Permanent Monitoring Well Network
Nitrate-N Summary Report

2003 – 2008

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Table of Contents

List of Tables

Table Page

Chapter 3

List of Figures

Table Page

Chapter 3

Chapter 1

1.1 Introduction

The Agricultural Sciences Division of the Montana Department of Agriculture includes the Groundwater Protection Program. In 1989, the Montana Agricultural Chemical Ground Water Protection Act was passed (Montana Department of Agriculture, 2005). MCA 80-15-103 states that it is the policy of the state to:

(1) protect ground water and the environment from impairment or degradation due to the use of agricultural chemicals
(2) allow for the proper and correct use of agricultural chemicals
(3) provide for the management of agricultural chemicals to prevent, minimize, and mitigate their presence in ground water
(4) provide for education and training of agricultural chemical applicators and the general public on ground water protection, agricultural chemical use, and the use of alternative agricultural chemicals

As part of its directive, the Groundwater Protection Program samples groundwater and surface water to determine the presence and concentrations of pesticides and fertilizers. The Permanent Monitoring Well (PMW) network consists of 44 monitoring wells located throughout the major agricultural regions in the state. In addition, investigative and special projects are conducted in vulnerable areas, watersheds, and urban environments.

The summary is presented as stand-alone data. Data in this report include the observations made by the Montana Department of Agriculture in the analysis of samples collected from the PMW network from 2003 through 2008.

Groundwater sampling by the MDA in Montana for nitrate-N is primarily focused on wells in areas with known or suspected nitrate detections and is concentrated in areas dominated by agriculture.

1.2 Objectives

The objectives of this compilation are to provide a concise summary of the range of concentrations of NO_3-N found in groundwater samples collected from the PMW network from 2003 through 2008. Simple summary statistics will be presented in order to provide a description of groundwater NO_3-N characteristics encountered in different regions of the state. In addition, NO_3-N data collected in the course of special projects executed by MDA will also be reviewed. This report will offer a baseline of observations and provide a resource for managers, producers, and other professionals with known findings of nitrate-N concentrations in groundwater in Montana.

Chapter 2

2.1 Methods

Groundwater sampling by the MDA is primarily focused on wells in areas with known or suspected nitrate detections and is concentrated in areas dominated by agriculture. The monitoring network has continuously expanded with 26 new wells completed from 2004-2007. A complete list of the locations and installation dates for all wells may be found in Appendix B.

Water samples from the PMW network were collected twice a year when possible. Well casing volumes were purged three times and water variables including pH, specific conductance, dissolved oxygen, and temperature were stabilized before a sample was collected. Samples were stored in labeled amber glass bottles and kept at approximately 4°C prior to and in transport to the laboratory. All field collection procedures are outlined in Standard Operating Procedures (SOPs) utilized by the Groundwater Protection Program in the collection and documentation of groundwater samples. Samples were analyzed at the Montana Department of Agriculture Analytical Laboratory Bureau using the ion chromatography method for nitrate/nitrite analysis and the electrode method when only nitrate was requested.

2.2 Data analysis

Summary statistics were utilized for comparisons between populations. Percent exceedance values were based on the accepted background nitrate-N concentrations in groundwater (≤ 2 mg L^{-1}) and the US EPA drinking water standard (≥ 10 mg L^{-1}) and were generated to highlight the incidence of NO_3-N concentrations found at or above a given concentration. These are procedures most often used by the United States Geological Survey (USGS) as part of the National Water-Quality Assessment Program and by other states such as the Minnesota Department of Agriculture. Individual well analyses were also performed in order to identify significant changes over time in groundwater NO_3-N concentrations.

Criteria for data inclusion incorporated all observations because a LOD (Limit of Detection) does not exist for NO_3-N. The Limit of Quantification (LOQ) for NO_3-N is 1.0 ppm. Therefore, all ND observations (non-detections) were assumed to be equal to zero. It was the interest of the author to provide as succinct and comprehensive a summary as the data would allow.

Due to the limitations of the monitoring network and the limited number of samples collected yearly from the monitoring wells, results are limited to the cropping systems and environmental conditions (precipitation, temperature, soil texture, etc.) found in proximity of the PMWs from which the samples were collected. The results reflect a snapshot of groundwater conditions, but are likely not comprehensive.

In addition to the PMW network data, all other nitrate-N data collected by the MDA from 2003-2008 was also analyzed for means of comparison. These data included several special projects that involved more intensive sampling designs over a single growing season in a specific geographic region.

