OPHEIM, MONTANA
PWS
SOURCE WATER PROTECTION DELINEATION

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INTRODUCTION

Acknowledgments

This Source Water Protection Plan was completed for the Town of Opheim by the firm of Damschen-Entranco, Helena, Montana.

Purpose

To meet the requirements of the federal SDWA, Public Law 104-182, Montana has implemented a source water protection program in which each community submits a plan for certification review following a format prescribed by the Department of Environmental Quality (DEQ).

This report is intended to meet the technical requirements for the completion of the source water protection delineation for the Town of Opheim Public Water Supply as required by the Safe Drinking Water Act (SDWA) as adapted by the State of Montana.

A source water protection delineation is designed to protect the water used by public water systems from contamination. For ground water-based systems the delineation establishes protected areas overlying the aquifer that is yielding water to the well and extends up-gradient a prescribed distance. For surface water-based systems the delineation establishes protected areas in the drainage basin or watershed upstream from the intake. In either case, the extent of the up-gradient protection area is determined by modeling the aquifer or watershed and projecting the well or intake capture zone to the hydrologic boundary. A "special protection region" is delineated based on a time-of-travel calculation, and this area is then inventoried to identify potential contaminant sources. Management of the potential contaminant sources is considered, priorities are established, and recommendations made to the local governing body. Source-water protection planning is necessary to provide an early warning mechanism if up-gradient contamination occurs. Preventing the contamination of a water supply through education and public awareness, however, remains the primary goal.

Most instances of source water contamination become known when trace levels of a contaminant are detected through routine monitoring. Water systems that have completed a source-water protection plan will have information on ground water flow, aquifer hydraulic characteristics, and/or the surface water flow system. Combining this information with an inventory of contaminant sources will put the system in a good position for determining the appropriate response to ensure the long-term protection of the water supply.

THE COMMUNITY

Demographics. Opheim is an incorporated town located 49 miles north of Glasgow and 10 miles south of the U.S./Canadian border in northeast Montana. Figure 1 shows the general location of the town with respect to Glasgow and Fort Peck Lake. The 1996 Census estimate put the community's population at 145, down from the 1970 Census count of 306. Population in Valley County as a whole has decreased as well, from 15,181 in 1940 to 8,239 in 1990.

Economic Base. Agriculture provides Opheim's economic base with dryland grain the predominant crop. Cattle are grazed on the rotated strip fields and in the coulees. Commercial establishments include a Cenex petroleum, seed, and fertilizer supplier, the Rural Electric Co-op yard, three active grain elevators, two auto repair shops, a hotel and restaurant, an American Legion Hall, and two taverns. Institutions in Opheim include the Post Office, Town Hall, and the local elementary and high schools.

Major Transportation Routes. Montana Highway 24 connects Opheim with Glasgow to the south and Canada to the north (Figure 1). Route 248 runs from Opheim through Glentana and Richland to Scobey, 46 miles to the east. A gravel county road leaves Opheim to the west and serves the agricultural country between Opheim and the Hinsdale/Saco area. Former Great Northern Railroad tracks, now abandoned and removed, dead headed in a switch yard on the south side of town adjacent to the existing three elevators.

Infrastructure. Figure 2 shows the layout of the town site and the surrounding area. The airport, immediately west of town, may be limited to single engine planes due to the length of the airstrip. Opheim is served by a central wastewater collection and treatment system and a community public water system. Figure 3 is a map of the collection system. Originally installed in 1955 using clay tile pipe, the system is comprised of approximately 15,000 feet of 8-inch and 10-inch mains and laterals and approximately 3000 feet of outfall line. According to the wastewater operator, the collection system is in good shape. However, older clay tile pipe typically develops leaks, cracks and mis-aligned joints that can evaluated best after a thorough cleaning and TV inspection. The wastewater treatment lagoons are located north of the airport in the bottom of a coulee at an elevation of about 3185 feet, or about 80 feet lower than the town elevation. According to DEQ, the aging treatment system is a total retention facility that is in need of fairly major improvements due to the combination of age, leakage, embankment deterioration and the routing of storm water runoff from the coulee into the lagoon.

Opheim's public water system, shown in Figure 4, is described in detail in a subsequent section. The system consists of two deep wells, a shallow well, a 50,000 gallon elevated steel storage tank and a distribution system with approximately 23,000 feet of mostly transite pipe.

Industrial/Commercial Activity There is no heavy industrial activity in Opheim but there are two auto repair shops, a transformer/power pole/equipment storage yard for the rural electric co-op, and a farm supply outlet. Truck traffic to and from Canada passes through the center of town on Highway 24.

Geographic Setting

Opheim occupies the southwest quarter of Section 19, Township 36 North, Range 41 East, MPM, approximately 50 miles north of Glasgow (Figure 1). At an elevation of approximately

3,265 feet, this prairie town site sits atop one of the highest benches in the upper reaches of the Poplar River drainage. The West Fork of the Poplar River, draining the area north and east of town, flows to the southeast toward its confluence with the Missouri River near Poplar.

