MBMG-275

WATER SUPPLY ASSESSMENT FOR THE CITY OF ROUNDUP, MONTANA

by

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INTRODUCTION

Municipal water supplies are sometimes difficult to identify and develop in eastern Montana. Some towns have found very creative solutions, such as the town of Roundup, where the voids of an underground coal mine, abandoned early in this century, are tapped as a storage reservoir for the city water supply. However, due to the poor quality of the city water, and questions about the quantity of water available, a joint project between the city of Roundup and the Montana Bureau of Mines and Geology was initiated. The objective of this project was to evaluate the water resources in the area of Roundup. Focus of this report is the potential for developing an alternative water supply for the city using several available resources.

The first recorded water supply system for the city of Roundup was a well dug in the alluvium along the Musselshell river (Ellis and Meinzer, 1924). The well was 8-feet by 16-feet in area and 35-feet deep. The well penetrated 15 feet of sand, 20 feet of gravel and ended in the shale underlying the alluvium. This well reportedly had a capacity of about 500 gallons per minute (gpm). The water quality was dominated by calcium and sulfate ions and had a dissolved solids content of 830 milligrams per litter (mg/L), as listed in Table 1.

Table 1. Results of water-quality analysis for selected sites near Roundup, Montana[*1]

Well Number	Location	Sample Date	Hydrologic Source	Collecting Agency[*2]	Lab[*2]	Lab specific Conductance (umhos/cm)	Calculated Dissolved Solids (mg/L)	Field Specific Conductance (umhos/cm)	pH Lab	Temp. (Deg. C)
R-143	08N26E18CBDD	07/16/89	alluvium	MBMG	ELI	2280	1690	1900	7.60	11.0
No. 22	08N26E18CBDD	01/11/18	alluvium	USGS	MSL		830[*3]			
R-147	08N25E24ABCB	12/16/13	mine	CMSPRR	MRR		820[*3]			
R-147	08N25E24ABCB	04/01/59	mine	MDH	MDH		1200			
R-147	08N25E24ABCB	03/19/75	mine	MDH	MDH	1730	1150		7.50	
R-147	08N25E24ABCB	07/14/86	mine	MBMG	MBMG		2530		7.20	
R-147	08N25E24ABCB	01/05/89	mine	MBMG	MDH	3000	2540		7.80	
R-147	08N25E24ABCB	10/27/93	mine	MDH	IML		2520[*3]		7.00	
RNDP-1A	05N25E16CCCC01	03/24/81	well	MBMG	MBMG	3266	2377	2810	8.76	
R-171	08N25E24BADD01	12/17/93	mine	MBMG	MBMG	1110	708		7.96	
R-199	08N25E18DBAD	12/22/89	river	MBMG	MBMG	3110	2360	2550	8.20	1.0

Well Number	Location	Sample Date	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Flouride (mg/L)	Nitrate (mg/L)	Iron (mg/L)	Manganese (mg/L)
R-143	08N26E18CBDD	07/16/89	165	97	251	5.0	34.0		-0.05	1.600	
No. 22	08N26E18CBDD	01/11/18	116	50	64		18.0		0.20	-0.001	
R-147	08N25E24ABCB	12/16/13	99	41	115		15.0				
R-147	08N25E24ABCB	04/01/59	120	80	167		12.0				
R-147	08N25E24ABCB	03/19/75	112	70	175	4.0	23.0				
R-147	08N25E24ABCB	07/14/86	212	117	455	6.0	24.0	0.20	3.05	2.000	0.290
R-147	08N25E24ABCB	01/05/89	204	121	483			0.26	0.03	1.150	0.307
R-147	08N25E24ABCB	10/27/93	211							1.200	0.340
RNDP-1A	05N25E16CCCC01	03/24/81	12.6	8.5	753	3.0	134	2.71	0.12	0.012	0.002
R-171	08N25E24BADD01	12/17/93	86.8	68.2	74.9	7.7	10.3	0.45	4.10	0.011	-0.003
R-199	08N25E18DBAD	12/22/89	187	155	356	6.0	39.0	0.41	0.30	0.110	0.040

Well Number	Location	Sample Date	Silica (mg/L)	Bicarbonate (mg/L)	Sulfate (mg/L)	Phosphate (mg/L)	Lithium (mg/L)	Aluminum (mg/L)	Arsenic (mg/L)	Barium (mg/L)	Bromide (mg/L)	Cadium (mg/L)
R-143	08N26E18CBDD	07/16/89		385	943	0.04	-0.100	-0.100				
No. 22	08N26E18CBDD	01/11/18		180								
R-147	08N25E24ABCB	12/16/13		333	359							
R-147	08N25E24ABCB	04/01/59		323	669							
R-147	08N25E24ABCB	03/19/75		349	600							
R-147	08N25E24ABCB	07/14/86	8.60	538	1440	0.10	0.040	-0.030	0.001		-0.100	-0.001
R-147	08N25E24ABCB	01/05/89		538	1460				-0.001	0.020		-0.001
R-147	08N25E24ABCB	10/27/93										
RNDP-1A	05N25E16CCCC01	03/24/81	3.30	314	1290		0.061					
R-171	08N25E24BADD01	12/17/93	8.70	559	171	-0.10	0.016	0.092	0.002	0.035	-0.500	0.002
R-199	08N25E18DBAD	12/22/89	8.30	457	1380		0.082	0.045		0.035		-0.005

Sodium

Table 1. Results of water-quality analysis for selected sites near Roundup, Montana *1 (continued)

Well Number	Location	Sample Date	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Mercury (mg/L)	Nickel (mg/L)	Molybdenum (mg/L)	Selenium (mg/L)	Silver (mg/L)	Strontium (mg/L)	Adsorption Ratio
R-143	08N26E18CBDD	07/16/89	-0.020	-0.010			-0.030	-0.005		-0.005	2.20	3.80
No. 22	08N26E18CBDD	01/11/18										2.40
R-147	08N25E24ABCB	12/16/13										2.90
R-147	08N25E24ABCB	04/01/59										2.90
R-147	08N25E24ABCB	03/19/75										6.20
R-147	08N25E24ABCB	07/14/86	-0.001	0.001		0.001	-0.100	-0.020	-0.001	-0.001	5.80	6.60
R-147	08N25E24ABCB	01/05/89	-0.005		-0.005	-0.001			-0.001	-0.001		40.20
R-147	08N25E24ABCB	10/27/93		-0.020	-0.005							1.46
RNDP-1A	05N25E16CCCC01	03/24/81										
R-171	08N25E24BADD01	12/17/93	0.002	0.008	-0.001		0.002	0.006	0.004	0.018	2.97	
R-199	08N25E18DBAD	12/22/89	-0.005	0.010	-0.050		-0.020	-0.040	0.004	-0.004	3.03	4.70

Well Number	Location	Sample Date	Titanium (mg/L)	Vanadium (mg/L)	Zinc (mg/L)	Zirconium (mg/L)	Hardness	Alkalinity	Oil and Grease (mg/L)	Comments
R-143	08N26E18CBDD	07/16/89			-0.100					Musselshell River Alluvium
No. 22	08N26E18CBDD	01/11/18					495.0			Musselshell River Alluvium
R-147	08N25E24ABCB	12/16/13								Republic No. 1 Mine
R-147	08N25E24ABCB	04/01/59								City Supply
R-147	08N25E24ABCB	03/19/75								City Supply
R-147	08N25E24ABCB	07/14/86	0.001	-0.001	-0.001	-0.003	1010.0	441.0		City Supply
R-147	08N25E24ABCB	01/05/89								City Supply
R-147	08N25E24ABCB	10/27/93						479.0		City Supply
RNDP-1A	05N25E16CCCC01	03/24/81					66.5	257.8	107	Fox Hills/Hell Creek Aquifer
R-171	08N25E24BADD01	12/17/93	-0.020	-0.001	0.006		497.5	458.8		Republic No. 1 Mine, slope
R-199	08N25E18DBAD	12/22/89	0.009	-0.004	0.013	-0.006				Musselshell River

*1 - Blank values indicate missing data or constituents that were not analyzed.
Negative values (i.e., - -0.1000 or -1) indicate the detection limits of the technique or instrument used and that the constituent was not detected
Sources: Ellis and Meinzer, 1924; Wheaton and Donato, 1992; MDHES file data; MBMG file data.

*2 - Collecting Agency and Lab: MBMG - Montana Bureau of Mines and Geology; USGS - US Geological Survey; MDHES - Montana Department of Health & Environmental Sciences; CMSPRR - Chicago, Milwaukee, ST Paul Railroad, IML - Inter-Mountain Laboratories, Inc., Bozeman, MT; ELI - Energy Lab, Inc; MSC - Montana State College, Bozeman.

*3 - 10/27/93 CDS is actually measured TDS at 180° C.

By 1923 the city water supply system consisted of the above described alluvial well, plus two 7-inch diameter wells that were drilled to depths of 150 feet and 200 feet and were completed in water bearing sandstones below the Roundup Coal bed. In addition, two infiltration galleries had been constructed in the alluvium, one being 450-feet long, and the other 500-feet long. These were completed with 12-inch and 15-inch diameter tiles. The total daily consumption during this period was 500,000 gallons to 800,000 gallons per day (350 gallons per minute (gpm) to 550 gpm). In good years, the drawdown was reported to be less than 2 feet. However, in dry years, the system was barely capable of meeting the demand (Ellis and Meinzer, 1924).

Many changes have occurred in the city water supply system since the 1920's. City records dated 1954 state that two wells, located near the current supply wells, were in use (Gary Thomas, Roundup water department, personal communication, 1994). These wells were both reportedly completed in abandoned and flooded mine workings. One of these wells was abandoned in 1977, and a new well drilled. No lithologic record is on file for the new well, but according to Gary Thomas, the drill dropped through about a 5-foot void, which was presumed to be the Republic No. 1 mine voids. No records exist that describe the methods used to abandoned wells that have been decommissioned.

Today, the public water supply for the city of Roundup is pumped from two wells that are reportedly completed in the Republic No. 1 mine (R-170 on Figure 1). Water is pumped from the wells into the caisson of a defunct infiltration gallery in the

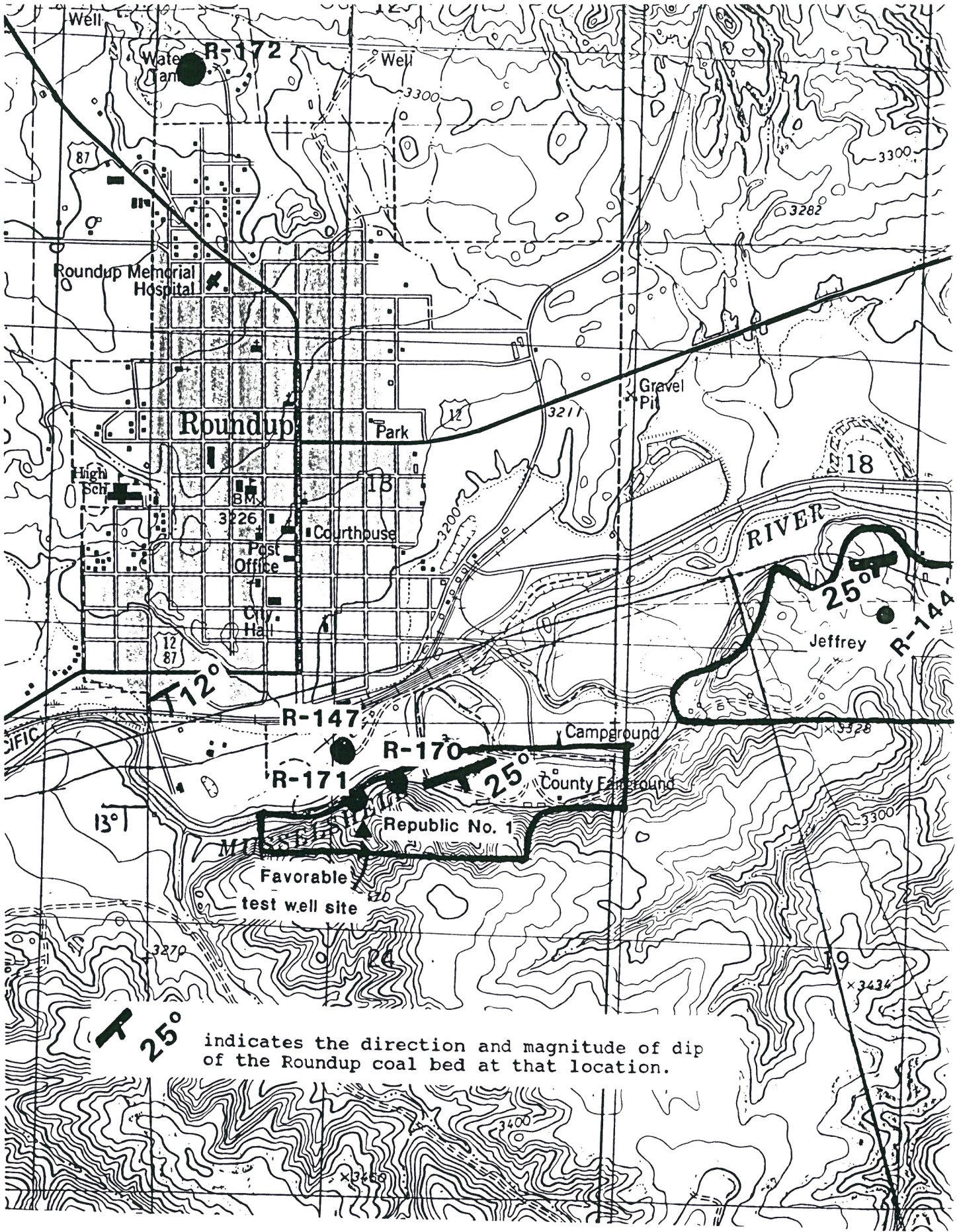

Figure 1. Location map of the Roundup area and components of the water supply system.

Musselshell River alluvium (R-147 on Figure 1). The water is then pumped out of the caisson to the storage facility north of town (R-172 on Figure 1). The city pumps at rates of about 1,100 - 1,200 gallons per minute (gpm) on a part-time basis. The total annual consumption is about 500 acre-feet per year, which is equal to just over 300 gpm of constant pumping (400,000 gallons per day), 365 days per year. Future growth in the population of the city would translate to additional water consumption. The quality of water currently being withdrawn from the city well in the Republic No. 1 mine voids is poor, and the quantity available at this site is questionable.

