Cover page

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Agency Name: Montana Bureau of Mines and Geology

Title: Montana NGWMN

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Overview

The Framework for the National Ground-Water Monitoring Network (NGWMN) calls for the use and enhancement of existing Federal, State, and local groundwater monitoring programs (SOGW, 2013). The Montana Bureau of Mines and Geology (MBMG) maintains a statewide groundwater monitoring network that collects water-level and water-quality data from the state's principal aquifers and was one of six states that conducted pilot studies to assess the feasibility of the NGWMN concepts. The Montana pilot study investigated how best to include MBMG network wells into a NGWMN and designated approximately one third of Montana's 1,000 groundwater monitoring sites as potential NGWMN sites (Patton and Buckley, 2011). Following the pilot study, the U.S. Geological Survey (USGS) and the Subcommittee on Ground Water (SOGW) revised guidance for "selecting" and "classifying" national network wells. The USGS developed "Tip sheets" that incorporated the revisions/lessons learned from the pilot study (http://cida.usgs.gov/ngwmn/learnmore.jsp).

As an existing data provider, the MBMG received an award under Cooperative Agreement Number G15AC00254 to:

1. Finish classifying wells in the Montana network and to revisit the initial NGWMN well selections using the revised classification and subnetwork selection guidance.
2. Insure that water quality fields are available to the NGWMN portal.
3. Provide documentation of field procedures.
4. Update the NGWMN registry and update the connection between MBMG databases and the NGWMN using ESRI's GeoServer.

This report describes the work performed and results obtained during the grant period.

Description of existing networks

As part of the Ground Water Assessment Program (GWAP), the MBMG maintains a statewide groundwater monitoring program of approximately 1,000 sites (fig. 1). Montana's network design is based primarily on aquifer extents and the level of development as measured by production wells. Therefore, Montana's statewide monitoring spatially represents its geology and those areas where groundwater is heavily utilized. The primary objectives are to provide data regarding the current status and long-term trends in groundwater storage and quality. Water levels are measured at least quarterly. Groundwater samples are collected from each well every 7 to 10 years for major ion, trace metal, and nutrient analysis. Sample schedules/frequencies are dependent upon available funding.

Groundwater levels and samples are collected by MBMG field personnel who follow standardized field procedures consistent with the standards outlined in Appendix 5 of the Framework Document (SOGW, 2013); a copy of MBMG field procedures is included in Appendix I.

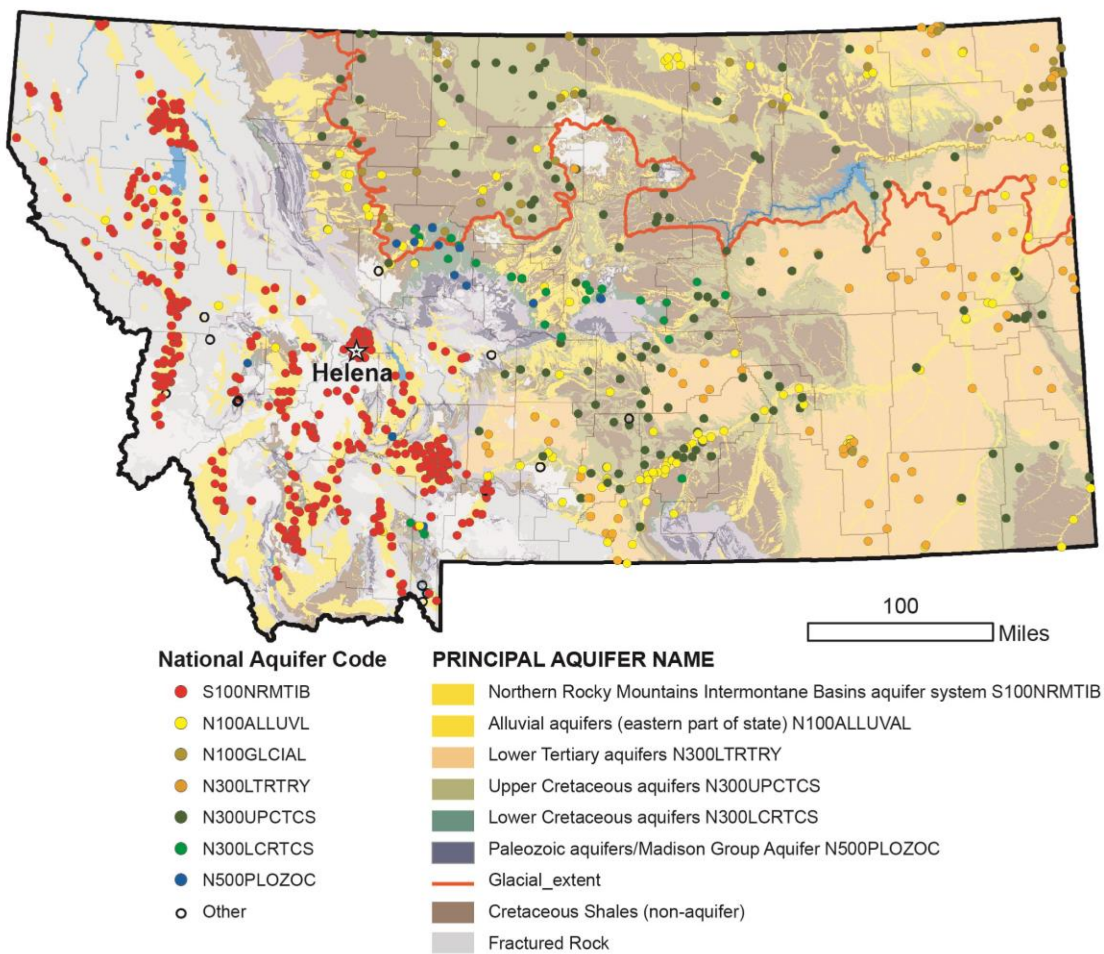


Figure 1. Distribution of Montana state-wide monitoring points and Principal aquifers.

Description of site selection criteria and process

The approximately 1,000 wells in the Montana network were reviewed to identify those that have a water-level record of at least 5 years and are completed in a principal aquifer. Then the water-level record and well settings were then evaluated to make a sub-network determination. Finally, the monitoring frequency was used to classify the sites as either trend or surveillance. This review and reclassification identified 227 wells (Appendix II) for inclusion in the NGWMN. The Framework document (SOGW, 2013) and “Tip Sheets” obtained from the National Ground Water Monitoring web page (http://cida.usgs.gov /ngwmn/learnmore.jsp) were used to guide the selection process.

Principal Aquifer review

The USGS defines a “Principal Aquifer” as a regionally extensive aquifer or aquifer system that has potential to be used a source of potable water across broad areas. Whitehead (1996) identified eight Principal Aquifers in Montana. However, the “Pacific Northwest volcanic rock aquifers” unit occurs only in a small area near Yellowstone National Park, is not a major aquifer in Montana, and is not included in the Montana Network. The Montana statewide network collects data from the other Principal Aquifers:

the heavily developed Intermontane Basins aquifers; and the less intensively developed, but widely used Alluvial, Lower Tertiary, Upper Cretaceous, Lower Cretaceous, and Paleozoic aquifers (Table 1).

Table 1 identifies the principal aquifers described in HA-370-I (Whitehead, 1996) that are monitored by Montana's statewide network.

National Aquifer/ System Name	National aquifer code	Montana comments	Typical Montana Aquifers (codes)*
Alluvial aquifers	N100ALLUVL	All non-glacial alluvial deposits not associated with intermontane basins. Includes Miocene/Pliocene aggradational sand and gravel aquifers important in northern Montana.	110ALVM, 110SNGR, 110TRRC, 111ALVM, 111SNGR, 111TRRC, 121FLXV and equivalents.
Sand and gravel aquifers (glacial regions)	N100GLCIAL	Includes sand and gravel deposits related to glaciations in northeastern Montana.	112SNGR, 112OTSH, 112TRRC, 112DRFT, 112GFLK, 112YTR3
Northern Rocky Mountains Intermontane Basins aquifer systems	S100NRMTIB	Includes Quaternary and Upper Tertiary basin-fill deposits and surrounding fractured rock aquifers associated with individual-basin flow systems. Includes glacial deposits in the Flathead, Mission, and Missoula valleys.	Codes ranging from 110, 111, 112 (ALVM, SNGR, etc.), 120 (SDMS, SNGR, etc.) to many differing bedrock codes for formations as old as Precambrian 400BELT.
Lower Tertiary aquifers	N300LTRTRY	The areas mapped in HA370-I generally correspond with Lower Tertiary aquifers important in Montana.	125FRUN, 125TGRV, 125LDLW, 125TLCK, 125LEBO, and codes specific to named coals.
Upper Cretaceous aquifers	N300UPCTCS	Includes important Upper Cretaceous sandstone aquifers in north-central Montana from areas outside those mapped in HA370-I. Most Upper Cretaceous aquifers within the mapped area are too far below land surface to be economically viable.	211CLRD, 211EGLE, 211VRGL, 211FXHL, 211HLCK, 211FHHC, 211LNCE, 211COGT, 211JDRV, 211TMDC
Lower Cretaceous aquifers	N300LCRTCS	Area mapped in HA370-I generally corresponds with Lower Cretaceous aquifers important in Montana.	217KOTN, 217FCCK, 217SCCK, 217TCCK, 221MRSN, 221SWFT
Paleozoic aquifers	N500PLOZOC	Area mapped in HA370-I generally corresponds with Paleozoic aquifers important in Montana.	330MDSN, 341JFRS

As part of the classification process the lithology, completion, water-level, and geologic setting for the 985 statewide network wells completed in the seven Principal Aquifers (fig. 1), were evaluated to determine if the aquifer was confined or unconfined.

Baseline review

A total of 856 Principal Aquifer wells had five or more years of water-level data and a monitoring frequency of at least quarterly. The NGWMN wells were selected from this set of wells. Final NGWMN candidates were selected from this group after considering the aquifer extent, groundwater development (indicated by the number of production wells), the groundwater flow system, and the monitoring well density.

The MBMG evaluated each well's hydrograph in conjunction with local hydrogeologic and land-use conditions to assign the candidate to the Background, Suspected Changes, or Documented Changes subnetworks. The hydrographs from most Montana network wells showed little or no anthropogenic effect and were assigned to the Background subnetwork. Hydrographs that showed known anthropogenic effects (assigned to the Documented Changes subnetwork) contained signals documenting:

1. Seasonal irrigation recharge—mostly in the irrigated intermontane basins and eastern alluvial aquifers.
2. Seasonal irrigation withdrawals—mostly in the irrigated intermontane basins and buried sand and gravel glacial aquifers.
3. Long-term depletion—locally in the Fox Hills-Hell Creek aquifer of the upper Cretaceous aquifer system in eastern Montana.

Because all Montana state-wide network wells are measured quarterly, they were all considered "Trend" sites. Table 2 summarizes the Montana NGWMN candidate wells by Principal Aquifer, a complete list of NGWMN Water-Level network wells is presented in Appendix II, a brief discussion is presented below.

Table 2. NGWMN water-level well summary

Aquifer	Trend	Surveillance	Background	Suspected Change	Documented Change
S100NRMTIB	109	0	83	0	26
N100ALLUVL	15	0	15	0	0
N100GLCIAL	9	0	8	0	1
N300LTRTRY	37	0	31	5	1
N300UPCTCS	46	0	44	0	2
N300LCRTCS	7	0	7	0	0
N500PLOZOC	4	0	4	0	0

Water-Level NGWMN Candidate wells

1) Northern Rocky Mountains Intermontane Basins aquifer systems

Montana's most-intense groundwater development is in its western intermontane basis where groundwater occurs in surficial alluvial aquifers and at depth within several thousand feet of Quaternary and Tertiary basin-fill sediments. These aquifers contain large amounts of groundwater, are highly productive, and heavily used. Many of the valleys are laced with thousands of miles of unlined irrigation ditches that convey water from main-stem streams to irrigated fields. Seepage from the canals is a significant source of groundwater recharge. The western basins are bounded by mountains composed of meta-sedimentary rocks (e.g. Belt Super Group and Precambrian gneiss and schist), intrusive rocks (e.g. Idaho and Boulder batholiths), and volcanic rocks (e.g. Lowland Creek, and Elkhorn Mountain Volcanics). All of these rocks are fractured and host less-productive aquifers.

Most of the NGWMN-wells (109) were selected from the intermontane basin aquifer systems (fig. 2 100NRMTIB); 83 wells were classified as "Background" and 26 were classified as "Documented Change." All are "Trend" wells, 81 are measured quarterly and 28 are equipped with pressure transducers that that log hourly water-level measurements (continuous monitoring).