Chapter 3

3.1 Permanent Monitoring Well Network

A total of 285 nitrate-N samples were collected from the PMW network from 2003-2008. An additional 203 nitrate-N samples were collected from special projects executed in different regions throughout the state. These data are included in Table 3.3.1. Initial analysis of the PMW data found that data points from three PMWs (B-2, GLA-1, and TH-1) were gross outliers of the sample distribution (*n* = 22). All data points from these three PMWs were observed to be outliers in the initial sample distribution and were excluded from the statewide analysis as they were unrepresentative and their inclusion skewed the distribution. Results from these wells may be found in Section 3.2.

For this analysis, 263 groundwater samples were collected for nitrate-N. Summary statistics and percent exceedance values are found in Table 1. The median concentration was 2.5 mg L^{-1} with 53.6% of the samples greater than the accepted background concentration of 2 mg L^{-1} and ~18% of samples greater than the water quality standard of 10 mg L^{-1}. Outliers are still present in the distribution, but came from several different PMWs and no PMW was only represented by outlier observations in the boxplot diagram. A boxplot of all PMW observations without the outlier well data from the PMWs B-2, GLA-1, and TH-1 is displayed (Figure 3.1.1.).

Table 3.1.1. Summary statistics for the PMW network (2003-2008)

							Percent exceedance	
	n*	**Mean**	**SE Mean**	**St Dev**	**Median**	**Maximum**	**> 2 mg L^{-1}**	**≥10 mg L^{-1}**
Statewide	263	5.373	0.495	8.029	2.5	68	53.6%	17.9%

**n* = sample population; number of data points available for analysis

Fig. 3.1.1. Boxplot of nitrate-N concentrations for the PMW network (2003-2008)

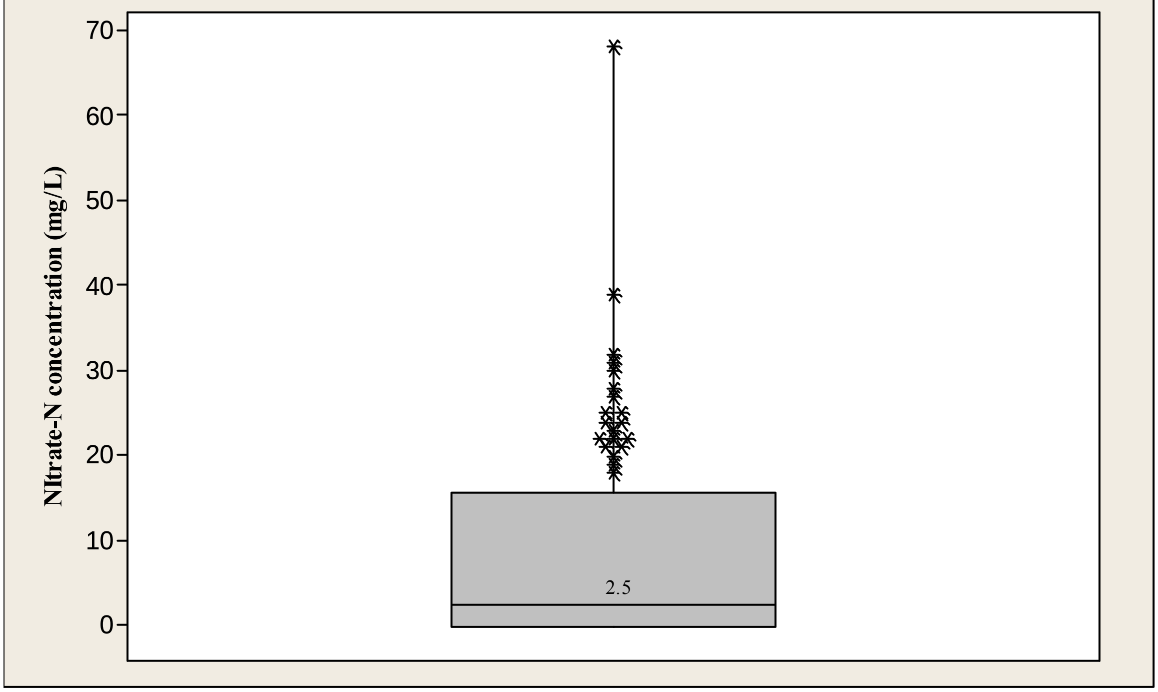
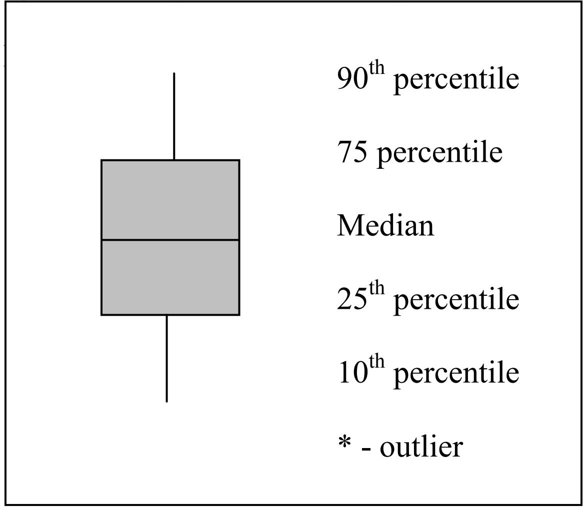
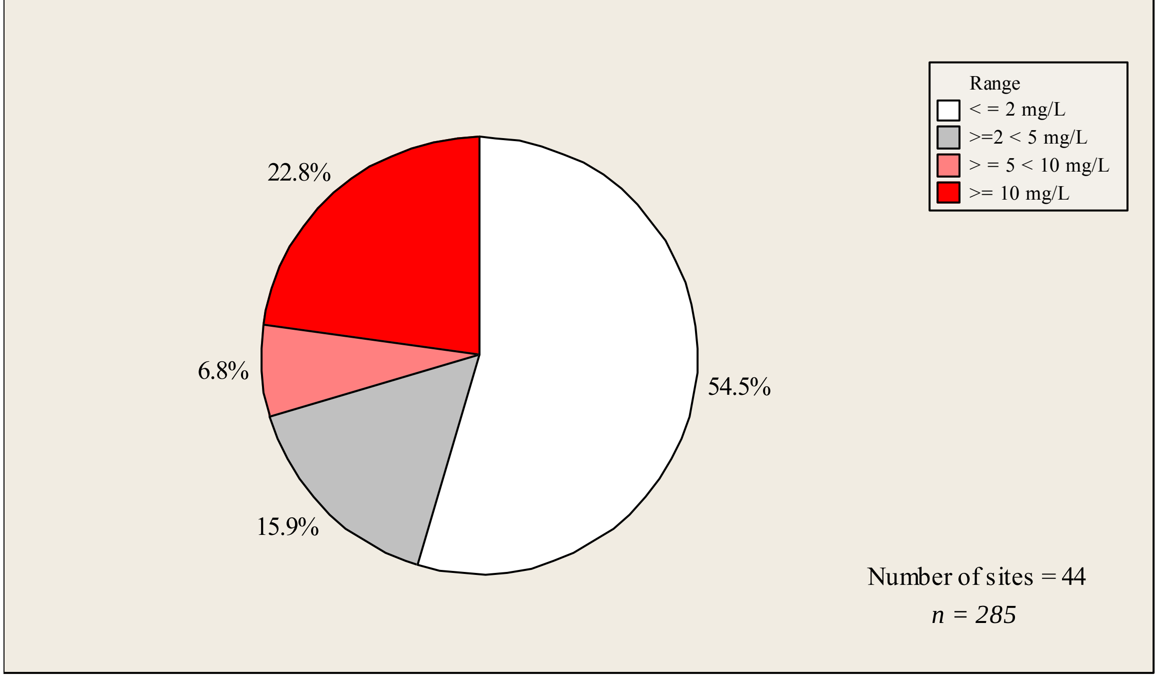