Dissolved solids content of water is an indication of the amount of salt being carried and can be measured and reported as total dissolved solids (TDS) or calculated analytical laboratory data and reported as calculated dissolved solids (CDS). The U. S. EPA secondary drinking water guidelines suggest a maximum dissolved solids level of 500 milligrams per liter (mg/L) which is equal to 500 parts per million. The guidelines also include recommended maximum levels of iron (0.3 mg/L) and manganese (0.05 mg/L).

As listed in Table 1, the most recent complete city water supply analysis (January 5, 1989) indicates that the city water significantly exceeds these standards (CDS: 2,540 mg/L, iron: 1.2 mg/L, and manganese: 0.3 mg/L). Other constituent concentrations are also high, including sodium (483 mg/L), and sulfate (1,460 mg/L). A list of analyses of the city water and other local water data are contained in Montana Bureau of Mines and Geology Open-file

Report 243 (Wheaton and Donato, 1992).

Dissolved solids are normally discussed in terms of mg/L or ppm. However, where desalinization treatment may be considered, tons per year are also of interest. Tons per year are calculated by converting the dissolved solids load of the water (mg/L) to tons per acre-foot and multiplying by the quantity of water used each year. Total annual dissolved solids is calculated to be about 1,700 tons per year, of which sodium is about 330 tons, sulfate is about 990 tons, iron is about 1 ton and manganese is less than one ton.

Due to the poor quality of water in the city-supply source and concerns about the quantity of water available, the city is investigating alternative sources. Stated briefly, there are several potential sources for the city water supply: 1) deeper local bedrock aquifers; 2) Musselshell River alluvium; 3) current source, a well in the eastern area of the Republic No. 1 mine; 4) western area of the Republic No. 1 mine; 5) Jeffrey mine voids; or 6) the river. Wells could be drilled to a deeper local bedrock aquifer in the area, however, the water quality is a serious problem, plus aquifer yield is not expected to be sufficient. A series of wells or infiltration systems might be constructed in the alluvium; however, the quantity of water that could be pumped from the alluvium appears to be less than anticipated demand. The Republic No. 1 mine voids might yield more and better quality water if developed differently. The city could use the Jeffrey mine voids, which do contain better quality water than is being produced

from the city well. However, the cost of a pipeline would be a consideration. The river could be directly tapped, and treated as all surface sources are required to be treated. However, treatment facilities are expensive.

HYDROGEOLOGIC RESOURCES

This section describes in more detail the potential sources for a city water supply. The hydrologic resources near Roundup have been described in several sources. The following discussion is based on MBMG field and file data, Montana Oil and Gas Commission data, and several general reports (Noble and others, 1982) (Rice, 1976), (Wheaton, 1992) and (Woolsey and others, 1917). This discussion is not intended to be of sufficient detail to use for designing a drilling program, but is intended to provide general background data. The depth information is based on available data and is probably accurate to within plus or minus 10 to 20 percent. The discussion of resources is broken into bedrock aquifers, the alluvial aquifer, underground mine voids and surface water.

Local bedrock aquifers

The estimated depths to the aquifers that exist near and beneath Roundup are shown on Figure 2. Those of interest for a large water supply are: Hell Creek/Fox Hills aquifer; Eagle Sandstone; Pryor Conglomerate (or Third Cat Creek sandstone) of the Kootenai Formation; and the Madison Formation.

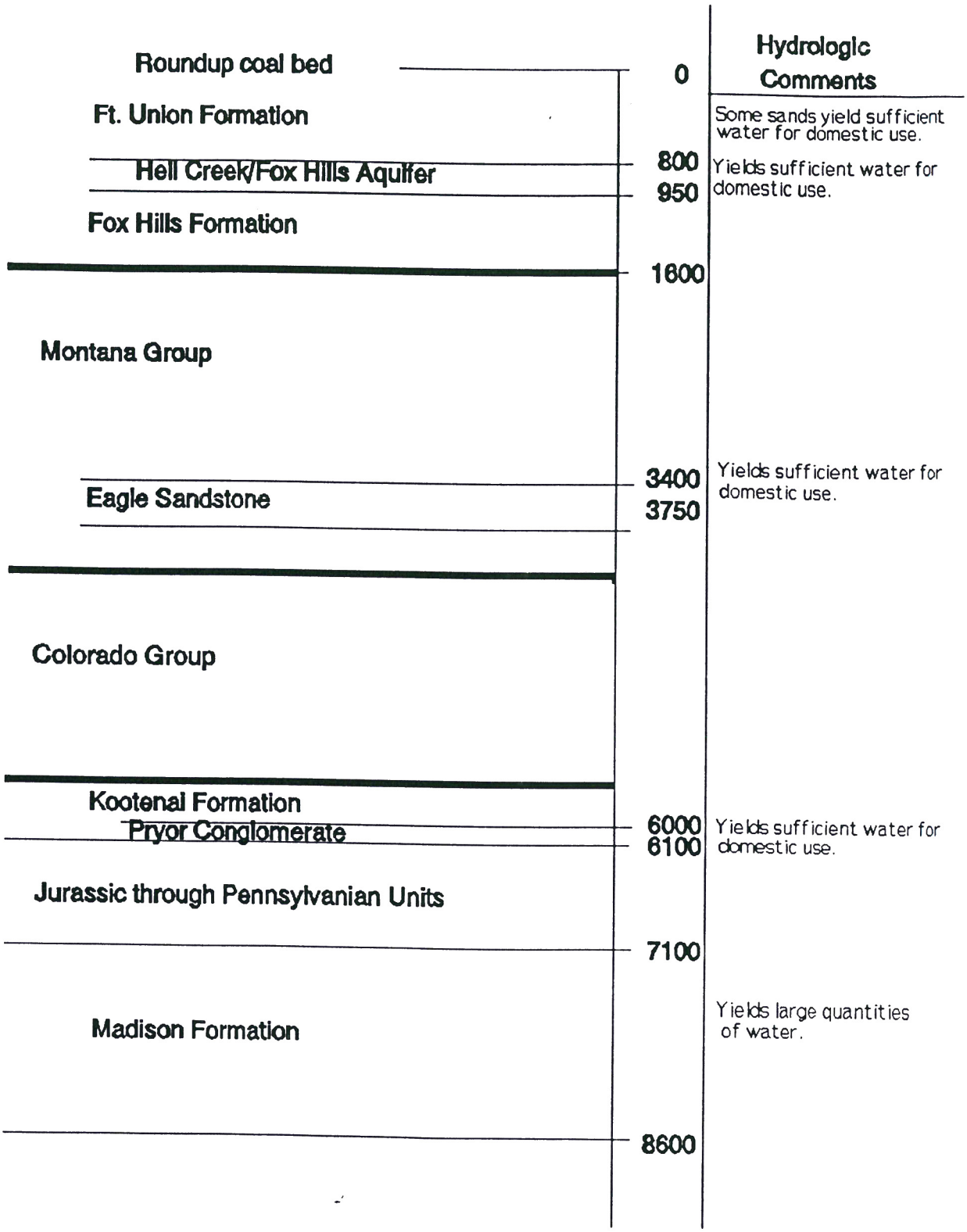

Figure 2. Generalized hydrostratigraphy in the Roundup, Montana area. Based on data from: Rice, 1976; Noble and others, 1982; Wheaton, 1992; Woolsey and others, 1917; and oil well logs.

The Hell Creek/Fox Hills aquifer produces much better yields in eastern Montana than in central Montana. MBMG tested monitor wells 36 miles east of Roundup (Township 8 North, Range 31 East Section 36) and 18 miles south of Roundup (Township 5 North, Range 25 East Section 16). Transmissivity values ranged between 0.6 feet squared per day and 8.5 feet squared per day with a mean of 3 feet squared per day. Available head in the test wells ranged up to 960 feet. Calculations using the Thiem steady state equation for a confined aquifer, indicate a yield of 10 to 30 gpm is probably realistic for this aquifer in the Bull Mountains and Roundup area. CDS for this aquifer would probably be near 2,000 mg/L, dominated by sodium and sulfate ions. The Hell Creek/Fox Hills aquifer would probably be in the range of 1,000 feet below ground surface in the Roundup area.

The Eagle Sandstone is not considered a high production aquifer and yields would be expected to be in the range of 10 gpm to 50 gpm (Levings, 1982). The Eagle Sandstone in the Roundup area would be expected to be about 3,500 feet below ground surface.

The Pryor conglomerate is the basal Kootenai Formation unit. No data were found on aquifer tests for the Pryor conglomerate in this area. Expected yields are in the range of 100 gpm or less. CDS levels would be expected to be in the range of 3,000 mg/L (Noble and others, 1982). The Pryor conglomerate in the Roundup area could be in the general range of 6,000 feet below ground surface.

The Madison Formation is a limestone, which produces large volumes of water throughout Montana. However, the water quality is poor in many areas. In the Roundup area, CDS levels of 5,000 mg/L could be expected (Noble and others, 1982). Drilling depths to fully penetrate this aquifer would probably be in the range of 8,000 feet to 9,000 feet.

None of these four deep aquifers have a combination of high yield and good water quality. To produce large quantities of water would require well fields. Drilling costs are hard to estimate, but could run between $20 and $40 per foot or more. For example, if ten wells were drilled to the Pryor conglomerate aquifer in order to provide up to 1,000 gpm of water, drilling alone could cost $1,200,000 to $2,400,000 or more. Pipelines would be an additional expense.

Musselshell River alluvium

The alluvium along the Musselshell River consists of fine-grained sands and clay, along with gravel. The original water supply for Roundup was based on infiltration galleries that drew water from the alluvium and the river. The possibility that large quantities of water could be withdrawn from the alluvial gravel was one of the main study objectives of this project.

Quality of water in the alluvium would be expected to vary seasonally, since it is connected closely to the surface-water system. Especially if a water supply were developed in the alluvium, infiltration of the river water would produce seasonal variations comparable to that found in the river. The only available alluvium water-quality data are from samples collected during July, 1989 and during January, 1918 (Table 1). These samples contained CDS concentrations of 1,690 mg/L and 830 mg/L, respectively.

One problem with developing large withdrawals from gravel deposits is in building high efficiency collectors or wells. The Ranney Corporation, Kennewick, Washington, designs and installs high efficiency collector systems that consist of large vertical caissons, with horizontal wells driven laterally for ten's or in some cases hundred's of feet. The horizontal wells are the collectors which transport water to the caisson, and the water is

pumped from the caisson. Additional information about this system is on file at the MBMG Billings office, and the city of Roundup water office. Mention of a particular trade name, such as Ranney Corporation, does not constitute an endorsement of that product by the Montana Bureau of Mines and Geology, but rather identifies that product as an example for clarification of discussion. A Ranney Corp. engineer (Susan Mikels) was on site during the alluvial drilling to help review the hydrologic data associated with the project.

High efficiency collector systems are designed to induce flow from a nearby surface-water source and allow for the interception of that water after it has been filtered through the alluvial gravel and sand. The system would be expected to be beneficial in a low yield situation, such as exists at Roundup. Other communities in and near Montana utilize this type of horizontal collector system including Fort Benton, Hysham, Big Timber, Columbus, Rapelje, and Ryegate (Jerry Burns, 1994, Department of Health and Environmental Sciences, personal communication).

Thickness of saturated gravel in the Musselshell River valley is widely variable (Reiten and Wheaton, 1988). While the gravel has not been tested for yields, infiltration to the Jeffrey mine during a pumping test indicated that as much as 700 gpm of water may be flowing through the gravel in the area of that mine (Wheaton, 1992).

In an effort to verify and describe the extent of the deepest alluvium (and therefore the most productive), the MBMG drill rig was used to drill a total of 15 boreholes (Figure 3). Also, shown on Figure 3, are alluvial wells drilled as part of the earlier mine-water project that are included in this analysis (Reiten and Wheaton, 1988). Alluvium depths in the 24 boreholes ranged from 11 to 27 feet and the thickness of gravel was between 1 and 21 feet (Appendices 1 and 2). Saturated gravel (gravel that was below the water table) ranged from 1 to 19 feet (Figure 4) and averaged about 6.5 feet. The thickest gravel occurs in an area about 300-feet wide, extending from just south of Main Street, east for about one-half mile.

The thickest gravel deposit occurs at and just below a spot where the valley is at its narrowest point. This narrow spot may represent down cutting by the river, and a slightly higher ancient energy regime. No other areas similar to this narrow one are indicated by the valley geomorphology within the area of investigation. For logistical and sanitation reasons the area of investigation was limited roughly by Halfbreed Creek to the west and the city sewage lagoon to the east.

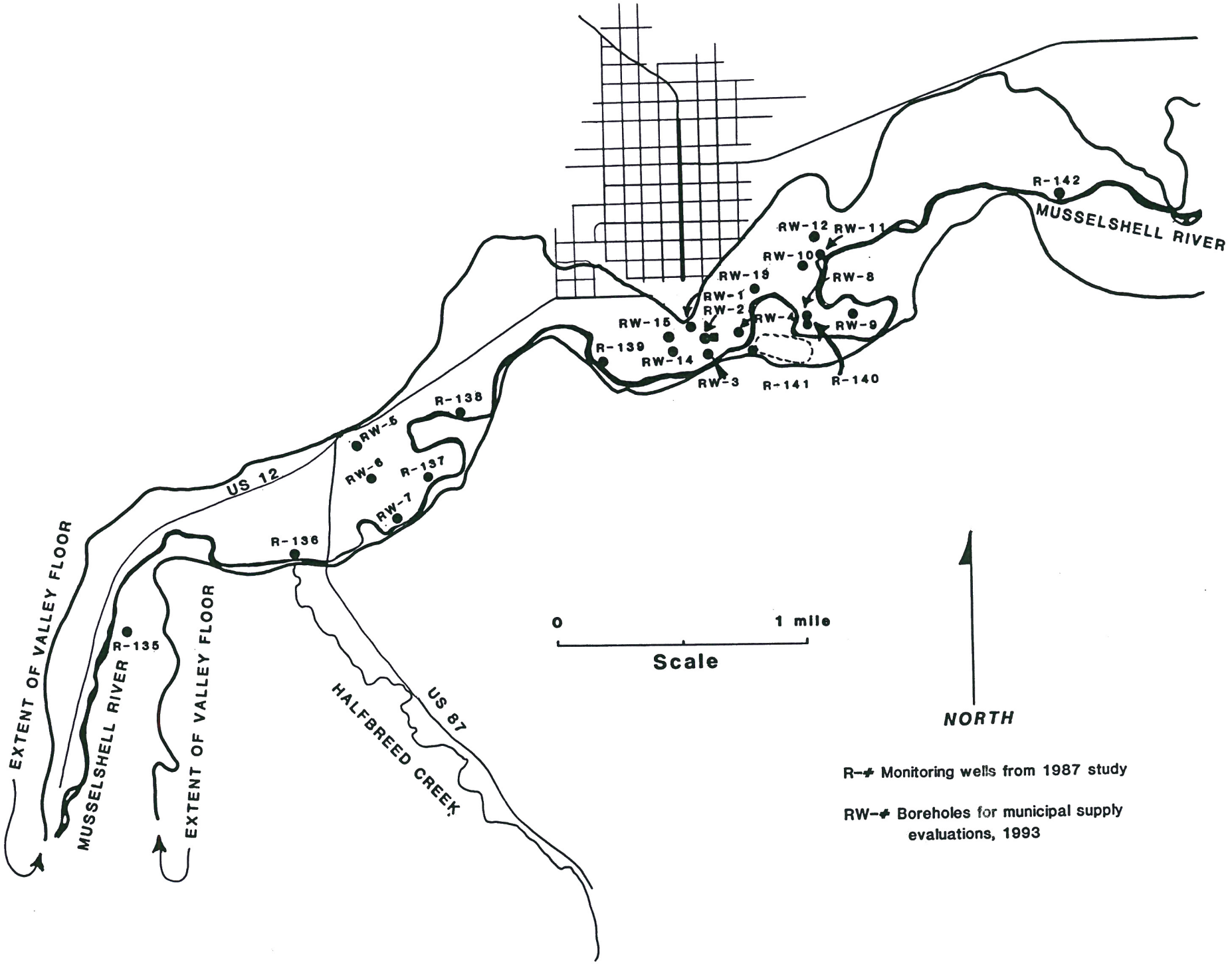

Figure 3. Location map of boreholes and monitor wells along the Musselshell River, near Roundup, Montana.

