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State of Washington

Quality Assurance Project Plan

Effects of Conventional versus Minimum Tillage on Groundwater Nitrate at a Manured Grass Field

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Quality Assurance Project Plan

Effects of Conventional versus Minimum Tillage on Groundwater Nitrate at a Manured Grass Field

October 2009

Approved by:

Signature:	Date: October 2009
Richard Grout, Client, Director, Bellingham Field Office	
Signature:	Date: September 2009
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Signatures are not available on the Internet version.
EIM - Environmental Information Management system.
EAP - Environmental Assessment Program.

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Abstract

In cooperation with the Washington State University, Whatcom Conservation District, and Washington State Department of Agriculture, the Washington State Department of Ecology (Ecology) conducted a nitrate study on a 22-acre grass field near Lynden, Washington from 2004 to 2008. One of the study findings was that nitrate concentrations in groundwater reached high levels (maximum of 43 mg/L nitrate+nitrite-N) beneath the field following conventional tillage of the field.

This Quality Assurance (QA) Project Plan describes a planned 2009-11 study to compare the effects of conventional tillage with the effects of minimum tillage. During conventional tillage, the soil is disturbed 8 times to a depth of 3 feet, while the minimum tillage method only disturbs the top few inches of soil one time. Because the soil is not completely turned over using the minimum tillage method, there is less opportunity for soil organic nitrogen to oxidize and mineralize to nitrate.

The field has been divided in half for the 2009-11 study, with three shallow monitoring wells in each half. One half received conventional tillage, and the other half minimum tillage. Groundwater monitoring will be conducted four times per year for both years.

Groundwater results will also be compared with soil nitrate, grass nitrogen uptake, manure nitrogen applied, and climate data. If minimum tillage of grass re-seeded into grass results in less nitrate release to groundwater and produces an equivalent crop, this could become a preferred alternative for maximizing crop uptake of manure nitrogen.

Each study conducted by Ecology must have an approved QA Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completion of the 2009-11 study, a final report describing the study results will be posted to the Internet.

Background

The concentration of nitrate in groundwater exceeds the Maximum Contaminant Level for drinking water, 10 mg/L nitrate-N, in a large number of drinking water wells in the Sumas Blaine Aquifer in Whatcom County, (Redding, 2008; Erickson, 2000; and Cox and Kahle, 1999). The depth to water is less than 10 feet below ground surface in most of the aquifer.

The Sumas Blaine Aquifer is the sole drinking water source for rural residents of the northern part of the county. Agriculture is a primary land use in the area, and dairies are a substantial part of the agricultural activity.

Ecology, along with Washington State University (WSU), the Washington State Department of Agriculture, and Whatcom Conservation District conducted a study to track nitrate concentrations in groundwater, soil, grass, and manure at a grass field where dairy manure is used as fertilizer over the Sumas Blaine Aquifer from 2004 through 2008 (VanWieringen, 2009; Carey, 2009, in progress). Figure 1 shows the study location.

Conventional and Minimum Tillage Methods

Although not part of the original study plan, the dairy producer tilled the grass field to be used for the study just prior to the start of the 2004-08 study using the local conventional tilling practice. Nitrate+nitrite-N concentration in groundwater beneath the field peaked at 43 mg/L in shallow groundwater the winter following tillage. (Nitrite-N is typically negligible in groundwater.) Groundwater nitrate concentrations gradually decreased over two years following the 2004 tillage.

An alternative to conventional tillage that causes less perturbation of the soil is available for grass using a subsurface deposition aerator (minimum tillage). Because the soil is not completely turned over using the minimum method, there is less opportunity for organic nitrogen in the soil to oxidize and subsequently mineralize to nitrate. This theoretically decreases the amount of nitrate available for leaching to groundwater.

The purpose of this study is to evaluate the difference in nitrate concentrations in soil, groundwater, and crop yield in a field where conventional tillage is used compared to a similar field receiving minimum tillage. The study site mentioned above, monitored from 2004-08, offers an opportunity for comparing the effects of the two management practices. A grant from the Washington State Department of Agriculture is helping to support this study.