The regional climate is of the continental type with a large annual temperature range. Winters are usually very cold with an average January temperature of 6.5 F^0. A record low winter temperature of -49^{0}F was recorded in January, 1954. Summers are typically warm and sunny with an average June through August temperature of 63.1^{0}F. A high of 105^{0}F was recorded in May, 1988. Precipitation averages 11.7 inches per year with the majority falling as rain between May and September. Nearly all the winter precipitation falls as snow which seldom accumulates to any depth except where blown into drifts.

According to the USDA Soil Conservation Service's Soil Survey of Valley County, Montana, soils in the Opheim vicinity are typically of the Martinsdale and Judith series. The relevant portions of the Soil Survey report are included in Appendix A. The Martinsdale and Judith series soils consist of deep, well drained loams and clay loams that formed in alluvium. Permeability ranges from 0.6 to 2.0 inches per hour with available water capacity ranging from 0.12 to 0.2 inches per inch of soil. Both soil series tend to be moderately alkaline with the Judith series increasing in alkalinity below 36 inches. Native vegetation includes western wheatgrass, needle-and-thread, plains muhly, prairie junegrass, bluebunch wheatgrass, and some forbs.

General Description of the Source Water

The water system in Opheim consists of five wells supplying a typical piping system and a water tower. The wells tap aquifers that lie between 170 and 350 feet below the ground surface and produce between 7 and 40 gallons per minute (gpm). Logs of the wells are included in Appendix B, and the locations of the wells are shown on Figure 2, Figure 3 and Figure 4. Table 1 summarizes some of the attributes of the water-supply wells.

The Park well was drilled in 1958-59, is 305 feet deep and screened or perforated at 285 to 305 feet, 160 to 163 feet and 92 to 95 feet. It was completed with eight-inch diameter steel casing in a boring that is 28 inches in diameter to 260 feet, then 18 inches to 340 feet. The well log notes that it was "gravel packed top to bottom." The well is housed by a frame structure and utilizes a submersible pump. At the time of this writing, the Park well is not servicing the system due to the presence of unacceptable levels of an organic pesticide contaminant.

The Airport well was completed in 1985, and is 350 feet deep. It was completed in a 36-inch diameter hole that reduces to 12-inches in diameter at 95 feet. There is an outer casing that is 12 inches in diameter to 95 feet. This casing is perforated from 80 to 95 feet, and is apparently open at the bottom. There is an "inner" eight-inch diameter steel casing that contains factory-cut 30-slot screens from 90 to 95 feet and from 295 to 335 feet. The well log notes that the hole is gravel packed, but does not note where or if the space between the two steel casings from the surface and 95 feet is filter-packed. It appears that the outer casing has filter packing around its annular space, and is open at 95 feet. The well is housed by a frame structure and utilizes a submersible pump. The initial static water level was measured at 71 feet below grade and the pumping level was reported as 313 feet below grade. Craig Pagel (Montana DEQ, personal communication) reported the static water level at about 132 feet below grade three days after the pump had been turned off, but that water could still be heard cascading down the casing indicating that the well had not yet fully recovered.

The remaining four wells were completed in 2000 and 2001 as part of a major water-supply improvement project. In general, the wells were all cased with steel to about 100 feet to isolate the screened intervals from the uppermost aquifer. The wells are all constructed with five-inch diameter steel inner casings and stainless steel screen. Screened intervals contain filter pack while the remainder of the annular space is filled with granular or pellet bentonite.

Table 1. Summary of water-supply well data, Town of Opheim, Montana

Well	Total Depth (feet)	Collar Elevation (MSL)	Static Water Level (MSL)	Pumping Water Level (MSL)	Pumping Rate (gpm)	Screened Interval (feet below ground level)	Hydraulic Conductivity (cm/sec)
OPP-1	285	3257.5	3040.5	2999.5	7	267-283	2e-04
OPP-2	291	3260.25	3000.21	2966.25	21	231-272	4e-04
OPP-3	327	3258.2	3033.75	2993.2	9	290-325	1e-04
OPP-4 (Airport well)	350	3263	3133.32	2950	40	90-95, 295-335	
OPP-5	167	3264	3186.2	3124	22	147-167	1e-03

The Public Water Supply Distribution System

Opheim's public water system, PWS #00301, serves a population of approximately 145. There are currently 68 residential hookups and 16 commercial hookups for a total of 84 connections. The water system was originally constructed in 1955. Currently, the system consists of two deep wells and one shallow well supplying water to a 50,000 gallon elevated steel tank. Figure 4 shows the location of the water system components and identifies the locations of the wells. Distribution piping comprises approximately 23,300 feet of 8 inch, 6 inch and 4 inch pipe, mostly asbestos cement, with some 11/2 inch and 2 inch galvanized steel lines still in use. At the time of this writing, the Park Well, installed in 1958, has been shut down by the town due to herbicide contamination. The contamination was thought to have originated near one of the grain elevators near the railroad right of way.