Fig. 3.1.2. Explanation of boxplot schematic



In Figure 3.1.3., the distribution of median NO_3-N concentrations by PMW (2003-2008) is shown. In order to provide a complete picture, Figure 3.1.3. includes data from the 3 gross outlier wells. Nearly a quarter (22.7%) of the PMWs had median observations greater than 10 mg L^{-1}. Over half (54.5%) of the wells did not exhibit NO_3-N concentrations greater than accepted background levels in groundwater. It is important to note that only 14 of the 44 wells were constructed prior to 2003. Therefore, only these 14 wells were sampled every year in the period analyzed (2003-2008).

Fig. 3.1.3. Distribution of median nitrate-N concentrations by PMW (2003-2008)



3.2 *PMW Individual Well Analysis*

Individual permanent monitoring wells were categorized using median NO_3-N values for each well over the study period (2003-2008) (Figure 3.2.1.). For wells with median ≥ 10 mg L^{-1}, 7 of the 10 are found along the northern tier of the state including the PMWs B-2, GLA-1 and TH-1 that were found to be distinct outliers (Table 3.2.1.). Well B-2 is located in Pondera County in the Marias watershed. Wells GLA-1 and TH-1 are both in the Milk watershed and are located in Glacier and Blaine Counties respectively. The datasets for these individual wells were not large enough to generate boxplot diagrams.