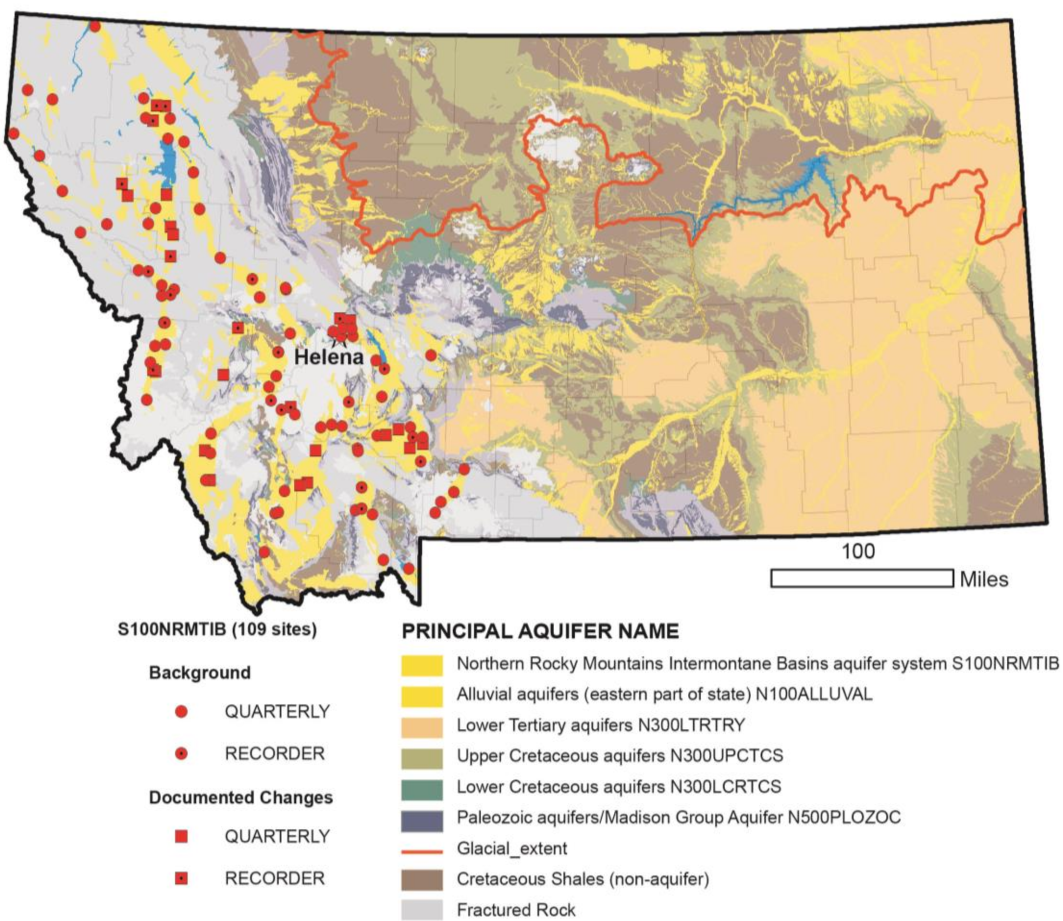


Figure 2. Proposed Northern Rocky Mountain Intermontane Basin aquifer system monitoring points.

2) Lower Tertiary aquifers

The sandstones and coal beds of lower Tertiary Fort Union formation are an important aquifer system in eastern Montana; 37 Fort Union wells were selected for the NGWMN. Most of the wells are classified as "Background." One well near current and reclaimed coal mining in the Powder River Basin is classified as "Known Changes" and 5 are classified as "Suspected Changes" (fig. 3). Three wells are monitored continuously with data loggers; the rest are measured quarterly.

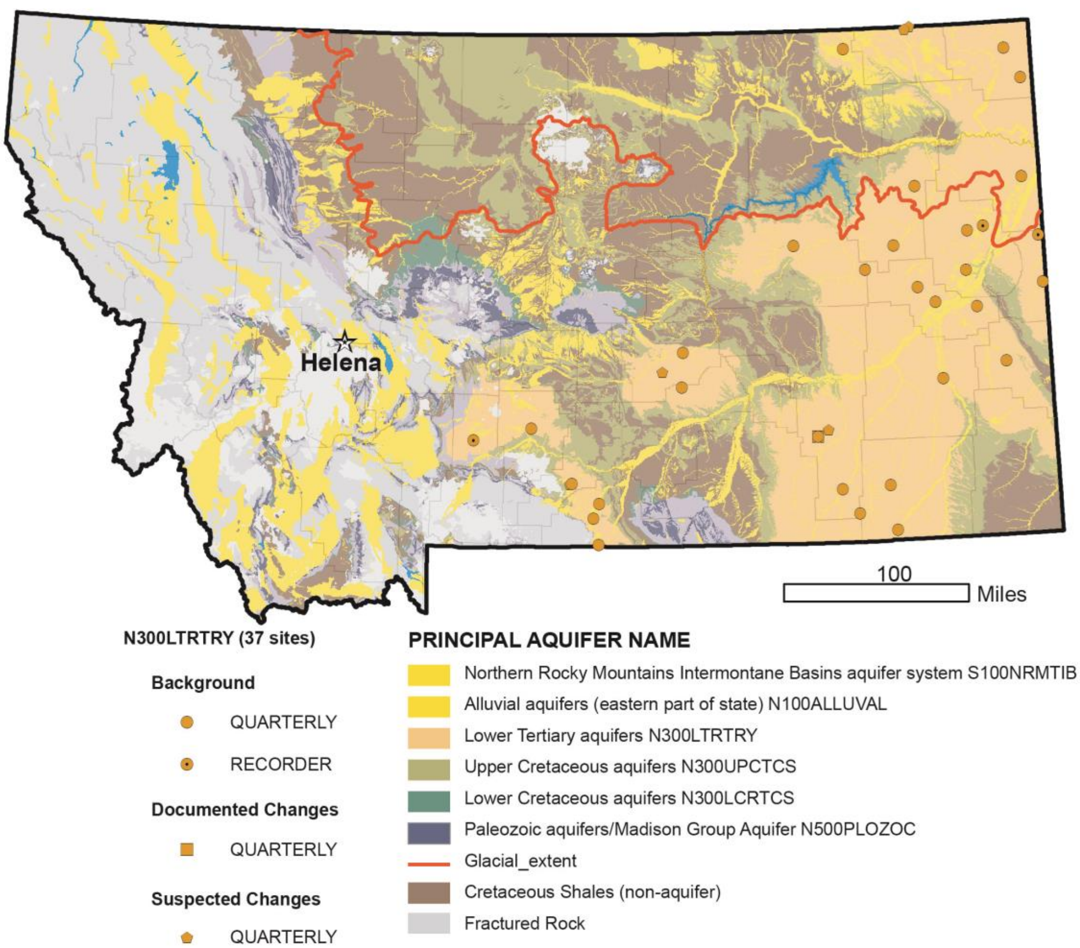


Figure 3. Proposed Lower Tertiary aquifer system monitoring points.

3) Upper Cretaceous aquifers

The upper Cretaceous aquifer system in Montana is made up of three different sandstones that vary in depth below land surface and that are separated by shale units: 1) sandstones in the lower part of the Hell Creek Formation and the Fox Hills Sandstone (The Fox Hills-Hell Creek aquifer), 2) sandstones in the Judith River Formation, and 3) the Eagle Sandstone. The upper Cretaceous aquifer system covers the eastern two-thirds of the state; 46 wells were selected for the NGWMN, 17 from the Fox Hills-Hell Creek aquifer, 15 from the Judith River aquifer, and 14 from the Eagle Sandstone (fig. 4). Two of the Fox Hill-

Hell Creek aquifer wells are monitoring "Known Changes" in the lower Yellowstone River valley where unrestricted flowing artesian wells are causing groundwater depletion (fig. 5). The remainder of the upper Cretaceous aquifer system wells are classified as "Background". The wells are measured quarterly except for one Fox Hills-Hell Creek well and one Eagle Sandstone well that are monitored continuously.

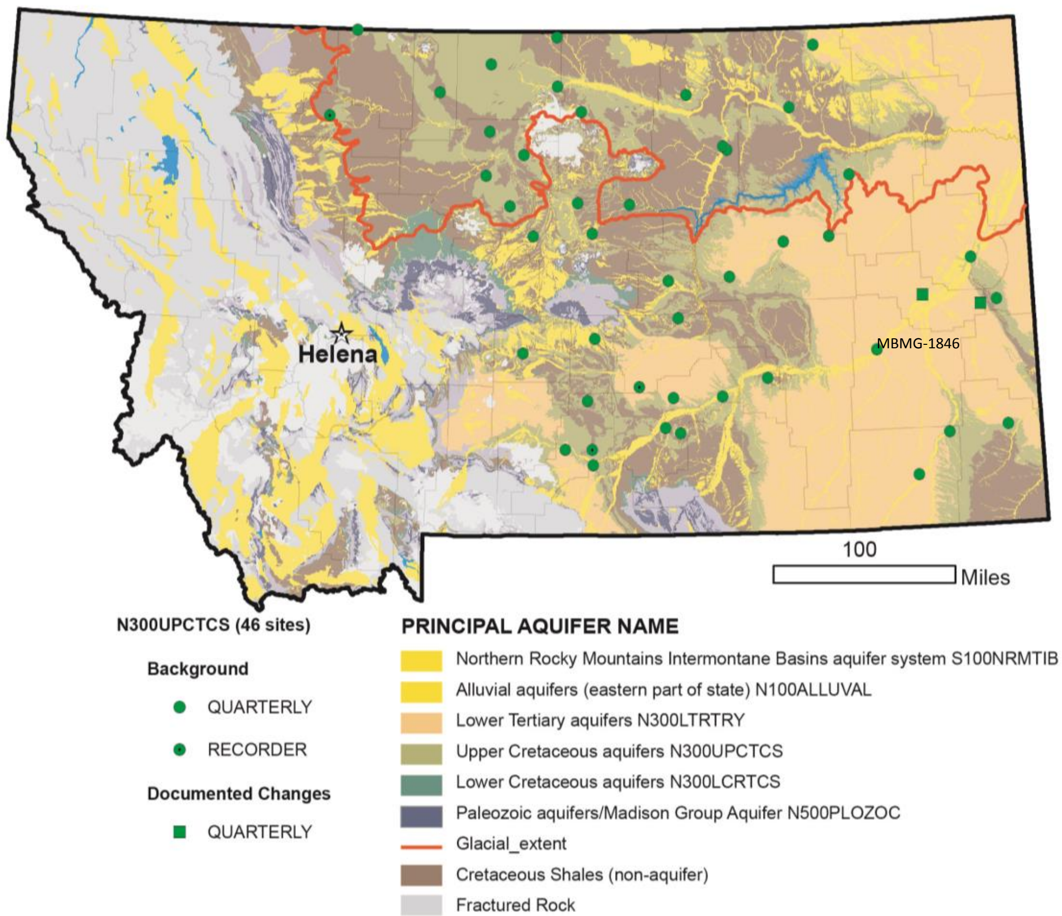
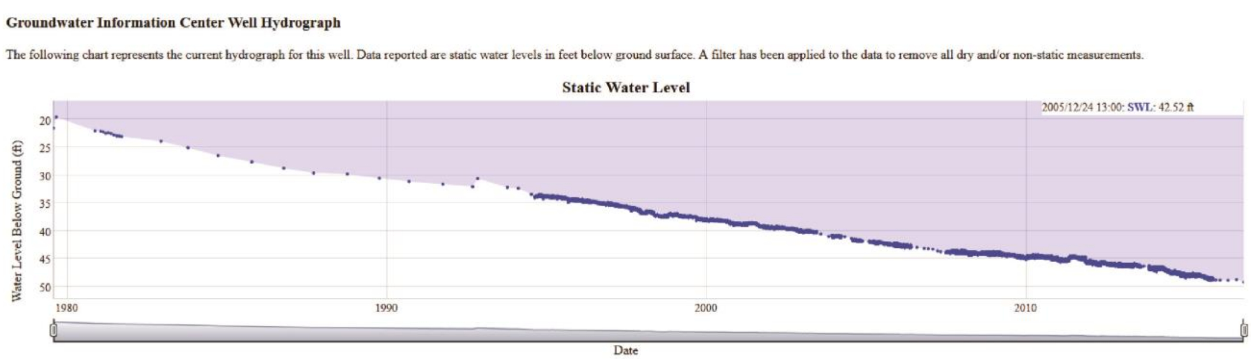


Figure 4. Proposed Upper Cretaceous aquifer system monitoring sites.



A. MBMG-1846 - Depletion response

Figure 5. Depletion response in Upper Cretaceous Fox Hill-Hell Creek aquifer.

4) Alluvial aquifers

The Alluvial aquifers are located in the major river valleys, and localized gravel terraces or “benches” in eastern part of the state. Fifteen wells were selected for the NGWMN, all are monitoring shallow unconfined aquifers (fig. 6). Five wells are monitoring “Documented Changes”, the other 10 are “Background” wells. The Documented Change wells are in aquifers used for seasonal irrigation withdrawals or that receive irrigation recharge (fig. 7). Ten of the wells are monitored continuously with data loggers, the other five are measured quarterly.