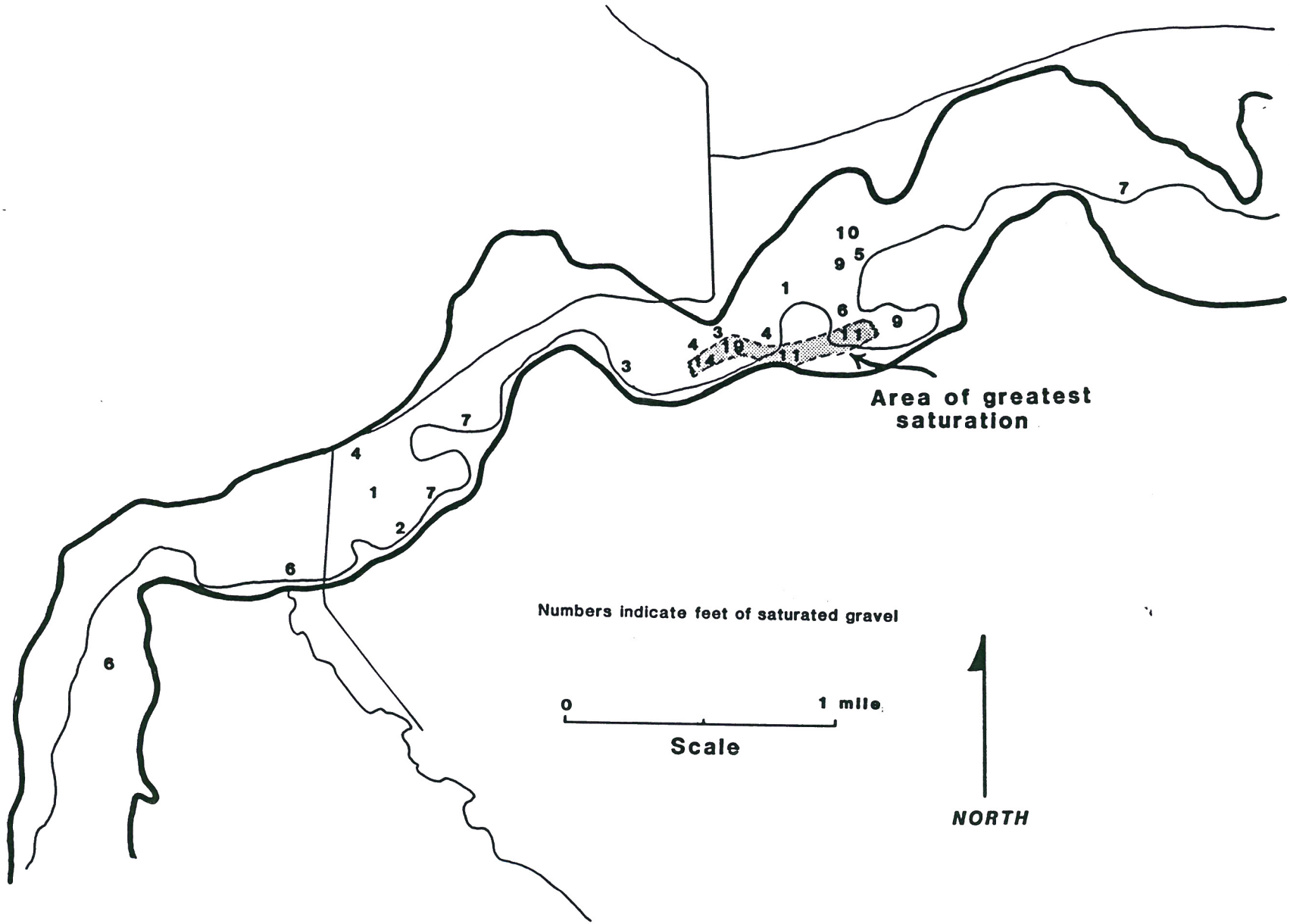

Figure 4. Map of borehole locations, showing the thickness of saturated gravel encountered.

The area of thickest saturated gravel shown on Figure 4 would probably be the most productive area in the alluvial aquifer. The maximum yield that could be achieved from this area can be estimated, by modeling a high efficiency nest of wells or a collector system. The collector system would be designed and installed to intercept all flow through the gravel lense. Pumping from the collector system would lower the water-pressure head in the gravel, inducing recharge from the river. The quantity of recharge would be a function of the pressure-head gradient, the hydraulic conductivity of the gravel, the thickness and width of the gravel lense, and the hydraulic efficiency of the contact of the gravel with the river.

In order to calculate the maximum possible flow through the gravel lense, four assumptions were required. First, the gravel was assumed to be in good hydraulic contact with the river. A problem with this assumption is that the river bed contains a layer of fine-grained silts and clays. These fine-grained materials will reduce the efficiency of the connection between the river and the aquifer by plugging the pores between the larger sand grains and cobbles. However, in order to estimate aquifer yield, an efficient hydraulic connection must be assumed and the results must be interpreted with this in mind.

Second, it was assumed that a high efficiency well (or nest of wells, or collector system) can be constructed to induce flow from the river, and capture all of that flow. Third, the gravel aquifer was assumed to be homogeneous. And fourth, the water-table

gradient was assumed to be small, and flow was horizontal.

Since the gravel is of limited extent, and the water source is recharge from the river, aquifer storativity was considered negligible for long-term pumping. The flow that was calculated below is the maximum obtainable infiltration from the river; actual yield would be expected to be somewhat less, due to the above assumptions. During pumping some additional flow would, however, be expected to reach the collector from other directions in the alluvium. This flow cannot be quantified without an aquifer test, and so was not considered in the following equations.

A simple mathematical model was used to calculate discharge from a hypothetical collector system in the thickest gravel. In the model, a collector system was located 100 feet from the river. Pumping from the collector system induced river water to flow through the gravel to the pumps. The rate of flow was controlled by: availability of river water; hydraulic conductivity of the gravel; and the area in the gravel through which water can flow or the saturated thickness of the gravel. For the purpose of the calculation, the static water table was estimated at 11 feet above the base of the aquifer (Figure 4). Adjacent to the river, the saturated thickness was maintained at 11 feet in the model. At the collector wells, the water table was lowered 8 feet to reflect pumping, so that 3 feet of saturated gravel were maintained. The estimated aquifer width was 300 feet (Figure 4). For the calculation, this is the length of river channel that contributes recharge to the collector system by parallel (non-radial) flow. A

line of horizontal interception wells was modeled at a position 100 feet from the river. Based on the lithologic descriptions from boreholes R-1 through R-15, the hydraulic conductivity was estimated at about 300 ft/day. Using the Dupuit equation (Fetter, 1980):

$$q = (K/2) \left[(h_1^2 - h_2^2) \right] / L$$

Where:

q = Discharge rate per unit width of aquifer (ft^3/day)(1/ft)
K = Hydraulic conductivity (300 ft/day)
h1 = saturated thickness at the river (11 ft)
h2 = saturated thickness at the collector wells (3 ft)
L = distance between the river and the collector wells (100 ft)

The steady state discharge per unit width of the aquifer calculated to be 168 ft^3 per day (about 1 gpm). Since the aquifer was estimated at 300 feet wide, the total potential discharge was 300 gpm. Due to the earlier assumptions, this discharge rate was probably optimistic.

Underground mine voids

Republic No. 1 mine voids

Water for the Roundup city supply is pumped from the Republic No. 1 mine at site R-170 (Figures 1 and 5). The two wells at this site are reportedly completed in flooded voids of the Republic No. 1 mine. These wells provide much of the information about these mine voids. The wells are about 10 ft apart, and reportedly about 90 ft deep. Vertical turbine pumps are installed in both wells, however, during recent maintenance, one pump was removed. This allowed access to the well, and water-level measurements were collected from the open well, while pumping was occurring at the other well. Water-quality samples were collected during this test from hoses on the pump discharge lines.

A water-quality sample was collected from the mine in 1913 and contained a dissolved-solids concentration of 820 mg/L (Table 1). Water-quality samples collected in 1959 and 1975 were probably a mixture of mine water, alluvial water and possibly bedrock-aquifer water. Samples collected from the city water system since 1980 were probably predominantly water from the east area of the Republic No. 1 mine where the wells are installed and contain over 2,500 mg/L dissolved solids.

Water-quality data from the mine slope (R-171) indicate the CDS value at this location in the mine was just over 700 mg/L (Table 1). This is less than one third the concentration at the city supply (R-147). Water quality in the mine voids is, therefore, not homogeneous.

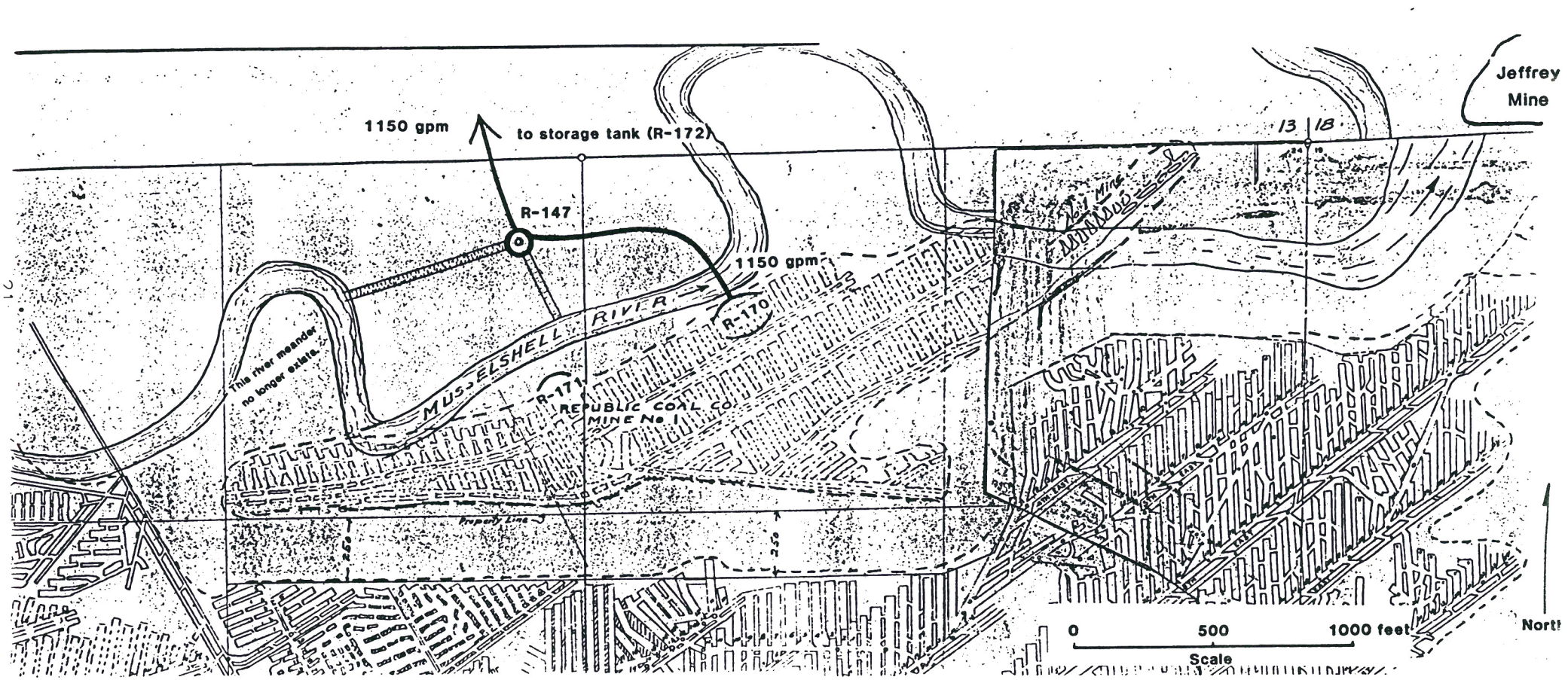

Figure 5. Location of Roundup city supply well (R-170) and mine slope (R-171) within the Republic No. 1 mine workings.

The mine room that the city well is completed in, is in the eastern part of the Number 1 mine, and may not be in complete communication with the rest of the mine. Water levels were measured at the city pump house (R-170) in one well while the other well was pumping. The measured water level was lowered by 50 feet (Figure 6). Water levels at the mine slope changed one tenth to several tenths of a foot during similar periods of pumping from the city well (Figure 7). At the mine slope no change in the response to pumping has occurred between 1991 and 1993 (Figure 7 a and b).

Equations that are used to described and predict ground-water flow to a well cannot be applied to an underground mine void. However, for the purpose of comparing available water from a supply, the specific capacity for the mine voids can be estimated. Based on the drawdown data (Figure 6), after about 400 minutes of pumping at about 1,150 gpm, the specific capacity was 25 gallons per minute per foot of drawdown.

