409	KINNEY LAVINA	TRS-SEC	01N	24E	36	CCDC		3360	---	---	---	---	---	---	2.8	---	---	3	3	2	poor log
2210	10406	PESTEL ROSE	TRS-SEC	01N	24E	36	CCD		3356	35	3321	35	>5	2	100	17.8	---	---	3	3	2	very general descriptions
2211	10407	PESTAL ROSE	TRS-SEC	01N	24E	36	CCD	3369	3356	---	---	---	---	---	---	---	---	---	3	3	2	no log
2214	93051	HARDESTY JAN E.	TRS-SEC	01S	25E	6			3350	25	3325	25	2	4	10	82.5	27	3323	3	3	3	poor log
2215	93052	SELWYN JEFF	TRS-SEC	01S	25E	6			3350	25	3325	25	>5	2	100	66.9	---	---	2	2	3	gravel in with silt
2217	93884	YELLOWSTONE INVESTORS	TRS-SEC	01S	25E	7			3340	---	---	0	33	2	100	49.8	37	3303	3	3	3	no cap?
2227	10393	REHBERG MARY A.	TRS-SEC	01N	24E	24	C		3501	---	---	---	---	---	---	---	---	---	3	3	3	no log
2231	190086	WEBER JOHN	TRS-SEC	01N	24E	24	BDB		3652	32	3620	26	15	2	100	---	47	3605	2	2	2	
2232	10411	PESTAL ROSE	TRS-SEC	01N	24E	36	CDC	3362	3356	---	---	---	---	---	---	---	---	---	3	3	2	no log
2239	221868	CITY OF BILLINGS PUD *MW-05-A	TRS-SEC	01S	25E	7	AB		3327	3	3324	3	22	2	100	---	---	---	2	2	3	
2252	248918	HILL DIANE	TRS-SEC	01N	24E	36	CA		3369	31	3338	30	3	2	100	---	36	3333	2	2	3	0.5' wet gravel in with clay
2253	10410	KINNEY LAVINA	TRS-SEC	01N	24E	36	CD		3356	---	---	---	---	---	---	---	---	---	3	3	3	no log
2254	200177	SCHERMERHORN SCOT	TRS-SEC	01N	24E	36	BDAB		3366	18	3348	18	20	2	100	---	38	3328	2	2	2	3' of quick sand
2259	150052	ANDERSON LAURA	TRS-SEC	01N	24E	36	BAD		3366	8	3358	8	20	4	10	1.9	28	3338	2	2	2	
2269	194002	SLOAN DAN	TRS-SEC	01N	24E	36	CADA		3363	39	3324	39	10	2	100	50.0	49	3314	2	2	2	
2276	10394	GOLDEN ACRES PARTNER	TRS-SEC	01N	24E	25			3468	---	---	---	---	---	---	---	46	3422	4	4	3	difficult to interpret log above shale
2277	10402	WEGNER ALBERT	TRS-SEC	01N	24E	36			3363	---	---	---	---	---	---	---	---	---	3	3	3	no log
2278	192072	LAMM FRANK AND JENNIFER	TRS-SEC	01N	24E	36			3363	17	3346	17	22	2	100	---	39	3324	2	2	3	9' of quick sand
2286	140464	BILLINGS WATER * BILLINGS PIPELINE	TRS-SEC	01N	24E	25	DCBB	3430	3422	0	---	0	>20	5	1	---	---	---	1	1	2	no distinct clay layer
2289	237607	COLD STONE ESTATES	TRS-SEC	01N	24E	36	DBBB		3360	26	3334	26	2	3	50	---	28	3332	2	2	2	
2292	190088	KNUTSON ROBERT E.	TRS-SEC	01N	24E	36	ACB		3360	8	3352	8	26	4	10	---	33	3327	2	2	2	quick sand and clay above water
2293	10412	BLANKENBAKER RALPH	TRS-SEC	01N	24E	36	DBC		3356	---	---	---	---	---	---	---	---	---	3	3	2	no log
2294	222905	SHENIDAN PAUL	TRS-SEC	01N	24E	36	DCC		3350	71	3279	49	0	---	---	---	71	3279	4	4	2	22' quick sand on top of clay
2295	93055	JONES THEODORE W AND MURIEL	TRS-SEC	01S	25E	6	DA		3317	---	---	---	---	---	---	---	---	---	3	3	3	no log
2296	176236	KUEHN DIANA & STEVE	TRS-SEC	01S	25E	6	DA		3317	13	3304	13	19	2	100	21.7	32	3285	2	2	3	
2315	235573	HANEY NATE	TRS-SEC	01N	24E	36	DB		3350	30	3320	30	>7	1	200	---	---	---	2	3	3	limited descriptions
2316	222158	ANDERSON JON	TRS-SEC	01N	24E	36	DC		3346	18	3328	18	3	3	50	---	21	3325	2	2	3	
2330	93053	US GEOLOGICAL SURVEY	TRS-SEC	01S	25E	6	AAAA	3343	3346	21	3322	21	9	5	1	---	30	3313	2	2	2	
2331	247491	GOODMAN JERRY	SUR-GPS	01N	25E	35	CAA		3625	53	3572	53	>7	1	200	---	---	---	4	4	1	limited aq description
2341	171419	BERNHARDT ROGER	TRS-SEC	01N	24E	36	DDB		3343	31	3312	31	14	3	50	143.2	45	3298	2	2	2	
2342	190089	COLBY SHAWN	TRS-SEC	01S	25E	5	BB		3340	---	---	---	---	---	---	---	---	---	3	3	3	poor log
2343	10419	BAILEY SHARON C.	TRS-SEC	01S	25E	5	CC		3307	---	---	---	---	---	---	---	---	---	3	3	3	no log
2371	232026	NIEHABER FRANK AND NICHOLE	TRS-SEC	01N	24E	36	AA		3360	0	---	0	>40	4	10	---	---	---	2	3	3	limited description. no clay?
2372	208704	NELSON SHELDON	TRS-SEC	01N	24E	36	DD		3340	28	3312	28	4	2	100	---	32	3308	2	2	3	
2373	216609	JONES & OLSON JIM & JOHN L.	TRS-SEC	01N	24E	36	DD		3340	20	3320	8	7	5	1	---	27	3313	2	3	3	12' quick sand mixed in with clay
2374	190090	WILCOX DAVID E.	TRS-SEC	01S	25E	5	CCA		3301	3	3298	3	25	2	100	---	28	3273	2	2	2	
2379	150469	TIMBERMEN BOB	TRS-SEC	01N	24E	1	AAD		3615	20	3595	20	0	---	---	---	20	3595	4	4	2	No sand described
2380	192605	CONNAGHAN ROBERT L.	TRS-SEC	01N	24E	36	DDD		3337	18	3319	18	>22	5	1	---	---	---	2	2	2	thin gravel on top of type 5
2381	192609	CONNAGHAN ROBERT	TRS-SEC	01N	24E	36	DDD		3337	41	3296	40	6	4	10	---	47	3290	2	2	2	"quick sand"
2382	195555	CONNRGHOR ROBERT	TRS-SEC	01N	24E	36	DDD		3337	48	3289	48	0	---	---	---	48	3289	4	4	2	no aq material described
2383	197012	CONNAGHAN ROBERT	TRS-SEC	01N	24E	36	DDD		3337	31	3306	31	9	2	100	11.1	40	3297	2	2	2	
2384	93042	AMEN DANIEL & GEORGE	TRS-SEC	01S	25E	5	B		3327	---	---	---	---	---	---	---	---	---	3	3	3	no log
2385	93043	AMEN DANIEL & GEORGE	TRS-SEC	01S	25E	5	C		3297	---	---	---	---	---	---	---	---	---	3	3	3	no log
2386	93045	AMEN HENRY JR.	TRS-SEC	01S	25E	5	C		3297	---	---	---	---	---	---	---	---	---	3	3	3	no log
2387	243013	ANDERSON HENRY	TRS-SEC	01S	25E	5	C		3297	58	3239	58	>1	1	200	---	---	---	3	3	3	some sand in with clay
2425	170113	MOMAHEN BRIAN	TRS-SEC	01N	25E	31	BBC		3353	---	---	---	---	---	---	16.8	---	---	3	3	2	difficult to interpret log
2426	144304	KAY LARRY	TRS-SEC	01N	25E	31	CBB		3337	28	3309	28	>19	2	100	92.8	---	---	2	2	2	

Table A-1. West Billings Study Well Log Review Summary

Identification			Geo	Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			Comment
										Btm Dpth	Btm Elev	Thkns	Thkns		K (ft/d)		Depth	Elev	Log Quality		Loc	
Map	GWIC	Name	Method	T	R	S	QS	Log	Map	(ft)	(ft MSL)	(ft)	(ft)	Type	Type	WL/Yld	(ft)	(ft MSL)	Contacts	Descr	Qual	
2427	204418	LOHRENZ DONALD R.	TRS-SEC	01N	25E	31	CBC		3327	49	3278	??	39	4	10	---	88	3239	2	3	2	upper 49' clay and sand
2428	220045	LOHRENZ DONALD	TRS-SEC	01N	25E	31	CBC		3327	0	---	0	53	3	50	---	53	3274	2	2	2	37' quick sand. No clay described
2446	183606	BUSCHER DEVELOPMENT	TRS-SEC	01N	25E	30	CB		3402	---	---	---	---	---	---	8.6	36	3366	3	3	3	difficult to interpret log above shale
2450	220044	STANICK JOHN	TRS-SEC	01N	25E	31	BCD		3340	0	---	0	38	4	10	---	38	3302	3	3	2	27' of quick sand, no clay?
2451	93041	GLENN JAME	TRS-SEC	01S	25E	5			3310	23	3287	23	>20	2	100	115.3	---	---	2	2	3	
2452	144454	FRANKS DOUG	TRS-SEC	01S	25E	5			3310	70	3240	65	>10	2	100	8.2	---	---	2	3	3	5' gravel in with clay
2453	150207	AMEN RALPH	TRS-SEC	01S	25E	5			3310	55	3255	55	20	2	100	23.5	75	3235	2	3	3	
2464	10421	BROWN CURTIS T.	TRS-SEC	01N	25E	6	C		3717	8	3709	8	21	4	10	0.4	29	3688	4	4	3	well in Eagle Sandstone
2465	238682	MURDOCK J.J.	TRS-SEC	01N	25E	31	B		3350	---	---	---	---	---	---	---	---	---	3	3	3	difficult to interpret log
2466	10453	ZIMMERMAN CHARLES	TRS-SEC	01N	25E	30	C		3389	72	3317	72	>8	4	10	---	---	---	2	3	3	limited aq description
2467	10454	ZIMMERMAN CHARLES	TRS-SEC	01N	25E	30	C		3389	58	3331	58	>14	4	10	---	---	---	2	3	3	limited aq description
2473	185707	SUNNYCOVE FRUIT FARM	TRS-SEC	01N	25E	31	CAB		3337	30	3307	30	>2	2	100	---	---	---	2	2	2	
2474	10441	ZIMMERMAN FAMILY LTD PARTNERSHIP	TRS-SEC	01N	25E	19	CDC		3445	---	---	---	---	---	---	---	---	---	3	3	3	no log
2475	93050	SCHILLINGER CLYDE	TRS-SEC	01S	25E	5	DB		3301	18	3283	10	>42	5	1	---	---	---	2	3	3	8' gravel on top of clay
2476	176235	HAWKINS TIM	TRS-SEC	01S	25E	5	DB		3301	63	3238	53	>15	1	200	4.1	---	---	2	3	3	10' sand interbedded in clay
2477	200582	AMEN MIKE AND CHERYL	TRS-SEC	01S	25E	5	DB		3301	67	3234	64	>13	1	200	---	---	---	2	3	3	
2495	185982	NELSON ED & LINDA	TRS-SEC	01N	25E	6	CD		3727	14	3713	14	6	4	10	---	22	3705	4	4	3	well in Eagle Sandstone
2496	144303	BORNE KEN COLLEN	TRS-SEC	01N	25E	31	BA		3360	---	---	---	---	---	---	---	---	---	3	3	3	difficult to interpret log
2497	171757	COSGROVE TAMMY & SHAWN	TRS-SEC	01N	25E	31	BA		3360	42	3318	40	>8	4	10	38.2	---	---	2	2	3	quick sand
2499	10455	STEWART L.J.	TRS-SEC	01N	25E	30	CD		3373	---	---	---	---	---	---	---	---	---	3	3	3	no log
2507	255176	"TERRACON CONSULTANTS, INC."	MAP	01N	25E	31	CDD		3320	>25	---	---	---	---	---	---	---	---	2	2	2	did not go through clay
2508	146356	BATTAGLIA JOHN AND CHRISTIE VICKIE	TRS-SEC	01N	25E	31	BAA		3366	25	3341	25	>6	5	1	1.1	---	---	2	2	2	
2509	204419	CATEN DAVE	TRS-SEC	01N	25E	31	BAA		3366	36	3330	20	2	3	50	23.1	37	3329	2	3	2	assume bottom is shale
2541	239993	TERRACON CONSULTANTS	NAV-GPS	01N	25E	30	CDD		3369	25	3344	25	>6	5	1	---	---	---	2	2	1	
2555	200178	STERNAD JAY	TRS-SEC	01N	25E	31	ACC		3340	34	3306	34	>3	3	50	---	---	---	2	3	2	limited aq description
2578	208688	HARRINGTON CORBIT	TRS-SEC	01N	25E	31	AB		3363	0	---	0	56	2	100	---	57	3306	2	3	3	2' clay laer 16-18'
2579	212686	PETERSON BOB	TRS-SEC	01N	25E	31	AB		3363	---	---	---	---	---	---	---	---	---	3	3	3	difficult to interpret log
2580	232011	COSGROVE SHAWN	TRS-SEC	01N	25E	31	AB		3363	46	3317	46	>4	3	50	---	---	---	2	2	3	
2581	200626	PLUHAR LARON	TRS-SEC	01N	25E	31	DC		3323	20	3303	20	38	4	10	---	58	3265	2	2	3	
2591	10452	YELLOWSTONE COUNTRY CLUB	TRS-SEC	01N	25E	30	ACAB		3448	---	---	---	---	---	---	---	---	---	3	3	2	Very limited shallow detail
2595	150199	GOODMAN RANDY	MAP	01S	25E	4	BB		3310	75	3235	75	17	2	100	13.7	92	3218	2	2	3	
2603	10442	ZIMMERMAN DOME OIL CO	TRS-SEC	01N	25E	19	D		3504	---	---	---	---	---	---	---	---	---	4	4	3	no log
2604	10439	REHBERG MARY A.	TRS-SEC	01N	25E	18	A		3550	---	---	---	---	---	---	---	---	---	4	4	3	no log
2605	10440	REHBERG MARY A.	TRS-SEC	01N	25E	18	D		3645	---	---	---	---	---	---	---	---	---	4	4	3	no log
2628	93035	WARD DURAND	TRS-SEC	01S	25E	4	BB		3310	85	3225	85	>13	2	100	2.3	---	---	2	3	3	details for clay not described
2629	93036	BELL RODGER	TRS-SEC	01S	25E	4	BB		3310	---	---	---	---	---	---	19.1	---	---	3	3	3	poor log
2630	221806	WARD DURAND	TRS-SEC	01S	25E	4	BB		3310	81	3229	81	>13	2	100	---	---	---	2	2	3	
2631	93037	LARSEN GARY	TRS-SEC	01S	25E	4	BC		3301	72	3229	72	>16	2	100	5.9	---	---	2	3	3	details for clay not described
2632	93038	OLSEN ROBERT	TRS-SEC	01S	25E	4	BC		3301	68	3233	68	14	2	100	24.2	82	3219	2	3	3	details for clay not described
2662	190094	MAHAN JOHN	TRS-SEC	01N	25E	31	DD		3317	38	3279	38	>2	1	200	---	---	---	2	3	3	limited aquifer description
2664	208669	RAMIREZ JACK	TRS-SEC	01N	25E	7	AA		3593	0	---	0	44	4	10	---	44	3549	4	4	3	well in Eagle Sandstone
2681	165980	SULLIVAN JIM	TRS-SEC	01S	25E	4	B		3301	70	3231	70	>22	2	100	28.7	---	---	2	2	3	
2682	238381	CARDWELL SARA	TRS-SEC	01S	25E	4	B		3301	84	3217	56	>4	2	100	---	---	---	2	3	3	28' sand and "soil" in with clay
2686	161465	MICHELS FRED	TRS-SEC	01N	25E	31	DAA		3330	11	3319	11	6	4	10	12.4	17	3313	2	2	2	
2687	171755	MACDONALD DONNA	TRS-SEC	01N	25E	31	DAA		3330	9	3321	9	1	4	10	---	10	3320	2	2	2	
2688	171756	MACDONALD DONNA	TRS-SEC	01N	25E	31	DAA		3330	10	3320	10	1	2	100	---	11	3319	2	2	2	
2726	128181	STURTAUNT SMOKEY TERRY	TRS-SEC	01N	25E	5	CCB		3609	>13	---	---	---	---	---	3.5	---	---	4	4	2	Eagle SS. Interbed sand rock & shale
2768	133284	JOHNSON CLIFF	TRS-SEC	01S	25E	4	BAD		3297	61	3236	61	>27	2	100	23.5	---	---	2	2	2	
2771	126397	RAY JERRY	TRS-SEC	01N	25E	32	BC		3340	60	3280	60	0	---	---	---	60	3280	4	4	3	no sand described
2772	10460	DEINES ROY	TRS-SEC	01N	25E	32	CC		3310	87	3223	72	10	2	100	11.8	97	3213	2	3	3	15' "sand rock" in with clay
2773	252514	JEFF JUNKENT CONSTRUCTION	TRS-SEC	01N	25E	32	CC		3310	92	3218	92	6	1	200	---	98	3212	2	2	3	general aquifer description
2774	10417	BAR DIAMOND RANCH	TRS-SEC	01N	25E	5	CB		3563	17	3546	17	---	---	---	---	---	---	4	4	3	well in Eagle Sandstone
2783	160954	KRESKE BILL	MAP	01S	25E	4	BAD		3297	70	3227	70	21	2	100	34.3	91	3206	2	2	2	
2793	247349	GRANITE PEAKS TOWN HOME ASSOC	NAV-GPS	01N	25E	32	C		3307	82	3225	59	13	2	100	---	95	3212	2	2	1	23' sand/soft sand on top of clay
2797	10418	BAR DIAMOND RANCH	TRS-SEC	01N	25E	5	CBA		3543	25	3518	25	---	---	---	---	75	3468	4	4	2	well in Eagle Sandstone
2819	10451	MILLS BOB	TRS-SEC	01N	25E	29	B		3793	---	---	---	---	---	---	0.4	---	---	1	1	3	sandstone & shale. well in Eagle SS

