PLANNING, CONSTRUCTION, AND INITIAL SAMPLING RESULTS FOR A WATER QUALITY MONITORING PROGRAM: CAMP GRAFTON SOUTH MILITARY RESERVATION, EDDY COUNTY, NORTH DAKOTA

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INTRODUCTION

In 1992 a plan outlining a ground-water quality monitoring program for the North Dakota National Guard Camp Grafton South (CGS) facility in Eddy County, North Dakota, was submitted to the North Dakota National Guard . In presenting this proposal it was recognized that "in a complex geological environment, the design of a water sampling network is never complete, and can never cover all possible contaminants and all possible modes and directions of movement for those contaminants. Rather we are forced to use limited information to optimize limited resources in assembling a sampling plan that will give the best possible information and the best possible level of protection with a reasonable and limited degree of funding." In designing the plan we attempted to consider existing geologic and hydrologic information, current and future use patterns of the facility, objectives and goals of protection - including the sensitivity of resources to be protected, and the limitations of funding and resources available for implementing the plan. An attempt was also made to consider objectives and resources in a balanced manner, and to maximize the information obtainable from limited field data.

The initial sampling plan was laid out in two phases. Phase I consisted of the selection of appropriate surface-water sites and the construction of appropriate observation wells for monitoring munitions and explosives residues, petroleum residues, and pesticide contamination. Phase I also included base-line samples for appropriate contaminants and for basic water quality and trace elements on each of the selected sites. Phase I was to implemented in 1992 and 1993. Phase II described a plan for continued sampling on a periodic basis, and for optimal use of the constructed well system. At this time (January 1994) Phase I has been completed. Wells have been constructed, and initial samples taken.

The purpose of this report is to document the completion of the Phase I. Documentation consists of:

1. actual well locations and sample locations as constructed after full consideration of field factors;

2. well completion information, including lithologies, materials, construction methods, development, and cleaning procedures;

3. sampling procedures, including well purging methods, sampling methods, and sample-handling methods and procedures;

4. sample data for the initial base-line sampling and testing;

5. data-base data for water quality and trace elements determined before the implementation of Phase I; and

6. a brief analysis and interpretation of results.

The initial plan as presented and implemented is considered to be a starting point, rather than a finished product. The provisions of the initial Phase II plan are deliberately intended to be flexible to allow for modification as understanding of area hydrology and its effect on water quality increases. It is hoped that this initial work will serve as a foundation for a flexible water sampling plan for the CGS facility, and that it will provide a sound frame of reference for ongoing impact analysis of land use on water resources on the CGS facility.

LOCATION AND NUMBERING SYSTEM

The location and numbering system used in this report is based on the public land classification system used by the U.S. Bureau of Land Management. The system is illustrated in figure 1. The first number denotes the township north of a base line, the second number denotes the range west of the fifth principal meridian, and the third number denotes the section in which the well or test hole is located. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). For example, well 149-063-4ADD is located in the SE 1/4 SE 1/4 NE 1/4 sec. 4, T. 149 N., R. 63 W. Consecutive terminal numerals are added if more than one well or test hole is located within a 10 acre tract.

ACKNOWLEDGEMENT

The work here reported was performed by many people. Particular credit is given to Gary Calheim and Albert Lachenmeier for patient and exacting work in constructing the observation wells under extremely difficult conditions: and Jim MacArthur for days of purging and sampling wells under difficult conditions. I also thank Merlyn Skaley, Joe Krieg, and Fred Anderson for help in developing, finishing, and setting the protective covers of the wells. Thanks also to Major Richard Mozier and Major David Anderson for assistance in location, timing, logistics, project review and funding.

CLIMATE, GEOLOGY, AND HYDROLOGY

The CGS facility is located in Eddy County in East Central North Dakota (figure 2). The facility occupies portions of four townships, Lake Washington (T149 R63), Colvin (T149 R62), Paradise (T148 R62), and Cherry Lake(T149 R62). The CGS facility is approximately bisected by State Highway 15 which runs from East to West.

Climate

The Climate of Eddy County North Dakota is continental, having cold winters and hot summers. The onset of cold weather usually begins in early November. The frost usually leaves the soil in mid April. The moisture regime is borderline between semi-arid and sub-humid, with a long term average precipitation of about 48 cm (19 inches).

Geologic and Hydrologic Setting

The general Geological setting of Camp Grafton South has been described by Bluemle (1965), and by Comeskey (1989). Most of the CGS facility consists of highlands formed by the McHenry End Moraine. Materials of the end moraine consist of ablation till formed by the abandonment of stagnant ice during a retreat of the glacier during the Grace City and Kensal Phases of the James Lobe of the late Wisconsin glaciation, followed by a subsequent advance of the ice during the McHenry-Heimdal-Cooperstown phases, which mixed and buried previous ice and till deposits. Fluvial-glacial features include kames mapped north of HWY 20 on sections 24 and 25 (T149 N, R63W). They also include an outwash plain extending northeastward through the Colvin Creek watershed to the Sheyenne River from the South Lake Washington, and southeastward from South Lake Washington and the area northwest of Coe lake through Cherry Lake (Bluemle 1965, Plate 1). A thin sandy mantle (mapped as the Maddock soil series) covers much of the moraine upland, and is underlain by a clay and clay loam glacial till.

Surface Drainage

The regional surface drainage pattern is related to the Cherry Lake aquifer, but is not identical with it. Surface features on the CGS facility can be divided into three major sub components of the McHenry end moraine. These subdivisions are divided by lowlands consisting of outwash plains, and occupied by strings of lake and littoral areas, and some small streams. The surface drainage can be described as follows.

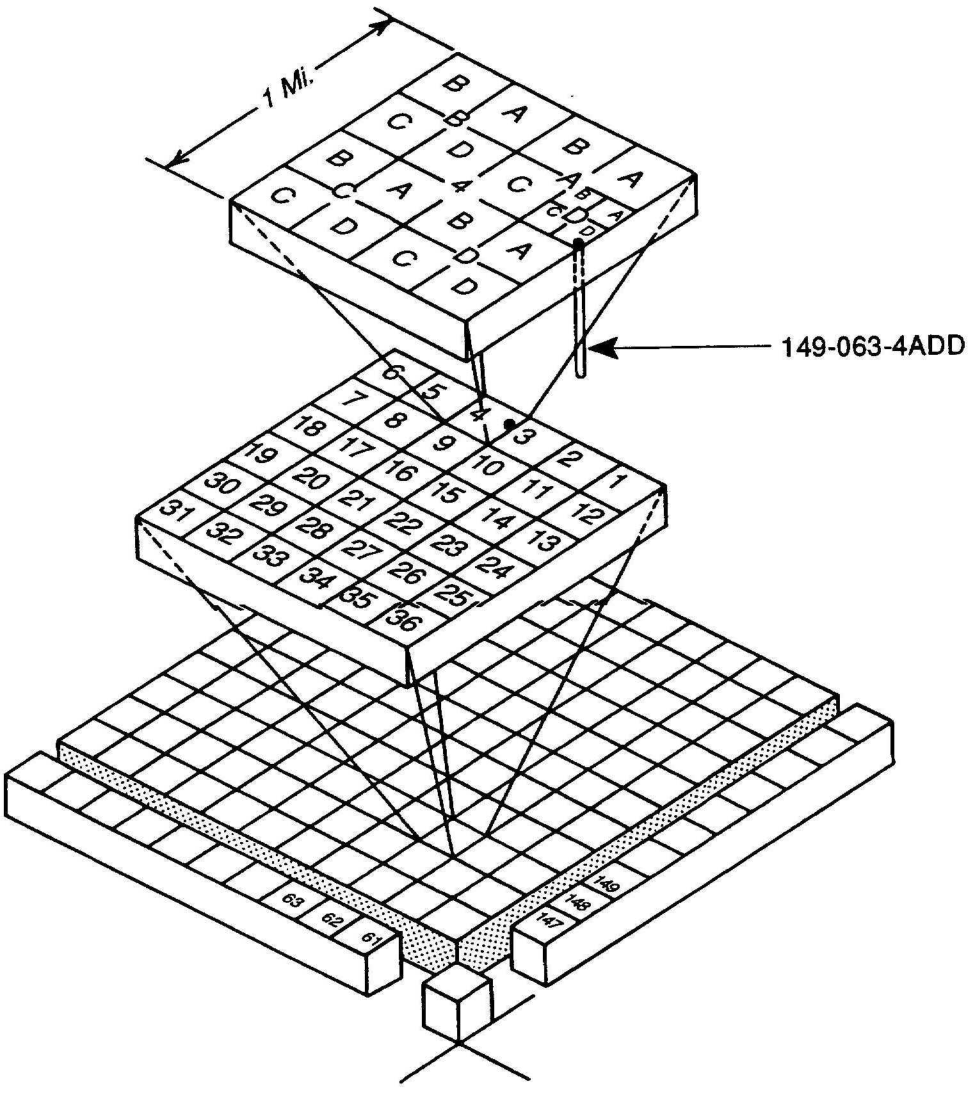

Figure 1. Map location and numbering system used in this report (from U.S. Bureau of Land Management).

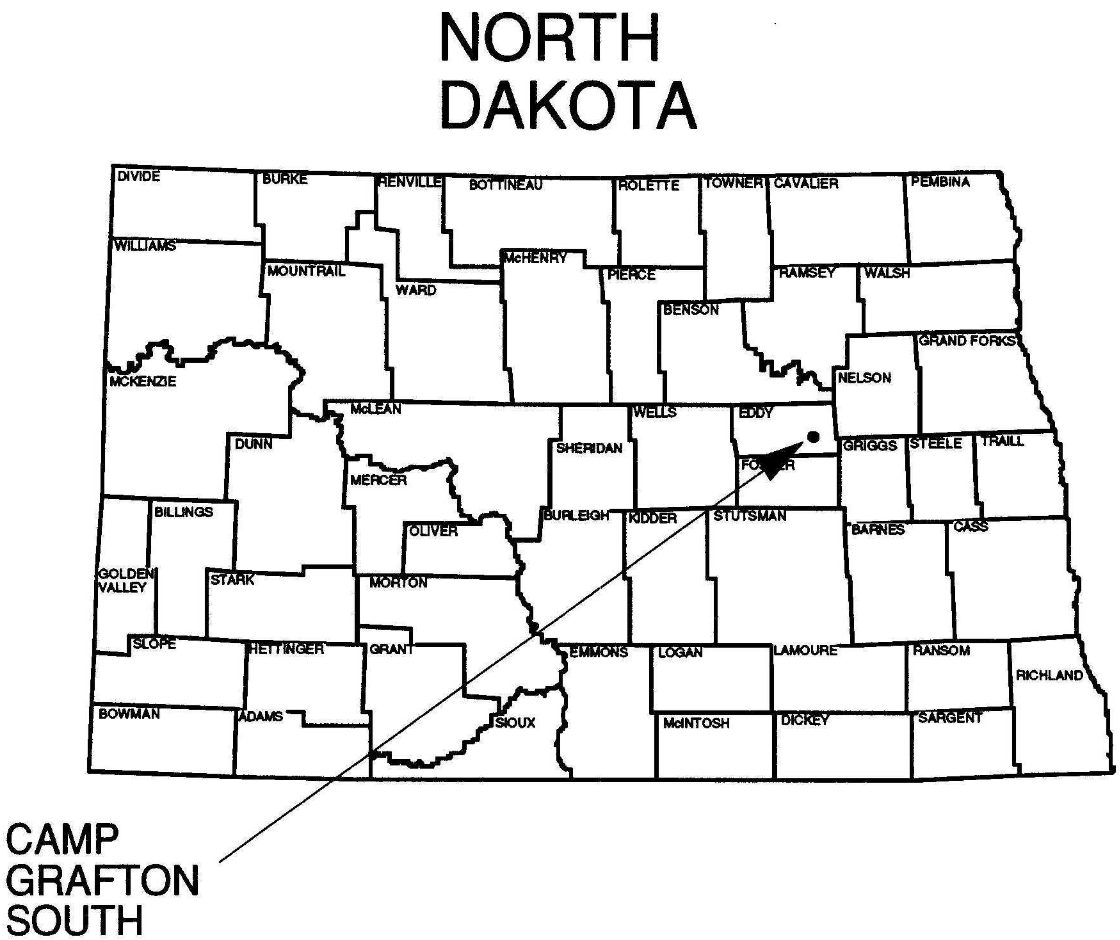

Figure 2. Location of the Camp Grafton South training facility.

North of HWY 15 the CGS reserve is bisected by a single component of the McHenry End Moraine (Moraine Unit 1, figure 3), which is drained by two watersheds trending northward toward the Sheyenne River. On the West, elevations drop off toward the Lake Washington, South Lake Washington, and Lake Coe chain of lakes, and the lowlands connected with them. On the East side of the McHenry End Moraine, elevations decrease steeply into the Colvin Creek Watershed, which then conveys water northward toward the Sheyenne River.

South of HWY 15 three subcomponents of the McHenry End Moraine comprise the highlands of the overall drainage system. On the East side, the moraine component described for the CGS facility north of HWY 15 (Moraine Unit 1, figure 3) extends south of the highway and beyond the limits of the CGS reserve. On the east side of the eastern moraine sub component drainage is toward the Spring Creek watershed. South of the CGS facility on sections 11, 12, 13, and 14 of T148 N, R62 W surface drainage appears to be southward toward the James River. The southward drainage beginning at Cherry Lake is south of the CGS reservation and should not be significantly affected by activities on the reservation. Movement of water is through connect lakes and littoral areas, and likely is interdependent with ground water movement for considerable distances.

West of the described lowland and littoral areas, a central sub component of the McHenry End Moraine occupies portions of sections 35 (T149N, R63W) and sections 2,3,4,10 and 16 (T148,R63W). The eastern portion of this moraine sub component (Moraine Unit 2) drains directly toward the Cherry Lake /Washington Lake (CLWL) system described above. The western side of this moraine sub component drains toward a lake, lowland, and littoral system beginning with South Twin lakes, trending northward, and connecting with the CLWL system at Lake Coe north of HWY 15.

A third and smaller moraine unit occurs in sections 5 and 8 (T148N, R63W). The eastern drainage from this moraine sub component is eastward toward the Twin Lakes system. The western drainage is toward the Nine Mile Lake, littoral, and lowland system which also connects with the CLWL system at Lake Coe.

Local surface drainage from the moraine subcomponents occurs primarily through coulees. The coulees were likely cut by glacial melt waters.

Ground-water movement

Trapp (1966B) and Comeskey (1989) described Cherry Lake aquifer system as composed of two confined units, separated by 20 to 40 feet of glacial till. The surface of the deepest (and least aerially extensive) unit is located approximately between 126 and 182

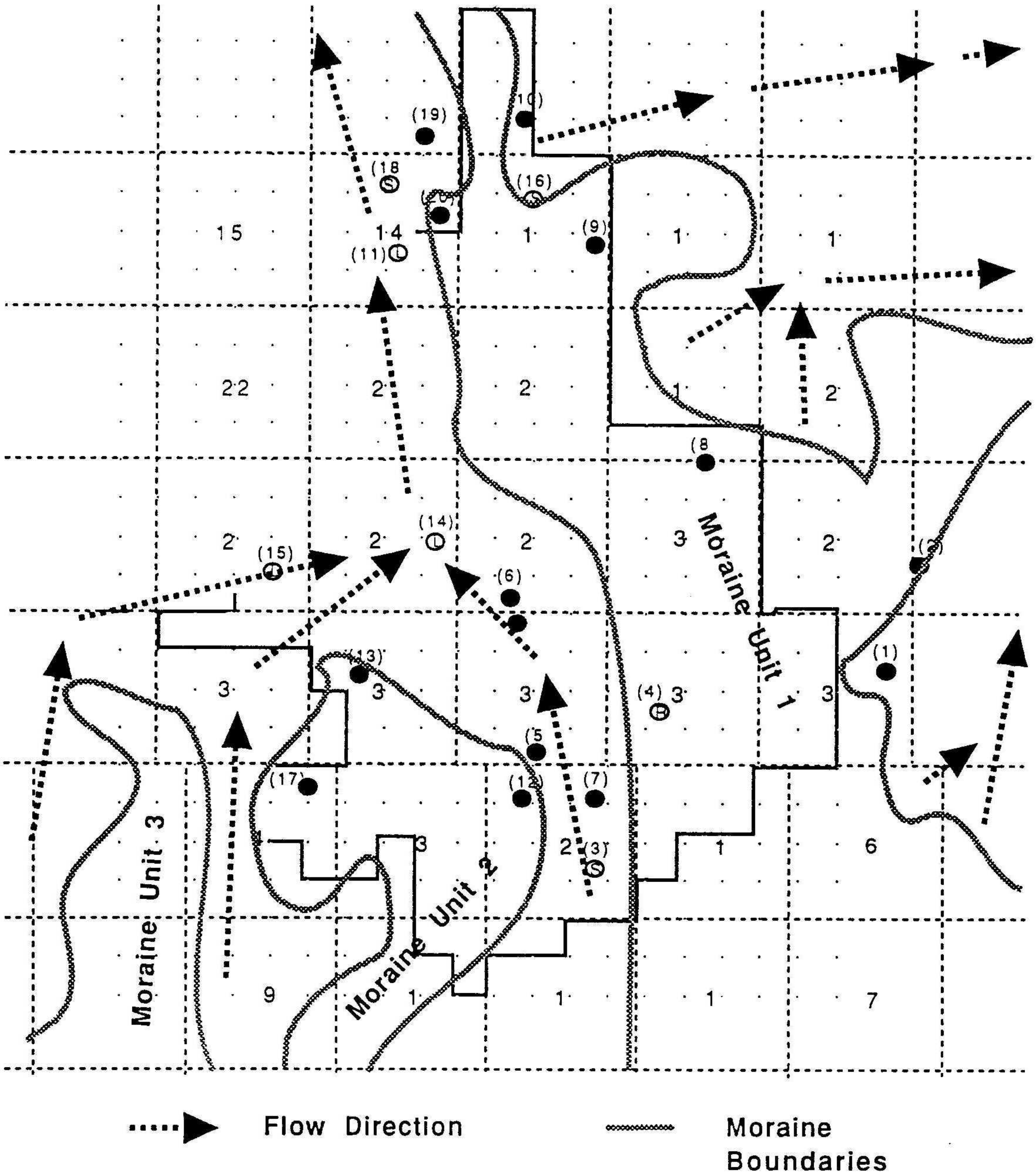

Figure 3. Generalized schematic of the CGS facility ground-water flow system, and locations of planned wells and surface-water sampling points in the proposed plan (Schuh 1992).

feet below land surface. It is 1/2 to 3/4 mile wide, extending northward from Cherry Lake through the south end of South Washington Lake, and includes Lake Coe. The shallower buried unit overlies the lower unit for much of its extent, but is more aerially extensive and trends more northwestward at Lake Coe. The depth of the surface of the upper confined unit is approximately between 18 and 25 feet below land surface. Trapp (1966B) indicated that an aquifer of lesser yield (possibly corresponding to the upper unit) extended southeastward through lake Coe, looped northward beneath the Colvin Creek watershed, and also extended southeastward toward the Johnson Lake aquifer. Trapp (1966B) has indicated that the upper and lower units of the Cherry Lake Aquifer may be connected, but that further work in defining the connection is necessary. The drilling of Comeskey (1989) did not succeed in mapping any connections between the shallower and deeper confined units.