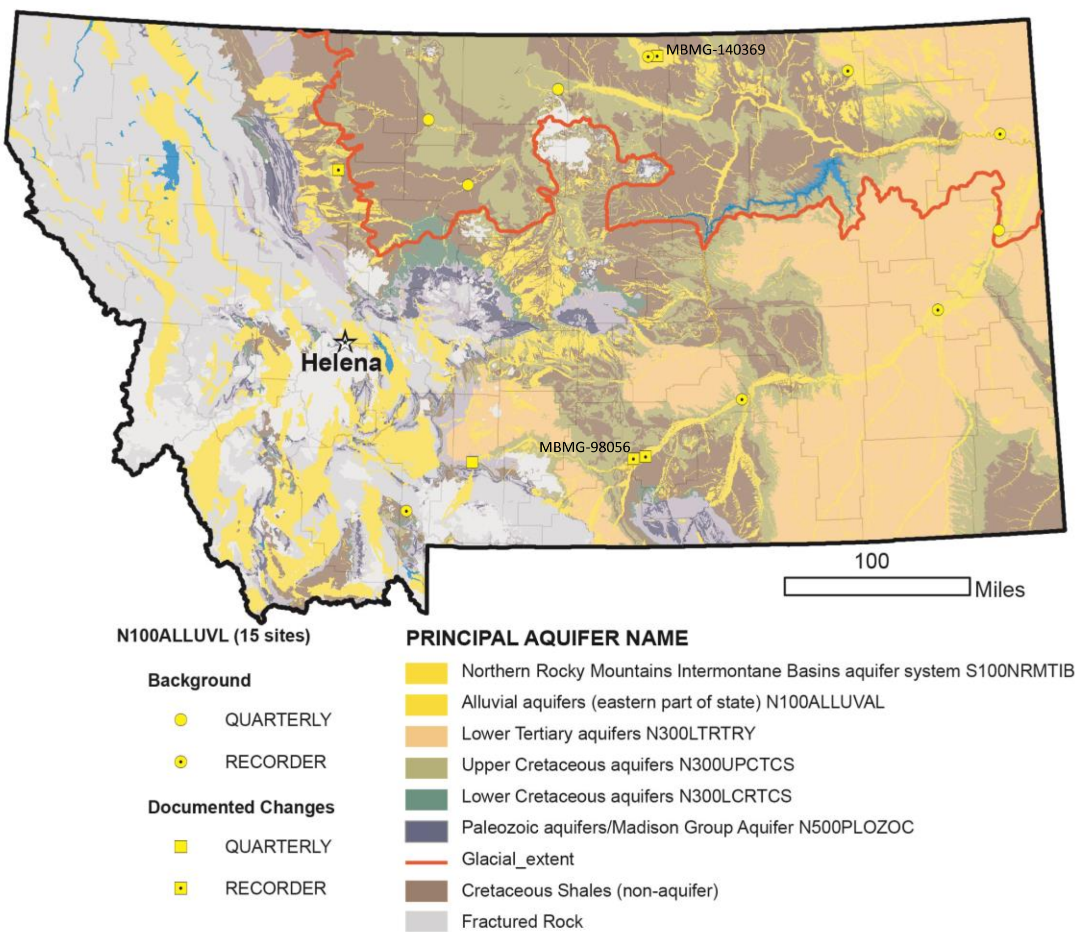
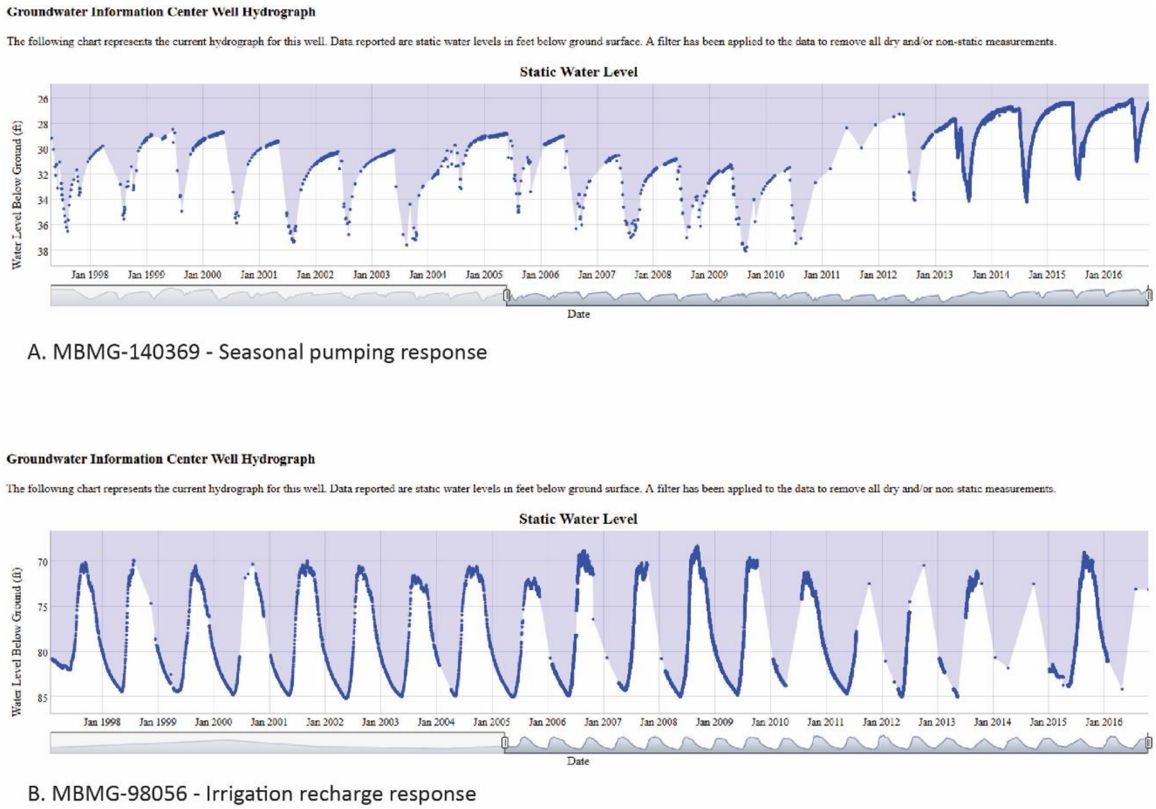


Figure 6. Proposed Alluvial aquifer system monitoring sites.



A. MBMG-140369 - Seasonal pumping response

B. MBMG-98056 - Irrigation recharge response

Figure 7. Hydrographs showing "Documented Changes" in alluvial aquifers.

5) Sand and gravel aquifers - glacial regions

Local buried-channel and outwash aquifers related to glacial deposition occur in north-central and northeastern Montana and are a source of irrigation and municipal water. Nine wells were selected for the NGWMN; two wells completed in the ancestral Missouri River channel in are monitoring “Known Changes” related to seasonal irrigation withdrawals and are equipped with data loggers (fig. 8). The others are “Background” wells and are measured quarterly.

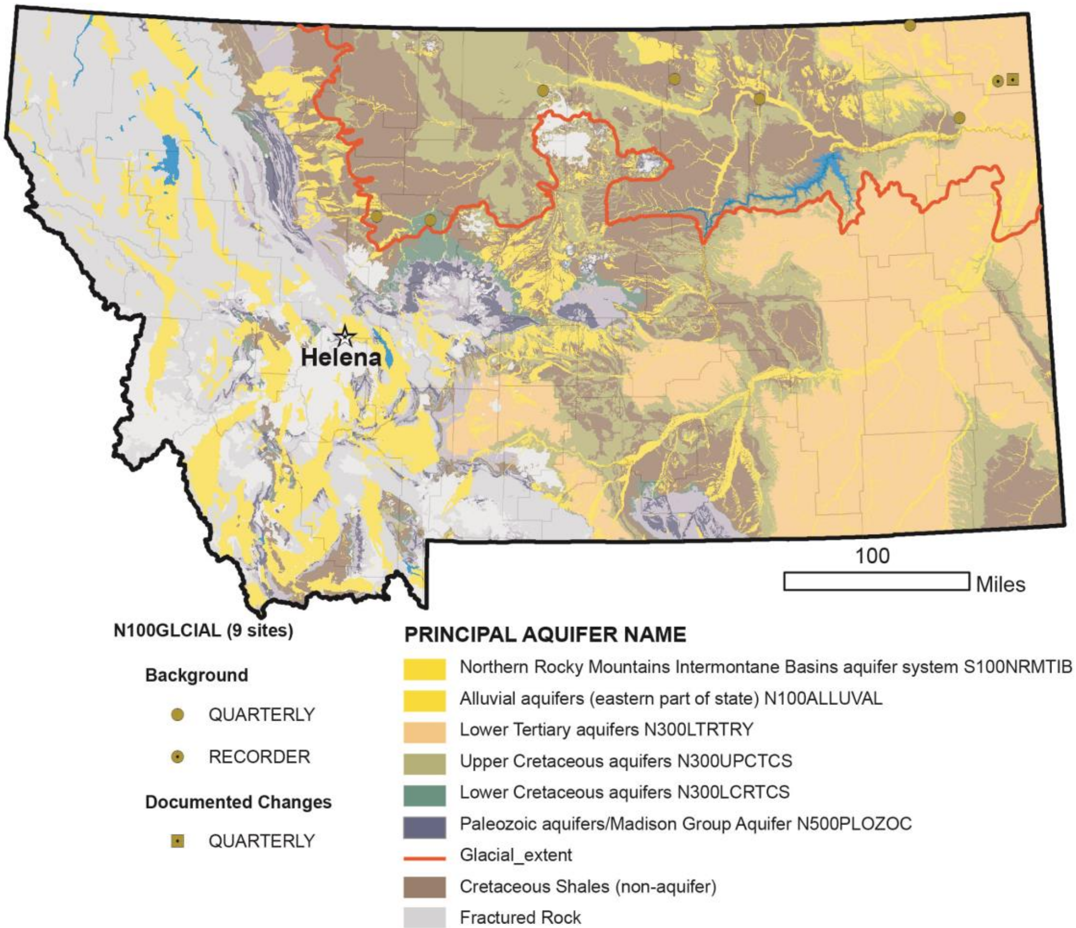


Figure 8. Proposed Glacial sand and gravel aquifer monitoring sites.

6) Lower Cretaceous aquifers

The Kootenai Formation is the primary Lower Cretaceous aquifer in Montana. It is exposed and near the land surface north of the Little Belt and Big Snowy mountains in central Montana. Seven wells were selected for the NGWMN; they are all “Background” wells measured quarterly (fig. 9).

7) Paleozoic aquifers

The Madison Limestone is Montana’s primary Paleozoic aquifer and underlies most of central and eastern Montana. Where it is close to, or exposed, at the land surface it is a productive and important source of municipal, domestic, industrial, and stock water; it also is the source for many large springs. The formation outcrops near the Little Belts and the Big Snowy mountain ranges in central Montana. Four wells were selected for the NGWMN, they are all “Background” wells, one is monitored continuously, and the other three are measured quarterly (fig. 9).

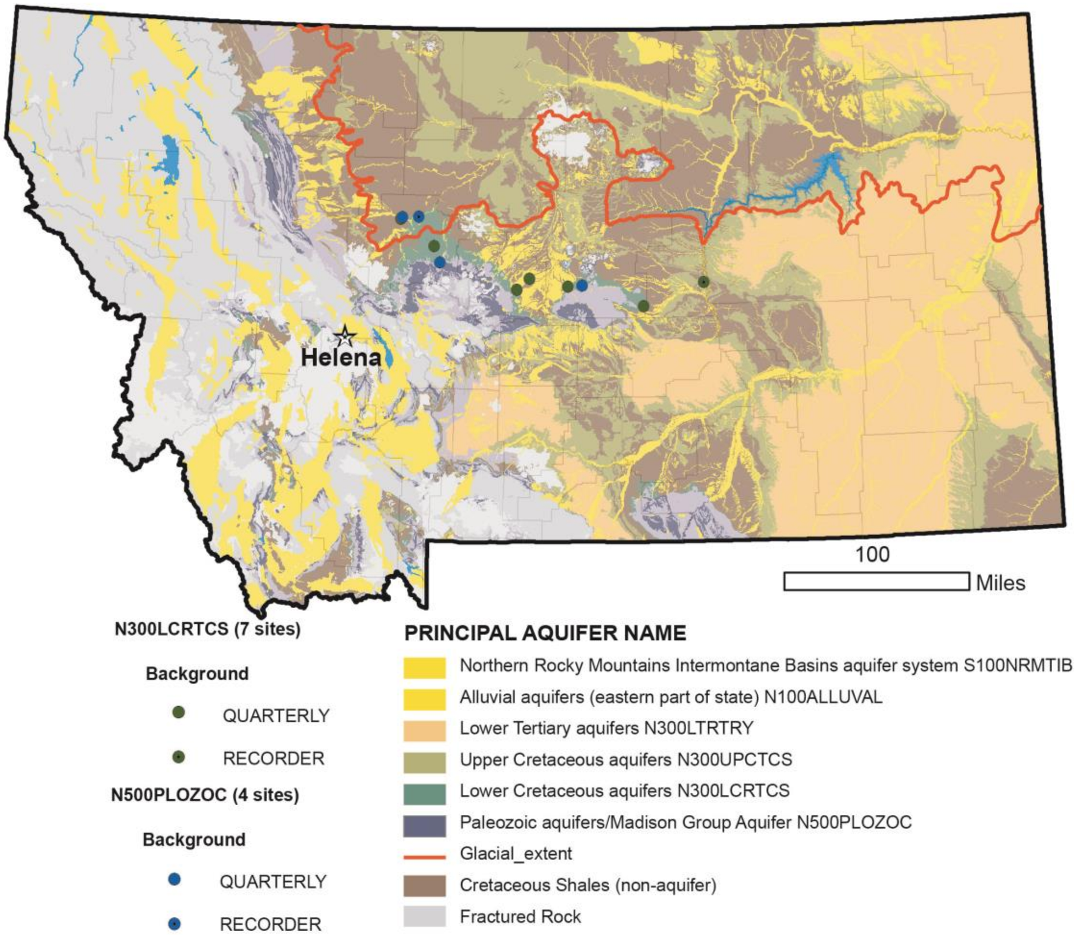


Figure 9. Proposed Lower Cretaceous and Paleozoic aquifer system monitoring sites.