Table A-1. West Billings Study Well Log Review Summary

Identification			Geo	Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			Comment
										Btm Dpth	Btm Elev	Thkns	Thkns		K (ft/d)		Depth	Elev	Log Quality		Loc	
Map	GWIC	Name	Method	T	R	S	QS	Log	Map	(ft)	(ft MSL)	(ft)	(ft)	Type	Type	WL/Yld	(ft)	(ft MSL)	Contacts	Descr	Qual	
2823	10431	OSGOOD LINDA DIANNE	TRS-SEC	01N	25E	17	B		3550	---	---	---	---	---	---	---	---	---	4	4	3	29' topsoil above Eagle SS
2824	127237	OSGOOD KIT	TRS-SEC	01N	25E	17	B		3550	---	---	---	---	---	---	2.2	---	---	4	4	3	well in Eagle Sandstone
2825	10433	REHBERG JACK	TRS-SEC	01N	25E	17	C		3648	---	---	---	---	---	---	0.4	---	---	4	4	3	sand & shale. well in Eagle SS
2867	201572	MILLS BOB	TRS-SEC	01N	25E	29	BA		3806	---	---	---	---	---	---	---	---	---	4	4	3	sandstone & shale. well in Eagle SS
2868	232013	DEINES JUDY	TRS-SEC	01N	25E	32	CD		3310	78	3232	48	>12	2	100	---	---	---	2	2	3	30' sand/gravel in with clay
2883	127734	HAYNES JOHNATHON	TRS-SEC	01N	25E	5	CDA		3573	>13	---	---	---	---	---	---	---	---	4	4	2	Eagle SS. Interbed sand rock & shale
2897	10434	RUBLE ROBERT T	TRS-SEC	01N	25E	17	CAD	3580	3576	---	---	---	---	---	---	0.03	---	---	4	4	2	sand & shale. well in Eagle SS
2930	254569	CHURCH OF JESUS CHRIST OF LATTER DAY SAIN	TRS-SEC	01N	25E	29			3796	---	---	---	---	---	---	---	26	3770	3	3	3	limited detail above shale
2933	10458	DEINES WILLIAM	TRS-SEC	01N	25E	32			3327	---	---	---	---	---	---	---	---	---	3	3	3	poor log
2934	126723	DEINES WILLIAM	TRS-SEC	01N	25E	32			3327	---	---	---	---	---	---	---	---	---	3	3	3	poor log
2937	10427	DANIELS WHEELER	TRS-SEC	01N	25E	17			3579	---	---	---	---	---	---	0.6	---	---	4	4	3	well in Eagle SS at top
2938	10428	REHBERG MARY A	TRS-SEC	01N	25E	17			3579	---	---	---	---	---	---	---	---	---	4	4	3	no log
2939	10429	REHBERG MARY A	TRS-SEC	01N	25E	17			3579	---	---	---	---	---	---	---	---	---	4	4	3	no log
3031	200627	DEINES BILL	TRS-SEC	01N	25E	32	DC		3304	72	3232	48	>17	2	100	---	---	---	2	3	3	24' sand/gravel in with clay
3032	200628	DEINES BILL	TRS-SEC	01N	25E	32	DC		3304	74	3230	66	14	2	100	---	88	3216	2	2	3	8' gravel in with clay
3042	156814	MUNSELL NEIL & CAROLYN	TRS-SEC	01N	25E	17	AB		3520	34	3486	34	0	---	---	0.4	34	3486	4	4	3	well below shale in Eagle SS
3066	209929	BLOTT HAROLD	TRS-SEC	01N	25E	5	DCD		3517	12	3505	12	14	2	100	---	26	3491	4	4	2	
3067	145013	ROMIREZ JACK	TRS-SEC	01N	25E	17	ABA		3501	51	3450	51	---	---	---	0.6	---	---	4	4	2	well in Eagle SS below clay
3083	10461	BROMENSHENK FLORENCE	TRS-SEC	01N	25E	32	D		3301	0	---	0	>58	2	100	---	---	---	2	3	3	limited descrip, no clay noted
3084	10462	BROMENSHENK FLORENCE	TRS-SEC	01N	25E	32	D		3301	---	---	---	---	---	---	---	---	---	3	3	3	no log
3085	10463	BROMENSHENK FLORENCE	TRS-SEC	01N	25E	32	D		3301	---	---	---	---	---	---	---	---	---	3	3	3	no log
3089	10430	REHBERG MARY A.	TRS-SEC	01N	25E	17	A		3560	---	---	---	---	---	---	---	---	---	4	4	3	no log
3157	238114	MACKEY SHEEP COMPANY	TRS-SEC	01N	25E	5	AA		3596	---	---	---	---	---	---	---	---	---	2	2	3	Eagle Sandstone
3158	212679	GRYGIEL ANDY	TRS-SEC	01N	25E	8	DA		3625	6	3619	6	79	4	10	---	85	3540	4	4	3	well in Eagle Sandstone
3159	157221	FENSKE BRIAN	TRS-SEC	01N	25E	17	AD		3635	6	3629	6	14	4	10	20.4	20	3615	4	4	3	well in Eagle Sandstone
3160	212685	SCHERER LEE	TRS-SEC	01N	25E	17	AD		3635	7	3628	7	22	4	10	---	29	3606	4	4	3	well in Eagle Sandstone
3161	10437	NANCE BOB	TRS-SEC	01N	25E	17	DA		3619	0	---	0	70	4	10	6.4	70	3549	4	4	3	well in Eagle SS below shale
3162	10438	SCOTT TOM	TRS-SEC	01N	25E	17	DA		3619	18	3601	18	---	---	---	---	---	---	4	4	3	well in Eagle Sandstone
3163	247440	CEDAR GROVE CONDO ASSOCIATION	NAV-GPS	01S	25E	11	DB		3596	6	3590	6	20	2	100	---	26	3570	4	4	1	limited aq description
3188	134371	TAYLOR PHILL	TRS-SEC	01N	25E	17	DDA		3602	11	3591	11	8	4	10	0.1	19	3583	4	4	2	well in Eagle SS below shale
3189	150471	STONE KEITH	TRS-SEC	01N	25E	17	DDD		3681	---	---	---	---	---	---	---	---	---	4	4	2	sandstone & shale. well in Eagle SS
3190	219960	ANDERSON DAVE	TRS-SEC	01N	25E	17	DDD		3681	---	---	---	---	---	---	---	---	---	4	4	2	sandstone & shale. well in Eagle SS
3191	147426	CANTON MARK	TRS-SEC	01N	25E	5	DDA		3586	0	---	0	22	4	10	26.7	22	3564	4	4	2	well in Eagle Sandstone
3219	10474	LENHARDT MARK	MAP	01N	25E	33	CD		3291	63	3228	63	20	2	100	---	83	3208	2	2	3	
3223	10473	LENHARDT JOHN & CAROLINE	TRS-SEC	01N	25E	33	CBC		3287	65	3222	65	>14	2	100	---	---	---	2	3	2	limited descriptions
3242	171753	BILLINGS URBAN FIRE SERVICE AREA	TRS-SEC	01N	25E	33	BC		3327	56	3271	56	>21	2	100	35.8	---	---	2	2	3	
3254	212681	BAKER JIM AND LINDA	TRS-SEC	01N	25E	9	CB		3635	---	---	---	---	---	---	---	---	---	4	4	3	hard to interpret log. well in Eagle SS
3255	177311	MARKEGARD ROD AND JANE	TRS-SEC	01N	25E	9	CC		3625	---	---	---	---	---	---	---	---	---	2	2	3	well in Eagle Sandstone
3256	216655	SWAIN JIM	TRS-SEC	01N	25E	9	CC		3625	---	---	---	---	---	---	---	---	---	4	4	3	interbedded "sand rock" & shale
3259	10443	REHBERG DENNIS	TRS-SEC	01N	25E	21	CCA		3737	---	---	---	---	---	---	0.03	---	---	4	4	2	poor log. well in Eagle SS
3260	131687	SWAIN DAVE	TRS-SEC	01N	25E	33	CBD		3287	62	3225	62	22	2	100	19.4	84	3203	2	2	2	
3261	140303	VULETICK MARK	TRS-SEC	01N	25E	33	CCA		3281	58	3223	58	>23	2	100	145.3	---	---	2	2	2	
3302	161466	NEUHOFF DOUG & KATHY	TRS-SEC	01N	25E	33	C		3281	55	3226	55	23	2	100	64.5	78	3203	2	2	3	
3303	171752	POPPLER MARILIAN	TRS-SEC	01N	25E	33	C		3281	50	3231	50	16	2	100	40.5	66	3215	2	2	3	
3309	171353	HOLLEY PAUL	TRS-SEC	01N	25E	9	C		3645	13	3632	13	97	4	10	4.1	110	3535	4	4	3	sand rock on shale. well in Eagle SS
3310	177312	ALAMAN PAUL AND JONI	TRS-SEC	01N	25E	9	C		3645	13	3632	13	15	4	10	---	28	3617	4	4	3	sand rock on shale. well in Eagle SS
3311	10426	MILLER SAUNDER	TRS-SEC	01N	25E	16	C		3609	---	---	---	---	---	---	---	---	---	4	4	3	no log
3314	203953	RLK HYDRO	TRS-SEC	01N	25E	33	BDB		3338	56	3282	56	>24	2	100	---	---	---	2	2	2	
3339	165959	RIETZ DAVE	TRS-SEC	01N	25E	33	BA		3361	125	3236	125	15	4	10	3.4	140	3221	2	2	3	
3340	232015	WALKER ENOCH	TRS-SEC	01N	25E	33	BD		3326	6	3320	6	20	2	100	---	26	3300	2	2	3	
3344	181036	GRYGIEL ANDY AND LAURIE	TRS-SEC	01N	25E	9	BD		3553	---	---	---	---	---	---	---	---	---	4	4	3	no log. Eagle SS
3345	226439	SCHREIBER CHRIS	TRS-SEC	01N	25E	9	CA		3645	17	3628	17	13	4	10	0.1	30	3615	4	4	3	sand rock on shale. well in Eagle SS
3346	185986	MORGANTHALER FRED	TRS-SEC	01N	25E	9	CD		3654	16	3638	16	8	4	10	---	24	3630	4	4	3	well in Eagle Sandstone
3382	142499	HIARING BOB	TRS-SEC	01N	25E	4	CDD		3585	---	---	---	---	---	---	0.3	---	---	4	4	3	interbedded "sand rock" & shale
3394	10464	RATCLIFF DWIGHT	TRS-SEC	01N	25E	33			3303	55	3248	35	>29	4	10	6.9	---	---	2	2	3	20' sand in with clay
3395	10465	STEVENS IRA	TRS-SEC	01N	25E	33			3303	75	3228	32	>17	4	10	9.6	---	---	2	2	3	43' sand in with clay