Comeskey (1989) also mapped a shallow surficial coarse lithologic unit occupying much of CGS facility north of HWY 15. However, drilled transects indicate that this unit is missing, or very shallow over the underlying till in many areas, and it seems likely that saturation of the shallow surficial unit is both spatially limited and temporally intermittent.

Aside from the surficial unit and the two buried units of the Cherry Lake aquifer, Comeskey observed numerous small buried units, which are likely limited in extent. These units may conform to the ice-fluvial deposits (such as Kames indicated by Bluemle 1965).

Comeskey (1989) has described recharge as occurring through closed depressional areas on the McHenry Moraine. The local flow system from the Moraine is described as occurring easterly and westerly toward the dividing lowlands. Numerous springs flow out from the moraine at lower elevations in coulees and near lowlands and littoral areas. Springs may be exposures of the contact of the surface coarse lithologic unit and the underlying till, and thus may be of shallow origin, or they may consist of exposures of deeper buried units.

The lake system has been described as a window on the water table, and has been used to describe a general regional flow system northward to the Sheyenne River. Water Table maps (Trapp 1986A) which may or may not be related to piezometric levels in the underlying aquifers, indicate that overall regional ground-water flow at the water table is toward the Sheyenne River through the Washington lakes chain, and through the Colvin Creek lowland. There is a very slight water table gradient southeastward toward the Johnson Lake aquifer, and some water movement may occur in that direction. Flow from or south of Cherry Lake is indicated to be southward toward the Juanita Lake aquifer and the James River. Generally, however, the CGS reserve is too far north to affect the southward drainage system. Also water-table gradients toward the Johnson Lake Aquifer are extremely small . All indications from current information are that most ground water and surface water moves on a regional scale northward to the Sheyenne River through the Cherry Lake /Washington Lake chain (and subunits), and through the Colvin Creek basin.

OBJECTIVES AND PRIORITIES

In designing a ground-water quality sampling program one must first decide what one wishes to protect. Ground water is almost everywhere. Many essential human activities may have some adverse effect on ground water. However, under some conditions the adverse influence may be very localized and limited in extent, while in others it might be extensive. In some circumstances adverse impacts might occur that can be gradually cleaned up and dissipated by the natural system, while in others the effect might be essentially permanent. In some circumstances adverse impact might occur for ground water that is nonusable or nonpumpable. In others it might occur in developed water supplies, or in undeveloped water supplies that comprise a valuable future resource. Finally, in some circumstances adverse impact might occur in such a manner as to cause minimal biological impact upon surrounding plant and animal communities. In others the impact might be considerable .

Recognizing certain priorities of use, it would seem to be reasonable to give the highest priority to protecting the rights and uses of those external to the military reservation. Such protection would include the prevention of movement of surface-water or ground-water contaminants beyond the confines of the reserve and into water supplies of others. It would also include prevention of serious damage to shared natural resources of a more mobile nature, such as migratory waterfowl or other wild game, that might temporarily nest or inhabit the lakes and littoral areas of the CGS reserve.

The next priority is protection of the local ground-water resources on the military reservation. This priority does not diminish the importance of protecting the major aquifers on the CGS facility, and certainly the North Dakota National Guard would not wish to pollute its own water supplies. However, it must be acknowledged that in the complex glacial terrain of the CGS reserve countless small discontinuous lenses of highly transmissive materials exist. Many are of extremely minor practical value as aquifers. Many are only intermittently saturated. Even extensive exploratory drilling would not properly locate and define all such materials. In this case the value of such small deposits must be weighed against the overall objectives of the activities on the military reserve.

Moreover, it would be unreasonable and unrealistic to attempt to undertake the protection of water-bearing materials that are not yet located or known to exist.

For these reasons the following priority scheme is suggested for the CGS Water Quality Monitoring Plan.

Priority 1: protection of ground-water and surface-water exterior to the CGS reserve. The primary focus is on detection of contaminants migrating to regional rather than local flow systems, before they can substantially effect the regional resource.

Priority 2: protection of the wildlife, such as migratory waterfowl, that inhabit the lakes and wetlands of the CGS reserve.

Priority 3: protection of the local fresh-water supply.

Placement of local water-supply protection (Priority 3) after wildlife (Priority 2) does not imply a belief that wildlife is more important than local human use. Rather it follows from the premise that the North Dakota National Guard, as owner and primary user, has more freedom in prioritizing the importance of protection of resources that effect only itself. It is likely, however, that the North Dakota National Guard would wish to adopt a very protective stance toward its own water supplies. It is also certain that EPA requirements will severely limit the amount of allowable contamination of any aquifer.

Monitoring Plan Criteria

Factors considered in the water quality monitoring plan include (1) the nature of local and regional surface drainage, (2) the nature of local and regional ground-water flow, (4) the disposition and use of water by others near the military reservation, (4) the sensitivity of specific water uses on and near the reservation to specific contaminants, and (5) land use patterns on the military reservation. Consideration is also given to the desirability of having all major use areas of the reserve given sample representation.

The ground-water monitoring plan for CGS is intended to be comprehensive, in the sense that no major area of use, or major avenue of water movement to regional flow systems or sensitive areas should be without some representative sampling point. However, it must be statistical in the sense that no cost effective monitoring program can cover all potential points of water movement and contaminant migration. In order to establish a comprehensive approach toward sampling, each of the five factors listed above must be considered. However, a systematic and orderly approach toward the consideration of those factors must be developed.

Hydrologic Assumptions

The major lake and littoral systems and the regional surface and ground-water flow systems are all in the dividing lowlands, so that a desirable point of sampling is in the paths of entry of local flow from recharge on the moraine complex into those regional systems. For much of the CGS water quality monitoring plan, primary focus will be placed on sampling in the lower reaches of coulees feeding into the Colvin Creek and CLWL basins and their tributaries.

The mouths of coulees are selected for two reasons. (1) The coulees provide the major conduits of surface water flow during periods of runoff. For this reason, they are the logical points of concentration for contaminants running off from higher elevations. The function of coulees in advancing contaminants ahead of slower or less extensive runoff from other areas would be expected to render ground water near the mouths of coulees more likely to exhibit contaminants moved by overland flow, or by recharge into the ground-water system along the course of the coulee.

(2) The coulees are frequently the locations of springs, where till and overlying coarse units meet along the cuts or walls of the coulees. In some cases seepage faces are extensive and relatively permanent, as in the coulee comprising the Devil's Thumb drainage way in sections 1 and 2 (T148,R63). In others they may flow only some of the time during wet years, or sporadically following particularly large rainfall events. When such springs are flowing, the flow lines for the local flow system of the moraine will bend toward the springs. This means that local ground water in the vicinity of springs should tend to receive any contaminant plumes from the upland recharge sites preferentially.

The general association should not be interpreted to mean that water flow lines are always skewed toward sites at mouths of coulees (although for permanent springs they likely will be). Rather it means that statistically, over a large number of years, cumulative ground water flow will tend to be preferentially weighted toward the springs, even those that are intermittent. Even if this does not hold true for a given location, over a large number of such sampling sites, the statistical chance of achieving a conservative or early warning over many years is still better than a random placement.

For these reasons, it is considered that the mouths of coulees should generally provide conservative locations for sampling contaminant movement from the upland areas through the local flow systems to the regional system. Such monitoring points should provide optimal early warning and protection for both the regional ground-water flow system and the lake and littoral areas.

WELL NETWORK AND SAMPLE PLAN

The primary land use contaminant considerations are those of (1) munitions and explosives; (2) herbicides and insecticides from weed and insect control; (3) petroleum spills from staging, fueling, and use of motor vehicles; (4) human use (sewage etc.); and (5) cattle and grazing (most of the reserve is leased for grazing during spring and fall).

Munitions and Explosives

Almost all activities using live ammunition and explosives on the CGS reserve are concentrated in the plateau area of the eastern component McHenry Moraine located on sections 31 and 32 (T148N, R62W) and in the lowland of section 36 (T148N, R63W). Facilities located within these bounds include a demolition range, a recoilless rifle range, a modified record fire range, an M-203 range, and machine gun range. As of March 1992 these ranges are only in the initial phases of development and the time is opportune for setting of baseline data for contaminants. Water Sampling for the munitions and explosives area will be designed as follows. Sample sites designated for munitions and explosives sampling are listed on table 1. A map of all proposed well and sampling sites is on figure 3. A map of the actual well and sampling sites is on figure 4.

(1) One principle coulee providing drainage from the machine gun range lies in the northeast quarter of section 32 (T149N, R62W). Drainage is to the Colvin Creek basin. It was not known whether any Cherry Lake aquifer subunits underlay this location. Sample wells were recommended for the base of this coulee at (T 149N, R62W, section 32AD) in the sample-network plan proposal to cover possible ground water contamination caused by either surface infiltration of runoff waters from the military reserve, or ground-water migration in the direction of the Colvin Creek flowage. However, this position was extremely difficult to access with a drill rig and with sampling equipment.

Instead a nest of wells was drilled at T149N, R62W, Section 28CCC. This location is in the south (HWY 15) road ditch, just east of the T intersection of the section 28-27 section road and HWY 15. The deepest of these wells (SWC 13103) was drilled into Pierre Shale, and the screen was in a sand and gravel layer at 139 to 144 ft. Lithology, construction, and completion information are in Appendix A. The second well of the nest

Table 1. List of wells and sampling points constructed and sampled from 1992 through 1993. Sample species include munitions (Mun), total petroleum hydrocarbons (TPH), herbicides (Herb), insecticides (Insect), basic water chemistry (Basic), and trace elements (Trace). Previously Sampled column indicates whether (Y =yes, N=no) water quality data taken before initiation of the sample plan described in this report exist.

Text No.	SWC Well No.	Township N	Range W	Section	Location	Previously Sampled	Mun	Petrol	Herb	Insect	Basic	Trace
(1)	13103	149	62	28	CCC1	N					x	x
(1)	13104	149	62	28	CCC2	N	x				x	x
(2)	13105	149	62	29	DAD	N	x		x	x	x	x
(3)	Spring	148	63	2	DA	Y	x				x	x
(4)	Reservoir	149	62	31	C	N	x				x	x
(5)	13097	149	63	36	ACA1	N					x	x
(5)	13098	149	63	36	ACA2	N	x				x	x
(6)	13101	149	63	25	CDC1	N					x	x
(6)	13102	149	63	25	CDC2	N	x		x	x	x	x
(7)	13086	148	63	2	ABC1	Y					x	x
(7)	13087	148	63	2	ABC2	Y	x				x	x
(8)	13090	149	62	19	DBD1	N					x	x
(8)	13091	149	62	19	DBD2	N						x
(8)	13106	149	62	19	DBD3	N		x	x	x	x	x
(9)	13089	149	63	13	DAA1	N					x	x
(9)	13090	149	63	13	DAA2	N		x	x	x	x	x
(10)	13092	149	63	12	CAC1	N					x	x
(10)	13093	149	63	12	CAC2	N		x	x	x	x	x
(11)	S W Lake*	149	63	14	CAC	Y		x	x	x	x	x
(12)	13084	148	63	2	BABC1	N					x	x
(12)	13085	148	63	2	BABC2	N		x	x	x	x	x
(13)	13099	149	63	35	CBA1	N					x	x
(13)	13100	149	63	35	CBA2	N		x	x	x	x	x
(14)	Lake Coe	149	63	26	ADD	Y		x	x	x	x	x
(15)	Lake Coe	149	63	27	DDB	Y		x	x	x	x	x
(16)	Spring	149	63	13	BDA	N			x	x	x	x
(17)	13095	148	63	4	ABA1	N			x	x	x	x
(17)	13096	148	63	4	ABA2	N			x	x	x	x
(18a)	P/NI	149	63	14	BAA	N			x	x	x	x
(18b)	P/NI	149	63	14	BAA	N			x	x	x	x
(18c)	P/NI	149	63	14	BAA	N			x	x	x	x
(19)	P/NI	148	63	11	DDC	N			x	x	x	x
(20)	13094	149	63	14	AAB	N			x	x	x	x

P/NI Planned but not implemented. See text for explanation.

* SW Lake = South Washington Lake

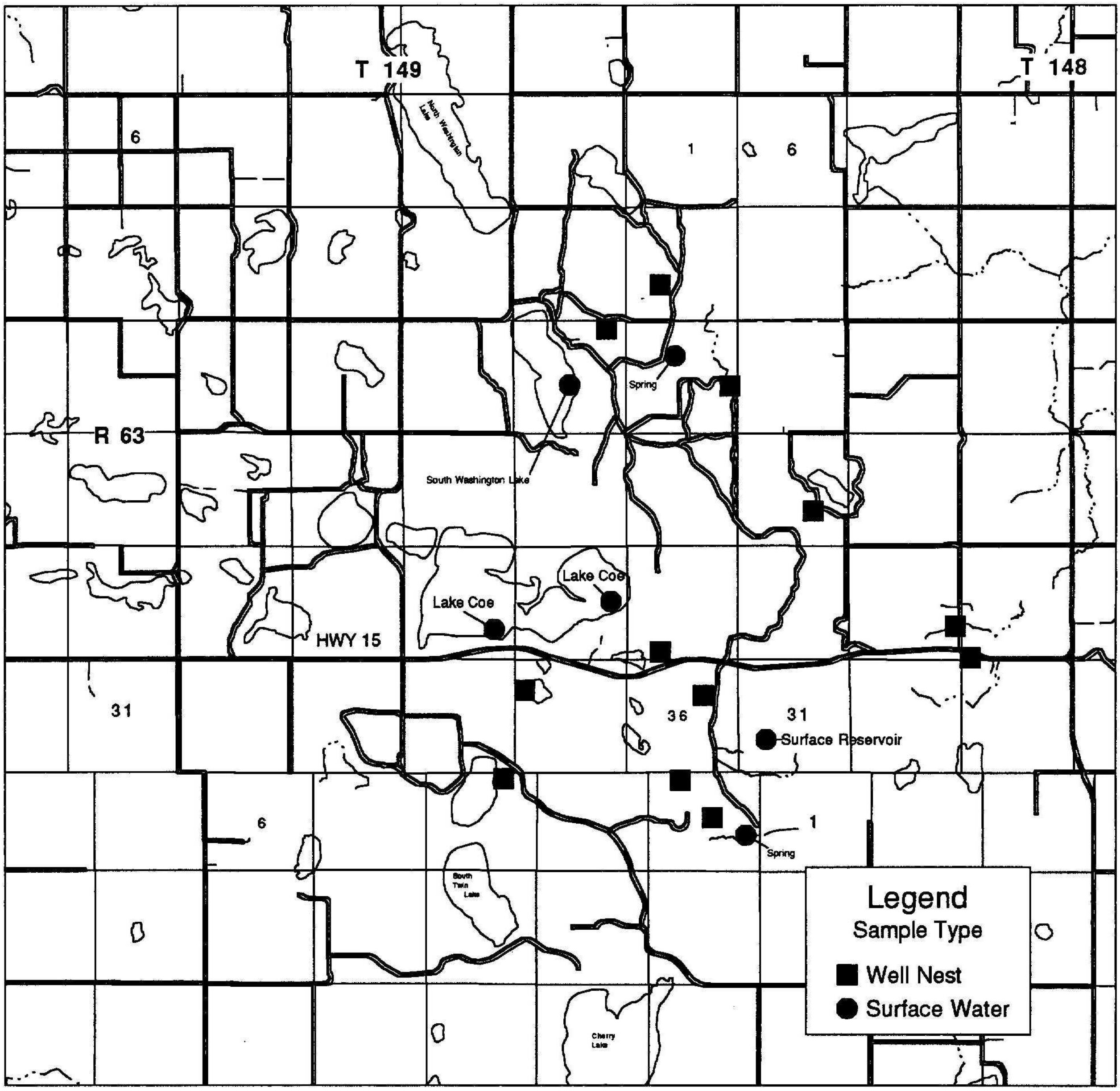

Figure 4. Map of all ground-water and surface-water sample locations on the CGS reserve during the 1992 to 1993 sample period. All well nests shown were drilled in 1992.

(SWC 13104) was placed about ten feet east of well 13103, with well screen near the bottom of a sand and gravel layer at 56 to 61 feet. The two coarse layers are separated by about 80 feet of gray sandy-clay till. This well nest still in a more advanced position of the major drainage way to Colvin Creek laid out in the initial plan.

(2) A second principle coulee extending eastward from the plateau north of HWY 15 crosses a north-south section road between sections 29DAD and 28CBC at (T149N, R62N). While this coulee is disconnected from the munitions/explosives area by the highway and surface drainage from the military reserve through this coulee is doubtful, it was recommended in the sample plan that possible migration of contaminants in this drainage system be monitored. A single well (SWC 13105) was drilled at T149 N, R 62W, Section 29DAD in the west ditch of the Section 28-27 section road. The well is located near the culvert passing water under the road from the designated coulee. The screen was placed near the bottom boundary of a sand layer at 50 to 55 feet. Lithology, well development, and completion information are in Appendix A.

(3) A third principle drainage way, particularly effected by the machine gun range, is the "Devil's Thumb" coulee, which trends southward through section 32 (T149N, R62W), and then cuts eastward across the center of section 1 (T148N, R63W) and enters the CLWL slough complex north of Cherry Lake in T148N, R63W S2. This coulee has numerous seepage faces along its course, and a reasonably persistent base flow enters the slough and littoral complex at its mouth. This spring was sampled previously at section 2 DA. It was sampled again as a part of Phase I, and will be sampled regularly as a part of the water quality network in the implementation of Phase II.

(4) A fourth coulee cuts diagonally southwestward across T149, R62 section 31D, and provides a surface drainage way for water from both the Modified Field Fire and Field Fire ranges, and from the Machine Gun Range. This coulee has a reservoir at approximately the center of its course. A nest of monitoring wells (Comeskey 1989) is placed on the west side of the access road, on the border of the Demolitions Range at section 36DDB (T149N, R62W). An additional smaller coulee on the east side converges northward at this site. The reservoir was sampled as a part of Phase I, and will be sampled regularly as a part of Phase II. Its purpose is to serve as an indicator of runoff of contaminants.

