DOUGLAS COUNTY NITRATE STUDY

Tri-County Health Department
May 30, 2008

Purpose

Nitrate, a form of nitrogen, is a common contaminant of sewage that can potentially seep into groundwater and impact drinking water in wells. Excessively high levels of nitrate in drinking water can cause health impacts, particularly in pregnant women and infants. The levels of nitrate contaminating water in a well may be influenced by nearby individual sewage disposal systems (ISDS). Factors such as the age of the sewage system, its proximity to a well, the well depth, and other factors may influence whether nitrate contaminants from sewage affect the water in the well. In order to further understand these factors, Tri-County Health Department (TCHD) conducted a study in Douglas County to assess the impacts of nearby ISDS on nitrate levels in wells. This report describes the results of this study.

Background

TCHD permits and inspects ISDS in Adams, Arapahoe, and Douglas Counties. In addition, TCHD reviews plans for new subdivisions served by ISDS to assess whether the proposed ISDS provide adequate sewage disposal and will not adversely impact the groundwater.

Conventional ISDS are comprised of four basic components: a wastewater source, a pretreatment unit (septic tank), and effluent delivery system (leachfield) and the soils in the vadose zone (the zone between the surface and the aquifer) above the groundwater. The leachfield is usually comprised of a series of perforated pipes within a rock storage media installed in either a trench or bed configuration (Figure 1).

The effluent from the septic tank infiltrates into the leachfield where it percolates through the vadose zone down to the groundwater. During percolation through the vadose zone, the effluent receives advanced treatment (Figure 1). However, conditions in the subsurface may exist that result in contaminants such as nitrogen not being removed before reaching the groundwater.

Of the many contaminants in domestic sewage, nitrogen, in the form of nitrate, is the most persistent and is most likely to reach the groundwater. Nitrate, as nitrogen, may be found in groundwater and surface water as a result of commercial fertilizers, animal manure, combustion byproducts of fossil fuels from atmospheric deposition, as well as ISDS. Nitrate is a biologically active nutrient. It is highly soluble in water and is readily carried by water through soils. In infants less than 6 months old, nitrate can cause a condition termed methemoglobanemia which is also known as “blue baby syndrome.” Methemoglobanemia results when the nitrate is converted to nitrite in the underdeveloped digestive tract of the infant, and the nitrite then prevents the infant’s blood from carrying oxygen. As a result of the health impacts associated with nitrate, the Colorado

Department of Public Health and Environment (CDPHE) has promulgated a drinking water standard for nitrate of 10 milligrams per liter (mg/L). Although the actual incidence of methemoglobanemia is rare, "at risk populations", i.e. pregnant and nursing women, infants, and adults with certain chronic health problems should avoid ingesting water containing nitrates above the 10 mg/l health standard.

Figure 1 Illustration of a common individual sewage disposal system (ISDS) that relies on subsurface infiltration for treatment and disposal.

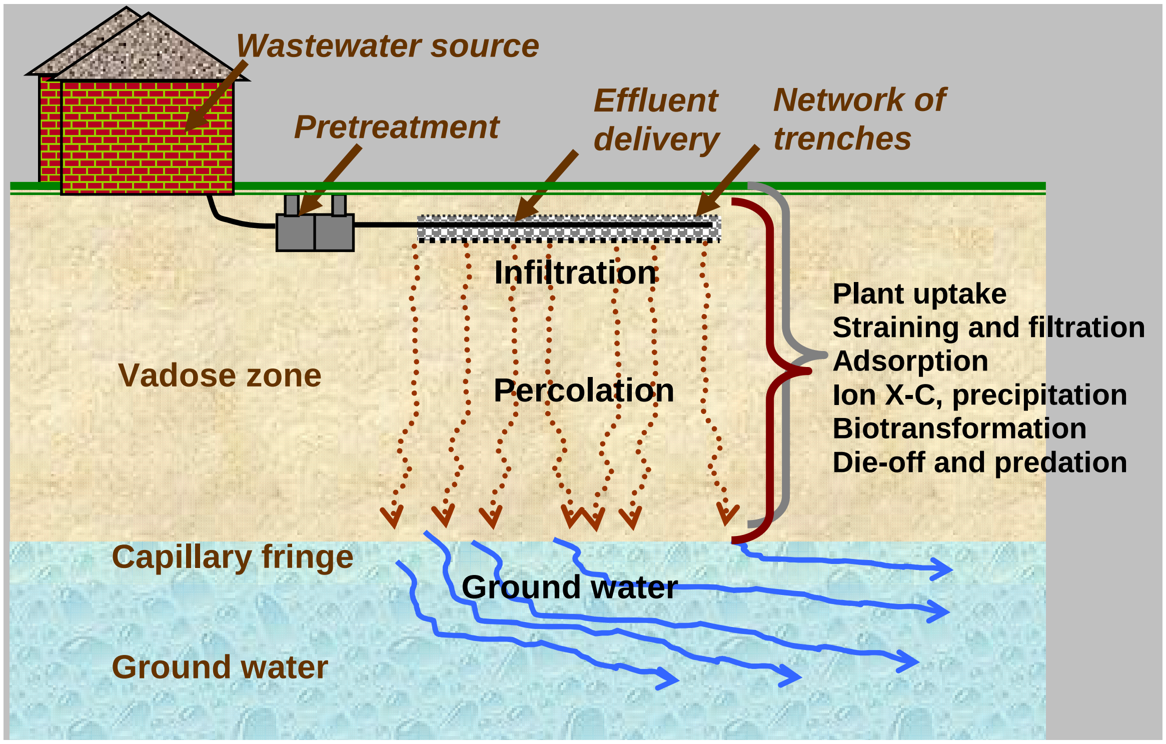


Diagram from Colorado School of Mines Environmental Science and Engineering Department

There are numerous factors that may impact the ability of nitrate to contaminate wells. Models used to predict nitrate impacts to groundwater indicate that it may take several decades for measurable levels of nitrate to appear in wells. Thus, TCHD decided to study the issue further, by assessing nitrate levels in older wells. Since Douglas County was identified as having a sufficient number of wells installed prior to 1973, Douglas County was selected as the study area.

In addition to sampling existing wells, TCHD chose to explore whether certain factors would "pre-dispose" a well to nitrate contamination from ISDS. Six factors were selected. Table 1 below summarizes each of the six factors and why it may be significant.

Table 1 **Hypotheses of six factors**

Factor	Hypothesis of Potential Impact
Distance from leachfield to well head	Closer distance may result in more impacts
Elevation of leachfield in relation to well	Higher elevation may cause more effluent to flow toward the well
Age of ISDS	Older systems have more impact due to increased amounts of nitrate entering the aquifer over time
Soil type of leachfield	Sandier soils are more likely to allow leachfield effluent to reach the well
Frequency of ISDS tank pumping	Lack of pumping increases nitrate load to aquifer
Depth of well (≤200 ft or >200ft)	Deeper wells are less vulnerable to nitrate due to the distance the contaminants would travel to groundwater

The primary aquifer utilized to provide water to residential wells in Douglas County is the Dawson Aquifer. The base of the Dawson aquifer ranges from a maximum of 1400 feet deep to ground surface at the outcrop (1). The eastern boundary of the Dawson aquifer outcrops approximately near Highway 105 and along an approximate north-south line from Sedalia to the Arapahoe-Douglas county line. Because the Dawson Aquifer is the closest bedrock aquifer to the ground surface, it is vulnerable to contamination from ISDS.

Methods

Participant Survey

In September 2007, TCHD sent a mailing to homeowners requesting sample sites (test wells) for nitrate testing. The sites were chosen based on county assessor’s data which stated that these homes were older than 1973 and likely used a well and an ISDS. Those homeowners who chose to participate completed a standard survey. The contents of the mailing can be found in Appendix A.2 Sample Letter and A.3 Participant Survey.

Sample Collection, Field Methods, and Reporting Results

A visual inspection of the property was conducted by TCHD staff, and diagrams and notes regarding the location of both the well and leachfield were noted on the field data form. Water samples were taken from the nearest accessible outside spigot to the well head. The standard operating procedure (SOP) for Water Quality Grab Sampling is included in Appendix C.1. The homeowner was then interviewed to assess the frequency of pumping the septic tank.

Educational information on both water quality and ISDS maintenance were left at the home. Once the water quality lab results were reviewed, a letter to the homeowner was generated and mailed. The letter included values for conductivity, hardness, and nitrate. If the nitrate levels were elevated, but did not exceed the health standard, a recommendation for additional testing at the homeowner's expense was included in the letter. If the nitrate level exceeded the health standard, the homeowner was called and TCHD offered to resample to confirm the nitrate level. The homeowner also received a written recommendation not to use the water for drinking and to seek water treatment advice from a water professional. An example of each type of letter is included in Appendix B.

Laboratory Methods

TCHD analyzed the samples for hardness using Hach Method 8213 (Appendix C.3) and for conductivity using Hach Method 8160 which is equivalent to USEPA Method 120.1 (Appendix C.4). The Colorado Department of Public Health and Environment (CDPHE) analyzed the samples for nitrate levels using US EPA Method 300.0 (Appendix C.5).

GIS Methods

Upon completion of sampling, TCHD staff identified the location of each well and leachfield in a Geographical Information System using aerial photos and field notes. GIS analysis was then used to determine four factors including elevation, distance of well to leachfield, hydraulic conductivity and well depth. The SOP for using the Well and Leachfield Location Tool is located in Appendix C.2.

Once the locations were mapped, GIS was used in conjunction with data from the United States Geological Survey (USGS) 10-meter Digital Elevation Models (DEMs), data from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database and Soil Data Mart, and data from the Colorado State Engineer's Office (SEO) database of well permits. A listing of soil types and their saturated hydraulic conductivity values is shown in Appendix D.

Statistical Analysis

Data were merged and analyzed using Excel 2003 and SAS 9.1. Certain factors were analyzed to determine their impact on the nitrate levels of water samples. These factors included the depth of the well, soil type as measured by saturated hydraulic conductivity of the leachfield, the distance from the well to the leach field, the elevation of the leachfield relative to the well, the number of years that the property had a residential structure that discharged sewage, and the location of the property in the county.

Results

Of the 1,938 letters sent to property owners, 339 (18.5 %) of the homeowners agreed to participate in the study. Of those 339, 17 were disqualified due to incorrect county, being served by municipal water and sewer, incomplete forms, or no signature. Another 27 were disqualified due to homeowner's changing their minds, no available water to sample, and padlocks preventing staff from entering the property. Water samples were obtained from 295 properties.

Nitrate levels ranged from non-detectable (less than 0.3 mg/L) to 75 mg/L with a mean (average) of 1.8 mg/L. Nine samples (3.1 %) exceeded the drinking water health standard of 10 mg/L, and the remaining 286 samples (96.9 %) had either non-detectable levels or levels less than the health standard. As shown in Table 2, the water samples exceeding the standard were from the communities of Franktown, Larkspur, and Parker. The average nitrate levels by community are shown in Table 3. Figure 4 graphically represents the minimum, maximum, and mean for each town sampled for the study. A map showing sample locations that were able to be mapped for each water sample included in the nitrate study is in Appendix F. The dots indicating each location are color coded to show the detection range. These are defined in the legend. None of the communities had an average nitrate level that exceeded the regulatory health standard.

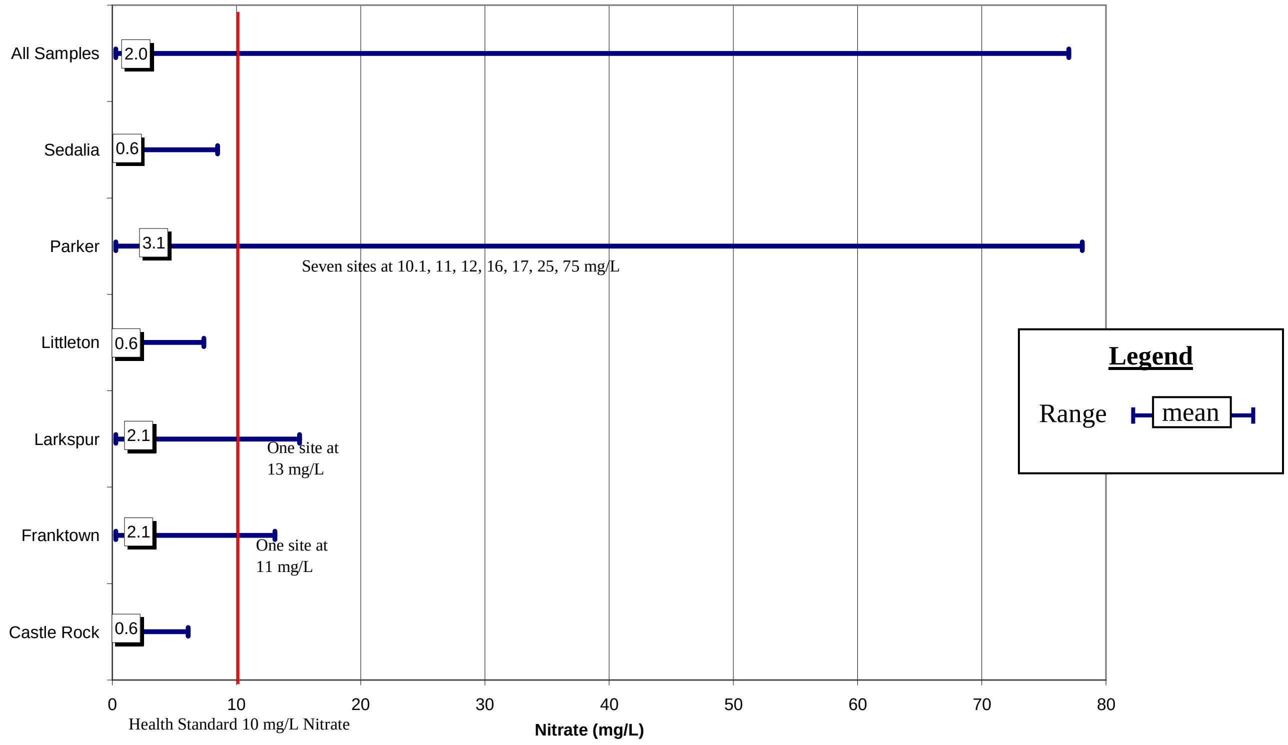
Table 2 Nitrate levels of selected water samples, October 2007 – March 2008 (n=295)

	City/Town													
	Castle Rock		Franktown		Larkspur		Littleton		Parker		Sedalia		All Samples	
Nitrate level (mg/L)	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
≥ 10 (Health Standard)	0	0.0	1	3.3	1	5.6	0	0.0	7	5.0	0	0.0	9	3.1
Detectable at < 10	16	29.1	26	86.7	15	83.3	7	30.4	110	79.1	11	36.7	185	62.7
Not detectable (≤ 0.30)	39	70.9	3	10.0	2	11.1	16	69.6	22	15.8	19	63.3	101	34.2
Total	55	100.0	30	100.0	18	100.0	23	100.0	139	100.0	30	100.0	295	100.0

Table 3 Range and average of nitrate levels from selected water samples, October 2007 – March 2008 (n=295)

		Nitrate Levels (mg/L)		
City/Town	No. of Samples	Minimum	Maximum	Mean (Average)
Castle Rock	55	< 0.3	5.5	0.6
Franktown	30	< 0.3	11.0	2.1
Larkspur	18	< 0.3	13.0	2.1
Littleton	23	< 0.3	6.8	0.6
Parker	139	< 0.3	75	3.1
Sedalia	30	< 0.3	7.9	0.6
All Samples	295	< 0.3	75	2.0

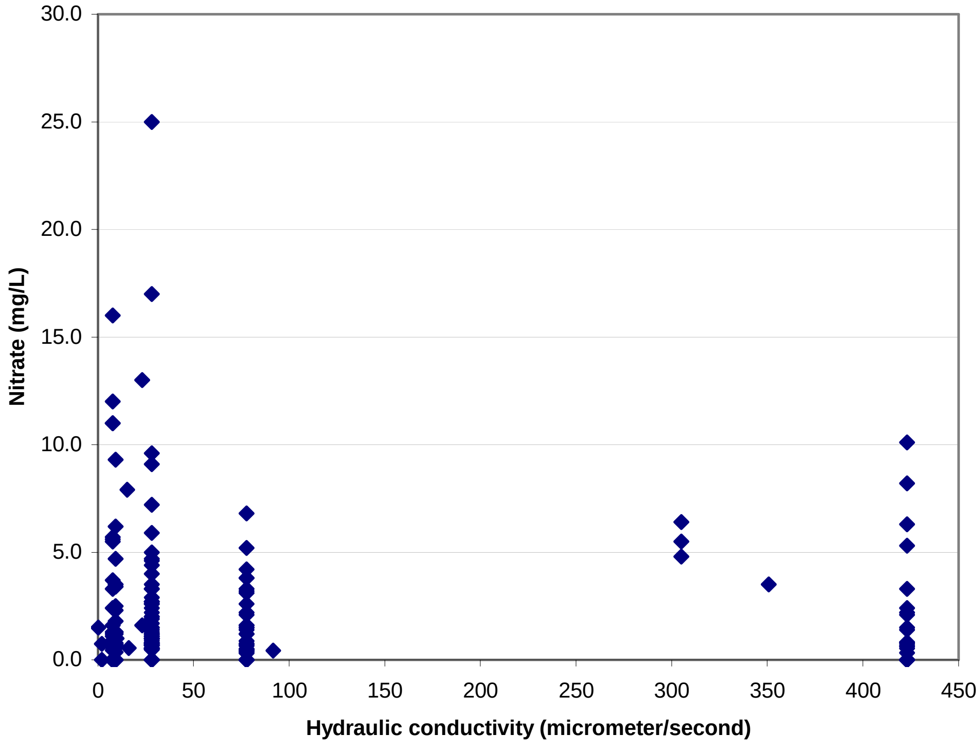
Figure 2 **Nitrate range for each town**



Of the 295 water samples, 284 had additional information available and were further analyzed for the factors listed in the Methods section. The goal of this analysis was to examine whether certain factors were important in determining whether a water sample would have higher levels of nitrate.