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
										Btm Dpth	Btm Elev	Thkns	Thkns		K (ft/d)		Depth	Elev	Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	(ft)	(ft MSL)	(ft)	(ft)	Type	Type	WL/Yld	(ft)	(ft MSL)	Contacts	Descr	Qual	Comment
3396	10466	RUSHTON RONALD A.	TRS-SEC	01N	25E	33			3303	75	3228	35	>19	4	10	9.1	---	---	2	2	3	40' sand in with clay
3397	10467	MOBELY GERALD E.	TRS-SEC	01N	25E	33			3303	---	---	---	---	---	---	---	---	---	3	3	3	poor log
3398	10468	KLEIN LYNN	TRS-SEC	01N	25E	33			3303	100	3203	100	>20	3	50	5.6	---	---	2	3	3	limited aq description
3399	10469	HALL JAMES	TRS-SEC	01N	25E	33			3303	123	3180	123	20	3	50	8.6	143	3160	2	3	3	limited aq description
3416	11856	WEISGERBER DONALD A.	TRS-SEC	01N	25E	33	ACC		3307	80	3227	32	>10	2	100	13.4	---	---	2	2	2	48' sand in with clay
3417	166250	LELEND / HAN WELLS	TRS-SEC	01N	25E	33	ACC		3307	6	3301	6	20	2	100	---	26	3281	2	2	2	
3440	239883	ELITE HOMES	TRS-SEC	01N	25E	33	AB		3355	5	3350	5	>20	2	100	---	---	---	2	3	3	limited aq description
3441	120315	SCHMIDT DELMER	TRS-SEC	01N	25E	33	AC		3315	94	3221	94	3	2	100	33.4	97	3218	2	2	3	
3442	10476	SHILOH UNITED METHODIST CHURCH	TRS-SEC	01N	25E	33	DB		3282	38	3244	38	20	1	200	---	58	3224	2	3	3	limited aq description
3443	171348	SYLVAN NORBERT AND RAMONA	TRS-SEC	01N	25E	33	DB		3282	36	3246	36	>15	2	100	216.8	---	---	2	1	3	
3444	190106	LIPP BRENT	TRS-SEC	01N	25E	33	DB		3282	55	3227	55	>21	1	200	---	---	---	2	3	3	limited aq description
3445	239921	DR NELSON	TRS-SEC	01N	25E	33	DB		3282	5	3277	5	>15	4	10	---	---	---	2	3	3	limited aq description
3451	195535	CEBULL RICK	TRS-SEC	01N	25E	9	AB		3574	6	3568	6	8	4	10	---	14	3560	4	4	3	well in Eagle Sandstone
3452	231998	MIKE NINICHUCK%ALL DESIGN LANDSCAPING	TRS-SEC	01N	25E	9	DB		3561	0	---	0	40	4	10	---	40	3521	4	4	3	well in Eagle Sandstone
3453	239886	"JOHNSON KIRK, AND KATHERINE HATCH"	TRS-SEC	01N	25E	9	DB		3561	6	3555	6	72	4	10	---	78	3483	4	4	3	well in Eagle Sandstone
3454	208685	REHBERG DENNIE AND JAN	TRS-SEC	01N	25E	16	DB		3505	---	---	---	---	---	---	---	---	---	4	4	3	all sand. well in Eagle Sandstone
3462	253483	FINN BRADLEY	NAV-GPS	01N	25E	9	ADA		3642	---	---	---	---	---	---	---	27	3615	2	2	1	sandstone above shale
3464	120314	SCHOOL DISTRICT # 2	TRS-SEC	01N	25E	33	A		3331	102	3229	102	23	2	100	23.8	125	3206	2	2	3	
3465	239920	HI TECH CONSTRUCTION	TRS-SEC	01N	25E	33	A		3331	29	3302	29	>115	2	100	---	---	---	2	3	3	limited descriptions
3466	10475	GOODMAN GERALD R.	TRS-SEC	01N	25E	33	D		3269	0	---	0	>50	2	100	24.1	---	---	2	3	3	limited descrip, no clay noted
3471	252194	FINN BRAD	NAV-GPS	01N	25E	9	ADA		3644	---	---	---	---	---	---	---	35	3609	4	4	1	sandstone above shale
3472	171629	MCKNIRE DENNIS	TRS-SEC	01N	25E	28	DDCC		3382	158	3224	158	9	1	200	---	167	3215	2	3	2	limited aq description
3499	190093	BARTA ALLAN	TRS-SEC	01N	25E	9	DAC		3522	4	3518	4	28	4	10	0.1	32	3490	4	4	2	well in Eagle Sandstone
3501	252508	CUMMINGS CHRISI	NAV-GPS	01N	25E	9	DA		3633	18	3615	18	0	---	---	---	18	3615	4	4	1	no sand above shale
3503	10470	BLACKFORD ALLEN DDS	TRS-SEC	01N	25E	33	AA		3348	106	3242	106	>5	4	10	5.5	---	---	2	2	3	
3504	171754	MISSIONS UNITED INC	TRS-SEC	01N	25E	33	AA		3348	120	3228	120	>16	2	100	47.8	---	---	2	2	3	
3505	171751	EGGEH ALLEN	TRS-SEC	01N	25E	33	DA		3275	64	3211	64	>16	2	100	---	---	---	2	3	3	24-64 described as "clay sand"
3511	185983	TALLMAN PHILLIP & LAURA	TRS-SEC	01N	25E	9	DA		3479	0	---	0	22	4	10	---	22	3457	4	4	3	well in Eagle Sandstone
3512	185984	BARNETT MARTIN K.	TRS-SEC	01N	25E	9	DD		3648	12	3636	12	14	4	10	0.2	26	3622	4	4	3	well in Eagle Sandstone
3513	200620	FISHER MIKE	TRS-SEC	01N	25E	9	DD		3648	0	---	0	30	4	10	---	30	3618	4	4	3	well in Eagle Sandstone
3550	252526	CUMMINGS CHRIS	NAV-GPS	01N	25E	9	DA		3650	10	3640	10	36	4	10	---	46	3604	4	4	1	
3560	161464	ALLEN WEBSTER & PRICILLA	TRS-SEC	01N	25E	27	CCC		3376	157	3219	157	11	4	10	1.7	168	3208	2	2	2	
3574	200630	BUSCHER DEVELOPMENT	TRS-SEC	01N	25E	34	BB		3344	57	3287	42	19	2	100	---	76	3268	2	2	3	15' of sand in with clay
3582	10488	KOBELT DARREL	TRS-SEC	01N	25E	34	BCA		3317	60	3257	60	>65	2	100	1.0	---	---	2	3	2	limited aq description
3639	10492	FOX WILLIAM	TRS-SEC	01N	25E	34	C		3262	---	---	---	---	---	---	---	---	---	3	3	3	poor log
3648	247357	BATERSLUB ROB	NAV-GPS	01N	26E	33	CB		3308	15	3293	15	11	2	100	---	27	3281	2	2	1	
3650	10424	REHBERG JACK	TRS-SEC	01N	25E	15	B		3442	---	---	---	---	---	---	1.6	---	---	4	4	3	limited description. well in Eagle SS
3651	10489	HOWARD CLYDE	TRS-SEC	01N	25E	34	BDB		3313	0	---	0	123	2	100	32.4	123	3190	2	1	2	clay layer 32-34'
3652	10490	STORY WILLARD F	TRS-SEC	01N	25E	34	BDC		3294	---	---	---	---	---	---	---	---	---	3	3	2	no log
3653	10493	STORY WILLARD F.	TRS-SEC	01N	25E	34	CAB		3276	---	---	---	---	---	---	---	---	---	3	3	2	no log
3669	98378	BOISE CASCADE - FLOBERG SALES	TRS-SEC	01N	25E	34	BDCA		3297	0	---	0	22	2	100	178.3	22	3275	2	2	2	
3673	10487	CHILDS PEGGY	TRS-SEC	01N	25E	34	BA	3330	3336	109	3221	19	>60	2	100	---	---	---	3	1	3	hard to discern upper zone
3674	10494	ZIMMERMAN RODNEY	TRS-SEC	01N	25E	34	CD		3250	---	---	---	---	---	---	---	---	---	3	3	3	no log
3679	212682	CELLMER LAWRENCE	TRS-SEC	01N	25E	10	CA		3447	---	---	---	---	---	---	---	---	---	4	4	3	well in Eagle Sandstone. no shale
3681	10491	IRVINE CALVIN & LEON	TRS-SEC	01N	25E	34	BDD		3283	62	3221	37	29	2	100	8.5	91	3192	2	3	2	25' sand in clay, limited aq desc
3697	211542	SULLINS MONTY	TRS-SEC	01N	25E	34	CAAA		3271	80	3191	59	15	2	100	22.1	95	3176	2	2	2	21' sand & quick sand in clay
3699	10450	MAXWELL CHARLES	TRS-SEC	01N	25E	27			3748	140	3608	140	22	1	200	---	162	3586	2	3	3	limited aq description
3700	10477	HAVIG DONALD R	TRS-SEC	01N	25E	34			3273	50	3223	50	23	2	100	24.9	73	3200	2	2	3	
3701	10478	REICHENBACH ERNEST	TRS-SEC	01N	25E	34			3273	48	3225	48	>18	2	100	51.8	---	---	2	2	3	
3702	10479	STEDMAN DENNIS	TRS-SEC	01N	25E	34			3273	7	3266	7	>122	4	10	0.6	---	---	2	2	3	
3703	10480	HALLAND DAVE	TRS-SEC	01N	25E	34			3273	---	---	---	---	---	---	5.3	120	3153	2	3	3	poor shallow description
3704	10481	BENDER LYLE	TRS-SEC	01N	25E	34			3273	---	---	---	---	---	---	0.1	---	---	3	3	3	poor log
3705	10482	BOGGESS VIOLA	TRS-SEC	01N	25E	34			3273	125	3148	125	15	2	100	50.9	140	3133	2	2	3	
3706	10483	BURGESS ARNOLD	TRS-SEC	01N	25E	34			3273	---	---	---	---	---	---	297.1	---	---	3	3	3	poor log
3738	170114	WYNDHAM PARK ASSOC.	TRS-SEC	01N	25E	34	DB		3258	41	3217	41	>21	2	100	121.2	---	---	2	2	3	
3739	239888	BILLSTEIN RON	TRS-SEC	01N	25E	34	DB		3258	126	3132	126	>14	2	100	---	---	---	2	3	3	limited aq description

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
										Btm Dpth	Btm Elev	Thkns	Thkns		K (ft/d)		Depth	Elev	Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	(ft)	(ft MSL)	(ft)	(ft)	Type	Type	WL/Yld	(ft)	(ft MSL)	Contacts	Descr	Qual	Comment
3740	10497	ZIMMERMAN E.M.	TRS-SEC	01N	25E	34	DC		3240	---	---	---	---	---	---	---	---	---	3	3	3	no log
3741	170131	YELLOWSTONE MEMORIAL PARK	TRS-SEC	01N	25E	34	DC		3240	30	3210	30	20	2	100	---	50	3190	2	2	3	
3750	212683	KOWALSKI PAUL	TRS-SEC	01N	25E	10	DB		3425	6	3419	6	30	4	10	---	36	3389	4	4	3	well in Eagle Sandstone
3751	190092	MPC	TRS-SEC	01N	25E	15	AB		3428	7	3421	7	18	2	100	---	25	3403	4	4	3	missing interval 7-18'
3754	131688	GREYSTONE CONDOMINIUM ASSOC	TRS-SEC	01N	25E	34	DBD		3250	33	3217	33	22	2	100	242.1	57	3193	2	2	2	
3755	145017	JOHNSON FLOYD	TRS-SEC	01N	25E	34	DBD		3250	38	3212	38	>22	2	100	105.6	---	---	2	2	2	
3766	10495	KOBER CONST.	TRS-SEC	01N	25E	34	D		3244	16	3228	16	20	2	100	160.4	36	3208	2	2	3	
3767	154979	PREMIER DEVELOPMENT LTD	TRS-SEC	01N	25E	34	D		3244	31	3213	31	20	2	100	69.3	51	3193	2	2	3	
3768	154980	PREMIER DEVELOPMENT LTD	TRS-SEC	01N	25E	34	D		3244	27	3217	27	22	2	100	48.3	49	3195	2	2	3	
3769	161468	PREMIER DEVELOPMENT LTD	TRS-SEC	01N	25E	34	D		3244	20	3224	15	24	2	100	99.0	44	3200	2	2	3	5' gravel in with clay
3777	10425	WALKER EUGENE	TRS-SEC	01N	25E	15	D		3560	0	---	0	>21	4	10	---	---	---	4	4	3	
3798	144306	MANKIN JIM	TRS-SEC	01N	25E	34	DAB		3266	54	3212	54	18	2	100	---	72	3194	2	2	2	
3799	131690	ASPEN MEADOWS	TRS-SEC	01N	25E	34	DDB		3238	24	3214	24	>24	2	100	560.7	---	---	2	2	2	
3815	145016	HOLLAR KENNETH	TRS-SEC	01N	25E	27	DA		3539	---	---	---	---	---	---	---	---	---	3	3	3	poor log
3820	10484	HICKEY J.R.	TRS-SEC	01N	25E	34	AA		3323	0	---	0	>20	2	100	---	---	---	3	3	3	limited description
3821	10485	HILL WALT S.	TRS-SEC	01N	25E	34	AD	3290	3288	0	---	0	24	1	200	14.3	24	3266	2	3	3	no clay. limited aquifer description
3822	10486	BELL DAVID W.	TRS-SEC	01N	25E	34	AD	3117	3288	10	3107	10	96	1	200	83.6	106	3011	2	2	3	assumed 10' clay
3823	192664	MAY FLOWER CHURCH	TRS-SEC	01N	25E	34	AD		3288	78	3210	78	>7	2	100	51.4	---	---	2	2	3	
3824	125035	MICHAEL CALVIN D AND DEBRA L	TRS-SEC	01N	25E	34	DA		3260	38	3222	38	>22	2	100	35.8	---	---	2	2	3	
3825	177314	WYNDHAM PARK ASSOCIATION	TRS-SEC	01N	25E	34	DA		3260	36	3224	36	>19	1	200	108.2	---	---	2	2	3	
3828	208680	SCHRENDER DAVE	TRS-SEC	01N	25E	15	AA		3402	6	3396	6	12	3	50	---	18	3384	4	4	3	
3829	200622	SPARBOE ARON	TRS-SEC	01N	25E	15	DD		3524	8	3516	8	22	3	50	---	30	3494	4	4	3	
3881	230094	APPLEWOOD PATIO HOMES	TRS-SEC	01N	25E	34	ADA		3295	80	3215	80	28	2	100	---	108	3187	2	2	2	
3882	10496	STRIBLEY JOE	TRS-SEC	01N	25E	34	DAA		3268	55	3213	55	20	2	100	64.2	75	3193	2	2	2	
3883	131689	ELIOT STEVE	TRS-SEC	01N	25E	34	DDA		3237	22	3215	22	>23	2	100	229.2	---	---	2	2	2	
3884	134373	WAYLANDER GARY	TRS-SEC	01N	25E	34	DDA		3237	25	3212	25	24	2	100	20.9	49	3188	2	2	2	
3945	10519	DONOVAN GARY W.	TRS-SEC	01N	25E	35	BB		3321	93	3228	93	24	2	100	16.7	117	3204	2	3	3	limited description
3946	10530	DAVIES J.M.	TRS-SEC	01N	25E	35	CC		3229	---	---	---	---	---	---	---	---	---	3	3	3	no log
3947	208480	FARMER DAN	TRS-SEC	01N	25E	35	CC		3229	25	3204	25	>23	2	100	---	---	---	2	3	3	
3954	145015	HAMILTON RICHARD D.	TRS-SEC	01N	25E	26	BCD		3717	---	---	---	---	---	---	---	---	---	4	4	2	Eagle Sandstone
3955	145038	HAMILTON RICHARD	TRS-SEC	01N	25E	26	BCD		3717	---	---	---	---	---	---	---	---	---	4	4	2	Eagle Sandstone
3956	161529	POOL STEVE	TRS-SEC	01N	25E	23	CBA		3690	23	3667	23	---	---	---	---	---	---	4	4	2	"sand rock" below clay
4059	10449	LILLEBERG PHILLIP A.	TRS-SEC	01N	25E	23	C		3696	6	3690	6	---	---	---	0.1	---	---	4	4	3	well in Eagle SS below clay
4062	10522	FRITZ GERALD L.	TRS-SEC	01N	25E	35	C		3240	---	---	---	---	---	---	---	---	---	3	3	3	no log
4063	10523	WALTER RONALD A. MR. & MRS.	TRS-SEC	01N	25E	35	C		3240	30	3210	30	>23	2	100	---	---	---	2	2	3	
4064	10524	SNETTING OMER H.	TRS-SEC	01N	25E	35	C		3240	27	3213	27	>8	2	100	---	---	---	2	2	3	
4065	10525	BROMENSHENK JIM	TRS-SEC	01N	25E	35	C		3240	---	---	---	---	---	---	---	---	---	3	3	3	poor log
4066	10526	RASMUSSEN EDGAR	TRS-SEC	01N	25E	35	C		3240	36	3204	36	36	4	10	40.5	71	3169	2	2	3	
4067	10527	VADNAIS DWIGHT	TRS-SEC	01N	25E	35	C		3240	40	3200	40	>22	2	100	48.6	---	---	2	3	3	10' of quick sand
4068	10528	SPATH RICHARD	TRS-SEC	01N	25E	35	C		3240	45	3195	45	>15	2	100	30.7	---	---	2	2	3	
4071	194004	ASKINS JOHN	TRS-SEC	01N	25E	35	CABB		3263	86	3177	55	>7	2	100	12.0	---	---	2	2	2	31' quick sand in with clay
4072	248992	HALLBERG DONALD AND SHARON	TRS-SEC	01N	25E	11	CDBC		3398	5	3393	5	---	---	---	---	---	---	4	4	2	sandstone below clay
4084	10529	DEMING RONALD L	TRS-SEC	01N	25E	35	CAB		3260	40	3220	40	26	2	100	25.9	66	3194	2	2	2	
4107	10520	LEISCHNER NORM	TRS-SEC	01N	25E	35	BD	3280	3283	26	3254	26	>38	2	100	9.2	---	---	2	2	3	
4108	10521	HIRT JIM	TRS-SEC	01N	25E	35	BD		3283	---	---	---	---	---	---	---	---	---	3	3	3	difficult to interpret log
4109	185988	FOREST PARK HOA *WELL #3	TRS-SEC	01N	25E	35	CA		3252	14	3238	14	21	1	200	---	35	3217	2	3	3	limited aq description
4110	10531	FOX LAND & CATTLE CO	TRS-SEC	01N	25E	35	CD		3232	---	---	---	---	---	---	---	---	---	3	3	3	no log
4111	185989	FOREST PARK HOA *WELL #4	TRS-SEC	01N	25E	35	CD		3232	14	3218	14	21	1	200	---	35	3197	2	3	3	general aquifer description
4112	185991	FOREST PARK HOME OWNERS	TRS-SEC	01N	25E	35	CD		3232	16	3216	16	>24	1	200	---	---	---	2	3	3	general aquifer description
4113	185992	J & E CONSTRUCTION *WELL #2	TRS-SEC	01N	25E	35	CD		3232	15	3217	15	20	2	100	---	35	3197	2	2	3	
4114	185993	J & E CONSTRUCTION *WELL#1	TRS-SEC	01N	25E	35	CD		3232	14	3218	14	20	2	100	---	34	3198	2	2	3	
4115	192667	FOREST PARK HOME OWNERS	TRS-SEC	01N	25E	35	CD		3232	14	3218	14	21	2	100	---	35	3197	2	2	3	
4139	127735	VADNAIS DWIGHT	TRS-SEC	01N	25E	35	CAA		3258	52	3206	51	>13	2	100	55.7	---	---	2	2	2	
4153	10444	NELSEN JOHN	TRS-SEC	01N	25E	23			3595	---	---	---	---	---	---	---	---	---	4	4	3	45' shale then sandstone
4154	252512	JENSEN BRUCE	NAV-GPS	01N	25E	35	BA		3301	95	3206	93	>13	2	100	---	---	---	2	3	1	limited aq description
4158	10499	ROGERS KALE	TRS-SEC	01N	25E	35			3263	65	3198	65	25	2	100	6.7	90	3173	2	2	3	