At the time of this writing, a major improvement project is underway. The improvements include the replacement of water mains and services, improvements on the Airport well, construction of new pump houses and new telemetry. The figures in this document reflect both the completed and uncompleted improvements.

Water Quality

In general, the water quality of the groundwater in the Opheim area is quite good, considering the water quality of the region generally. The water contains generally high levels of dissolved solids, which is common in the region, and some of the wells show fairly high dissolved iron concentrations. Some basic water-quality data from the system are provided in Appendix C.

In 1993, the herbicide dinoseb was detected in Opheim's water supply. 1993 was the first year that the federal government mandated testing for synthetic organic chemicals (SOC's) in public water supplies. The reported concentrations of dinoseb in water samples were approximately three and one half times the maximum allowable contaminant level (MCL). According to a technical fact sheet provided by the EPA, long-term exposure to this compound can result in decreased body and thyroid weight, degeneration of testes and thickening of the intestinal lining.

Results of soil sampling conducted by the DEQ in 1998 and 1999 indicated the contamination source may have been located in the area surrounding one of the three grain elevators. Migration pathways of the contaminant to the water system have yet to be clearly delineated.

In 1999, unacceptable levels of fecal coliform bacteria were detected in water samples from the shallow BN well east of town. As a result, DEQ required that this well be removed from service, leaving Opheim with only one well free from contamination.

The Montana Department of Environmental Quality Remediation Division, under Multi-Site Cooperative Agreement #V008430 with the US Environmental Protection Agency, has produced a Preliminary Assessment of the scope of contamination in Opheim. A site investigation that included drilling and sampling to the uppermost aquifer has also been completed. Information about these and other publications are included at the end of this document.

Emergency funding was made available to the Town in 1999 as part of the funding required for overall water-system improvements. Improvements include the replacement of water mains and the installation of new water wells. At the time of this writing the water line improvements have not been completed.

DELINEATION

Previous Investigations

There have been a number of investigations concerning the geology of the area around Opheim, but few regional hydrological studies. The geological studies have been conducted by Alden (1932), Collier (1918) and Colton and others (1989). A preliminary site study was conducted by the Montana Department of Environmental Quality (2001; *as* Pagel, 1998). Other studies have been conducted by Damschen & Associates, Inc. (1999), Damschen-Entranco (1999).

Geologic Conditions and Aquifer Characteristics

Geology. The general geology is summarized in Collier (1918) and Alden (1932). The stratigraphic descriptions offered by these two writers are reflected in the well logs that were gathered for this study (Appendix B). The most recent publication is a geologic map of the area compiled by Colton and others (1989). The area is underlain by a sequence of sedimentary deposits typical to the northeastern portion of Montana. A set of cross sections based upon the water-supply wells is included in Appendix D

The uppermost deposit in the area around Opheim appeared in the field to be very similar to widespread glacially-derived diamict (ground moraine), however Colton and others (1989) indicate that the surface is immediately underlain by a Tertiary-aged (Miocene) deposit known as the Ogallala formation equivalent. The material comprises a generally unsorted mass of clay- to cobble-sized clasts, and is very similar in appearance to the ground moraine found widely across north-central and northeastern Montana. This uppermost deposit is commonly less than 10 feet thick.

Underlying the Ogallala formation is a stratum of gravel and sandy gravel known regionally as the Flaxville gravel. This Tertiary-aged (upper Pliocene) gravel deposit is variable in thickness, ranging from a few feet to nearly 100 feet, and is widespread across northern and eastern Montana. It is composed predominately of medium to coarse, iron-stained gravel, with some fairly thick sand beds in places. The formation carries water where the gravel lies atop low-permeability deposits. The Flaxville gravel is considered to be early Pliocene or Miocene (22.5 to 4 million years) in age. According to Alden (1932), the area around Opheim represents the highest bench formed by the Flaxville deposits.

The Flaxville gravel was deposited at an unconformity at the top of the Fort Union formation. The unconformity represents a period of erosion. The Fort Union formation in the area of Opheim comprises a sequence of interbedded sand, clay and coal of Eocene (55 to 40 million years) age. While no outcrops have been described in the available literature, an examination of the geological map provided by Collier (1918) shows that the Fort Union formation thins in the vicinity of Opheim to the point of being completely eroded away just a few miles north and west of town. The sediments composing this deposit are described as generally light-colored to yellow sandstone and shale. Colton and others (1989) also show exposures of the Fort Union formation to occur in the coulees around Opheim.

Conformably underlying the Fort Union formation is the Hell Creek formation, also known in the older literature as the Lance formation. It, too, comprises sands, clays and some carbonaceous deposits, but is generally described as being “somber” in color (Collier, 1918;

Alden, 1932), meaning darker grey or brown. Near Opheim, however, Collier (1918) describes the lower member of the Lance formation as “yellowish and rusty sands grading into arenaceous clay toward its base.” More recent divisions in the stratigraphy include this lower portion of the Lance formation as the Fox Hills formation. Just northwest of Opheim, the Hell Creek formation, defined in the older reports as the upper member of the Lance formation, consists of about 180 feet of “somber” shale and silty sandstone. Both the Hell Creek and Fox Hills formations are considered to be important water resources in eastern Montana (Fetter, 1988). Some contradictory nomenclature was used in earlier reports, but Colton and others (1989) have adopted the Hell Creek and Fox Hills designations.