(5) A Demolition Range intervenes between the base of the coulee described above in item (4) and the CLWL flow system. Wells were planned for placement at T149 R63 section 36CDD, to serve as indicators of movement of contaminants from the machine gun and modified record fire ranges (through the coulee described in (4) above) as well as the

Demolition Range toward the CLWL flow system. Actual wells were placed at T149-R63-S36ACA. The deepest of these wells (13097) was drilled to 74 feet. The well screen interval was placed at 41 to 48 feet in very coarse sand, just above the upper boundary (48 feet) of the clay till. The shallower well (13098) was drilled to 31 feet, and the well screen was placed at 21 to 27 feet in a predominantly medium sand. Lithology, construction, and completion information are in Appendix A.

(6) Drainage from the proposed Modified Field Fire Range is expected to occur westward and into the road ditch on the south side of HWY 15. This water should drain into the slough complex which crosses the highway and rains northward toward Lake Coe in the NW corner of section 36 (T149N, R63W). Sampling wells were planned for placement North of HWY 15 adjacent to the slough complex to detect possible contamination from both ditch drainage, and drainage through the slough complex.

Wells were placed at T149N, R63 W, S25CDC, NE of the culvert under HWY 15, and about 150 yards north from the highway. Well 13101 was drilled to 136 feet in sandy clay till (the Pierre shale had not been reached). The well was screened at 110 to 115 feet in predominantly coarse sand and gravel. The shallow well on site, (13102) was drilled to 32 feet, and the well screen was placed at 25 to 30 feet in predominantly medium and coarse sand and gravel. Lithology, construction, and completion information are in Appendix A.

(7) The M-203 Range is being constructed in T148N R63W section 2A and section 1B. Ground water between the M-203 Range and the CLWL flow system will be sampled using wells constructed at T148N R63W S2ACA. Well 13086 was drilled to 120 feet, and the well screen was placed at 97 to 102 feet in predominantly medium and coarse sand and gravel. Well 13087 was drilled to 27 feet, and the well screen was placed at 18 to 23 feet in predominantly coarse gravely sand. Lithology, construction, and completion information are in Appendix A.

Bivouac Sites

On the CGS reserve there are no concentrated fueling or repair depots. Fueling is done at bivouac sites using tank trucks. Mosquito control measures, and spraying of insecticides is also primarily associated with bivouac sites and with maneuver areas. For this reason, insecticide and petroleum sampling will be done near bivouac sites. In addition, nitrates will be used as indicators of possible contamination from human waste, and alloy metals (cadmium and zinc) will be used as possible indicators of contaminants from discarded lubricants. Placement of wells was planned based upon water flow and drainage considerations discussed above, near bivouac sites. Sample sites designated for petroleum, and nitrate sampling are listed on table 1. A map of all proposed ground-water and surface-water sampling sites is on figure 3. A map of the actual sampling sites is on figure 4.

(8) One bivouac area is located in section 30ABA (T149N,R62W) near the top of a coulee oriented eastward toward the Colvin Creek Basin. Sample wells were planned for placement in the coulee, near the mapped trail at location T149N R62W section 30ABBB about 800 feet from the bivouac site. Actual placement of the well nest was near the mouth of the coulee at T149N R62W S19DBD3.

Well 13090 was drilled to 112 feet (Pierre shale was reached at 107 feet). The well screen was placed at 95 to 100 feet in coarse sandy till (about 25% clay). Well 1091 was drilled to 40 feet. The well screen was placed at 25 to 30 feet in predominantly medium sand. After drilling in 1992, however, well 1091 was dry and could not be sampled. A third well (13106) was drilled to 51 feet, and the screen was placed from 43 to 48 feet in coarse and very coarse sand.

Two problems were encountered during well construction at site 8. For well 13090 drilling was impeded several times by collapse of the sand into the hole. Bentonite was used to enable well placement. During the drilling of well 13106 a spray plane appeared a few hundred feet upwind and sprayed the area with picloram. The smell of the spray was strong on site, and both the drill rig and the well casing were sprayed. This well was cleaned and purged several times after construction. First samples taken for pesticides in 1993 indicated no detections of picloram, so this well should be adequate for sampling in the future. Lithology, construction, and completion information are in Appendix A.

(9) Two bivouac areas are located in section 13DAC and 13DCA. (T149N, R63W), at the head of a coulee draining northeastward into a littoral area feeding into the Colvin Creek drainage. Two wells were placed at T149N R 63W S13DAA, southeast of the engineering training site (1992) near the mouth of the coulee. Well 13088 was drilled to 110 feet (Pierre shale bedrock boundary was at 100 feet). The well screen was placed at 95 to 100 feet in brittle sandy clay. Well 13089 was drilled to 40 feet, and the well screen was placed in predominantly medium and coarse sand at 30 to 35 feet. Lithology, construction, and completion information are in Appendix A.

(10) One bivouac area is located in section 12CDC (T149N, R63W) and another is located at section 12 (CCC). This area is drained by a series of minor coulees trending eastward into a littoral areas that drains both northeastward into the Colvin Creek basin, and also directly northward into an ephemeral lake which appears to be connected with Lake Washington (as evidenced by intervening littoral areas mapped between the two lakes.) A steep coulee extends northeastward from the upper plateau in section 12CAC. A nest of two

wells was placed in this coulee. The coulee is crossed by a road extending north from abandoned farm buildings (1992) and leading off the military reserve on the north boundary. The coulee is located between abandoned buildings and a well and pump (1992) on the north crest of the coulee. Well 13092 was drilled to 130 feet (bedrock was not reached). Well screen was placed at 105 to 110 feet in coarse silicate, carbonate, and shale gravel. Well 13093 was drilled to 55 feet, and well screen was placed at 45 to 50 feet in predominantly medium sand, just above the till contact. Lithology, construction, and completion information are in Appendix A.

(11) A bivouac site is located near the eastern shore of South Washington Lake, in section T149N, R63W 14DBD . A site previously selected and sampled on Washington Lake, at section 14DBC should be adequately placed for gauging possible contamination from this site. The location of the sampling site on the lake is approximately 1000 feet from the bivouac site. Water samples were taken on South Washington Lake in August 1993 at the approximate location of T149N, R63W section 14CAC, and will be taken regularly in the implementation of Phase II of the water quality monitoring plan.

(12) South of HWY 15, one bivouac area is located in section T148N,R63W 2BB. This bivouac site is located near the head of a coulee oriented northeastward toward the CLWL littoral system, between Cherry Lake and Lake Coe. Sample wells were placed at T148N,R63W section 2BABC, which lies in the coulee approximately 600 feet northeast of the bivouac site. The well nest is located just north of the abandoned Pinkerton farm, on the east border fence before descending to the slough-littoral complex. Well 13084 was drilled to 89 feet (Pierre shale bedrock was reached at 80 feet). The well screen was placed at 69 to 74 feet in predominantly fine and medium sand. Well 13085 was drilled to 20 feet. The well screen was placed at 12 to 17 feet, also in predominantly fine and medium sand. This site is within the safety fan of the machine gun and recoilless rifle ranges, and will likely be used only for limited periods, or possibly it may be abandoned in the future. Sampling schedule will be adjusted to accommodate land use practices. Lithology, construction, and completion information are in Appendix A.

(13) South of HWY 15 two bivouac sites are located on T129N, R63W section 35ACA. These sites are on a promontory overlying the CLWL littoral system on the northward facing slope. Although no clearly defined coulee is located near this site, a nest of two wells was placed between the plateau near one of the bivouac sites and the lake and littoral system. The location is T129N, R63W section 35CBA. Well 13099 was drilled to 48 feet (Pierre shale contact was at 47 feet). The well screen was placed at 39.5 to 43.5 feet in predominantly medium and coarse sand. Well 13100 was drilled to 30 feet and the

well screen was placed from 23 to 28 feet in predominantly medium and coarse sand. As with bivouac sample site (12) above, this site is within the safety fan of the machine gun and recoilless rifle ranges, and will likely be used only for limited periods, or possibly it may be abandoned in the future. Sampling will be adjusted to land use practices. Lithology, construction, and completion information are in Appendix A.

(14 and 15) Four bivouac areas are located along the south shore of Lake Coe in sections 26 and 27 (T129N, R63W). Two lake samples have been previously taken on Lake Coe. Both previous sample locations were well placed for a representative sample position on two of the four bivouac sites. The first sample position was located at T129N, R63W section 26ADD and is approximately 1200 feet northeast of the eastern-most bivouac site. The second sample position is located at T129N, R63W section 27DBD, and is 1200 feet northeast of the western-most Lake Coe bivouac site. Two Lake Coe samples were taken in August of 1993, and will sampled at regular intervals in the implementation of phase II.

There are several other factors that render these specific lake sampling sites particularly useful. (1) All four Lake Coe bivouac sites are bracketed on east and west sides. (2) The section 26ADD site is directly in line with and close to the inlet of the Cherry Lake littoral unit to Lake Coe, and also lies on a direct line of that littoral unit with South Lake Washington. (3) All three lowland littoral systems (Cherry Lake, South Twin Lake, and Nine Mile Lake) appear to converge into the Cherry Lake and Lake Washington flow system at this approximate point. (4) Both of the buried Cherry Lake aquifer units are mapped as present under this sampling site. Finally, (5) the 26ADD site is near the eastern bank of Lake Coe approximately 1200 feet southwest of a training site, and approximately 1200 feet south southeast of an area planned for a Classification IV facility (nature of the facility is at present unknown).

Herbicide Sampling.

Herbicide use is primarily for leafy spurge control. The main body of the leafy spurge control area is located north of HWY 15, and centered on sections 13, 24, 25, and 30 (and peripheral areas of adjoining sections) of T149N,R63W(figure 4). In this area, water samples for pesticide analysis were planned to be taken from wells associated with bivouac areas within or near the leafy surge management areas (Sites 8 through 15 above).. Samples were also planned for an active spring (located northwest of the engineering training site [1993]). A water sample for pesticide anslysis was also be taken from Site (6) discussed above.

(16) In addition to sampling for herbicides at wells associated with bivouac sites north of HWY 15, a spring located on T149N, R63W S 13BDA was sampled, and will continue to be sampled in the implementation of Phase II. The spring has been sampled previously, and is a part of the network sampled for basic water quality and trace elements. Because this spring is likely formed along the interface of the shallow surface sandy unit and the underlying glacial till, it should serve as an indicator of the extent of contamination shallow water on the uplands of section 13, as it converges and enters into the northern slough and littoral complex leading to the Colvin Creek Basin, and also to the ephemeral lake connected with Lake Washington, northwest of the CGS reserve.

(17) A second leafy spurge control area is located in the NE quarter of section 4, T148N, R63W, along the eastern border of the North Twin Lake. Although this area is currently the focus of experiments in natural control (sheep, goats, etc.), eventual control measures may be modified or changed. A nest of two wells was placed at T148N-R63W S4ABA. Well 13095 was drilled to 60 feet. Pierre shale bedrock contact was at 46 feet. The well screen was placed from 39 feet and eight inches to 44 feet and 8 inches in predominantly medium gray sand. Well 13096 was drilled to 31 feet and the well screen was placed at 25 to 30 feet in predominately medium sand. As with previous strategy, well placement is in the broad mouth of a coulee at a position intervening between the highlands and North Twin Lake. A clay layer intervenes between the two wells. At the time of drilling (September 24 1992), the deeper well had an initial water level at approximately 6.4 feet below land surface while the shallower well had an approximate initial water level at 5.7 feet. However, at the time of sampling in August of 1993 (after a very wet summer) the deeper well (13095) was flowing and the shallower well was not. Lithology, construction, and completion information are in Appendix A.

Current well placement plans are based on present, and likely future monitoring needs. Leafy spurge is a persistent problem that has affected North Dakota for many years, and ongoing control measures can be reasonably expected. However, it must be recognized that other insects or weed species may enter the CGS facility in the future, and changes in control measures may have to be made based on those changes. In implementation of Phase II, it is important to review the current plan periodically to reevaluate the sufficiency of the sample plan.

Special Applications and Concerns

One area of particular concern is the Crystal Pure bottled water enterprise, which draws spring water from three springs on the northeast side of South Lake Washington

(T129N, R63W, section 14BAA) for commercial sale. Water Permit 3736 for the bottling of 1.5 acre feet of water per year was granted to Ms. Fran Gillis by the North Dakota State Water Commission in 1984. As of the present (March 1994) Crystal Pure bottled water has discontinued operation, and has received notification that the water permit may be cancelled. Nonetheless, the possibility of future resumption of bottling must be considered.

The State of North Dakota has not yet completed its overall ground-water protection plan, and currently the State ground-water pesticide protection plan is still in the initial phases of its planning. However, it is likely that EPA-MDL (minimum detection levels) will be applied for pesticide species and other contaminants in ground water. The nature of the Crystal Springs product, however, is likely to demand a much higher level of protection from contamination. Buyers of bottled water are frequently buying "purity". As such, measures to determine baseline levels of contamination at the Crystal Springs sources, and to protect the springs from upland activities, can be considered as an important priority. Even were the Crystal Springs enterprise not present, it might be considered important to protect the purity of such a spring resource. And the direct flowage of the springs into South Lake Washington also is of interest because of the obvious function of the springs as a conduit of water from the moraine complex into the CLWL regional flow system.

(18a,b,c)It was suggested in the initial proposal that the three springs be initially tested for basic water quality, trace elements, nitrates, locally used pesticides, and petroleum products. The purpose of this sampling was to be to the establishment base-line data for comparison with any possible future incidence of contamination.

In addition, it was suggested that two observation wells be placed between the National Guard activities on the moraine uplands and the springs as an early warning of any advancing potential pollutants originating on the CGS reserve property.

(19) The first suggested observation well location was along a trail at T129N, R63W S 11DDC. The site is located on the northeasterly transect line between the springs and the bivouac areas on the upper moraine in adjoining section 12. The location is approximately equidistant (about 2000 ft) from both the nearest bivouac area and the springs.

(20) The second suggested observation well location was planned for T129N, R63W S 14ADC. This position is occupies a low elevation approximately 3000 ft. distant from the springs in the southeast direction, and lies directly between the CGS activity and spray areas on the moraine and the springs. A single well (13094) was drilled in an enclosed pasture at T149N R63W S 14AAB. The well was drilled to 40 feet. Pierre shale bedrock was reached at 22 feet. The well screen was placed at 17 to 22 feet in fine to very coarse sand. The first

sample was taken in August of 1993. Ongoing sampling under Phase II should be adjusted to land use practices. Lithology, construction, and completion information are in Appendix A.

Both the springs and the recommended well at site 19 are on property not currently owned by the North Dakota National Guard. The establishment of sampling and monitoring points suggested were dependent upon cooperation and permission from current land owners. Mr. Doug Gillis was contacted on two occasions. An informal home contact with Doug Gillis was made by myself and Major Richard Mosier prior to drilling in which the objective of protecting the springs was explained, and permission was asked to sample the springs and place a well on the Gillis property. A letter of formal inquiry was sent thereafter (August 25 1992: copy on file SWC project 1856). There was no written reply to the letter of inquiry. While making a final check of phone cables I encountered Mr. Gillis and inquired concerning his decision. He replied that they did not wish to give permission. For this reason, well site 19 (as described above) was not drilled and the springs were not sampled. Well 20, however, was drilled and sampled. Basic water quality of the springs was determined in conjunction with the issuance of the water permit and can be obtained, if necessary, from the file of water permit 3736.

Human and Livestock Waste

In the past, troops on bivouac dug latrines to dispose of human waste. In the future the North Dakota National Guard will be using portable latrine facilities. For most of the year CGS land is rented for pasturing of cattle. This raises the possibility of contamination from livestock waste. Possible contamination from human or livestock detritus should be indicated in basic water chemistry. Nitrate levels would serve as one such indicator of contamination. A sampling of general water chemistry, including nitrate levels, was recommended and implemented for all wells after construction. After baseline levels are set, continuing measurements are suggested for selected wells.

OBSERVATION WELL CONSTRUCTION

Although in recent years there has been much discussion of stainless steel and polypolytetrafluoroethylene (PTFE), commonly known by the brand name teflon, as contact materials for use in monitoring organic chemicals in ground water, more recent research has indicated that for low level organic contaminants polyvinyl chloride (PVC) is less sorptive than PTFE. Stainless steel is least sorptive, but releases trace metals. Hence, for general water quality sampling most indications are that PVC casing and screen are adequate, and in some cases preferred. Moreover, there have been some indications that use of PTFE might have some drawbacks. PTFE casing, for example, does not have the tensile strength of PVC and is more prone to breakage and more difficult to handle. Some practitioners have indicated that lack of friction surface impedes the joining of grout to casing and may facilitate annular leakage from the surface. The issue of sample well material suitability has been reviewed by Parker et al. (1990), Schuh et al. (1993), and by the EPA in its RCRA Ground-water monitoring draft guidance (1992).

Before drilling clearance was obtained from the United States Air Force to assure that communication cables to missile silos would not be jeopardized (clearance copy in SWC project file 1856). All wells were drilled with a foreward rotary drill. No bentonite or non aqueous drilling fluids were used, except for well 13090 where bentonite was used. General well construction materials on the CGS facility consisted of 2-inch PVC casing, with a 5 foot long 2-inch PVC well screen of appropriate slot size. Screens and joints were joined using stainless steel screws rather than solvent weld cements. Sand pack (number 10 sand) was placed to about 3 feet above the well screen. A bentonite slurry grout was used to within a few feet of the surface. The last 3 to 5 feet of each well was cemented, and a 4 inch-PVC protective cover was placed over each well in August of 1993. Each well was covered with several plastic bags after completion and development to prevent contamination. It is planned that the North Dakota National Guard will provide locking caps on each well, and that the measuring point elevations of each well will be surveyed.

Well Development

Each well was thoroughly developed after placement. Development methods were based on water levels and upon proposed sample purpose. Wells having a water level at less than 20 feet were pumped using a suction pump. For water levels deeper than 20 feet a compressed air lift was used. The tip of the air hose was always left more than 20 feet above the top of the well screen to avoid introduction of aerated water into the aquifer. Development continued until the water was clear of sediment. In most cases, at least 7 hours of air lift were used. For wells to be used for screening of petroleum products several additional well volumes of water were removed with a bladder pump after completion of air lift to insure that water was not petroleum contaminated from the initial well development process. Additional cleaning with a bladder pump was also used in areas where pesticide spraying, and consequent likelihood of residue in road dust, increased the likelihood of contamination of the compressor hose. Details of well development are described in Appendix A with basic well information and lithology.

Sample Network Design

The sample plan for organic contaminants (petroleum and pesticides) was designed to concentrate on the upper saturated zones of the Cherry Lake aquifer. In all cases an attempt was made to place a well screen within a coarse saturated unit closest to land surface, because this is considered to be the most likely zone of contamination. In a few cases, sample wells were placed in saturated till, if this was found to be the most suitable sampling depth.

Despite the primary focus on shallow sampling it was considered important that each sampling site be constructed with the capability to provide sampling capability and hydrologic information to greater depths. Thorough understanding of the stratigraphic position of the sample well, the capability to assemble essential information concerning the hydrologic context of a given sample well, and the ability to confirm deeper movement (or lack of movement) of a given contaminant locally without resorting to later drilling was considered necessary to guarantee maximum utility from each site. Nested wells should help to avoid large unnecessary expense in further investigation of intermittent or ephemeral detections, should detections occur.