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
										Btm Dpth	Btm Elev	Thkns	Thkns		K (ft/d)		Depth	Elev	Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	(ft)	(ft MSL)	(ft)	(ft)	Type	Type	WL/Yld	(ft)	(ft MSL)	Contacts	Descr	Qual	Comment
4159	10500	CHRESTINASEN DEE	TRS-SEC	01N	25E	35			3263	66	3197	66	>19	2	100	8.4	---	---	2	3	3	limited aq description
4160	10501	GRANLIE HAROLD N.	TRS-SEC	01N	25E	35			3263	69	3194	39	19	2	100	14.3	88	3175	2	3	3	limited aq description
4161	10502	RITTER RAY	TRS-SEC	01N	25E	35			3263	35	3228	35	20	1	200	30.9	55	3208	2	3	3	limited aq description
4162	10503	LAMBRECHT JACK	TRS-SEC	01N	25E	35		3160	3263	38	3122	38	25	2	100	---	63	3097	2	3	3	limited descriptions
4163	10504	MCCORMICK RICHARD/ROWLING TIM	TRS-SEC	01N	25E	35			3263	25	3238	25	31	1	200	---	56	3207	2	3	3	limited aq description
4164	10505	YEGON PETER III	TRS-SEC	01N	25E	35			3263	---	---	---	---	---	---	---	---	---	3	3	3	no log
4165	10506	ERICKSON LARRY	TRS-SEC	01N	25E	35			3263	55	3208	55	>40	4	10	5.3	---	---	2	3	3	limited aq description
4166	10507	REINKE HAROLD W.	TRS-SEC	01N	25E	35			3263	40	3223	40	25	2	100	12.7	65	3198	2	2	3	
4167	10508	FERRIS MORTY	TRS-SEC	01N	25E	35			3263	30	3233	30	20	2	100	13.3	50	3213	2	3	3	limited aq description
4168	10509	JOHNSON BOYD W.	TRS-SEC	01N	25E	35			3263	50	3213	50	>7	2	100	14.9	---	---	2	2	3	
4169	10510	PECKHAM JOHN	TRS-SEC	01N	25E	35			3263	70	3193	70	>12	2	100	---	---	---	2	2	3	
4204	177313	PALMER MITCH	TRS-SEC	01N	25E	26	AB		3721	24	3697	24	---	---	---	---	---	---	4	4	3	sandy clay & claystone on sandstone
4211	10448	LECLAIRE ROBERT & FRANCIS	TRS-SEC	01N	25E	23	AC		3592	---	---	---	---	---	---	---	---	---	4	4	3	all sandstone. well in Eagle SS
4212	145014	LECLAIRE ROBERT & FRANCIS B.	TRS-SEC	01N	25E	23	AC		3592	---	---	---	---	---	---	---	---	---	4	4	3	all sandstone. well in Eagle SS
4220	10515	KREJCI ERVIN	TRS-SEC	01N	25E	35	AB		3319	20	3299	20	99	3	50	13.3	119	3200	2	2	3	48' of quick sand
4221	170116	RICE LAUUNNE	TRS-SEC	01N	25E	35	AB		3319	90	3229	90	>12	2	100	48.6	---	---	2	2	3	
4222	177315	KOVASH BRYAN	TRS-SEC	01N	25E	35	AB		3319	91	3228	76	>19	2	100	---	---	---	2	3	3	limited aq description
4223	10516	FERRO ANGELO	TRS-SEC	01N	25E	35	AC		3268	55	3213	55	23	2	100	54.0	78	3190	2	2	3	
4224	10517	MACK GUS	TRS-SEC	01N	25E	35	AC		3268	55	3213	55	20	2	100	57.5	75	3193	2	2	3	
4225	136426	DAVIS JOHN (RESIDENCE) * MW-1	TRS-SEC	01N	25E	35	AC		3268	60	3208	60	>5	4	10	---	---	---	2	2	3	
4226	171758	COLTON HEIGHTS APARTMENT	TRS-SEC	01N	25E	35	DB		3237	33	3204	33	>19	2	100	---	---	---	2	2	3	
4227	10539	ROLANDSON HAZEL	TRS-SEC	01N	25E	35	DC		3227	12	3215	12	>16	2	100	62.7	---	---	3	3	3	12' "topsoil" assumed as clay
4228	195526	STEVENSON ROB	TRS-SEC	01N	25E	35	DC		3227	0	---	0	40	2	100	---	40	3187	2	3	3	no apparent clay cap
4229	208701	STICHMAN BOB	TRS-SEC	01N	25E	35	DC		3227	0	---	0	40	2	100	---	40	3187	2	3	3	no apparent clay cap
4230	208702	EGAN MYLES	TRS-SEC	01N	25E	35	DC		3227	17	3210	17	>23	2	100	---	---	---	2	2	3	
4231	239923	REGER STEVE	TRS-SEC	01N	25E	35	DC		3227	27	3200	27	>22	2	100	---	---	---	2	2	3	
4235	170982	BUILDERS MANAGEMENT INVESTMENT CO.	TRS-SEC	01N	25E	35	DBA		3244	30	3214	30	22	2	100	57.3	52	3192	2	2	2	
4250	10445	WEBER KEN	TRS-SEC	01N	25E	23	A		3596	7	3589	7	---	---	---	0.1	---	---	4	4	3	well in Eagle SS below clay
4251	10511	GAUDET ART	TRS-SEC	01N	25E	35	A		3285	82	3203	82	20	4	10	8.7	102	3183	2	3	3	45' "sand rock" in with clay
4252	10532	KOLPIN N V	TRS-SEC	01N	25E	35	D		3228	0	---	0	59	2	100	25.7	59	3169	2	2	3	no clay described
4253	10533	VALLEY NURSING HOME	TRS-SEC	01N	25E	35	D		3228	0	---	0	>40	2	100	---	---	---	2	2	3	no clay described
4254	10534	FARNHAM FRANK	TRS-SEC	01N	25E	35	D		3228	25	3203	25	31	1	200	51.4	56	3172	2	3	3	limited aq description
4255	10535	ROSE PARK PLAZA PARTNERSHIP	TRS-SEC	01N	25E	35	D		3228	12	3216	12	>19	2	100	84.9	---	---	2	3	3	limited aq description
4256	10536	ROSE PARK PLAZA PARTNERSHIP	TRS-SEC	01N	25E	35	D		3228	7	3221	7	>20	2	100	59.4	---	---	2	3	3	limited aq description
4257	10537	ROSE PARK PLAZA PARTNERSHIP	TRS-SEC	01N	25E	35	D		3228	9	3219	9	>19	2	100	74.3	---	---	2	3	3	limited aq description
4258	10538	ST.THOMAS CATHOLIC CHURCH	TRS-SEC	01N	25E	35	D		3228	30	3198	30	25	1	200	7.0	55	3173	2	3	3	
4281	161462	HERBERT LARRY & DAWN	TRS-SEC	01N	25E	23	AAC		3615	---	---	---	---	---	---	---	---	---	4	4	2	all sandstone
4283	204415	WEBER SHANON	TRS-SEC	01N	25E	2	AAC		3515	18	3497	18	>22	2	100	---	---	---	4	4	2	
4293	10512	HANSEN VICTOR W.	TRS-SEC	01N	25E	35	AA		3309	---	---	---	---	---	---	21.4	---	---	3	3	3	poor log
4294	10513	SARDENSON R. LORIN	TRS-SEC	01N	25E	35	AA		3309	---	---	---	---	---	---	38.2	---	---	3	3	3	poor log
4295	144307	GILMOR CHARLES	TRS-SEC	01N	25E	35	AA		3309	78	3231	78	>17	2	100	---	---	---	2	3	3	limited aq description
4296	10518	KENNEDY DANIEL	TRS-SEC	01N	25E	35	AD		3260	---	---	---	---	---	---	122.9	---	---	3	3	3	poor log
4297	221795	RICHARDSON BLAKE	TRS-SEC	01N	25E	35	AD		3260	33	3227	33	>19	2	100	---	---	---	2	2	3	
4298	253845	DIOCESE OF GREAT FALLS AND BILLINGS	TRS-SEC	01N	25E	35	DA		3230	13	3217	13	26	2	100	---	39	3191	2	2	3	
4299	10540	LEISCHNER HAROLD	TRS-SEC	01N	25E	35	DD		3225	11	3214	11	>17	1	200	125.8	---	---	2	2	3	
4300	10447	KENNEDY KEN	TRS-SEC	01N	25E	23	AA		3629	---	---	---	---	---	---	0.1	---	---	4	4	3	well in Eagle Sandstone
4304	192614	PIHLASA LARRY	TRS-SEC	01N	25E	11	DD		3361	0	---	0	30	4	10	---	30	3331	4	4	3	well in Eagle Sandstone
4305	192650	WISLER JOHN	TRS-SEC	01N	25E	11	DD		3361	0	---	0	25	4	10	---	25	3336	4	4	3	well in Eagle Sandstone
4306	10423	WISLER JOHN	TRS-SEC	01N	25E	14	AA		3418	---	---	---	---	---	---	0.5	---	---	4	4	3	all sandstone. well in Eagle SS
4319	10514	PELLAT JAMES & JONES JAMES	TRS-SEC	01N	25E	35	AAA		3320	---	---	---	---	---	---	9.9	---	---	3	3	2	poor log
4320	170115	NIEBUHN DARIN	TRS-SEC	01N	25E	35	AAD		3288	85	3203	85	19	2	100	139.3	104	3184	2	2	2	
4347	131691	ABBOTT BRUCE	TRS-SEC	01N	25E	36	CCB		3223	7	3216	7	>25	2	100	63.7	---	---	2	2	2	
4355	10572	GUSTAFSON F W	TRS-SEC	01N	25E	36	BB		3295	70	3225	70	24	1	200	8.4	94	3201	2	3	3	limited aq description
4356	10573	COLBERG MAURICE R.	TRS-SEC	01N	25E	36	BB		3295	73	3222	73	30	1	200	1.1	103	3192	2	3	3	limited aq description
4357	10574	ELLIOT MRS H. W.	TRS-SEC	01N	25E	36	BB		3295	---	---	---	---	---	---	4.3	95	3200	2	3	3	only shale contact clear
4358	10575	VOCHEM ROBERT H.	TRS-SEC	01N	25E	36	BB		3295	95	3200	95	20	1	200	---	115	3180	2	3	3	limited aq description