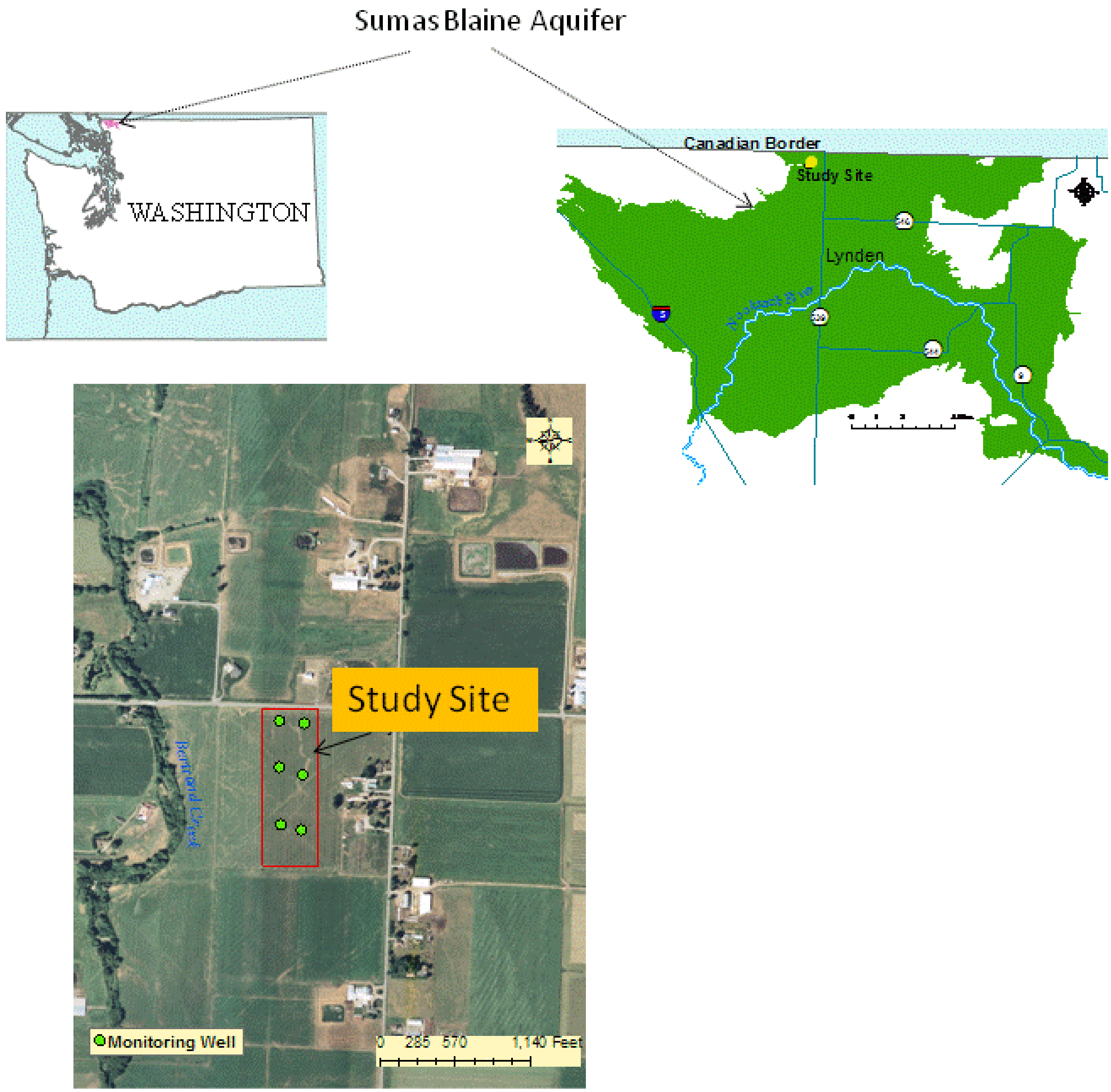


Figure 1. Study site location.

In May 2009, the field was divided in half north to south (Figure 2). The eastern half of the field was conventionally tilled, while the western half was minimally tilled. Three monitoring wells are located in each half of the field. The same groundwater sampling methods will be used in the 2009-11 study as those used in the 2004-08 study (Carey, 2004) to facilitate data comparisons. WSU will likewise use the same methods for sampling manure, soil, and crop nitrogen.

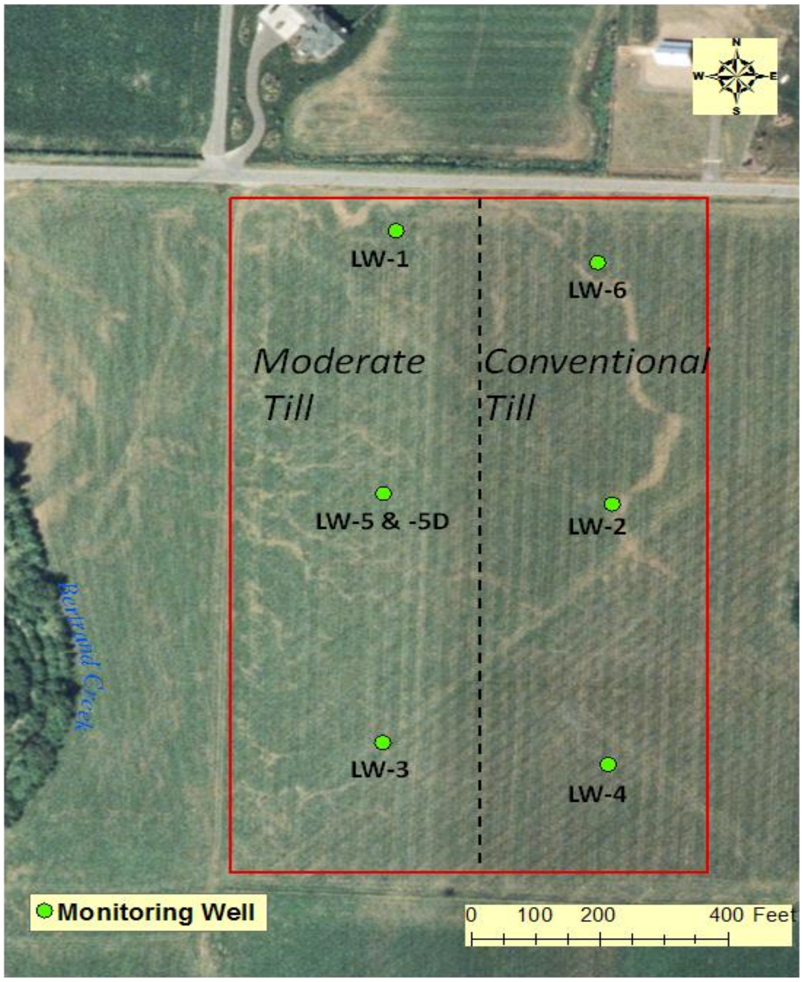


Figure 2. Study site showing where conventional and minimum tillage was conducted in May 2009.

Why Do We Care About Nitrate in Groundwater?

Widespread areas of the shallow Sumas-Blaine Aquifer, where the study is located, do not meet (exceed) the drinking water standard of 10 mg/L (Chapter 246-290). Most rural residents of northern Whatcom County obtain their drinking water from shallow wells near agricultural land where nitrate or manure are used for fertilizer. Heavy precipitation in the winter months carries nitrate not used by crops to the underlying groundwater.

Nitrate contamination reduces the ability of red blood cells to carry oxygen (Washington Department of Health, 2007). Infants who ingest high levels of nitrate may develop methemoglobinemia, or "blue baby syndrome," a serious condition due to lack of oxygen.

Older children and adults can also experience health problems from ingesting water high in nitrate if they have inadequate stomach acid or lack an enzyme that converts nitrate-affected red blood cells back to normal.

Weyer et al. (2001) found a positive association between nitrate exposure and bladder cancer as well as ovarian cancer in women.