None of the factors studied were associated with nitrate levels over the health standard. We then looked at all possible nitrate levels, and conducted analysis to see if there were factors that contributed to any detectable level of nitrate. The number of years that the property had an occupied residential structure that discharged sewage, the distance between the well and the leachfield, and the elevation difference between the well and the leachfield were not associated with detectable nitrate levels. Soil type as measured by saturated hydraulic conductivity was available for 221 properties. Saturated hydraulic conductivity is a measure of the rate at which water moves through soild under saturated conditions. Gravels and sands have a much higher saturated hydraulic conductivity than silt and clay soils. No trends or patterns were identified and this factor was not associated with detectable nitrate levels (Figure 5).

Figure 3 **Saturated hydraulic conductivity of leachfield and nitrate level of water (n=221)**



Depth of well measurements were available for 104 of the 295 wells sampled. This factor appeared to be a potentially important factor in determining whether a well would have detectable levels of nitrate, since analysis of the 104 properties having well depth data indicated that the more shallow the well, the more likely the water sample was to have a detectable nitrate level. Table 4 shows the range and average of well depths by communities. Of note, those communities with the shallowest mean well depth (Franktown, Larkspur, and Parker) were also those communities that had water samples exceeding the health standard (Tables 2 and 4). However, we could not directly relate well shallowness as a contributing factor to the nine wells with nitrate levels over the health standard, because depth measurements were not available for the majority of them.

Table 4 Range and average depth of selected wells (n=104)

		Depth of Well (ft)		
City/Town	**No. of Samples**	**Minimum**	**Maximum**	**Mean**
Castle Rock	22	75	804	480
Franktown	10	165	528	318
Larkspur	10	85	870	316
Littleton	8	120	925	501
Parker	43	90	765	306
Sedalia	11	227	600	363
All Samples	104	75	925	366

Discussion and Conclusions

Based on the 104 samples from which specific well information could be obtained from the State Engineer's Office (SEO) database, and the locations of most of the wells, it can be concluded that the majority of wells sampled were constructed in the Dawson aquifer. In order to make statistical inferences about the entire groundwater supply in the Dawson aquifer for Douglas County, the samples taken would need to have been randomly selected. Conversely, the 295 wells tested in this study comprised a "convenience sample" rather than a random sample, since the wells tested were "self-selected" based on the willingness of owners to participate. Consequently, the ability to use statistics to draw conclusions about the overall groundwater quality in the Dawson aquifer of Douglas County is limited. Despite the method of well selection, the test results do provide an indication that the groundwater quality in the Dawson aquifer in Douglas County, with respect to nitrate, is good; non-detectable or below the health standard.

As shown in the "Results" section of this report, the study determined that 34.2% of the wells had non-detectable levels of nitrate, 62.7% of the wells had detectable levels of nitrate and 3.1% of the samples (9 wells) were above the 10 mg/L drinking water standard. Based on the nitrate data, it is plausible that nitrate from ISDS has impacted the groundwater to result in detectable nitrate levels. It is also likely that nitrate from other sources such as plant material, fertilizers, animal urine and manures and atmospheric deposition have contributed to detectable levels of nitrate. While nitrogen from all these sources has impacted groundwater, the overall magnitude of the impact is relatively low, when evaluated against the 10 mg/L drinking water standard. Nitrate levels below the 10 mg/L standard are not considered to be detrimental to human health.

Six Factors

Of the six factors evaluated, only the shallowness of the well was shown to be significantly associated with detectable levels of nitrate. Well depth was initially hypothesized to be an important factor in predicting nitrate contamination, since deeper wells should be less vulnerable to nitrate contamination from ISDS. In this study, the nitrate level was shown to be increased in shallow wells and decreased in deeper wells., There are two potential reasons for this finding:

1) The depth of the vadose zone is greater for deeper wells and the nitrate from the source (ISDS) has to travel a greater distance to reach the groundwater table. This greater depth of travel offers more opportunity for the removal of nitrate in the vadose zone, prior to reaching the groundwater.

2) The deeper wells may be completed within the lower Dawson aquifer. The presence of a shale layer separating the upper and lower Dawson aquifers (1) may serve to significantly attenuate the downward flow of nitrate-laden waters into those wells.

The lack of complete data on well information may have prevented a more thorough and detailed analysis of this factor.

Nitrate Levels Greater than 10 mg/L

The six factors did not provide information about why nine of the wells had nitrate levels above the CDPHE drinking water standard of 10 mg/L. Poor well construction or subsequent damage to the wellhead may have resulted in these wells becoming more vulnerable to contamination. In addition, the proximity of these wells to intermittent surface water streams or topographic valleys may have increased their vulnerability. Finally, these wells may have been historically exposed to additional sources of nitrogen, such as animal waste and fertilizers.

Nitrate concentrations in septic tank effluent discharged from a typical ISDS are about 60 mg/L. Since 286 wells had non-detectable nitrate levels or below the 10 mg/L nitrate standard, it is apparent that significant nitrate removal is occurring within the vadose zone above the aquifers. The continued lateral flow of water within the aquifer may also dilute or flush the aquifer, further reducing the nitrate levels.

Based on the study, Tri-County Health Department does not believe that any change to its Regulation Number I-02, Individual Sewage Disposal Systems (I-02) is indicated. TCHD will continue to review the results of ongoing research concerning impacts from ISDS on groundwater to explore whether changes to its ISDS regulation would be valuable in protecting groundwater. In addition, several simplified models have been provided to TCHD to evaluate potential impacts from new subdivisions served by ISDS. TCHD has and will continue to use the models in its subdivision review process.

Recommendations

Based on the results of the study, Tri-County Health Department (TCHD) proposes several recommendations:

- While only a small percentage of the wells tested had nitrate levels above the 10 mg/L health standard, TCHD recommends that all well owners have their wells tested for nitrate. Although the likelihood of having a nitrate level exceeding the standard is low, the health impacts if the well water exceeds the standard can be serious. If owners find that their water exceeds the health standard, they should treat the water to be used for cooking or drinking by using an appropriate point-of-use unit that removes nitrate from the water. The owner should consult a qualified water professional to determine the most appropriate treatment system.

- Owners should be educated about wellhead protection. Flyers, pamphlets, websites and seminars are all useful educational tools.

- Additional research is needed to develop the necessary tools to protect our valuable water resources. The Colorado School of Mines and the United States Geological Survey (USGS) are two prominent organizations conducting ongoing research in this field. Partnerships between county governments, health departments and research organizations have been, and can continue to be, a valuable means of furthering the knowledge base in protection of water supplies.

Reference

1. Geologic Structure, Hydrology, and Water Quality of the Dawson Aquifer in the Denver Basin, Colorado. United States Geological Survey, Hydrologic Investigations Atlas, HA-643. S.G. Robson, USGS and John C. Romero, Colorado Division of Water Resources.

Appendix A

A.1 Intergovernmental Agreement between Douglas County and Tri-County Health Department

A.2 Sample Letter

A.3 Participant Survey

A.1 Intergovernmental Agreement between Douglas County and Tri-County Health Department Including Exhibits A and B

INTERGOVERNMENTAL AGREEMENT
BETWEEN THE BOARD OF COUNTY COMMISSIONERS OF THE COUNTY OF DOUGLAS AND TRI-COUNTY HEALTH DEPARTMENT CONCERNING THE FUNDING AND IMPLEMENTATION OF THE NITRATE TESTING PROGRAM

This Intergovernmental Agreement (the "Agreement") is made and entered into this _____ day of ______________________, 2007, by and between the Board of County Commissioners of the County of Douglas, a political subdivision of the State of Colorado ("County"), and Tri-County Health Department, a political subdivision of the Counties of Adams, Arapahoe and Douglas and the State of Colorado ("Tri-County"), hereinafter jointly referred to as the "Parties."

RECITALS:

WHEREAS, pursuant to the provisions of Section 30-11-101(d), C.R.S., the County has authority to enter into contracts related to the concerns of the County; and

WHEREAS, pursuant to Colorado Constitution, Article XIV, Section 18(2)(a), and Section 29-1-203, C.R.S., the County and Tri-County may cooperate or contract with each other to provide any function, service, or facility lawfully authorized to each, and any such contract may provide for the sharing of costs, or other matters; and

WHEREAS, the Parties desire to set forth the terms and conditions in connection the funding and implementation of a testing program that will include the testing of levels of nitrate present in 300 qualifying residential wells in Douglas County (the "Program"); and

WHEREAS, in exchange for Tri-County organizing and managing the Program, the County shall compensate Tri-County for the cost of conducting testing on 250 residential wells.

NOW, THEREFORE, in consideration of the mutual covenants contained herein, and for other consideration, the receipt and sufficiency of which is expressly acknowledged, the Parties agree as follows:

1. The Program. Tri-County agrees to conduct the testing of 300 residential wells located within Douglas County for the presence of nitrate. The selected wells have been made available for testing at the request of homeowners that have a qualifying well on their property. The Program shall be conducted as set forth in the proposal attached hereto as Exhibit A.

2. Allocation of Costs. The County will pay the cost of conducting a nitrate test on 250 residential wells for the total cost of $27,249.00. Tri-County will pay any

remaining costs to conduct a nitrate test on 50 additional residential wells. The County's payment of its share of costs shall be made to Tri-County in two payments: a) the first payment in the amount of $13,624.50 shall be made on or before November 30, 2007; and, b) the second payment of $13,624.50 shall be made upon the County's receipt of the Final Summary Report from Tri-County, but not later than May 30, 2008. A Detail of Costs is attached hereto as Exhibit B.

3. Term. The term of this Agreement shall be from October 30, 2007, through June 1, 2008.

4. Reports. Tri-County agrees to provide to the County, a report containing the results of all tests that were conducted as part of the Program. Tri-County agrees to provide to the owners of the wells that were tested, the results of their well test.

5. No Third Party Beneficiaries. The enforcement of the terms and conditions of this Agreement and all rights of action relating to such enforcement, shall be strictly reserved to the County and Tri-County, and nothing contained in this Agreement shall give or allow any such claim or right of action by any other or third person under such Agreement.

6. Notices. All notices, bills or other communication hereunder required as permitted to be sent pursuant to this Agreement will be in writing and will be deemed served, given, delivered and received upon the earlier of: (a) when personally received by the Party to whom it is addressed; or (b) one business day after being deposited with a commercial overnight courier for overnight delivery with all required charges prepaid; or (c) when confirmed if sent by telephone facsimile with duplicate copy by U.S. Mail; and addressed to Tri-County and the County at the appropriate address as set forth below. Each Party hereto may change its address for the purpose of this section by giving written notice of such change to the other Party in the manner provided for in this section.

If to Tri-County:
Tri-County Health Department
7000 E. Belleview Avenue, Suite 301
Greenwood Village, CO 80111
Telecopy: 303-220-9208
Attention: Warren S. Brown

If to the County:
Douglas County
100 Third Street
Castle Rock, CO 80104
Telecopy: 303-688-6596
Attention: County Administrator

7. Default. If any Party is in default of this Agreement, and said default is not cured within five (5) days after delivery of written notice of said default to defaulting

Party, then the other Party may seek right or remedy it may have at law or equity, including specific performance.

8. Appropriation. Pursuant to § 29-1-110, C.R.S., the financial obligations of Tri-County and the County contained herein, which are payable after the current fiscal year, are contingent upon funds for the Program being annually appropriated, budgeted and otherwise made available.

9. Assignment. This Agreement may not be assigned or delegated in whole or in part without the prior written consent of the other Party. Any purported attempt to assign or delegate this Agreement shall be void and of no force or effect. Consent to one assignment or delegation shall not be consent to any subsequent assignment or delegation.

10. Indemnification. To the extent allowed by law, Tri-County agrees to release, indemnify and hold harmless the County, its commissioners, officers, directors, agents and employees from any and all claims, damages, suites, costs, expenses, liability, actions or procedures of any kind or nature whatsoever, including worker's compensation claims, of or by anyone whomsoever in any way resulting from or arising out of, directly or indirectly, its performance of this Agreement or its operations in connection herewith, including acts and omissions of Tri-County's officers, employees, representatives, suppliers, invitees, contractors and agents' provided, however, that Tri-County need not release, indemnify or save harmless the County, its commissioners, officers, directors, agents, and employees from damages resulting from the sole negligence of the County's commissioners, officers, directors, agents and employees.

Tri-County shall require its contractors providing services for this Agreement to indemnify Douglas County.

11. Additional Documents. The Parties agree to execute any additional documents or take any additional action that is necessary to carry out the intent of this Agreement.

12. Governing Law. This Agreement shall be governed and enforced in accordance with the laws of the State of Colorado. Venue for any action hereunder shall be in the District Court, County of Douglas, State of Colorado.

13. Modification. This Agreement may not be modified, amended, changed or terminated, in whole or in part, except by an agreement in writing duly authorized and executed by each of the Parties.

14. Waiver. The waiver of any right or the breach of any provision, of this Agreement by any Party shall not constitute a continuing waiver or a waiver of any subsequent breach of the same of any other provision of this Agreement.

15. Severability. Invalidation of any of the provisions of this Agreement or of any paragraph, sentence, clause, phrase, or word herein, or the application thereof in any given circumstances, shall not affect the validity of any other provision of this Agreement.

16. Telecopies. A telecopied facsimile of a duly executed counterpart of this Agreement will be sufficient to evidence the binding agreement of each Party to the terms herein, and delivery of this Agreement will be deemed to occur upon transmission of a facsimile counterpart to this Agreement to the intended recipient. However, each Party agrees to promptly return an original executed counterpart of this Agreement following the delivery of a telecopied facsimile hereof.

17. Recitals. The recitals to this Agreement are incorporated herein by this reference.

18. Counterparts. This Agreement may be signed in counterparts. Execution by facsimile signature shall constitute the binding execution hereof.

19. Governmental Immunity. All activities performed under this Agreement are hereby declared to be governmental functions. The parties to this Agreement, and their personnel complying with or reasonably attempting to comply with this Agreement or any ordinance, order, rule, or regulation enacted or promulgated pursuant to the provisions of this Agreement shall be deemed to be operating within the scope of their duties and responsibilities and in furtherance of said governmental functions.

The parties also acknowledge that each party, their officers and employees, are relying on, and do not waive or intend to waive, by any provision of this Agreement, the monetary limitations or any other rights, immunities, and protections provided by the Colorado Governmental Immunity Act, C.R.S. 24-10-101 et seq. as it is from time to time amended, or otherwise available to the parties, their officers, or employees.