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Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
										Btm Dpth	Btm Elev	Thkns	Thkns		K (ft/d)		Depth	Elev	Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	(ft)	(ft MSL)	(ft)	(ft)	Type	Type	WL/Yld	(ft)	(ft MSL)	Contacts	Descr	Qual	Comment
4359	10576	STEEDMAN JOHN	TRS-SEC	01N	25E	36	BC		3254	25	3229	25	>15	1	200	171.9	---	---	2	2	3	
4360	121698	FORSYTHE ANDY (WM A. & PATRICIA S.)	TRS-SEC	01N	25E	36	BC		3254	50	3204	50	>21	2	100	28.8	---	---	2	2	3	
4361	203476	ROCKY MOUNTAIN COLLEGE *MW4-MV4	TRS-SEC	01N	25E	36	BC		3254	---	---	---	---	---	---	---	---	---	3	3	3	poor log
4362	203480	ROCKY MOUNTAIN COLLEGE *MW5-MV5	TRS-SEC	01N	25E	36	BC		3254	---	---	---	---	---	---	---	---	---	3	3	3	poor log
4363	10594	ESTEN ROBERT F.	TRS-SEC	01N	25E	36	CB		3228	---	---	---	---	---	---	---	---	---	3	3	3	no log
4364	10595	SCHREIBER DEAN & DONNA	TRS-SEC	01N	25E	36	CB		3228	---	---	---	---	---	---	---	---	---	3	3	3	no log
4365	10596	BAKER LEO B.	TRS-SEC	01N	25E	36	CB		3228	---	---	---	---	---	---	---	---	---	3	3	3	no log
4366	10597	PARKS EDWARD	TRS-SEC	01N	25E	36	CC	3250	3221	---	---	---	---	---	---	59.4	---	---	3	3	3	poor log
4436	10577	LLOYD HAROLD	TRS-SEC	01N	25E	36	BCA	3440	3261	62	3378	62	17	2	100	8.1	79	3361	2	3	2	limited aq description
4437	122629	TESKY THEUPHIL	TRS-SEC	01N	25E	36	BCA		3261	40	3221	40	>26	2	100	34.3	---	---	2	2	2	
4453	10569	REICHERT ED	TRS-SEC	01N	25E	36	B		3266	---	---	---	---	---	---	7.1	---	---	3	3	3	poor log
4454	145298	SASICH MIKE	TRS-SEC	01N	25E	36	B		3266	72	3194	72	19	2	100	---	91	3175	2	3	3	limited aq description
4455	10581	STRATTON JAMES	TRS-SEC	01N	25E	36	C		3222	---	---	---	---	---	---	---	---	---	3	3	3	no log
4456	10582	STALEY GEORGE H. & MARY A.	TRS-SEC	01N	25E	36	C		3222	---	---	---	---	---	---	---	---	---	3	3	3	no log
4457	10583	MARCUS CHARLES E. & CARROLL E.	TRS-SEC	01N	25E	36	C	3117	3222	---	---	---	---	---	---	45.7	---	---	3	3	3	no log
4458	10584	JOVANOVICH GEORGE	TRS-SEC	01N	25E	36	C		3222	---	---	---	---	---	---	---	---	---	3	3	3	no log
4459	10585	GRENG CARL C.	TRS-SEC	01N	25E	36	C		3222	0	---	0	>21	2	100	---	---	---	3	3	3	limited descrip, no clay noted
4460	10586	SCHLEINGER EDWARD J. SR.	TRS-SEC	01N	25E	36	C	3220	3222	0	---	0	>21	2	100	---	---	---	3	3	3	limited descrip, no clay noted
4461	10587	MCPANN DOROTHY G.	TRS-SEC	01N	25E	36	C		3222	---	---	---	---	---	---	133.7	---	---	3	3	3	no log
4462	10588	WRIGHT HERBERT J. & SHIRLEY N.	TRS-SEC	01N	25E	36	C		3222	---	---	---	---	---	---	---	---	---	3	3	3	no log
4463	10589	MCBRIDE JACK	TRS-SEC	01N	25E	36	C		3222	---	---	---	---	---	---	---	---	---	3	3	3	no log
4464	10590	HAHM ED	TRS-SEC	01N	25E	36	C		3222	4	3218	4	>21	1	200	935.9	---	---	2	3	3	limited descrip, no clay noted
4465	10591	JAMISON BURL	TRS-SEC	01N	25E	36	C		3222	---	---	---	---	---	---	84.9	---	---	3	3	3	poor log
4466	10592	RINEHART GARTH W.	TRS-SEC	01N	25E	36	C		3222	5	3217	5	>21	4	10	---	---	---	2	3	3	limited aq description
4507	124852	LOGAN MARJORIE P	TRS-SEC	01N	25E	25	CD		3339	---	---	---	---	---	---	---	---	---	3	3	3	no log
4508	254250	CITY OF BILLINGS	TRS-SEC	01N	25E	25	CD		3339	30	3309	30	5	4	10	---	---	---	2	3	3	limited aq description
4510	10570	SCARIANO RONALD & SUE	TRS-SEC	01N	25E	36	BA		3281	76	3205	24	22	2	100	167.1	98	3183	2	1	3	sand/clay on top of clay
4511	10571	LDS MISSION CENTER	TRS-SEC	01N	25E	36	BA		3281	104	3177	104	16	2	100	---	120	3161	2	3	3	limited aq description
4512	145018	STANFORD COURT CONDO ASSO.	TRS-SEC	01N	25E	36	BA		3281	80	3201	80	23	3	50	15.8	103	3178	2	2	3	
4513	145019	STANFORD COUNT CONDO ASSC.	TRS-SEC	01N	25E	36	BA		3281	81	3200	76	18	2	100	60.4	99	3182	2	2	3	
4514	162981	BILLING CONOCO POLLY DR & 17TH W	TRS-SEC	01N	25E	36	BA		3281	52	3229	52	>3	2	100	---	---	---	2	2	3	
4515	162990	BILLINGS CONOCO POLY DR & 17TH WEST	TRS-SEC	01N	25E	36	BA		3281	51	3230	51	>6	2	100	---	---	---	2	2	3	
4516	162992	BILLINGS CONOCO POLY DR & 17TH WEST	TRS-SEC	01N	25E	36	BA		3281	51	3230	51	>5	2	100	---	---	---	2	2	3	
4517	162994	BILLINGS CONOCO POLY DR & 17TH WEST	TRS-SEC	01N	25E	36	BA		3281	51	3230	51	>6	2	100	---	---	---	2	2	3	
4518	162997	BILLINGS CONOCO POLY DR & 17TH WEST	TRS-SEC	01N	25E	36	BA		3281	48	3233	48	>7	2	100	---	---	---	2	2	3	
4519	163000	BILLINGS CONOCO POLY DR & 17TH WEST	TRS-SEC	01N	25E	36	BA		3281	47	3234	47	>10	2	100	---	---	---	2	2	3	
4520	163002	BILLINGS CONOCO POLY DR & 17TH WEST	TRS-SEC	01N	25E	36	BA		3281	47	3234	47	>9	2	100	---	---	---	2	2	3	
4521	216658	THE GRANARY	TRS-SEC	01N	25E	36	BA		3281	38	3243	38	>20	2	100	---	---	---	2	2	3	
4522	10578	LA FEVER NEAL	TRS-SEC	01N	25E	36	BD		3243	54	3189	54	>12	2	100	---	---	---	3	2	3	unclear clay-sand contact
4523	10579	PAMAN RALPH F.	TRS-SEC	01N	25E	36	BD	3135	3243	19	3116	19	>19	1	200	24.8	---	---	3	3	3	interbedded, limited description
4524	216665	JOHNSON NANCY	TRS-SEC	01N	25E	36	BD		3243	8	3235	8	>22	2	100	---	---	---	2	3	3	limited aq description
4525	10593	REESE GUY	TRS-SEC	01N	25E	36	CA		3223	4	3219	4	>21	1	200	---	---	---	2	3	3	limited descriptions
4526	192669	KURKOWSKI JOE	TRS-SEC	01N	25E	36	CD		3218	5	3213	5	22	2	100	22.5	27	3191	2	2	3	
4540	247370	ROLFSON ERLING	NAV-GPS	01N	25E	36	AC		3222	14	3208	14	>22	2	100	---	---	---	2	2	1	
4541	140306	MILLS BILL	TRS-SEC	01N	25E	36	BAA		3287	70	3217	70	>26	2	100	76.4	---	---	2	2	2	
4542	10580	PETERSON D.E.	TRS-SEC	01N	25E	36	BDA		3248	44	3204	44	>21	2	100	---	---	---	2	2	2	
4543	170611	AYRE DAVE & CHARLOTTE	TRS-SEC	01N	25E	36	BDA		3248	---	---	---	---	---	---	---	---	---	3	3	2	no log
4544	211530	GULBRANDSON DAVID AND DANIELLE	TRS-SEC	01N	25E	36	CDA		3216	10	3206	10	20	2	100	247.3	30	3186	2	2	2	
4545	239838	MONTANA MUNICIPAL INSURANCE	NAV-GPS	01N	25E	25	CDA		3349	0	---	0	16	5	1	---	16	3333	2	3	1	bedrock interp not certain
4549	239894	MONTANA MUNICIPAL INSURANCE	NAV-GPS	01N	25E	25	CDA		3332	10	3322	10	>7	5	1	---	---	---	3	3	1	clay/sand descriptions not clear
4556	239900	MONTANA MUNICIPAL INSURANCE	NAV-GPS	01N	25E	25	CDA		3342	0	---	0	>15	4	10	---	---	---	2	2	1	no distinct clay layer
4558	239898	MONTANA MUNICIPAL INSURANCE	NAV-GPS	01N	25E	25	CDA		3341	0	---	0	10	5	1	---	10	3331	2	3	1	bedrock interp not certain
4559	10541	HOPKINS LARRY	TRS-SEC	01N	25E	36			3227	65	3162	65	25	2	100	10.1	90	3137	2	2	3	
4560	10542	WRENCH J A	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	---	---	---	3	3	3	poor log
4561	10543	BROWN KEITH	TRS-SEC	01N	25E	36			3227	50	3177	50	26	2	100	108.4	76	3151	2	2	3	
4562	10544	OFFT HENRY S.	TRS-SEC	01N	25E	36			3227	6	3221	6	>22	2	100	62.7	---	---	2	2	3	

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Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
															K (ft/d)				Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	Btm Dpth (ft)	Btm Elev (ft MSL)	Thkns (ft)	Thkns (ft)	Type	Type	WL/Yld	Depth (ft)	Elev (ft MSL)	Contacts	Descr	Qual	Comment
4563	10545	CERNOHLAVEK LEWIS	TRS-SEC	01N	25E	36		3115	3227	11	3104	11	>10	2	100	---	---	---	3	3	3	assumed clay thkns, lim aq desc
4564	10546	BAILEY EARL C.	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	---	---	---	3	3	3	no log
4565	10547	GOOD LLOYD R.	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	297.1	---	---	3	3	3	poor log
4566	10548	MASSICK JOHN L.	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	222.8	---	---	3	3	3	poor log
4567	10549	LUNNEY JOHN	TRS-SEC	01N	25E	36			3227	17	3210	17	>8	1	200	---	---	---	2	3	3	limited descriptions
4568	10550	SCHMIDT JERRY	TRS-SEC	01N	25E	36			3227	5	3222	5	>20	1	200	---	---	---	2	3	3	limited descriptions
4569	10551	LARSEN R.L.	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	148.6	---	---	3	3	3	poor log
4570	10552	MAJERUS GERALD F.	TRS-SEC	01N	25E	36			3227	20	3207	20	50	2	100	---	70	3157	2	3	3	limited aq description
4571	10553	COREY HOWARD	TRS-SEC	01N	25E	36			3227	10	3217	10	>13	1	200	1050.5	---	---	2	3	3	limited descriptions
4572	10554	CORCORAN EDWARD	TRS-SEC	01N	25E	36			3227	10	3217	10	>14	1	200	1050.5	---	---	2	3	3	limited descriptions
4573	10555	HELGER EDWIN	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	9.0	---	---	3	3	3	poor log
4574	10556	JOHNSON RODGER	TRS-SEC	01N	25E	36			3227	0	---	0	>20	2	100	222.8	---	---	2	2	3	no clay described
4575	10557	KOBER JOHN	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	---	---	---	3	3	3	no log
4576	10558	MITCHELL BERNE	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	---	---	---	3	3	3	no log
4577	10559	MERCHEN GEORGE M.	TRS-SEC	01N	25E	36			3227	25	3202	25	21	2	100	133.7	---	---	2	2	3	
4578	10560	SIMONS LOIS	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	---	---	---	3	3	3	no log
4579	10561	HENSLEY CHARLES	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	---	---	---	3	3	3	no log
4580	10562	WHITMYER CARL	TRS-SEC	01N	25E	36			3227	0	---	0	>28	2	100	123.8	---	---	2	3	3	no clay described
4581	10563	BOLAND FLOYD J	TRS-SEC	01N	25E	36			3227	---	---	---	---	---	---	107.0	---	---	3	3	3	no log
4582	10564	RICKETT GLEN E.	TRS-SEC	01N	25E	36			3227	52	3175	52	23	1	200	6.4	---	---	2	3	3	limited aq description
4583	103055	CITY OF BILLINGS	TRS-SEC	01N	25E	36			3227	0	---	0	>28	2	100	---	---	---	2	3	3	no clay, limited aq desc
4584	103066	BILLINGS CITY OF	TRS-SEC	01N	25E	36			3227	0	---	0	>29	2	100	---	---	---	2	3	3	no clay, limited aq desc
4585	239899	MONTANA MUNICIPAL INSURANCE	NAV-GPS	01N	25E	25	CDA		3340	0	---	0	14	5	1	---	14	3326	2	3	1	bedrock interp not certain
4615	144308	ROCKY MOUNTAIN COLLEGE	TRS-SEC	01N	25E	36	ABCC		3257	46	3211	46	29	2	100	---	75	3182	2	2	2	
4624	180468	ROCKY MOUNTAIN COLLEGE	TRS-SEC	01N	25E	36	AB		3273	---	---	---	---	---	---	---	---	---	3	3	3	no log
4625	180469	ROCKY MOUNTAIN COLLEGE	TRS-SEC	01N	25E	36	AB		3273	---	---	---	---	---	---	---	---	---	3	3	3	no log
4626	177316	LEGACY HOMES	TRS-SEC	01N	25E	36	AC		3237	44	3193	44	>23	2	100	197.2	---	---	2	2	3	
4627	10619	KENNEDY DAVID W.	TRS-SEC	01N	25E	36	DB		3215	10	3205	10	>15	2	100	---	---	---	2	3	3	assumed top 10 ft is clay
4628	10620	JOHANNES JOHN F.	TRS-SEC	01N	25E	36	DB		3215	---	---	---	---	---	---	---	---	---	3	3	3	no log
4647	10422	WESTON KENNETH S	TRS-SEC	01N	25E	12	D		3348	---	---	---	---	---	---	3.6	---	---	4	4	3	well in Eagle Sandstone
4648	10598	MORSE SIDNEY & FRAN	TRS-SEC	01N	25E	36	D		3209	15	3194	15	>10	1	200	---	---	---	2	3	3	limited aq description
4649	10599	LAWRENZ MARTIN E.	TRS-SEC	01N	25E	36	D		3209	0	---	0	>27	2	100	81.9	---	---	2	2	3	no clay described
4650	10600	MCCANN THOMAS	TRS-SEC	01N	25E	36	D		3209	---	---	---	---	---	---	27.9	---	---	3	3	3	poor log
4651	10601	KOBER AMELIA	TRS-SEC	01N	25E	36	D		3209	---	---	---	---	---	---	---	---	---	3	3	3	no log
4652	10602	RAMSETT WILLARD H.	TRS-SEC	01N	25E	36	D		3209	0	---	0	>25	2	100	---	---	---	2	3	3	no clay described, lim aq descrip.
4653	10603	BEVEN THOMAS D.	TRS-SEC	01N	25E	36	D		3209	---	---	---	---	---	---	---	---	---	3	3	3	no log
4654	10604	ISAACSON BRUCE D.	TRS-SEC	01N	25E	36	D	3200	3209	16	3184	16	>9	4	10	107.7	---	---	2	3	3	limited aq description
4655	10605	BAILEY WILLIAM	TRS-SEC	01N	25E	36	D		3209	4	3205	4	>21	1	200	719.9	---	---	2	2	3	
4656	10606	COOK KENNARD K	TRS-SEC	01N	25E	36	D	3200	3209	15	3185	15	>8	4	10	101.9	---	---	2	3	3	limited aq description
4657	10607	CLAXTON ROY C.	TRS-SEC	01N	25E	36	D		3209	---	---	---	---	---	---	37.1	---	---	3	3	3	poor log
4675	10618	MCKINNEY CHARLES G.	TRS-SEC	01N	25E	36	DAC		3210	---	---	---	---	---	---	---	---	---	3	3	2	no log
4684	209840	MANDIN DALE	TRS-SEC	01N	25E	1	AABA		3351	5	3346	5	24	2	100	---	29	3322	4	4	2	
4691	171759	ROCKY MOUNTAIN COLLEGE	TRS-SEC	01N	25E	36	AA		3267	53	3214	53	22	2	100	135.5	75	3192	2	2	3	
4692	172049	ROCKY MOUNTAIN COLLEGE	TRS-SEC	01N	25E	36	AA		3267	72	3195	72	20	3	50	35.9	92	3175	2	2	3	
4693	10565	CAIN GLENN M.	TRS-SEC	01N	25E	36	AD		3226	---	---	---	---	---	---	---	---	---	3	3	3	no log
4694	10566	LANG JACK C.	TRS-SEC	01N	25E	36	AD		3226	---	---	---	---	---	---	---	---	---	3	3	3	no log
4695	10567	HARLOW FRANK	TRS-SEC	01N	25E	36	AD		3226	4	3222	4	>18	1	200	649.4	---	---	2	2	3	
4696	10568	DOMAN LLOYD E.	TRS-SEC	01N	25E	36	AD		3226	---	---	---	---	---	---	48.6	---	---	3	3	3	no log
4697	195524	ROCKY PLAZA	TRS-SEC	01N	25E	36	AD		3226	32	3194	32	18	2	100	---	50	3176	2	2	3	
4698	10609	PURSELL DAVID	TRS-SEC	01N	25E	36	DA		3212	---	---	---	---	---	---	---	---	---	3	3	3	no log
4699	10610	DROSTE LEONARD H & MARJORIE A	TRS-SEC	01N	25E	36	DA	3600	3212	0	---	0	>45	2	100	---	---	---	2	3	3	no clay described
4700	10611	DEWEY KIRK M.	TRS-SEC	01N	25E	36	DA		3212	---	---	---	---	---	---	---	---	---	3	3	3	no log
4701	10612	BARNES LETA	TRS-SEC	01N	25E	36	DA		3212	8	3204	8	>13	1	200	---	---	---	2	3	3	limited descriptions
4702	10613	KUHL SYDNEY M & VALBERG S	TRS-SEC	01N	25E	36	DA		3212	---	---	---	---	---	---	148.6	---	---	3	3	3	no log
4703	10614	CITY OF BILLINGS	TRS-SEC	01N	25E	36	DA		3212	10	3202	10	>17	2	100	178.3	---	---	2	2	3	
4704	10616	STEELE BILL	TRS-SEC	01N	25E	36	DA		3212	3	3209	3	>21	1	200	649.4	---	---	2	2	3	