Project Description

The purpose of the study is to compare the effects of conventional tillage of a manured grass field to the effects of minimum tillage on nitrate concentrations in groundwater. During 2004-08, Ecology collected detailed background data (water quality and water level) for the study site, including results following conventional tillage in 2004 (Carey, 2009, in progress).

Most grass fields fertilized by manure in the Whatcom County area are tilled every 4-5 years and re-seeded into corn and then tilled back to grass after 1-2 years. Because a corn crop generally has a lower nitrogen content than grass, corn is less effective for nitrate removal. Carey (2009, in progress) observed that nitrate-N concentration in groundwater reached 43 mg/L following conventional tillage of a grass field. If minimum tillage of grass re-seeded into grass results in less nitrate release to groundwater and produces an equivalent crop, this could become a preferred alternative for maximizing crop uptake of manure nitrogen.

The grass field that we monitored from 2004-08 was divided in half in May 2009 (Figure 2). One half of the field was conventionally tilled, the other half minimally tilled. Both halves were also re-seeded into grass immediately following tillage. We will monitor the same parameters and environmental media as in the 2004-08 study using the same methods (Carey, 2004). The weather station located in the field will continue to be used for continuous recording of temperature and precipitation.

Beginning in August 2009, shallow groundwater quality will be monitored in the six existing monitoring wells (12-13 feet deep), once in the spring of 2009 following the first manure application and three times in the fall/winter for two years. Soil, manure, and crop nitrogen will be monitored by WSU at the same frequency and using the same methods as in the 2004-08 study (Carey, 2004). Groundwater samples will be analyzed for the following parameters:

- Temperature
- pH
- Conductivity
- Dissolved oxygen
- Nitrate+nitrite-nitrogen*
- Ammonia-nitrogen*
- Total dissolved persulfate nitrogen*
- Chloride*
- Total dissolved organic carbon*
- Total dissolved solids*

*Filtered (0.45 μm) in-line in the field.

Organization and Schedule

Staff involved in the groundwater monitoring aspects of the project and their responsibilities are listed in Table 1. All are employees of the Washington State Department of Ecology.

Table 1. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Richard Grout Director, Bellingham Field Office Phone: (360) 715-5213	EAP Client	Clarifies scopes of the project, provides internal review of the QAPP, and approves the final QAPP.
Barbara Carey GFFU Statewide Coordination Section Phone: (360) 407-6769	Project Manager, Principal Investigator, and EIM data engineer	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, enters data into EIM. Writes the draft report and final report.
Martha Maggi GFFU Statewide Coordination Section Phone: (360) 407-6453	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Will Kendra Statewide Coordination Section Phone: (360) 407-6698	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Robert F. Cusimano Western Operations Section Phone: (360) 407-6596	Section Manager for the Study Area	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Stuart Magoon Manchester Environmental Laboratory Phone: (360) 871-8801	Director	Approves the final QAPP.
William R. Kammin Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

EAP – Environmental Assessment Program.
GFFU – Groundwater/Forest & Fish Unit.
EIM – Environmental Information Management system.
QAPP – Quality Assurance Project Plan.

Table 2. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	January 2011	Barbara Carey
Laboratory analyses completed	March 2011	
Environmental Information System (EIM) database		
EIM user study ID	BCAR0003	
Product	Due date	Lead staff
EIM data loaded	August 2011	Barbara Carey
EIM QA	September 2011	Barbara Carey
EIM complete	November 2011	Barbara Carey
Final report		
Author lead	Barbara Carey	
Schedule		
Draft due to supervisor	June 2011	
Draft due to client/peer reviewer	July 2011	
Draft due to external reviewer(s)	August 2011	
Final (all reviews done) due to publications coordinator	October 2011	
Final report due on web	November 2011	

Quality Objectives

The quality objective of this study is to provide data representative of field conditions for comparison with data collected at other locations on the study site, at other sites, or at other times.

Measurements of water quality and hydrogeologic conditions may be used to:

- Compare groundwater quality data (especially nitrate) from conventionally tilled versus minimally tilled locations at the field site.
- Compare groundwater quality data with historical data for the site.
- Compare groundwater quality data with data collected by WSU for soil, applied manure, and grass crop.
- Compare groundwater quality results with data from other studies.

Table 3 lists the measurement quality objectives (MQOs) for assessing the quality of field and laboratory data. These are the same MQOs used in the 2004-08 study at the site (Carey, 2004). Manchester Environmental Laboratory is expected to meet quality control requirements for the laboratory methods selected for the project.

Table 3. Measurement quality objectives for groundwater analytes.

Analyte	Check standards (% recovery limits)	Duplicate samples (RPD)	Reporting limit (concentration units)
Field			
Temperature	NA	<2	4-30^{0}C
pH	NA	<10	1-14 S.U.
Specific Conductivity	80-120	<15	1 µmho/cm
Dissolved Oxygen	NA	<10	0.2 mg/L
Laboratory			
Ammonia-N	80-120	<20	0.01 mg/L
Nitrite+Nitrate-N[1]	85-115	<10	0.01 mg/L
Total Persulfate N	80-120	<10	0.025 mg/L
Chloride	80-120	<5	0.1 mg/L
Total Dissolved Solids	80-120	<20	10 mg/L
Dissolved Organic Carbon	80-120	<20	1 mg/L

[1] Nitrite-nitrogen is typically negligible in groundwater.

Sampling Process Design (Experimental Design)

This study (2009-11) immediately follows a study (2004-08) at the same location to track nitrogen from manure in a grass field (VanWieringen, 2009; Carey, 2009, in progress). During 2004-08, the quantity of nitrogen applied as manure and taken up by the grass crop was measured. Concentrations of nitrate in soil and groundwater were also measured.

During the 2009-11 study, we will monitor and evaluate the same media and parameters as the previous study. We will also test whether groundwater nitrate in monitoring wells beneath each half of the field (conventionally-tilled and minimally-tilled) is different from that measured in 2004-08.

The same six shallow monitoring wells will be sampled as in the 2004-08 study, three wells in each half of the field (Carey, 2004).