TRI-COUNTY HEALTH DEPARTMENT By: ______________________________ Richard L. Vogt, M.D. Executive Director Date:___________________________ **ATTEST:** ____________________________	**THE BOARD OF COUNTY COMMISSIONERS OF THE COUNTY OF DOUGLAS, COLORADO** By: ____________________ Steven A. Boand, Chair Date:____________________

	ATTEST: __________________________________ Mary A. Niblack, Deputy Clerk **APPROVED AS TO FORM**: ____ Myron A. Clark Senior Assistant County Attorney

EXHIBIT A

Tri-County Health Department (TCHD) Regulation No. I-02 tasks TCHD staff with permitting and inspecting new individual sewage disposal systems (ISDS) and those involved in a complaint, being relocated or repaired. Modeling is used to support decisions regarding the appropriateness for ISDS in an area, especially in sensitive areas due to slopes or existing high levels of nitrate in aquifers.

TCHD initiated a descriptive study of the potential impacts of ISDS on underground sources of drinking water, specifically residential water wells. The contaminant of concern is nitrate. Nitrate, as nitrogen, may be found in groundwater as a result of nitrogen fertilizers, animal manure, combustion byproducts of fossil fuels from atmospheric deposition, or individual sewage disposal systems (septic systems). It is commonly found in shallow groundwater as an agricultural or waste water contaminant. The regulated value for nitrate in public drinking water supplies is 10 mg/L. Excess nitrate is the primary cause of methemoglobinemia, or blue baby syndrome, which predominantly affects infants and pregnant women.

TCHD does not plan to survey people in regards to illness or symptoms of nitrate poisoning. The level of nitrate would have to be significantly higher than hypothesized which is unlikely in a non-agricultural area without an industrial fertilizer component. Although TCHD is not receiving reports of methemoglobinemia, the concern remains that nitrate may be present in residential drinking water wells. TCHD is taking a proactive approach to prevent illnesses caused by nitrate. The goal of the study is to assess the drinking water quality for nitrate levels and determine based on these findings whether further study is warranted. A second goal is to determine if certain factors related to ISDS “pre-dispose” wells to have nitrate impacts above a level of 2 mg/L. These factors are discussed in more detail later in this Exhibit.

During the initial evaluation, TCHD researched other jurisdictions who have conducted similar studies, considered the recommendations from a 2005 nitrate study completed by Colorado School of Mines (CSM) for TCHD in Adams County, surveyed nitrate levels in groundwater sources for Douglas County public drinking water systems, and took into consideration concerns about nitrate from watershed and regulatory groups. Based on this evaluation TCHD identified that nitrate could potentially be seen in drinking water wells associated with ISDS older than 34 years.

Douglas County was identified as having a sufficient number of ISDS meeting this age requirement. A list of these properties had been created in 2003 and used to remind ISDS owners of normal ISDS maintenance procedures. To be included in the study, the home also needs a residential drinking water well. Private wells are unregulated, therefore, water quality information about each well would be difficult to obtain. The assumption was made that most residential homes with an ISDS system will also be served by a well. The second decision made was to include wells of various depths.

Although alluvial wells may be particularly susceptible to nitrate contamination from both agricultural practices and wastewater infiltration, the CSM study indicated nitrates originating from ISDS in the vadose zone (the zone between the surface and the aquifer) may be transported to the Denver Formation bedrock aquifer where most residential wells can be found. Based on the goal to determine if nitrate was in drinking water near older ISDS, the reminder list was deemed appropriate for the nitrate study.

For a statistically representative sample, a random sample should be taken from all of the homes meeting the study's criteria. Due to the resource constraints of this project, it was not deemed possible to perform random sampling.

On September 11, 2007, TCHD sent a mailing requesting sample sites (test wells) with a caveat that only the first fifty responses would be accepted. The mailing included a letter describing the study, a form for the participant to complete, and a return postage-paid envelope. The response form requested the address and contact information for both the homeowner and/or occupant, confirmation that the water supply was a well and the sewage disposal method was an ISDS, permission for staff to enter the property, and a signature acknowledging the homeowner was aware of disclosure requirements and that the information would be subject to the Open Records Act. The form also asks for a signature granting permission for TCHD to enter the property and collect the sample. The contents of the mailing can be found in Attachment A-1. Mailings were sent to approximately 1700 addresses in Douglas County including Castle Rock, Franktown, Larkspur, Parker and Sedalia with the expectation of a 5% return rate. This low return rate was based upon conversations with neighboring public health departments that had experience with mailings to ISDS owners.

The return response was much higher than anticipated. TCHD has received 302 potential participants to date. As promised in the initial letter, TCHD has begun sampling the first fifty respondents. Samples for hardness, conductivity, and nitrate are being taken at the nearest, accessible outside spigot to the wellhead. This sample location is logged in a GPS unit to be available for future mapping. If the homeowner is home, questions are asked pertaining to the well and the ISDS. If the homeowner is not at home, the questions are asked by phone or email. General information on both water quality and ISDS maintenance are left at the home. Samples for hardness and conductivity are taken to TCHD for analysis and samples for nitrate are taken to the Colorado Department of Public Health and Environment (CDPHE) for laboratory analysis. When the results are received and entered into a database, a letter to the homeowner will be generated and mailed, that will include their values for conductivity, hardness, and nitrate. If there is a need to recommend additional testing at the homeowner's expense, this is noted. Also if there is a need for water treatment due to a nitrate level that exceeds the health standard, this is also noted. These letters are being drafted by TCHD.

During the first phase of the study, TCHD tested several nitrate methods for accuracy and feasibility. For the first eighteen samples, nitrate was analyzed by EPA 300, a laboratory method used for detecting nitrate in drinking water, and by Hach Method 8039, a method used primarily in the field to obtain a number quickly. This comparison showed the Hach Method was insufficiently accurate for the needs of the study. The next eight samples were analyzed using EPA 300 and SM4500, a method used to detect nitrate in groundwater. This was done to ascertain any inconsistencies between the drinking water method (EPA 300) which costs $30 per sample and requires that samples be taken to the lab within 24 hours, with results received in less than a week, and the standard method (SM 4500) used regularly in environmental monitoring which costs $15 per sample and which requires that samples be taken to the lab within 7 days with results received in three weeks. These results have not been received to date. TCHD will use EPA 300, due to its higher accuracy.

Standard operating procedures have been developed for the study. These include field sampling procedures and TCHD lab procedures, which are followed by staff.

Considering that nitrate may be present in a number of wells tested, the study will examine several factors that may predispose those wells to impacts from ISDS. The following factors are hypothesized to lead to wells experiencing impacts from nitrate.

Factor	**Hypothesis of Potential Impact**
Distance from leachfield to well head	Closer distance may result in more impacts
Elevation of leachfield in relation to well	Higher elevation may cause more effluent to flow toward the well
Age of ISDS	Older systems have more impact due to increased cumulative mass loading to aquifer
Soil type of leachfield	Sandier soils are more likely to allow leachfield effluent to reach the well
Frequency of ISDS tank pumping	Lack of pumping increases nitrate load to aquifer
Depth of well (≤200 ft or >200ft)	Deeper wells are less vulnerable to nitrate

The data will be managed and maintained by TCHD. Once the data is obtained for GPS readings, hardness, conductivity, nitrate, distance from leachfield to wellhead, relative elevation of the leachfield to the wellhead, ISDS age, soils, frequency of septic tank pumping, and well depth, the data will be entered into a database. This database will also include the sample date, the participant’s name, address, and contact information, and any relevant comments pertaining to the sample location or sampling event.

Upon completion of the field work, TCHD will prepare and submit a final summary report as a deliverable to Douglas County. The final summary report will include a discussion of the basis for the study, a discussion of results, analysis of results, conclusions and recommendations. The analysis will be conducted to determine whether any of the six factors hypothesized influenced the level of nitrate in the well. For example, most of the factors could be reduced to a 2x2 analysis. With this type of analysis, one can tally nitrates greater than 2 mg/l, and less than 2 mg/l by the applicable factor, e.g. well depth less than 200 feet and greater than 200 feet. This will determine whether nitrates are associated with the well depth factor.

Exhibit B *Detail of **Costs** for **Additional 250** locations*

Field & Lab Instruments owned by TCHD	No cost
Lab Supplies for Field Tests-Hardness & Conductivity *(250 samples * $2.50 per sample)*	$625.00
250 Samples Sent to Lab for Nitrate Analysis *(250 samples * $30 per sample EPA Method 300)*	$7,500.00
25 Duplicate Samples to Lab for Nitrate Analysis *(25 samples * $30 per sample EPA Method 300)*	$750.00
Mileage to Laboratory for Sample Bottles (28 miles x 20 trips x 0.485 cents)	$275.00
Average Mileage to Each Sample Location (25 mi per sample location) *(250 locations * 25 miles * 0.485 cents)*	$3,031.00
Staff Time Spent at each location (40 min) *(250 samples * 40min)/60min in 1 hr =167hrs* **167 hours** @ $30/hr	$5,010.00
Staff Time Required for Field Test Analyses (Hardness, Conductivity & Quality Control 20min/sample) *(250 samples * 20min)/60min in 1 hr =84hrs* **84 hours** @ $30/hr	$2,520.00
Planning/Scheduling Sample Sites (call owner & locate home 5 hours for 250 samples) **5 hours** @ $30/hr	$150.00
Data Entry (6 min/sample) *(250 samples * 6min)/60min in 1 hr =25hrs* **25 hours** @ $30/hr	$750.00
Data Interpretation (40 hours for 250 samples) **40 hours** @ $30/hr	$1,200.00
Follow-up Letter to Homeowner Explaining Results (15 hours for 250 samples) **15 hours** @ $30/hr	$450.00
Total Staff Time (167hr+84hr+5hr+25hr+40hr+15hr)	336 total hours
Fringe Benefits for 336 staff hours at 25% of paid time (336 hr * $30/hr) * 0.25	$2,520.00
Indirect for 560 staff hours at 2007 rate of 24.48% (336 hr * $30/hr) * 0.2448	$2,468.00
Total	$27,249.00

A.2 Sample Letter

Tri-County Health Department
Serving Adams, Arapahoe and Douglas Counties

Richard L. Vogt, M.D.
Executive Director

September 11, 2007

Dear Resident,

Nitrate from individual sewage disposal systems (septics) has the potential over time to impact drinking water supplied by groundwater wells. The drinking water health standard is 10 milligrams per liter. Levels at or above the standard may be particularly harmful to the health of children in their first six months and for pregnant women. Due to this concern, Tri-County Health Department is planning a pilot study of 50 wells in Douglas County. The wells will be sampled for nitrate, hardness and conductivity.

The sampling procedure itself will take about thirty minutes per well and consists of collecting a sample from an outdoor spigot receiving water from an on-site well. The sampling should use two gallons or less of water. Although you are welcome to supervise the sampling, residents are not required to be present for the sampling process to be completed, unless an indoor tap is the only working sample point.

Please be advised that there is no charge for this service, the sample results will be mailed to you in approximately one month. If the results indicate the level of nitrate exceeds the health standard (10 milligrams per liter), you will be advised to take actions to resolve the situation. Additionally, you may be required to disclose the results to any prospective purchasers, future owners or tenants of the property. Also please be aware that Tri-County Health Department may be required to provide sampling results upon request from an outside agency or individual under the Colorado Open Records Act.

Due to the limited scope of the trial study, Tri-County Health Department can only test 50 wells at no charge. Therefore, we will accept the first 50 residents who submit the enclosed form for this study. This form gives us permission to perform the sampling from an outside tap. Please complete and sign the enclosed form and return it to us via fax, email, or regular mail. Questions about this study can be answered by Hope Yu, Water Quality Specialist, who can be contacted by phone at 303-846-2013, by email at hyu@tchd.org, or fax 303-220-9208. Thank you.

Sincerely,

Richard L. Vogt, M.D.
Executive Director
Tri-County Health Department

Enclosures

A.3 Participant Survey

Tri-County
Health Department

NITRATE PILOT STUDY

Environmental Health Division

This study addresses the relationship if any between individual sewage disposal systems (septics) and wells. Please take the time to complete this survey and mail it to Tri-County in the enclosed, postage-paid envelope.

DATE: ____________________

HOMEOWNER'S NAME ____

Address ____

____

City ____________________ Zip Code __________ Phone (___)_____-_________ County ___________

Email Address(es) ____

OCCUPANT'S NAME (if different from homeowner) ____

Address ____

____

City ____________________ Zip Code __________ Phone (___)_____-_________ County___________

Email Address (es) ____

Water Supply ☐ Municipal ☐ Well **Sewage Disposal Method** ☐ Municipal ☐ ISDS

1. **Can Tri-County staff sample the well from an outside faucet?**

   ☐ Yes ☐ No

2. **If YES, Can Tri-County staff sample the well while the owner is away?**

   ☐ Yes ☐ No

3. **If NO to Question 1, Would you be willing to receive sample bottles by mail, collect the sample yourself, and call Tri-County staff to schedule pick-up?**

   ☐ Yes ☐ No

3. **If NO to Question 3, please indicate in the COMMENTS section how we should contact you to arrange sampling of the well.**

COMMENTS:

____

Please sign below and return to Tri-County Health Department in the prepaid envelope. Please be advised that you may be required to disclose the results of the test to any prospective purchasers, future owners or tenants of the property. In addition, Tri-County Health Department may also be required to provide sampling results upon request from an outside agency or individual. Thank you for participating.

I authorize Tri-County Health Department to enter the property for the purpose of sampling water from my well.

__________________________________ printed name __________________________ Signature

Appendix B
Results Letters to Participants

B.1 No Nitrate Found

B.2 Nitrate Range 0.3 - 1.9 mg/L

B.3 Nitrate Range 2.0 - 6.0 mg/L

B.4 Nitrate Range 6.1 -9.9 mg/L

B.5 Nitrate Exceeds Health Standard of 10 mg/L

B.1 No Nitrate Found

Tri-County Health Department
Serving Adams, Arapahoe and Douglas Counties

Richard L. Vogt, M.D.
Executive Director

<<Date>>

<<Name>>
<<Address>>
<<City, CO zip>>

Dear **<<Name>>**,

Thank you for allowing Tri-County Health Department to sample your well as part of the Nitrate Pilot Study. Your well was analyzed for nitrate, hardness and specific conductance. Although nitrate is not regulated in private wells, the regulated value for nitrate in community water supply systems is stated for comparison.

- **Conductivity** was measured in your well water at **«conduct»** microSiemens/cm. Conductivity is a measure of the electrical current across naturally occurring dissolved compounds in water. The higher the value the more likely there will be impacts on drinking water appearance and taste.

- **Hardness** was measured at **«hardness»** parts per million (ppm) as calcium carbonate ($CaCO_3$). It is a measure of the calcium and magnesium ions in the water. Your well water is considered **«hardorsoft»**.

- **Nitrate**, as nitrogen, was not detected in the sample.

If you have any questions, Hope Yu, Water Quality Specialist, can be contacted by phone at 303-846-2013, by email at hyu@tchd.org, or fax 303-220-9208. Thank you again for your time and participation.
Sincerely,

Hope Yu

Hope Yu
Water Quality Specialist
Tri-County Health Department
Phone: 303-846-2013
Email: hyu@tchd.org

B.2 Nitrate Range 0.3 - 1.9 mg/L

Tri-County Health Department
Serving Adams, Arapahoe and Douglas Counties

Richard L. Vogt, M.D.
Executive Director

<<Date>>

<<Name>>
<<Address>>
<<City, CO zip>>

Dear <<**Name**>>,

Thank you for allowing Tri-County Health Department to sample your well as part of the Nitrate Pilot Study. Your well was analyzed for nitrate, hardness and specific conductance. Although nitrate is not regulated in private wells, the regulated value for nitrate in community water supply systems is stated for comparison.

- **Conductivity** was measured in your well water at **«conduct»** microSiemens/cm. Conductivity is a measure of the electrical current across naturally occurring dissolved compounds in water. The higher the value the more likely there will be impacts on drinking water appearance and taste.

- **Hardness** was measured at **«hardness»** parts per million (ppm) as calcium carbonate ($CaCO_3$). It is a measure of the calcium and magnesium ions in the water. Your well water is considered **«hardorsoft»**.

- **Nitrate** was measured at **«nitrate»** milligrams per liter (mg/L). Nitrate, as nitrogen, may be found in groundwater resulting from the use of nitrogen fertilizers, animal manure, burning of fossil fuels, or individual sewage disposal systems (septic systems). It is commonly found in shallow groundwater as an agricultural or waste water contaminant. The regulated value for nitrate is 10 mg/L. The level of nitrate detected does not indicate a need for retesting or for treatment.

Questions about this study can be answered by Hope Yu, Water Quality Specialist, who can be contacted by phone at 303-846-2013, by email at hyu@tchd.org, or fax 303-220-9208. Thank you again for your time and participation.