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
															K (ft/d)				Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	Btm Dpth (ft)	Btm Elev (ft MSL)	Thkns (ft)	Thkns (ft)	Type	Type	WL/Yld	Depth (ft)	Elev (ft MSL)	Contacts	Descr	Qual	Comment
4705	10621	SAUNDERS MRS EARLICE	TRS-SEC	01N	25E	36	DD		3208	---	---	---	---	---	---	---	---	---	3	3	3	no log
4706	10622	HOLT NORMA	TRS-SEC	01N	25E	36	DD		3208	4	3204	4	>20	1	200	1470.7	---	---	2	2	3	
4707	10623	EVERGREEN SHOPPING CENTER	TRS-SEC	01N	25E	36	DD		3208	---	---	---	---	---	---	---	---	---	3	3	3	no log
4708	208703	KETTERLING BONNIE	TRS-SEC	01N	25E	36	DD		3208	8	3200	8	>20	2	100	---	---	---	2	2	3	
4709	234852	HENRICKSON BOB*LS-1	TRS-SEC	01N	25E	36	DD		3208	6	3202	6	>14	2	100	---	---	---	2	2	3	
4710	234853	HENRICKSON BOB*LS-2	TRS-SEC	01N	25E	36	DD		3208	5	3203	5	>15	2	100	---	---	---	2	2	3	
4711	234854	HENRICKSON BOB*LS-5	TRS-SEC	01N	25E	36	DD		3208	5	3203	5	>15	2	100	---	---	---	2	2	3	
4712	234855	HENRICKSON BOB*LS-4	TRS-SEC	01N	25E	36	DD		3208	5	3203	5	>15	2	100	---	---	---	2	2	3	
4713	234856	HENRICKSON BOB*LS-3	TRS-SEC	01N	25E	36	DD		3208	5	3203	5	>15	2	100	---	---	---	2	2	3	
4731	10617	JOHNSTON JOHN F. & SHIRLEY	TRS-SEC	01N	25E	36	DAA		3214	12	3202	12	>16	2	100	---	---	---	2	3	2	assumed upper 12' is clay
8056	207217	OLSEN PETE AND LINDA	NAV-GPS	01S	24E	6	ADC		3442	35	3407	27	7	2	100	135.5	42	3400	2	3	1	8' "rubble" in clay
8059	92730	OLSEN PETER	MAP	01S	24E	6	DABA	3440	3438	30	3410	30	20	2	100	11.0	50	3390	2	3	2	
8060	158555	OLSEN PETE	MAP	01S	24E	6	DAAB	3440	3428	---	---	---	---	---	---	---	---	---	3	3	2	no log
8080	10332	MCFARLAND CLINTON	MAP	01N	24E	6	CCAD		4154	---	---	---	---	---	---	1.5	---	---	4	4	2	sandstone?
8085	10333	MCFARLAND CLINTON B.	MAP	01N	24E	6	CDC	4155	4150	---	---	---	---	---	---	---	---	---	4	4	2	no log
8115	202562	PELICAN FRANK	NAV-GPS	01S	24E	28	BCA	---	3744	---	---	---	---	---	---	---	---	---	4	4	3	very poor log
8116	10336	MCFARLAND CLINT AND TED	MAP	01N	24E	7	ADAD	4175	4177	---	---	---	---	---	---	---	---	---	4	4	2	no log
8125	124880	PETERSON RICHARD	MAP	01S	24E	9	BAAB	3420	3422	38	3382	38	7	2	100	40.1	45	3375	2	2	2	
8165	158556	NORTHERN SKIES AVIATION	MAP	01S	24E	34	CBCB	3475	3469	---	---	---	---	---	---	---	---	---	3	3	3	no log
8166	224969	TEEGARDON TOM	NAV-GPS	02S	24E	3	CDB	---	3459	24	3435	11	24	2	100	---	48	3411	2	2	1	13' gravel on top of clay
8173	187143	HATTON JAY/SANDRA	NAV-GPS	02S	24E	3	CD		3396	15	3381	15	9	2	100	11.6	24	3372	2	2	1	
8180	705275	KRAFT B	UNKNOWN	01S	24E	10	BDAA	3380	3379	---	---	---	---	---	---	---	---	---	3	3	2	no log
8182	218658	COONEY TODD	NAV-GPS	01S	24E	34	ADA	---	3448	53	3395	53	>8	2	100	---	---	---	2	2	1	
8185	145415	MELBY ED	MAP	01S	24E	34	DDCD	3380	3376	10	3370	10	>45	1	200	22.7	---	---	2	2	2	16' clay in the gravel
8186	705277	RATLIFF R	UNKNOWN	01S	24E	15	AAAB	3440	3399	---	---	---	---	---	---	---	---	---	3	3	2	no log
8190	705281	KRAFT R	UNKNOWN	01S	24E	35	BCCC	3390	3386	---	---	---	---	---	---	---	---	---	3	3	3	no log
8192	92731	PAULSEN WELDON	MAP	01S	24E	11	BDDC	3370	3376	60	3310	60	5	2	100	0.05	65	3305	2	2	2	wekk in shale
8193	91	WORMSER JOSEPH * 3 MI NW RIMROCK MT	UNKNOWN	01N	24E	10	C		3829	---	---	---	---	---	---	---	---	---	4	4	3	no log
8205	126396	MCFARLAND TED	MAP	01N	24E	10	DBBD	3780	3783	---	---	---	---	---	---	0.1	---	---	4	4	2	no shallow detail
8207	10345	MCFARLAND TED	MAP	01N	24E	10	DBDB		3763	---	---	---	---	---	---	0.3	---	---	4	4	2	Eagle Sandstone
8208	126414	YAGER JIM	MAP	01S	24E	11	DAAD	3355	3353	48	3307	48	4	2	100	---	52	3303	2	2	2	
8209	6961	KRAFT J * 13 MI SW BILLINGS	MAP	01S	24E	23	DDDD	3370	3357	---	---	---	---	---	---	---	---	---	4	4	2	poor log
8210	705276	BEARTOOTH FARM	MAP	01S	24E	14	AAAD	3340	3333	---	---	---	---	---	---	---	---	---	3	3	2	no log
8211	705280	FOX L	UNKNOWN	01S	24E	26	DDAA	3350	3342	---	---	---	---	---	---	---	---	---	3	3	3	no log
8213	92738	GRICE PAUL	MAP	01S	24E	12	CCCC	3325	3323	---	---	---	---	---	---	---	---	---	3	3	2	no log
8214	218576	LOVE JEFF	NAV-GPS	02S	24E	2	DCA		3465	0	---	0	>35	1	200	495.9	---	---	4	4	1	no apparent clay
8219	145000	LINDA	MAP	01N	24E	22	AAAA	3580	3560	---	---	---	---	---	---	---	---	---	3	3	2	difficult to interpret log
8220	158591	DALTON JESSIE	MAP	01N	24E	35	CCCB	3435	3435	---	---	---	---	---	---	---	---	---	4	4	2	no log
8223	204922	STRAW MARIE	NAV-GPS	01N	24E	23	BDA		3547	---	---	---	---	---	---	---	---	---	2	3	1	sandstone and shale
8228	138308	HENDERSON ED	UNKNOWN	01N	24E	23	ABCC	3530	3537	35	3495	35	37	4	10	---	72	3458	2	2	2	sandstone on top of shale
8232	10364	AMAN MELVIN	UNKNOWN	01N	24E	23	ACBA		3520	---	---	---	---	---	---	10.8	---	---	3	3	2	all sandstone
8233	138310	CAMPEN EDWARD AND ELIZABETH	UNKNOWN	01N	24E	23	ACBD		3507	37	3470	37	14	4	10	9.1	51	3456	2	2	2	sandstone on top of shale
8236	10362	BIRLZ ALLEN G	UNKNOWN	01N	24E	23	ACA		3527	---	---	---	---	---	---	---	55	3472	3	3	2	poor shallow detail
8237	138309	BIRLZ ALLEN G	UNKNOWN	01N	24E	23	ACA	3620	3527	---	---	---	---	---	---	---	---	---	3	3	2	no log
8238	6959	LENHARDT E * 11.5 MI WSW BILLINGS P.O.	MAP	01S	24E	13	AADD	---	3307	---	---	---	---	---	---	---	---	---	3	3	2	poor log, indicates "quick sand"
8239	10384	KAERCHER JAMES	UNKNOWN	01N	24E	23	ABD		3560	40	3520	40	50	4	10	---	90	3470	2	2	2	sandstone on top of shale
8241	92	HUSBAND R.W. * 11.5 MI SE MOLT MT	UNKNOWN	01N	24E	11	D		3793	---	---	---	---	---	---	---	---	---	4	4	3	no log
8245	10326	CELLMER LAWRENCE	MAP	01N	24E	2	AABC		3698	---	---	---	---	---	---	---	13	3685	4	4	2	difficult to interpret log above shale
8247	10374	BARKER JAMES	UNKNOWN	01N	24E	23	ADB		3570	---	---	---	---	---	---	2.2	40	3530	3	3	2	40' sand and clay on top of shale
8248	10376	TOAVS WARREN OR BONNY	UNKNOWN	01N	24E	23	ADC	3500	3501	30	3470	30	---	---	---	1.1	---	---	2	3	2	poor detail below clay
8254	10368	BARNHART BILL	UNKNOWN	01N	24E	23	ADCB	3500	3501	39	3461	39	21	4	10	5.0	72	3428	2	2	2	
8255	143880	LENHARDT FREDERICK	MAP	01S	25E	18	BBCA	3310	3307	26	3284	26	14	4	10	1.4	40	3270	2	2	2	
8257	10400	WILSON BARB	MAP	01N	24E	35	DDAB	3390	3386	28	3362	28	12	3	50	20.3	40	3350	2	2	2	
8263	155351	HERMES CYNTHIA	NAV-GPS	01N	24E	23	ADDB	3500	3501	---	---	---	---	---	---	---	---	---	3	3	1	no log
8264	6964	FISHER H	MAP	01S	25E	6	BBDA	3396	3392	---	---	---	---	---	---	---	---	---	3	3	3	no log
8265	10399	WILSON BARB	MAP	01N	24E	35	DADD		3389	53	3336	53	0	---	---	---	53	3336	4	4	2	well in shale