Because of the need for detailed lithologic and hydrologic information, it was considered desirable to drill to bedrock wherever possible. However, excessive open drill hole beneath the well screen is detrimental to both piezometric measurements and to measurement of local water chemistry. If drilling depth beneath a level for desired well-screen placement was becoming excessive, and if bedrock had not yet been reached, drilling was discontinued and the well placed.

SAMPLING PLAN OVERVIEW

The overall sampling plan for the CGS facility was planned in two phases. The first phase was that of laying down baseline data for each of the sampling sites and wells. The second phase is the ongoing monitoring program. Phase I has been completed and is summarized in this report. Phase II remains to be implemented.

PHASE I SAMPLE DESCRIPTION

For phase I it was recommended that one set of general water chemistry data, and one set of trace elements data, including lead, zinc, and cadmium, be run initially on each well and each site. These measurements were recommend because basic water chemistry data can be used to help interpret water sources, hydrologic connections, and relationships between depths and sites. In addition, certain types of mishaps, such as inadvertent or accidental dumping or spilling of used motor oils, might result in changes in trace element chemistry. Vehicle staging areas are located at individual bivouac sites, Similarly, lead from munitions and explosives might effect surface water or shallow ground water under some conditions. If mishaps or spills occur comparison of basic water chemistry and trace element analysis with earlier conditions would be useful. It would not be expected that basic water chemistry be monitored at all sites routinely in the ongoing sampling program.

Sample Procedures

Sample procedures were adapted to requirements of individual analytes. At least three well volumes were removed before sampling for basic water chemistry and for trace elements. At least five well volumes were removed before sampling for petroleum products or pesticides. Wells to be sampled for basic water quality and trace elements alone were first evacuated for several well volumes using compressed air lift or a jet pump. Wells were purged additionally for 2 to three well volumes using a gas-squeeze pump, and general water chemistry and trace metals samples were taken with the gas-squeeze pump.

Wells to be sampled for pesticides and petroleum indicators were purged using a gas-squeeze pump. The pump (and hose near the pump) were cleaned with alkanox detergent and water spray before placement in each well. The entire length of the hose for the gas-squeeze pump were also washed with alkanox and water before placement in the well. After purging a clean PTFE bailer was used for sampling in the fall of 1992. In 1993, after a review of the literature that indicated that short-term bailer contact of organics on most rigid bailer materials did not influence results (Schuh et al. 1993), disposable rigid polyethylene bailers were used. Bailer contact time for each sample never exceeded one minute. At least one additional well volume of water was bailed from the well with the bailer before sampling.

Lake samples were taken from a boat. A stainless steel Kemerer sampler was used. Before each sampling the stainless steel was washed with alkanox soap and with distilled water, and wrapped in a polyethylene protective bag.

Clean-clean measures, including new rope for each bailer, a clean sample person touching only clean materials, and assisted by a utility person who handled all other materials, use of clean latex rubber gloves for each well, were employed on each site. All samples for pesticides and petroleum products were placed immediately on ice in a cooler, and were stored overnight in a refrigerator. All were transported on ice to a shipping point within three days of sampling, and were shipped on ice to a laboratory with transit time of less than 24 hours. Pesticide and total petroleum hydrocarbon (TPH) samples were extracted in less than 7 days, and were measured in the laboratory within 21 days of sampling.

General Water Chemistry and Trace Elements

Initial general water chemistry [pH, total dissolved solids (TDS), hardness, specific conductivity, temperature, sodium adsorption ration (SAR), bicarbonate (HCO_3), potassium (K), sodium (Na), sulfate (SO_4),, nitrate (NO_3), chloride (Cl), fluoride (F), boron (B), silicate (SiO_2), iron (Fe), manganese (Mn), calcium (Ca), and magnesium (Mg.); and trace elements [arsenic (As), molybdenum (Mo), mercury (Hg), selenium (Se), lead (Pb), strontium (Sr), lithium (Li), boron (Bo), cadmium (Cd), and zinc (Zn)] were taken from each well in the fall of 1992 and in August of 1993. All samples were taken after purging of at least three well volumes of water from the well. Samples were stored in 500 ml polyethylene bottles. All basic chemistry bottles were washed with well water before collecting the sample. Trace metal bottles were washed with concentrated nitric acid, two distilled water washes, and one deionized water wash before use. Trace metal samples were acidified in the field with 2 ml of concentrated nitric acid per 500 ml sample. Lab methods were described previously by Shaver (1991).

A summary of samples taken for inorganic analyses is on table 1. Results of general water chemistry analysis are presented in table B.1 of Appendix B. Base-line trace elements for the wells drilled in 1992 are presented in table B.2. In 1991, follow-up samples from wells drilled and previously sampled by Comeskey (1989) were taken. General chemistry data for these samples are presented on table B.3. Earlier data from Comeskey (1989) are also recapitulated for comparison. Trace element data for the resampling are presented on table B.4. Trace element data from the earlier sampling was not presented. by Comeskey (1989) and are included for the first time on this table. Well lithologies and maps of well locations are not presented, however. This information can be found in Comeskey (1989).

Initial Pesticide Screening

Initial pesticide samples were to be taken from areas where spraying for mosquito control (chlorpyrifos [Dursban or Lorsban] and malathion) and leafy spurge control (picloram [or Tordon]) had been implemented. Sampling procedures were described above. At least one distilled water field blank was run for each field sample period. Distilled water was decanted from a bottle into a clean bailer with clean rope under field conditions and then poured into clean bottles. Pesticides tested include alachlor, atrazine, butylate, chloramben, chlorpyrifos, cyanazine, diallate, dicamba, dimethoate, EPTC, ethalfluralin, fonofos, linuron, malathion, methyl parathion, metolachlor, metribuzin, pendimethalin, picloram, phorate, propachlor, prometon, propazine, simazine, terbufos, triallate, triclopyr. trifluralin, 2,4-D, 2,4-DB, 2,4,5-T, 2,4,5-TP. Wells to be sampled for both munitions and pesticides were sampled in the fall of 1992. Acid extractions had poor lab recoveries and had to be resampled for acid extractions alone in 1993.

Lab extraction (done by Minnesota Valley Testing Laboratory, New Ulm Minnesota) was performed using EPA method 608.1 (Pressley and Longbottom, 1982) for base neutrals and EPA method 515 for acides (Graves, 1989). Detections were made on a Shimadzu 14 A gas chromatograph with dual electron capture and dual flame thermionic detectors. Columns used were Restek RTx5 and Rtx 35. A distilled water lab quality control blank was run with each sample set. There were no detections of any of the target analytes in the screening, except for triclopyr, which was detected at low (0.131 µg/L) levels. Triclopyr was not an analyte of concern for the sample site. Results of pesticide analyses are summarized in Appendix C. Signed laboratory reports with accompanying lab quality control reports are on file under project 1856 of the North Dakota State Water Commission.

Pesticide samples were planned to be taken only from the shallow wells. However, in the wet summer of 1994 two of the deeper wells (well 13101 on site 6 and well 13095 on site 17) were found to be flowing. On site 17 (Table 1 and figure 4) the deeper well (13095) was flowing while the shallower well (13096) was not. Between the two wells there was an intervening clay layer. The cause of the increased pressure could be attributed to either increased overburden from the weight of the additional water in the shallower well on the overlying clay layer, or to pressure induced by recharge from the nearby highlands.

The increase in pressure from an initial piezometric level approximately 6 feet beneath land surface to a flowing condition was most likely caused by recharge in the nearby uplands. The reason for this conclusion lies in the potential effects of grain matrix on pressure rise in both (upland recharge and overburden) situations. Upland recharge occurs under conditions where the aquifer is unconfined. Pressure is then transmitted through the confined portions of the aquifer to the well, with some pressure loss due to resistance. Under water table recharge conditions and for an unconfined aquifer having a storage coefficient of about 0.23, only about one fourth of 6 feet , or 16 inches of water would be necessary to affect a pressure change of 6 feet. In this condition, the grain matrix acts as a filler, and increases the amount of piezometric rise per unit of recharge input by a factor of about four.

Conversely, for the case of overburden, under optimal conditions and with no efficiency loss the maximum rise in piezometric pressure cannot exceed the weight of water added to the system overlying the confining layer. This means that at least six feet of water would have to be added to the vadose and aquifer system overlying the confining unit to affect a piezometric rise of 6 feet in the aquifer. However, the effect of the overlying grain matrix in this case is to decrease the piezometric effectiveness of the added water, since only a fraction of the weight of the added water is transmitted to the underlying aquifer, and a large portion of the weight is born by grain matrix of the confined system. The fraction of the pressure born by the water is usually greater than 0.1, but is almost always considerably less than 1 (Van Der Kamp and Maathuis). This means that to affect a 6 foot rise in pressure in the deeper aquifer unit would require an addition of 6 to 60 feet of water to the materials overlying the confining layer.

In southern Eddy County May through August rainfall exceeded 20 inches, which is consistent with the measured piezometric rise from the standpoint of upland recharge (that is about 16 inches of added water). In order to affect a 6 foot pressure-head increase, however, the North Twin Lake water level would have risen above the wells. Thus, the flowing well was undoubtedly influenced by upland recharge. Because of the evidence of movement of recharge water from the sprayed uplands to the deeper well on site 17, an additional pesticide sample was taken from the deep well in August of 1993. A summary of pesticide samples taken is on table 1.

Initial Petroleum Samples

Because of the general association of vehicle staging with bivouac areas, initial samples taken for measurement of TPH were taken primarily from wells associated with bivouac areas, and from springs in bivouac areas. TPH samples sites include sites 8, 9, 10,11,12,13,14, and 15 (table 1). Only the shallow wells were sampled on each well site. Laboratory analysis for TPH was performed by Minnesota Valley Testing Laboratory (New Ulm, Minnesota) using methods OA-1 and OA-2 of the University of Iowa Hygenics Laboratory (1990). A summary of TPH results is in Appendix D. Original signed laboratory reports are on file as North Dakota State Water Commission project number 1856.

Initial Munitions Samples

Several of the sampling sites described above and on table 1, were placed to provide thorough coverage for the munitions and explosives facilities being constructed south of

HWY 15. However, only one of the planned sites, the Demolition Range, was in operation at the time of initial sampling (1992 and 1993). The heavy metals (i.e.. lead) portion of the contamination concern should be covered by base-line sampling of trace elements described above. On the Camp Grafton facility, where soil pH values are commonly between 7.8 and 8.2 it is expected that lead should be quickly immobilized through precipitation with carbonates and through adsorption on clay particles. However, under some specific conditions of localized acidity, or in some surface bodies of water elevated lead may occur. This uncommon prospect is covered in the sample plan.

Specific explosives screened include HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine), RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine), Nitrobenzene, Tetryl (methyl-2,4,6-trinitrophenylnitramine), 1,3,5-trinitrobenzene, 1,3-Dinitrobenzene, 2,4,6-TNT (TNT is trinitrotoluene), 2,4-DNT (DNT is dinitrotoluene), and 2,6-DNT (DNT is dinitrotoluene). Only the shallow wells will be sampled on each designated well site. The laboratory method used was developed by Data Chem Laboratories, is designated as method USA-EC, and has been approved by the United States Army (verbal communication, Ken. M. Spaulding, Laboratory Supervisor, February 7 1994). All inquiries concerning methods should be addressed to Mr. Spaulding (see REFERENCE section). Original signed laboratory reports are on files as North Dakota State Water Commission Project 1856.

RESULTS

Inorganic Water Quality Data

There are two sets of inorganic water quality samples taken from the CGS facility. The first set included data from water quality samples for wells drilled in 1986 and 1987 which were presented by Comeskey (1989). This data set also included samples taken from Lake Coe, South Washington Lake, and two springs on the CGS facility (table 2).

The second data set, presented in this report, included two components. The first component included samples for basic water quality and trace metals in all of the wells and bodies of water used for sampling petroleum, pesticides, and munitions parameters in this study. General water chemistry and trace element data are in tables B.1 and B.2 of Appendix B respectively. The second component consisted of follow-up samples for determination of basic water chemistry and trace elements in each of the previously sampled wells and lakes (table 2). Sampling for this component was conducted in the fall of 1991. General water chemistry and trace elements (along with previous water chemistry data) are in tables B.3 and B.4 respectively.

Table 2. Wells drilled and sampled previously by Comeskey (1989) in 1986 and 1987. Sample species include munitions (Mun), total petrolium hydrocarbons (TPH), herbicides (Herb), Insecticides (Insect), basic water chemistry (Basic), and trace elements (Trace). * S W Lake = South Washington Lake

SWC Well Number	Township	Range	Section	Location	Mun	TPH	Herb	Insect	Basic	Trace
12024B	148	63	1	CBBC2					x	x
Spring	148	63	2	DA					x	x
12021A	149	63	13	BAAB1					x	x
Spring	149	63	13	BD					x	x
Spring	148	63	14	BAD					x	x
S W Lake*	148	63	14	CA					x	x
12020A	149	63	14	DACD1					x	x
12020B	148	63	14	DACD2					x	x
12020C	148	63	14	DACD3					x	x
12019A	149	63	23	ADBB1					x	x
12019B	149	63	23	ADBB2					x	x
12019C	149	63	23	ADBB3					x	x
12017A	149	63	25	DBBC1					x	x
12017B	149	63	25	DBBC2					x	x
12017C	149	63	25	DBBC3					x	x
12017D	149	63	25	DBBC4					x	x
Lake Coe	149	63	26	DA					x	x
12025	149	63	26	DCA					x	x
Lake Coe	149	63	27	CA					x	x
12022	149	63	27	DDDC2					x	x
12015B	149	63	31	ABBC2					x	x
12026A	149	63	34	BBB1					x	x
12026B	149	63	34	BBB2					x	x
12011B	149	63	35	ABBD2					x	x
12014B	149	63	36	AACB2					x	x
12014C	149	63	36	AACB3					x	x
12014D	149	63	36	AACB4					x	x
12013B	149	63	36	BBDA2					x	x
12023A	149	63	36	DDBC1					x	x
12023B	149	63	36	DDBC2					x	x
12023C	149	63	36	DDBC3					x	x

Samples taken from Lake Coe and South Washington Lake in 1993 are very high in TDS, and pH is above 9.0. Nitrate is low in both lakes. Neither lake has detectable concentrations of lead, mercury, selenium, or cadmium. South Washington Lake is primarily of the sodium sulfatic type, with large concentrations of bicarbonate and chloride as well. Sodium Adsorption Ratio (SAR) is high (20). Arsenic is above the Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 50 µg/l, at 71 µg/l. Previous lake samples taken in 1986 were also high (above or approaching MCL) in arsenic. Lake Coe was also very high in sodium. sulfate, and chloride. SAR was very high at 47. Arsenic levels were somewhat elevated at 24 µg/l, but were still below MCL.

The reservoir located at site 4 (table 1) near the new M60 machine gun range (in construction) has no detectable concentrations of lead, molybdenum, mercury, cadmium, or selenium. TDS and ECE are low. pH is neutral. Sulfate and chloride are low. Water is primarily of the calcium bicarbonate type.

All of the wells placed in the fall of 1992 were sampled in October of 1992 and August of 1993 for basic water chemistry and trace elements. All were low in nitrate (one to two orders of magnitude below EPA-MCL). TDS ranged from approximately 300 to 800 mg/l. The higher TDS was usually in deeper wells. Ph ranged from slightly acidic (near 6.5) to slightly basic (near 7.8), but were usually near neutral. There were no wells with water high in sulfate or chloride (> 250 ppm). Water from most shallow wells was primarily of the calcium and magnesium bicarbonate type. Water in deeper wells, completed in aquifers confined within the till or in proximity to the bedrock shale were frequently of the sodium-bicarbonate or sodium-sulfate type. None of the water was found to have detectable lead, cadmium, mercury, or selenium. Background levels of arsenic were usually around 4 to 10 µg/l (compared with EPA-MCL of 50) in the shallow wells, but were sometimes higher in deeper (as high as 51 µg/l on site 8) wells in closer proximity to the bedrock shale or imbedded within the till. An exception was site 1 (table 1) at which the arsenic level in the shallow aquifer unit was higher (52 µg/l) than the deeper aquifer (4 µg/l). <u>The arsenic source is almost certainly natural and not anthropogenic. There are no indications of any significant inorganic contaminants resulting from human use at this time.</u>

Data from the follow-up samples taken on the previously placed and samples wells (Comeskey 1993) are similar to those discussed above. Deeper wells are frequently associated with elevated sodium, sulfate, and chloride, and also with slightly elevated TDS. In many cases elevated arsenic detections also occur at greater depths. Although there are some detections of mercury, lead, and selenium, all are more than one order of magnitude below levels of toxicological concern. Barium was also sampled. Results varied from 75 to

250 μg/l. Because of wide spatial variability comparative use of barium must be confined to time trends on individual wells. Local arsenic levels should be considered in placement of wells for drinking water supplies.

Pesticides

A summary of wells sampled for pesticides is on table 1. Results are summarized in Appendix C. Of all samples taken, there was only one pesticide detection. Dimethoate was detected in the shallow well (13102) on site 6. There is no EPA maximum contaminant level (MCL) for dimethoate, but the detected concentration (0.8 mg/l) is close to the lifetime health advisory level of 1 mg/l.

There is no record of dimethoate having been sprayed on the CGS reserve. However, during construction of well 13102 in September of 1992, aerial spraying for leafy spurge was in progress about one and a half miles to the northeast of the well site. The wind was from the northeast, and pesticide could be smelled on the drill site. It is possible that some dimethoate residual from crop spraying could have been sprayed with the picloram, and that the well was directly contaminated during construction. This likelihood is increased by the fact that site 6 was one of two sites sampled in October 1992, rather than August 1993. Thus, the sampling time was less than two months after construction. The day following construction of site 6, well 13106 was also directly sprayed during construction. However, there were no detections of pesticides in well 13106 when sampled in August of 1993 (about one year after construction.)

It is also possible that the single dimethoate detection was spurious. Since there is no known source on the reserve, it is unlikely that this detection represents a case of environmental contamination. Well 13102 should be resampled in 1994 for dimethoate. If there is a second detection, then both wells on site 6 (Figure 4) should be sampled at least annually until no further detections occur.

Because of unusually large rainfall, infiltration, and runoff, 1993 should have been a prime year for contaminant movement to ground water. There were no indications that such contamination occurred. Previously, in 1986, the springs at site 3 and at site 16 (table 1) had been sampled for picloram and 2,4-D. There were no detections. Results of samples taken in 1986 are in table 3. The spring at site 16 was sampled for pesticides in August of 1993. There were no detections of any pesticides. Generally speaking, current data indicate that ground-water contamination caused by routine use of the reserve is not likely occurring.