Jeffrey mine voids

The Jeffrey mine voids are located about 1 mile east of Roundup, south of the river. The mine-void reservoir capacity was estimated at between 200 acre-feet and 300 acre-feet (Wheaton, 1992). The water in the mine voids during 1989 and 1991 had a CDS concentration ranging from 1,320 mg/L to 1,420 mg/L (Table 1). Iron concentrations ranged from 0.2 mg/L to 1.9 mg/L and manganese

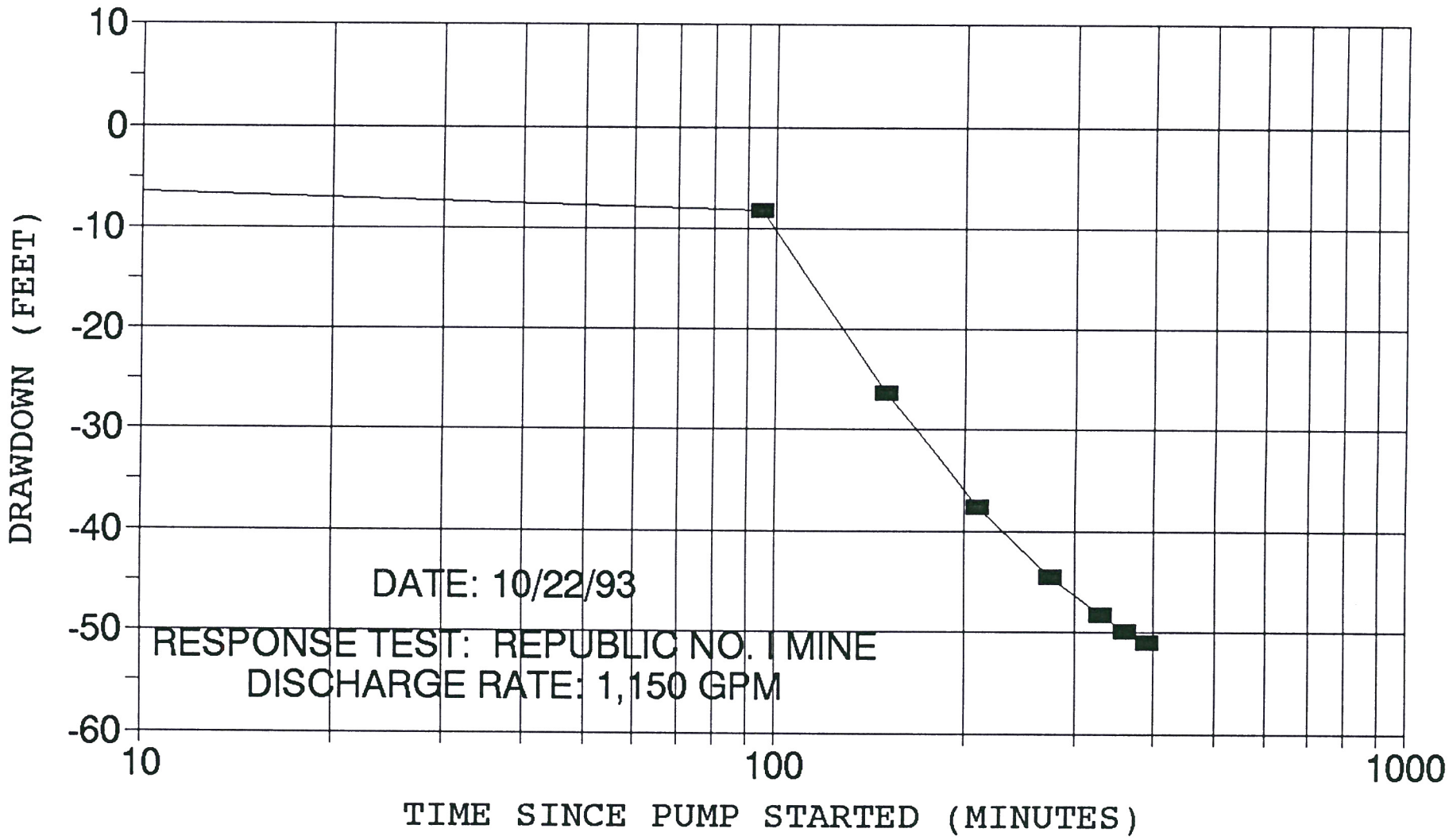

Figure 6. Water-level response data from the Republic No. 1 mine at the city supply well (R-170) due to pumping 1,150 gpm. Water levels were measured in nearby well, 10 feet from the pumping. Both wells are reportedly completed in the Republic No. 1 mine voids.

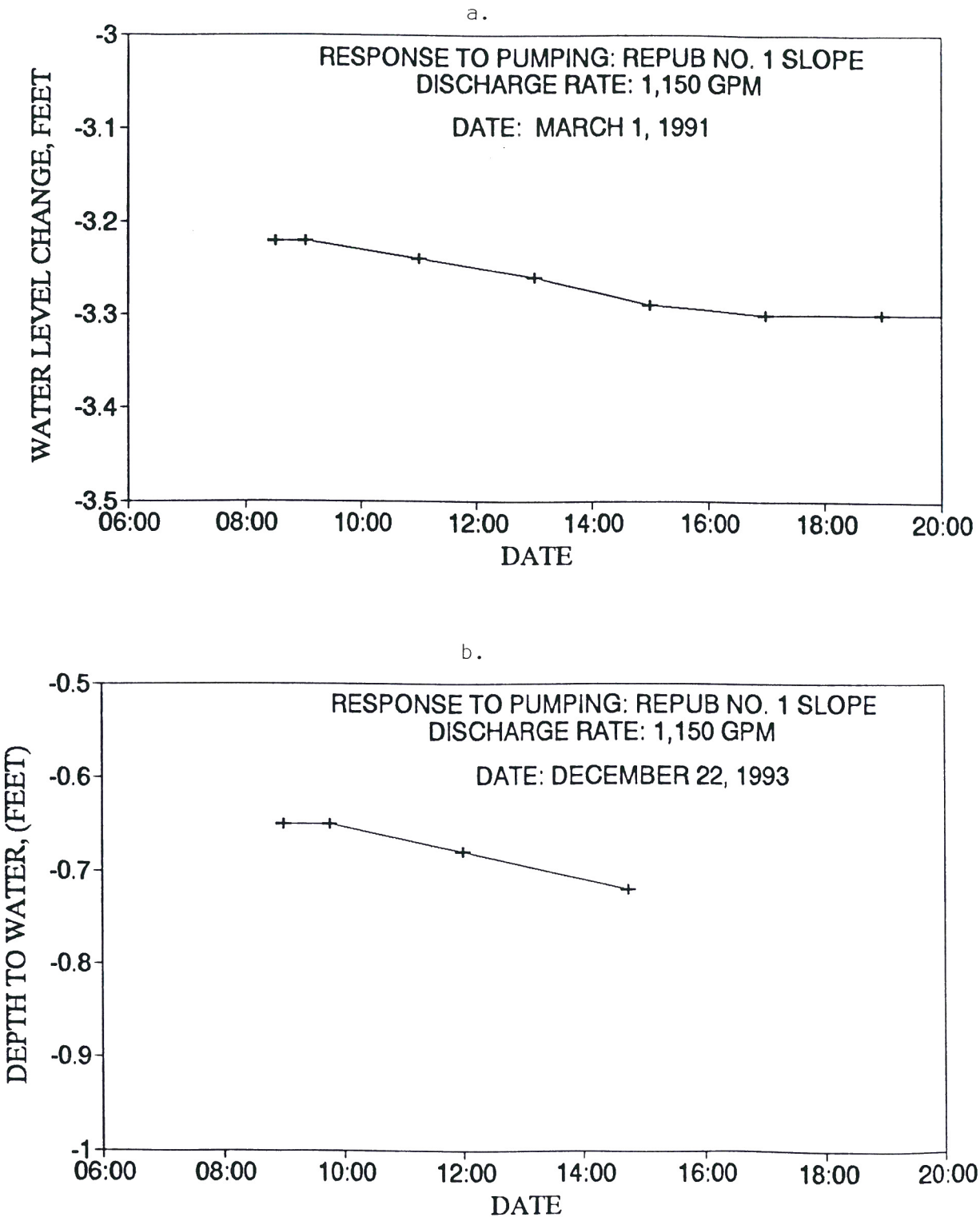

Figure 7. Water level data for the Republic No. 1 mine slope, in response to pumping the city supply well. The response measured at the mine slope has not changed during the period from 1991 through 1993.

concentrations were consistently about 0.1 mg/L. These are lower than the concentrations in the current city water supply, but still exceed the EPA recommended limits.

A response test of the mine voids was conducted during 1989 (Wheaton, 1992). The mine was pumped at about 830 gpm for 6.5 days. The water level in the mine was lowered 44.7 feet (Figure 8). Several private wells nearby were also lowered during the test pumping. Recharge and mass balance data indicate that the mine voids may have been receiving up to 700 gpm of inflow from the Musselshell River alluvium during the test. No changes in water quality were detected during the pumping period. The specific capacity for the Jeffrey mine after about 400 minutes of pumping at 830 gpm was 140 gallons per minute per foot of drawdown.

Discussion of mine voids

The Republic No. 1 mine is elongated perpendicular to the strike of the coal bed, near the Musselshell River, which is the highest portion of the mine (Figure 1). During the early stages of pumping, the storage volume that should be drained is large, and drawdown should be small. On the other hand, the Jeffrey mine is narrower near the river (up dip direction), and widens with depth, away from the river (Figure 1). For this reason the Republic No. 1 mine was expected to have a higher void volume and therefore higher specific capacity, and was expected to draw down at a slower rate during the early stages of pumping than did the Jeffrey mine.

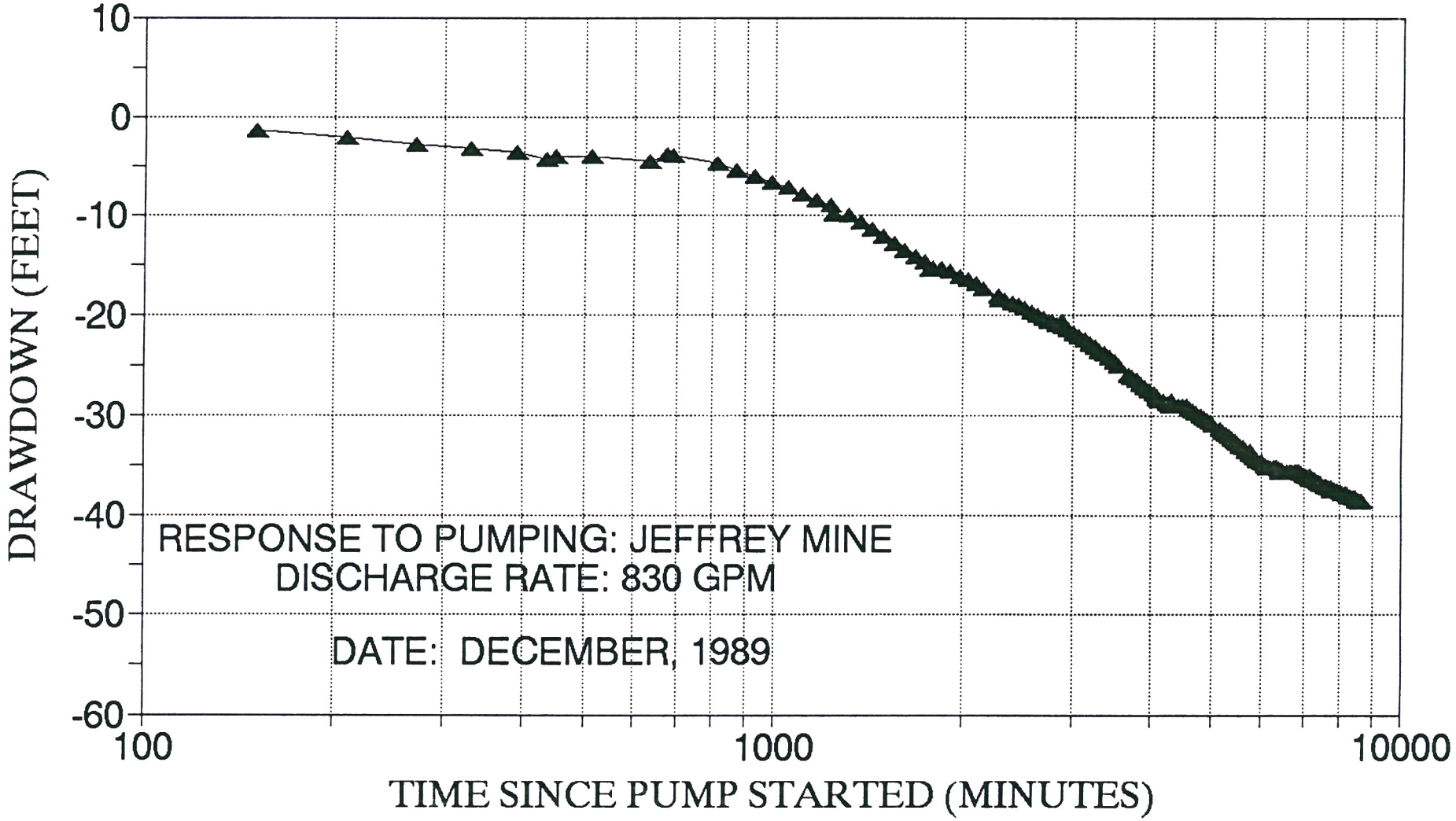

Figure 8. Water-level response data from the Jeffrey mine due to pumping at 830 gpm.

However, the calculated specific capacity after 400 minutes of pumping for the Republic No. 1 mine at the city supply well was about 20 percent of the specific capacity value for the Jeffrey mine at the same pumping duration.

Since the specific capacity for the Jeffrey mine was significantly higher than that for the Republic No. 1 mine, it would be expected that more water could be withdrawn from the Jeffrey mine. This could result in a more dependable supply, over the long term, and a reduced energy demand due to the reduced pumping drawdown.

During pumping at the Jeffrey mine, the water level response was the same throughout the mine. However, at the Republic No. 1 mine, the water level at the slope (R-171) lowered only about one-tenth of a foot while at the city well, it lowered about 50 feet. Both the water level response, and the water-quality results indicate that the city well is not tapping the entire volume of the Republic No. 1 mine.

A better location for a supply well may exist in another area of the Republic No. 1 mine. The area where the city well is located is hydraulically isolated from other portions of the mine. The better water quality, and less drawdown measured in the mine slope may indicate more direct recharge from the river in the western part of the mine.

Musselshell River

No data were collected from the Musselshell River during this project. The U. S. Geologic Survey measures the flow and specific conductance of the river near Roundup on a regular basis, and a sample was collected from the river during the Jeffrey mine pumping project, the data of which are listed in Table 1 (R-199). The mean annual discharge rate for the period of record for the Musselshell River was 211 cubic feet per second or about 95,000 gpm (U. S. Geologic Survey, 1993). Specific conductivity values and daily mean flow rates are presented in Figure 9.