Table A-1. West Billings Study Well Log Review Summary

Identification				Location				Ground Elev. (ft MSL)		Fine-Grained Cap			Aquifer Material				Bedrock/Clay		Data Qualifiers			
															K (ft/d)				Log Quality		Loc	
Map	GWIC	Name	Geo Method	T	R	S	QS	Log	Map	Btm Dpth (ft)	Btm Elev (ft MSL)	Thkns (ft)	Thkns (ft)	Type	Type	WL/Yld	Depth (ft)	Elev (ft MSL)	Contacts	Descr	Qual	Comment
8266	10401	WILSON BARBARA	MAP	01N	24E	35	DADD	3390	3389	0	---	0	>36	2	100	22.1	---	---	2	3	2	limited descrip, no clay noted
8267	10382	COE MRS	MAP	01N	24E	23	ADDA	3540	3527	---	---	---	---	---	---	---	---	---	2	2	2	17' clay and sand on top of sandstone
8283	705285	SCHLAEPPI NEIL	MAP	01S	25E	6	AABB	3355	3350	---	---	---	---	---	---	---	---	---	3	3	2	no log
8287	158590	CDP CONSTRUCTION	MAP	01S	25E	7	ADAC	3320	3327	---	---	---	---	---	---	---	---	---	3	3	2	no log
8295	192661	GUNDLACH SHANE *WELL NO.3	NAV-GPS	01N	25E	19	DBD		3638	---	---	---	---	---	---	---	---	---	4	4	1	poor log
8297	158941	YELLOWSTONE COUNTRY CLUB	NAV-GPS	01N	25E	30	BBCA	3415	3409	---	---	---	---	---	---	---	---	---	3	3	1	no log
8298	131686	CELLMER LAWRENCE	MAP	01N	25E	6	BBDC	3600	3586	44	3556	44	3	4	10	3.3	47	3553	4	4	2	well in Eagle Sandstone
8301	192654	GUNDLACH SHANE *WELL NO.2	NAV-GPS	01N	25E	19	DBB		3596	49	3547	49	0	---	---	---	49	3547	4	4	1	no sand
8305	212782	CAFTE TAMMY	NAV-GPS	01N	25E	31	BDC		3343	34	3309	34	>14	3	50	13.2	---	---	2	3	1	limited aq description
8306	158940	YELLOWSTONE COUNTRY CLUB	MAP	01N	25E	30	CACB	3390	3392	---	---	---	---	---	---	---	---	---	3	3	2	no log
8307	10457	CARAWAY HERB	UNKNOWN	01N	25E	31	BABA	3370	3366	---	---	---	---	---	---	607.7	---	---	3	3	2	no log
8308	705257	CARAWAY H	UNKNOWN	01N	25E	31	BABA	3370	3366	---	---	---	---	---	---	---	---	---	3	3	2	no log
8310	192658	GUNDLACH SHANE *WELL NO.1	NAV-GPS	01N	25E	19	DBD		3481	12	3469	12	---	---	---	---	---	---	3	3	1	sandstone below clay
8311	158552	OWNER UNKNOWN FROM GWCP03	MAP	01N	25E	31	BAAD	3360	3363	---	---	---	---	---	---	---	---	---	3	3	2	no log
8313	10456	MESSER JOHN	MAP	01N	25E	31	BAAA	3370	3369	0	---	0	39	5	1	0.2	39	3331	3	3	2	error in depths
8316	145012	HOPE EVANGELICAL CHURCH	MAP	01S	25E	4	BBBB		3317	81	3236	79	>15	2	100	---	---	---	2	3	2	
8330	95	DEINES S * 6 MI BILLINGS MT	MAP	01N	25E	32	CCCC	3313	3310	---	---	---	---	---	---	---	---	---	3	3	2	log starts at 130'
8331	10459	DEINES SOLOMAN	UNKNOWN	01N	25E	32	CCCC	3313	3310	---	---	---	---	---	---	---	---	---	3	3	2	no log
8342	149794	PIERCE CHARLES D.	MAP	01N	25E	29	BBAD	3800	3799	---	---	---	---	---	---	---	---	---	4	4	2	sandstone & shale. well in Eagle SS
8350	10435	RUBLE ROBERT T	MAP	01N	25E	17	CDAB	3580	3573	0	---	0	60	4	10	0.1	60	3520	4	4	2	well in Eagle SS below shale
8353	144298	CELLMER LAWRENCE	MAP	01N	25E	8	CDDD	3515	3507	---	---	---	---	---	---	---	35	3480	4	4	2	Eagle ss. 5' clay above shale
8379	142500	HOLZHEIMER DON	MAP	01N	25E	5	DACD	3530	3533	0	---	0	18	5	1	2.5	18	3512	4	4	2	well in Eagle Sandstone
8383	13293	CELLMER LAWRENCE	MAP	01N	25E	5	AB	3600	3589	30	3570	30	10	4	10	---	40	3560	4	4	3	well in Eagle Sandstone
8386	248803	ALEFTERAS KENNY AND ECHO	SUR-GPS	01N	25E	9	CB		3635	0	---	0	48	4	10	---	48	3587	4	4	1	sandstone on shale. long well screen
8393	93	MALIN YATES CO * 10 MI NW BILLINGS MT	UNKNOWN	01N	25E	4	C		3586	---	---	---	---	---	---	---	---	---	4	4	3	no log
8396	186845	CULVER GENE/ KINCADE LAND LLC	NAV-GPS	01N	25E	33			3288	63	3225	63	>12	2	100	---	---	---	2	2	1	
8399	10471	HANSON CLARENCE	MAP	01N	25E	33	ABDD	3342	3345	---	---	---	---	---	---	4.2	---	---	3	3	3	difficult to interpret log
8400	705258	HANSON	UNKNOWN	01N	25E	33	ABDC	3341	3344	---	---	---	---	---	---	---	---	---	3	3	2	no log
8439	890470	DEELEEUW	UNKNOWN	01N	25E	26	CAAB	3705	3704	---	---	---	---	---	---	---	---	---	4	4	2	no log
8448	150171	JOHNSON DAVID F. & DENISE D.	MAP	01N	25E	23	AACB		3594	---	---	---	---	---	---	---	---	---	4	4	2	all sandstone. well in Eagle SS
8449	10446	JOHNSON DAVE	MAP	01N	25E	23	AACD	3560	3555	---	---	---	---	---	---	0.04	---	---	4	4	2	160' of sandstone. well in Eagle SS
8460	705262	CITY OF BILLINGS	UNKNOWN	01N	25E	36	CBDA	3222	3225	---	---	---	---	---	---	---	---	---	3	3	2	no log
8461	705263	CITY WATER DEPT	UNKNOWN	01N	25E	36	CCAA	3222	3220	---	---	---	---	---	---	---	---	---	3	3	2	no log
8464	705256	USGS	UNKNOWN	01N	25E	25	CD	3310	3309	---	---	---	---	---	---	---	---	---	3	3	3	no log
8465	705261	CITY WATER DEPT	UNKNOWN	01N	25E	36	CABD	3220	3225	---	---	---	---	---	---	---	---	---	3	3	2	no log
8467	705264	CITY OF BILLINGS	UNKNOWN	01N	25E	36	CDDD	3215	3212	---	---	---	---	---	---	---	---	---	3	3	2	no log
8468	171256	WEBER-1	MAP	01S	26E	18	DDCC	3169	3216	10	3159	10	>10	2	100	---	---	---	1	1	2	bottom may be shale?
8471	240219	SMITH GREG	NAV-GPS	01N	25E	36	DB		3211	4	3207	4	>23	2	100	---	---	---	2	2	1	
8474	135879	ALGRA JERRY	MAP	01N	25E	12	DCDD	3360	3369	0	---	0	27	4	10	---	27	3333	4	4	2	well in Eagle Sandstone
8475	10615	EVERGREEN PARK (BILLINGS)	NAV-GPS	01N	25E	36	DDBB	3205	3209	8	3197	8	>13	2	100	297.1	---	---	2	2	1	

Appendix B

MBMG Model and Recharge Simulations

This Appendix provides a general summary of the models being developed by MBMG for the West Billings area. Also included are some modeling results of potential groundwater recharge events MBMG completed for this Flood Mitigation and Groundwater Recharge Study.

Two groundwater models are currently being developed by MBMG for portions of the West Billings area. These models were briefly discussed in the *Additional Data Report* (PBSJ, 2010). Additional information on the models is presented in this section courtesy of the MBMG. Because the models have not been finalized the information presented below should be considered preliminary and subject to change.

The MBMG model development was begun prior to and is independent of the Flood Mitigation and Groundwater Recharge Study. MBMG model information is provided below to illustrate the similarity with the preliminary model presented in **Section 3**, and because the MBMG has provided simulation results of potential effects of groundwater recharge from flood mitigation alternatives. In addition, much of the analyses presented elsewhere in this document were performed to facilitate the extension of their modeling efforts further north. Although a preliminary model for the area north of the MBMG has been developed, it is expected that at some point in the future the MBMG will refine that modeling effort.

B.1 Current Groundwater Modeling Coverage and Status

The areas covered by the two MBMG models are shown on **Figure B-1**. The two models were successfully calibrated to steady-state conditions representing spring time prior to irrigation. The models are currently being modified to simulate transient conditions to better evaluate groundwater changes due to seasonal variations in recharge and longer-term changes in land use.

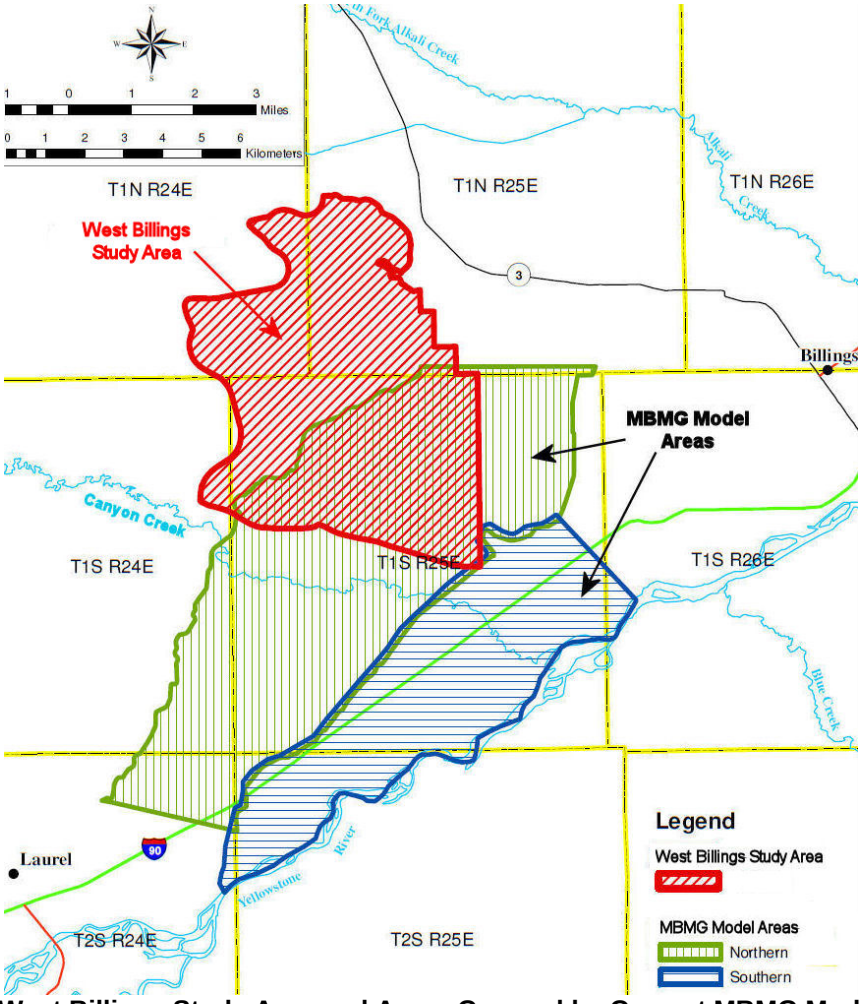

Figure B-1. West Billings Study Area and Areas Covered by Current MBMG Modeling Efforts

B.2 Preliminary Model Information

The models were constructed to simulate conditions for 2000 and for 2009. The 2000 conditions are simulated because there is a significant amount of data available from a previous MBMG study for that time (Olson and Reiten, 2002). The 2009 conditions represent the current time period.

Based on preliminary model information provided by MBMG, the models consist of three layers representing the fine-grained cap material, the unconsolidated aquifer, and the underlying shale. Three north-south cross-sections through their northern model, shown on **Figure B-2**, illustrate the thicknesses of the three layers as represented in the model. The cross-section shows how the aquifer generally thins toward the northern extent of the model while the fine-grained cap thickens.

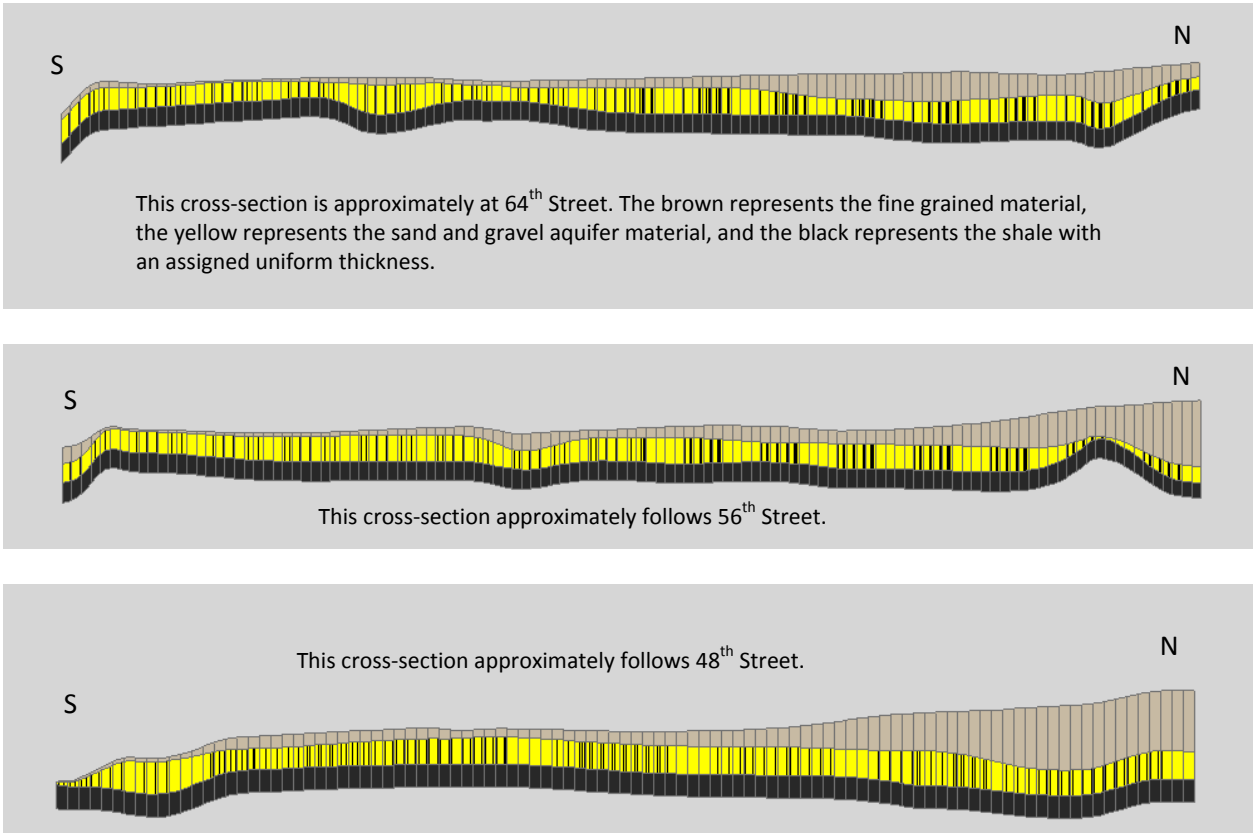

Figure B-2. North-South Cross Sections from the MBMG Northern Model

Boundary conditions consist of General Head cells representing flow into or out of the model. Ditches, and creeks and sloughs are represented with drains and river cells.

Model properties include hydraulic conductivity estimated from pumping test data and recharge (infiltration from precipitation and irrigation) estimated from Land Use designations. Horizontal (Kh) and vertical (Kv) hydraulic conductivity designations for the steady-state calibrated models are as follows (in ft/d):

- Fine-grained cap: Kh = 5, Kz = 1.5;
- Unconsolidated Aquifer: Kh = 90, Kz = 30; and
- Bedrock: Kh = 0.5, Kz = 0.1.

Model layer elevations, illustrated on **Figure B-2** above, were established by interpolating borehole contacts elevations. The contact elevations were assigned using well logs from GWIC wells in the model area.

Recharge values vary seasonally in the transient models, with recharge set at 0 for the months of December through February. For the other months, at the time this document was produced the values range as follows (in ft/d):

- Irrigated Agriculture: 0.0005-0.0075;
- Gravel Pit: 0.00042-0.00444;
- Big Ditch: 0.006-0.1;
- Housing: 0.00042-0.0014; and
- Small Ditch: 0.075-0.08.

B.3 Model Results

As previously noted, the MBMG models are being developed for purposes other than this study, and are in the process of being calibrated and modified. As a result, detailed model results have not yet been documented and presenting them here is premature and beyond the scope of this document. However, MBMG has provided the preliminary modeled groundwater contours shown on **Figure B-3**. These results from their steady-state model, illustrate the general pattern of modeled heads which are used to help develop the model results for the preliminary model discussed in **Section 3**.