Groundwater sampling in the 2009-11 study will occur before and after soil porewater typically leaches to groundwater. Wells will be sampled four times per year: once in the spring following the first manure application and spring rain, and three times in the fall/winter period (August or September, November, and December or January). We will determine exact timing of fall/winter sampling to represent the pre-leaching dry conditions (late August-September) and the post-leaching conditions after significant rainfall (November-January). Sampling will begin in August 2009 and continue through January 2011.

Dissolved oxygen concentrations in samples from four of the six monitoring wells are sometimes in the range of 0-3 mg/L, the range where denitrification is likely to occur (Buss et al., 2005). Dissolved organic carbon, the common electron donor for bacterial denitrification, is also in good supply in the water from the wells (1-10 mg/L). Samples from the two wells that have consistently high dissolved oxygen concentrations show no signs of denitrification. Both of the wells with high dissolved oxygen are located on the minimally tilled half of the field (Figure 2).

Because denitrification conditions are not consistent in the monitoring wells, we will compare the results of each well to its individual record.

Sampling Procedures

The six existing monitoring wells will be sampled four times per year for two years (Figure 2). LW-1, LW-3, and LW-5 are located in the minimally tilled half of the field; LW-2, LW-4, and LW-6 in the conventionally tilled half. Drilling logs for the monitoring wells are shown in Appendix B. The geologic logs are shown in Appendix C.

Groundwater sampling procedures will be the same as those described in Carey (2004). Water level measurements will be made using the procedures in Marti (2009).

Measurement Procedures

Field and laboratory methods will be the same as those described in Carey (2004). These methods are listed in Table 4.

Table 4. Field and laboratory analysis methods and expected range of results.

Analyte	Standard Methods Test Method (APHA, 1998)	Expected Range of Results
Field		
Temperature	WTW Field meter	10-17°C
pH	WTW Field meter EPA Method 150.1	4.0-7.7 SU
Specific Conductivity	WTW Field meter EPA Method 120.1	100-600 umhos/cm
Dissolved Oxygen	WTW Field meter EPA Method 360.1	0-10 mg/L
Laboratory		
Ammonia-N*	4500-NH3 H	0.01- 70 mg/L
Nitrate+Nitrite-N*	4500-NO3 I	0.01- 70 mg/L
Dissolved Total Persulfate N*	4500-NO3 B Modified	0.01- 70 mg/L
Chloride*	EPA Method 300	1-40 mg/L
Total Dissolved Solids*	2540 C	100-500 mg/L
Dissolved Organic Carbon*	EPA Method 415.1	1-15 mg/L

* Field-filtered (0.45 µm pore size).
WTW: Wissenschaftlich-Technische-Werkstetten (Weilheim, Germany).

Quality Control Procedures

Field

Field quality control procedures will be the same as those described in Carey (2004) and are summarized as:

- Calibrate all field meters at the beginning, middle, and end of each field day.
- Install new silastic tubing in the peristaltic pump for sampling monitoring wells at the beginning of each sampling event.
- Collect one field duplicate during each sampling episode for all field and laboratory analyses.
- Collect one blind reference sample for nitrate+nitrite-N as part of each sampling event.
- Collect one blank sample (laboratory de-ionized water) for nitrate+nitrite-N as part of each sampling event.

Laboratory

Routine laboratory quality control testing will be used to estimate the accuracy, precision, and bias introduced by laboratory procedures. The results of this testing will be reported to the project lead (MEL, 2008). MEL's quality control sampling and test procedures are outlined in detail in the laboratory's Quality Assurance Manual (MEL, 2006).

The laboratory budget is shown in Table 5.

Table 5. Estimated laboratory costs for two years.

Analyte	Number of Samples/ Event	Cost/ Sample[1]	Cost/ Sampling Event	Number of Sampling Events	Cost/ Analyte
Ammonia-N	9	$13	$117	8	$936
Nitrate+Nitrite-N	9	$13	$117	8	$936
Total Persulfate N	9	$17	$153	8	$1,224
Chloride	9	$13	$117	8	$936
Total Dissolved Solids	9	$11	$99	8	$792
Dissolved Organic Carbon	9	$35	$315	8	$2,520
		Total Cost:	$918	8	$7,344

1: Costs include 50% planned discount for Manchester Environmental Laboratory.

Data Management Procedures

Field data management procedures will be the same as those for the 2004-08 study (Carey, 2004). Analytical data from MEL will be stored in electronic format in the MEL data management system (LIMS). After the data are verified, they will be summarized in case narratives and provided to the project manager.

Field and laboratory data for the project will be entered into Ecology's EIM system. Laboratory data will be downloaded directly into EIM from the LIMS system. Data entry into EIM is conducted using established data entry business rules. The EIM data will be reviewed by the project manager, staff entering the data (if different than the project manager), and an independent reviewer.

Audits and Reports

MEL participates in performance and system audits of their routine procedures. Reported results of these audits are available on request. Ecology's Accreditation Program establishes whether the laboratory has the capability to provide accurate and defensible data. To demonstrate the laboratory's ability to provide accurate and defensible data, the accreditation involves an evaluation of the laboratory's quality system, staff, facilities, equipment, test methods, records, and reports.

At the conclusion of the 2009-11 study, the project manager will prepare a technical report documenting the study procedures, findings, and recommendations. This report will include a quality assurance evaluation describing data acceptability and qualification. The final report will receive technical peer review by staff with appropriate expertise not directly connected to the project. Publication of the final report is planned for October 2011.

Data Verification

Data verification is a review process to assess the quality and completeness of analytical datasets.

Verification of laboratory data is performed by a MEL unit supervisor or an analyst experienced with the analytical method(s) used. Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL Lab Users Manual (MEL, 2008) and the MEL Laboratory Quality Assurance Manual (MEL, 2006). Data will be examined for errors, omissions, and compliance with quality control acceptance criteria; data qualifiers will be assigned where necessary.

Findings of the data verification effort will be documented in a case narrative prepared by the appropriate MEL staff member. The case narrative will be forwarded to the project manager for use during data evaluation.