Sincerely,

Hope Yu

Hope Yu
Water Quality Specialist
Tri-County Health Department
Phone: 303-846-2013
Email: hyu@tchd.org

B.3 Nitrate Range 2.0 - 6.0 mg/L

Tri-County Health Department
Serving Adams, Arapahoe and Douglas Counties

Richard L. Vogt, M.D.
Executive Director

<<Date>>

<<Name>>
<<Address>>
<<City, CO zip>>

Dear **<<Name>>**,

Thank you for allowing Tri-County Health Department to sample your well as part of the Nitrate Pilot Study. Your well was analyzed for nitrate, hardness and specific conductance. Although nitrate is not regulated in private wells, the regulated value for nitrate in community water supply systems is stated for comparison.

- **Conductivity** was measured in your well water at **«conduct»** microSiemens/cm. Conductivity is a measure of the electrical current across naturally occurring dissolved compounds in water. The higher the value the more likely there will be impacts on drinking water appearance and taste.

- **Hardness** was measured at **«hardness»** parts per million (ppm) as calcium carbonate ($CaCO_3$). It is a measure of the calcium and magnesium ions in the water. Your well water is considered **«hardorsoft»**.

- **Nitrate** was measured at **«nitrate»** milligrams per liter (mg/L). Nitrate, as nitrogen, may be found in groundwater resulting from the use of nitrogen fertilizers, animal manure, burning of fossil fuels, or individual sewage disposal systems (septic systems). It is commonly found in shallow groundwater as an agricultural or waste water contaminant. The regulated value for nitrate is 10 mg/L.

Please be advised the nitrate level is below the drinking water standard of 10 mg/L and should be considered safe to drink; however, Tri-County recommends retesting the drinking water **within 5 years** for nitrate. If the retest shows higher levels of nitrate, retest again every year. If the nitrate level exceeds the drinking water standard of 10 mg/L, the water is considered to be a health hazard. In that case, Tri-County Health Department recommends that you do not drink the water and that you consult with a qualified professional regarding treatment of the water.

Questions about this study can be answered by Hope Yu, Water Quality Specialist, who can be contacted by phone at 303-846-2013, by email at hyu@tchd.org, or fax 303-220-9208. Thank you again for your time and participation.
Sincerely,

Hope Yu
Water Quality Specialist
Tri-County Health Department
Phone: 303-846-2013
Email: hyu@tchd.org

B.4 Nitrate Range 6.1 -9.9 mg/L

Tri-County Health Department
Serving Adams, Arapahoe and Douglas Counties

Richard L. Vogt, M.D.
Executive Director

<<Date>>

<<Name>>
<<Address>>
<<City, CO zip>>

Dear **<<Name>>**,

Thank you for allowing Tri-County Health Department to sample your well as part of the Nitrate Pilot Study. Your well was analyzed for nitrate, hardness and specific conductance. Although nitrate is not regulated in private wells, the regulated value for nitrate in community water supply systems is stated for comparison.

- **Conductivity** was measured in your well water at **«conduct»** microSiemens/cm. Conductivity is a measure of the electrical current across naturally occurring dissolved compounds in water. The higher the value the more likely there will be impacts on drinking water appearance and taste.

- **Hardness** was measured at **«hardness»** parts per million (ppm) as calcium carbonate ($CaCO_3$). It is a measure of the calcium and magnesium ions in the water. Your well water is considered **«hardorsoft»**.

- **Nitrate** was measured at **«nitrate»** milligrams per liter (mg/L). Nitrate, as nitrogen, may be found in groundwater resulting from the use of nitrogen fertilizers, animal manure, burning of fossil fuels, or individual sewage disposal systems (septic systems). It is commonly found in shallow groundwater as an agricultural or waste water contaminant. The regulated value for nitrate is 10 mg/L.

Please be advised the nitrate level is below drinking water standards and should be considered safe to drink; however, nitrate appears to be impacting your well. Tri-County Health Department recommends retesting the drinking water within **one** year. If the retest indicates an increase, retest every year. If the nitrate level exceeds the drinking water standard of 10 mg/L, the water is considered to be a health hazard. In that case, Tri County Health Department recommends that you do not drink the water and that you consult with a qualified professional regarding treatment of the water.

Questions about this study can be answered by Hope Yu, Water Quality Specialist, who can be contacted by phone at 303-846-2013, by email at hyu@tchd.org, or fax 303-220-9208. Thank you again for your time and participation.
Sincerely,

Hope Yu
Water Quality Specialist
Tri-County Health Department
Phone: 303-846-2013
Email: hyu@tchd.org

B.5 Nitrate Exceeds Health Standard of 10 mg/L

Tri-County Health Department
Serving Adams, Arapahoe and Douglas Counties

Richard L. Vogt, M.D.
Executive Director

<<Date>>
<<Name>>
<<Address>>
<<City, CO zip>>

Dear **<<Name>>**,

Thank you for allowing Tri-County Health Department to sample your well as part of the Nitrate Pilot Study. Your well was analyzed for nitrate, hardness and specific conductance. Although nitrate is not regulated in private wells, the regulated value for nitrate in community water supply systems is stated for comparison.

- **Conductivity** was measured in your well water at **«conduct»** microSiemens/cm. Conductivity is a measure of the electrical current across naturally occurring dissolved compounds in water. The higher the value the more likely there will be impacts on drinking water appearance and taste.

- **Hardness** was measured at **«hardness»** parts per million (ppm) as calcium carbonate ($CaCO_3$). It is a measure of the calcium and magnesium ions in the water. Your well water is considered **«hardorsoft»**.

- **Nitrate** was measured at **«nitrate»** milligrams per liter (mg/L). Nitrate, as nitrogen, may be found in groundwater resulting from the use of nitrogen fertilizers, animal manure, burning of fossil fuels, or individual sewage disposal systems (septic systems). It is commonly found in shallow groundwater as an agricultural or waste water contaminant. The regulated value for nitrate is 10 mg/L.

The nitrate levels in this sample met or **exceeded** the drinking water standard of 10 mg/L. The water is considered to be a health hazard. Infantile methemoglobinemia, or blue baby syndrome can result from excessive nitrate levels in drinking water in infants and pregnant women. **Refrain from using this water for drinking**.

Your water should be retested. If the nitrate value continues to exceed 10 mg/L, have your water system evaluated for treatment by a qualified professional.
Questions about this study can be answered by Hope Yu, Water Quality Specialist, who can be contacted by phone at 303-846-2013, by email at hyu@tchd.org, or fax 303-220-9208. Thank you again for your time and participation.

Sincerely,

Hope Yu
Water Quality Specialist
Tri-County Health Department
Phone: 303-846-2013
Email: hyu@tchd.org

Appendix C
Standard Operating Procedures

C.1 Water Quality Grab Sampling

C.2 Well and Leachfield Location Tool

C.3 Hach Method 8213—Total Hardness

C.4 Hach Method 8160 (EPA 120.1)—Conductivity

C.5 EPA 300 as used by CDPHE Labs—Nitrate

C.1 Water Quality Grab Sampling

Standard Operating Procedure for Water Quality Grab Sampling

Prior to leaving the office

- ✍Gather sampling equipment
- ✍Inspect all sampling equipment for damage, dirt, etc.
- ✍Pack a cell phone and telephone number directory
- ✍Pack the GPS unit and batteries.
- ✍Check equipment batteries, replace if expired and carry extras.
- ✍ Pack field notebook, thank you (letter to resident), extra paper, SOP, QAPP, Chain of Custody (COC) sheets, and shipping addresses
- ✍ Pack Septic System Guidelines brochure, well disinfection brochure, CDPHE’s When to Test Your Well, CDPHE’s Iron and Sulfur Bacteria in Water Supplies, CDPHE’s How to Interpret Water Test Results for a Private Well, and CDPHE’s Water Testing Packages. Include enough for each well sampled.
- ✍ Pack cooler for carrying samples, ice, CDPHE COC, and nitrate study forms with all of the information on them.
- ✍Pack sample containers needed for sampling
- ✍Affix labels to appropriate bottles or pack appropriate labels

At the sampling site:

- ✍Fill in the labels on the bottles
- ✍Collect all necessary samples
- ✍Store samples in a cooler on blue ice
- ✍Fill out field log sheet and COC sheet
- ✍If homeowner is home, obtain answers to questions regarding well and ISDS

After sampling

- ✍Place samples in refrigerator and prepare sample to be delivered to CDPHE
- ✍Clean and Store field equipment
- ✍Make copies of information or scan into computer and send to Water Specialist.

The field procedures discussed herein will be followed for private well nitrate sampling by Tri-County Health Department (TCHD) staff. Procedures for containerization and preserving groundwater, and completing of chain-of-custody and shipping are discussed.

1.0 INTRODUCTION

Field personnel collecting groundwater samples will consist of a one-person team. This individual will collect sample, complete COC, and deliver samples to appropriate locations.

2.0 FIELD EQUIPMENT

Field personnel will have on hand copies of SOP, equipment list, including field equipment (with owners manual), sampling equipment and documented calibration standards. The components of each field kit will be contained within a 100 quart cooler and will include the following:

1. Conductivity meters: a complete set of probes, cables, and spare batteries for each instrument.
2. Labeled calibration standard solution for conductivity and detailed calibration procedure instructions for all instruments.
3. 100-foot measuring tape
4. Latex or vinyl gloves
5. Various equipment and records, such as business cards, survey forms, release signature forms, indelible ink marking pens, duct tape, clear tape, paper towels, clipboard, calculator, and tools for troubleshooting equipment.
6. One cooler containing samples taking that day, chain-of-custody forms, and blue ice packs
7. Field log sheet, map of area, list of well locations to be sampled.
8. Camera and cell phone

Each field kit will be restocked as necessary by the field team at the close of each day of sampling. Additional field equipment (i.e. distilled water, standard solutions, etc.) will be re-stocked as necessary by each field team.

3.0 GROUNDWATER SAMPLING PROCEDURES (GRAB SAMPLE)

A daily schedule of field activities and a sample cooler prepared by field personnel containing; sampling bottles, packing material, labels, frozen ice packs, and COC will be completed by field personnel. The sample bottle is used to collect a water grab sample. Care is exercised not to disturb sediment while sampling. Avoid surface debris when collecting samples. The sample bottle will be rinsed with sample water three times. If bottles are pre-preserved, rinsing with sample water is not appropriate prior to collecting the sample. Do not disturb the location where sampling is to be taken with discarded rinse water. The preferred method of collecting will be from a spigot directly from the well.

Upon arrival at the well site, the following procedures will be implemented:

1. Once at the sampling location, the field log sheet will be completed with sample identification, date, pertinent observations (i.e. weather, well condition), and GPS coordinates.
2. If necessary, calibrate field instruments used for monitoring conductivity, using known standard. Record instrument calibration responses, times, and calibration standards used in field log sheet
3. Wells will be purged for 3-5 minutes or until the water has a change in temperature (approximately 2 gallons of water). A sample will be collected, placed in a cooler for transportation. Conductivity will be obtained in the field or a sample will be taken to Tri-County’s laboratory.

4. GPS reading will be taken at the sample location.
5. Field personnel will sign field log sheet on completion of sampling.
6. All sampling equipment will be decontaminated at the well site prior to storage. Equipment will be cleaned with DI water and properly stored.
7. The final activities at the well site will be to secure equipment and instruments in vehicle and record time sampling completed in field log sheet. Provide well-owner with approximate date that laboratory results are expected and educational materials.

4.0 WATER SAMPLE PRESERVATION

Samples

The samples have a hold time of 48 hours according to the EPA Method 300.0 for nitrate. Once collected the samples will be placed in a cooler chilled to ~4° C in the field.

5.0 SAMPLE HANDLING AND TRANSPORTATION

By the end of each sampling day, all samples should be brought back to an office of designated location for proper delivery of samples to the laboratory. The COC will be completed at this time. Sample handling and transportation vary depending primarily on the distance to the laboratory.

All water samples will be shipped in a cooler or ice chest. This provides protection, insulation, and containment in case of breakage or spillage. When shipping samples that require chilling, pack adequate quantities of frozen blue ice with the samples.

6.0 FIELD NOTEBOOK

A binder field notebook is used to document collection of the sample, sample identification, field observations, and other pertinent information necessary to reconstruct the sample collection processes. All entries are made in permanent waterproof ink. Any corrections make to the field notes are lined out, initialed, and dated. The person who collected sampling signs the field log sheet. Field personnel will carry the field log sheet during sampling.

1. Sample Identification Information (physical address)
2. Field Measurements (conductivity)
3. Equipment Information (serial number, model number, manufacturer, etc.)
4. Sample Collected (name of analysis)
5. Date and Time of Collection
6. Weather Conditions
7. Comments related to well and ISDS

7.0 CHAIN OF CUSTODY

A COC accompanies all samples to record possession and transportation of samples. Field identification number, sample type, requested analysis, date of collection, and time of collection as well as other information is recorded on the COC. COC's are completed with permanent ink. Any corrections made to the COC's are lined out, initialed, and dated. All samples are kept in a secured area accessible only to authorized personnel during sample collection and transport. Upon completion of the field collection of the samples, the COC sheet accompanies the samples to the lab. COC sheets are also legally binding and act as work order for the laboratory. It is critical that the field identification numbers are properly recorded on the field log sheet and COC forms. Sample collectors, individuals transferring samples, and those receiving samples, all sign the COC.

8.0 RINGED FIELD BINDER

A ringed binder is used to store information pertinent to a sampling project. The binder can be used to store a copy of the SOP, COC sheets, copies of field sheet log, and other pertinent information.

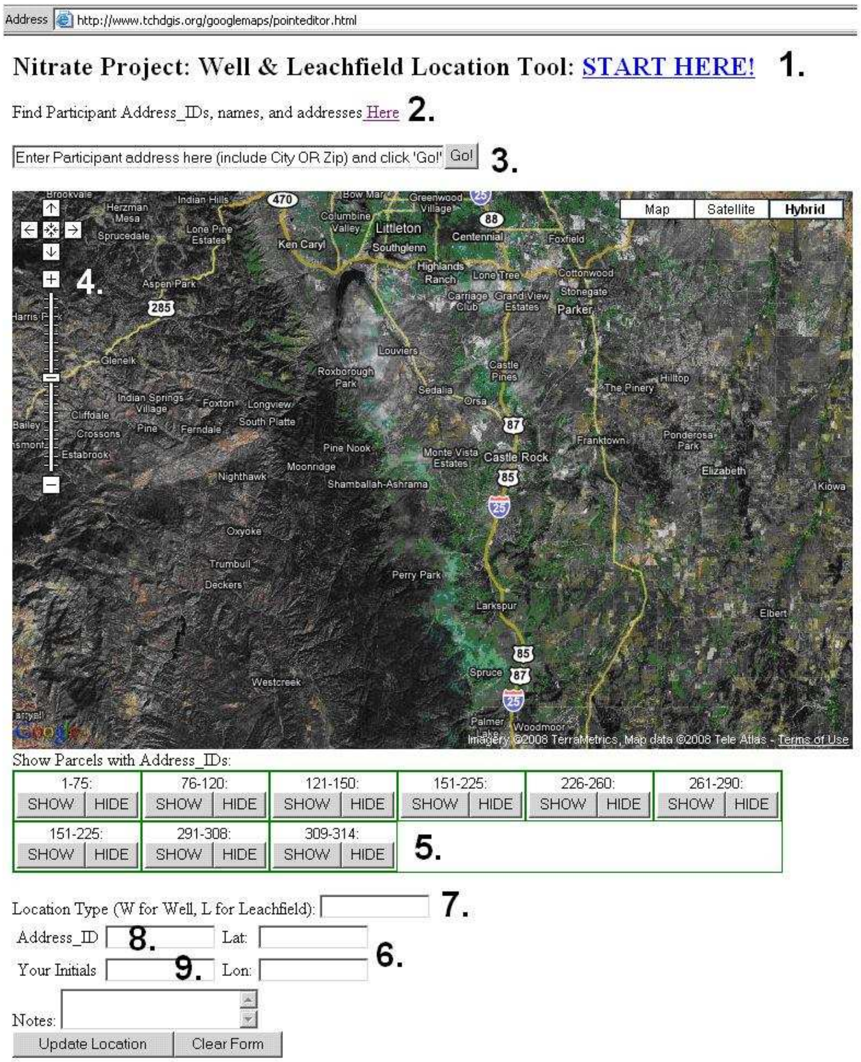
C.2 Well and Leachfield Location Tool

Well and Leachfield Location Tool Instructions

Background:
This tool was created to collect accurate location information for both Wells and Leachfields at the Nitrate Project Participant sites. Using this tool, you can view high quality aerial photographs of the sites, and click on the locations of the well, and leachfield, enter some associated data about them, and save this information to a database.