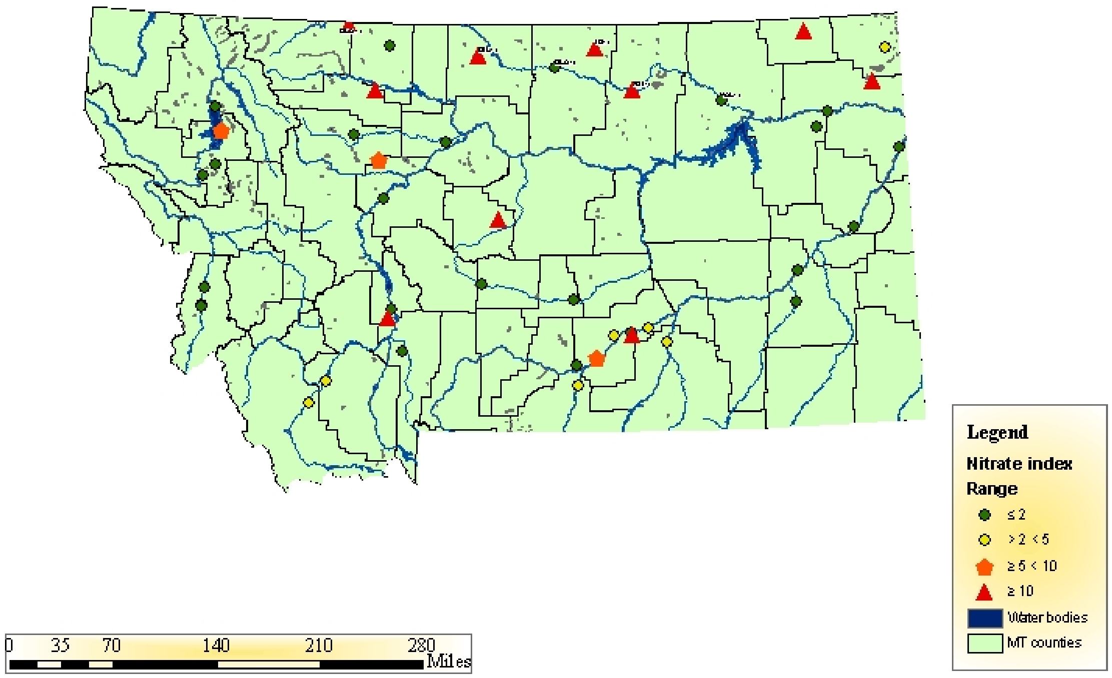
Table 3.2.1. Summary statistics and percent exceedance values for outlier wells (2003-2008)

PMW ID	*n*	Mean	SE Mean	St Dev	Median	Max.	Percent exceedance > 2 mg L^{-1}	 ≥ 10 mg L^{-1}
B-2	8	158.25	2.79	7.89	160.0	172	100.0%	100.0%
GLA-1	8	43.50	2.82	7.98	46.5	52	100.0%	100.0%
TH-1	6	25.17	1.17	2.86	24.0	30	100.0%	100.0%

**n* = sample population; number of data points available for analysis

The three PMWs with high median nitrate values not located in the northern tier are located south of Canyon Ferry Lake (T-1), west of Lewistown (M-1), and along the Yellowstone River east of Billings (Y-2) respectively. Nearly half (21 of 44) of the monitoring wells have concentrations greater than accepted background levels (2 mg L^{-1}) of NO_3-N in groundwater. A complete table of all PMWs with NO_3-N data and 2000 census information may be found in Appendix A. The census data was included to identify the potential number of persons affected by shallow groundwater nitrate concentrations.