Verification of field-generated measurements will consist of review of the completeness and accuracy of field notes as well as evaluation of field quality assurance test results. The field lead will check data received from LIMS for omissions against the “Request for Analysis” forms.

Data Quality (Usability) Assessment

If measurement quality objectives have been met for all sampling episodes, the data will be considered acceptable for use except as qualified during the data review and validation process. A paired t-test (or non-parametric analysis if appropriate) will be used to evaluate differences between water quality before and after the tillage treatment at each monitoring well. We will also conduct time-series analysis of the groundwater data and compare to results for manure application, soil nitrate, grass nitrogen uptake, and climate data.

Results from this 2009-11 study should be comparable to results from previous studies conducted in the Sumas-Blaine Aquifer area by Ecology, the U.S. Geological Survey (USGS), WSU, and Western Washington University. The test methods and sampling procedures described in this Quality Assurance Project Plan are the same as those used in previous Ecology studies and are comparable to USGS methods. Routine test methods will be adequate for this study.

References

APHA, AWWA, and WEF, 1998. Standard Methods for the Examination of Water and Wastewater 20th Edition. American Public Health Association, Washington, D.C.

Buss, S.R., M.O. Rivett, P. Morgan, C.D. Bemmet, 2005. Attenuation of nitrate in the sub-surface environment. Environment Agency, Science Report SC030155/SR2 (United Kingdom). 100 p.

Carey, B.M., 2004. Quality Assurance Project Plan: Groundwater, soil, and crop nitrogen at a field where dairy waste is used as fertilizer in Whatcom County. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-112. 32 p. www.ecy.wa.gov/biblio/0403112.html.

Carey, B.M., 2009. In progress. Groundwater, soil, and crop nitrogen at a field where dairy waste is used as fertilizer in Whatcom County. Washington State Department of Ecology, Olympia, WA.

Cox and Kahle, 1999. Hydrogeology, ground water quality, and sources of nitrate in lowland glacial aquifers of Whatcom County, Washington and British Columbia, Canada. USGS Water-Resources Investigations Report 98-4195. 251 p., 5 plates.

Erickson, D. 2000. Northcentral Sumas-Blaine Aquifer nitrate characterization project, June 1999. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-010. 13 p. + appendices. www.ecy.wa.gov/biblio/0003010.html

Marti, P., 2009. Standard Operating Procedure (SOP) for Manual Well-Depth and Depth-to-Water Measurements, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP052. www.ecy.wa.gov/programs/eap/quality.html.

MEL, 2006. Manchester Environmental Laboratory Quality Assurance Manual. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

MEL, 2008. Manchester Environmental Laboratory Lab Users Manual, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Redding, M., 2008. Nitrate Trends in the Central Sumas-Blaine Surficial Aquifer. Washington State Department of Ecology, Olympia, WA. Publication No. 08-03-018. 117 p. www.ecy.wa.gov/biblio/0803018.html.

VanWieringen, L., 2009. Fate of Manure Nitrogen Applied for Grass Silage Production. Final Report submitted by Washington State University Livestock Nutrient Management Program to the Washington State Department of Agriculture. 27 p.

Washington State Department of Health, 2009. Nitrate in Drinking Water, Fact Sheet. DOH, 2 pages. Publication No. 331-214. www.doh.wa.gov/ehp/dw/programs/nitrate.htm.

Weyer PJ, Cerhan JR, Kross BC, Hallberg GR, Kantamneni J, Breuer G, Jones MP, Zheng W, Lynch CF., 2001. Municipal drinking water nitrate level and cancer risk in older women: the Iowa Women's Health Study. Epidemiology 12(3):327-38.

Appendices

Appendix A. Glossary, Acronyms, and Abbreviations.

Glossary

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Conventional tillage: A common tillage method used to prepare soil for re-seeding a crop in western Washington using the following equipment: sub-soiler, plow, disk, seed-bed conditioner, cultimulcher, and rototiller. The top 3 feet of soil are disturbed using this method.

Groundwater: Water in the subsurface that saturates the rocks and sediment in which it occurs. The upper surface of groundwater saturation is commonly termed the water table.

Manure nitrogen: Nitrogen derived from animal waste in the form of ammonia, nitrate, organic nitrogen, or total nitrogen.

Minimal tillage: A method for preparing soil for re-seeding using a subsurface deposition aerator. Only the top few inches of soil are disturbed using this method.

Parameter: Water quality constituent being measured (analyte).

Porewater: Water occupying the spaces between sediment grains located between the land surface and the water table. Water pressure in this zone is usually less than atmospheric pressure. Flow is dependent on the degree of saturation.

Tillage: Prepare land to raise a crop.

Acronyms and Abbreviations

Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
GPS	Global Positioning System
LIMS	Laboratory Information Management System
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
QA	Quality assurance
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SRM	Standard reference materials
USGS	U.S. Geological Survey
WSU	Washington State University

Units of Measurement

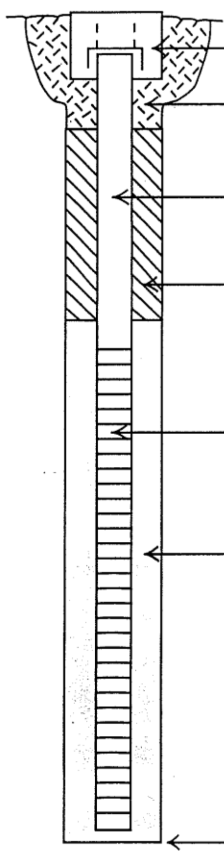
°C	degrees centigrade
cfs	cubic feet per second
ft	feet
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliters
s.u.	standard units
µg/L	micrograms per liter (parts per billion)
umhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter, a unit of conductivity

Appendix B. Driller Logs.

HOLT DRILLING, INC.