Water-Quality NGWMN Candidate wells

The Montana statewide groundwater monitoring program calls for the periodic sampling and analysis of groundwater to build long-term records of base-line water quality. The initial program design called for wells in the water-level network to be sampled for inorganic analyses every 7 to 10 years. Although budgetary constraints have hindered the sampling schedule, most monitoring wells have been sampled at least once, and many have been sampled three times.

The 237 wells selected for the NGWMN water-level network were candidates for the NGWMN water-quality network. Any well that had been sampled three or more times during five or more years was considered to have met the Baseline Process. Only 58 of the 237 water-level wells met the baseline criteria for water-quality monitoring. Although some of the wells meeting water-quality baseline are included in the water-level “Documented” or “Suspected” changes subnetworks, all of the water-quality network wells were considered “Background Subnetwork” wells—they show no or minimal anthropogenic effects with respect to water quality. Because of the low and uncertain sampling frequency, the wells are considered to be “Surveillance” sites.

Most of the water-quality NGWMN wells (28) are completed in the Intermontane Basins aquifer system. In descending order the remainder are in the Lower Tertiary aquifers (12), the Upper Cretaceous (8), Lower Cretaceous (4), Glacial sand and gravel aquifers (4), Paleozoic Madison Limestone aquifer (1), and the Alluvial aquifers (1); a complete list of NGWMN Water-Quality network wells is presented in Appendix II. Table 3 summarizes the water quality sites and Figure 10 shows the distribution of the water-quality network sites.

Table 3. NGWMN Water-Quality well summary

Aquifer	Surveillance
N100ALLUVL	1
N100GLCIAL	4
N300LCRTCS	4
N300LTRTRY	12
N300UPCTCS	8
N500PLOZOC	1
S100NRMTIB	28

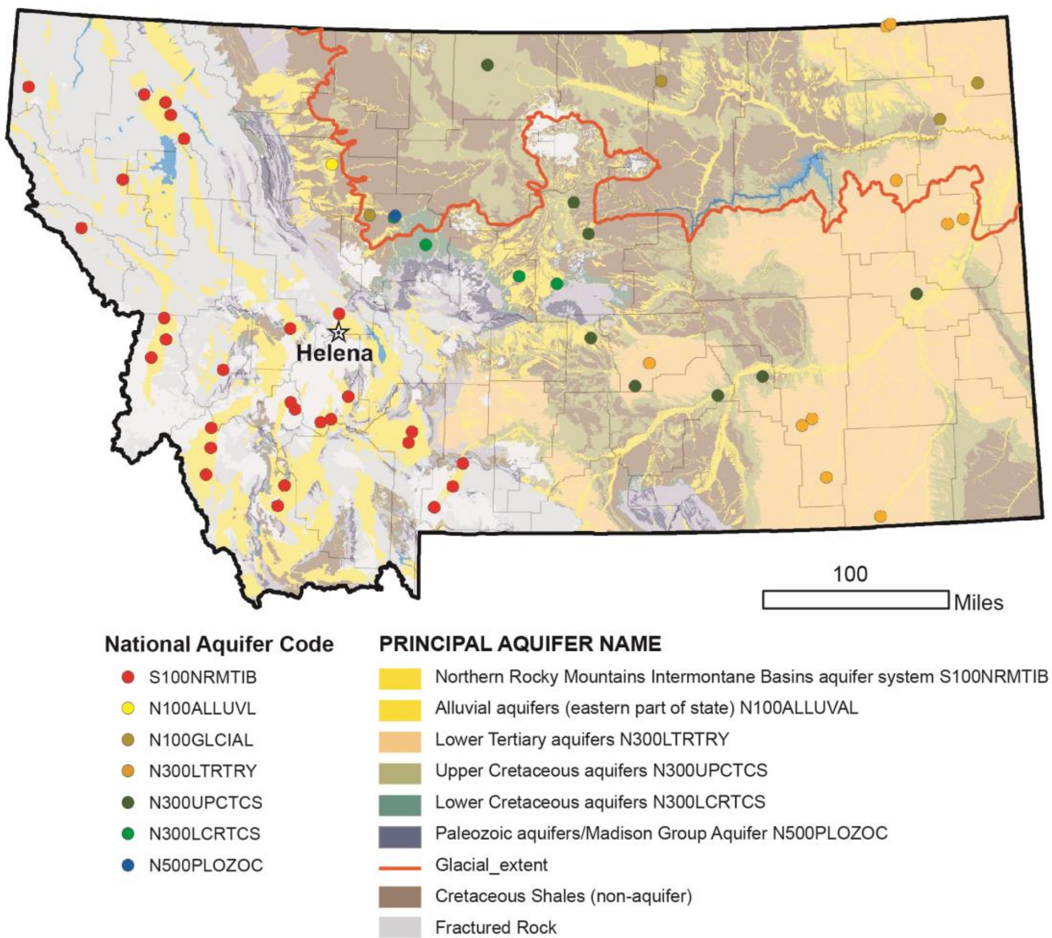


Figure 10. Proposed water-quality monitoring network sites.

Water-Quality Fields

Water quality data includes major ions, trace metals and nutrients. The MBMG analyte fields and other water-quality parameter fields are consistent with NGWMN formats, however the verification process is ongoing with CIDA. Once complete, the views that populate the services will be modified to contain the all fields. As a final step, the services that connect to the views will be refreshed to make the new content available.

Water-Level and Water Quality Data Gaps

1) Upper Cretaceous system: The Fox Hills-Hell Creek (FHHC) aquifer in northeast Montana. In the lower Yellowstone River valley there are about 1,500 wells completed in the FHHC aquifer. The widespread use of the aquifer has resulted in persistent water-level decline (fig. 5). Water use by energy development in the Williston Basin in Montana and North Dakota has raised concerns about FHHC water quantity and quality. There are no FHHC monitoring sites in northeastern Montana, near the North Dakota border, where the most intense oil and gas development has occurred.

2) For the water-quality monitoring network, most of the wells have not been sampled long enough or enough times to complete the baseline process. Lack of funding has prevented sufficient sample collection. Wells will continue to be sampled as funding allows; priority will be given to wells already in the NGWMN water-level network in order to establish water-quality baselines.

References

Patton, T.P., and Buckley, L.J., 2013, Results of the Montana Pilot Study for the National Ground Water Monitoring Network Water Monitoring Network, Prepared for the Advisory Committee on Water Information Subcommittee on Ground Water, 74 p.

Subcommittee on Ground Water (SOGW), 2013, A National Framework for the Ground-Water Monitoring in the United States, 182 p.

Whitehead, R.L., 1996, Ground Water Atlas of the United States Segment 8- Montana, North Dakota, South Dakota, Wyoming: U.S. Geological Survey Hydrologic Investigations Atlas 370-I. 24p.

Appendix I – Field Procedures

Standard Operating Procedure (SOP) for
Water-Level measurements on Non-Flowing and
Artesian wells

Prepared By:
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1994

Updated By:
Camela Carstarphen
2010

Updated By:
Camela Carstarphen
2015

Updated By:
Dan Blythe
2016

Prepared For:
Montana Bureau of Mines and Geology
Ground Water Assessment Program

Document File Location:
\\mbmgs1a\gwap\SOPS

1.0 Title
Standard Operating Procedure for Collecting Water-Level Measurements on Non-Flowing and Artesian Wells

2.0 Location
Groundwater level measurements are made in the field at the well head.

3.0 Purpose
The purpose of these guidelines is to provide technical guidance and to outline a standard procedure to ensure that accurate and consistent water-level measurements are made in the field for the Ground Water Assessment Program. This report describes the more common methods of water-level measurement. Water-levels are commonly measured using a graduated steel tape, electrical measuring lines, or pressure gauge.

4.0 Scope
The scope of this report is to provide citable documentation for the technical field procedures used by MBMG technicians and hydrogeologists in collection of water-level data for the Ground Water Assessment Program. These procedures are used for general field-based guidance, standardization of measurements and are restricted to common field-based procedures. Procedures used in the collection of water-level data to meet special objectives may vary. This report does not provide documentation for all procedures used by the MBMG in the collection of water-level data.

5.0 References

Garber, M. S., and Koopman, F. C., 1968, Methods of Measuring Water Levels in Deep Wells, Techniques of Water-Resource Investigations of the U. S. Geological Survey, Book 8, Chapter A1, 23 p.

U. S. Geological Survey, 2013, National Ground Water Monitoring Framework Report, htp://acwi.gov/sogw/ngwmn_framework_report_july2013.pdf

U. S. Geological Survey, 1980, National Handbook of Recommended Methods For Water-Data Acquisition - Chapter 2, Ground Water, 149 p.

6.0 Sample Handling and Preservation
See Standard Operating Procedure for Field Visit and Water-Quality Sampling.

7.0 Apparatus and Materials
-Steel surveyors tape, of appropriate length, graduated in 0.01 foot increments. Carpenters chalk.
-Graduated electrical line or tape (sounder), e.g. Solinst, Sinco, or equivalent.
-Some method of cleaning the tape (clorox diluted with water in a spray bottle, a container of disinfecting wipes, paper towel or cloth rag).
-Extra batteries for the electric sounder.
-Pressure gauge and series of graduated metal attachments
-Sonic Sounder
-Mirror and/or flashlight

-Site-Inventory Sheet
-Land-owner Water Level Cards/Route Sheet
- Tool kit (plumbers tape, crescent wrenches, allen wrench set, hammer, needle-nosed pliers, pipe wrenches, engin driver, socket wrench and socket set, permanent markers)

8.0 Establishing a site and measuring point

A clearly established measuring point (typically the top of the well casing), should be established where water levels are to be measured. Clearly describe the measuring point and document on MBMG *Site-Inventory Sheet* (appendix I). Document the distance between the land surface and the measuring point. The measuring point for a flowing well should be placed as close to the outlet as possible.

9.0 Procedures

All water level measurements should be conducted before purging the well.

9.1 Steel Tape Measurements

1. Apply chalk to the first few feet of the tape by pulling the tape across a piece of carpenters chalk. A smooth coating of chalk on the tape should result.
2. Lower the tape into the well from the measuring point until a short length of the tape is submerged.
3. When the tape is submerged, hold the tape at the measuring point and read the value and record the "hold" value in the field notes.
4. Retrieve the tape from the well and note the water mark, or "cut" mark, on the chalked part of the tape. Record the "cut" mark in the field notes.
5. Subtract the "cut" reading from the "hold" reading to determine the distance to water below the measuring point. Record the resulting distance to water value in the field notes.
6. Repeat the measurement by lowering the tape into the well a second time and "holding" at a point on the tape 1 foot greater than the initial "hold" point. Subtract the new "cut" mark and determine a second distance-to-water value for the well. If two measurements made within a few minutes do not agree within 0.02 foot (in wells having a depth-to-water less than 300 feet), repeat measurements until a reason for the lack of agreement is determined, the results are shown to be reliable, or until it is determined that an accurate measurement is not possible. For depths greater than 300 feet, measurements should agree to within ± 0.1 ft. Record both measurements on the inventory or route sheet (appendix II).
7. After completing the water-level measurement, disinfect, rinse, and dry the portion of the tape that was submerged should be thoroughly rinsed with distilled water and dried.

9.2 Electric Line (Sounder) Measurements

1. Test the probe by dipping it in water and observing the indicator or by activating the "test" switch.
2. Lower the probe slowly into the well until contact with the water surface is indicated.
3. Read the electric line at the measuring point while the probe is just touching the water surface, and record the distance to water.
4. Repeat the measurement. If two measurements of static water level made within one minute do

not agree within 0.01 foot, repeat the measurements until a reason for the lack of agreement is determined, the results are shown to be reliable, or until it is determined that an accurate measurement is not possible. In cases of a recovering water level, remain for a reasonable time until consecutive water level measurements agree. Otherwise record both measurements on the inventory or route sheet and note that they are "non-static".

9.3 Pressure Gauge Measurements

1. Turn off the valve controlling flow from the well; note its position when open.
2. Carefully wire brush the threads on the pipe extending from the well. Put Teflon tape around the threads. If the pipe is cross-threaded or if there is any uncertainty about the integrity of the well casing and piping on a discharging well, do not attempt to measure pressure.
3. Carefully attach the necessary fittings to reduce to the diameter of the fitting on the pressure gauge. Attach the pressure gauge.
4. Completely open the valve controlling flow from the well.
5. Give the pressure gauge time to respond a recommended 15 minutes. Read the pressure gauge reading twice several minutes apart. If two measurements of pressure level made within a few minutes do not agree within 0.05 PSI, repeat the measurements until a reason for the lack of agreement is determined or until the results are shown to be reliable or until it is determined that an accurate measurement is not possible.
6. Record both measurements on the inventory or route sheet.