The older deposits, including the Fox Hills, Hell Creek, Fort Union and, possibly, the Flaxville gravel, all dip gently toward the east on a regional scale (Collier, 1918). There is some variability locally, especially in the Flaxville gravel, which was deposited on an unconformity, or previously-exposed erosional surface. Thus, the base of the gravel is a reflection of the pre-existing topography, and so will follow the drainage patterns established across the top of the Fort Union formation. These patterns may or may not reflect the existing topography.

Aquifer Characteristics. Damschen-Entranco (1999) conducted a hydrogeological investigation to determine the appropriate target(s) for additional water supplies. The study was undertaken in response to the need for overall water system improvements and the presence of a contaminant in the water system. The study performed by the DEQ (Pagel, 1998) was also a response to contamination of the water-supply system.

Flaxville Gravel. A DEQ investigation (MSE-HKM, 2001) has investigated the nature of the Flaxville gravel and did not find it to be water-bearing in the area south and east of the town park.. However, springs on the north side of Opheim along the rims above Roanwood Creek lie at roughly the same elevation as the base of the Flaxville. It may be that the top of the rise upon which Opheim is situated represents a recharge zone for a small saturated zone perched atop the Fort Union formation within the Flaxville gravel. This has yet to be confirmed by field studies, however.

Hell Creek Formation. The water-bearing unit within the Hell Creek formation was investigated at the ground-water monitoring wells denoted as OPMW-1 (Damschen & Associates, Inc., 1999) and OPMW-2 (Damschen-Entranco, 1999). This unit lies 85 to 100 feet beneath the ground surface at Opheim, and is tapped by both of the existing deep wells. The hydraulic conductivity of this aquifer was determined by slug test to be 2.68×10^{-3} centimeters per second (cm/sec), or about 7.6 feet per day (ft/day). Based on static water levels in these and local domestic wells, the Hell Creek aquifer appears to be flowing east-northeast at a gradient of approximately 0.1.

Fox Hills Formation. The contact between the Hell Creek and Fox Hills formations is not well defined in the Opheim area. For the purpose of this document, the Fox Hills formation will be considered as those deposits found deeper than 125 feet below the ground surface and above the top of the Bearpaw shale. The occurrence of groundwater within the Fox Hills is difficult to predict. This is the result of the geological environment in which the Fox Hills formation developed. The sediments were deposited in a deltaic environment which consisted of meandering, low-gradient stream channels cutting mud flats. The result of this is that groundwater today occurs only in the old stream channels, which carried fine sand as bed load. Because the streams meandered and avulsed (changed channel location over time), the depth and location of water-bearing sands are difficult to predict.

The pumping tests that were conducted on seven wells (Damschen-Entranco, 1999; Entranco, 2000) did not show conclusive evidence that the various Fox Hills saturated zones are connected. The drill cuttings between the sand-rich zones were primarily silt and silty clay, so any interconnections are not likely to be very good. The saturated zones are likely expressions of old river channels cutting through a relatively flat outwash plain or delta. Thus, there are apt to be complexes of linear sand bodies that may prove to be relatively isolated from one another locally, even though their respective recharge zones may be proximal.

The static water levels in each of the supply wells varies significantly, probably as a result of the wells being screened within different sand bodies in the Fox Hills formation. However, there are some indications from measurements taken from previously-drilled test wells that the groundwater flow is generally toward the northeast. This compares well with the flow within the overlying Hell Creek formation, which is to the northeast at a gradient of 0.01, as measured by the investigator in 1999. According to Colton (1989) the regional dip falls gently to the northeast as a result of the presence of a structural Bowdoin dome in the vicinity of Malta, Montana, and this fact would support the general direction of groundwater flow.

Pumping tests showed the hydraulic conductivity of the saturated zones to range from 1×10^{-4} cm/sec (~0.3 ft/day) to about 1×10^{-3} cm/sec (~3 ft/day). Given these data, the rate of flow through the Fox Hill aquifer calculated as seepage velocity ($V_s = KI/n$, where V_s = seepage velocity, K = hydraulic conductivity, I = hydraulic gradient, and n = estimated porosity) is on the order of 2.86×10^{-6} cm/sec (0.008 ft/day) to 2.86×10^{-5} cm/sec (0.08 ft/day), assuming a porosity of 0.35 in the silty sand aquifers. The porosity has been estimated on the basis of the experience of the investigator and the poorly-sorted, fine-grained nature of the water-bearing zones.

Existing Ground-Water Contamination. Two investigations of ground-water contamination have been undertaken in Opheim to date (Pagel, 1998; Damschen & Associates, 1999). The reader is referred to these two documents for more specific information. At the time of this writing, the Montana Department of Environmental Quality is working with the U.S. Environmental Protection Agency (EPA) to initiate a detailed investigation to determine the extent of contamination and the migration path that the allowed the contaminant to enter the water-supply system.