Resource Protection Well Report

Project Name: Jackman Rd & "H" St Rd
Date: 8-25-04 Through 8-27-04
Well Identification #: AKG 721, 22, 23, 24, 25 + 27
County: Whatcom, NE ¼ NW ¼
Drilling Method: 4" HSA
Section: 1 T. 40N R. 2E
Driller: R. Kerns / D. Smith
Street Address: Jackman Rd & "H" St. Rd. Lynden
License #: 2701 / 1229
Start Card: R65098
Consulting Firm: Dept. of Ecology

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	MONUMENT TYPE: Flush CONCRETE SURFACE SEAL: 2 ft. PVC BLANK: 2 "x 7 ' BACKFILL: 4 ft. TYPE: Bentonite chips PVC SCREEN: 2 "x 7 ' SLOT SIZE: .020 TYPE: PVC GRAVEL PACK: 8 ft. MATERIAL: WELL DEPTH: 14 '	0 - 1 ft. Topsoil 1 - 13 ft. Fine sand 13 - 14 ft. silty fine sand - ft. - ft. REMARKS

Signature: Dale Smith 1229/2784

HOLT DRILLING, INC.

Resource Protection Well Report

Project Name Jackman Rd + "H" St. Rd

Well Identification # AKG726

Drilling Method 4" HSA

Driller R. Kerns / D. Smith

License # 2701 1229

Date 8-26-04

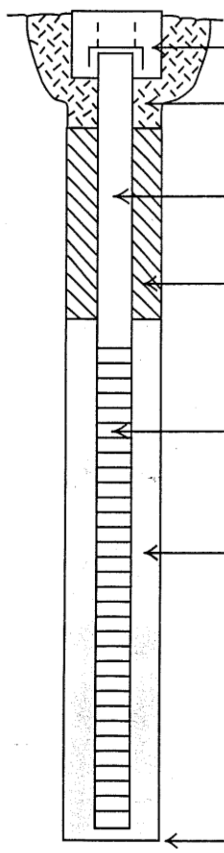
County Whatcom, NE ¼ NW ¼

Section 1 T. 40N R. 2E

Street Address Jackman Rd. + "H" St. Rd. Lynden

Start Card R65098

Consulting Firm Dept. of Ecology

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	MONUMENT TYPE: Flush CONCRETE SURFACE SEAL 2 ft. PVC BLANK 2 "x 30' BACKFILL 27 ft. TYPE: Bentonite Grout + chips PVC SCREEN 2"x 10' SLOT SIZE: .020 TYPE: PVC GRAVEL PACK 11 ft. MATERIAL: 10/20 Sand WELL DEPTH 40'	0 - 1 ft. Topsoil 1 - 14 ft. Fine Sand 14 - 32 ft. silty fine sand 32 - 40 ft. Fine Sand - ft. REMARKS

Signature Dale Smith 1229/2784

332.FDB/D41029.EPS

Appendix C. Geologic Logs.

Geologic Log

Study ID: LW-1

Unique Ecology Well ID Tag No. AKG-721

Site Address H St. Rd.

City Lynden County: Whatcom

Location ___1/4- 1/4 ___1/4 Sec___ Twn___ R___ EWM or WWM *circle one*

Lat/Long (s, t, r Lat Deg 48 Lat Min/Sec 59/583

Long Deg 122 Long Min/Sec 30/356

Cased or Uncased Diameter 2" Static Level 10.7'

Date 8/25/04

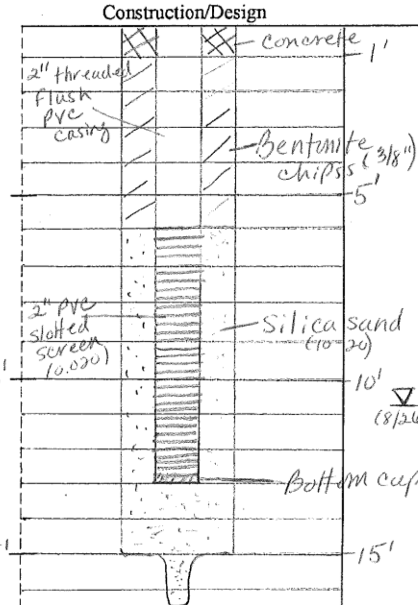
Driller Holt Drilling, Milton, WA.

Hydrogeologist Barbara Carey, Ecology

Drilling Method: Hollow-stem auger

Ground surface elevation: 130.00' (from USGS 1:24,000 map)

Depth	Construction/Design	Well Data: Soil sample	Well Data: Blow Counts	Formation Description
0–1'	Concrete (1'); 2" threaded flush PVC casing			Dark brown, topsoil
				Fine SAND with silt, dark brown
	Bentonite chips (3/8") to 5'	S1	4/3/3	Medium gray SAND
5'		S2	0/2/4	SILT mottled, compacted
	2" PVC slotted screen (0.020); Silica sand (10-20)	S3	5/5/7	Fine SAND, gray and light brown
10'	10'; ▽ (8/26/04)	S4	5/7/8	Fine gray SAND with silt, WET
	Bottom cap	S5		Fine - medium gray SAND, water-bearing
15'	15'	S6	5/8/9	
20'				



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ECY 050-12 (Rev 2/01)

Geologic Log

Study ID: LW-2

Unique Ecology Well ID Tag No. AKG-722

Site Address H St. Rd.

City Lynden County: whatcom

Location ____1/4- 1/4 ____1/4 Sec____ Twn____ R____ EWM or WWM *circle one*

Lat/Long (s, t, r Lat Deg ______ Lat Min/Sec ______

Long Deg ______ Long Min/Sec ______

Cased or Uncased Diameter ______ Static Level 8.4'

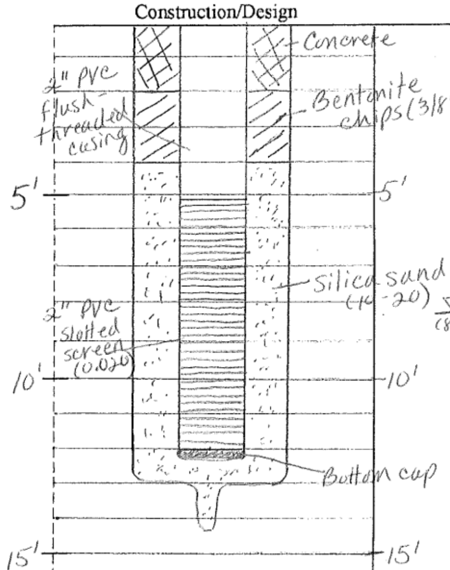
Date 8/25/04

Driller Holt Drilling, Milton, WA

Hydrogeologist Barbara Carey, Ecology

Drilling Method: Hollow-stem auger,
Ground Surface Elevation: 126.80'
(from USGS 1:24,000 map, relative to AKG-721.)