Figure 3.2.1.
Montana Department of Agriculture
Median nitrate-N index by PMW

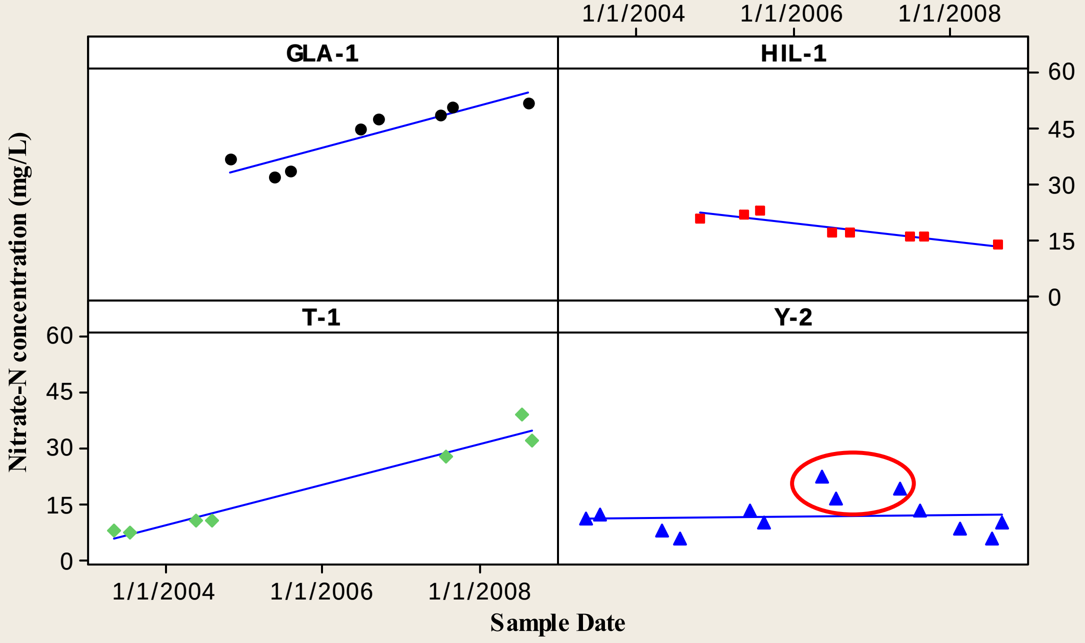


One-way analysis of variance was performed on PMWs with median NO_3-N concentrations ≥ 5 mg L^{-1}. Sample year was used as the response variable. Due to the relatively small number of observations per PMW, this is not a strong statistical model, but the most practical way to determine if NO_3-N concentrations are changing significantly in wells with median NO_3-N concentrations $\geq 50\%$ of the human health standard (10 mg L^{-1}). It should also be noted that several PMWs had datasets too small to be effectively analyzed.

Three wells were observed to have significantly increasing NO_3-N concentrations ($\alpha = 0.05$; $P \leq 0.05$). GLA-1 has a median concentration of 43.50 mg L^{-1} NO_3-N and is located in the northeastern corner of Glacier County ($P = 0.007$). T-1 is located south of Canyon Ferry Lake near Toston (med. = 11.00 mg L^{-1} NO_3-N; $P = 0.006$) and Y-2 is located near the Yellowstone River east of Billings (med. = 11.00 mg L^{-1} NO_3-N; $P = 0.017$). One well was found to have significantly decreasing NO_3-N concentrations over time ($\alpha = 0.05$; $P \leq 0.05$). PMW HIL-1 is located in central Hill County (med. = 17.00 mg L^{-1} NO_3-N; $P = 0.001$). All four of these PMWs have median concentrations of NO_3-N greater than the human health standard for drinking water.

In Figure 4, scatter plots by PMW display the NO_3-N concentrations in GLA-1, HIL-1, T-1 and Y-2 over the sample period (2003-2008). It is important to note that PMWs are not consistently sampled twice a year due to the size of the network and lab scheduling. Significant increases were observed in 2006 thru 2008 at GLA-1 and in 2007 and 2008 at T-1. A significant increase in NO_3-N was observed in 2006 before decreasing in late 2007 and 2008 at well Y-2. At HIL-1, a significant decrease was observed for every subsequent field season over the study period.

Figure 3.2.2. PMWs with significant changes in nitrate-N over time (alpha=0.05)



It may be in the interests of the Department of Agriculture to research the changing NO_3-N concentrations observed in the GLA-1, HIL-1 and T-1 PMWs and establish the cause(s) or influential variables responsible. At Y-2, the increase in NO_3-N in 2007 may be linked to crop rotation or climatic variables. Further study may be warranted.

3.3 Special Investigation MDA Projects

As part of the Groundwater Protection Program, specific regions are targeted for more concentrated sampling efforts every year. A statistical summary and percent exceedance values were generated to provide ancillary NO_3-N data. These are supporting data highlighting results from more region-specific, intensive sampling projects since 2003.

Table 3.3.1. Summary statistics and percent exceedance values for special investigation projects (2003-2008)

							Percent exceedance	
Project Name	**N**	**Mean**	**SE Mean**	**St Dev**	**Median**	**Max.**	**> 2 mg L^{-1}**	**≥10 mg L^{-1}**
2005 Flathead Lake Delta	6	3.95	2.91	7.12	0.50	18.0	33.3%	16.7%
2005 Yellowstone River Valley	30	3.153	0.822	4.502	1.35	17.0	43.3%	6.7%
2005-06 Helena Valley	13	1.408	0.669	2.412	0.0	8.0	15.4%	0.0%
2006 Gallatin Valley	56	1.582	0.500	1.498	1.35	7.8	35.7%	0.0%
2007 Beaverhead/Ruby Valleys	52	0.808	0.135	0.971	0.0	2.9	11.5%	0.0%
2008 Bitterroot Valley	46	1.737	0.508	3.449	1.05	17.0	26.1%	4.3%

*n = sample population; number of data points available for analysis

Nitrate-N in groundwater was not found to be of great concern. There is some evidence of elevated NO_3-N concentrations from anthropogenic sources in the Flathead Lake Delta and the Yellowstone River valley as the percent exceedance values suggest (Table 3.3.1.) Investigations in the intermontane valleys in southwestern MT have found some NO_3-N concentrations in excess of accepted background levels, but, in general, these aquifers have not been impacted as severely by nitrate-N as other areas of the state. The Bitterroot Valley investigation had a few samples in exceedance of the human health standard, but had much fewer samples impacted by anthropogenic additions than in the Yellowstone River Valley as reflected in Table 3.3.1. None of these special projects were located in regions of intensive dryland-farming practices, but have been concentrated in intermontane valleys of western and southwestern Montana. Future special projects may focus on more rural, xeric regions of the state where dryland farming is the main form of agriculture.