What follows is a summary of what is known about the situation. In 1995 the herbicide dinoseb, which has been banned in the U.S. since 1986, was added to the list of analytes for community system water quality testing. In that year, dinoseb was discovered in the Opheim water system in excess of the maximum contaminant level (MCL) of 5 micrograms per liter (µg/l) in samples taken at the Park well. In July, 1998 an initial field investigation was undertaken by the DEQ and the Montana Department of Agriculture to determine the source of the contamination. A subsequent investigation by the DEQ (2000) determined that the soil around a grain elevator contains extremely high concentrations of dinoseb (Figure 5). While a specific source for the contamination has yet to be defined, several possibilities exist, the primary one involving the presence of the railroad line terminus immediately north of the grain elevator. It may be that a large storage container of dinoseb, perhaps a tanker car, leaked a significant quantity of the herbicide. It is also possible that storage containers at the elevator leaked, but the breadth of the contaminated area, the concentrations found in the soil, and the possibility that the herbicide was spilled several decades ago all lead to the conclusion that a large quantity of the contaminant was released in a single event. Regardless of the source, the contamination currently lies within the BN right-of-way and is somehow being transmitted to the Park well. Additional contamination has been found in the Northern Electric Co-op yard (MSE-HKM, 2001).

The migration pathway of the contaminant to the water system has yet to be clearly delineated. Damschen & Associates (1999) and the MSE-HKM (2001) proposed two possible pathways. There is little doubt that the dinoseb has migrated into the Flaxville gravel: There are simply no features, natural or man-made closer to the site that could allow for lateral surface migration of the contamination. Upon migrating into the Flaxville gravel, one of two things is occurring: The dinoseb is either migrating through the Fort Union formation into the Hell Creek aquifer, or it is migrating laterally to the Park well along the top of the Fort Union formation or within a laterally-transmissive stratum within the Fort Union. The final DEQ study (MSE-HKM, 2001) did not ascertain any clear migration pathway.

The crucial aspect of this situation revolves around the construction details of the Park well and the Airport well. The logs of both indicate that they were installed in large-diameter borings and filter-packed with coarse sand throughout their entire lengths. That is, there is no seal in the annular space outside of the well casing. So, not only are two or three saturated zones screened within the same well, but the water can move freely between zones both inside and outside of the casing. Since there is no exterior casing in either hole, contaminants can also easily find a path into the boring, via saturated zones or unsaturated zones above the static water level.

Funding for mitigation or remediation of the situation is not forthcoming from any agency at the time of this writing. It is doubtful that the dinoseb will be removed, or even that it can be removed at a reasonable cost. There is speculation that the release may have occurred as long ago as 1948, and even if it was more recent, the dinoseb has had at least 20 years to migrate. The obvious mitigation with regard to the water-supply system is to completely and thoroughly plug the Park well, which is the only clear remedial path. The DEQ (MSE-HKM, 2001) made a recommendation to abandon the Park well, which may allow for the release of funds for the mitigation process.

Conceptual Models and Assumptions

While a good deal of data are available for the hydrological characterization, the nature of the geology makes some data difficult to collect. In some cases collection of data, such as observation well drawdown data, went beyond the scope and budget of the improvements project. In addition, the geological/hydrogeological situation frustrated attempts to determine some characteristics of the groundwater system underlying Opheim.

Aquifer Characteristics. The geology and hydrostratigraphic units are described above. The most recently-installed wells are screened within the Fox Hills aquifer, which consists of variably-interconnected, confined saturated zones within a matrix of silt and clay. The saturated zones consist of fine-grained silty sand and most likely represent “fossil” stream channels, relicts of their depositional environment. It is likely that lateral fluid migration rates are several orders of magnitude higher than vertical fluid migration rates. Many of the clay strata intercepted during drilling were essentially dry, having only an ambient moisture content, probably on the order of less than ten percent by mass. This clearly indicates that the entire formation is not saturated and that there are significant barriers to the vertical movement of water. Lateral boundaries of this hydrostratigraphic section are arguable. It is the considered opinion of the investigator that attempting to place boundary limits on this particular unit is a futile exercise. Enough minor hydraulic differences exist between the various sand bodies that an argument could be made for treating each one individually. That, of course, is impractical for the purposes of attempting to build a numerical model, and is also beyond the scope of what is practical for this investigation.

Direction of Flow. Based on the data from all available studies, it is assumed that the general direction of groundwater flow is toward the northeast at a gradient of about 0.01. It is also presumed that the maximum hydraulic conductivity is about 1×10^{-3} cm/sec (~3 ft/day) and that the porosity of the saturated zones is about 0.35. The porosity has been estimated on the basis of the experience of the investigator and the poorly-sorted, fine-grained nature of the water-bearing zones. Using a seepage velocity calculation, $V_s = KI/n$ (V_s = seepage velocity, K = hydraulic conductivity, I = hydraulic gradient, and n = estimated porosity) along with a presumed hydraulic gradient of 0.01, a maximum seepage velocity of 2.86×10^{-5} cm/sec (0.08 ft/day) can be assumed.