Detailed Steps:

1. **Read these instructions**! The step numbers correspond to number items on the figure below.
2. Open the web page listing the Participant Address_IDs, names and addresses. The Address_ID is very important, because it is used to link each site to information about it. Note this number for each site you are mapping. You will need to know, and enter, this number for each site you visited.



Address http://www.tchdgis.org/googlemaps/pointeditor.html

Nitrate Project: Well & Leachfield Location Tool: START HERE! 1.

Find Participant Address_IDs, names, and addresses Here 2.

Enter Participant address here (include City OR Zip) and click 'Go!' Go! 3.

3. Enter the address for your first site into the Participant address text box and click “Go”. The Google Map application should find the address you entered and zoom to it. If it doesn’t, you will need to Pan and Zoom to the address using Google Map tools.

Google Map Pan and Zoom Tools:
Pan (moving the map left-right, up-down): Hover your mouse over the map. You will see a Hand ✋. Left-click and hold the left mouse button down, while moving the mouse left-right, and up-down.
Zoom: The map will always zoom to the center of whatever is shown on the map. Use the Plus (+) and Minus (-) bar on the left of the map to zoom in or out.

4. The goal is to be zoomed in on your specific site so that you can see where the well and leachfield are, based on your site visit.
5. To help you visualize the parcel boundaries associated with each site, there are boundaries lines that can be turned on by clicking the SHOW button for the range of Address IDs that includes your site's Address_ID. Not all sites have parcel boundaries. If there are parcel boundaries for your site, they will show up in blue. You may need to Pan or Zoom your map to fully see these. If you click in the center of the parcel, you will be given a pop-up that shows the Address_ID, owner's name, and address of the parcel.
6. **IMPORTANT** – At this step, turn off the parcel boundary by clicking HIDE. Make sure you are zoomed to where you can see the location of the Well at the site, and next click on the map where the well is. After you click, you should see a red marker 📍 at the location of the well, and the Latitude/Longitude text boxes at the bottom of the web page will be populated.
7. Next, enter into the "Location Type" text box either a "W", if you've just located a well, or an "L" if you've just located a leachfield.
8. Next, enter the Address_ID that corresponds to the site you are locating the well and leachfield for. It is very important that you enter this accurately.
9. Enter your initials.
10. Finally, enter any notes you want to about the location you have just placed.
11. **Double-Check that everything is accurate!** If not you can press Clear Form, to start over. When you are sure you are ready, click "Update Location". The location will be saved to the database. If you get a note that says "The webpage you are viewing is trying to close the window", just click "OK".
12. You will now repeat the process for the leachfield, or the well, depending on which you still need to locate. Note; you won't need to update the Address_ID and Initials fields if you are at the same participant site, when you click on the second location, the Latitude/Longitude fields will update. **You DO need to make sure you change the Location Type (7.), since it won't be the same for both locations.**

A note on Leachfields. You may be able to determine the location of the leachfield from your site visit notes. Also, many times you can see a leachfield on the aerial photos themselves. They will appear as greener or darker spots on brownish lawns. Here is an example:

This dark rectangular area is the leachfield for this house.

When you mark your leachfield on the map, just select anywhere within it to place the marker.

13. You are done now with one participant site. Continue in the same way with all the sites you visited. Remember, you must locate both a Well, and Leachfield for each site, and you must change the text (W or L) entered into the Location Type textbox to reflect which one you are placing.

C.3 Hach Method 8213—Total Hardness

Hardness, Total

Method 8213 | **Digital Titrator with EDTA Method**

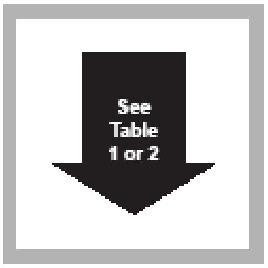
Digital Titrator | **(10 to 4000 mg/L as $CaCO_3$)**

Scope and Application: For water, wastewater, and seawater

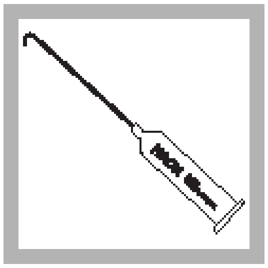
Tips and Techniques

- One German degree of hardness (G.d.h.) = 17.9 mg/L hardness as $CaCO_3$
- You can substitute a 0.1-g scoop of ManVer® 2 Hardness Indicator Powder or four drops of ManVer Hardness Indicator Solution for the ManVer 2 Hardness Indicator Powder Pillow.
- For added convenience when stirring, use the TitraStir apparatus (Cat. No. 19400-00, -10).
- mg/L Total Hardness as Ca = mg/L Total Hardness as $CaCO_3$ x 0.40
- mg/L Total Hardness as $CaCO_3$ = mg/L Ca as $CaCO_3$ + mg/L Mg as $CaCO_3$
- The magnesium concentration may be determined by subtracting the results of the calcium determination from the total hardness determination.

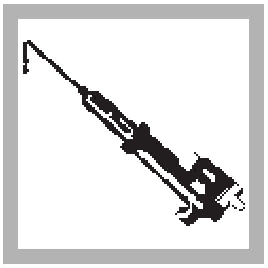
Digital Titration — Method 8213



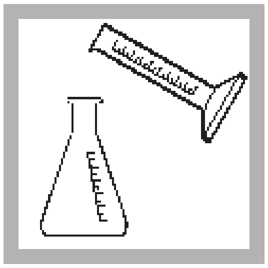
1. Select a sample size and an EDTA Titration Cartridge that corresponds to the expected calcium as calcium carbonate ($CaCO_3$) concentration. Use *Table 1* for concentrations in mg/L and *Table 2* for concentrations in German degrees of hardness.



2. Insert a clean delivery tube into the titration cartridge. Attach the cartridge to the titrator body.



3. Turn the delivery knob to eject a few drops of titrant. Reset the counter to zero and wipe the tip.

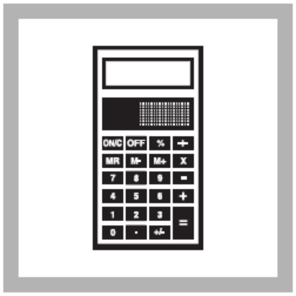


4. Use a graduated cylinder or pipet to measure the sample volume from *Table 1* or *Table 2*. Transfer the sample into a clean 250-mL Erlenmeyer flask. Dilute to about the 100-mL mark with deionized water, if necessary.

5. Add 2 mL of Buffer Solution, Hardness 1 and swirl to mix.

6. Add the contents of one ManVer 2 Hardness Indicator Powder Pillow and swirl to mix.

7. Place the delivery tube tip into the solution and swirl the flask while titrating with EDTA from red to blue. Record the number of digits required.



8. Calculate the sample concentration using one of the formulas below:

Total Digits Required x Digit Multiplier from *Table 1* = mg/L Total Hardness as $CaCO_3$

Total Digits Required x Digit Multiplier from *Table 2* = G.d.h.

Table 1

Range (mg/L as $CaCO_3$)	Sample Volume (mL)	Titration Cartridge (M EDTA)	Catalog Number	Digit Multiplier
10–40	100	0.0800	14364-01	0.1
40–160	25	0.0800	14364-01	0.4
100–400	100	0.800	14399-01	1.0
200–800	50	0.800	14399-01	2.0
500–2000	20	0.800	14399-01	5.0
1000–4000	10	0.800	14399-01	10.0

Table 2

Range (G.d.h.)	Sample Volume (mL)	Titration Cartridge (M EDTA)	Catalog Number	Digit Multiplier
1–4	100	0.1428	14960-01	0.01
4–16	25	0.1428	14960-01	0.04
10–40	50	0.714	14959-01	0.1
25–100	20	0.714	14959-01	0.25
>100	10	0.714	14959-01	0.5

Interferences

WARNING:

Potassium cyanide is toxic. Always add it after the potassium hydroxide. Excess potassium cyanide does not affect results. Dispose of all cyanide wastes by adding an excess of strongly alkaline sodium hypochlorite solution (bleach) with stirring. Use good ventilation. Allow to stand for 24 hours before disposal.

Some transition and heavy metals complex the indicator and prevent the color change at the end point.

Interfering Substance	Interference Levels and Treatments
Acidity	Does not interfere at 10,000 mg/L (as $CaCO_3$).
Alkalinity	Does not interfere at 10,000 mg/L (as $CaCO_3$).
Aluminum	A 0.5-gram scoop of potassium cyanide* (Cat. No. 767-14) raises the permissible aluminum level to 1 mg/L.
Barium	Titrates directly.
Cobalt	Interferes at all levels and must be absent or masked. A 0.5-gram scoop of potassium cyanide* (Cat. No. 767-14) removes interference from up to 100 mg/L cobalt.
Copper	Interferes at levels of 0.10 and 0.20 mg/L. A 0.5-gram scoop of potassium cyanide* (Cat. No. 767-14) removes interference from up to 100 mg/L copper.
Iron	Does not interfere up to 15 mg/L. Above this level it causes a red-orange to green end point which is sharp and usable up to 30 mg/L iron. Substitute a 0.0800 M CDTA (Cat. No. 14402-01) or 0.800 M CDTA (Cat. No. 14403-01) titration cartridge for the 0.0800 M EDTA or 0.800 M EDTA titration cartridges, respectively, if iron interference is probable.
Manganese	Titrates directly up to 20 mg/L but masks the end point above this level. Adding a 0.1-gram scoop of hydroxylamine hydrochloride monohydrate (Cat. No. 246-14) raises this level to 200 mg/L manganese.
Nickel	Interferes at all levels and must be absent or masked. A 0.5-gram scoop of potassium cyanide* (Cat. No. 767-14) removes interference from up to 100 mg/L nickel.
Orthophosphate	Causes a slow end point.
Polyphosphates	Polyphosphate must be absent for accurate results.
Polyvalent Metal Ions	Although less common than calcium and magnesium, other polyvalent metal ions cause the same hardness effects and will be included in the results.
Sodium Chloride	Saturated sodium chloride solutions do not give a distinct end point, but the titration can be run directly on sea water.
Strontium	Titrates directly.
Zinc	Titrates directly. A 0.5-gram scoop of potassium cyanide* (Cat. No. 767-14) removes interference from up to 100 mg/L zinc.
Highly buffered samples or extreme sample pH	May exceed the buffering capacity of the reagents and require sample pretreatment: see *Section 3.3 Interferences* on page *50*.

* Metals masked with cyanide will not be included in the hardness result.

Adding the contents of one CDTA Magnesium Salt Powder Pillow removes metal interferences at or below the levels shown in *Table 3*.

Table 3

Metal	CDTA Removes Interference Below This Level
Aluminum	50 mg/L
Cobalt	200 mg/L
Copper	100 mg/L
Iron	100 mg/L
Manganese	200 mg/L
Nickel	400 mg/L
Zinc	300 mg/L

If more than one metal is present at or above the concentrations shown above, an additional CDTA Magnesium Salt Powder Pillow may be required.

Results obtained by this procedure include the hardness contributed by the metals. If the concentration of each metal is known, a correction can be applied to obtain the calcium and magnesium hardness concentration. The hardness (in mg/L as $CaCO_3$) contributed by each mg/L of metal is listed below, and can be subtracted from the total hardness value obtained above to determine the calcium and magnesium hardness. See *Table 4*.

Table 4

Metal	Hardness Contributed by Each mg/L of Metal
Aluminum	3.710
Barium	0.729
Cobalt	1.698
Copper	1.575
Iron	1.792
Manganese	1.822
Nickel	1.705
Strontium	1.142
Zinc	1.531

Sampling and Storage

Collect at least 100 mL of sample in a glass or polyethylene container. Samples may be held up to seven days before analysis if stored at 4 °C and acidified to pH 2 with concentrated nitric acid (Cat. No. 2540-49). Neutralize acidified sample to pH 7 with ammonium hydroxide (Cat. No. 14736-32) before testing.

When significant amounts of preservative are used, a volume correction should be made for the extra acid and base. Divide the total volume (sample + acid + base) by the volume of the sample, and multiply the result by the final test outcome.

Accuracy Check

Standard Additions Method (Sample Spike)

To verify analytical technique use 20 mL of the Calcium Standard Solution, 1000-mg/L as $CaCO_3$. Perform the procedure as described above. This solution will read 1000 mg/L or 55.9 G.d.h.

Perform this accuracy check when interferences are suspected.

1. Snap the neck off a Hardness Voluette Ampule Standard, 10,000-mg/L as $CaCO_3$.
2. Use a TenSette Pipet to add 0.1 mL of standard to the sample titrated in *step 7*. Resume titration back to the same end point. Record the number of digits required.
3. Repeat, using two more additions of 0.1 mL. Titrate to the end point after each addition.
4. Each 0.1 mL addition of standard should require 10 additional digits of 0.800 M titrant, 100 digits of 0.0800 M titrant, 11 digits of 0.714 M, or 56 digits of 0.1428 M titrant. If these uniform increases do not occur, refer to *Section 3.2.2 Standard Additions* on page *46*.

Summary of Method

After the sample is buffered to pH 10.1, ManVer 2 Hardness Indicator is added, and forms a red complex with a portion of the calcium and magnesium in the sample. EDTA titrant reacts first with the free calcium and magnesium ions, then with those bound to the indicator, causing it to change to a blue color at the end point.

Required Reagents

Description	Unit	Cat. No.
Total Hardness Reagent Set (about 100 tests)		22720-00
Water, deionized	4 L	272-56
Select one or more based on sample concentration		
EDTA Titration Cartridge, 0.0800 M	each	14364-01
EDTA Titration Cartridge, 0.1428 M	each	14960-01
EDTA Titration Cartridge, 0.714 M	each	14959-01
EDTA Titration Cartridge, 0.800 M	each	14399-01

Required Apparatus

Description	Unit	Cat. No.
Digital Titrator	each	16900-01
Select one or more based on sample concentration		
Cylinder, graduated, 10-mL	each	508-38
Cylinder, graduated, 25-mL	each	508-40
Cylinder, graduated, 50-mL	each	508-41
Cylinder, graduated, 100-mL	each	508-42
Flask, Erlenmeyer, 250-mL	each	505-46

Required Standards

Description	Unit	Cat. No.
Calcium Chloride Standard Solution, 1000-mg/L as $CaCO_3$	1000 mL	121-53
Calcium Standard Solution, Voluette® Ampule, 10,000-mg/L as $CaCO_3$, 10-mL	16/pkg	2187-10

C.4 Hach Method 8160 (EPA 120.1)—Conductivity

HACH® WATER ANALYSIS HANDBOOK

Conductivity

Method 8160

Direct Measurement Method*

Conductivity Meter

(0–199.9 mS/cm)

Scope and Application: For water and wastewater

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* USEPA accepted for reporting. Procedure is equivalent to USEPA Method 120.1 and Standard Method 2510-B for wastewater.

Tips and Techniques

- Collect samples in clean plastic or glass bottles.
- Analyze samples as soon as possible after collection. However, samples may be stored at least 24 hours by cooling to 4 °C (39 °F) or below. The conductivity meter will compensate for any variation of temperature from 20 or 25 °C.
- Water samples containing oils, grease, or fats will coat the electrode and affect the accuracy of the readings. If this occurs, clean the probe with a strong detergent solution, then thoroughly rinse with deionized water.
- Mineral buildup on the probe can be removed with 1:1 Hydrochloric Acid Solution, as directed in the sension™5 Instrument Manual.

Electrochemistry

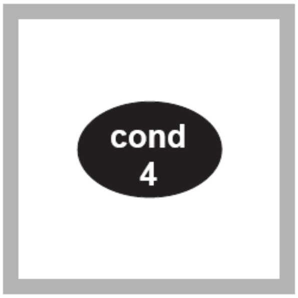
1. Prepare the *sension*5 Conductivity Meter for operation as directed in the *Operation* section of the instrument manual. The *sension*5 automatically selects the appropriate range.

***Note:** If the probe has been in storage, soaking before use may be necessary to ensure the probe is thoroughly wetted.*

2. Immerse the probe in a beaker containing the sample solution. Move the probe up and down and tap it on the beaker to free any bubbles from the electrode area.