The specific conductance of water from the river shows an increase since about the mid-1980's (Figure 9 a). Flow rates have also changed somewhat and show a much less flashy response after 1983 than before. The hydrograph (Figure 9 b) indicates the effects of storage in upstream reservoirs, and subsequent release in response to irrigation demands. Likewise the quality of the water may be suffering due to irrigation return flow, or due to an overall decrease in the flow rate. Higher flow rates which would normally dilute dissolved solids loads are now being diverted for irrigation use.

CURRENT CITY WATER SUPPLY

The Roundup city water supply system has changed several times over the years. All available well log information for municipal supply points are included as Appendix 4.

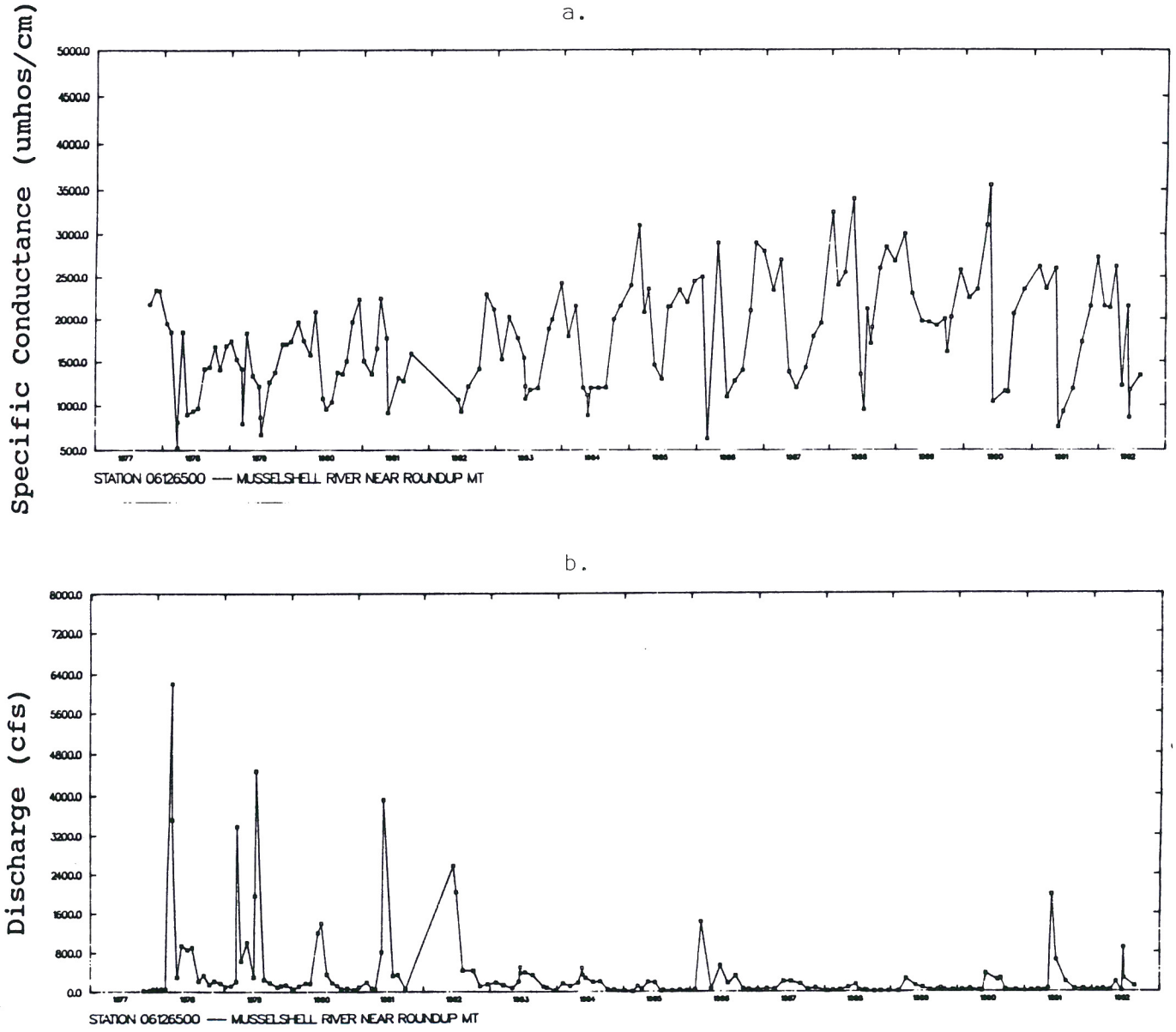

Figure 9. Specific conductance (a) and discharge rates (b) for the Musselshell River near Roundup, Montana for water years 1977 through 1992 (US Geological Survey, annual reports).

As shown on figures 1 and 5, city water is pumped from wells at R-170 to a caisson (R-147) and then to the storage tank north of town (R-172). There are two wells at site R-170; both are part of the city water supply system. Usage is alternated between the two wells, to provide backup during maintenance. The two wells are about 10 feet apart, located in a small pump house and reportedly completed in the flooded workings of the Republic No. 1 mine.

Water from the mine (R-170) is discharged into the caisson of the old infiltration gallery (R-147), located north of the river. This caisson was originally part of an infiltration gallery that is now reportedly defunct but that supplied part of the city water from the Musselshell River alluvium. Based on flow-meter readings at R-147 and R-170 the discharge rate from the mine wells was approximately equal to that from the caisson booster pumps. Water-level data collected at the caisson during a pumping period indicate 0.9 ft of drawdown after 5 hours of pumping at about 1,150 gpm. Booster pumps in the caisson transported the mine water to the storage tanks north of town (R-172).

The water quality in the Republic No. 1 mine appears to have been deteriorating since the first sample was collected in 1913 (Table 1). CDS values are plotted versus time on Figure 10 for samples collected from the mine and from the city water supply system. At times water in the city system may have been a composite of mine water, alluvial water, and bedrock ground water. The sample collected in 1913 was collected from the mine (Ellis and

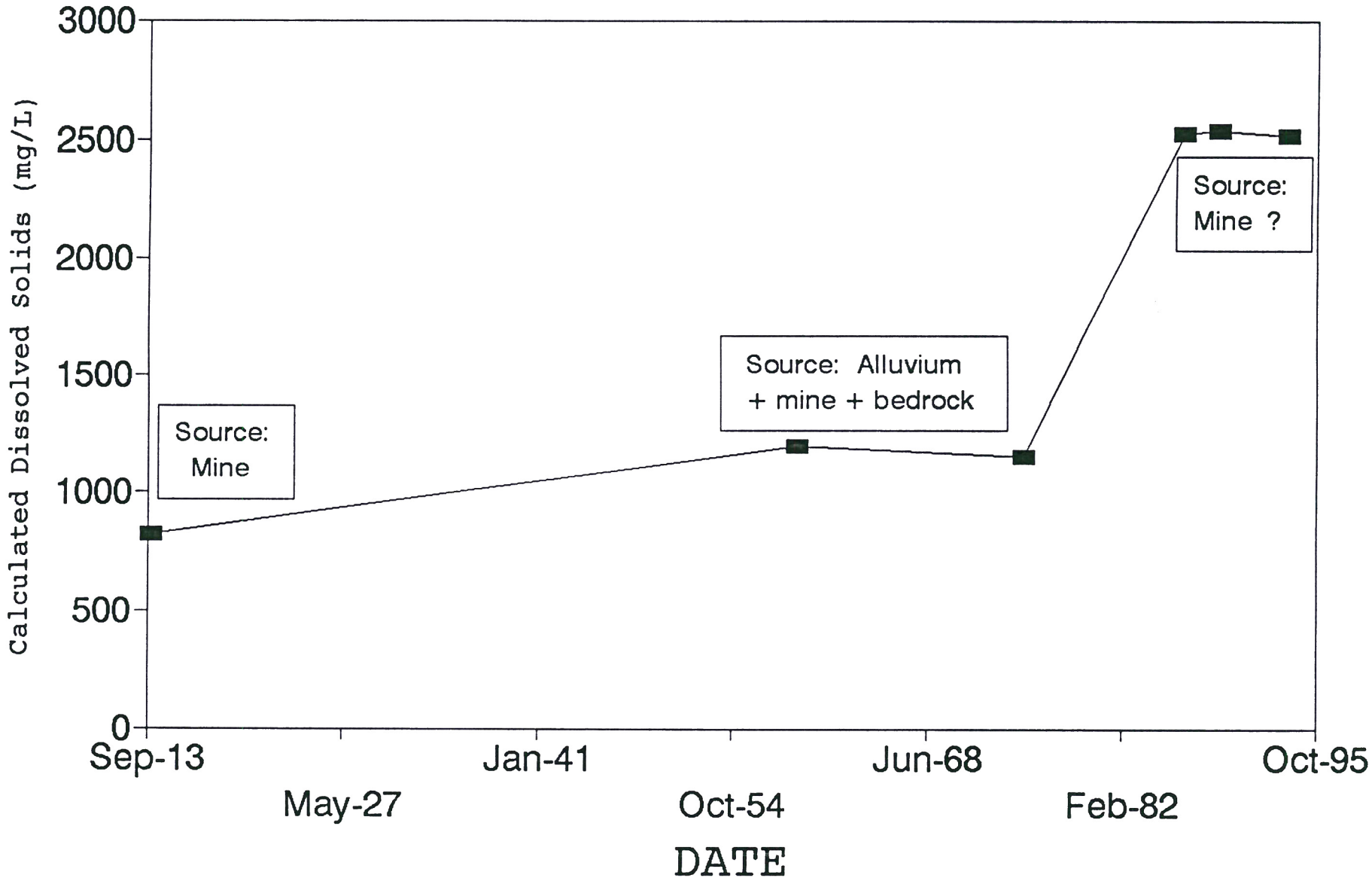

Figure 10. Dissolved solids concentrations for samples from the Republic No. 1 mine which is the Roundup city water supply source.

Meinzer, 1924). The samples collected in 1959 and 1975 likely represent a mixture of mine water, alluvial water and possibly bedrock ground water. The samples after 1977 are more likely to represent water from the wells completed in the eastern portion of the Republic No. 1 mine (R-170). Future water quality in the Republic No. 1 mine cannot be accurately predicted, but it can be assumed that no improvement is in sight.

In order to document changes in water quality between R-170 (mine voids) and the city storage tank, specific conductance was measured at three points along the system. The data are listed in Appendix 5. No significant change was occurring in the quality of the water as it moved from the supply well in the No. 1 mine (R-170), to the infiltration gallery (R-147) and into the storage reservoir (R-172). Based on the lack of change in specific conductance and the small amount of drawdown at R-147, apparently very little or no alluvial water was being discharged to the supply system from the caisson.

Though alluvial water was probably not being mixed into the supply system at the caisson (R-147), there are indications that other mixing was occurring. The water discharged from the supply wells (R-170) was probably a combination of water from two sources. The water at the mine slope was lower in dissolved solids than the city supply water. Water in other mines near the Republic No. 1 was much higher in dissolved solids (Wheaton and Donato, 1992).

A chemical mass balance was performed in order to help determine if mixing is occurring, and if so, from what possible sources. Table 2 list the milliequivalents per liter (meq/L) for the water samples taken from the city supply, the mine slope and the adjacent Prescott mine. The major ion concentrations in the sample from the mine slope were subtracted from those in a sample from the supply water (R-147). The difference is a hypothetical analysis (referred to here as delta R-147 - R-171), which had a cation/anion balance of 0.08 percent, and an estimated dissolved-solids concentration of 1,840 mg/L. Since the ion balance is within acceptable limits for a water sample, the supply water may well be a mixture of water that is similar to the mine slope sample, plus water from one other source.

The relative concentrations of ions in the computed hypothetical sample (delta R-147 - R-171) are similar to the relative concentrations in a sample collected from the Prescott mine (R-154), although the Prescott mine water contains a much higher dissolved-solids concentration. On Table 2, the sample (identified as mixture R-154 + R-171) is a calculated concentration of ions based on mixing about 40 percent water from the Prescott mine with 60 percent water from the Republic No. 1 mine slope. The result is a synthesized water analysis with ion concentrations very similar to those measured in the sample from the city supply. The mass balance of Republic No. 1 slope water with Prescott mine water strongly indicates that the current city supply is a mixture of 60 percent and 40 percent respectively of the two sources.

Table 2. Milliequivalents per liter for selected samples near Roundup, Montana

Site No.	Date	Calculated Dissolved Solids (mg/L)	Calcium (meq/L)	Magnesium (meq/L)	Potasium (meq/L)	Sodium (meq/L)	Bicarbonate (meq/L)	Chloride (meq/L)	Sulfate (meq/L)	Cation Anion Balance (percent)
R-147	7/14/86	2520	10.58	9.63	0.15	19.79	8.82	0.67	29.98	0.85
R-171	12/17/93	695	4.34	5.6	0.2	3.26	9.16	0.28	3.56	1.51
R-154	7/10/89	5080	23.55	16.79	0.36	38.76	15.62	0.76	62.46	0.39
DELTA R-147 - R-171	N/A	1840	6.24	4.11	0	16.53	0	0.39	26.44	0.08
MIXTURE R-154 + R-171	N/A	2520	12.33	10.29	0.28	18.05	11.83	0.48	28.07	0.70

Comments: Delta R-147 - R-171 is the calculated difference between the city supply and the mine slope water quality. Mixture R-154 + R171 is a theoritical mixture containing 41.6% water from R-154 and 58.4% water from R-171.

Drawdown at the city supply wells may induce flow from the western area of the Republic No. 1 mine and flow from the Prescott mine or another ground-water source with a similar chemical make--up. Water levels were continuously recorded at all mines in the area during the earlier underground-mine water project, and city pumping related drawdown was not identified except at the Republic No. 1 mine (Wheaton and Donato, 1992). However, storage capacity in the larger mines such as the Prescott is very large. Probably more than 5,000 acre-feet of water are in storage in the Prescott and Roundup No. 3, which are hydraulically connected. Drawdown due to the city pumping 1 acre-foot (325,000 gal) of water per day from the Republic No. 1 mine would be too small to measure in the large mines.

DISCUSSION

The city of Roundup is looking at local water resources for a new water supply. The choices are: 1) drill to a deeper aquifer; 2) develop a horizontal collector system or series of vertical wells in the alluvium; 3) treat the water from the existing source (Republic No. 1 mine) for CDS, iron and/or manganese; 4) investigate the possibility of withdrawing water from a different portion of the Republic No. 1 mine; 5) withdraw water from the Jeffrey mine voids; or 6) treat surface water from the Musselshell River.