10.0 Quality Control

Quality control will be maintained by collecting two consecutive water level measurements within acceptable agreement for the procedure used. If agreement is not achieved, record the lack of agreement on the inventory or route sheet.

11.0 Documentation

The location and water level measuring point is documented on the *Site-Inventory Sheet* (appendix I) including a map of the site, directions, and notes about any special circumstances or locations of additional wells (see Standard Operating Procedure for Field Visit and Water-Quality Sampling (\\mbmgs1a\gwap\SOPS). Record the well casing diameter, and collect latitude and longitude from a hand-held GPS unit. If this is a state-wide monitoring network well, then record water-level measurements on the field route sheet. Monitoring site will be tagged and photographed.

Site Inventory Sheet

☐ **QAQC** ☐ **entered** ☐ **scanned** ☐ **juno** **SAMPLE**________ ☐

Date ______________ **SITE INVENTORY SHEET** **Project Code**__________

GWIC Id: ______________ **Aquifer Code**_________

Owner

Name________________________________

Address ______________________________

____

Phone ______________________________

User/Resident (if different)

Name ______________________________

Address______________________________

____

Phone ______________________________

LOCATION: T _____$^{N}_{S}$ R ______$^{E}_{W}$ S ______ Tract ___/___/___/___ Irreg. Sect? Y__N__

Latitude_________________Longitude________________Datum_________ Geomethod__________

County________________ USGSMap7$^{1}/_{2}$' ______________________________ Altitude ___________

WELL DETAILS

Water Use ______ Casing I.D. _____(in) Total Depth From Ground ____________________________

Measuring Point (M.P.) ________ft(+ above, - below land surface) M.P. Elev.____________________

Water-Level Measuring Point Description:____

Sampling-Point Description: ____

Can sample be collected?Y__ N__Before pressure tank?Y__ N__Unk__Before Treatment?Y__N__Unk___

STATIC WATER LEVEL (E-Line___/Steel Tape___/Pressure Gauge___sonic sounder___&temp___)

Time	Depth Below M.P.	PSI	Head	Water level altitude	Remarks

PURGING PARAMETERS ORP Probe: discharge

Time	Temp C°	S.C .(μS/cm)	pH	Redox (mv)	DO mg/L		notes
FINAL							

PUMPING WATER LEVEL (E-Line___/Steel Tape___/Pressure Gauge___sonic sounder___&temp___)

Time	Depth Below M.P.	Water level altitude	Remarks: pump cycling? ☐ yes ☐ unk

SITE NOTES:

____

____

____

____

_____

SITE SKETCH MAP
Show location of well and sampling point. If necessary show site location in relation to roads.
^ North

INVENTORY NOTES:____

____

____

____

General condition of well and surface seal (Good ___ Fair ___ Poor __)

Condition of water: Clear ___ Turbid ___ Other____________________________

SAMPLE: Standard (250ml **FU**, 500ml **FA**{HNO_3},500ml **RU,** 10ml **FU** 2H&O18) ☐

Other (nitrate only, tritium, etc.) ______________________________________

ALKALINITY TITRATION **Bottle Number**__________________

Vol. Of Sample	Total Vol. Titrated	Acid Conc.	Original pH	Digits to Reach 8.3 pH	Actual Endpoint	Digits to Reach 4.5 pH	Actual Endpoint	Total Digits

Alkalinity Concentration ☐ (mg/L as CaCO3)______________________________

FEET OF WATER	gal/ft by casing diameter	total gal	/DISCHARGE RATE	MINUTES PER WELL VOLUME
	(2"x.163),(4"x.65),(6"x1.47),(8"x2.61),(10"x4.08),(24"x23.5)			

Name________________________________ **Agency** ______________________

Example of monthly or state-wide monitoring network route sheet

Site Id (Last Date/Meas) Site Name Location	Date	Time	Steel Tape Only			DTW Sounder	Remarks
			Hold	Cut	DTW/MP		
175011 (W) (9/3/2015 - 122.71) LEPROWSE, WALT AND TERRI 03S09W1AABA							
SITE COMMENT:							
221292 (W) (9/3/2015 - 8.63) GARRISON, LETISHA & TODD 04S08W30CBBA							
SITE COMMENT: THIS WELL IS CLOSER TO HOUSE OF 2 WELLS							
108962 (W) (9/16/2015 - 30.42) STODDARD, SPENCE 06S07W34BADA							
SITE COMMENT:							
108949 (W) (9/16/2015 - 22.17) CHRISTIANSEN, TED 06S07W10DACC							
SITE COMMENT:							
108531 (W) (9/3/2015 - 12.24) COLE, GOODMAN 05S07W22CDCD							
SITE COMMENT: BEAVERHEAD ROCK							
131577 (W) (6/10/2015 - 23.3) EAST BENCH...OBS * 312A 05S07W14DDDD							
SITE COMMENT:							
130177 (W) (9/3/2015 - 137.84) EAST BENCH... * 10-5-6A 05S06W10BBCC							
SITE COMMENT:							
130176 (W) (9/3/2015 - -23.86) EAST BENCH...4-6 (DEEP) 04S06W35BBBB							
SITE COMMENT:							
260970 (W) (9/3/2015 - 34.3) EAST BENCH...OBS * 352A 04S06W16AAAA							
SITE COMMENT: WEST SIDE OF NYE RD 1.9 MILES NORTH OF INTERSECTION							

Montana Bureau of Mines and Geology

Standard Operating Procedure SOP
For
Collection of Ground-Water Samples For Inorganic Analyses
From Wells and Springs

Prepared by:
John I. LaFave and Dennis P. McKenna

Updated by Dan Blythe
2016

Prepared For:
Montana Bureau of Mines and Geology

Document File Location:
\\mbmgs1a\gwap\SOPS

1.0 Title
Standard Operating Procedure for Collection of Groundwater Samples for Inorganic Analysis.

2.0 Location
Groundwater samples are collected upstream from any water treatment, or as close as possible, the well head

3.0 Purpose
The purpose of this document is to provide a description of the requirements, recommendations and guidelines used by the MBMG to collect water-quality samples from wells and springs. These water-quality data are used for the Ground Water Assessment Program. The methods described in this SOP are fundamental to the collection of water-quality samples that are representative of the ambient environment.

4.0 Scope
The scope of this report is to provide citable documentation for the technical field procedures used by MBMG technicians and hydrogeologists in collection of groundwater samples for inorganic analysis. These procedures are used for general field-based guidance, standardization of measurements and are restricted to common field-based procedures. Procedures used in the collection of groundwater samples to meet special objectives may vary. This report does not provide documentation for all procedures used by the MBMG in the collection of groundwater samples.

5.0 References
U.S. Geological Survey, 2006, Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, September 2006, accessed [date viewed], at http://pubs.water.usgs.gov/twri9A4/.

6.0 Apparatus and Materials
Submersible pump & generator or bailer (if well does not have a pump)
Conductivity, pH, temperature, redox, and DO probes with meters
Alkalinity titration equipment and supplies
Flow-through chamber
Filters (0.45 um), regular or high density
Sample bottles (250-mL and 500-mL)
Acid preservatives
Site Inventory Sheets (Appendix I)
1-gallon Ziplock bags
Waterproof pens (Sharpies)
Ice chest and ice
Plastic bucket
Garden hose/y-valves/small diameter tubing that fits filter
Decontamination solution – water and Clorox or disinfectant wipes
Extra batteries for all equipment
Nitrate strips

Water-Level indicator, steel tape, pressure gage (needed bushings)

7.0 Procedures

7.1 Wells

At each well site, the following activities will be conducted.

1) Confirm landowner permission to sample the well.
2) Measure static water level in well and calculate volume of water in well.
3) Set up flow-through chamber and field meters.
4) Pump well until purging parameters stabilize.
5) Collect ground-water samples and QA/QC samples as necessary.
6) Conduct titration to determine total alkalinity of sample.
7) Confirm that all bottles are properly labeled and that the Site Inventory sheet is completely and accurately filled out.

7.2 Equipment Setup

The following are general steps for equipment setup:

1) Rinse the faucet threads and Y-adapter coupling with DI water.
2) Attach the Y-adapter to the sampling faucet.
3) Attach the garden hose to one end of the Y-adapter and place the other end of the garden hose at an appropriate drainage area.
4) Rinse the threaded coupling on the end of the tubing on the flow-through cell with DI water and attach the tubing to the faucet Y-adapter.
5) Use the long length of tubing to route the discharge water from the flow-through cell to an appropriate drainage area.

7.3 Stabilization of Purging Parameters

At least one well volume should be pumped from the well and the purging parameters temperature, pH, and specific conductance should stabilize before collecting the sample. Redox and dissolved oxygen are also monitored. The purging parameters should be recorded at regular intervals on the *Site Inventory Sheet*. If the field parameters do not exhibit stability after three well volumes have been removed, the well may be sampled. Temperature is considered stable when three consecutive readings are within 0.5 degrees, pH when three consecutive readings are within 0.1 units, and specific conductance is considered stable if three consecutive readings are within +/- 5 percent.

7.4 Springs

Attach the y-valve to the spring outlet and connect flow-through cell. Return to 7.1. and follow sampling steps.

7.5 Sample Collection

In general, at each sample location a total of four sample bottles will be filled:

1) a 250-mL sample that has been filtered but not preserved (for inorganic anions and fluoride),
2) a 500-mL sample that has been filtered and preserved with nitric acid (for dissolved metals and trace metals),
3) a 250-mL filtered sample that has been preserved with sulfuric acid (for nitrate-nitrite), and
4) a 500-mL unfiltered, unpreserved sample (for laboratory alkalinity and specific conductance).

8.0 Sample Handling and Preservation

Following sample collection the samples should be transferred to coolers packed with ice and cooled to 4^{o} C. Storing the samples in a cooler also helps protect the sample bottles from damage during transport. Samples should not be frozen.

9.0 Documentation

In general, the information documented on the *Site Inventory Sheet* should include what type of sample was collected, who collected sample, when the sample was collected, the location of the sampling point, why or for what program the sample was collected, condition of the sample, stabilization criteria and the purging method. In addition, the total number of bottles, the filter and preservation status, and the desired analyses should be documented. It is impossible to over document your work; if you are not sure if a bit of information is necessary, record it.

☐ **QAQC** ☐ **entered** ☐ **scanned** ☐ **juno** **SAMPLE________** ☐

Date ______________ **SITE INVENTORY SHEET** **Project Code__________**

GWIC Id: ______________ **Aquifer Code_________**

Owner
Name______________________________
Address ______________________________
____
Phone ______________________________

User/Resident (if different)
Name ______________________________
Address______________________________
____
Phone ______________________________

LOCATION: T _____ N/S R _____ E/W S _____ Tract ___/___/___/___ Irreg. Sect? Y__N__

Latitude________________Longitude________________Datum_________ Geomethod__________

County________________ USGSMap7 1/2' ______________________________ Altitude ___________

WELL DETAILS

Water Use ______ Casing I.D. _____(in) Total Depth From Ground ___________________________

Measuring Point (M.P.) _______ft(+ above, - below land surface) M.P. Elev.____________________

Water-Level Measuring Point Description:____

Sampling-Point Description: ____

Can sample be collected?Y__ N__Before pressure tank?Y__ N__Unk__Before Treatment?Y__N__Unk___

STATIC WATER LEVEL (E-Line___/Steel Tape___/Pressure Gauge___sonic sounder___&temp___)

Time	Depth Below M.P.	PSI	Head	Water level altitude	Remarks

PURGING PARAMETERS ORP Probe: discharge

Time	Temp C°	S.C .(µS/cm)	pH	Redox (mv)	DO mg/L		notes
FINAL							

PUMPING WATER LEVEL (E-Line___/Steel Tape___/Pressure Gauge___sonic sounder___&temp___)

Time	Depth Below M.P.	Water level altitude	Remarks: pump cycling? ☐ yes ☐ unk

SITE NOTES:

____

____

____

____

______

SITE SKETCH MAP
Show location of well and sampling point. If necessary show site location in relation to roads.
^ North

INVENTORY NOTES:____

____

____

____

General condition of well and surface seal (Good ___ Fair ___ Poor __)

Condition of water: Clear ___ Turbid ___ Other____

SAMPLE: Standard (250ml **FU**, 500ml **FA**{HNO_3},500ml **RU,** 10ml **FU** 2H&O18) ☐

Other (nitrate only, tritium, etc.) ____

ALKALINITY TITRATION **Bottle Number**____________________

Vol. Of Sample	Total Vol. Titrated	Acid Conc.	Original pH	Digits to Reach 8.3 pH	Actual Endpoint	Digits to Reach 4.5 pH	Actual Endpoint	Total Digits

Alkalinity Concentration ☐ (mg/L as CaCO3)________________________________

FEET OF WATER	gal/ft by casing diameter	total gal	/DISCHARGE RATE	MINUTES PER WELL VOLUME
	(2"x.163),(4"x.65),(6"x1.47),(8"x2.61),(10"x4.08),(24"x23.5)			

Name_________________________________ **Agency** ________________________

Example of Completed Site Inventory Sheet

☒ QAQC ☒ entered ☒ scanned ☑ juno **SAMPLE** FULL ☒

Date 6/4/2014 **SITE INVENTORY SHEET** **Project Code** GWCP09

GWIC Id: 153624 **Aquifer Code** 210 UDFD JLRY – Eagle

Owner **User/Resident** (if different)

Name David Duncan & Ellen Winter Name ____

Address 607 Swingley Rd Address ____

Livingston, MT 59047

Phone (406) 224-1513 Phone email davidtduncan@icloud.com

LOCATION: T 02 N R 11 E S 19 Tract C D B A Irreg. Sect? Y__N X

Latitude 45.64105500 Longitude -110.4191650 Datum NAD83 Geomethod NAV GPS juno

County Park USGSMap7 1/2' MISSION Altitude 5360

WELL DETAILS ← on ccp (Hillman!)