Construction/Design



Well Data: Soil Sample	Well Data: Blow Counts	Formation Description
		Dark brown, humic topsoil
S1	6/7/6	Fine to medium gray SAND with some silt at 5.'
S2	2/5/6	
S3	4/8/11	Fine gray SAND with some silt, damp at 8,' wet at 10.'
S4	5/8/11	
S5	5/9/15	

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ECY 050-12 (Rev 2/01)

Geologic Log

Study ID: LW-3

Unique Ecology Well ID Tag No. AKG-723

Site Address H St. Rd.

City Lynden County: Whatcom

Location ____1/4- 1/4 ____1/4 Sec____ Twn____ R____ EWM or WWM *circle one*

Lat/Long (s, t, r Lat Deg 48 Lat Min/Sec 59/465

Long Deg 122 Long Min/Sec 30/365

Cased or Uncased Diameter ________ Static Level 9.7'

Date 8/25/04

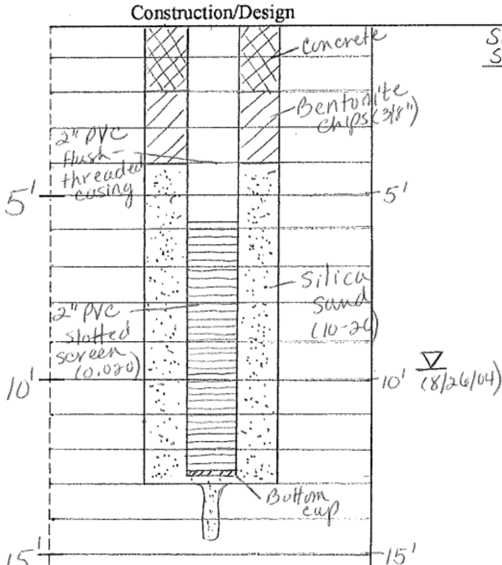
Driller Holt Drilling, Milton, WA.

Hydrogeologist Barbara Carey, Ecology

Drilling Method: Hollow-stem auger

Ground surface elevation: 126.84' (From USGS 1:24,000 map, relative to AKG-721.)

Construction/Design



Well Data

Soil Sample	Blow Counts	Formation Description
		Topsoil
S1	1/3/4	Gray SILT with some sand, orange mottling, compacted
S2	1/1/1	Fine brown SAND
		Medium to fine SAND, gray + black
S3	1/1/3	Fine to medium SAND, brown + gray, damp at 8.5'
S4	2/3/9	Medium to fine SAND, gray + black, some orange staining about 10-10.5' WET
S5	5/10/14	

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ECY 050-12 (Rev 2/01)

Geologic Log

Study ID: LW-4

Unique Ecology Well ID Tag No. AKG-724

Site Address H St. Rd.

City Lynden County: Whatcom

Location ___1/4-1/4 ___1/4 Sec___ Twn___ R___ EWM or WWM (circle one)

Lat/Long (s, t, r Lat Deg 48 Lat Min/Sec 59/447

Long Deg 122 Long Min/Sec 30/303

Cased or Uncased Diameter 2" Static Level 8.25'

Date 8/26/04

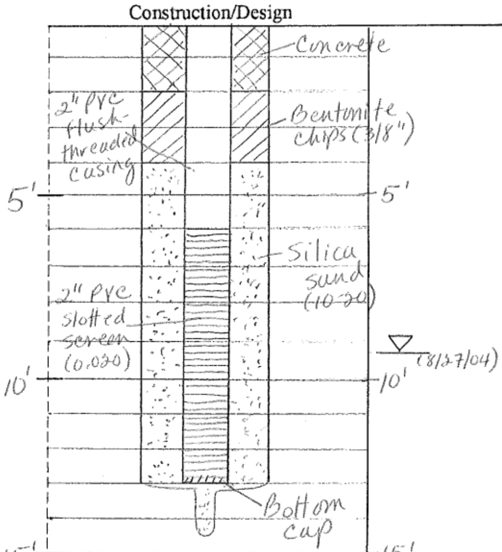
Driller Holt Drilling

Hydrogeologist Barbara Carey

Drilling Method: Hollow Stem Auger

Ground Surface Elevation: 124.97'
(From USGS 1:24,000 map, relative to AKG-721.)

Construction/Design



Depth	Soil sample	Blow counts	Formation Description
0–2'			Dark brown topsoil
2–5'	S1	2/2/3	Brown SILT
5–6'	S2	5/7/11	Fine brown SAND with some dark brown silt
6–9.5'	S3	6/11/12	Medium gray and black SAND, 10% gravel up to 1/2" rounded, small amount of fine sand, damp at 8'
9.5–14'	S4	6/8/11	Medium to coarse brown SAND with 10%-20% gravel, rounded to subrounded, WET
	S5	4/12/18	

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ECY 050-12 (Rev 2/01)

Geologic Log

Study ID: LW-5

Unique Ecology Well ID Tag No. AKG-725

Site Address H St. Rd.