Chapter 4

4.1 Discussion

Over the long term there are three primary controlling factors affecting the amount of nitrate that reaches groundwater: (1) amount of N source available; (2) amount of infiltrating or percolating water (and the hydraulic conductivity of the surface and subsurface material); (3) and the potential for nitrate reduction and/or denitrification (Canter, 1997). Water is the most limiting factor to plant growth in Montana highlighting the importance of irrigation and the prevalence of dryland cropping systems in the state. Of the approximately 16.5 million acres of cropland in production in Montana in 2007, 14.5 million acres are dryland and 2 million are irrigated (Clark, 2009). Bauder et al. (1993) observed that summer fallow practices and associated mineralization of organic matter may contribute to regional NO_3-N contamination of shallow groundwater in Montana.

Analysis of the Permanent Monitoring Well network database found a range of concentrations between wells in the network. In reviewing the median NO_3-N concentrations for each PMW for the period 2003-2008, a few distinct patterns emerge. The majority of PMWs reporting median NO_3-N concentrations ≥ 10 mg L^{-1} are located along the Hi-Line in north-central and northeastern MT. These regions have the greatest number of planted acres and the highest N fertilizer sales in the state (MT Department of Agriculture data). Agriculture along the northern tier of Montana is dominated by dryland crop-fallow production of small grains (spring wheat, winter wheat, barley, and durum). Irrigated agriculture is utilized in river basins such as near the Teton and Marias Rivers in north-central Montana and the Milk and Lower Missouri Rivers in northeastern Montana. Interestingly, PMWs located in the proximity to the river bottoms of the Lower Missouri and Lower Yellowstone rivers were found to have low median

NO_3-N concentrations. This may be due to dilution effects of irrigated agriculture in these regions.

Much of northern Montana has little topographic relief and is almost entirely covered by a continuous deposit of glacial detritus from the Laurentide Ice Sheet. The Laurentide Ice Sheet covered much of northern Montana east of the Rocky Mountain Front skirting around the Bears Paw Mountains. These deposits are generally less than 50 feet deep. High dissolved solids also typify groundwater in these shallow, unconfined aquifers in this region due to the nature of the glacial deposits and low annual precipitation. Dissolved solids in water from alluvium normally ranges from 300 mg/L to 2,500 mg/L (Noble et al., 1982). The dissolved solids content increases where alluvial deposits are in contact with Cretaceous shale or where it is influenced by salt migration from irrigated areas. The high NO_3-N concentrations are likely most closely linked with the crop-fallow small grains rotation so commonly practiced in central and eastern Montana.

Fine-grained aquifers composed of glacial till have been studied extensively in Montana because of their proclivity for saline seep development. Saline seeps are *intermittent or continuous saline-water discharge at or near the soil surface, downslope from recharge areas, under dryland conditions, that reduces or eliminates crop growth in the affected area because of increased soluble-salt concentrations in the root zone* (Miller and Bergantino, 1983). These seeps tend to develop where groundwater recharge is increased by crop-fallow farming practices. During the fallow rotation, the soil surface is exposed with minimal cover to encourage water storage in the solum. In crop-fallow systems, fields are fallowed for 21 of 24 months versus continuous cropping or re-crop systems where fields are fallowed for 18 of 24 months. However, soil storage efficiency is only 25-35% depending on soil texture and hydraulic transmissivity. Increased recharge to groundwater mobilizes salts, including NO_3-N, in solution. Groundwater then discharges the dissolved salts often in a low-lying area or at the base of a slope, where the groundwater discharges to the surface. The water then evaporates leaving salt deposits behind.

In a study on the Fort Peck Indian Reservation in northeast MT, the USGS found that NO_3-N concentrations were ≥ 10 mg L^{-1} in 84% of the 45 wells completed in the Flaxville aquifer and in samples from more than half of the 112 wells sampled (Nimick and Thamke, 1998). Groundwater in the study area is generally less than 100 feet from the surface and is susceptible to NO_3-N contamination from surface sources. The authors hypothesized that the fallow sequence of dryland agriculture in the region was responsible for the slow release of NO_3-N from soil organic N to groundwater. Interestingly, several PMWs are established in Flaxville gravels or similar formations. These include PMWs TH-1 (med. = 24.0 mg L^{-1} NO_3-N), M-1 (med.= 20.0 mg L^{-1} NO_3-N) and F-1 (med.= 5.40 mg L^{-1} NO_3-N).