Water Use DOM Casing I.D. 6 (in) Total Depth From Ground 100

Measuring Point (M.P.) 2.1 ft(+ above, - below land surface) M.P. Elev. 5362.1

Water-Level Measuring Point Description: top of casing

Sampling-Point Description: hydrant in yard close to tank & fence

Can sample be collected? Y ✓ N___, Before pressure tank? Y ✓ N___ Unknown ___

Before treatment? Y ✓ N___ Unknown ___, Comments ____

STATIC WATER LEVEL (E-Line X /Steel Tape___/Pressure Gauge___sonic sounder___&temp___)

Time	Depth Below M.P.	PSI	Head	Water level altitude	Remarks
1233	46.15			5315.95	8
1234	46.15				

5362.10
46.15
5315.95

PURGING PARAMETERS ORP Probe: WTW discharge

Time	Temp C°	S.C .(µS/cm)	pH	Redox (mv)	DO mg/L	gal/min	notes
1240	10.2	420	7.73	58.4	8.0		
1245	8.9	413	7.4	41.6	7.60	20/3gal	58 pump cycling
1250	8.6	409	7.27	34.5	4.53		
1255	8.9	406	7.31	27.3	4.38		holding steady
1300	8.6	405	7.31	21.3	2.64	if not on, just off	
FINAL	8.6	405	7.3	21.3	2.64	9gpm	

PUMPING WATER LEVEL (E-Line___/Steel Tape___/Pressure Gauge___sonic sounder___&temp___)

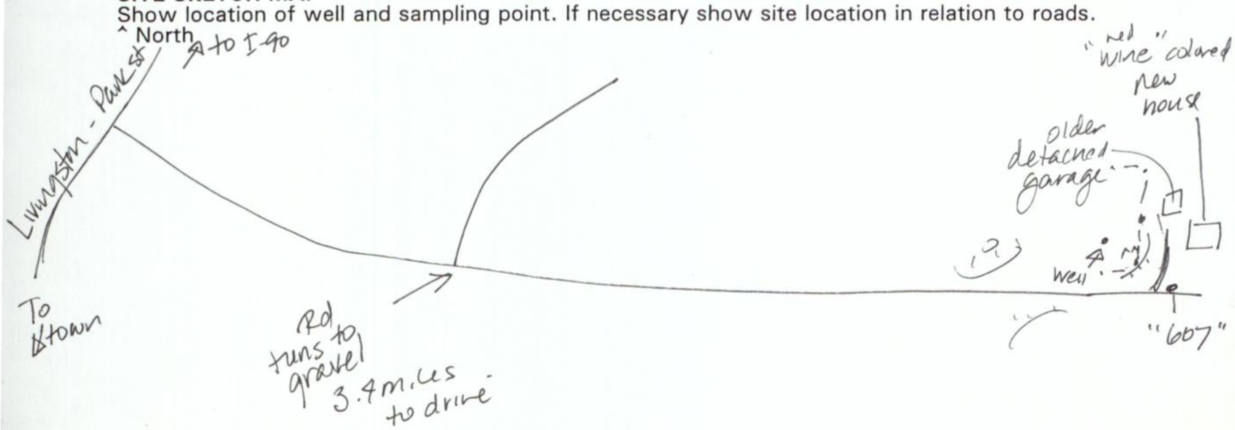
Time	Depth Below M.P.	Water level altitude	Remarks: pump cycling? ☐yes ☐ unk
	Pump Cycling		

FIELD NITRATE (HACH) 0.0 (mg/L-N) **Comments** ____

Montana Bureau of Mines and Geology 1300 West Park St. Butte, MT 59701 (406) 496-4306 Version 6.1 08/12

SITE NOTES: Travel S. from Livingston's Main Rd onto Swingley. Drive is 3.4 miles on left past pavement end. New 2 story house w/ older detached garage. Address on post. Well is to SE. of house across fence - due east of rocky outcrop.

SITE SKETCH MAP
Show location of well and sampling point. If necessary show site location in relation to roads.
^ North



INVENTORY NOTES: Bull snake on the prowl!

General condition of well and surface seal (Good ✓ Fair ___ Poor __)
Condition of water: Clear ✓ Turbid ___ Other___

SAMPLE: Standard (250 ml ~~RA~~ FA $\{H_2SO_4\}$, 250 ml **FU**, 500 ml **FA** $\{HNO_3\}$, 500 ml **RU**) ☑

Other (nitrate only, tritium, etc.) 2 500 ml for tritium + 10ml O18+2H

ALKALINITY TITRATION **Bottle Number** 153624

Vol. Of Sample	Total Vol. Titrated	Acid Conc.	Original pH	Digits to Reach 8.3 pH	Actual Endpoint	Digits to Reach 4.5 pH	Actual Endpoint	Total Digits
100m	100ml	1.6	8.1	—	—		4.31	186
[illegible]								

Alkalinity Concentration 186 (mg/L as CaCO3)___

FEET OF WATER	gal/ft by casing diameter	total gal	/DISCHARGE RATE	MINUTES PER WELL VOLUME
54	(2"x.163),(4"x.65),(6"x1.47),(8"x2.61),(10"x4.08),(24"x23.5)	81	9	9 minutes

Name Camela A Carstarphen **Agency** MBMG

Montana Bureau of Mines and Geology 1300 West Park St. Butte, MT 59701 (406) 496-4306 Version 6.1 08/12

Landowner Information Sheet

Your well was visited on _________by______________________________
of the Montana Bureau of Mines and Geology Well GWIC ID____________Total Depth_____

The following parameters were measured:

Depth to groundwater	**________feet below casing**	
Groundwater temperature	**________F**	
Specific conductance*	**________micromhos**	
	________estimated TDS	
pH**	**________**	
Nitrate***	**________mg/l**	
Pumping rate and drawdown	**________gallons/minute**	**_________ (ft)**

***Specific Conductance** is a measure of how easily water conducts electricity and provides an indication of the amount of minerals in the water. When minerals dissolve in water they form ions that can conduct electricity. The more minerals dissolved in water the greater the conductance. The total dissolved solids (TDS), in parts per million, can be estimated by multiplying the Specific Conductance by 0.6.

****pH** is a measure of how acidic or basic the water is. Water with a pH of 7 is neutral; less than 7 is acidic, and greater than 7 is basic. Low values of pH, particularly below pH 4, indicate a highly corrosive water. High values, particularly above pH 8.5, indicate alkaline water. Most groundwater has a pH between 6.5 and 9.0.

*****nitrate mg/l** is a field measurement of the nitrate concentration from your well. This field measurement is made using a colorometric method and is less accurate than a lab test, but is useful as a reference. Source of nitrates in groundwater can range from the geologic deposits that form the aquifer, to infiltration from septic tank seepage, fertilizers, or animal wastes. The national drinking water standard for nitrate is 10 mg/l.

For more information about your well or wells in your area visit the Ground Water Information Center on the web: www.mbmggwic.mtech.edu.

For more information contact:

John I. LaFave
Groundwater Characterization Program
Montana Bureau of Mines and Geology
Montana Tech of the University of Montana
1300 West Park Street
(406) 496 – 4306

Appendix II – NGWMN Water-Level and Water Quality network wells

Northern Rocky Mountains Intermontane Basins - S100NRMTIB

aquifer_national	NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category
S100NRMTIB	MBMG-108595	45.404	-113.486	BEAVERHEAD	UNCONFINED	Trend
S100NRMTIB	MBMG-108966	45.345	-112.594	BEAVERHEAD	UNCONFINED	Trend
S100NRMTIB	MBMG-110163	44.852	-112.797	BEAVERHEAD	UNCONFINED	Trend
S100NRMTIB	MBMG-129084	45.776	-113.454	BEAVERHEAD	UNCONFINED	Trend
S100NRMTIB	MBMG-129151	45.618	-113.448	BEAVERHEAD	CONFINED	Trend
S100NRMTIB	MBMG-133392	45.164	-112.686	BEAVERHEAD	UNCONFINED	Trend
S100NRMTIB	MBMG-149512	45.177	-112.657	BEAVERHEAD	CONFINED	Trend
S100NRMTIB	MBMG-108590	45.406	-113.437	BEAVERHEAD	UNCONFINED	Trend
S100NRMTIB	MBMG-153311	45.638	-113.518	BEAVERHEAD	CONFINED	Trend
S100NRMTIB	MBMG-20667	46.403	-111.602	BROADWATER	UNCONFINED	Trend
S100NRMTIB	MBMG-130432	46.118	-111.530	BROADWATER	UNCONFINED	Trend
S100NRMTIB	MBMG-120777	46.338	-111.501	BROADWATER	UNCONFINED	Trend
S100NRMTIB	MBMG-51775	46.165	-112.821	DEER LODGE	CONFINED	Trend
S100NRMTIB	MBMG-128682	46.254	-112.740	DEER LODGE	UNCONFINED	Trend
S100NRMTIB	MBMG-51325	46.060	-112.788	DEER LODGE	CONFINED	Trend
S100NRMTIB	MBMG-80745	48.095	-114.137	FLATHEAD	CONFINED	Trend
S100NRMTIB	MBMG-84687	48.248	-114.421	FLATHEAD	CONFINED	Trend
S100NRMTIB	MBMG-88197	48.402	-114.461	FLATHEAD	CONFINED	Trend
S100NRMTIB	MBMG-130530	48.072	-113.950	FLATHEAD	CONFINED	Trend
S100NRMTIB	MBMG-702934	48.254	-114.127	FLATHEAD	CONFINED	Trend
S100NRMTIB	MBMG-148187	48.348	-114.197	FLATHEAD	CONFINED	Trend
S100NRMTIB	MBMG-148191	48.348	-114.298	FLATHEAD	CONFINED	Trend
S100NRMTIB	MBMG-169098	48.226	-114.328	FLATHEAD	CONFINED	Trend
S100NRMTIB	MBMG-9271	45.809	-111.566	GALLATIN	CONFINED	Trend
S100NRMTIB	MBMG-135735	45.802	-111.165	GALLATIN	UNCONFINED	Trend
S100NRMTIB	MBMG-234909	45.803	-111.045	GALLATIN	UNCONFINED	Trend
S100NRMTIB	MBMG-235474	45.879	-111.194	GALLATIN	UNCONFINED	Trend

Appendix II – Montana NGWMN wells – Water-Level Network Wells

S100NRMTIB	MBMG-230551	44.760	-111.178	GALLATIN	CONFINED	Trend
S100NRMTIB	MBMG-96132	45.613	-111.070	GALLATIN	UNCONFINED	Trend
S100NRMTIB	MBMG-135081	45.755	-111.048	GALLATIN	UNCONFINED	Trend
S100NRMTIB	MBMG-32	45.814	-111.468	GALLATIN	CONFINED	Trend
S100NRMTIB	MBMG-91244	45.715	-111.197	GALLATIN	UNCONFINED	Trend
S100NRMTIB	MBMG-226763	45.860	-111.328	GALLATIN	UNCONFINED	Trend
S100NRMTIB	MBMG-154583	46.621	-113.207	GRANITE	CONFINED	Trend
S100NRMTIB	MBMG-154593	46.244	-113.348	GRANITE	CONFINED	Trend
S100NRMTIB	MBMG-154584	46.621	-113.207	GRANITE	UNCONFINED	Trend
S100NRMTIB	MBMG-48667	45.859	-112.210	JEFFERSON	CONFINED	Trend
S100NRMTIB	MBMG-49147	45.884	-112.091	JEFFERSON	UNCONFINED	Trend
S100NRMTIB	MBMG-215992	45.874	-111.975	JEFFERSON	UNCONFINED	Trend
S100NRMTIB	MBMG-121965	46.071	-111.902	JEFFERSON	CONFINED	Trend
S100NRMTIB	MBMG-127166	47.836	-113.817	LAKE	CONFINED	Trend
S100NRMTIB	MBMG-133880	47.410	-114.308	LAKE	UNCONFINED	Trend
S100NRMTIB	MBMG-133891	47.536	-114.236	LAKE	CONFINED	Trend
S100NRMTIB	MBMG-133839	47.334	-114.011	LAKE	CONFINED	Trend
S100NRMTIB	MBMG-133842	47.399	-114.049	LAKE	CONFINED	Trend
S100NRMTIB	MBMG-133895	47.651	-114.115	LAKE	CONFINED	Trend
S100NRMTIB	MBMG-77168	47.623	-114.573	LAKE	CONFINED	Trend
S100NRMTIB	MBMG-703168	47.163	-114.027	LAKE	CONFINED	Trend
S100NRMTIB	MBMG-62261	46.582	-112.018	LEWIS AND CLARK	UNCONFINED	Trend
S100NRMTIB	MBMG-70688	46.945	-112.669	LEWIS AND CLARK	UNCONFINED	Trend
S100NRMTIB	MBMG-110196	46.650	-111.895	LEWIS AND CLARK	UNCONFINED	Trend
S100NRMTIB	MBMG-131018	46.956	-112.670	LEWIS AND CLARK	UNCONFINED	Trend
S100NRMTIB	MBMG-191525	46.652	-111.995	LEWIS AND CLARK	UNCONFINED	Trend
S100NRMTIB	MBMG-191548	46.592	-111.878	LEWIS AND CLARK	UNCONFINED	Trend
S100NRMTIB	MBMG-248640	46.624	-112.107	LEWIS AND CLARK	UNCONFINED	Trend