Recharge. The most difficult aspect of the hydrogeological system in Opheim involves accurately defining the recharge zones for the Fox Hills aquifer. However, a simple investigation of the topography and an understanding of the available information give a strong indication that the recharge for the saturated zones intercepted beneath Opheim are recharged within the upper reaches of Porcupine Creek and Willow Creek (Figure 6). This conclusion is based upon the northeasterly flow of the groundwater and the northeasterly regional dip of the sedimentary pile. The water-bearing sand bodies must be exposed at or near the ground surface in order to be hydraulically recharged. It may be assumed that the static water levels observed in the wells at Opheim represent elevations close to the maximum elevations of the recharge zone exposures. If the strata dip to the northeast and the groundwater is flowing correspondingly, it stands to reason that the sand bodies in question must be exposed somewhere to the southwest at approximately 3200 feet MSL. The only places this is possible are within the Porcupine Creek and Willow Creek drainages.

The head of the Porcupine Creek drainage is only a few miles west of Opheim, but the recharge zone is likely to be six to ten miles south where the elevations are appropriate. The Willow Creek drainage starts about four miles west of Opheim, with the recharge area lying some six to eight miles west, encompassing a wide area along a relatively low-relief slope. Willow Creek flows generally to the south, draining into Rock Creek north of Hinsdale. The Willow Creek recharge area would appear to offer the larger surface collection area and may represent the more significant recharge zone. The recharge areas delineated herein contain only ephemeral stream channels. Recharge probably occurs primarily as seasonal infiltration.

The base of the Fox Hills formation, at the contact with the Bearpaw shale, lies between 3,010 and 3,045 feet MSL. The Bearpaw acts as a regional aquitard and represents the lowest point of recharge in the system. When applied to the question of recharge, this information can be interpreted to mean that the full extent of the recharge zone may be extended considerably.

The rate and exact nature of recharge is unknown due the complexity of the stratigraphic environment of the Fox Hills aquifer. It can be assumed that precipitation infiltrates exposed sand bodies at some point to the southwest of Opheim, thus recharging the water-bearing sands encountered beneath Opheim. If the calculated seepage velocity is accurate, water could require as much as 180 years to travel just a mile in the subsurface. It is more likely that there are more transmissive zones within the sand bodies that allow for freer flow. However, given the very fine-grained, silty nature of the sands within the Fox Hills formation in this area, it is entirely conceivable that many decades are required for water to migrate from the recharge zone to the Opheim supply wells.

Please note that additional data collected in the future may render these interpretations invalid. The conclusions herein are based upon available data.

Source-Water Protection Regions

Control Zones. The area within a 100-foot radius of the water-supply wells will be designated as the Control Zones. Activities within these areas will be limited and the wells will be fenced off.

Inventory Region. Because of the relatively low hydraulic conductivity values within the Fox Hills formation, the Inventory region will encompass a 1,000-foot radius around the wells. These zones will overlap due to the proximity of the wells to one another, so a general depiction of the Inventory region is outlined on the protection region map (Figure 7).

Recharge Region. The Recharge Region is described above and delineated on Figure 6.

Inventory

Owing to the very small size and the very limited number of businesses in the Town of Opheim, inventory sheets have not been completed for this document. Of greater importance in Opheim is the existence of several sites of known significant contamination and several more potential contaminated locations. The known and potential sources of contamination in Opheim are noted on Figure 5.

Other activities taking place in and around Opheim that could represent potential threats to the quality of the groundwater are limited to grazing livestock and dryland farming. Most of the southwest part of town, which is where three of the wells are located, is private ground that is currently utilized for graze. Outside of the Town limits, both grazing and dryland farming are being undertaken.

Two transportation-related situations are worthy of note. The presence of a sharp curve on Montana Highway State Highway 24 less than 500 feet south of Well #1 represents a potential hazard from vehicular accidents. Wells #4 and 5 are located proximal to the Town's airstrip, making them vulnerable to possible incidents related to light plane accidents.

There are no EPA-regulated facilities (RCRA, CERCLA) within the Inventory Region. The inventory region is occupied by residential plots, pasture, the airport and the golf course (Figure 8).

SUSCEPTIBILITY

Susceptibility for Specific Contaminants

One known contaminant, dinoseb, has appeared repeatedly in samples taken from a well (Park well) in the Opheim water system. This contaminant has been detected repeatedly at levels exceeding the EPA maximum contaminant limit (MCL), and the well was taken off line in 1999. The discovery of this contamination prompted the installation of new wells as part of a water-system improvement project aimed at providing appropriate flow and pressure to meet the recommendations of the State of Montana. The dinoseb issue has been discussed in numerous reports (Pagel, 1998; Damschen-Entranco, 1999; DEQ, 2000; MSE-HKM, 2001; various unpublished reports to the Montana DEQ) and will not be further addressed herein. Suffice it to say that considerable effort has been exerted by the DEQ, Montana Department of Agriculture, Montana Department of Natural Resources and the Town of Opheim to ensure that the new water-supply wells were sited and constructed in the most protective manner possible.