The influence of crop-fallow production agriculture on groundwater quality could become more pronounced if large acreages of Conservation Reserve Program (CRP) land are returned to annual crop production. Conversion of CRP land back to agricultural production is happening in Montana. However, based on the re-enrollment data from the Farm Service Agency (FSA), it is not occurring in large acreages. FSA reported that 91% of eligible acres received new contracts or contract extensions for contracts set to expire between 2007 and 2010. This success rate does not account for lands withdrawn from the program under penalty which may account for significant acreages. In addition, the contracts of an additional 1.8 million acres in CRP will expire in Montana between 2011 and 2015.

4.2 Conclusions

Local parameters influencing NO_3-N concentrations at individual PMWs need to be better understood in order to predict NO_3-N concentrations in groundwater on a larger scale. This is especially relevant to those PMWs that have displayed significant changes in NO_3-N concentrations over the study period (2003-2008) and for outlier wells. If the cause(s) can be determined this may prove useful in mitigating high NO_3-N at other locations. In addition, investigation of domestic water supplies in close proximity to PMWs that exceed the human health standard may be warranted to gauge the extent of high NO_3-N concentrations both at depth and distance from the respective PMW. This is critical in areas of high population density where untreated groundwater supplies domestic needs.

In general, nitrate concentrations in groundwater in Montana are not excessive when compared with other agricultural regions in the United States such as California's Central Valley and the Corn Belt in the Midwest. There may be localized regions of high groundwater NO_3-N in Montana, but overall quality is good to excellent particularly in the deep, basin-fill aquifers of the intermontane valleys of western and southwestern Montana.

4.3 Future investigations

The Montana Department of Agriculture may utilize testing of stable isotopes of $\delta^{15}N$ and $\delta^{18}O$ to identify NO_3-N sources in groundwater. This would prove particularly useful if a method could be developed to determine geologic sources of NO_3-N versus agricultural (fertilizer, manure). Special projects should also shift focus from western intermontane valleys to dryland farming regions and communities in central and eastern Montana. In 2009, MDA will conduct a special project in the Judith River sub-basin in the area west of Lewistown, MT. This centralized location could include parts or all of the communities of Moore, Stanford, and

Denton, MT. A case study in this or a similar location will have more applicability to larger regions of the state in contrast to the previous studies performed in the western valleys.

In addition, the Groundwater Protection Program will continue to monitor the wells that have displayed significant changes in NO_3-N concentrations (GLA-1, HIL-1, T-1, and Y-2). It is possible that increases in soil temperatures have led to increases in mineralization of soil N or climatic variables may be leading to a lack or increase in dilution at depth. Changes in crop rotation and land management strategies (i.e. enrollment in the CRP program, change in ownership, etc.) may also be responsible for significant changes in NO_3-N concentrations over time. Again, isotope testing of $\delta^{15}N$ and $\delta^{18}O$ may be utilized to identify the source(s).

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Population Division US Census Bureau (www.census.gov)