Previous samples for picloram taken in Lake Washington and Lake Coe in September of 1986 indicated no detections (table 3). For August of 1993 picloram was detected in each of three lake samples: Two samples (sites 14 and 15) on Lake Coe were found to have 0.2 µg/l of picloram (MDL is 0.1 µg/l). One sample taken from Lake Washington had 0.4 µg/l of picloram. At the time of sampling no picloram had been sprayed since the previous fall (11 months previous to sampling). It is suspected that picloram reached the lakes in runoff during the extremely wet summer. It is recommended that another set of picloram samples be taken from Lake Coe and Lake Washington to be certain that runoff and spray drift are not persistently contaminating the lake. Picloram detections are more than one thousand times below levels of current EPA toxicological concern (maximum permissible contaminant level [MCL] is 500 µg/l). However, picloram should be monitored in the lakes on at least an annual basis.

Petroleum Products

All samples for total petroleum hydrocarbons (TPH) as gasoline and TPH as fuel oil were taken in August of 1993. Summary of wells sampled for TPH is on table 1. Results for each well are summarized in Appendix D. No indications of petroleum contamination were found in any of the wells sampled.

Table 3. Data for pesticide samples taken in 1986.

Location	Date	picloram µ g/l	2,4-D µ g/l	comments
149-63-14CA	9/15/86	<	< 0.1	South Washington Lake (2 ft. level)
149-063-27CA	9/15/86	<	< 0.1	Lake Coe, West End (3 ft. level)
149-63-26DA	9/15/86	<	< 0.1	Lake Coe, East End (2 ft. level)
149-63-16BD	9/15/86	<	< 0.1	Spring outfall pipe

Munitions and Explosives

Wells sampled for munitions and explosives in October of 1992 are indicated on table 1. Results for each well are in the Appendix E. There were no indications of any munitions and explosives analytes in any of the wells sampled.

PHASE 2

A second phase of the water quality monitoring plan for CGS (Schuh 1992) was designed to provide ongoing data for comparison with baseline data, and to provide assurance of noncontamination. It was recommended that after the initial base-line samples a representative number of the total wells for each type of potential contaminant be sampled in 3 year sets within a decade overall sampling cycle. A three year period was suggested because in current practice of environmental monitoring on military reserves one sample per year is often considered sufficient for monitoring the local status of the chemical. Less intense monitoring should be appropriate for facilities where no contamination has been shown to exist. Also, ground water flow rates are often very slow. Migration of contaminants between locations would be small in one year. Thus, for low intensity monitoring (assuming that a serious contamination problem does not exist) a three year period should be sufficient.

Various approaches toward sampling could be taken. One would be to sample a full complement of sites together every 3 three years. Another would be to take samples annually from one-third of the wells. A third approach would be to implement a predominant single sampling every three years, but with a few interim samples planned between major samplings.

A preestablished number of samples is suggested for each three year period in order to facilitate planning and preparation. It is suggested that general objectives for the ten year cycle should include the full completion of each sample-use battery for each designated sample site (Table 1) at least once. However, within the ten year cycle, each three year sampling scheme should be weighted toward use areas during the previous three year period. Moreover, it is recommended that flexibility be maintained so that unwarranted sampling can be avoided. For example, if no herbicide is used anywhere near a designated pesticide site in an allotted three year period (or within a decade) there would be no reason to sample it. On the other hand, some sites should probably be sampled for designated uses every three years. In some cases, even more frequent samples may be required, if problems arise.

(1) General chemistry: at least 25 wells (and sites) should be sampled every 3 years (There are total of 63 sites). After base-line data is established (Phase I) 25 wells should be selected at varying locations over the entire CGS facility for repeated sampling on a regular basis. Particular emphasis should be put on bivouac sites. A portion of the wells should be rotated so that every decade or so, every one of the sites and wells will be sampled

at least once. All wells and sites, including the well set placed previously by the SWC should be included in this sample set. (Approximate cost for the SWC lab based on 1994 cost structure would be about $1750.00. Adjustment for rising costs must be considered in future planning.)

(2) Trace element: a total of approximately 25 samples should be taken every three years. This should include all of the shallowest sample wells and the surface bodies of water associated with the munitions and explosives ranges (7 samples), and a rotating spot check on other wells and sites, with particular attention to the shallower units (13 samples). Some preference should be given to bivouac sites and other vehicular staging areas in the selection of additional sites. (Approximate cost for the SWC lab based on 1994 cost structure would be about $1250.00. Adjustment for rising costs must be considered in future planning.).

(3) Munitions and explosives samples should be taken from shallowest wells (and all surface bodies) of sample sites associated with firing and explosives range areas (7 samples plus 2 quality control samples). (Approximate cost for the contract lab based on 1992 laboratory cost structure would be about $2745.00. Adjustment for rising costs must be considered in future planning.).

(4) There are 8 designated petroleum sample sites. Petroleum contaminant samples should be taken from three of the most heavily used bivouac areas (or from areas where spills are known to have been likely). (Approximate cost for the contract lab based on 1992 contract laboratory cost structure would be about $350.00 Adjustment for rising costs must be considered in future planning.).

(5) Approximately 8 of the wells and sites in most active pesticide use areas (including insecticide and herbicide) should be sampled (there are a total of 8 sampling designated sampling sites). Shallow wells should be stressed. Some lake samples should also be taken. Two quality control samples should also be taken. (Approximate cost for the contract lab based on 1994 contract laboratory cost structure would be about $4250.00. Adjustment for rising costs must be considered in future planning.).

In addition, at least one sample should be taken each year from each of Lake Coe and South Washington Lake for picloram. This is necessary because of repeated picloram detections in surface waters in August of 1994. Additional surface water samples should also be considered. (Approximate cost for the contract lab based on 1994 contract laboratory cost structure would range from about $750.00 to $1250.00. Adjustment for rising costs must be considered in future planning). Sample collection, shipping fees, and reporting fees would be additional

Approximate sampling and data collation cost for a 3 year sample battery would be about $5,000.00 based on 1994 cost structure. Cost includes preparation, sampling, travel expense, and collation time for organizing new data and appending to original report. (Adjustment for rising costs must be considered in future planning). Annual surface water sampling cost would be considerably less.

ADDITIONAL CONCERNS AND ADDITIONAL WORK

This report, and the proposed future sampling plan will result in compilation of an organized set of data for reference in case of public or other concerns over the possibility of water resources contamination on the CGS facility. They do not provide, however, a detailed analysis of these data. The next proposed full sampling year is 1996. This will be 10 years after the initial sampling by Comeskey. It is suggested that in 1996 the North Dakota National Guard may wish to have both the hydraulic data and the chemical data analyzed to determine detailed local hydrology, and changes and trends in water chemistry caused by land use or natural processes.

It is noted that this plan and its cost estimate is based on routine sampling. If a major and repeated detection of contamination occurred, further activities, other than those outlined here, might be required.

SUMMARY

Basic water quality of the Cherry Lake aquifer on the Camp Grafton South military reservation is of low to average TDS (TDS < 800), near-neutral pH, and low to slightly high SAR. Shallow ground water is usually of the calcium bicarbonate type, while deeper aquifer units are frequently of the sodium sulfate type. There was no significant lead, mercury, selenium, or cadmium in any of the wells sampled. However, arsenic is present in most samples, and in some of the deeper aquifer units can approach and even exceed EPA-MCL. Natural lakes are very high in TDS, sulfate, chloride, and sodium, with pH above 9 and very high SAR. There was no significant lead, mercury, selenium, or cadmium in any of the samples. However, arsenic approached and exceeded EPA-MCL in most samples. Nitrates were low in both surface and ground water. There were no indications of anthropogenic degradation of basic water quality on the reserve.

Of the wells sampled in 1992 and 1993 there was only one pesticide detection. Dimethoate was detected at a level just below the EPA Lifetime Health Advisory Level in one well near Lake Coe. However, dimethoate was never deliberately sprayed on the CGS reserve. The well site of the detection was within spray drift zone of aerially sprayed picloram during drilling and construction of the well. Dimethoate residual in the picloram spray is a likely source. The dimethoate detection does not indicate a likely case of environmental ~~protection~~ contamination from routine facility use and care. There were no detections of picloram, malathion, chlorpyrifos, or any other pesticides used on the reserve in any of the well or spring samples.

There were detections of picloram (at extremely low levels) in Lake Coe and South Washington Lake in August of 1993. Because no picloram was detected in 1986, and because of the exceptionally heavy rainfall in 1993 it is suspected that these detections were a result of exceptional runoff. It is extremely unlikely that contaminants entered through ground water.

There were no indications of total petroleum hydrocarbons (gasoline or fuel oil) in any of the samples taken from ground water in August of 1993.

There were no detections of munitions and explosives residues (HMX, RDX, Nitrobenzene, tetryl, 1,3-dinitrobenzene, 2,4,6-TNT, 2,4-DNT, and 2,6-DNT) in any of the water samples taken in the fall of 1992.

RECOMMENDATIONS

1. South Washington Lake and Lake Coe should be sampled at least once per year to determine if contamination with pesticides during spraying for leafy spurge is causing a serious or long-term problem. This should continue until detection levels remain below zero for at least three years. Other surface water samples may also be considered for annual pesticide sampling. Pesticide samples from other designated wells should be taken as planned for the three year resampling schedule laid out in PHASE II of the initial proposal.

2. Well 13102 on site 6 should be sampled for dimethoate again in early 1994. If any detections are made, the entire site (wells 13101 and 13102) should be sampled at least once per year until no further detections are found.

3. Selected basic water quality, trace element, TPH, pesticide, and munitions and explosives residue samples should be taken again in 1996, and on a three year rotating schedule as described under Phase II above.

4. All wells drilled in 1992 should be surveyed for measuring point elevation by the North Dakota National Guard.

5. All wells drilled in 1992 should be fitted with locked caps on the 4-inch protective covers by the North Dakota National guard.

6. After the next sampling period (1996), the North Dakota National Guard may wish to consider a comparative analysis and report on trends in water quality from 1986 to 1994.

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APPENDIX A: SAMPLE WELL LITHOLOGY AND COMPLETION INFORMATION*

* Includes only information for wells drilled in 1992. Wells previously drilled (1986 and 1987) were described by Comeskey (1989)

SITE 1 149-062-28CCC1

NDSWC 13103

Date Completed:	9/30/92	Purpose:	Observation Well
L.S. Elevation (ft):	1510	Well Type:	2" PVC
Depth Drilled (ft):	156	Aquifer:	Cherry Lake
Screened Interval (ft):	139-144	Source:	

Completion Info: Construction: #8 well screen. No Glue. All joints secured with stainless steel screws. 5-100 lb. bag #10 sand, 5-50 lb. bag bentonite grout.

Development: Neither compressor nor suction pump alone was adequate. Merlin Skaley surged with compressor at 100 ft. and suction pumped simultantously. Pumped at 3/4 gpm for 5 h (225 gal, or @ 13 well casing volumes) Well yield gradually increased. Pumped an additional 2 h with compressor alone. Water began dirty but cleaned well.

Completion: Cemented and covered before spray. Fred Anderson set PC in August 1993.

Remarks: Initial WL @ 13 ft.
Location: South of HWY 15, SW of county road intersection in ditch. Visible from road. West well.

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	sandy, olive brown, gravel inclusions, shield silicate gravel, rounded and subrounded, (TILL)	1-10
CLAY	gray, carbonate rock at 13-14 ft; (TILL)	10-22
SAND	coarse, and gravel, shale, (subangular to angular), quartz shield silicates, very fine grained gravel carbonates	22-33
SAND	gravel and (TILL) interbedded	33-40
CLAY	sandy, gray, (TILL)	40-56
SAND	very fine to very coarse, predominantly medium, brownish gray	56-60

SITE 1 149-062-28CCC1 Continued

CLAY	sandy, gray, (TILL); at 62 ft drill chatter (granite rock); at 66 ft very slow (gravelly clay till); at 71 ft hard, greater silt and fine sand, less coarse sand; drill chatter at 82 ft; rock at 84 ft; at 88 ft drill chatter, carbonate and silicate gravel, rounded and subrounded, detrital shale, coarse sand, and fine gravel; at 97 ft less shale, gravel, and coarse sand imbedded in till (25-30% finer clay); slight drill slip at 107 ft; drill chatter at 119 ft; at 131 ft drill chatter; more sticky (approximately 30% clay)	60-140
GRAVEL & SAND	coarse sand, carbonates, quartz, and silicate; subrounded	140-145
CLAY	sandy, gray, same as above	145-151
SHALE	(PIERRE), angular flakes and cuttings	151-156

SITE 1 149-062-28CCC2

NDSWC 13104

Date Completed:	9/30/92	Purpose:	Observation Well
L.S. Elevation (ft):	1510	Well Type:	2" PVC
Depth Drilled (ft):	65	Aquifer:	Cherry Lake
Screened Interval (ft):	56-61	Source:	

Completion Info: Construction: #18 screen. No glue. All joints secured with stainless steel screws. 2.5 -100 lb. bag #10 sand. 2-50 lb. bag bentonite grout.

Development: Merlin Skaley surged with compressor for 3.5 h. Then suction pumped (300 gal., @ 43 well casings). Pumped and cleaned well.

Completion: Cement grout and covered before spray. PC set by Fred Anderson August 1993.

Initial WL @ 7.06 ft.

Remarks: Location: in nest with 13103 (east well) in road ditch south of HWY 15, SW of country road intersection. Visible from road. No contamination from any spray likely. West of Camp Grafton spray zone.

Lithologic Log

Unit	Description	Depth (ft)
	see test hole 13103; sand at 57 ft instead of 56 ft	0-0

SITE 2 149-062-29DAD

NDSWC 13105

Date Completed:	9/30/92	Purpose:	Observation Well
L.S. Elevation (ft):	1530	Well Type:	2" PVC
Depth Drilled (ft):	60	Aquifer:	Cherry Lake
Screened Interval (ft):	50-55	Source:	

Completion Info: Construction: #8 screen. No glue. All joints secured with stainless steel screws. 2.5-100 lb. bag # 10 sand (to 6 ft. above screen top.) 2-50 lb. bag bentonite grout.

Development: Surged 8 h with compressor. Purged and cleared well.

Completion: PC set by Fred Anderson, August 1993.

Initial WL @ 8.84 ft.

Remarks: Location: in west road ditch off gravel road, north of 13103-13104 site. No nest. Visible from road. Located near culvert under road. Southwest of farmstead (farmstead located on opposite side of road).

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SILT	brown and yellow, rock at 3 ft	1-3
CLAY	(approximately 15%), silty, black, (buried topsoil)	3-6
CLAY	yellow and olive brown with iron stains	6-11
CLAY	gray, unoxidized	11-36
SAND	very fine to medium, predominantly fine, gray	36-55
CLAY	sandy, imbedded coarse sand, gray, (TILL)	55-60

SITE 3 **148-063-02DA**

NDSWC

Date Completed:		Purpose:	
L.S. Elevation (ft):		Well Type:	Spring
Depth Drilled (ft):		Aquifer:	Cherry Lake
Screened Interval (ft):		Source:	

SITE 4 **148-062-31C**

NDSWC

Date Completed:		Purpose:	
L.S. Elevation (ft):		Well Type:	Surface Reservoir
Depth Drilled (ft):		Aquifer:	
Screened Interval (ft):		Source:	

SITE 5 149-063-36ACA1

NDSWC 13097

Date Completed:	9/29/92	Purpose:	
L.S. Elevation (ft):	1512	Well Type:	2" PVC
Depth Drilled (ft):	74	Aquifer:	Cherry Lake
Screened Interval (ft):	41-48	Source:	

Completion Info: Construction: #12 screen. No glue. All joints secured with stainless steel screws. 4.5-100 lb. bag #10 sand. Bentonite grout and cement grout.

Development: Merlin Skaley developed with compressor for 8 h. No problems. Water clear.

Completion. Cemented and covered before spray. Fred Anderson set PC in August 1993.

Initial WL @ 3 ft.

Remarks: Location: through rifle grenade range, and northwest. West well of nest.

Lithologic Log

Unit	Description	Depth (ft)
SAND & CLAY	[topsoil]	0-2
SAND	very fine to coarse, predominantly fine, brown	2-9
SILT	sandy, and clay, gray	9-11
SAND	very fine to coarse, predominantly fine, gray	11-16
SILT	and clay, gray, slightly cohesive and sticky	16-21
SAND	very fine to very coarse, predominantly fine and medium, gray; predominantly quartz, shield silicates, coarse sand and fine gravel size carbonates	21-27
SAND & CLAY	interbedded	27-30
CLAY	(approximately 20%), silty, gray, somewhat sticky and cohesive	30-41
SAND	very fine to coarse, predominantly medium sand	41-48
CLAY	sandy, (TILL), at 54 ft harder till (approximately 32% clay), cohesive and sticky, very coarse carbonate sand grains in till	48-74

SITE 5 149-063-36ACA2

NDSWC 13098

Date Completed:	9/29/92	Purpose:	Observation Well
L.S. Elevation (ft):	1512	Well Type:	2" PVC
Depth Drilled (ft):	31	Aquifer:	Cherry Lake
Screened Interval (ft):	21-27	Source:	

Completion Info: Construction: #12 screen. No glue. All joints are secured with stainless steel screws. 2.5-100 lb. bag #10 sand. 1-50 lb. bag bentonite grout.

Development: Merlin Skaley suction pumped 3 h (720 gal. , @ 267 casing volumes). No problems. Water clean.

Completion: Cemented and covered before spray. PC set by Fred Anderson in August 1993.

Initial WL @ 5 ft.

Remarks: Location: in nest with 13097. East well. Located in low area through and northwest of rifle grenade range.

Lithologic Log

Unit	Description	Depth (ft)
SAND	[topsoil], silt clay	0-3
SAND	silty	3-11
SAND	very fine to very coarse, predominantly medium, gray	11-14
SILT	sandy	14-18
SAND	and silt and clay (approximately 15%), dark brown (buried topsoil)	18-22
SAND	very fine to very coarse, predominantly medium, grayish brown, predominantly quartz, shield silicates, detrital shale gravel and coarse sand	22-29
	see test hole 13097 bottom 31 ft	29-31

SITE 6 149-063-25CDC1

NDSWC 13101

Date Completed:	9/29/92	Purpose:	Observation Well
L.S. Elevation (ft):	1510	Well Type:	2" PVC
Depth Drilled (ft):	145	Aquifer:	Cherry Lake
Screened Interval (ft):	110-115	Source:	

Completion Info: Construction: # 18 screen. No glue. All joints secured with stainless steel screws. 4-100 lb. bag # 10 sand. 5 or 6 -50 lb. bag bentonite grout.

Development: Bill Schuh developed 2.5 h, Merlin Skaley developed 4.5 h (7 h total) with air compressor.

Completion: PC set by Fred Anderson in August 1993.

Initial WL: none measured.

Remarks: Location: Slough north of HWY 15, NE of culvert under highway about 100 to 200 yards. South of Lake Coe.