Other contaminants have been detected at various locations: penta has been found in soil samples from the Northern Electric Co-op yard and there have been minor hydrocarbon releases related to underground storage tanks at existing and former service stations. In addition, agricultural activities are extant for many miles around Opheim. In spite of this, the dinoseb is the only chemical contaminant ever detected in the water system.

The potential for recurrence of dinoseb contamination is considered to be very low for several reasons. First, there has only been one site at which the chemical has been detected in the public water supply, and that is the Park well, which is to be abandoned. Second, there have never been any samples taken directly from ground water that have had any trace of dinoseb. Third, there are only two locations where the contaminant was found deeper than 24 inches in the soil (MSE-HKM, 2001). Last, the release occurred 30 to 50 years ago; regardless of where the dinoseb is located, it will ultimately degrade.

These observations are tempered by the fact that dinoseb has been found at two locations, one of which (Northern Electric Co-op yard) is probably unrelated to the original release. Thus, the chemical has been "smeared" through various means, and its potential as a groundwater contaminant should not be discounted. Due diligence will be required to ensure that additional contamination does not occur while the Park well is still open and while the Airport (#4) well remains in operation.

Hazard Determination

Table 2 and 3 show the Hazard Determination format as outlined in PWS-6. The individual categories are described below.

Septic Systems. There are no independent septic systems in Opheim.

Table 2. List of potential hazards proximal to the Opheim, Montana Public Water Supply Wells.

Source Category	Information
Septic Systems	N/A
Animal Feeding Operations	N/A
EPA Regulated Facilities	N/A
Class V Injection Wells	N/A
Wastewater Treatment	N/A
Storm Water Discharges	N/A
MPDES Wastewater Discharges	N/A
Highways, Roads, Railroad, Pipelines	State Route 24 about 300 feet south
Land Use	grazed part of the year by two to four horses; proximal to grass airstrip with no facilities

Table 3. Hazard Determination for the Wells of potential contaminant sources associated with proximity to the Opheim, Montana Public Water Supply wells.

Source Type	Hazard		
	high	moderate	low
Septic Systems			0
Cropped Agricultural Land			0
Urban Land Use			0
EPA Regulated Facilities			0
Conditionally Exempt Facilities			0
Other Significant Point Sources			
dinoseb (Ruffcorn elevator, Northern Electric Co-op)		2	
pentachlorophenol (Northern Electric Co-op)		1	
Class V Injection Wells			0
Highways or railroads			0
Animal Feeding Operations			0
Wastewater Treatment Facilities			0

Cropped Agricultural Land. Wells #1, 2, and 3 are located in a pasture that may be used occasionally for livestock grazing. Wells #4 and 5 are proximal to the airport. It appears that some of the grass mowed along the edges of the runways is baled for hay, however, the airport has no facilities and is not managed as agricultural land as such.

Urban Land Use. Opheim currently has about 140 residents in a small town setting. It has no storm water drainage system or other major infrastructure that could be considered a hazard to the wells, with the possible exception that the #4 well is close to a road where there is a small potential for vehicular mishaps.

EPA-Regulated Facilities. There are no such facilities in Opheim.

Conditionally Exempt Facilities. There are no such facilities within 1000 feet of the supply wells.

Other Sources. Two potential sources of dinoseb have been delineated in Opheim. The primary source appears to be around the old Ruffcorn grain elevator south of the abandoned railroad line (Figure 5). The other is in the vicinity of the Northern Electric Co-op yard. Pentachlorophenol, has also been detected at the Northern Electric Co-op yard, and should be considered a potential source for contamination of the water system.

Class-V Underground Injection Wells. There are no known injection wells in the vicinity of Opheim.

Landfills. There is a closed landfill on the northeast side of Opheim that serves as a solid waste transfer station. This facility is not considered a hazard because of its distance from the supply wells, the presence of natural barriers and the overall direction of groundwater flow away from the wells.

Highways and Railroads. Opheim was formerly the terminus of a railroad line, but the tracks have been removed. The locations of the wells were selected specifically to avoid proximity to the former railroad line and any contamination that might be related to it.

Wells #1, 2 and 3 are located 300 to 400 feet north of State Highway 24.

Animal Feeding Operations. There are no commercial animal feeding operations in Opheim.

Wastewater Treatment Facilities. The Town of Opheim has a community wastewater system. The wastewater lagoon lies north of town, down-gradient from the supply wells.

Natural Barriers

Significant natural barriers to vertical fluid flow exist in the strata underlying Opheim. This can be seen from the drill logs as well as the general descriptions of the geology in the area. The barriers start right at the surface, with the Ogallala formation, which consists of pebbles and cobbles in a clay-rich matrix that ranges from a few feet to about ten feet in thickness.. This stratum is very similar to glacial deposits observed almost everywhere in northeastern Montana. The formation's relatively low permeability is exemplified by the absence of a contaminant, dinoseb, below a couple of feet below the ground surface. While stochastic processes may have allowed the dinoseb to penetrate the Ogallala formation, it is clear that overall permeation in the low-lying area from which the samples were taken is minimal. Consider that the contaminant may have been in the soil for as long as 50 years but has only penetrated a couple of feet.