S100NRMTIB	MBMG-170202	46.716	-111.913	LEWIS AND CLARK	UNCONFINED	Trend
S100NRMTIB	MBMG-191532	46.728	-112.036	LEWIS AND CLARK	UNCONFINED	Trend
S100NRMTIB	MBMG-86863	48.343	-115.540	LINCOLN	CONFINED	Trend
S100NRMTIB	MBMG-90525	48.943	-115.099	LINCOLN	CONFINED	Trend
S100NRMTIB	MBMG-132577	48.399	-115.845	LINCOLN	CONFINED	Trend
S100NRMTIB	MBMG-149530	45.182	-111.601	MADISON	UNCONFINED	Trend
S100NRMTIB	MBMG-163677	45.700	-111.785	MADISON	CONFINED	Trend
S100NRMTIB	MBMG-171672	45.211	-111.787	MADISON	UNCONFINED	Trend
S100NRMTIB	MBMG-184470	45.681	-111.780	MADISON	CONFINED	Trend
S100NRMTIB	MBMG-245592	44.826	-111.460	MADISON	UNCONFINED	Trend
S100NRMTIB	MBMG-256852	45.226	-111.720	MADISON	UNCONFINED	Trend
S100NRMTIB	MBMG-256853	45.226	-111.720	MADISON	UNCONFINED	Trend
S100NRMTIB	MBMG-256854	45.393	-111.730	MADISON	CONFINED	Trend
S100NRMTIB	MBMG-256859	45.393	-111.730	MADISON	CONFINED	Trend
S100NRMTIB	MBMG-107340	45.674	-112.262	MADISON	CONFINED	Trend
S100NRMTIB	MBMG-130177	45.420	-112.340	MADISON	UNCONFINED	Trend
S100NRMTIB	MBMG-131577	45.394	-112.423	MADISON	UNCONFINED	Trend
S100NRMTIB	MBMG-129117	46.457	-110.973	MEAGHER	CONFINED	Trend
S100NRMTIB	MBMG-159523	47.304	-115.093	MINERAL	UNCONFINED	Trend
S100NRMTIB	MBMG-72114	47.035	-114.389	MISSOULA	CONFINED	Trend
S100NRMTIB	MBMG-120512	47.169	-113.449	MISSOULA	CONFINED	Trend
S100NRMTIB	MBMG-133045	47.545	-113.721	MISSOULA	CONFINED	Trend
S100NRMTIB	MBMG-151188	46.849	-114.102	MISSOULA	UNCONFINED	Trend
S100NRMTIB	MBMG-157212	46.929	-114.109	MISSOULA	CONFINED	Trend
S100NRMTIB	MBMG-157214	46.900	-113.966	MISSOULA	UNCONFINED	Trend
S100NRMTIB	MBMG-151190	46.858	-114.003	MISSOULA	UNCONFINED	Trend
S100NRMTIB	MBMG-151204	47.031	-114.273	MISSOULA	UNCONFINED	Trend
S100NRMTIB	MBMG-21567	45.556	-110.576	PARK	UNCONFINED	Trend
S100NRMTIB	MBMG-102486	45.374	-110.686	PARK	UNCONFINED	Trend
S100NRMTIB	MBMG-103644	45.295	-110.835	PARK	CONFINED	Trend
S100NRMTIB	MBMG-104586	45.205	-110.894	PARK	UNCONFINED	Trend
S100NRMTIB	MBMG-131374	46.870	-112.968	POWELL	CONFINED	Trend

S100NRMTIB	MBMG-134562	46.598	-112.600	POWELL	CONFINED	Trend
S100NRMTIB	MBMG-71610	47.014	-113.067	POWELL	CONFINED	Trend
S100NRMTIB	MBMG-219909	46.444	-112.726	POWELL	CONFINED	Trend
S100NRMTIB	MBMG-219913	46.444	-112.726	POWELL	UNCONFINED	Trend
S100NRMTIB	MBMG-257455	46.444	-112.726	POWELL	CONFINED	Trend
S100NRMTIB	MBMG-50808	46.015	-114.201	RAVALLI	UNCONFINED	Trend
S100NRMTIB	MBMG-136050	46.312	-114.186	RAVALLI	UNCONFINED	Trend
S100NRMTIB	MBMG-136969	46.441	-114.147	RAVALLI	UNCONFINED	Trend
S100NRMTIB	MBMG-136970	46.464	-114.030	RAVALLI	UNCONFINED	Trend
S100NRMTIB	MBMG-136486	46.632	-114.062	RAVALLI	UNCONFINED	Trend
S100NRMTIB	MBMG-257424	46.633	-114.050	RAVALLI	CONFINED	Trend
S100NRMTIB	MBMG-257425	46.633	-114.050	RAVALLI	CONFINED	Trend
S100NRMTIB	MBMG-163226	46.244	-114.128	RAVALLI	CONFINED	Trend
S100NRMTIB	MBMG-136964	46.255	-114.155	RAVALLI	UNCONFINED	Trend
S100NRMTIB	MBMG-74121	47.384	-114.794	SANDERS	CONFINED	Trend
S100NRMTIB	MBMG-127172	47.889	-115.639	SANDERS	CONFINED	Trend
S100NRMTIB	MBMG-132575	48.047	-115.965	SANDERS	CONFINED	Trend
S100NRMTIB	MBMG-149183	47.622	-115.344	SANDERS	UNCONFINED	Trend
S100NRMTIB	MBMG-6283	47.714	-114.649	SANDERS	CONFINED	Trend
S100NRMTIB	MBMG-4483	45.955	-112.506	SILVER BOW	UNCONFINED	Trend
S100NRMTIB	MBMG-131579	45.988	-112.669	SILVER BOW	CONFINED	Trend
S100NRMTIB	MBMG-892116	46.010	-112.562	SILVER BOW	CONFINED	Trend

Alluvial aquifers - N100ALLUVL

aquifer_national	**NGWMN-Name**	**Latitude**	**Longitude**	**County**	**Aquifer type**	**Monitoring Category**
N100ALLUVL	MBMG-3977	48.829	-108.564	BLAINE	UNCONFINED	Trend
N100ALLUVL	MBMG-140369	48.834	-108.456	BLAINE	UNCONFINED	Trend
N100ALLUVL	MBMG-122839	47.823	-110.669	CHOUTEAU	CONFINED	Trend
N100ALLUVL	MBMG-32717	47.369	-104.556	DAWSON	UNCONFINED	Trend
N100ALLUVL	MBMG-257677	45.270	-111.298	GALLATIN	UNCONFINED	Trend
N100ALLUVL	MBMG-149986	48.582	-109.628	HILL	UNCONFINED	Trend
N100ALLUVL	MBMG-41464	48.329	-111.144	LIBERTY	UNCONFINED	Trend

N100ALLUVL	MBMG-96983	45.657	-110.574	PARK	UNCONFINED	Trend
N100ALLUVL	MBMG-148500	46.779	-105.303	PRAIRIE	UNCONFINED	Trend
N100ALLUVL	MBMG-150965	48.122	-104.474	RICHLAND	UNCONFINED	Trend
N100ALLUVL	MBMG-78891	47.919	-112.178	TETON	UNCONFINED	Trend
N100ALLUVL	MBMG-45679	48.674	-106.215	VALLEY	UNCONFINED	Trend
N100ALLUVL	MBMG-98056	45.690	-108.780	YELLOWSTONE	UNCONFINED	Trend
N100ALLUVL	MBMG-158554	46.140	-107.556	YELLOWSTONE	UNCONFINED	Trend
N100ALLUVL	MBMG-158589	45.705	-108.644	YELLOWSTONE	UNCONFINED	Trend

Sand and gravel aquifers - Glacial regions - N100GLCIAL

aquifer_national	NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category
N100GLCIAL	MBMG-121622	47.521	-111.716	CASCADE	UNCONFINED	Trend
N100GLCIAL	MBMG-136927	47.504	-111.090	CASCADE	CONFINED	Trend
N100GLCIAL	MBMG-4287	48.965	-105.453	DANIELS	UNCONFINED	Trend
N100GLCIAL	MBMG-140484	48.525	-109.802	HILL	UNCONFINED	Trend
N100GLCIAL	MBMG-3802	48.607	-108.254	PHILLIPS	UNCONFINED	Trend
N100GLCIAL	MBMG-3539	48.223	-104.931	ROOSEVELT	UNCONFINED	Trend
N100GLCIAL	MBMG-3766	48.491	-104.454	SHERIDAN	CONFINED	Trend
N100GLCIAL	MBMG-3769	48.498	-104.281	SHERIDAN	CONFINED	Trend
N100GLCIAL	MBMG-155732	48.438	-107.263	VALLEY	UNCONFINED	Trend

Lower Tertiary aquifers - N300LTRTRY

aquifer_national	NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category
N300LTRTRY	MBMG-161429	45.017	-109.172	CARBON	UNCONFINED	Trend
N300LTRTRY	MBMG-197444	45.336	-109.164	CARBON	UNCONFINED	Trend
N300LTRTRY	MBMG-199495	45.225	-109.222	CARBON	CONFINED	Trend
N300LTRTRY	MBMG-183561	46.244	-105.272	CUSTER	UNCONFINED	Trend
N300LTRTRY	MBMG-4227	48.999	-105.464	DANIELS	UNCONFINED	Trend
N300LTRTRY	MBMG-4248	48.983	-105.519	DANIELS	CONFINED	Trend
N300LTRTRY	MBMG-2384	47.384	-104.914	DAWSON	UNCONFINED	Trend
N300LTRTRY	MBMG-138227	47.080	-104.949	DAWSON	CONFINED	Trend

N300LTRTRY	MBMG-137973	47.414	-104.726	DAWSON	UNCONFINED	Trend
N300LTRTRY	MBMG-143948	46.355	-104.551	FALLON	CONFINED	Trend
N300LTRTRY	MBMG-31087	47.324	-106.915	GARFIELD	UNCONFINED	Trend
N300LTRTRY	MBMG-132734	47.120	-106.104	GARFIELD	UNCONFINED	Trend
N300LTRTRY	MBMG-157581	47.753	-105.492	MCCONE	UNCONFINED	Trend
N300LTRTRY	MBMG-120639	47.299	-105.765	MCCONE	UNCONFINED	Trend
N300LTRTRY	MBMG-122303	46.512	-108.205	MUSSELSHELL	UNCONFINED	Trend
N300LTRTRY	MBMG-1575	46.359	-108.441	MUSSELSHELL	UNCONFINED	Trend
N300LTRTRY	MBMG-9950	45.828	-110.561	PARK	CONFINED	Trend
N300LTRTRY	MBMG-8863	45.081	-105.863	POWDER RIVER	CONFINED	Trend
N300LTRTRY	MBMG-105007	45.215	-106.270	POWDER RIVER	CONFINED	Trend
N300LTRTRY	MBMG-183565	45.427	-105.918	POWDER RIVER	UNCONFINED	Trend
N300LTRTRY	MBMG-1845	46.841	-105.319	PRAIRIE	UNCONFINED	Trend
N300LTRTRY	MBMG-132904	46.963	-105.516	PRAIRIE	CONFINED	Trend
N300LTRTRY	MBMG-143791	46.789	-104.849	PRAIRIE	UNCONFINED	Trend
N300LTRTRY	MBMG-36423	47.781	-104.246	RICHLAND	UNCONFINED	Trend
N300LTRTRY	MBMG-210	45.832	-106.708	ROSEBUD	UNCONFINED	Trend
N300LTRTRY	MBMG-183559	45.411	-106.455	ROSEBUD	CONFINED	Trend
N300LTRTRY	MBMG-206	45.832	-106.708	ROSEBUD	UNCONFINED	Trend
N300LTRTRY	MBMG-1115	45.881	-106.592	ROSEBUD	UNCONFINED	Trend
N300LTRTRY	MBMG-3772	48.555	-104.182	SHERIDAN	UNCONFINED	Trend
N300LTRTRY	MBMG-182531	48.794	-104.354	SHERIDAN	UNCONFINED	Trend
N300LTRTRY	MBMG-150349	45.495	-109.459	STILLWATER	UNCONFINED	Trend
N300LTRTRY	MBMG-185284	45.491	-109.486	STILLWATER	UNCONFINED	Trend
N300LTRTRY	MBMG-138914	45.925	-109.915	SWEET GRASS	UNCONFINED	Trend
N300LTRTRY	MBMG-47501	48.849	-106.251	VALLEY	UNCONFINED	Trend
N300LTRTRY	MBMG-136678	46.947	-104.081	WIBAUX	UNCONFINED	Trend
N300LTRTRY	MBMG-31653	47.318	-104.100	WIBAUX	UNCONFINED	Trend
N300LTRTRY	MBMG-18368	46.241	-108.220	YELLOWSTONE	UNCONFINED	Trend