City Lynden County: whatcom

Location ___1/4- 1/4 ___1/4 Sec___ Twn___ R___ EWM or WWM *circle one*

Lat/Long (s, t, r Lat Deg 48 Lat Min/Sec 59/512

Long Deg 122 Long Min/Sec 30/364

Cased or Uncased Diameter 2" Static Level 10.58'

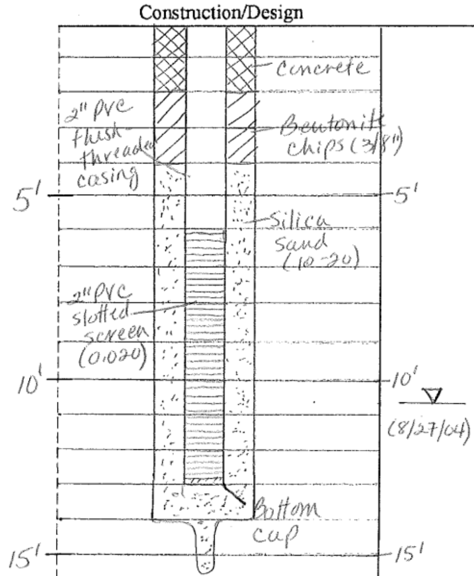
Date 8/26/04

Driller Holt Drilling

Hydrogeologist Barbara Carey

Drilling Method: Hollow Stem Auger
Ground Surface Elevation: 128.73'
(From USGS 1:24,000 map, relative to AKG-721.)

Construction/Design



Well Data

Soil Sample	Blow Counts	Formation Description
		Topsoil
S1	3/3/4	Fine brown SAND with silt, orange mottling
S2	4/4/5	Fine SAND, some medium grained SAND to 6.5' and at 14' and >. Brown at shallow depth, gray deeper.
S3	4/5/7	
S4		
S5	6/9/12	

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ECY 050-12 (Rev 2/01)

Geologic Log

Unique Ecology Well ID Tag No. AKG-726

Study ID: LW-5D

Site Address H St. Rd.

City Lynden County: Whatcom

Location ___1/4-1/4 ___1/4 Sec___ Twn___ R___ EWM or WWM (circle one)

Lat/Long (s, t, r) Lat Deg 48 Lat Min/Sec 59/512

Long Deg 122 Long Min/Sec 30/364

Cased or Uncased Diameter 2" Static Level 10.61'

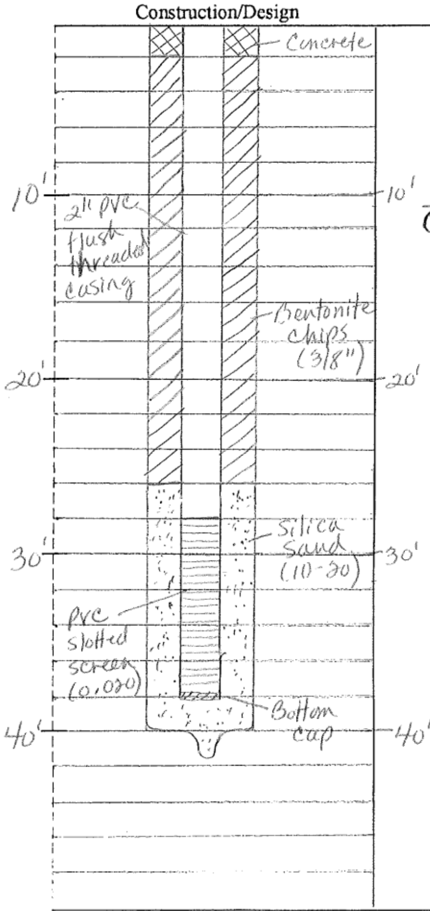
Date 8/26/04

Driller Holt Drilling

Hydrogeologist Barbara Carey

Drilling method: Hollow-stem Auger
Ground Surface Elevation: 128.68'
(from USGS 1:24,000 map, relative to AKG-721.)

Construction/Design



Well Data: Soil sample	Blow Counts	Formation Description
		Topsoil.
		Fine brown SAND w/ silt, mottling
10' ▽ (8/27/04)		Fine SAND, some medium grained. Brown at shallow depth, gray deeper. (10')
S1	5/10/14	Fine gray SAND with silt.
S2	4/8/12	(20')
S3	4/8/12	Fine to medium gray and black SAND
S4	12/20/55½	(30')
S5	no sample	
S6	—	Fine gray SAND turning to compacted gray SILT at 41,' very hard (40')

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ECY 050-12 (Rev 2/01)

Geologic Log

Study ID: LW-6

Unique Ecology Well ID Tag No. AKG-727

Site Address H St. Rd.

City Lynden County: Whatcom

Location ____1/4- 1/4 ____1/4 Sec____ Twn____ R____ EWM or WWM *circle one*

Lat/Long (s, t, r Lat Deg______ Lat Min/Sec ______

Long Deg______ Long Min/Sec ______

Cased or Uncased Diameter 2" Static Level 9.18'

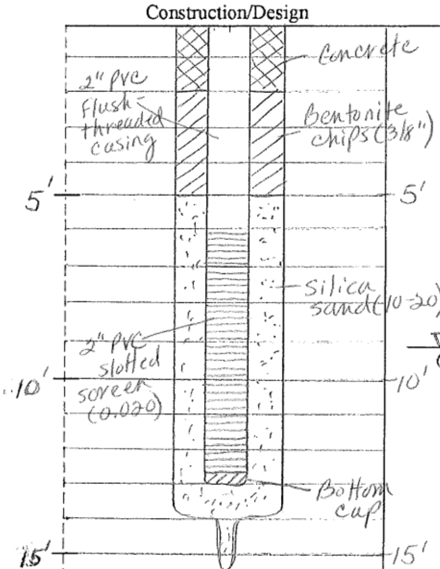
Date 8/26/04

Driller Holt Drilling

Hydrogeologist Barbara Carey

Well drilling method: Hollow-stem auger
Ground surface elevation: 127.43'
(from USGS 1:24,000 map, relative to AKG-721.)

Construction/Design



Well Data: Soil sample	Blow counts	Formation Description
		Topsoil
I	2/2/4	Fine SAND with silt, brown with orange mottling
I	3/4/5	
I	3/5/6	Fine to medium gray and brown SAND, wet at 8'
I	3/6/10	
I	5/8/12	

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ECY 050-12 (Rev 2/01)