The deeper aquifers in the area of Roundup are expected to have very low potential yields or have very high dissolved solids contents. The alluvium may be capable of yielding several hundred gallons per minute, but the water quality would be expected to vary seasonally, and be very poor at times. The future water quality in the existing supply cannot be predicted. Removal of the dissolved solids load in the current supply would produce as much as 1,700 tons per year of salts for disposal. The western area of the Republic No. 1 mine may be a better source of water than the current supply. The Jeffrey mine is hydrologically connected to several private water wells. Also, it would require a pipeline across the river to supply water for the city. The Musselshell River could provide a supply source, with proper treating facilities.

Several water resources could be developed, providing a diversified supply. Water could be withdrawn from the alluvium, from the Jeffrey mine and could be mixed with water from the two areas of Republic No. 1 mine.

A test well in the western portion of the Republic No. 1 mine would provide data for the possibility of producing a large amount of water from that area. A suggested site for a test well would be in the small valley located southwest of the mine slope, and is marked on Figure 1 with a triangle. The most favorable location for a test well appears to be in Township 8 North, Range 25 East, Section 24, in tract BAD. Field reconnaissance and surveying would be required to verify the location. A cross-section through this

site is shown on Figure 11. To the south, the ground surface rises away from the river, and the depth to the coal bed and mine voids increases. The estimated depth of a well at the location shown on the figure is 170 feet and the static water level is estimated to be about 70 feet below ground surface.

Several water resources exist in the Roundup area. None of the sources are likely to produce large volumes of high quality water. However, several sources, or combination of sources could be expected to provide a more dependable supply of higher quality water than that currently in use.

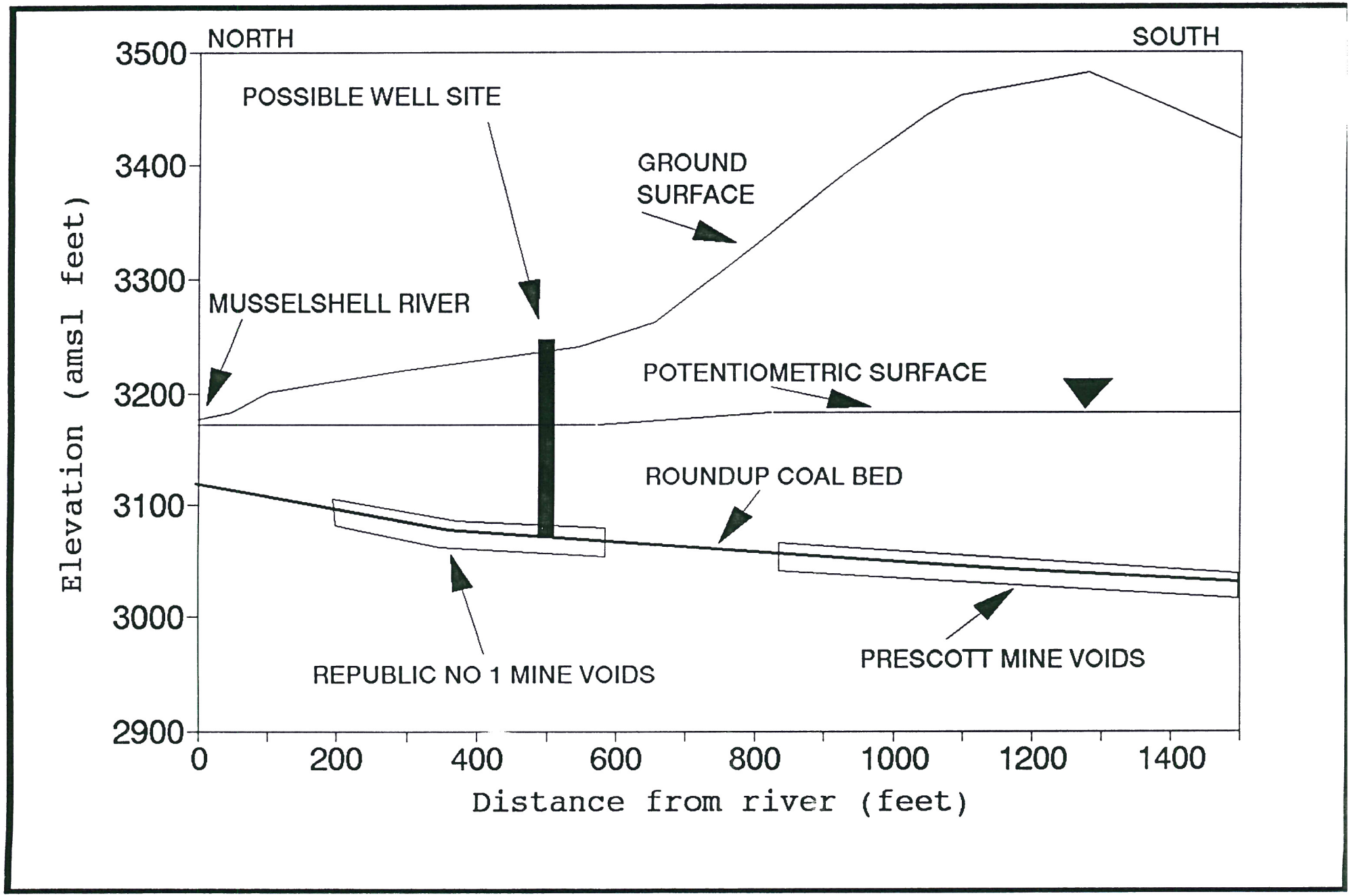

Figure 11. Cross-section showing relationship between ground surface, Roundup coal bed and a posible location for a test well in Township 8 North, Range 25 East, Section 24 BAAD.

REFERENCES

Ellis, A.J., Meinzer, O.E., 1924, Ground water in Musselshell and Golden Valley counties Montana: US Geological Survey Water Supply Paper 518, 92 p.

Emery, P. A., 1966, Use of analog model to predict streamflow depletion, Big and Little Blue River Basin, Nebraska: Ground Water, Vol 4, No. 4, p 13-19.

Fetter, C.W., 1980, Applied Hydrogeology: Charles E. Merrill Publishing Company, Columbus, 488 p.

Freeze, R. Allan and Cherry John A., 1979, Groundwater: Prentice-Hall, Inc., Englewood Cliffs, NJ, 604 p.

Levings, Gary W., 1982, Potentiometric-surface map of water in the Eagle Sandstone and equivalent units in the Northern Great Plains area of Montana: US Geological Survey Open-File Report 82-565, 1 sheet.

Noble, Roger A., Bergantino, R. N., Patton, T. W., Sholes, B., Daniel, F. and Scholfield, J., 1982, Occurrence and characteristics of ground water in Montana, Vol I: Montana Bureau of Mines and Geology, MBMG Open-File Report 99, 82 p.

Reiten, J.C., and Wheaton, J.R., 1988, Hydrogeological reconnaissance of abandoned underground coal mines and the adjacent area near Roundup, Montana: Montana Bureau of Mines and Geology Open-File Report MBMG 211, 98 p.

Rice, Dudley D., 1976, Stratigraphic sections from well logs and outcrops of Cretaceous and Paleocene rocks, Northern Great Plains, Montana: US Geological Survey, Oil and Gas Investigations Chart OC-71.

U. S. Geological Survey, 1993, Water resources data, Montana (Water Year 1992): U. S. Geological Survey Water Data Report MT-92-1, 534 p.

Wheaton, John and Donato, Teresa, 1992, Hydrologic data from the Roundup and Bull Mountains areas, Montana: Montana Bureau of Mines and Geology, MBMG Open-File Report 243, 254 p.

Wheaton, John, 1992, Hydrologic assessment of abandoned coal mines in the Bull Mountains near Roundup, Montana: Montana Bureau of Mines and Geology, MBMG Memoir 63, 29 p.

Woolsey, L., Richards, R. W., and Lupton, C. T., 1917, The Bull Mountains coal field, Musselshell and Yellowstone counties, Montana: US Geological Survey Bulletin 647, 218 p.

Appendix 1. Thickness of saturated gravel in monitor wells and boreholes along the Musselshell River.

Site Number	Total Gravel (feet)	Saturated Gravel (feet)	Depth to Bedrock (feet)
R-135	10	6	19
R-136	17	6	25
R-137	5	4	15
R-138	8	4	18
R-139	6	3	11
R-140	9	8	19
R-141	12	11	19
R-142	9	7	14
R-143	9	1	19
RW-1	8	3	15
RW-2	19	19	27
RW-3	7	7	23
RW-4	4	4	19
RW-5	4	4	16
RW-6	1	1	19
RW-7	2	2	20
RW-8	11	6	17
RW-9	9	9	19
RW-10	14	9	21
RW-11	5	5	20
RW-12	10	10	20
RW-13	1	1	21
RW-14	4	4	20
RW-15	21	14	24

Appendix 2

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 24 Tract: BACA Hole name or Number RW-1

Hole location: _____

Recorded by: JW Date hole Started: 09/22/93 Date hole Completed: 09/22/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 17.5 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 12 ft based on water on stem

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DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	7.5	Sand, very fine grained, silty, tan.
7.5	15.5	Gravel, cobbles to 2", well rounded, crystalline.
15.5	17.5	Bedrock, hard drilling, no returns.

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 24 Tract: BADC Hole name or Number RW-2

Hole location: 50 feet due west of city pump house south end.

Recorded by: JW Date hole Started: 09/22/93 Date hole Completed: 09/22/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 28 Well diameter: Casing diameter(s) and length (s): Elevation:

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened:

Has well been test pumped?: Were material samples taken?: Was a water sample taken?:

Remarks: Plugged and abandoned. SWL = approx. 8 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Sandy loam, tan, silty.
1	4	Sand and gravel with debris such as bricks and coal fines.
4	8	Sand, tan, very fine grained, silty with occasional thin lenses of gravel (up to 1", well round clasts)
8	27	Gravel and sand, poor sorting, medium-grained to 2" cobbles, water at 8 feet, sand grains are mostly quartz, cobbles are crystalline.
27	28	Bedrock, shale, medium gray, silty

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 24 Tract: BDAB Hole name or Number RW-3

Hole location: _____

Recorded by: JW Date hole Started: 09/23/93 Date hole Completed: 09/23/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 25 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 6 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	8	Sand, fine grained, tan, silty, clayey.
8	18	Sand with gravel lenses.
18	23	Gravel, sandy.
23	25	Bedrock, shale, medium gray, silty.

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 24 Tract: ABCA Hole name or Number RW-4

Hole location: _____

Recorded by: JW Date hole Started: 09/22/93 Date hole Completed: 09/22/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 19.5 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 8 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	15	Sand, silty, clayey, tan, fine grained.
15	19	Gravel, no returns.
19	19.5	Bedrock, sandstone, gray, fine grained, clayey.

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 23 Tract: CBBA Hole name or Number RW-5

Hole location: _____

Recorded by: JW Date hole Started: 09/22/93 Date hole Completed: 09/22/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 17 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL > 5 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	2	Sandy loam, fine sand, tan.
2	11.5	Sand, very fine grained, brown, very silty and clay filled.
11.5	16	Gravel, up to 1".
16	17	Bedrock, no returns, hard drilling.

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 23 Tract: CBBD Hole name or Number RW-6

Hole location:

Recorded by: JW Date hole Started: 09/22/93 Date hole Completed: 09/22/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 23 Well diameter: Casing diameter(s) and length (s): Elevation:

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened:

Has well been test pumped?: Were material samples taken?: Was a water sample taken?:

Remarks: Plugged and abandoned. SWL = approx. 10 ft.

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	18	Sand, brown, very fine grained, silty and clayey.
18	19	Gravel, up to 1" cobbles.
19	23	Bedrock, shale, gray and green-gray, silty.

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 23 Tract: CBDD Hole name or Number RW-7

Hole location: _____

Recorded by: JW Date hole Started: 09/22/93 Date hole Completed: 09/22/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 23 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 7 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	18	Sand, tan, very fine to fine grained, very clean, silty with depth, water at 7 or 8 ft.
18	20	Gravel.
20	23	Bedrock, no returns, hard drilling.

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 24 Tract: AACA Hole name or Number RW-8

Hole location: _____

Recorded by: JW Date hole Started: 09/22/93 Date hole Completed: 09/22/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 17.5 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 11 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	6.5	Sand, fine grained, silty, clayey
6.5	17	Gravel, up to 2 " cobbles.
17	17.5	Bedrock, no returns, hard drilling.

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 24 Tract: AAAD Hole name or Number RW-9

Hole location: _____

Recorded by: JW Date hole Started: 09/22/93 Date hole Completed: 09/22/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 19.5 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 8.5 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	10	Sand, tan, with some gravel.
10	19	Gravel, up to 1-1/2 " cobbles.
19	19.5	Bedrock, shale, gray, silty.

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 13 Tract: DDCC Hole name or Number RW-10

Hole location: _____

Recorded by: JW Date hole Started: 09/23/93 Date hole Completed: 09/23/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 23 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 12 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Railroad grade, gravel, coal fines.
1	7	Sand, tan, very fine grained, silty.
7	21	Gravel, cobbles up to 1-1/2".
21	23	Bedrock, clay, light gray, silty.

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 13 Tract: DDCA Hole name or Number RW-11

Hole location:

Recorded by: JW Date hole Started: 09/23/93 Date hole Completed: 09/23/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 26.5 Well diameter: Casing diameter(s) and length (s): Elevation:

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened:

Has well been test pumped?: Were material samples taken?: Was a water sample taken?:

Remarks: Plugged and abandoned. SWL = approx. 11 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	5	Railroad bed fill, gravel and sand.
5	15	Sand, tan, very fine grained, silty, some gravel lenses, less than 1 ft. Water at about 11 ft.
15	20	Gravel.
20	25	Bedrock? Drilled fairly hard, smooth. No returns.
25	26.5	Bedrock, gray silty clay.

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 13 Tract: DDBC Hole name or Number RW-12

Hole location: _____

Recorded by: JW Date hole Started: 09/23/93 Date hole Completed: 09/23/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 21 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 10 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	10	Sand, tan, silty.
10	20	Sand and gravel lenses.
20	21	Bedrock, no returns, hard drilling.

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 24 Tract: ABBA Hole name or Number RW-13

Hole location: _____

Recorded by: JW Date hole Started: 09/23/93 Date hole Completed: 09/23/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 22 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 10 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Railroad bed fill.
1	13	Sand, fine grained, tan, clean.
13	14	Gravel, up to 1".
14	21	Sand, tan, silty, clayey.
21	22	Bedrock, clay, silty gray.