Notes: During drilling picloram was aerial sprayed about 1 mile NE of site. Wind from NE @ 5 mph. Chemical could be smelled on site. Also, there was a problem setting screen. Some bentonite may have worked into empty cavity before natural formation collapsed on screen. Site was worked with air (into formation) to collapse. Air blasting used several times.

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-3
CLAY	silty and sandy, olive brown	3-5
SAND	(brown) fine to coarse, predominantly medium	5-7
CLAY	(sandy) coarse sand and gravel imbedded; brown; (TILL)	7-9
CLAY	(sandy) same as above but gray; at 29-31 ft chatter; greater than 31 ft is coarser till (approximately 15-20%); rock at 38-39 ft (granite); chatter at 43 ft; at 44 ft hard, till, silt, plastic, and cohesive; drill chatter at 52-55 ft; carbonate rock at 71-72 ft; drill chatter at 78 ft; (TILL)	9-82
SILT	clayey, gray	82-91

SITE 6 149-063-25CDC1 Continued

CLAY	(approximately 25-30%); sandy, interbedded coarse sand	91-101
SAND	fine to very coarse, predominantly coarse and gravel, predominantly gravel is carbonates, rounded and subrounded	101-136
CLAY	(sandy), gray, coarse sand inclusions; (TILL)	136-145

SITE 6 149-063-25CDC2

NDSWC 13102

Date Completed:	9/30/92	Purpose:	Observation Well
L.S. Elevation (ft):	1510	Well Type:	2" PVC
Depth Drilled (ft):	33	Aquifer:	Cherry Lake
Screened Interval (ft):	25-30	Source:	

Completion Info: Construction: # 8 screen. No glue. All joints secured with stainless steel screws. 2.75-100 lb. bag #10 sand. 1.5-50 lb. bag bentonite grout.

Development: Merlin Skaley suction pumped @ 1140 gal. (@ 325 well volumes). This was after picloram spray.

Completion. 4-inch PC set by Fred Anderson in August 1993.

Initial WL @ 1.5 ft.

Remarks: Location: in nest with 13101 (east well). North of HWY 15 and south of Lake Coe on east edge of slough. NE of culvert under HWY @ 100 to 200 yards. Visible from road. Access through barb wire fence gate (nongrated access).
Vehical access to sight with caution, only during dry years and seasons. Was not accessable by vehical in August 1993, only on foot.

Note: picloram was sprayed about 1 mile NE of site during drilling. Wind from NE at @ 5 mph. Chemical could be smelled on site.

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	sandy, olive brown	2-8
SAND	very fine to very coarse, predominantly medium brown	8-9
CLAY	sandy, olive brown	9-13

SITE 6 149-063-25CDC2 Continued

CLAY	sandy, gray	13-26
SAND	very fine to very coarse, predominantly medium and coarse; and gravel, quartz and carbonate gravel inclusions	26-33

SITE 7 148-063-02ACA1

NDSWC 13086

Date Completed:	9/22/92	Purpose:	Observation Well
L.S. Elevation (ft):	1515	Well Type:	2" PVC
Depth Drilled (ft):	120	Aquifer:	Cherry Lake
Screened Interval (ft):	97-102	Source:	

Completion Info: Construction: #8 screen. No glue. All joints stainless steel screws. 4.5 -100 lb. bag #10 sand. 3.75-50 lb. bag bentonite.

Development: Bill Schuh pumped 5 h with compressor (9/22-9/23/92). Merlin Skaley pumped 2.5 h with compressor (total 7.5 h). Skaley notes clear, good tasting water.

Completion: Well cemented and covered before aerial spraying. Fred Anderson set PC in August, 1993.

Initial WL @ 5.8 ft.

Remarks: Location: in coulee off causeway crossing slough to the old Pinkerton Farm.

Lithologic Log

Unit	Description	Depth (ft)
SAND	very fine to very coarse, predominantly fine to medium; dark brown, (soil)	0-4
SAND	very fine to very coarse, predominantly fine to medium; dark brown, (soil)	0-4
SAND	very fine to very coarse, predominantly medium to coarse, gravelly, less than 5% gravel, drill smooth, yellow stained, oxidized, stratified sequence, quartz, carbonate, shale, shield silicates, (water table indistinct)	4-23
CLAY	light gray and dark brown, silty clay with shell fragments, very soft, some organic	23-26
SAND	as above	26-35
CLAY	[TILL], silty, sandy, pebbly, olive gray	35-43
SAND	very fine to very coarse, predominantly medium, some gravel, predominantly quartz, some carbonates, shield silicate, shale	43-51
CLAY	[TILL], sandy, some pebbles and shells, sticky	51-62
SAND	(quick drill slip)	62-63
CLAY	[TILL], sandy, (same as 51-62 ft)	63-84

SITE 7 148-063-02ACA1 Continued

SAND	very fine to coarse, predominantly medium, interbedded with till	84-110
SAND	fine to very coarse, predominantly medium to coarse, moderate gravel, quartz rounded and subrounded, shale, shield silicates, (coarser than 84 110); interbedded with till	110-120

SITE 7 148-063-02ACA2

NDSWC 13087

Date Completed:	9/22/89	Purpose:	Observation Well
L.S. Elevation (ft):	1515	Well Type:	2" PVC
Depth Drilled (ft):	27	Aquifer:	Cherry Lake
Screened Interval (ft):	18-23	Source:	

Completion Info: Construction: #8 screen. No glue. All joints stainless steel screws. 2-100 lb. bag #10 sand (16 ft. to top of sand). 0.75-50 lb. bag bentonite grout.

Development: Bill Schuh pumped 2.5 h with compressor (9/23/92). Merlin Skaley pumped 1 h with suction pump at 4 gpm (@ 240 gallons or 120 casing volumes). No problems. Started cloudy, ended up real clean (Skaley).

Completion: Well cemented before initiation of spraying. Fred Anderson set PC August 1993.

Initial WL @ 7.6 ft.

Remarks: Location: west of 13086, in coulee north of causeway to old Pinkerton farm.

Lithologic Log

Unit	Description	Depth (ft)
	same as test hole 13086	0-0

SITE 8 149-062-19DBD1

NDSWC 13090

Date Completed:	9/22/92	Purpose:	Observation Well
L.S. Elevation (ft):	1550	Well Type:	2" PVC
Depth Drilled (ft):	112	Aquifer:	Cherry Lake
Screened Interval (ft):	95-100	Source:	

Completion Info: Construction: #12 screen. No glue. All stainless steel screws on couplings. 5-100 lb. bag. #10 sand. 10-20 lb. bag bentonite grout. Hole collapsed several times in gravel layer. Had to be redrilled. Drilling mud was used. Extensive cleaning required.

Development: Bill Schuh pumped five h with compressor. Later pumped 3 more h (total 8 h). Joe Kreig pumped 2 h with bladder pump to purify(47 gallons, @ 5 well volumes). Water dark grayish tan at beginning. Cleared to light grayish tan at 2nd gallon and cleared up by the 9th gallon (< 1 well volume) .

Completion: Site was cemented (9/28/92) and covered with polyethylene before spraying in fall 1992. PC set by Fred Anderson in August, 1993.

Initial WL @ 30.45

Remarks: Location: East of engineering training site. Well set farthest west on reserve, north of HWY 15. On border of coulee, below skunk hollow.

Lithologic Log

Unit	Description	Depth (ft)
SAND	[topsoil], very fine to very coarse, predominantly medium	0-2
SAND	very fine to very coarse, predominantly medium, brown	2-8
CLAY	sandy	8-11
SAND	very fine to very coarse, and gravel, brown; predominantly quartz, some shield silicates and carbonates, rounded and subrounded	11-14
ROCK		14-15
SAND & GRAVEL		15-22
SAND	(same?), slower, hit rock at 35 ft; (see 13091)	22-35
SAND	same	35-47

SITE 8 149-062-19DBD1 Continued

CLAY	(approximately 25%), sandy, gray; greater clay and less sand with depth, (TILL)	47-97
CLAY	(approximately 25%), sandy, gray, coarser than above, at 97 ft detrital shale, some drill chatter, short duration; (TILL)	97-107
SHALE	(PIERRE), angular cuttings	107-120

SITE 8 149-062-19DBD2

NDSWC 13091

Date Completed:	9/23/92	Purpose:	Observation Well
L.S. Elevation (ft):	1550	Well Type:	2" PVC
Depth Drilled (ft):	40	Aquifer:	Cherry Lake
Screened Interval (ft):	45-30	Source:	

Completion Info: Construction: #12 screen. No glue. All joints secured with stainless steel screws. 1.5 -100 lb. bag #10 sand. 2 -50 lb. bag bentonite grout.

Development: None - dry.

Completion: Cemented after spraying. PC set by Fred Anderson, August 1993.

Remarks: Location: Located in nest with 13090 and 13106. Located in nest farthest west north of HWY 15. Middle Well. 13091 was dry, and 13106 was placed as a replacement sampling well.

Lithologic Log

Unit	Description	Depth (ft)
SAND	[topsoil]	0-2
SAND	very fine to very coarse, predominantly medium, brown, predominantly quartz, some shield silicates and carbonates	2-7
CLAY	yellow	7-8
SAND	same, rock at 12 ft	8-12
GRAVEL & SAND	very fine to very coarse, predominantly quartz, some shield silicates, rounded and subrounded, subrounded detrital shale	12-21
SAND	very fine to very coarse, predominantly medium, brown; mineral same as above	21-40

SITE 8 149-062-19DBD3

NDSWC 13106

Date Completed:	10/1/92	Purpose:	Observation Well
L.S. Elevation (ft):	1550	Well Type:	2" PVC
Depth Drilled (ft):	53	Aquifer:	Cherry Lake
Screened Interval (ft):	43-48	Source:	

Completion Info: Construction: #8 screen. no glue. All joints secured with stainless steel screws. 2-100 lb. bag #10 sand. 2-50 lb. bag bentonite grout. Sprayed before setting of cement and covering.

Development: Well wouldn't air or suction pump. Bailed 100 times (48 gallons, 21 well volumes).

Completion: Fred Anderson set PC August 1993.

Initial WL @ 31.19 ft.

Remarks: Location: Nested with 13090 and 13091, 3rd well south, nest located at site on border of coulee south of road. Site farthest east, north of Highway 15. Located at bottom of skunk hollow. Well was drilled because well 13091 was dry after completion. Substituted for 13091.

Note: During drilling area was sprayed with picloram directly. Subsequent contamination of equipment undoubtedly occurred. Check baseline pesticide levels in first sampling of this well for initial reference.

Lithologic Log

Unit	Description	Depth (ft)
SAND	[topsoil], medium, black	0-4
SAND	very fine to very coarse, predominantly medium brown	4-8
CLAY	(approximately 20%), sandy, brown	8-11
GRAVEL		11-18
CLAY	(approximately 20%), sandy, brown, (TILL)	18-20
SAND	very fine to very coarse, predominantly medium and coarse, red	20-51
CLAY	(approximately 15-20%), sandy, gray, (TILL)	51-53

SITE 9 149-063-13DAA1

NDSWC 13088

Date Completed:	9/22/92	Purpose:	Observation Well
L.S. Elevation (ft):	1520	Well Type:	2" PVC
Depth Drilled (ft):	110	Aquifer:	Cherry Lake
Screened Interval (ft):	95-100	Source:	

Completion Info: Construction. #8 screen. No glue. All joints secured with stainless steel screws. 3-100 lb. bag #10 sand. 3-50 lb. bag bentonite grout.

Development: Bill Schuh developed five h with compressor. Later (10/7/92) was developed 5.5 h with compressor (total 10.5 h). Well was further developed by Joe Kreig (at least two casing volumes) using a bladder pump (1992). Pumped 2 h with bladder pump (@ 35 gal.). Water light grayish tan at beginning. Cleared up completely by 13 gal.

Completion: Cemented and bag before spraying with picloram (9/30/92). PC set by Fred Anderson, August 1993.

Initial WL @ 23.59

Remarks: Location: Directly south of engineering training site, near compass marker.

Lithologic Log

Unit	Description	Depth (ft)
SAND	very fine to fine, black to brown; topsoil	0-2
SAND	very fine to fine, predominantly fine; brown	2-16
CLAY	[TILL], yellow brown; approximately 25% clay, and silt, and sand; more clay at 26 ft; less sand at 27-28 ft; clay, gray	16-28
SAND	very fine to very coarse, predominantly medium and coarse, brown; predominantly quartz, carbonates, shale, shield silicates, some gravel, rounded and subrounded	28-40
CLAY	silty, gray color	40-51
CLAY	[TILL], sandy, some silt and pebbles; hard brittle clay and more sand at 73 ft; few rocks and gravel at 74 ft; at 77-78 ft cobbles, (gravel layer), drill chatter	51-83
CLAY	[TILL], sandy, harder, brittle, hard aggregates; at 96-97 ft drill chatter	83-98
ROCK	white carbonates	98-100
SHALE	(PIERRE)	100-110

SITE 9 149-063-13DAA2

NDSWC 13089

Date Completed:	9/22/92	Purpose:	Observation Well
L.S. Elevation (ft):	1520	Well Type:	2" PVC
Depth Drilled (ft):	40	Aquifer:	Cherry Lake
Screened Interval (ft):	30-35	Source:	

Completion Info: Construction: #8 screen. No glue. All stainless steel screws for connectors. 2-100 lb bag # 10 sand. 1 50# bag bentonite grout.

Development: Suction pumped 1.5 h (270 gal - total @ 216 well volumes pumped). Joe Kreider pumped @ 6 gal. (5 well volumes) with bladder pump. Water cleared after 2 well volumes. First squirt of water was dark tan. All after was clear.

Completion: Cemented before area sprayed with picloram (fall 1992). Fred Anderson set PC in August 1993.

Initial WL @ 29 ft.

Remarks: Location: Directly south of engineering training center. South of 13088 (same nest).

Lithologic Log

Unit	Description	Depth (ft)
	same as test hole 13088	0-0

SITE 10 149-063-12CAC1

NDSWC 13092

Date Completed:	9/24/92	Purpose:	Observation Well
L.S. Elevation (ft):	1520	Well Type:	2" PVC
Depth Drilled (ft):	130	Aquifer:	Cherry Lake
Screened Interval (ft):	105-110	Source:	

Completion Info: Construction: 8# screen. No glue. All joints fastened with stainless steel screws. 6-100 lb. 10# sand. 3-50 lb. bag. bentonite grout.
Development: Before spraying Bill Schuh purged with compresor for 2.5 h. After spray, compressor purged for 10 h. Joe Kreig pumped @ 45 g (4.5 well casing volumes) with bladder pump. Water grayish-tan at beginning and cleaned to light graysh-tan at about 5th gallon. Cleaned up completely after 28th gallon (@ 3 well volumes).

Completion: Well cemented and covered before spraying (fall 1992). PC set by Fred Anderson, August 1993.

Initial WL @ 28 ft.

Remarks: Location: North past abandoned house, east end of deep coulee, near fence. Before pump on main trail (on hill top after coulee). Area was sprayed with picloram (Fall 1992). Site may have been directly sprayed, or may have been within the drift zone. Drilling did not reach bed rock.

Lithologic Log

Unit	Description	Depth (ft)
SAND	[topsoil], fine to coarse, black	0-3
SAND	very fine to very coarse, predominantly medium, brown and yellow, predominantly quartz and shield silicates	3-6
SILT	and clay, yellow	6-9
SAND	very fine to very coarse, predominantly medium, brown	9-42
SAND	same, unoxidized, (gray)	42-49
CLAY	(approximately 20-25%), and sand (predominantly fine), gray, unoxidized, gritty, hard, no shells, at 58 ft carbonate and silicate gravel mixed with till; greater at 76 ft, more clay (25-30%), coarser sand grains; at 95 ft subrounded shale and carbonate gravel mixed	49-104

SITE 10 149-063-12CAC1 Continued

GRAVEL	coarse, silicate, carbonate, shale, rounded and subrounded	104-112
CLAY	(approximately 25-30%), gravelly, gritty, (TILL)	112-130
SAND	[topsoil], fine to coarse, black	0-3
SAND	very fine to very coarse, predominantly medium, brown and yellow, predominantly quartz and shield silicates	3-6
SILT	and clay, yellow	6-9
SAND	very fine to very coarse, predominantly medium, brown	9-42
SAND	same, unoxidized, (gray)	42-49
CLAY	(approximately 20-25%), and sand (predominantly fine), gray, unoxidized, gritty, hard, no shells, at 58 ft carbonate and silicate gravel mixed with till; greater at 76 ft, more clay (25-30%), coarser sand grains; at 95 ft subrounded shale and carbonate gravel mixed	49-104
GRAVEL	coarse, silicate, carbonate, shale, rounded and subrounded	104-112
CLAY	(approximately 25-30%), gravelly, gritty, (TILL)	112-130

SITE 10 149-063-12CAC2

NDSWC 13093

Date Completed:	9/24/92	Purpose:	Observation Well
L.S. Elevation (ft):	1520	Well Type:	2" PVC
Depth Drilled (ft):	55	Aquifer:	Cherry Lake
Screened Interval (ft):	45-50	Source:	

Completion Info: Construction: # 12 screen. No glue. All joints secured with stainless steel screws. 2-100 lb. bag #10 sand. 1-50 lb. bag bentonite grout.

Development: Surged with compressor 1/2 h, then suction pumped for 3 h (166 gal., 8 well volumes).

Completion: Cemented and covered before spraying with picloram. PC set by Fred Anderson, August 1993.

Initial WL @ 30.63.

Remarks: Location: West of 13092 in nest. North of abandoned line house, at bottom of coulee east of main trail, near fence, turn off main trail before pump located at top of hill. Area was sprayed after construction. May have been direct or in drift zone.

Lithologic Log

Unit	Description	Depth (ft)
	see test hole 13092	0-0

SITE 11 149-063-14DBB

NDSWC South Washington Lake

Date Completed:	00/00/00	Purpose:	Surface Water Sample
L.S. Elevation (ft):	1472 .	Well Type:	Surface Water Sample Site
Depth Drilled (ft):	0	Aquifer:	Surface Water
Screened Interval (ft):	0-0	Source:	

Completion Info:

Remarks: South Washington Lake. Sampled by W.M. Schuh and J. MacArthur on 8/24/93 from boat using stainless steel Kemerer Sampler. Sampler washed with alkanox soap and multiple distilled water rinses before sampling. Boat launched @ 100 yards south of spring. @1/3 lake distance west of east lakeshore.

SITE 12 148-063-02BABC1

NDSWC 13084

Date Completed:	9/21/92	Purpose:	Observation Well
L.S. Elevation (ft):		Well Type:	2" PVC
Depth Drilled (ft):	89	Aquifer:	Cherry Lake
Screened Interval (ft):	69-74	Source:	

Completion Info: Construction: #8 screen. No glues. All joints stainless steel screws. 4.25-100 lb. bag #10 sand. 3.75-50 lb. bag bentonite grout.