Appendix A – Permanent Monitoring Well Statistics

Table A1. Median nitrate-N concentrations and census data by PMW location

			2003-2008 NO_3-N		
MDA Site ID	**Watershed**	**County**	**N**	**Median (mg L^{-1})**	**2000 Population Density (persons sq.mi.)**
B-2	Marias	Pondera	8	160.00	1.34
BEA-1	Upper Missouri	Beaverhead	8	2.10	12.63
BIG-1	Middle Yellowstone	Big Horn	4	2.50	6.13
BLA-1	Milk	Blaine	4	0.00	9.80
BRO-1	Upper Missouri	Broadwater	8	0.60	8.96
CAS-1	Missouri-Sun-Smith	Cascade	4	0.00	10.55
CHO-1	Marias	Chouteau	5	1.10	1.28
CUS-1	Lower Yellowstone	Custer	5	0.00	13.73
CUS-2	Middle Yellowstone	Custer	3	0.00	5.59
DAN-1	Lower Missouri	Daniels	7	13.00	1.20
DAW-2	Lower Yellowstone	Dawson	8	0.00	4.00
E-1	Upper Yellowstone	Carbon	9	4.00	243.01
F-1	Missouri-Sun-Smith	Teton	11	5.40	5.68
FLA-1	Flathead	Flathead	4	0.00	11.80
GAL-1	Upper Missouri	Gallatin	5	1.30	67.12
GLA-1	Milk	Glacier	8	46.50	11.49
HIL-1	Milk	Hill	8	17.00	0.00
L-1	Musselshell	Golden Valley	6	0.00	14.25
LAK-1	Flathead	Lake	9	7.40	118.53
LAK-2	Lower Clark Fork	Lake	5	0.00	21.10
M-1	Middle Missouri	Judith Basin	7	20.00	3.00
MAD-1	Upper Missouri	Beaverhead	4	3.10	2.52
PHI-1	Milk	Phillips	4	12.50	10.80
R-3	Lower Clark Fork	Lake	6	0.55	79.83
RAV-1	Upper Clark Fork	Ravalli	4	0.00	92.95
RAV-2	Upper Clark Fork	Ravalli	4	0.00	127.10
RAV-3	Upper Clark Fork	Ravalli	4	1.40	36.50
RIC-1	Lower Yellowstone	Richland	8	0.00	15.93
RIC-2	Lower Missouri	Richland	3	0.00	0.50
ROS-1	Lower Missouri	Roosevelt	4	26.00	10.03
SHE-1	Lower Missouri	Sheridan	4	3.05	2.00
T-1	Missouri-Sun-Smith	Broadwater	7	11.00	10.31
TD-1	Musselshell	Wheatland	6	0.00	1.29
TET-1	Missouri-Sun-Smith	Teton	9	1.30	8.07
TH-1	Milk	Blaine	6	24.00	2.00
TOL-1	Marias	Toole	4	0.00	0.89
VAL-1	Milk	Valley	7	1.80	6.13
W-1	Lower Missouri	McCone	4	0.00	0.80
Y-1	Middle Yellowstone	Yellowstone	6	1.30	28.54
Y-2	Middle Yellowstone	Yellowstone	13	11.00	39.39
Y-3	Middle Yellowstone	Yellowstone	12	4.55	28.13
Y-4	Upper Yellowstone	Yellowstone	6	0.00	17.83
Y-5	Middle Yellowstone	Yellowstone	10	3.80	113.31
Y-6	Middle Yellowstone	Yellowstone	12	6.85	74.70

**n* = sample population; number of data points available for analysis

Appendix B – PMW well location and length of record

Table B1. Table of PMW network additions in new wells constructed from 2003-2007

			PMW Construction[a]				
MDA Site ID	**Watershed**	**County**	**2003**[b]	**2004**	**2005**	**2006**	**2007**
B-2	Marias	Pondera	*X*				
BEA-1	Upper Missouri	Beaverhead		*X*			
BIG-1	Middle Yellowstone	Big Horn					*X*
BLA-1	Milk	Blaine		*X*			*X*
BRO-1	Upper Missouri	Broadwater		*X*			
CAS-1	Missouri-Sun-Smith	Cascade					*X*
CHO-1	Marias	Chouteau		*X*			
CUS-1	Lower Yellowstone	Custer					*X*
CUS-2	Middle Yellowstone	Custer					*X*
DAN-1	Lower Missouri	Daniels		*X*			
DAW-2	Lower Yellowstone	Dawson			*X*		
E-1	Upper Yellowstone	Carbon	*X*				
F-1	Missouri-Sun-Smith	Teton	*X*				
FLA-1	Flathead	Flathead					*X*
GAL-1	Upper Missouri	Gallatin					*X*
GLA-1	Milk	Glacier		*X*			
HIL-1	Milk	Hill		*X*			
L-1	Musselshell	Golden Valley	*X*				
LAK-1	Flathead	Lake		*X*			
LAK-2	Lower Clark Fork	Lake			*X*		
M-1	Middle Missouri	Judith Basin	*X*				
MAD-1	Upper Missouri	Beaverhead					*X*
PHI-1	Milk	Phillips					*X*
R-3	Lower Clark Fork	Lake	*X*				
RAV-1	Upper Clark Fork	Ravalli					*X*
RAV-2	Upper Clark Fork	Ravalli					*X*
RAV-3	Upper Clark Fork	Ravalli					*X*
RIC-1	Lower Yellowstone	Richland		*X*			
RIC-2	Lower Missouri	Richland					*X*
ROS-1	Lower Missouri	Roosevelt					*X*
SHE-1	Lower Missouri	Sheridan					*X*
T-1	Missouri-Sun-Smith	Broadwater	*X*				
TD-1	Musselshell	Wheatland	*X*				
TET-1	Missouri-Sun-Smith	Teton		*X*			
TH-1	Milk	Blaine	*X*				
TOL-1	Marias	Toole	*X*				
VAL-1	Milk	Valley		*X*			
W-1	Lower Missouri	McCone	*X*				
Y-1	Middle Yellowstone	Yellowstone	*X*				
Y-2	Middle Yellowstone	Yellowstone	*X*				
Y-3	Middle Yellowstone	Yellowstone	*X*				
Y-4	Upper Yellowstone	Yellowstone	*X*				
Y-5	Middle Yellowstone	Yellowstone	*X*				
Y-6	Middle Yellowstone	Yellowstone	*X*				

[a] No new wells were added to the PMW network in 2006

[b] Includes wells installed prior to 2003