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 24 Tract: BBDD Hole name or Number RW-14

Hole location: _____

Recorded by: JW Date hole Started: 09/23/93 Date hole Completed: 09/23/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 24 Well diameter: _____ Casing diameter(s) and length (s): _____ Elevation: _____

Type of casing(s): _____ Weight or gage of casing: _____ Method-perforated or screened: _____

Interval-perforated or screened: _____

Has well been test pumped?: _____ Were material samples taken?: _____ Was a water sample taken?: _____

Remarks: Plugged and abandoned. SWL = approx. 10 ft.

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil, sand, loam, tan.
1	16.5	Sand, fine grained, tan, clean, gravel lense, 4-5 ft, and below 10 ft.
16.5	20	Gravel, up to 1-1/2" cobbles, with clean sand.
20	24	Bedrock clay, light gray, silty.

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 24 Tract: BBDA Hole name or Number RW-15

Hole location:

Recorded by: JW Date hole Started: 09/23/93 Date hole Completed: 09/23/93 Driller: J. FELDMAN Drilling Company MBMG

Total well depth (ft) 25 Well diameter: Casing diameter(s) and length (s): Elevation:

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened:

Has well been test pumped?: Were material samples taken?: Was a water sample taken?:

Remarks: Plugged and abandoned. SWL = approx. 7.5 ft

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	3	Fill material, clinker, sand, coal fines.
3	8	Gravel, cobbles up to 2", maybe fill.
8	15	Sand and gravel.
15	24	Gravel.
24	25	Bedrock, clay, gray.

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 26 Tract: DCDD01 Hole name R-132 or Number RU-05 (065000132)

Hole location: West of Gibbtown next to creek Lat = 46°24'43" Long = 108°33'14"

Recorded by: JR Date hole Comp.: 10/06/87 Date hole Started: 10/06/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 8 Well diameter: 2" Casing diameter(s) and length (s): 5'2" 5' screen 2' PVC out of ground

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 3-8 2" #20 slot PVC

Has well been test pumped?: Were material samples taken? Was a water sample taken?:

Remarks: Right next to creek, drilled with solid stem auger, surface bentonite seal

Elevation = 3250 est 3251.8 MP elevation MP = 1.80

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; dark brown, sandy
1	3	Fine sand; brownish gray, silty, wet
3	8	Fine to coarse sand; brownish gray, slightly silty, a few gravel fragments, poorly sorted

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 8N R. 25E Sec. 26 Tract: BDCB01 Hole name R-133 or Number RU-06 (065000133)

Hole location: By creek NW of cemetery behind Marsh residence Lat = 46°25'12" Long = 108°33'48"

Recorded by: JR Date hole Started: 10/06/87 Date hole Comp.: 10/06/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 13 Well diameter: 2" Casing diameter(s) and length (s):

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 8-13' 2" #20 slot PVC

Has well been test pumped?: Were material samples taken? Was a water sample taken?:

Remarks: Drilled with solid stem auger; surface bentonite seal, gravel packs

Elevation = 3230 est. 3231.70 MP elevation MP = 1.70

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; dark brown, sandy
1	5	Very fine to fine sand; grayish brown, silty, saturated below 3 feet
5	10	Fine sand; grayish brown, silty - Interbedded with - silt; gray sandy, moderately cohesive, thinly bedded
10	13	Silt; gray, sandy, moderately cohesive, thinly bedded

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 08N R. 25E Sec. 26 Tract: BBCC01 Hole name R-134 or Number RU-07 (065000134)

Hole location: On Paul Thayers land, near garden, above Halfbreed Creek, Lat = 46°35'22" Long=108°34'05"

Recorded by: JR Date hole Started: 10/07/87 Date hole Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 22 Well diameter: 2" Casing diameter(s) and length (s): 2" PVC, 16'

Type of casing(s): Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: 13.5-18.5 2" #20 slot PVC screen

Has well been test pumped?: Were material samples taken? Was a water sample taken?:

Remarks: Bedrock at 22' drilled with solid stem auger, bentonite seal at surface

Elevation = 3220 est. 3222.05 MP elevation

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; gray brown, silty
1	7	Silt; pale brown to grayish brown, very fine sandy, soft, non-bedded
7	15	Very fine sand; grayish brown to gray, silty, slightly clayey, a few pebbles
15	22	Sandstone and gravel; silty, poorly sorted, wet
22		Sandstone or siltstone, very hard drilling, auger would not penetrate

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

Hole name R-135
County: Musselshell Location: T. 8N R. 25E Sec. 27 Tract: BBAD01 or Number RU-08
(065000135)

Hole location: On land owned by Bruno Rhodegeiro, towards river from house Lat 46°25'28", Long 108°35'07"

Recorded by: JR Date hole Started: 10/07/87 Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 16 Well diameter: 2" PVC Casing diameter(s) and length (s): 13' of 2" PVC 2' MP

Type of casing(s): Plastic Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 11'-16', 2" #20 slot PVC screen

Has well been test pumped?: No Were material samples taken? No Was a water sample taken?: No

Remarks: Bedrock at 19 ft. drilled with solid stem auger, bentonite seal at surface
Elevation = 3212 est. 3214 MP elev. MP=2.00

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; light yellowish brown, silty
1	5	Silt; yellowish brown, very fine sandy
5	9	Very fine sand; yellowish brown, silty
9	19	Sand and gravel; silty, clayey, poorly sorted, coarsens with depth
19		Sandstone?; very hard drilling, bedrock

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 08N R. 25E Sec. 22 Tract: DDBD01 Hole name R-136 or Number RU-09 (065000136)

Hole location: Next to USGS gauging station Lat = 46°25'41" Long = 108°34'19"

Recorded by: JR Date hole Started: 10/07/87 Date hole Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 14.5' Well diameter: 2" Casing diameter(s) and length (s): 12' of 2" PVC

Type of casing(s): Plastic Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 9.5-14.5, 2" #20 slot screen

Has well been test pumped?: No Were material samples taken? No Was a water sample taken?: No

Remarks: Drilled to 25' hole collapsed could not set screen past 14.5 ft, used solid stem auger bentonite seal at surface, Elevation = 3200 est. 3202.04 MP elevation

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; grayish brown, sandy
1	5	Silt; pale brown to yellowish brown, sandy
5	8	Very fine to fine sand; yellowish brown, silty
8	25	Sand and gravel; silty, slightly clayey, poorly sorted

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 08N R. 25E Sec. 23 Tract: CABA01 Hole name or Number R-137 RU-10 (065000137)

Hole location: Near Musselshell River east of Lyle Stortz, Lat = 46°25'58", Long = 108°33'42"

Recorded by: JR Date hole Started: 10/07/87 Date hole Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 18 Well diameter: 2" PVC Casing diameter(s) and length (s): 15' of 2" PVC

Type of casing(s): Plastic Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI=13'-18', 5' of 2" " #20 slot screen

Has well been test pumped?: No Were material samples taken? No Was a water sample taken?: No

Remarks: Drilled with hollow stem auger, surface bentonite seal

Elevation = 3192 est. 3193.65 MP elevation MP = 1.65

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; pale brown, silty
1	6	Silt; pale yellow, very fine sandy, loose, dry
6	8	Very fine to fine sand; yellowish brown, silty
8	10	Very fine to fine sand; light olive grey
10	15	Sand and gravel; silty, poorly sorted
15	18	Very fine to fine sand; bluish gray, silty

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 08N R. 25E Sec. 23 Tract: BDAA01 Hole name R-138 or Number RU-11 (065000138)

Hole location: End of trail overlooking Musselshell River Lat = 46°26'09" Long=108°33'33"

Recorded by: JR Date hole Started: 10/07/87 Date hole Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 18 Well diameter: 2" PVC Casing diameter(s) and length (s): 15' of 2" PVC

Type of casing(s): Plastic Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI = 13'-18', 5' of 2" " #20 slot screen

Has well been test pumped?: No Were material samples taken? No Was a water sample taken?: No

Remarks: Drilled with hollow stem auger, surface bentonite seal

elevation = 3190 est. 3192.38 MP elevation MP = 2.38

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; grayish brown, silty
1	5	Silt; pale yellow, very fine sandy, loose, dry
5	8	Silt; grayish brown, very fine sandy
8	10	Silt; yellowish brown, sandy, interbedded with very fine sand; grayish brown, silty
10	18	Sand and gravel; silty, poorly sorted

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 08N R. 25E Sec. 23 Tract: BBCB01 Hole name or Number R-139 RU-12 (065000139)

Hole location: Above Musselshell River near Locker Plant, Lat = 46°26'18", Long = 108°32'50"

Recorded by: JR Date hole Started: 10/07/87 Date hole Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 11 Well diameter: 2" PVC Casing diameter(s) and length (s): 8' of 2" PVC

Type of casing(s): Plastic Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI=6'-11', 2" " #20 slot screen

Has well been test pumped?: Were material samples taken? Was a water sample taken?:

Remarks: Drilled with hollow stem auger, surface bentonite seal

Elevation = 3180 est. 3182.36 MP elevation MP = 2.36

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; dark grayish brown, silty
1	3	Silt; pale brown, sandy, loose
3	5	Silt; pale brown, sandy, pebbly
5	11	Sand and gravel; silty, poorly sorted, hard drilling
11		Sandstone?; hard drilling, auger could not penetrate

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 08N R. 25E Sec. 24 Tract: ABBD01 Hole name or Number R-140 RU-13 (065000140)

Hole location: West end of fairgrounds, near city well, Lat = 46°26'20", Long = 108°32'10"

Recorded by: JR Date hole Started: 10/07/87 Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 19 Well diameter: 2" PVC Casing diameter(s) and length (s): 16' of 2" PVC

Type of casing(s): Plastic Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI=14'-19', 2" " #20 slot screen

Has well been test pumped?: Were material samples taken? Was a water sample taken?:

Remarks: Drilled with hollow stem auger, surface bentonite seal

Elevation = 3180 est. 3181.30 MP elevation MP = 1.30

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; dark brown, silty
1	4	Silt; pale brown, sandy, loose
4	10	Silt; grayish brown, sandy, clayey, moist
10	19	Sand and gravel; silty, poorly sorted

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 08N R. 25E Sec. 24 Tract: ABBD01 Hole name R-141 or Number RU-14 (065000141)

Hole location: East of County Fairgrounds, NW side of bridge, Lat = 46°26'23", Long = 108°31'52"

Recorded by: JR Date hole Started: 10/07/87 Date hole Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 18 Well diameter: 2" PVC Casing diameter(s) and length (s): 15' of 2" PVC

Type of casing(s): Plastic Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI=13'-18', 2" #20 slot screen

Has well been test pumped?: No Were material samples taken? No Was a water sample taken?: No

Remarks: Drilled with hollow stem auger, surface bentonite seal

Elevation = 3175 est. 3177.15 MP elevation MP = 2.15

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; dark brown, silty
1	3	Silt; pale brown, sandy, loose
3	5	Silt; grayish brown, sandy, slightly clayey
5	7	clay; bluish gray, silty, slightly sandy
7	19	Sand and gravel; silty, poorly sorted

Appendix 2 (continued)

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 08N R. 26E Sec. 18 Tract: DABC01 Hole name or Number R-142 RU-15 (065000142)

Hole location: NE of Newton Bridge, Lat = 46°26'48", Long = 108°30'42"

Recorded by: JR Date hole Started: 10/07/87 Date hole Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 14 Well diameter: 2" PVC Casing diameter(s) and length (s): 10' of 2" PVC

Type of casing(s): Plastic Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI=9'-14', 2" #20 slot screen

Has well been test pumped?: No Were material samples taken? No Was a water sample taken?: No

Remarks: Drilled with hollow stem auger, surface bentonite seal

Elevation = 3168 est. 3170.35 MP elevation MP = 2.35

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; dark brown, silty
1	3	Silt; yellowish brown, sandy
3	5	Fine sand; brownish gray, silty
5	14	Sand and gravel; silty, poorly sorted

WELL LOG
MONTANA BUREAU OF MINES AND GEOLOGY
GROUND WATER DIVISION

County: Musselshell Location: T. 08N R. 26E Sec. 18 Tract: CACC01 Hole name R-143 or Number RU-16 (065000143)

Hole location: 1/4 mile upstream from Jeffries Mine Slope (pump site), Lat = 46°26'43", Long = 108°31'17"

Recorded by: JR Date hole Started: 10/07/87 Date hole Comp.: 10/07/87 Driller: F. Schmidt Drilling Company: MBMG

Total well depth (ft) 13 Well diameter: 2" PVC Casing diameter(s) and length (s): 10' of 2" PVC

Type of Casing(s): Plastic Weight or gage of casing: Method-perforated or screened:

Interval-perforated or screened: SI=3'-13', 2" #20 slot PVC screen

Has well been test pumped?: Were material samples taken? Was a water sample taken?:

Remarks: Drilled to 19', 6 feet collapsed, drilled with solid stem auger, surface bentonite seal

Elevation = 3172 est. 3174.60 MP elevation MP = 2.60

DRILLING LOG
Geological, drilling, and water conditions; remarks and sampling

From	To	
0	1	Topsoil; dark brown, silty
1	4	Coarse gravel
4	10	Silt; interbedded bluish gray and yellowish brown, sandy, clayey, finely bedded
10	19	Sand and gravel; silty, poorly sorted

Appendix 3. Water levels measured in the Republic No. 1 mine at the city supply well in response to pumping at about 1,200 gpm.

Date	Time (24-hour)	Depth to water (ft)	Pump status
10-21-93	1345		off
10-21-93	1615	21	off
10-22-93	0815	14	on
10-22-93	0945		on
10-22-93	0950	22.2	on
10-22-93	1045	40.3	on
10-22-93	1145	51.6	on
10-22-93	1250	58.4	on
10-22-93	1345	62.3	on
10-22-93	1415	63.8	on
10-22-93	1445	64.9	on
10-22-93	1450		off
10-22-93	1515	45.4	off
10-22-93	1600	31.4	off
10-22-93	1700	23.6	off

Q_{Total} = 339,000 gallons

Pump was off for 2 days

10-25-93	0750	14.0	on
10-25-93	0755	20.3	on
10-25-93	0900	41.8	on
10-25-93	1005	52.5	on
10-25-93	1110	59.4	on
10-25-93	1150	61.8	on
10-25-93	1300	65.1	on
10-25-93	1355	67.1	on
10-25-93	1500	68.7	on
10-25-93	1600	69.9	on
10-25-93	1605		off

APPENDIX 4

GW 4—Helena Independent Record

File No. 065 08N 25E 24AB

TRIPLICATE Musselshell

065

T. 8 N., R. 25 E. 24AB

County Musselshell

STATE OF MONTANA
ADMINISTRATOR OF GROUNDWATER CODE
OFFICE OF STATE ENGINEER

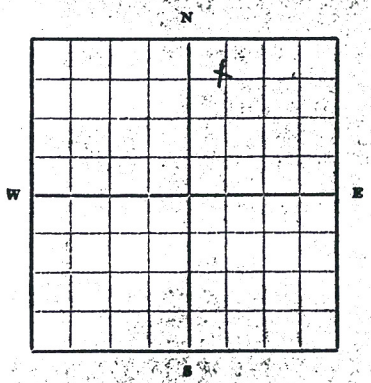
023030

RECEIVED
SEP. 6 1962
Montana Bureau of Mines and Geology

Declaration of Vested Groundwater Rights

(Under Chapter 237, Montana Session Laws, 1961)

1. City of Roundup, Montana (Name of Appropriator), of (Address) Roundup (Town), County of Musselshell, State of Montana have appropriated groundwater according to the Montana laws in effect prior to January 1, 1962, as follows:



NW ¼NE¼ Sec. 24 T. 8N. R. 25E

Indicate point of appropriation and place of use, if possible. Each small square represents 10 acres.