Development: Bill Schuh pumped 5 h using compressor (9/22/92). Merlin Skaley pumped 4 h with compressor (total = 9 h). No problems in development.

Completion: 4-inch PC placed in July 1993 by Fred Anderson.

Initial WL @ 5.7 ft.

Remarks: Location: North of Pinkerton Farm, in pasture. North well.

Lithologic Log

Unit	Description	Depth (ft)
SAND	very fine to very coarse, topsoil	0-4
SAND	very fine to very coarse, predominantly fine and medium, yellow	4-11
CLAY	soft, gray	11-12
SAND	very fine to very coarse, predominantly fine and medium, predominantly quartz, some carbonates and detrital shale, shield silicates	12-40
SAND	as above, interbedded with thin clay layers, one layer at 40 ft	40-74
ROCK	pink and white granite	74-76
SAND	(bit slipped fast)	76-78
SHALE	cobbles	78-80
SHALE	(PIERRE), hard, black, angular chips, some sticky clay	80-89

SITE 12 148-063-02BABC2

NDSWC 13085

Date Completed:	9/22/93	Purpose:	Observation Well
L.S. Elevation (ft):	1540	Well Type:	2" PVC
Depth Drilled (ft):	20	Aquifer:	Cherry Lake
Screened Interval (ft):	12-17	Source:	

Completion Info: Construction: #8 screen. No glue. All joints stainless steel screws, 3 -100 lb. bag #10 sand (to 10'), 50 lb. bentonite grout.

Development: Bill Schuh pumped 2.5 h with compressor (9/22/92), air set 5' above screen, yield slow. Merlin Skaley pumped 3 h using suction pump, yield constant, @720 gallons (1107 casing volumes) pumped.

Completion: cemented and covered before aerial spraying. Top cemented, PC set, 4-inch PC set, August 1993 by Fred Anderson.

Initial WL @ 11.82 ft.

Remarks: Location: North of Pinkerton farm in pasture. Nest with 13084 (south well).

Lithologic Log

Unit	Description	Depth (ft)
	see test hole 13084	0-20

SITE 13 149-063-35BCBA1

NDSWC 13099

Date Completed:	9/29/92	Purpose:	Observation Well
L.S. Elevation (ft):	1515	Well Type:	2" PVC
Depth Drilled (ft):	48	Aquifer:	Cherry Lake
Screened Interval (ft):	39.5-43.5	Source:	

Completion Info: Construction: #18 screen. No glue. All joints fastened with stainless steel screws. 3.5-100 lb. bag #10 sand. 1.25-50 lb. bag bentonite grout.

Development: Merlin Skaley surged 3.5 h with compressor. Then pumped @ 60 gal. (@ 13 casing volumes) with suction pump alone. Water very clean. No problems in developing.

Completion: cemented and covered before spray. PC set by Fred Anderson, August 1993.

Initial WL @ 6.53 ft.

Remarks: Location: Pasture through first cattle grate and gate south side of HWY 15, west of water truck filling station and well house. East well.

Lithologic Log

Unit	Description	Depth (ft)
SAND	[topsoil], silty, black	0-3
CLAY	sandy, olive brown and yellow with red iron stains, (TILL)	3-14
CLAY	sandy (TILL)	14-22
CLAY	gray; more silty (drill slip)	22-24
SAND	very fine to very coarse, predominantly medium and coarse gray, quartz, shield silicate, carbonate, detrital shale, some small gravel; (42-47 ft) gravel same, mineral	24-47
SHALE	(PIERRE)	47-48

SITE 13 149-063-35BCBA2

NDSWC 13100

Date Completed:	9/29/92	Purpose:	Observation Well
L.S. Elevation (ft):	1515	Well Type:	2" PVC
Depth Drilled (ft):	30	Aquifer:	Cherry Lake
Screened Interval (ft):	23-28	Source:	

Completion Info: Construction: #12 screen. No glue. All joints secured with stainless steel screws. 2.5-100 lb. bag #10 sand. 0.75-50 lb. bag bentonite grout.

Development: Merlin Skaley pumped 2 h with suction pump (@ 480 gal., 192 casing volumes).. Water clear. No problem in development.

Completion: cemented and covered before spray. Fred Anderson set PC and protective outside casing in August 1993.

Initial WL @ 7.5 ft.

Remarks: Location: Located West side of small lake (dry at time of drilling), south of HWY 15, in nest with 13099 (west of 13099). Access through locked gate and cattle grate south of HWY.

Lithologic Log

Unit	Description	Depth (ft)
SAND	[topsoil], silty, black	0-3
CLAY	silty, some sand, olive brown and yellow, red stains, (TILL)	3-13
CLAY	gray; approximately 20 ft; fine, more silt and finer sand with clay	13-23
SAND	very fine to very coarse, predominantly medium and coarse gray, quartz, shield silicate, carbonate	23-30

SITE 14 149-063-26ADD

NDSWC Lake Coe

Date Completed:	00/00/00	Purpose:	Surface Water Sample
L.S. Elevation (ft):	1492	Well Type:	0" Surface Water Sample Site
Depth Drilled (ft):	0	Aquifer:	Surface Water
Screened Interval (ft):	0-0	Source:	

Completion Info:

Remarks: Lake Coe. Sampled by W.M. Schuh and J. MacArthur from a boat on 8/24/93 using stainless steel Kemerer sampler. Sampler washed with low phosphate detergent and multiple distilled water washes. Pesticide sample also taken.

SITE 15 149-063-27DDB

NDSWC Lake Coe

Date Completed:	00/00/00	Purpose:	Surface Water Sample
L.S. Elevation (ft):	1492	Well Type:	0" Surface Water Sample Site
Depth Drilled (ft):	0	Aquifer:	Surface Water
Screened Interval (ft):	0-0	Source:	

Completion Info:

Remarks: Lake Coe. Sampled by W.M. Schuh and J. MacArthur on 8/24/93. Sampled from boat using stainless steel Kemerer sampler. Sampler washed with low phosphate detergent and multiple distilled water washes. Sampled also for pesticide.

SITE 16 149-063-13BDA

NDSWC

Date Completed:	00/00/00	Purpose:	Surface Water Sample
L.S. Elevation (ft):	1500	Well Type:	0" Surface Water Sample Site
Depth Drilled (ft):	0	Aquifer:	Cherry Lake
Screened Interval (ft):	0-0	Source:	

Completion Info:

Remarks: This location is a spring. Access to spring is between the entry gate on the north end of section 13 and the engineering training site (1993).

SITE 17   148-063-04ABA1

NDSWC 13095

Date Completed:	9/24/92	Purpose:	Observation Well
L.S. Elevation (ft):	1510	Well Type:	2" PVC
Depth Drilled (ft):	60	Aquifer:	Cherry Lake
Screened Interval (ft): 39.67-44.67		Source:	

Completion Info: Construction: #12 screen. No glue. All joints secured with stainless steel screws. 4 -100 lb. bag #10 sand. 2-50 lb. bag bentonite grout.

Development: Bill Schuh developed 5 h with compressor. Merlin Skaley an additional 7.5 to 9 h. Pumped well. No problem cleaning.

Completion: cemented and covered before spray (fall 1992). Fred Anderson set PC in August 1993.

Initial WL @ 6.4 ft.

Remarks: Location: Located in pasture east of North Twin Lake. Fence access through north side of pasture, through the pasture on the side of the lake. West well in nest.

Lithologic Log

Unit	Description	Depth (ft)
CLAY	sandy, black topsoil	0-2
SAND	very fine to very coarse, predominantly medium, brown	2-7
SAND	same, but gray, unoxidized	7-10
CLAY	(approximately 30%), silty, gray	10-16
SAND	very fine to very coarse, gray, predominantly quartz, some carbonates, detrital shale, rounded and subrounded	16-25
SAND	same, but brown, oxidized	25-32
CLAY	sandy, gray	32-36
GRAVEL	and sand (shale, rounded)	36-38
CLAY	fine sand, (gray)	38-41
SAND	very fine to very coarse, predominantly gray	41-43
GRAVEL & COBBLES	chatter on bit	43-46
		46-60

SITE 17 148-063-04ABA2
NDSWC 13096

Date Completed:	9/24/92	Purpose:	Observation Well
L.S. Elevation (ft):	1510	Well Type:	2" PVC
Depth Drilled (ft):	31	Aquifer:	Cherry Lake
Screened Interval (ft):	25-30	Source:	

Completion Info: Construction: 12# screen. No glue. All joints secured with stainless steel screws. 3.5-100 lb. bag #10 sand. 1-50 lb. bag bentonite grout.

Development: Merlin Skaley purged 2.5 h with compressor and 1h with suction pump (240 gal. or @ 80 casing volumes in addation to air lift). No problems. Water cleared well.

Completion: cemented and covered before spray. Fred Anderson set PC in August 1993.

Initial WL @ 5.7 ft.

Remarks: Location: Nested with 13095, In pasture east of North Twin Lake. East well in nest.

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	clay, sandy	0-3
CLAY	silty, oxidized, yellow	3-6
SAND	very fine to very coarse, predominantly medium, brown	6-8
SAND	(same), gray	8-11
CLAY	silty (ranges to very silty), gray	11-21
SAND	(same as above), brown, oxidized	21-31

SITE 20 149-063-14AAB

NDSWC 13094

Date Completed:	9/24/92	Purpose:	Observation Well
L.S. Elevation (ft):	1510	Well Type:	2" PVC
Depth Drilled (ft):	40	Aquifer:	Cherry Lake
Screened Interval (ft):	17-22	Source:	

Completion Info: Construction: #12 screen. No glue. All joints secured with stainless steel screws. 3-100 lb. bag #10 sand (to 2.5 ft. above screen). 1-50 lb. bag bentonite grout.

Development: Suction pumped 4 h (total 240 gal.), then bailed 30 times (@ 10 well volumes).

Completion: Cemented (grout) and covered with polyethylene before spraying. PC set by Fred Anderson, August 1993.

Initial WL @ 8 ft.

Remarks: Location: Located just south of section line, west of 13092 and 13093 , in pasture with cattle pond (dry 1992, full 1993).

Lithologic Log

Unit	Description	Depth (ft)
CLAY	sandy topsoil	0-2
CLAY	silty, gray	2-8
CLAY	(approximately 20-25%), and silt and fine sand, gray	8-14
CLAY	(approximately 20-25%), silty, gray	14-16
GRAVEL	fine to very coarse sand, quartz predominantly, some shield silicates and carbonates, rounded and subrounded, angular lignite (detrital); granite rock (4 ft at top, approximately 16 ft)	16-22
SHALE	(PIERRE)	22-40

APPENDIX B: BASIC WATER CHEMISTRY AND TRACE ELEMENT DATA

Table B.1 Basic water quality data for surface water and wells sampled in 1992 and 1993. Record also includes data for springs previously sampled in 1986 and 1987. This group of wells was drilled in 1992 specifically for the purpose of sampling for petroleum, pesticide, and munitions contamination. Lithology is contained in the previous Appendix (A).

Site	Location	Screened Interval (ft)	Date Sampled	SiO_2 (milligrams per liter)	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH
Site 1	149-062-28CCC1	139-144	10/21/92	25	0.06	0.55	32	8	180	8.8	482	0	130	6.1	0.3	2.9	0.58	631	110	0	76	7.5	958	8	7.26
Site 1	149-062-28CCC2	56-61	10/21/92	30	0.3	0.4	78	20	27	10	372	0	49	3.5	0.2	4.3	0.15	406	280	0	17	0.7	661	8	7.07
Site 2	149-062-29DAD	50-55	10/21/92	33	0.1	0.52	88	24	12	7.3	365	0	54	1.7	0.2	2	0.11	403	320	20	7	0.3	608	10	7
Site 3	148-063-02DA	0-0	09/11/86	33	0.02	0.04	72	21	5.5	2.2	310	0	27	2.6	0.1	0	0.03	316	270	12	4	0.1	540	13	
Site 3	148-063-02DA	0-0	10/22/92	25	0.06	0.03	71	21	6	4	294	0	34	2.7	0.2	0	0.03	309	260	23	5	0.2	502	9	6.8
Site 4	148-062-31C	0-0	10/22/92	3	0.12	0.01	36	9.5	3.5	18	182	0	0.8	2.8	0.1	0.6	0.02	164	130	0	5	0.1	331	10	7.25
Site 5	149-063-36ACA1	41-48	10/22/92	25	0.12	0.34	60	15	23	6.7	302	0	23	2.6	0.2	1.8	0.13	307	210	0	18	0.7	543	10	6.65
Site 5	149-063-36ACA2	21-27	10/22/92	24	0.61	0.66	67	16	8	5.3	288	0	17	3.5	0.2	0	0.05	284	230	0	7	0.2	491	10	6.63
Site 6	149-063-25CDC1	110-115	10/22/92	25	0.04	1.5	94	19	120	13	250	0	300	46	0.4	2.2	0.47	745	310	110	44	3	1041	10	
Site 6	149-063-25CDC2	25-30	10/22/92	25	0.27	0.46	77	25	11	4.3	359	0	22	3.1	0.2	0.1	0.06	345	300	2	7	0.3	579	10	6.58
Site 7	148-063-02ACA1	97-102	10/22/92	25	0.02	1.3	83	21	23	5.1	371	0	37	3.8	0.2	1.1	0.12	384	290	0	14	0.6	623	8	6.42
Site 7	148-063-02ACA2	18-23	10/22/92	26	0.23	0.37	53	15	2.5	1.6	236	0	4.5	2.2	0.1	0.8	0.03	222	190	1	3	0.1	464	10	6.6
Site 8	149-062-19DBD1	95-100	08/25/93	31	0.18	0.56	89	21	16	13	375	0	45	3.7	0.2	5.6	0.04	410	310	1	10	0.4	673	10	7.55
Site 8	149-062-19DBD3	43-48	08/25/93	40	0.04	0.71	69	18	8	7.8	311	0	23	4.7	0.2	1.1	0.09	326	250	0	6	0.2	1109	10	6.87
Site 9	149-063-13DAA1	95-100	08/25/93	59	0.04	0.07	13	4	300	8.9	716	0	150	8.4	0.7	5	1.7	904	49	0	92	19	1299	9	8.13
Site 9	149-063-13DAA2	30-35	08/25/93	28	0.02	0.02	83	31	9	4.5	383	0	35	6.2	0.2	1.2	0.05	387	330	21	5	0.2	776	11	7.69
Site 10	149-063-12CAC1	105-110	08/25/93	28	0.18	0.28	38	11	150	9.9	453	0	79	30	0.4	5.4	0.05	575	140	0	68	5.5	867	11	7.23
Site 10	149-063-12CAC2	45-50	08/25/93	26	0.14	0.48	78	23	13	5.1	346	0	27	2.7	0.2	1.3	0.73	348	290	6	9	0.3	581	12	6.35
Site 11	149-063-14DBB	0-0	08/24/93	32	0.03	0.01	20	35	630	200	778	100	710	260	0.1	1.1	0.06	2370	190	0	75	20	3720	26	9.05
Site 12	148-063-02BABC1	69-74	08/26/93	29	0.12	0.39	27	8.5	110	6.2	399	0	26	12	0.3	4.5	0.22	421	100	0	68	4.8	653	7	7.8
Site 12	148-063-02BABC2	12-17	08/26/93	26	0.02	0.04	110	35	9.5	3.2	450	0	65	7.1	0.1	5.7	0.04	484	420	50	5	0.2	746	8	7.56
Site 13	149-063-35BCBA1	39.5-43.5	08/24/93	6.5	0.18	0.5	83	30	40	5.7	385	0	100	7.8	0.1	1.5	2.3	468	330	15	20	1	728	13	7.08
Site 13	149-063-35BCBA2	23-28	08/24/93	26	0.71	0.79	84	27	19	4.7	364	0	60	7.7	0.2	0.9	0.08	410	320	22	11	0.5	629	14	7
Site 14	149-063-26ADD	0-0	08/24/93	9.7	0.05	0.01	20	33	900	120	1060	200	730	370	0.1	2	3.8	2910	190	0	85	28	3950	27	9.2
Site 15	149-063-27DDB	0-0	08/24/93	9.4	0.13	0.01	20	35	1500	200	1510	400	1200	630	0.1	0	1.5	4740	190	0	88	47	6430	26	9.46
Site 16	149-063-13BDA	0-0	08/25/93	34	0.09	1	90	30	15	4.8	428	0	22	2.9	0.2	0	0.07	411	350	0	8	0.3	660	18	7.22
Site 17	148-063-04ABA1	39.67-44.67	08/24/93	28	0.41	0.19	57	16	39	7	311	0	41	6.7	0.2	4	0.13	353	210	0	28	1.2	656	10	7.35
Site 17	148-063-04ABA2	25-30	08/26/93	26	0.43	0.68	81	25	46	4.6	369	0	94	11	0.1	1	0.09	472	310	3	24	1.1	718	11	7.47
Sites 18 &19*																									
Site 20	149-063-14AAB	17-22	08/25/93	29	1.9	0.58	88	30	12	3.9	409	0	24	7.6	0.2	2.3	0.06	401	340	8	7	0.3	633	11	7.06

Table B.2 Toxic trace elements [arsenic (As), cadmium (Cd),lead (Pb), mercury (Hg), and Selenium (Se)] data for sample wells drilled in 1992, and sampled in 1992 and 1993.