***Note:** The probe must be immersed beyond the vent holes.*

***Note:** The sension5 Portable Conductivity/TDS meter automatically compensates for sample temperature deviation from 20 or 25 °C depending on the reference temperature setting (S-2).*



3. Assure that the meter is in COND mode and read the value in the display.

***Note:** For proof of accuracy, use a known conductivity standard solution in place of the sample (see Accuracy Check following these steps).*

4. Rinse the probe thoroughly with deionized water after each measurement.

***Note:** To display units as TDS press the mode key until the meter is in TDS mode. The sension5 reports TDS in mg/L of Sodium Chloride, estimated from the conductivity of the measurement. Salinity is also a measurement capability of the sension5. Salinity is a relative scale based on a KCl Solution, see the sension5 Instrument Manual for more information.*

Conversions

The following table provides equations for converting the conductivity readings to other units of measure.

Table 1 Conversions

From	To	Use this Equation
mS/cm	µS/cm	mS/cm x 1000
µS/cm	mS/cm	µS/cm x 0.001
µS/cm	µmhos/cm	µS/cm x 1
mS/cm	mmhos/cm	mS/cm x 1
µS/cm	mg/L TDS	µS/cm x 0.5*
g/L TDS	mg/L TDS	g/L TDS x 1000
mS/cm	g/L TDS	mS/cm x 0.5
mg/L TDS	g/L TDS	mg/L TDS x 0.001
mg/L TDS	gpg TDS	mg/L TDS x 0.05842
g/L TDS	gpg TDS	g/L TDS x 58.42
µS/cm	ohms cm	1,000,000 ÷ µS/cm
mS/cm	ohms cm	1,000 ÷ mS/cm

* TDS is an empirically-derived value from the conductivity measurement. A 0.5 value is selected here for simplicity and suitability to a wide variety of waters. The *sension*5 uses a more complex algorithm, based on additional factors, such as temperature, to determine TDS.

Interferences

When measuring conductivity, the following items should be considered in order to ensure accurate results:

- If measuring very low levels of conductivity, protect the sample from atmospheric gases (carbon dioxide, ammonia). These gases dissolve readily in water and may cause a rapid change in conductivity. To minimize these effects, boil the sample, then place in a covered container for cooling.
- If the sample contains high levels of hydroxide (boiler water for example), neutralize to avoid inaccurate high results. Neutralize by adding 4 drops of Phenolphthalein Indicator Solution to 50 mL of sample, then adding Gallic Acid Solution, drop-wise, until the pink color completely disappears.

Accuracy Check

Pour a Sodium Chloride Standard Solution (with a conductivity value in the same range as the sample) into a beaker. Perform the conductivity measurements as described above. The conductivity reading should be the same (within accuracy limits) as listed on the Standard Solution label if the meter is calibrated correctly. Calibration can be performed using this solution. See the *sension*5 Instrument Manual.

Summary of Method

Electrolytic conductivity is the capacity of ions in a solution to carry electrical current and is the reciprocal of the solution resistivity. Current is carried by inorganic dissolved solids (e.g., chloride, nitrate, sulfate, and phosphate anions) and cations (e.g., sodium, calcium, magnesium, iron, and aluminum). Organic material like oils, phenols, alcohols, and sugars do not carry electrical current well and thus do not have enough conductivity for a useful estimate of concentration.

Measuring conductivity is done by measuring the resistance occurring in an area of the test solution defined by the probe's physical design. Voltage is applied between the two electrodes immersed in the solution, and the voltage drop caused by the resistance of the solution is used to calculate conductivity per centimeter. The basic unit of measure for conductivity is the Siemen (or mho), the reciprocal of the ohm in the resistance measurement. Because ranges normally found in aqueous solutions are small, milliSiemens/cm (10^{-3} S or mS/cm) and microSiemens/cm (10^{-6} S or µS/cm) are most commonly used.

Required Reagents

Description	Unit	Cat. No.
*sension*5 Conductivity Meter, portable, (with probe 51975-00)	each	51800-00
Conductivity Probe, 1-meter cable	each	51975-00

Optional Apparatus

Beaker, poly, 100-mL	each	1080-42
Gallic Acid Solution	50 mL SCDB	14423-26
Hydrochloric Acid Solution, 1:1	500 mL	884-49
Low Ionic Strength Chamber (LIS)	each	51899-00
Phenolphthalein Indicator Solution	15 mL SCDB	162-36
Sodium Chloride Standard Solution, 180 ±10 µS/cm, 90 ±1 mg/L TDS	100 mL	23075-42
Sodium Chloride Standard Solution, 1000 ±10 µS/cm, 500 ±5 mg/L TDS	100 mL	14400-42
Sodium Chloride Standard Solution, 1990 ±20 µS/cm, 995 ±10 mg/L TDS	100 mL	2105-42
Sodium Chloride Standard Solution, 18,000 ±50 µS/cm, 9000 ±25 mg/L TDS	100 mL	23074-42
Wash Bottle, 125-mL	each	620-14
Water, deionized	4L	272-56

C.5 EPA 300 as used by CDPHE Labs—Nitrate

Colorado Department of Public Health and Environment

Laboratory Services Division
Inorganic Chemistry

Anions (Chloride, Fluoride, Nitrate, Nitrite, Ortho-Phosphate and Sulfate), Ion Chromatography, Aqueous

Revision 1

January 2006

TITLE **62**
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Title

Anions (Chloride, Fluoride, Nitrate, Nitrite, O-phosphate, Sulfate), Ion

Chromatography, Aqueous

Reference

Method for the Determination of Inorganic Substances in Environmental Samples,

Method 300.0, EPA/600/R-93/100, and August 1993.

Methods for Chemical Analysis of Waters and Waste, EPA-600/4-76-020, March 1983.

Dionex Corporation. Application Note 154; Sunnyvale, CA

Dionex Chromeleon 6.5 chromatography workstation manual

Standard Methods for the Examination of Water and Wastes, PHA/AWWA/WEF, 18th Edition.

Less is Better: Laboratory Chemical Management for Waste Reduction, American Chemical Society's Department of Government Regulations and Science Policy, Washington D.C.

Reagent Chemicals, American Chemical Society's Committee on Analytical Reagents, Washington D.C.

Mulit-Agency Radiological Laboratory Analytical Protocols Manual, Chapter 19, Measurement Uncertainty.

Method

Ion Chromatography

Principle

This is an electrolytic suppression ion chromatography (IC) method. The anions are separated based on their affinities towards the stationary phase of the column. The suppressor automatically produces the regenerant required for the application and provides continuous regeneration. It also reduces background conductivity and at the same time, converts the anionic species into species of higher conductance.

25 µL of sample is introduced into an ion chromatograph. The anions of interest are separated and measured using a system comprised of a guard column, an analytical column, an electrolytic suppressor, and a conductivity detector.

Sample

At least 5 ml of a neutral water sample collected in plastic bottle, stored at 4 ^{0} C. This method is applicable to drinking water, surface water, mixed domestic and industrial wastewater, groundwater and reagent water.

Sample preservation and holding times for the anions that can be determined by this method are as follows:

Analyte	**Preservation**	**Holding Time**
Chloride	Cool to 4^{o}C	28 days
Fluoride	None required	28 days
N-Nitrate	Cool to 4^{o}C	48 hour
N-Nitrite	Cool to 4^{o}C	48 hour
P-Phosphate-ortho	Cool to 4^{o}C	48 hour
Sulfate	Cool to 4^{o}C	28 days

NOTE: All samples must be filtered through a 0.45-um syringe filter to prevent damage to the valves and columns. The domestic wastewaters must be filtered through a 0.20-um syringe filter before injection into the IC. To prolong column lifetime, some domestic wastewater samples may require pretreatment with a C18 cartridge.

Safety

Read all MSDS sheets before handling unfamiliar reagents. Use precautions found in the Chemical Hygiene Plan (Appendix I – Safety Manual) when working in the laboratory

Equipment

1. Dionex ICS-2000 Reagent-Free Ion chromatography system (RFIC)
2. Anion guard column, IonPac AG18 4 x 50 mm
3. Anion Analytical column, IonPac AS18 4 x 250 mm
4. Self-Regenerating Suppressor ASRS Ultra II 4 mm
5. Continuously Regenerated Anion Trap Column (CR-ATC)
6. Eluent Generator Hydroxide Cartridge EGC II KOH
7. AS50 Auto sampler
8. Chromeleon 6.5 Chromatography workstation
9. Type I reagent-grade, 18 Megaohms-cm resistivity or better
10. Filter 0.45 and 0.25-micron filter.
11. Digital Conductor

12. Volumetric glassware.
13. 5 ml plastic Poly Vials with filter caps.
14. Sample Cassettes
15. On-guard Cartridge C18

Reagents

Reagent grade chemicals shall be used in all tests unless otherwise indicated. It is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficient high purity to permit its use without lessening the accuracy of the determination.

Note: Prior to use, inspect all reagents for expiration, contamination or deterioration. Contact the Chemical Hygiene Officer for disposal.

1. Sodium Fluoride (NaF).
2. Sodium Sulfate (Na_2SO_4).
3. Reagent Water, ASTM Type I.
4. Sodium Nitrite ($NaNO_2$).
5. Sodium Nitrate ($NaNO_3$).
6. Potassium Phosphate, monobasic (KH_2PO_4).
7. Sodium Chloride (NaCl).

Reagent Preparation

NOTE: All "working" chemical solutions, mixtures or dilutions shall be labeled with the following information; chemical name, concentration, date prepared, analysts' initials, and special storage instructions.

1. Stock Anion Standard Solutions (1000mg/L). Commercial Standards can be used, but when they are not available, 1000mg/L standards can be prepared by dissolving the appropriate amounts of the required analytes in 250 ml of reagent water. Standards are stable for at least one month when stored at 4^{o}C.

Stock Standard Solution Preparation

Reagent	***Concentration (mg/L)***	***Weight (g)***	***Final volume (mL)***
Sodium Fluoride	1000	0.5525	250
Sodium Chloride	1000	0.4120	250
Sodium Nitrite	1000	1.2315	250
Sodium Nitrate	1000	1.5170	250
Sodium Sulfate	1000	0.3698	250
Potassium phosphate monobasic	1000	1.0985	250

2. Working standard mix A: In a 200 ml volumetric flask, add appropriate amount of stock solutions as shown below in Table 2. Dilute to the mark with reagent water and invert to mix. Working standard standards solution should be prepared daily.

Working Standard Mix A Preparation

Stock Standard (mg/L)	*Concentration (mg/L)*	*ml to add*
Fluoride, 1000 mg/L	5	1 ml
Chloride, 1000 mg/L	50	10 ml
Nitrite-N, 1000mg/L	5	1 ml
Nitrate-N, 1000mg/L	5	1 ml
Phosphate-p 1000mg/L	5	1 ml
Sulfate, 1000mg/L	100	20 ml

3. Working standard mixes B through F: Working mixed standards B through F are prepared by diluting working mixed standard A (step 1) as summarized below. Working standard standards solution should be prepared daily.

Working Standard Mix B-F Preparation

			Concentrations (mg/L)					
Std	**Std A (ml)**	**Final volume mL)**	**F^-**	**Cl^-**	**NO_2^-**	**NO_3^-**	**HPO_4^{2-}**	**SO_4^{2-}**
B	30	50	3	30	3	3	3	60
C	10	50	1.0	10	1.0	1.0	1.0	20
D	4	50	0.4	4.0	0.4	0.4	0.4	8.0
E	1	50	0.1	1.0	0.1	0.1	0.1	2.0
F	0.5	50	0.05	0.5	0.05	0.05	0.05	1.0

Procedure

Conditions

Columns:	IonPac AS18 Analytical, (4 x 250 mm P/N 060549) IonPac AG18 Guard, (4 x 50 mm P/N 060551)
Eluent:	22-40 mM KOH from 7-8 min
Eluent Source:	ICS-2000 with CR-ATC (continuous regenerated anion trap Column)
Flow Rate:	1.0 mL/min
Temperature:	30°C
Injection:	25 µL
System Backpressure:	~ 2500 psi
Run Time:	20 min
Detection:	Suppressed Conductivity, ASRS ULTRA, 4 mm (P/N 053947) Auto suppression Recycle Mode; 100 mA current

Detection

No	***Ret. Time (min)***	***Parameter name***	***Parameter Value***	***Channel***
1	0.000	Minimum Area	0.01 “(signal)”min	All channels
2	0.000	Fronting Sensitivity factor	2.3	All channels
3	0.000	Tailing sensitivity factor	Off	All channels
4	9.000	Valley to valley	On	All channels
5	10.00	Tailing Sensitivity Factor	2.0	All channels

NOTE: This is the sample table only. As the user gains experience, he/she may program these events graphically.

Peak Table

Name	***Retention Time***	***Units***
Fluoride	3.250	mg/L
Chloride	5.024	mg/L
Nitrite-N	6.277	mg/L
Sulfate	10.237	mg/L
Nitrate-N	10.903	mg/L
Phosphate-P	14.007	mg/L

NOTE: These parameters may have to be adjusted slightly for the software labels each analyte peak.

Software Setup

1. Turn on the power to computer at CPU and instrument at main power strip.
2. Double click on the ***Chromelion*** icon, and then click on ***OK***.
3. Click start up and click on connect.
4. The instrument is now equilibrating; let it do so for 20-30min.

5. To check the baseline trace, go to control and select acquisition on. To turn off, click acquisition off.
6. Go to file, select browser.
7. While the system is equilibrating:
8. Click on the last sequence that was run.
9. Click on File in the top menu bar and click on Save As.
10. Type the sequence name using YYMMDD- Description where YY= The last digits of the year. MM= The month (01, 02…10, 11, 12) and DD= The day (01, 02, …28, 29, 30, 31). Description will be (Daily Anion Run), (Weekly Anion Run), (Calibration Sequence).
11. This creates a sequence with the Method, pump program and stop method. It does not copy calibration information.
12. To copy the calibration information first select the sequence that was selected in step 8 to be “Saved As” in steps 9 and 10.
13. Highlight the names of the standards files by click on the gray number to the left of the name of the first standard.
14. While holding the shift key click on the gray number to the left of the last standard file.
15. Next right click on the highlighted area and from the menu select copy.
16. Select the newly created sequence and highlight the standard files as described previously.
17. Note the fact that the status of the standard file is “single”.
18. Right click on the highlighted area and select paste.
19. Pick all and click ok.
20. Click ok. The “single” status should change to “finished” on the standards.
21. Steps 12-20 are not necessary if a new calibration curve is generated.
22. Daily sample names may now be edited.
23. Left click on sample name to highlight it.
24. Press F2 to enter edit mode and change the name.
25. Press enter.
26. Continue with step 23 & 24 for each sample.
27. To add samples. Use Edit, Insert Sample (ctrl+I) being sure to be on or above the “stop” sample line.
28. To remove samples, either change their status to finished or left click on the sample name and use Edit, Delete (Ctrl + D) to remove the sample.
29. Save the sequence.
30. The sequence is now ready to run.

Setting up the Eluent Reservoir

1. Rinse the eluent reservoir.
2. Fill the reservoir with reagent water (18 megaohms-cm) or better.
3. Place the reservoir on top of the ICS-2000.
4. Install the cap and hand tighten

Priming the Pump

1. Verify that the eluent reservoir is set up.
2. Verify that the waste lines are directed to a waste container.
3. The priming procedure consists of two parts:

Priming - Syringe

Perform this procedure at initial installation, after changing eluents, or when eluents lines are empty.

1. Verify that the pump is off.
2. Connect a 10 ml syringe (P/N 054578) to the port in the priming pump head.
3. Open the priming valve by turning it one-quarter to one-half turn counterclockwise.
4. On the ICS-2000 touch screen, touch **Pump** to open the pump page, under Eluent valve, touch the open button.
5. Draw the syringe back to begin pulling eluent through the flow path. It may take several syringe draws to remove all air or previous eluent from the tubing. Draw out a minimum of 20 ml of eluent to ensure that the vacuum degas assembly is primed.
6. After priming the lines thoroughly, close the priming valve. Do **not** over tighten the priming valve.
7. Turn the eluent valve closed on the touch screen pump page.

Priming - Button

Perform this procedure after the eluents lines are primed.

1. Check that the priming valve on the primary valve is closed.
2. Open the waste valve on the secondary pump head by turning the knob one-quarter to one-half turn counterclockwise.
3. Touch prime on the ICS-200 screen **Home page.** Confirm that the waste valve is open by pressing **OK** when reminder message appears. The pump will begin pumping at approximately 3.0 ml/min.
4. Continue priming the ICS-200 until no air bubbles are exiting the pump waste line.
5. Press **Pump off.**
6. Close the waste valve. **Do not over tighten**. The pump is now ready for operation.