HKM-MSE (2001) reported that the top of the Fort Union formation, which underlies the Flaxville gravel at depths of 30 to 50 feet below the ground surface, was a silty sand. Their conclusion was that the top of the Fort Union formation did not compose a significant barrier to fluid flow. However, deeper strata within the formation are clay beds 25 to 30 feet thick. These do not appear to be continuous across the entire area, as some areas show only a few feet of clay reported on the driller's log.

The Fox Hills formation contains significant quantities of clay. The base of the uppermost aquifer in the Fort Union formation, which is held up by a clay aquitard, and the uppermost water-bearing sand body in the Fox Hills formation is separated by at least 50 feet of clay (well #5). Some of the logs show nearly 100 feet of clay in the stratigraphic section. Thus, very significant natural barriers exist to the vertical migration of fluids.

Man-Made Barriers

All of the wells that have been installed for the water-improvement project in Opheim were constructed with steel outer casings to depths of at least 100 feet. The space between this long outer casing and the well casing itself is sealed with bentonite to within a few feet below the pitless unit. This design was arrived at by the engineer and the DEQ as the most efficient method by which to isolate the drill hole from the possibility of contamination that might exist in the uppermost aquifer. This design will also preclude the possibility of contamination entering the well from the more permeable Flaxville gravel formation.

The wells were also completed with a pure bentonite seal in the well annulus from the top of the filter pack to the base of the upper casing. Thus, significant man-made barriers have been put into place as a direct response to the contamination as understood at that point in time.

Assumptions and Limiting Factors

Due to the complexity of the stratigraphy within the Fox Hills formation the direction of groundwater flow cannot be clearly established. Each water-bearing sand body had a distinctly different static water level from others encountered at different locations. Therefore, the direction of flow is merely assumed to be similar to that of the overlying Hell Creek aquifer.

The pathway of the dinoseb contamination from the surface to the Park well has yet to be clearly established, and probably will never be established. Therefore, the assumption is that either the dinoseb will eventually deteriorate or that it is being transported away from any other wells in the area via the groundwater within the Hell Creek formation.

CONCLUSIONS

The four newest wells in the Opheim Public Water Supply System were constructed in such a manner as to protect the Fox Hills aquifer from contamination that might be introduced at the surface. That is, the boring and casings will not be conduits for contamination. The Airport well was constructed in such a manner as to be a possible pathway, should contaminants be introduced to the casing at the surface or through the uppermost aquifer. However, improvements on that well will reduce the potential for it to be a contaminant pathway, as will the proper abandonment of the Park well.

There are significant natural barriers and little activity that might compose a threat to the Fox Hills aquifer. While agricultural and urban activities can generate potentially hazardous waste, the Town of Opheim is small enough that such activities are very limited or not of unusual density. Grazing in the area of the wells is limited to a few horses and industrial activity is virtually non-existent.

Time of travel from the recharge areas to the wells is rather long, on the order of many dozens of years, thus greatly reducing the possibility of contaminant transport to the wells via the recharge system. A one-year radius of travel would encompass a distance of only a few tens of feet under natural conditions, which combined with the significant natural clay barriers, nearly eliminates the possibility of contamination entering the Fox Hills aquifer as a result of a release proximal to the wells.

Therefore, the Opheim water-supply system wells are well protected from the possibility of contamination from any source, save direct introduction of contaminants into the well casing. Such an event could be the result of direct human intervention or a rather catastrophic incident, such as a vehicular accident that sheared the top of a well casing. Standard protective measures can be taken to reduce the possibility of such occurrences, such as erecting protective posts and fences.

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APPENDICES

Appendix A. Soil survey and climatic information for the vicinity of Opheim, Montana.

Appendix B. Drill logs for Opheim, Montana water supply wells.

Appendix C. Selected water quality data from the Opheim, Montana water supply system.

Appendix D. Geological cross sections based on water-supply well logs from Opheim, Montana.

Figure 8. Cross section A-A’ through the production and test wells in the public water supply system, Opheim, Montana.

Figure 9. Cross section B-B’ through the production and test wells in the public water supply system, Opheim, Montana.

Figure 10. Aerial photograph of the Town of Opheim, Montana.

Appendix E. Drawdown evaluations from pump tests performed on four water-supply wells in the Town of Opheim, Montana.

Figure 11. Time versus drawdown during pumping test of production well OPP-1, Town of Opheim, Montana.

Figure 12. Drawdown vs. time graph of the pumping test on Opheim municipal well OPP-2.

Figure 13. Drawdown vs. time graph of a pump test performed on Opheim municipal well OPP-3.

Figure 14. Drawdown vs. time graph of a pump test performed on Opheim municipal well OPP-5.