Site	Location	Screened Interval (ft)	Date Sampled	(micrograms per liter)|						
				As	Ba	Cd	Hg	Pb	Se	Zn
Site 1	149-062-28CCC1	139-144	10/21/92	4		0	0.0	0	0	
Site 1	149-062-28CCC2	56-61	10/21/92	52		0	0.0	0	0	
Site 2	149-062-29DAD	50-55	10/21/92	25		0	0.0	0	0	
Site 3	148-063-02DA	0-0	09/11/86	1			0.1	1	1	
Site 3	148-063-02DA	0-0	10/22/92	2		0	0.0	0	0	
Site 4	148-062-31C	0-0	10/22/92	2		0	0.0	0	0	
Site 5	149-063-36ACA1	41-48	10/22/92	26		0	0.0	0	0	
Site 5	149-063-36ACA2	21-27	10/22/92	13		0	0.0	0	0	
Site 6	149-063-25CDC1	110-115	10/22/92	4		0	0.0	0	0	
Site 6	149-063-25CDC2	25-30	10/22/92	7		0	0.0	0	0	
Site 7	148-063-02ACA1	97-102	10/22/92	52			0.0	0	0	
Site 7	148-063-02ACA2	18-23	10/22/92	2		0	0.0	0	0	
Site 8	149-062-19DBD1	95-100	08/25/93	51		0	0.0	0	0	
Site 8	149-062-19DBD3	43-48	08/25/93	6		0	0.0	0	0	
Site 9	149-063-13DAA1	95-100	08/25/93	2		0	0.0	0	0	
Site 9	149-063-13DAA2	30-35	08/25/93	10		0	0.0	0	0	
Site 10	149-063-12CAC1	105-110	08/25/93	14		0	0.0	0	0	
Site 10	149-063-12CAC2	45-50	08/25/93	5		0	0.0	0	0	
Site 11	149-063-14DBB	0-0	08/24/93	71		0	0.0	0	0	
Site 12	148-063-02BABC1	69-74	08/26/93	1		0	0.0	0	0	
Site 12	148-063-02BABC2	12-17	08/26/93	2		0	0.0	1	0	
Site 13	149-063-35BCBA1	39.5-43.5	08/24/93	2		0	0.0	0	0	
Site 13	149-063-35BCBA2	23-28	08/24/93	10		0	0.0	0	0	
Site 14	149-063-26ADD	0-0	08/24/93	10		0	0.0	0	0	
Site 15	149-063-27DDB	0-0	08/24/93	24		0	0.0	0	0	
Site 16	149-063-13BDA	0-0	08/25/93	2		0	0.0	0	0	
Site 17	148-063-04ABA1	39.67-44.67	08/24/93	20		0	0.0	0	0	
Site 17	148-063-04ABA2	25-30	08/26/93	4		0	0.0	0	0	
Sites 18 &19*										
Site 20	149-063-14AAB	17-22	08/25/93	3		0	0.0	0	0	

Table B.3 Basic water quality data for samples taken in 1991. Samples were folluw-up for previous samples of Comeskey (1989) taken in 1986 and 1987. For convenience, data previously reported by Comeskey (1989) are recapitulated on this table. Lithologies for wells was described by Comeskey (1989).

Location	Screened Interval (ft)	Date Sampled	|←(milligrams per liter)														→|	Hardness as		%	SAR	Spec Cond	Temp	pH
			SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	$CaCO_3$	NCH	Na		(µmho)	(∞C)	
148-063-01CBBC2	151-156	09/02/87	30	0.01	0.79	40	11	75	7.9	339	0	40	4.8	0.3	1.7	0.27	379	150	0	51	2.7	590	11	
148-063-01CBBC2	151-156	10/23/91	30	0.02	0.68	37	11	80	9.1	341	0	42	7.3	0.3	0	0.3	386	140	0	54	2.9	583	6	8.03
149-063-13BAAB1	96-101	09/01/87	25	0.02	0.22	64	18	470	17	633	0	140	490	0.4	5.5	1.2	1540	230	0	80	13	3710	12	
149-063-13BAAB1	96-101	10/23/91	26	0.03	0.44	110	30	820	20	755	0	79	1100	0.3	0.1	2.4	2560	400	0	81	18	4440	6	8.03
149-063-14DACD1	212-217	09/01/87	31	0.03	0.39	20	6	640	12	752		430	360	0.5	0.6	3.4	1870	75		94	32	3070	12	
149-063-14DACD1	212-217	10/23/91	30	0.02	0.16	13	4	510	9.5	772	0	340	160	0.6	3.7	2	1450	49	0	95	32	2310	6	8.62
149-063-14DACD2	151-156	09/01/87	31	0.01	0.22	14	4	310	8.4	659		200	20	0.7	0.5	1.1	915	52		92	19	1460	12	
149-063-14DACD2	151-156	10/23/91	29	0.02	0.17	15	3	320	7.9	671	0	190	23	0.6	1.8	1.3	923	50	0	92	20	1384	6	8.41
149-063-14DACD3	38-43	09/01/87	32	0.01	0.06	73	23	18	6.8	341		35	3.9	0.2	2.4	0.06	362	280		12	0.5	580	12	
149-063-14DACD3	38-43	10/23/91	29	0.08	0.07	70	23	15	5.8	335	0	35	5.6	0.2	1.4	0.05	350	270	0	11	0.4	567	6	8.04
149-063-23ADBB1	218-223	09/01/87	30	0.09	0.43	41	10	76	6.9	322		19	21	0.2	2.9	0.15	367	140		52	2.8	590	12	
149-063-23ADBB1	218-223	10/23/91	28	0.11	0.41	44	11	67	6.3	331	0	23	16	0.2	4.3	0.14	363	160	0	47	2.3	569	6	8.3
149-063-23ADBB2	32-37	09/01/87	28	0.21	0.44	74	21	6.5	3.6	298		40	1.6	0.2	0.4	0.04	323	270	27	5	0.2	515	11	
149-063-23ADBB2	32-37	10/23/91	26	0.05	0.35	72	21	8	3.3	304	0	45	3.9	0.2	0.7	0.05	331	270	17	6	0.2	524	9	8.08
149-063-23ADBB3	7-12	09/01/87	38	0.11	0.33	77	18	4	2.3	287		16	1	0.2	3.4	0.05	301	270	31	3	0.1	585	14	
149-063-23ADBB3	7-12	10/23/91	27	0	0.05	82	20	3.5	1.2	331	0	9.9	3.4	0.2	24	0.03	334	290	16	3	0.1	537	10	8.08
149-063-25DBBC1	263-268	09/01/87	30	0.01	0.24	19	4.5	240	7.5	444	0	100	99	0.4	0.6	0.65	721	66	0	87	13	1200	12	
149-063-25DBBC1	263-268	10/24/91	27	0	0.24	18	4.5	250	8	454	0	100	96	0.4	0	0.71	729	64	0	88	14	1144	5	8.15
149-063-25DBBC2	78-83	09/02/87	22	0.01	0.15	26	7.5	160	14	376	0	150	4.1	0.5	3.1	0.55	573	96	0	75	7.1	860	11	
149-063-25DBBC2	78-83	10/24/91	26	0.01	0.11	25	7.5	130	7.9	416	0	45	7.5	0.5	5.6	0.47	460	94	0	73	5.8	706	7	8.16
149-063-25DBBC3	51-56	09/02/87	31	0.09	0.5	72	20	6	5.1	314	0	25	1	0.3	0.4	0.06	316	260	5	5	0.2	490	11	
149-063-25DBBC3	51-56	10/24/91	24	0	0.03	62	17	6.5	3.9	264	0	23	4.8	0.2	2.4	0.03	274	220	8	6	0.2	457	9	7.84
149-063-25DBBC4	23-28	09/02/87	32	1.1	0.93	72	19	5.5	5.2	319	0	19	1.3	0.2	1	0.07	314	260	0	4	0.1	500	9	
149-063-25DBBC4	23-28	10/24/91	32	1.8	0.74	70	19	7	4.9	316	0	18	4	0.2	3	0.04	317	250	0	5	0.2	500	9	7.32
149-063-26DCA	38-43	09/01/87	28	0.61	0.34	71	46	83	12	444	0	170	14	0.3	2	0.26	647	370	2	32	1.9	975	11	
149-063-26DCA	38-43	10/24/91	27	0.49	0.28	73	53	82	14	476	0	190	14	0.3	0	0.21	688	400	10	30	1.8	996	7	7.87
149-063-27DDDC2	158-163	09/01/87	10	0.15	0.24	29	8.5	2.5	14	161	0	61	1.8	0.1	1	0.07	207	110	0	4	0.1	241	13	
149-063-27DDDC2	158-163	11/19/91	28	0.01	1.1	53	15	64	9.2	299	0	89	15	0.3	1.2	0.31	423	190	0	40	2	638	7	7.53
149-063-34BBB1	251-256	09/01/87	27	0.03	0.68	47	23	120	14	428	0	110	23	0.5	1	0.28	577	210	0	53	3.6			
149-063-34BBB1	251-256	11/19/91	30	0.01	0.73	49	15	59	7.7	328	0	47	13	0.5	0	0.2	384	180	0	40	1.9	595	7	7.05
149-063-34BBB2	27-32	09/01/87	27	0.01	0.34	74	25	28	4.7	298	0	89	8.5	0.2	1	0.1	405	290	44	17	0.7	670	11	
149-063-34BBB2	27-32	10/24/91	25	0.01	0.04	71	23	18	3.6	289	0	72	8	0.2	5.1	0.05	368	270	35	12	0.5	566	6	7.95
149-063-34BBB2	27-32	10/22/92	25	0.02	0.01	70	23	16	3.1	281	0	66	5.6	0.1	7.6	0	354	270	39	11	0.4			
149-063-35ABBD2	45-50	09/01/87	29	0.76	0.29	68	25	93	9.6	422	0	120	8.5	0.2	1.8	0.3	564	270	0	42	2.5	880	10	
149-063-35ABBD2	45-50	10/24/91	27	0.37	0.34	68	26	94	9.9	432	0	130	10	0.3	5.5	0.24	585	280	0	41	2.4	869	7	8.02
149-063-36AACB2	181-186	09/02/87	31	0.03	1.1	63	13	140	9.8	452	0	110	32	0.2	2.7	0.5	626	210	0	58	4.2	950	10	
149-063-36AACB2	181-186	10/22/91	28	0.03	1	62	13	140	9	457	0	110	30	0.1	0.8	0.48	619	210	0	58	4.2	929	7	7.75
149-063-36AACB3	64-69	09/02/87	32	0.18	0.81	110	30	11	7.4	401	0	57	3	0.2	0.4	0.06	450	400	70	6	0.2	740	10	
149-063-36AACB3	64-69	10/22/91	29	0.23	0.61	120	32	11	7.4	486	0	55	5	0.1	0	0.04	499	430	33	5	0.2	763	8	7.41
149-063-36AACB4	24-29	09/02/87	29	0.02	0.03	79	23	5.5	3.5	305	0	29	2.9	0.2	3.2	0.03	325	290	42	4	0.1	540	12	
149-063-36AACB4	24-29	10/22/91	26	0.01	0.02	78	23	6	5.6	329	0	36	6	0.1	10	0.03	353	290	20	4	0.2	597	8	7.59
149-063-36BBDA2	22-27	09/01/87	31	0.01	0.11	59	22	47	7.5	358	0	43	8	0.3	1	0.23	395	240	0	29	1.3	620	14	
149-063-36BBDA2	22-27	10/24/91	30	0.01	0.34	60	19	49	7.7	358	0	42	8.9	0.3	0.2	0.19	394	230	0	31	1.4	620	9	7.96
149-063-36DDBC1	131-136	09/02/87	31	0.02	0.93	30	8	130	7.5	399	0	49	18	0.5	2	0.38	474	110	0	71	5.4	720	11	
149-063-36DDBC1	131-136	10/22/91	27	0.29	0.77	28	7	140	6.9	413	0	48	20	0.3	0	0.35	482	99	0	74	6.1	748	6	8.18
149-063-36DDBC2	83-88	09/02/87	32	0.01	1.4	55	15	61	7.6	353	0	38	9.4	0.3	0.4	0.22	394	200	0	39	1.9	620	10	
149-063-36DDBC2	83-88	10/22/91	29	0.02	1.3	56	16	52	7.6	353	0	35	9.2	0.2	0.4	0.16	381	210	0	34	1.6	598	6	7.83
149-063-36DDBC3	46-51	09/02/87	30	0.4	0.32	77	22	8	4.4	329	0	28	3.3	0.2	0.5	0.08	336	280	13	6	0.2	540	10	
149-063-36DDBC3	46-51	10/22/91	27	0.31	0.3	72	21	16	5.6	339	0	30	5.5	0.2	3.7	0.05	349	270	0	11	0.4	548	7	2

Table B.4 Barium, and toxic trace elements [arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb), selenium (Se), and Zinc (Zn)] resampling of wells sampled previously by Comeskey (1989) during 1986 and 1987. Previously sampled data are first reported in this table.

Location	Screened Interval (ft)	Date Sampled	(micrograms per liter) As	Ba	Cd	Hg	Pb	Se	Zn
148-063-01CBBC2	151-156	09/02/87	0			0.0	0	0	
148-063-01CBBC2	151-156	10/23/91	0	58	0	0.0	0	0	6
149-063-13BAAB1	96-101	09/01/87	25			0.0	0	4	
149-063-13BAAB1	96-101	10/23/91	25	230	0.1	0.0	0	4	15
149-063-14DACD1	212-217	09/01/87	6			0.0	0	0	
149-063-14DACD1	212-217	10/23/91	4				1		
149-063-14DACD2	151-156	09/01/87	4			0.0	0	0	
149-063-14DACD2	151-156	10/23/91	4	21	0	0.0	0	0	29
149-063-14DACD3	38-43	09/01/87	8			0.0	0	0	
149-063-14DACD3	38-43	10/23/91	8	86	0	0.0	0	0	12
149-063-23ADBB1	218-223	09/01/87	3			0.0	0	0	
149-063-23ADBB1	218-223	10/23/91	3	170		0.0	0	0	5
149-063-23ADBB2	32-37	09/01/87	2			0.1	1	1	
149-063-23ADBB2	32-37	10/23/91	2	170	0	0.1	1	1	7
149-063-23ADBB3	7-12	09/01/87	1			0.1		2	
149-063-23ADBB3	7-12	10/23/91	1	50	0	0.1	1	3	6
149-063-25DBBC1	263-268	09/01/87	1			0.2	0	0	
149-063-25DBBC1	263-268	10/24/91	2	26	0	0.1	1	0	14
149-063-25DBBC2	78-83	09/02/87	13			0	0	0	
149-063-25DBBC2	78-83	10/24/91	19	38	0.4	0.1	0	0	11
149-063-25DBBC3	51-56	09/02/87	6			0.3	0	0	
149-063-25DBBC3	51-56	10/24/91	3	85	0	0.1	0	0	9
149-063-25DBBC4	23-28	09/02/87	8			0	0	0	
149-063-25DBBC4	23-28	10/24/91	2	150	0	0.1	0	0	6
149-063-26DCA	38-43	09/01/87	15			0.1	0	0	
149-063-26DCA	38-43	10/24/91	13	51	0	0.1	0	0	14
149-063-27DDDC2	158-163	09/01/87	7			0.1	0	2	
149-063-27DDDC2	158-163	11/19/91	1	30	0.4	0.0	0	1	43
149-063-34BBB1	251-256	09/01/87	2			0	0	0	
149-063-34BBB1	251-256	11/19/91	4	60	0.8	0.0	0	1	24
149-063-34BBB2	27-32	09/01/87	1			0	0	0	
149-063-34BBB2	27-32	10/24/91	1	39	0.1	0.1	0	2	5
149-063-35ABBD2	45-50	09/01/87	22			0	0	0	
149-063-35ABBD2	45-50	10/24/91	16	47	0.1	0.1	0	0	9
149-063-36AACB2	181-186	09/02/87	1			0	0	1	
149-063-36AACB2	181-186	10/22/91	1	62	0	0.0	0	0	7
149-063-36AACB3	64-69	09/02/87	13			0.1	0	1	
149-063-36AACB3	64-69	10/22/91	11	210	0	0.0	0	0	13
149-063-36AACB4	24-29	09/02/87				0	0	1	
149-063-36AACB4	24-29	10/22/91	0	77	0.1	0.0	0	0	18
149-063-36BBDA2	22-27	09/01/87	20			0	0	0	
149-063-36BBDA2	22-27	10/24/91	12	62	0.1	0.1	0	0	9
149-063-36DDBC1	131-136	09/02/87	1			0.2	0	0	
149-063-36DDBC1	131-136	10/22/91	2	62	0	0.0	0	0	5
149-063-36DDBC2	83-88	09/02/87	1			0	0	0	
149-063-36DDBC2	83-88	10/22/91	1	66	0	0.0	0	0	6
149-063-36DDBC3	46-51	09/02/87	11			0	0	0	
149-063-36DDBC3	46-51	10/22/91	9	100	0	0.0	0	0	12

APPENDIX C: PESTICIDE DATA

Table C.1. Pesticide data from surface- and ground-water samples taken in October of 1992 and August of 1993. ND is no detection at the MDI level, and NA means the sample was not analyzed for the specified analyte. SW Lake is South Washington Lake.

SWC Well Number	13085	13090	13093	13094	13095	13096	13100	13102	13105	13106	SW Lake	Lake Coe	Lake Coe	Spring	Field Blank	Field Blank	Lab MDL
Sample Date	8/26/93	8/25/93	8/25/93	8/25/93	8/26/93	8/26/93	8/24/93	10/28/92 8/26/93*	10/28/92 8/26/93*	8/25/93	8/26/93	8/24/93	8/24/93	8/25/93	8/25/93	10/28/92	
Site Number	12	9	10	20	17-1	17-2	13	6	2	8	11	14	15	16			
Analyte	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/	µg/
alachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
atrazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
butylate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
chloramben	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.1
chlorpyrifos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
cyanazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
diallate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
dicamba	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1
dimethoate	ND	ND	ND	ND	ND	ND	ND	**0.8**	ND	ND	ND	ND	ND	ND	ND	ND	0.5
EPTC	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
ethalfluralin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
fonofos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
linuron	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
malathion	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
methyo parathion	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
metolachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
metribuzin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
pendimethalin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
picloram	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**0.4**	**0.2**	**0.2**	ND	ND	NA	0.1
phorate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
propachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
prometon	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
propazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
simazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1
terbufos	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
triallate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
triclopyr	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.1
trifluralin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.5
2,4-D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.5
2,4-DB	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.5
2,4,5-T	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.1
2,4,5-TP	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	0.1

APPENDIX D: PETROLEUM RESIDUE DATA

Table D.1. Total petroleum hydrocarbon (TPH) as gas and as diesel for ground- and surface-water sampled in August 1993. * SW is South Washington Lake.

SWC Well Number	13084 mg/l	13090 mg/l	13092 mg/l	13100 mg/l	SW Lake* mg/l	Lake Coe mg/l	Field DW blank mg/l	lab MDL mg/l
Site Number	12	13	10	8	1	14		
Analyte								
TPH (gas)	ND	ND	ND	ND	ND	ND	ND	0.5
TPH (diesel)	ND	ND	ND	ND	ND	ND	ND	1.0

APPENDIX E: MUNITIONS AND EXPLOSIVES RESIDUE DATA

Table E.1. Detections of residues from munitions and explosives in ground- and surface-water from sampling in October 1992.

Well Number	HMX µg/l	RDX µg/l	Nitrobenzene µg/l	TETRYL µg/l	1,3,5-Tri nitrobenzene µg/l	1,3-Di nitrobenzene µg/l	2,4,6-TNT µg/l	2,4-DNT µg/l
13104	ND	ND	ND	ND	ND	ND	ND	ND
13105	ND	ND	ND	ND	ND	ND	ND	ND
Spring	ND	ND	ND	ND	ND	ND	ND	ND
Reservoir	<5.33*	<4.16*	ND	ND	<2.10*	ND	ND	ND
13098	ND	ND	ND	ND	ND	ND	ND	ND
13102	ND	ND	ND	ND	ND	ND	ND	ND
13087	ND	ND	ND	ND	ND	ND	ND	ND
Det. Limit	0.533	0.416	0.682	0.631	0.210	0.458	0.426	0.397

* < sign indicates that higher detection limits were caused by laboratory interferences.