2. The beneficial use on which the claim is based: City water supply

3. Date or approximate date of earliest beneficial use; and how continuous the use has been: 1934 and continuously thereafter

4. The amount of groundwater claimed (in miner's inches or gallons per minute): 4,000 gal. per minute

5. If used for irrigation, give the acreage and description of the lands to which water has been applied and name of the owner thereof: Not applicable

6. The means of withdrawing such water from the ground and the location of each well or other means of withdrawal: Deep well and centrifical pump

7. The date of commencement and completion of the construction of the well, wells, or other works for withdrawal of groundwater: Commenced and completed in 1934. New pump added in 1954

8. The depth of water table: approximately 75'

9. So far as it may be available, the type, size and depth of each well or the general specifications of any other works for the withdrawal of groundwater: 90'. The well is drilled into the old Prescott No. 1 mine that has filled with water.

Note! Probably Republic No. 1 mine. Prescott is further south.

10. The estimated amount of groundwater withdrawn each year: 200 million gallons

11. The log of formations encountered in the drilling of each well if available: unknown

12. Such other information of a similar nature as may be useful in carrying out the policy of this act, including reference to book and page of any county record: not applicable

City of Roundup, Montana

Signature of Owner: By: John J. White, Mayor

Date: September 5, 1962

Three copies to be filed by the owner with the County Clerk and Recorder of the county in which the well is located.

Please answer all questions. If not applicable, so state, otherwise the form will be returned

T 8N R 25E
Section 24 AB
Probably one of the city wells of the pumphouse south of the river

APPENDIX 4 (cont.)

GW 4 — Approved Stock Form—State Publishing Co., Helena, Montana—38496

File No. Musselshell — 025 08N 25E 24 BA

T. 8 N. R. 25 E. — 24/E

County Musselshell

TRIPLICATE

STATE OF MONTANA
ADMINISTRATOR OF GROUNDWATER CODE
OFFICE OF STATE ENGINEER

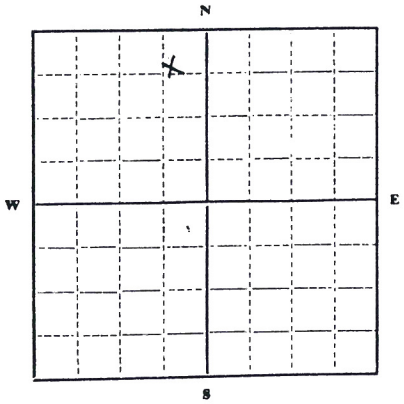
023031

Declaration of Vested Groundwater Rights

(Under Chapter 237, Montana Session Laws, 1961)

1. City of Roundup, Montana (Name of Appropriator) of (Address) Roundup (Town)

County of Musselshell State of Montana have appropriated groundwater according to the Montana laws in effect prior to January 1, 1962, as follows:



NE 1/4 NW 1/4 Sec. 24 T. 8N R. 25E

Indicate point of appropriation and place of use, if possible. Each small square represents 10 acres.

2. The beneficial use on which the claim is based City Water Supply

3. Date or approximate date of earliest beneficial use; and how continuous the use has been 1919 and continuously thereafter

4. The amount of groundwater claimed (in miner's inches or gallons per minute) 5,000 gal. per minute

5. If used for irrigation, give the acreage and description of the lands to which water has been applied and name of the owner thereof Not applicable

6. The means of withdrawing such water from the ground and the location of each well or other means of withdrawal Deep Well and centrifical pumps

7. The date of commencement and completion of the construction of the well, wells, or other works for withdrawal of groundwater Commenced and completed in 1919. Larger pump added 1947

8. The depth of water table 4 to 8 feet.

9. So far as it may be available, the type, size and depth of each well or the general specifications of any other works for the withdrawal of groundwater This well is approximate 40' and has drainage pipe to it from north, south, west and east.

10. The estimated amount of groundwater withdrawn each year 200 million gallons

11. The log of formations encountered in the drilling of each well if available unknown

12. Such other information of a similar nature as may be useful in carrying out the policy of this act, including reference to book and page of any county record not applicable

City of Roundup, Montana

Signature of Owner By: John J. White Mayor

Date September 5, 1962

Three copies to be filed by the owner with the County Clerk and Recorder of the county in which the well is located.

Please answer all questions. If not applicable, so state, otherwise the form will be returned.

T8N R25E Section 24 BA alluvium, north side of river; At, or near city pumphouse

APPENDIX 4 (cont.)

CODED

MONTANA BUREAU OF MINES AND GEOLOGY
WELL-DATA SHEET

COUNTY Musselshell T. 8 (N) or S R. 25 (E) or W SEC. 24 TRACT A

LAT. ° ' " N. LONG. ° ' " W. UTM N E

TOWN SUBDIVISION BLOCK

023029

OWNER'S NAME City of Roundup ADDRESS

PHONE NUMBER YEAR

ALT. LAND SURF. AT WELL MSL ft.
TOTAL DEPTH BELOW LSD 93 ft.
PUMPING LEVEL BELOW LSD ft.
STATIC WATER LEVEL* BELOW LSD ft.
YIELD IN GALLONS PER MIN.
HOW TESTED TIME (HR.)
IF F, SHUT-IN PRESS. IN PSI
GEOLOGICAL SOURCE OF H_2O

CASING DIA. 12¾ in. FROM 0 ft. TO 22 ft.
in. FROM ft. TO ft.
CASING TYPE 34 #
PERFORATED INTERVAL ft. TO ft.
ft. TO ft.
ft. TO ft.
PERFORATION DESC.
PUMP SIZE (HP.) TYPE
DATE WELL COMPLETED 1950
HOW DRILLED
BY WHOM LIC.
WELL USE
SOURCE OF INFO: WELL APPROP.
DRILLER OWNER USGS SCS ✓
OTHER:

HAS WELL LOCATION BEEN VERIFIED
BY WHOM AGENCY
DATE VERIFIED
MEAS. POINT ABOVE LSD ft. DATE
TOTAL DEPTH BELOW LSD ft.
PUMPING LEVEL BELOW LSD ft.
SWL* BELOW LSD ft.
YIELD IN GPM
WATER TEMP. °C
SPECIFIC COND. at 25 °C
MBMG FILE NUMBER
DNR FILE NUMBER
WELL FORM NUMBER
MBMG WQ LAB. NUMBER
SYS 2000 NUMBER
OTHER:

REMARKS: Casing — 22FT. - CEMENTED w/ 35 SACKS.

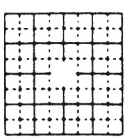
MUNICIPAL WELL.

*F = FLOWING

LITHOLOGIC LOG

INTERVAL (FT.) FROM	TO	DESCRIPTION
0	11	TOP SOIL
11	16	SAND & GRAVEL
16	32	GRAY SANDSTONE
32	38	GREEN SHALE - HARD
38	48	GRAY SANDSTONE
48	62	GRAY SANDY SHALE
62	68	COAL BED (Roundup bed)
68	69	GRAY SANDY SHALE
69	75	GRAY SANDSTONE
75	84	GREEN SHALE - DARK
84	93	GRAY SANDSTONE

SKETCH MAP



Probably one of the city wells at the pumphouse south of the river.

Form No. 603 (Rev. 7/76)

STATE OF MONTANA 8-25-5 File No. _____

Department of Natural Resources and Conservation

WELL LOG REPORT O8N 25E 24 BA

White-Department
Yellow-Department
Pink-Well Owner
Gold-Driller

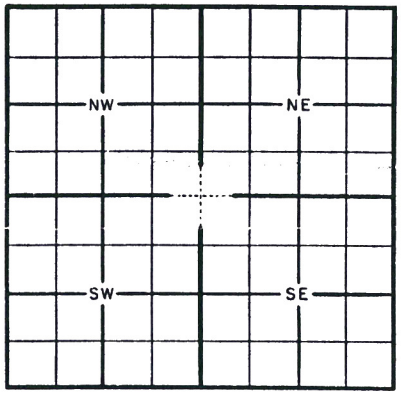
State law requires that this form be filed by the water well driller within 60 days after completion of the well, and Form 602, Notice of Completion of Groundwater Development, be filed by the well owner within 60 days after the water has been put to beneficial use.

1. WELL OWNER
Name City of Roundup

2. CURRENT MAILING ADDRESS
Roundup, Mont

3. PROPOSED USE _____ domestic (includes lawn and garden); _____ stock; X municipal; _____ industrial; _____ irrigation; _____ other (specify) _____

4. WELL LOCATION



NE ¼ NW ¼ ¼ ¼ Section 24
T. — 8 R. 25
N or S E or W
OR, Lot _____ Block _____
Subdivision _____
City Roundup County Musselshell
Elevation _____ Accuracy: __ ±10'; __ ±50'; __ ±100';

5. DRILLING METHOD _____ cable, _____ bored, X forward rotary, _____ reverse rotary, ___ jetted, _____ other (specify) _____

6. WELL CONSTRUCTION AND COMPLETION

Size of drilled hole	Size and weight of casing	From (feet)	To (feet)	Perforations _____ and/or Screen _____ Kind Size	From (feet)	To (feet)
24"	21" Cemented w/665 sks Cement	0	32	None By Howco		
16"	12" 40# Cemented w/100 sks Cement	0	81	None By Howco		

Was casing left open end? X Yes, ___ No
Was a packer or seal used? ___ Yes, ___ No
If so, what material _____
Was the well gravel packed? ___ Yes, ___ No
Was the well grouted? X Yes, ___ No
To what depth? 81 ft
Material used in grouting Cement
Well head completion: Pitless adapter _____
12 in. above grade X, other _____
(if other, specify) _____
Pump horsepower 100, pump type _____
Pump intake level _____ feet below land surface
Power (electric, diesel, etc.) Elec

7. WATER LEVEL
Static water level 28 feet below land surface
If flowing, closed-in pressure _____ psi
_____ gpm flow through _____ inch pipe
Controlled by: ___ valve, ___ reducers, ___ other
(if other, specify) _____

8. WELL TEST DATA ___ pump ___ bailer ___ other
(if other, specify) Drilled into Mine
Pumping level below land surface:
28 ft. after ___ hrs. pumping 1000 gpm
___ ft. after ___ hrs. pumping ___ gpm

9. WAS WELL PLUGGED OR ABANDONED? ___ Yes X No
If yes, how? _____

10. DATE STARTED August 23, 1977
DATE COMPLETED Sept 2, 1977
Encounter 12" Casing Oct 4, 1977
Drilled out 15' Plug of Mine

11. WELL LOG

Depth (ft.) From	To	Formation
0	10	Topsoil Brown Sandy Soil
10	14	Gravel
14	17	Sandy Bentonite
17	21	Sand
21	29	Blue gray Shale
29	30	Hard gray Sand
30	35	Blue gray Shale
35	36	Hard gray Sand
36	40	Blue gray Shale
40	42	Dirty Coal & Bent
42	50	Blue gray Shale & Bentonite
50	51	Sand (65%)
51	60	Blue gray Shale
60	62	Coal
62	69	Blue gray Shale & Bentonite
69	71	Hard Sand (40%)
71	95	Blue gray Shale
	T.D.	
Top of Mine = 95 ft w/ 10 ft OE		
Mine open = 105 ft in Depth		

(use separate sheet if necessary)

12. DRILLER'S CERTIFICATION
This well was drilled under my jurisdiction and this report is true to the best of my knowledge.
Oct 29, 1977
Date
Merlin E Hunt
Signature License No.
Firm name
Address

Appendix 5. Specific conductance measurements made on December 22, 1993 at points along the city supply system.

R-170 Pump house on the south side of the river

Time (24-hour)	Specific Conductance (umhos/cm)	Temp (C)	Pump status	Discharge gauge (gpm)	Depth to water reading (feet)
1000			off	0	
1001			on		
1003	3,000	10	on	1,250	No access
1008	3,000	10	on	1,250	
1013	3,010	10	on	1,250	
1018	3,010	10	on	1,250	
1023	3,010	10	on	1,250	
1028	3,020	10	on	1,250	
1033	3,020	10	on	1,250	
1106	3,150	9	on	1,250	
1219	3,250	8	on	1,250	
1325	3,150	10	on	1,225	
1450	3,150	11	on	1,175	
1505			off		

R-147 Pump house on north side of the river

Time (24-hour)	Specific Conductance (umhos/cm)	Temp (C)	Pump status	Discharge gauge (gpm)	Depth to water reading (feet)
0955	3,050	10	off	0	11.98
1001			on	1,250	
1003	3,150	10	on	1,250	10.96
1007			on	1,250	12.12
1011	3,100	10	on	1,250	12.14
1017	3,050	10	on	1,250	12.25
1022	3,050	10	on	1,225	12.22
1026	3,050	10	on	1,225	12.24
1032	3,050	10	on	1,225	12.26
1136	3,050	10	on	1,200	12.28
1057	3,050	10	on	1,200	12.38
1230	3,100	9	on	1,200	12.66
1338	3,100	10	on	1,200	12.78
1500	3,150	10	on	1,200	12.89
1505			off	0	

Appendix 5. Specific conductance measurements made on December 22, 1993 at points along the city supply system (continued).

R-171 Republic No. 1 mine slope

Time (24-hour)	Specific Conductance (umhos/cm)	Temp (C)	Pump status	Discharge gauge (gpm)	Depth to water reading (feet)
0945			off		0.35
1200	1,625	7	on		0.32
1445			on		0.28

R-172 Water storage tank north of town

Time (24-hour)	Specific Conductance (umhos/cm)	Temp (C)	Pump status	Discharge gauge (gpm)	Depth to water reading (feet)
1420	3,050	9	on		8