Sample Preparation

Batch Run: A batch includes a calibration curve, blanks, Laboratory Fortified Matrix, reference(s), and sample(s).

1. Prepare the sample vials by rinsing with an ultra-pure 18 megaohm conductance, reagent water.
2. Fill the vials with filtered samples to the fill line marked on the vial body.
3. After filling, inspect to make sure no air bubbles are trapped at the bottom. Place the caps on top of the vials.
4. Use the insertion tool (P/N 037987) to ensure that the cap is properly installed on the vial
5. One end of the tool inserts the cap to the proper depth for a sample (i.e. the top of the cap is flush with the lip of the vial); the other end inserts the cap to the proper depth for a rinse (i.e. the top of the cap extends one-quarter inch below the lip of the vial.
6. After pushing the cap into the vial, shake off any liquid that has been forced into the cap socket.
7. Load the vials into the sample cassettes.
8. Make sure the switch on the sampler is on the hold position, slide the spring-loaded cassette pusher back and hold on it. Place the filled cassettes into tray, with the **black dots to the right**.
9. After all the cassettes are in place, allow the pusher to slide forward into place against the last cassette.

10. Select the sequence and click on open button.
11. Click on the ready check and verify that all is well with your setup.
12. If all is well click OK and then start or click on Batch, start.

Data Processing

1. In the browser, click the sequence of interest.
2. Open a sample in the sequence by double-clicking the sample name.
3. The sample opens in the integration window. The integration window usually displays the chromatogram and the report table. Sometimes, only the chromatogram opens. This depends on the report definition file (RDF).
4. Go to file, select print, and repeat this process for each of the sample.
5. Results may be printed during automatic sample processing (online batch). Make the corresponding settings in the batch dialog box.
6. Select the reporting command on the batch menu in the browser or on a control panel.
7. Enable the print/export check box to print or export the sample processing results.
8. Select print each sample immediately to start printing immediately after the sample has been analyzed. Select print when the entire batch has finished to print all sample results after the entire sequence is completed.
9. To print the calibration curve, click on the calibration plot icon, which displays the calibration curve.

Instrument Shutdown

1. When setting up the sequence for any run, the shut down button has to be the last on each run. This automatically shut down the instrument.
2. Remove the cassettes from the tray and dispose of the vials
3. Store all standards in refrigerator after use.

Quality Control and Interpretation

1. Initial Demonstration of Performance. The initial demonstration of performance is used to characterize instrument performances and laboratory performance prior to performing analysis by this method.
    a) Instrument performance is characterized analysis of a QCS. The QCS is run in quadruplicate.
    b) Laboratory performance is characterized through the determination of MDLs/PQLs. MDLs/PQLs are established for each analyst using reagent water fortified at a concentration of two to three times the estimated instrument detection limit. Seven replicate aliquots of the fortified reagent water are processed through the entire analytical method. The MDLs/PQLs is calculated as follows:

    Method Detection Limit = (t) *x* (S)

    where: MDL = Method detection limit.
    t = Student’s value for a 99 % confidence level and a standard deviation estimate with n-1 degrees of freedom (t = 3.14 for seven replicates).
    S = Standard deviation of the replicate analyses.

   c) MDLs/PQLs should be determined every year, when a new operator begins work or whenever there is a significant change in the background or instrument response.

2. Measurement Uncertainty is determined across the calibration ranges by taking several replicate aliquots at the same concentration as the highest calibration standard and processing them through the entire analytical method. The measurement uncertainty is calculated using the spreadsheet J:/Inorganic/MDL PQL/4 MDL PQL Expanded.xls.

3. The system will prepare a calibration curve by plotting peak area versus standard concentration. Sample concentration is calculated from the regression equation. Multiply answer by appropriate dilution factor.

   a) The correlation coefficient of the regression of the standard curve must be equal to or greater than 0.995. If the curve is unacceptable, the cause must be determined and corrected, and the associated analytical batch must be reanalyzed.

   b) Report only those values that fall between the lowest and highest calibration standards. Samples with values exceeding the highest standard should be diluted and reanalyzed. Samples with values below the lowest standard should be reported as less than the PQL.

4. If greater that 28 days or 48 hours (depending upon analyte) have elapsed since sample collection the sample result must be qualified with an “H”.

5. Quality Control Standard: on a quarterly basis or as required to meet data quality needs, verify the calibration standards and acceptable instrument performance with the preparation and analyses of a QCS.

   a) The analyzed value of the QCS must be within manufacturer’s acceptance range or within ± 10% of the true value if the manufacturer does not provide performance acceptance limits. If the value for any QCS element is outside of this range, the source of the problem must be identified and corrected before the analysis is restarted and affected samples are reanalyzed. The percent recovery of the analyte in the QCS is recorded on the QC chart.

6. Laboratory Reagent Blank:

   a) Laboratory reagent blanks are analyzed after the calibration standards and after every ten samples.

   b) Values that exceed the PQL indicate laboratory or reagent contamination should be suspected and corrective actions must be taken before continuing the analyses.

   c) When the source of contamination is identified, corrected, and documented, associated samples are reanalyzed.

7. Laboratory Fortified Blank:

   a) Laboratory fortified blank (LFB) are analyzed with each batch of samples. The percent recovery is calculated as follows:

$$Percent\ Recovery = \frac{LFB\ \text{-}\ LRB}{S} \bullet 100$$

where:
LFB = Laboratory fortified blank concentration.
LRB = Laboratory reagent blank concentration.
S = Concentration equivalent of analyte added fortify the LRB solution.

b) If the recovery falls outside of the required control limits of 80- 120 %, the source of the problem must be identified, corrected, and documented before the analysis is restarted. The percent recovery is recorded on the QC chart.

8. Instrument Performance Check

   a) In addition to method blanks, instrument performance check (IPC) solutions are analyzed immediately following the calibration standards and after every ten samples.

   b) Analysis of the IPC solution immediately following the calibration must verify that the instrument is within ± 10% of calibration (initial calibration verification - ICV).

   c) If the recovery falls outside of the required control limits of 90-110 %, the instrument must be re-calibrated. The percent recovery in the ICV is recorded on the QC chart.

   d) Subsequent analyses of the IPC solution must be within ± 20% of calibration (continuing calibration verification – CCV).

   e) If that recovery falls outside of the required control limits of 80-120 %, values in samples above and below that affected CCV (to the next acceptable CCV) are not reported. The source of the problem must be identified, corrected and documented before the later reanalysis of the affected samples. The percent recovery of the CCV is recorded on the respective QC chart.

9. Laboratory Fortified Matrix

   a) An additional aliquot of one sample in every set of ten is spiked (fortified) with known amounts of each anion.

   b) The percent recovery is calculated as follows:

$$Percent\ \ Recovery = \frac{Cs\ \ \text{-}\ C}{S} \bullet 100$$

where:
C_S = fortified sample concentration
C = original (unfortified) sample concentration
S = concentration equivalent of analyte added to fortify the sample.

c) If the recovery falls outside of the required control limits of 80-120 % and the laboratory performance is shown to be in control (acceptable LRB, LFB, and IPC), the recovery problem encountered with the LFM is judged to be matrix related, not system related. The sample is qualified with a “Q” to inform the data user that the results are suspect due to matrix effects.

10. Laboratory Fortified Matrix Duplicates/Sample Duplicate:

a) An additional aliquot of one sample in every set of ten is analyzed in duplicate. This aliquot might be fortified.

b) The percent relative difference is calculated as follows:

$$\mathit{Relative\ Percent\ Difference} = \frac{C_1 - C_2}{(C_1 + C_2)/2} \bullet 100$$

where: RPD = Relative Percent Difference.
C_1 = analyte concentration in first replicate
C_2 = analyte concentration in second replicate

c) If the RPD falls outside of the required control limits (25 % for concentration < 20 x the MDL and 10 % for concentration >20 x the MDL) and the laboratory performance is shown to be in control (acceptable LRB, LFB, and IPC), the reproducibility problem encountered with the LFM duplicate is judged to be matrix related, not system related. The sample is qualified with a “Q” to inform the data user that the results are suspect due to matrix effects.

Pollution Prevention

1. Pollution prevention encompasses any technique that reduces or eliminates the quantity or toxicity of waste at the point of generation. Numerous opportunities for pollution prevention exist in a laboratory operation. The United States Environmental Protection Agency (US EPA) has established a preferred hierarchy of environmental management techniques that places pollution prevention as the management option of first choice. Whenever feasible, laboratory personnel should use pollution prevention techniques to address waste generation. When wastes cannot feasibly be reduced at the source, the US EPA recommends recycling as the next best option.
2. The quantity of chemicals purchased should be based on expected usage during the shelf life and disposal cost of unused material. Actual reagent preparation volumes should reflect anticipated usage and reagent stability.
3. For information about pollution prevention that may be applicable to laboratories, consult “Less is Better: Laboratory Chemical management for Waste Reduction”, available from the American Chemical Society’s (ACS) Department of Government Regulations and Science Policy, 1155 16th Street N.W., Washington D.C. 20036, (202) 872-4477.

Waste Management

1. The US EPA requires that laboratory waste management practice be consistent with all-applicable rules and regulations. Excess reagents, samples and method process wastes should be characterized and disposed of in an acceptable manner. The agency urges laboratories to protect the air, water, and land by minimizing and controlling all releases from hoods and bench operations, complying with the letter and spirit of any waste discharge permit and regulations, particularly the hazardous waste identification rules and land disposal restrictions.
2. For further information on waste management consult the “Waste Management Manual for Laboratory Personnel.” Available from The American Chemical Society at the address listed above.
3. Contact the Chemical Hygiene Officer for proper disposal of reagents, standards and samples.

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Appendix D

D.1 USDA NRCS Saturated Hydraulic Conductivity for Castle Rock Area, Colorado

Saturated Hydraulic Conductivity (Ksat)

Layer Option: Depth Range 36 to 1200 Inches
Units of Measure: micrometers per second
Aggregation Method: Dominant Component
Tie-break Rule: Fastest
Interpret Nulls as Zero: No

Castle Rock Area, Colorado
Survey Area Version and Date: 3 - 12/16/2005

Map symbol	Map unit name	Rating
BlE	Blakeland sandy loam, 1 to 15 percent slopes	423.0700
Bo	Blakeland-Orsa association, 1 to 4 percent slopes	423.0700
BrB	Bresser sandy loam, 1 to 3 percent slopes	77.6200
BrD	Bresser sandy loam, 3 to 9 percent slopes	77.6200
BsE	Bresser-Louviers complex, 7 to 30 percent slopes	77.6200
BtE	Bresser-Truckton sandy loams, 5 to 25 percent slopes	77.6200
BuD2	Bresser and Truckton soils, 3 to 12 percent slopes, eroded	77.6200
BvB	Brussett loam, 1 to 3 percent slopes	9.1700
BvD	Brussett loam, 3 to 9 percent slopes	9.1700
BwD	Buick-Satanta loams, 3 to 9 percent slopes	7.7600
CoG	Coni rocky loam, 3 to 100 percent slopes	
CP	Pits, clay	
CrE	Crowfoot-Tomah sandy loams, 5 to 25 percent slopes	305.0992
CsD	Cruckton sandy loam, 1 to 9 percent slopes	27.3292
CtE	Cruckton-Peyton sandy loams, 7 to 20 percent slopes	27.3292
Dam	Dam	
DeD	Denver clay loam, 5 to 12 percent slopes	1.7921
En	Englewood clay loam	2.3200
FoB	Fondis clay loam, 1 to 3 percent slopes	7.7600
FoD	Fondis clay loam, 3 to 9 percent slopes	7.7600
Fu	Fondis-Kutch association	7.7600
GaE	Garber gravelly sandy loam, 5 to 30 percent slopes	28.2200
GoE	Gove sandy loam, 5 to 20 percent slopes	16.1452
GP	Pits, gravel	360.0000
GsF	Gove-Shale outcrop complex, 5 to 65 percent slopes	16.1452
He	Heldt clay	0.9200
Hg	Hilly gravelly land	
IW	Playas	
Jb	Jarre-Brussett association	77.6200
JuF	Juget rocky complex, 20 to 65 percent slopes	
JvF	Juget very rocky complex, 20 to 65 percent slopes	
Ka	Kassler gravelly sandy loam	423.0700
KeE	Kettle loamy sand, 5 to 25 percent slopes	77.6200
KfF	Kettle-Falcon complex, 9 to 65 percent slopes	77.6200
KnE	Kippen loamy sand, 1 to 20 percent slopes	91.7400
KpD2	Kippen and Pring soils, 1 to 12 percent slopes, eroded	91.7400
KtE	Kutch sandy loam, 5 to 20 percent slopes	
KuD	Kutch clay loam, 4 to 8 percent slopes	
KuE	Kutch clay loam, 8 to 20 percent slopes	
KwF	Kutch-Newlin-Stapleton complex, 8 to 40 percent slopes	
LaD	Larkson fine sandy loam, 3 to 9 percent slopes	2.3200
Lo	Loamy alluvial land	350.7243
Lu	Loamy alluvial land, dark surface	350.7243
Lw	Loamy wet alluvial land	70.7800
M-W	Miscellaneous water	

Saturated Hydraulic Conductivity (Ksat)

Layer Option: Depth Range 36 to 1200 Inches
Units of Measure: micrometers per second
Aggregation Method: Dominant Component
Tie-break Rule: Fastest
Interpret Nulls as Zero: No

Castle Rock Area, Colorado
Survey Area Version and Date: 3 - 12/16/2005

Map symbol	Map unit name	Rating
Ma	Manzanola clay loam	1.9528
NeE	Newlin gravelly sandy loam, 8 to 30 percent slopes	423.0700
NsE	Newlin-Satanta complex, 5 to 20 percent slopes	423.0700
PdE	Perrypark sandy loam, 3 to 20 percent slopes	28.2200
PeB	Peyton sandy loam, 1 to 3 percent slopes	9.1700
PeD	Peyton sandy loam, 3 to 9 percent slopes	9.1700
PfC	Peyton sandy loam, wet, 1 to 5 percent slopes	23.2800
PpE	Peyton-Pring-Crowfoot sandy loams, 5 to 25 percent slopes	9.1700
PrE2	Peyton-Pring-Crowfoot complex, 3 to 15 percent slopes, eroded	9.1700
PsE	Plome loamy sand, 5 to 25 percent slopes	77.6200
PvE	Pring and Kippen gravelly sandy loams, 1 to 25 percent slopes	28.2200
QU	Quarry	
RaE	Razor clay, 3 to 25 percent slopes	0.9200
RdD	Rednun loam, 3 to 10 percent slopes	2.8200
ReE	Rednun-Redridge complex, 8 to 40 percent slopes	2.8200
RgF	Redridge-Chaseville gravelly sandy loams, 10 to 70 percent slopes	91.7400
RlE	Redtom-Lonetree complex, 5 to 25 percent slopes	88.3030
RmE	Renohill-Buick complex, 5 to 25 percent slopes	
RnE	Renohill-Manzanola clay loams, 3 to 20 percent slopes	
RoE	Renohill sandy loam, reddish variant, 5 to 20 percent slopes	
RtG	Rock land-Lonetree complex, 10 to 100 percent slopes	0.2100
Sa	Sampson loam	23.2800
Sd	Sandy alluvial land	77.6200
Se	Sandy wet alluvial land	91.7400
Sn	Satanta loam	9.1700
SrD	Satanta loam, calcareous variant, 3 to 9 percent slopes	2.4070
SrE	Satanta loam, calcareous variant, 9 to 25 percent slopes	2.4070
SsE	Stapleton loamy sand, 6 to 30 percent slopes	28.2200
St	Stapleton-Bresser association	28.2200
Su	Stony rough land	
Sv	Stony steep land	
Sw	Stony steep land, cold	
TaF	Tarryall gravelly loam, 10 to 50 percent slopes	
TcE	Tinytown-Cheeseman complex, 5 to 30 percent slopes	77.6200
TrB	Truckton sandy loam, 1 to 3 percent slopes	77.6200
TrD	Truckton sandy loam, 3 to 8 percent slopes	77.6200
W	Water	
WeE	Westcreek gravelly loam, 10 to 30 percent slopes	15.3928

Saturated Hydraulic Conductivity (Ksat)

Rating Options

Attribute Name: Saturated Hydraulic Conductivity (Ksat)

Saturated hydraulic conductivity refers to the ability of a soil to transmit water or air. The term "permeability" also indicates saturated hydraulic conductivity (Ksat). The estimates, expressed in micrometers per second, indicate the rate of water movement. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Ksat is considered in the design of soil drainage systems and septic tank absorption fields.