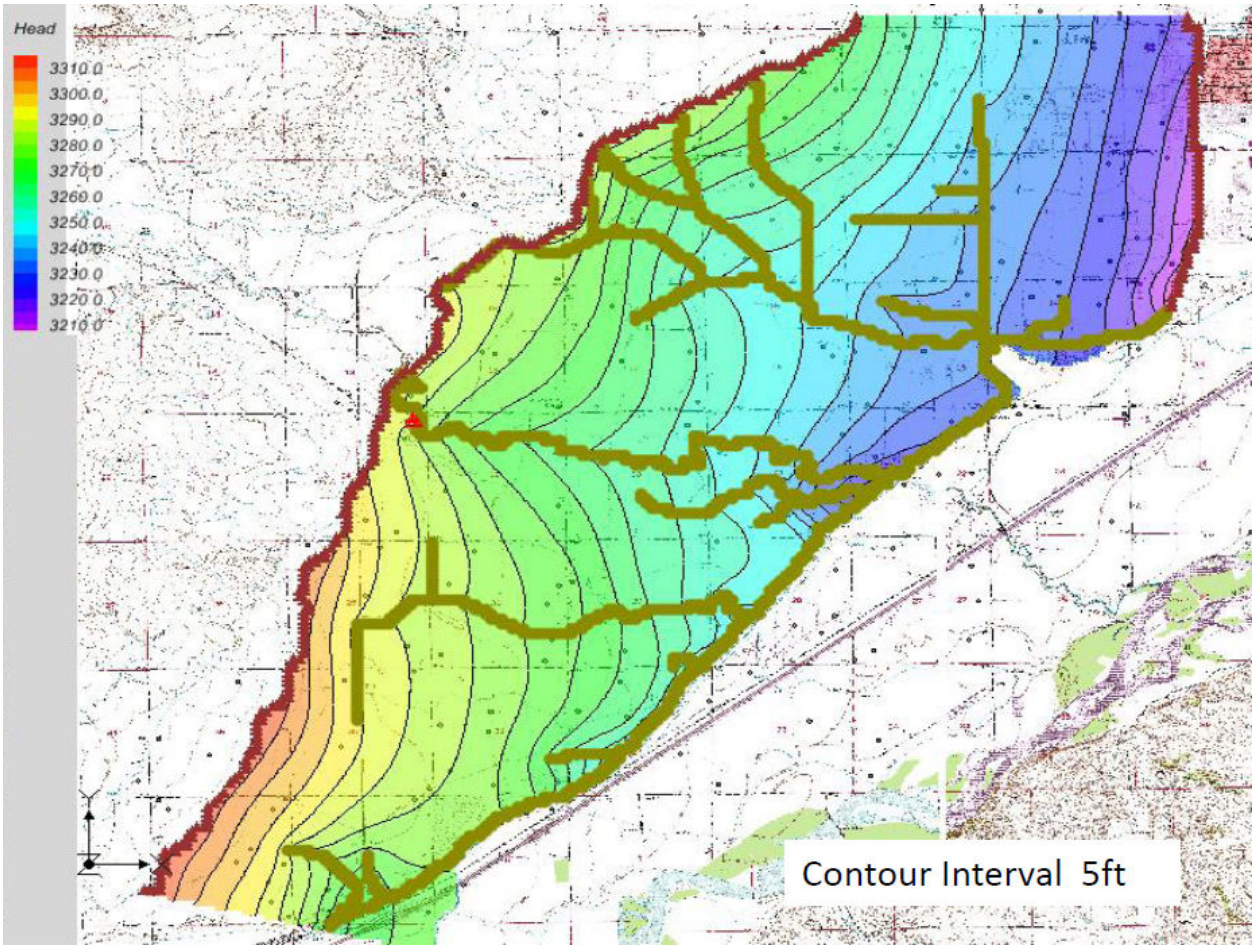

Figure B-3. MBMG North Steady-State Model Groundwater Elevation Contours

Sharptail Pond Recharge Simulation

MBMG has completed model simulations of potential groundwater recharge from flood mitigation at Sharptail Pond (shown as Site 3 on **Figure 3-1**). The site would cover an area of approximately 30 acres, but the exact location has not yet been specified. An approximation of the Sharptail Pond reservoir area was developed in the MBMG-north model using a polygon that is shown on **Figure B-4**. The polygon was sized to include

approximately 32.67 grid cells or 30 acres. Also shown on the figure are the location of three monitoring points. One monitoring point is located at the pond, and the two others are located at distances of roughly 400 and 1,000 ft from the downgradient end of the potential reservoir.

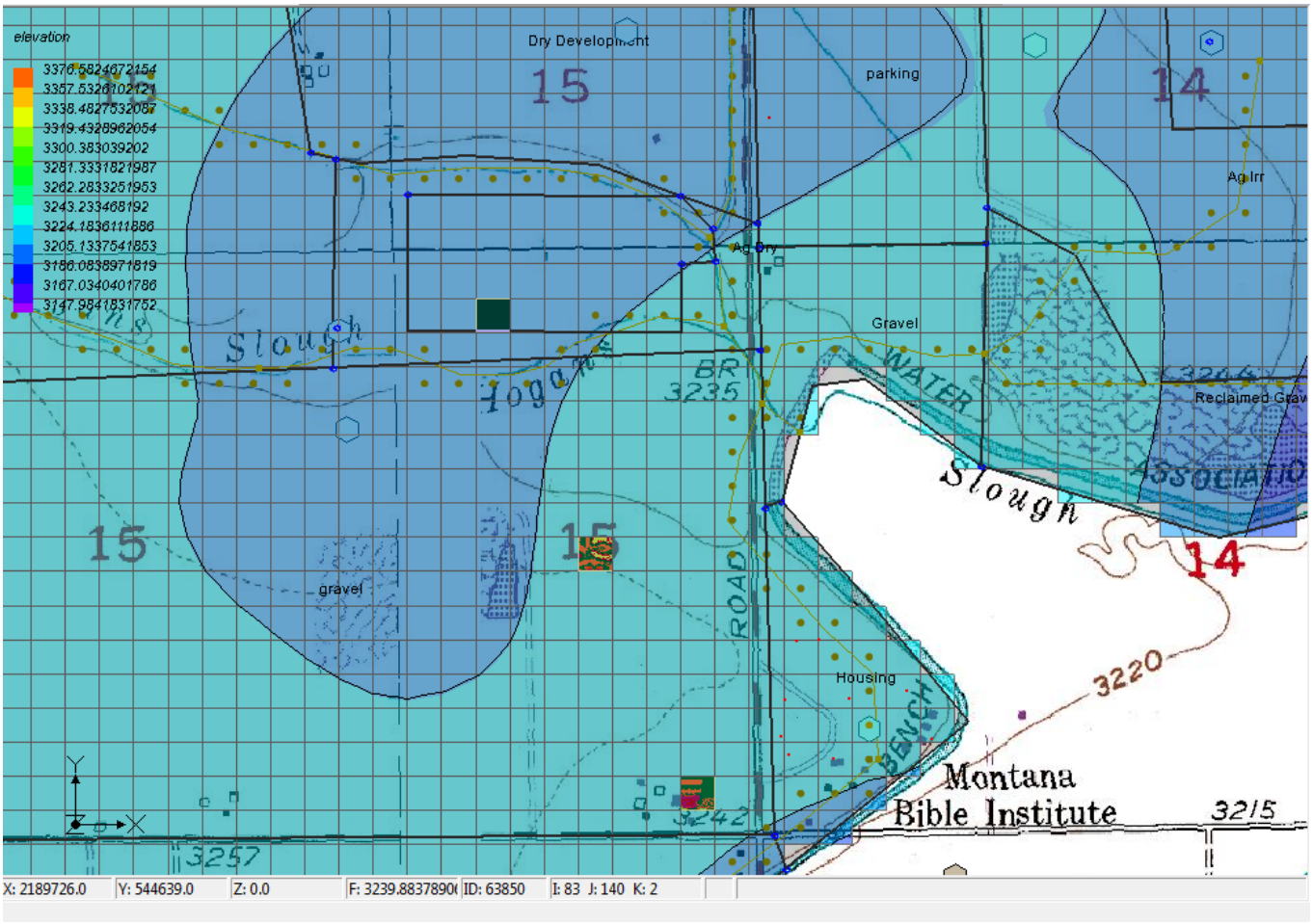

Figure B-4. Model Setup for Sharptail Pond Groundwater Recharge Simulations

The reservoir was represented in the model by modifying the recharge rates in the area of the pond. The rates were modified for the month of July. Rates used are shown in **Table B-1** and are 4,320 ft^3/d per cell for the 100-year event and 2,388 ft^3/d per cell for the 10-year event for each cell.

Table B-1. Recharge Values for Sharptail Pond Groundwater Recharge Simulations

Simulation	Recharge Rate (ft/day)	Recharge (ft^3)	Recharge (af)
Base Conditions	0.00366	148,270	3.4
10-year Flood	0.0597	2,418,495	55.5
100-year Flood	0.108	4,375,166	100.4

Results of the 100-year and 10-year recharge events are shown on **Figure B-5** and **Figure B-6**, respectively. The results show that, given the model limitations and the assumptions of a 32-acre reservoir that can route 83% of the water from a 100-year or 10-year flood event into the groundwater, that water levels might be expected to rise 2.6-4.7 ft beneath the reservoir. Downgradient of the reservoir the effect decreases significantly, with a rise of only 0.02 ft at a distance of roughly 400 ft from the reservoir, and virtually no change 1,000 ft away. The maximum water level rise will occur within one month of the recharge event, however at 1,000 ft away the maximum rise is delayed for 2-3 months.

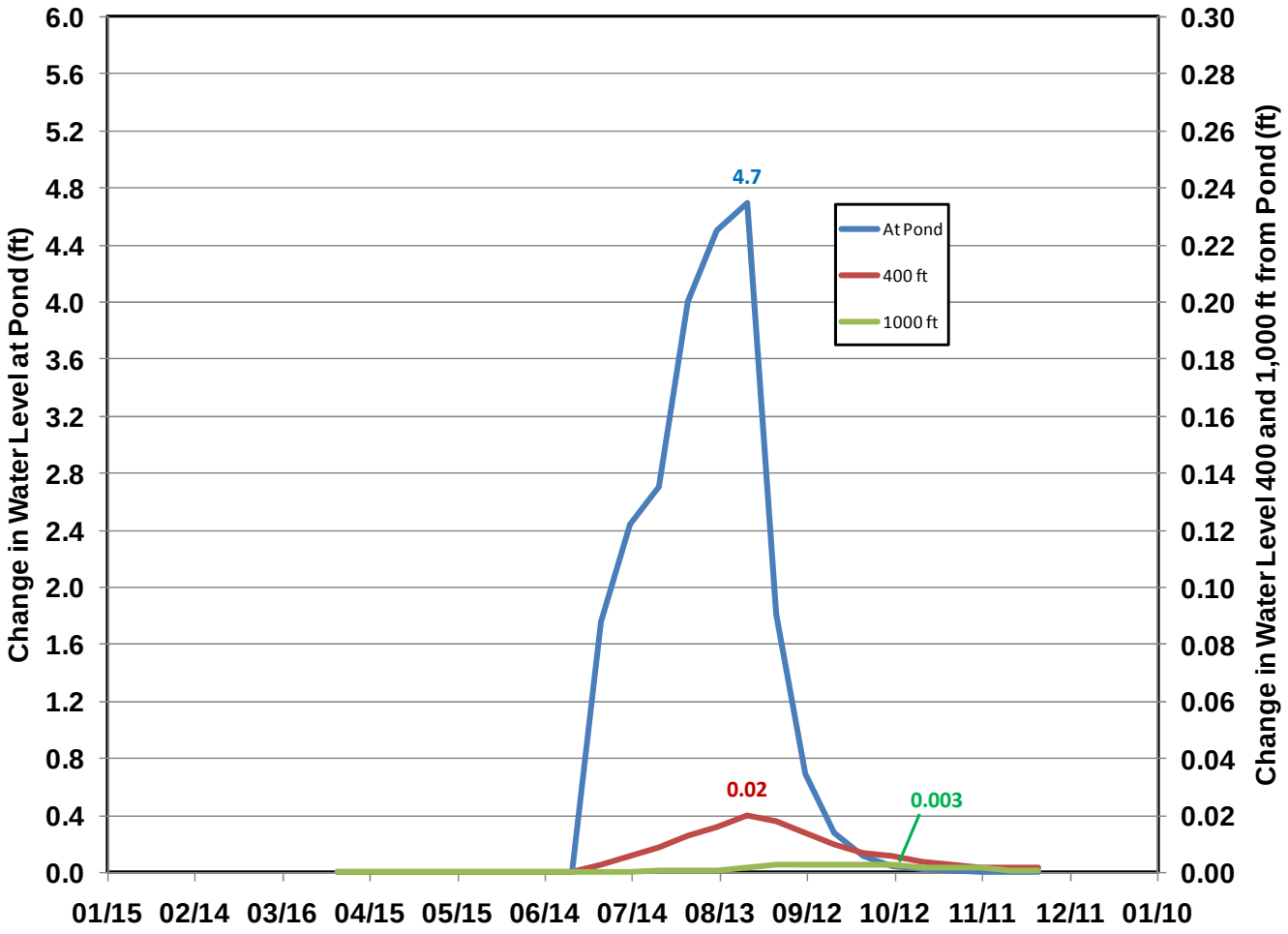

Figure B-5. Monitoring Point Hydrographs: Sharptail Pond Reservoir 100-year Flood Event

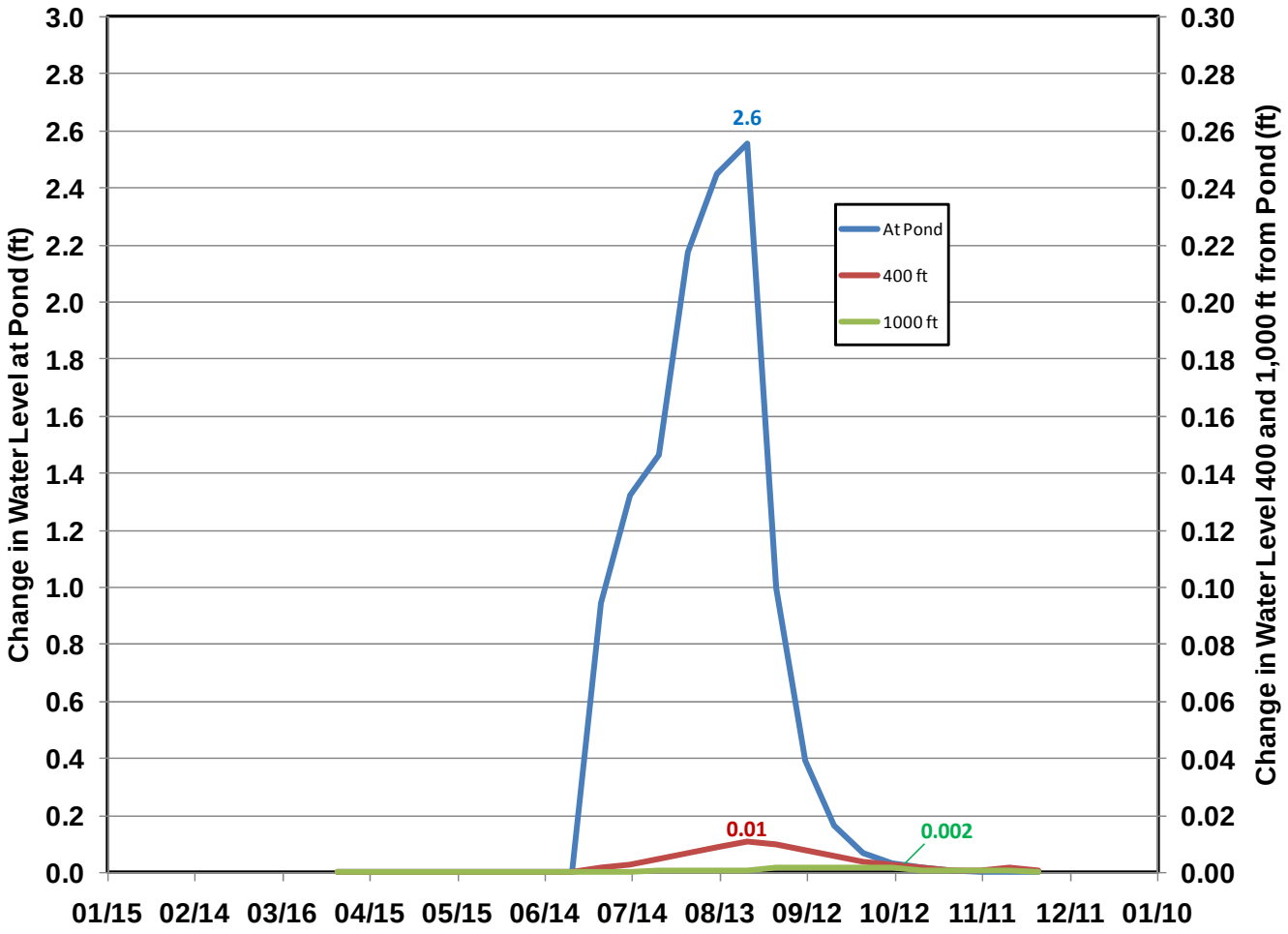

Figure B-6. Monitoring Point Hydrographs: Sharptail Pond Reservoir 100-year Flood Event