Upper Cretaceous aquifers - N300UPCTCS

aquifer_national	**NGWMN-Name**	**Latitude**	**Longitude**	**County**	**Aquifer type**	**Monitoring Category**

N300UPCTCS	MBMG-3563	48.366	-109.264	BLAINE	UNCONFINED	Trend
N300UPCTCS	MBMG-95030	45.781	-104.421	CARTER	CONFINED	Trend
N300UPCTCS	MBMG-3384	48.206	-110.355	CHOUTEAU	CONFINED	Trend
N300UPCTCS	MBMG-35402	47.613	-110.108	CHOUTEAU	CONFINED	Trend
N300UPCTCS	MBMG-36883	47.855	-110.387	CHOUTEAU	CONFINED	Trend
N300UPCTCS	MBMG-38260	48.020	-109.941	CHOUTEAU	CONFINED	Trend
N300UPCTCS	MBMG-171183	46.426	-105.876	CUSTER	CONFINED	Trend
N300UPCTCS	MBMG-121589	47.117	-104.735	DAWSON	UNCONFINED	Trend
N300UPCTCS	MBMG-2333	47.395	-109.137	FERGUS	CONFINED	Trend
N300UPCTCS	MBMG-2743	47.644	-109.311	FERGUS	CONFINED	Trend
N300UPCTCS	MBMG-32119	47.378	-109.830	FERGUS	CONFINED	Trend
N300UPCTCS	MBMG-128313	47.624	-108.704	FERGUS	CONFINED	Trend
N300UPCTCS	MBMG-27377	47.039	-107.553	GARFIELD	CONFINED	Trend
N300UPCTCS	MBMG-31165	47.310	-106.911	GARFIELD	CONFINED	Trend
N300UPCTCS	MBMG-147175	47.339	-106.371	GARFIELD	CONFINED	Trend
N300UPCTCS	MBMG-22380	46.563	-109.116	GOLDEN VALLEY	CONFINED	Trend
N300UPCTCS	MBMG-43880	48.565	-109.547	HILL	UNCONFINED	Trend
N300UPCTCS	MBMG-46155	48.741	-110.346	HILL	CONFINED	Trend
N300UPCTCS	MBMG-132221	48.954	-109.554	HILL	CONFINED	Trend
N300UPCTCS	MBMG-43211	48.513	-110.952	LIBERTY	CONFINED	Trend
N300UPCTCS	MBMG-138002	47.825	-106.106	MCCONE	CONFINED	Trend
N300UPCTCS	MBMG-23991	46.720	-108.155	MUSSELSHELL	CONFINED	Trend
N300UPCTCS	MBMG-1388	46.176	-108.613	MUSSELSHELL	CONFINED	Trend
N300UPCTCS	MBMG-25223	45.851	-108.313	PETROLEUM	CONFINED	Trend
N300UPCTCS	MBMG-164863	47.021	-108.262	PETROLEUM	CONFINED	Trend
N300UPCTCS	MBMG-38920	48.078	-107.590	PHILLIPS	CONFINED	Trend
N300UPCTCS	MBMG-38924	48.047	-107.540	PHILLIPS	UNCONFINED	Trend
N300UPCTCS	MBMG-153975	48.495	-108.012	PHILLIPS	UNCONFINED	Trend
N300UPCTCS	MBMG-85046	48.312	-112.255	PONDERA	CONFINED	Trend
N300UPCTCS	MBMG-98860	45.745	-105.091	POWDER RIVER	CONFINED	Trend
N300UPCTCS	MBMG-103306	45.418	-105.457	POWDER RIVER	CONFINED	Trend
N300UPCTCS	MBMG-1846	46.841	-105.319	PRAIRIE	CONFINED	Trend
N300UPCTCS	MBMG-136642	46.749	-104.652	PRAIRIE	CONFINED	Trend

N300UPCTCS	MBMG-152675	45.682	-109.454	STILLWATER	CONFINED	Trend
N300UPCTCS	MBMG-15907	46.071	-109.204	STILLWATER	UNCONFINED	Trend
N300UPCTCS	MBMG-171103	45.559	-109.138	STILLWATER	CONFINED	Trend
N300UPCTCS	MBMG-126044	45.679	-109.157	STILLWATER	CONFINED	Trend
N300UPCTCS	MBMG-90371	48.992	-111.957	TOOLE	CONFINED	Trend
N300UPCTCS	MBMG-1502	46.232	-107.141	TREASURE	CONFINED	Trend
N300UPCTCS	MBMG-3572	48.370	-106.793	VALLEY	UNCONFINED	Trend
N300UPCTCS	MBMG-177421	48.862	-106.478	VALLEY	UNCONFINED	Trend
N300UPCTCS	MBMG-137779	46.447	-109.945	WHEATLAND	UNCONFINED	Trend
N300UPCTCS	MBMG-24903	46.777	-104.464	WIBAUX	CONFINED	Trend
N300UPCTCS	MBMG-1330	46.091	-107.660	YELLOWSTONE	CONFINED	Trend
N300UPCTCS	MBMG-131693	45.805	-108.146	YELLOWSTONE	CONFINED	Trend
N300UPCTCS	MBMG-157936	46.089	-108.221	YELLOWSTONE	UNCONFINED	Trend

Lower Cretaceous aquifers - N300LCRTCS

aquifer_national	NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category
N300LCRTCS	MBMG-2395	47.510	-111.431	CASCADE	CONFINED	Trend
N300LCRTCS	MBMG-30542	47.299	-111.046	CASCADE	UNCONFINED	Trend
N300LCRTCS	MBMG-25200	46.839	-108.644	FERGUS	CONFINED	Trend
N300LCRTCS	MBMG-1872	46.996	-109.509	FERGUS	CONFINED	Trend
N300LCRTCS	MBMG-1862	46.968	-110.092	JUDITH BASIN	UNCONFINED	Trend
N300LCRTCS	MBMG-1929	47.056	-109.953	JUDITH BASIN	CONFINED	Trend
N300LCRTCS	MBMG-27321	47.025	-107.958	PETROLEUM	CONFINED	Trend

Paleozoic aquifers - N500PLOZOC

aquifer_national	NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category
N500PLOZOC	MBMG-2394	47.523	-111.413	CASCADE	CONFINED	Trend
N500PLOZOC	MBMG-28054	47.177	-110.973	CASCADE	CONFINED	Trend
N500PLOZOC	MBMG-216851	47.530	-111.230	CASCADE	CONFINED	Trend
N500PLOZOC	MBMG-120525	47.003	-109.343	FERGUS	UNCONFINED	Trend

Northern Rocky Mountains Intermontane Basins - S100NRMTIB

NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category	Subnetwork
MBMG-108595	45.404	-113.486	BEAVERHEAD	UNCONFINED	Surveillance	Background
MBMG-108966	45.345	-112.594	BEAVERHEAD	UNCONFINED	Surveillance	Background
MBMG-129084	45.776	-113.454	BEAVERHEAD	UNCONFINED	Surveillance	Background
MBMG-129151	45.618	-113.448	BEAVERHEAD	CONFINED	Surveillance	Background
MBMG-149512	45.177	-112.657	BEAVERHEAD	CONFINED	Surveillance	Background
MBMG-88197	48.402	-114.461	FLATHEAD	CONFINED	Surveillance	Background
MBMG-130530	48.072	-113.950	FLATHEAD	CONFINED	Surveillance	Background
MBMG-702934	48.254	-114.127	FLATHEAD	CONFINED	Surveillance	Background
MBMG-148187	48.348	-114.197	FLATHEAD	CONFINED	Surveillance	Background
MBMG-135735	45.802	-111.165	GALLATIN	UNCONFINED	Surveillance	Background
MBMG-91244	45.715	-111.197	GALLATIN	UNCONFINED	Surveillance	Background
MBMG-154593	46.244	-113.348	GRANITE	CONFINED	Surveillance	Background
MBMG-48667	45.859	-112.210	JEFFERSON	CONFINED	Surveillance	Background
MBMG-49147	45.884	-112.091	JEFFERSON	UNCONFINED	Surveillance	Background
MBMG-121965	46.071	-111.902	JEFFERSON	CONFINED	Surveillance	Background
MBMG-191532	46.728	-112.036	LEWIS AND CLARK	UNCONFINED	Surveillance	Background

MBMG-132577	48.399	-115.845	LINCOLN	CONFINED	Surveillance	Background
MBMG-159523	47.304	-115.093	MINERAL	UNCONFINED	Surveillance	Background
MBMG-21567	45.556	-110.576	PARK	UNCONFINED	Surveillance	Background
MBMG-102486	45.374	-110.686	PARK	UNCONFINED	Surveillance	Background
MBMG-104586	45.205	-110.894	PARK	UNCONFINED	Surveillance	Background
MBMG-134562	46.598	-112.600	POWELL	CONFINED	Surveillance	Background
MBMG-136050	46.312	-114.186	RAVALLI	UNCONFINED	Surveillance	Background
MBMG-136970	46.464	-114.030	RAVALLI	UNCONFINED	Surveillance	Background
MBMG-136486	46.632	-114.062	RAVALLI	UNCONFINED	Surveillance	Background
MBMG-6283	47.714	-114.649	SANDERS	CONFINED	Surveillance	Background
MBMG-4483	45.955	-112.506	SILVER BOW	UNCONFINED	Surveillance	Background
MBMG-892116	46.010	-112.562	SILVER BOW	CONFINED	Surveillance	Background

Alluvial aquifers - N100ALLUVL

NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category	Subnetwork
MBMG-78891	47.919	-112.178	TETON	UNCONFINED	Surveillance	Background

Sand and gravel aquifers - Glacial regions - N100GLCIAL

NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category	Subnetwork

MBMG-121622	47.521	-111.716	CASCADE	UNCONFINED	Surveillance	Background
MBMG-3802	48.607	-108.254	PHILLIPS	UNCONFINED	Surveillance	Background
MBMG-3539	48.223	-104.931	ROOSEVELT	UNCONFINED	Surveillance	Background
MBMG-3766	48.491	-104.454	SHERIDAN	CONFINED	Surveillance	Background

Lower Tertiary aquifers - N300LTRTRY

NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category	Subnetwork
MBMG-4227	48.999	-105.464	DANIELS	UNCONFINED	Surveillance	Background
MBMG-4248	48.983	-105.519	DANIELS	CONFINED	Surveillance	Background
MBMG-2384	47.384	-104.914	DAWSON	UNCONFINED	Surveillance	Background
MBMG-137973	47.414	-104.726	DAWSON	UNCONFINED	Surveillance	Background
MBMG-157581	47.753	-105.492	MCCONE	UNCONFINED	Surveillance	Background
MBMG-1575	46.359	-108.441	MUSSELSHELL	UNCONFINED	Surveillance	Background
MBMG-8863	45.081	-105.863	POWDER RIVER	CONFINED	Surveillance	Background
MBMG-1845	46.841	-105.319	PRAIRIE	UNCONFINED	Surveillance	Background
MBMG-210	45.832	-106.708	ROSEBUD	UNCONFINED	Surveillance	Background
MBMG-183559	45.411	-106.455	ROSEBUD	CONFINED	Surveillance	Background
MBMG-206	45.832	-106.708	ROSEBUD	UNCONFINED	Surveillance	Background
MBMG-1115	45.881	-106.592	ROSEBUD	UNCONFINED	Surveillance	Background

Appendix II – Montana NGWMN wells – Water-Quality Network Wells

Upper Cretaceous aquifers - N300UPCTCS

NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category	Subnetwork
MBMG-2333	47.395	-109.137	FERGUS	CONFINED	Surveillance	Background
MBMG-2743	47.644	-109.311	FERGUS	CONFINED	Surveillance	Background
MBMG-22380	46.563	-109.116	GOLDEN VALLEY	CONFINED	Surveillance	Background
MBMG-46155	48.741	-110.346	HILL	CONFINED	Surveillance	Background
MBMG-1388	46.176	-108.613	MUSSELSHELL	CONFINED	Surveillance	Background
MBMG-1846	46.841	-105.319	PRAIRIE	CONFINED	Surveillance	Background
MBMG-1502	46.232	-107.141	TREASURE	CONFINED	Surveillance	Background
MBMG-1330	46.091	-107.660	YELLOWSTONE	CONFINED	Surveillance	Background

Lower Cretaceous aquifers - N300LCRTCS

NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category	Subnetwork
MBMG-2395	47.510	-111.431	CASCADE	CONFINED	Surveillance	Background
MBMG-30542	47.299	-111.046	CASCADE	UNCONFINED	Surveillance	Background
MBMG-1872	46.996	-109.509	FERGUS	CONFINED	Surveillance	Background
MBMG-1929	47.056	-109.953	JUDITH BASIN	CONFINED	Surveillance	Background

Paleozoic aquifers - N500PLOZOC

NGWMN-Name	Latitude	Longitude	County	Aquifer type	Monitoring Category	Subnetwork
MBMG-2394	47.523	-111.413	CASCADE	CONFINED	Surveillance	Background