For each soil horizon or layer in the underlying database, this attribute is actually recorded as three separate values. A low value and a high value indicate the range of this attribute for the corresponding component. A "representative" value indicates the expected value of this attribute for the corresponding component. For this soil property, only the representative value is used.

For this attribute, the numeric Ksat values are presented using dynamic natural class breaks.

Layer Option: Depth Range 36 to 1200 Inches

Units of Measure: micrometers per second

Aggregation Method: Dominant Component

Aggregation is the process by which a set of component attribute values is reduced to a single value to represent the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. The components in the map unit name represent the major soils within a map unit delineation. Minor components make up the balance of the map unit. Great differences in soil properties can occur between map unit components and within short distances. Minor components may be very different from the major components. Such differences could significantly affect use and management of the map unit. Minor components may or may not be documented in the database. The results of aggregation do not reflect the presence or absence of limitations of the components which are not listed in the database. An on-site investigation is required to identify the location of individual map unit components.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be generated. Aggregation must be done because, on any soil map, map units are delineated but components are not.The aggregation method "Dominant Component" returns the attribute value associated with the component with the highest percent composition in the map unit. If more than one component shares the highest percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher attribute value should be returned in the case of a percent composition tie.

The result returned by this aggregation method may or may not represent the dominant condition throughout the map unit.

Tie-break Rule: Fastest

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

Interpret Nulls as Zero: No

This option indicates that a null value for a component should be converted to zero before aggregation occurs. This will be done only if a map unit has at least one component where this value is not null.

Appendix E

E.1 Conductivity, Hardness, and Nitrate Values for all 295 locations

E.2 Frequency Distribution of Nitrate Samples in Douglas County, n=295

E.1 Conductivity, Hardness, and Nitrate Values for all 295 locations

Table 1 Results of 295 Samples, Douglas County, Completed March 2008

Location	Zip	Hardness (mg/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Sample Date
Castle Rock	80104	115	273	Non-Detect	10/11/2007
Castle Rock	80104	159	308	Non-Detect	10/11/2007
Castle Rock	80104	73	311	Non-Detect	2/21/2008
Castle Rock	80104	109	342	Non-Detect	3/25/2008
Castle Rock	80104	117	347	Non-Detect	2/20/2008
Castle Rock	80104	122	375	Non-Detect	3/26/2008
Castle Rock	80104	125	347	Non-Detect	1/24/2008
Castle Rock	80104	128	326	Non-Detect	2/20/2008
Castle Rock	80104	153	361	Non-Detect	2/27/2008
Castle Rock	80108	6	267	Non-Detect	10/11/2007
Castle Rock	80108	93	274	Non-Detect	10/11/2007
Castle Rock	80108	98	263	Non-Detect	10/11/2007
Castle Rock	80108	104	271	Non-Detect	10/11/2007
Castle Rock	80108	161	404	Non-Detect	10/11/2007
Castle Rock	80108	88	230	Non-Detect	1/10/2008
Castle Rock	80108	93	239	Non-Detect	1/10/2008
Castle Rock	80108	97	257	Non-Detect	1/10/2008
Castle Rock	80108	114	297	Non-Detect	2/7/2008
Castle Rock	80108	88	209	Non-Detect	1/24/2008
Castle Rock	80108	90	223	Non-Detect	1/17/2008
Castle Rock	80108	96	254	Non-Detect	1/17/2008
Castle Rock	80108	108	281	Non-Detect	2/27/2008
Castle Rock	80108	109	308	Non-Detect	1/31/2008
Castle Rock	80108	112	297	Non-Detect	1/24/2008
Castle Rock	80108	115	281	Non-Detect	1/24/2008
Castle Rock	80108	117	317	Non-Detect	1/31/2008
Castle Rock	80108	137	290	Non-Detect	3/25/2008
Castle Rock	80108	0	310	Non-Detect	3/25/2008
Castle Rock	80108	136	351	Non-Detect	1/31/2008
Castle Rock	80108	316	735	Non-Detect	1/31/2008
Castle Rock	80108	88	217	Non-Detect	1/17/2008
Castle Rock	80109	115	263	Non-Detect	2/27/2008
Castle Rock	80109	118	263	Non-Detect	2/20/2008
Castle Rock	80109	121	252	Non-Detect	3/25/2008
Castle Rock	80109	135	212	Non-Detect	3/25/2008
Castle Rock	80109	145	301	Non-Detect	3/25/2008
Castle Rock	80109	165	362	Non-Detect	1/24/2008
Castle Rock	80109	180	413	Non-Detect	2/21/2008
Castle Rock	80109	186	434	Non-Detect	2/27/2008
Castle Rock	80108	97	246	0.47	10/11/2007
Castle Rock	80108	82	195	0.55	1/10/2008
Castle Rock	80108	97	172.6	0.56	3/27/2008
Castle Rock	80108	0	306	0.63	1/24/2008
Castle Rock	80108	177	384	0.64	3/25/2008
Castle Rock	80108	104	260	0.82	2/28/2008
Castle Rock	80109	92	215	0.99	10/11/2007
Castle Rock	80108	123	267	1.1	3/25/2008
Castle Rock	80104	110	340	1.2	3/26/2008
Castle Rock	80104	158	389	1.6	2/20/2008

Location	Zip	Hardness (mg/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Sample Date
Castle Rock	80104	140	360	2.4	1/31/2008
Castle Rock	80108	26	562	2.4	10/11/2007
Castle Rock	80108	0	469	3.3	1/31/2008
Castle Rock	80108	220	507	3.7	1/31/2008
Castle Rock	80108	452	963	4.5	3/25/2008
Castle Rock	80108	295	708	5.5	1/31/2008
Franktown	80116	45	294	Non-Detect	10/23/2007
Franktown	80116	54	329	Non-Detect	11/1/2007
Franktown	80116	62	314	Non-Detect	11/1/2007
Franktown	80116	50	175	0.43	10/30/2007
Franktown	80116	54	151	0.44	10/25/2007
Franktown	80116	56	136.5	0.54	2/21/2008
Franktown	80116	72	199	0.56	10/23/2007
Franktown	80116	101	187.3	0.58	11/29/2007
Franktown	80116	67	171	0.63	10/30/2007
Franktown	80116	46	136	0.71	10/23/2007
Franktown	80116	122	186	0.71	10/25/2007
Franktown	80116	62	162	0.72	10/25/2007
Franktown	80116	82	505	0.73	3/27/2008
Franktown	80116	65	188	0.79	10/30/2007
Franktown	80116	66	177	0.87	10/25/2007
Franktown	80116	74	209	0.87	10/25/2007
Franktown	80116	96	266	0.96	10/25/2007
Franktown	80116	79	233	1.0	10/25/2007
Franktown	80116	173	425	1.1	10/30/2007
Franktown	80116	73	198	1.2	10/25/2007
Franktown	80116	55	142	1.3	10/23/2007
Franktown	80116	101	237	1.4	10/25/2007
Franktown	80116	86	245	1.6	10/30/2007
Franktown	80116	214	206	2.6	11/29/2007
Franktown	80116	88	237	3.2	11/1/2007
Franktown	80116	160	257	4.7	10/30/2007
Franktown	80116	160	395	6.2	11/1/2007
Franktown	80116	173	425	8.2	10/30/2007
Franktown	80116	130	357	9.3	10/23/2007
Franktown	80116	231	627	11	10/23/2007
Larkspur	80118	53	132	Non-Detect	10/18/2007
Larkspur	80118	147	357	Non-Detect	11/19/2007
Larkspur	80118	52	145	0.35	10/18/2007
Larkspur	80118	45	107.5	0.37	11/29/2007
Larkspur	80118	54	329	0.48	11/1/2007
Larkspur	80118	38	197.9	0.50	11/19/2007
Larkspur	80118	67	207.6	0.51	11/19/2007
Larkspur	80118	165	449	0.74	3/27/2008
Larkspur	80118	103	155.9	1.0	11/29/2007
Larkspur	80118	134	297	1.2	11/19/2007
Larkspur	80118	56	135	1.2	11/29/2007
Larkspur	80118	119	141	1.5	11/1/2007
Larkspur	80118	119	202	1.5	3/20/2008
Larkspur	80118	76	266	2.4	11/1/2007

Location	Zip	Hardness (mg/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Sample Date
Larkspur	80118	27	123.7	2.5	11/19/2007
Larkspur	80118	200	127.5	4.8	3/27/2008
Larkspur	80118	81	272	6.4	11/1/2007
Larkspur	80118	277	587	13	11/19/2007
Littleton	80124	128	299	Non-Detect	1/9/2008
Littleton	80124	138	318	Non-Detect	1/9/2008
Littleton	80124	145	284	Non-Detect	1/9/2008
Littleton	80125	46	659	Non-Detect	10/18/2007
Littleton	80125	76	319	Non-Detect	10/18/2007
Littleton	80125	102	332	Non-Detect	12/18/2007
Littleton	80125	76	437	Non-Detect	3/20/2008
Littleton	80125	99	320	Non-Detect	1/23/2008
Littleton	80125	157	443	Non-Detect	1/23/2008
Littleton	80125	19	1401	Non-Detect	12/18/2007
Littleton	80125	22	759	Non-Detect	12/18/2007
Littleton	80125	235	539	Non-Detect	12/19/2007
Littleton	80125	251	581	Non-Detect	12/19/2007
Littleton	80129	31	451	Non-Detect	1/23/2008
Littleton	80135	217	531	Non-Detect	12/18/2007
Littleton	80160	117	313	Non-Detect	1/15/2008
Littleton	80125	135	341	0.31	12/18/2007
Littleton	80125	315	766	0.45	1/15/2008
Littleton	80124	165	386	0.74	1/9/2008
Littleton	80125	147	378	0.79	12/18/2007
Littleton	80125	293	589	1.6	12/18/2007
Littleton	80125	231	563	3.2	12/18/2007
Littleton	80125	119	335	6.8	1/15/2008
Parker	80134	73	360	Non-Detect	2/21/2008
Parker	80134	108	503	Non-Detect	2/21/2008
Parker	80134	83	391	Non-Detect	1/10/2008
Parker	80138	59	340	Non-Detect	10/16/2007
Parker	80138	62	352	Non-Detect	10/16/2007
Parker	80138	63	326	Non-Detect	10/16/2007
Parker	80138	79	410	Non-Detect	10/16/2007
Parker	80138	96	338	Non-Detect	10/16/2007
Parker	80138	4	327	Non-Detect	3/13/2008
Parker	80138	63	327	Non-Detect	1/16/2008
Parker	80138	65	342	Non-Detect	1/11/2008
Parker	80138	70	336	Non-Detect	2/13/2008
Parker	80138	72	327	Non-Detect	1/24/2008
Parker	80138	75	336	Non-Detect	1/16/2008
Parker	80138	77	342	Non-Detect	2/28/2008
Parker	80138	82	333	Non-Detect	1/16/2008
Parker	80138	208	563	Non-Detect	1/16/2008
Parker	80138	63	335	Non-Detect	1/10/2008
Parker	80138	69	344	Non-Detect	1/9/2008
Parker	80138	72	323	Non-Detect	1/15/2008
Parker	80138	73	389	Non-Detect	1/15/2008
Parker	80138	95	379	Non-Detect	1/9/2008
Parker	80138	75	333	0.33	1/30/2008

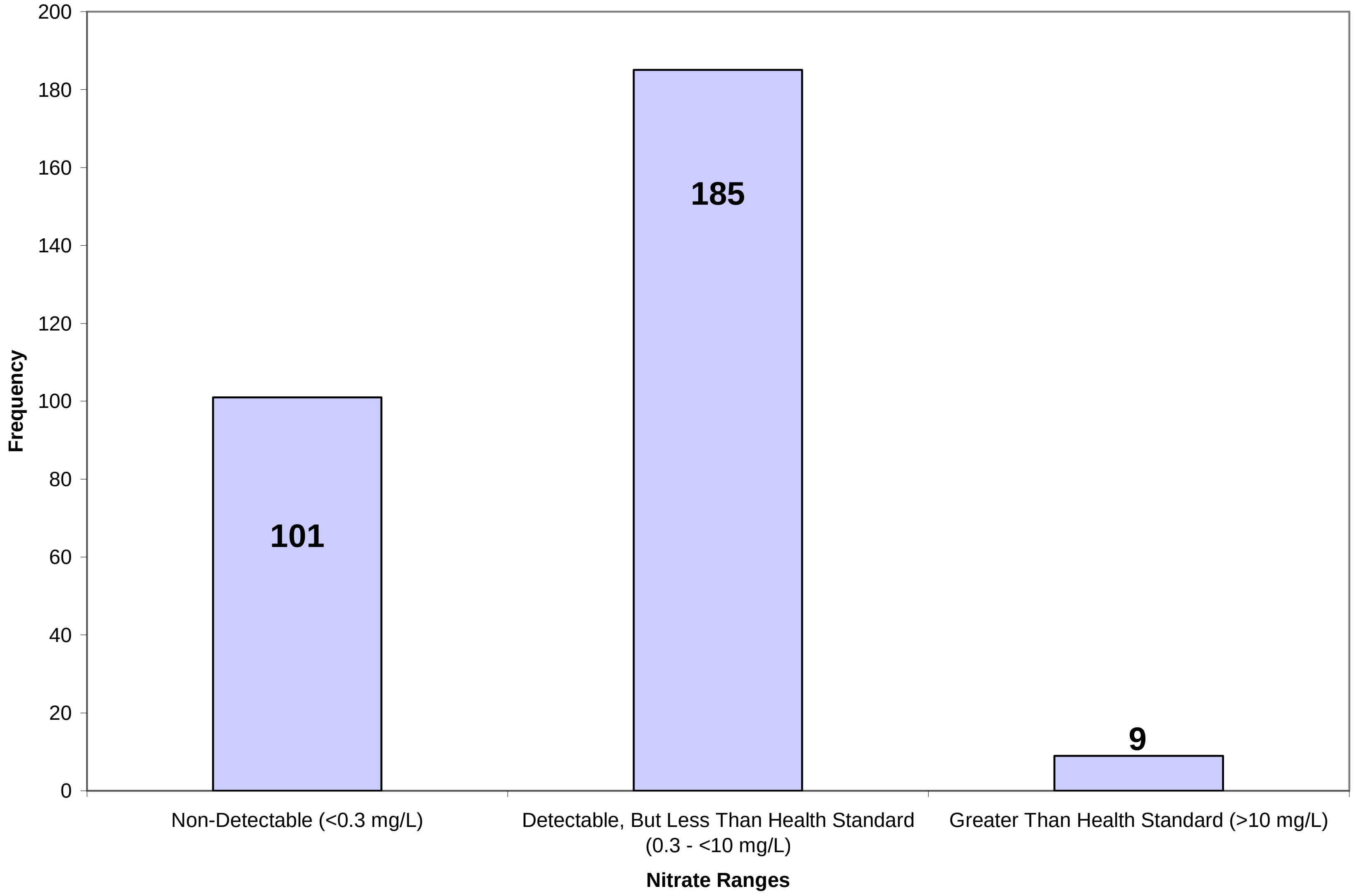
Location	Zip	Hardness (mg/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Sample Date
Parker	80134	74	163.6	0.50	2/7/2008
Parker	80134	76	185.1	0.50	3/6/2008
Parker	80134	67	175.8	0.51	2/13/2008
Parker	80134	70	172.8	0.53	1/30/2008
Parker	80134	72	161.1	0.53	1/30/2008
Parker	80138	150	356	0.54	2/20/2008
Parker	80134	65	184.2	0.55	1/24/2008
Parker	80134	67	163.7	0.55	1/30/2008
Parker	80134	68	166.1	0.63	2/7/2008
Parker	80138	89	208	0.65	10/16/2007
Parker	80134	66	162.9	0.66	2/7/2008
Parker	80138	117	289	0.66	2/20/2008
Parker	80138	152	324	0.67	10/16/2007
Parker	80138	85	380	0.67	1/9/2008
Parker	80138	102	278	0.69	1/30/2008
Parker	80138	105	252	0.69	2/20/2008
Parker	80138	91	237	0.70	2/20/2008
Parker	80138	87	213	0.72	2/12/2008
Parker	80138	102	231	0.72	2/20/2008
Parker	80138	130	311	0.75	1/9/2008
Parker	80134	80	198.7	0.76	1/30/2008
Parker	80138	124	331	0.76	1/15/2008
Parker	80134	72	185	0.77	1/30/2008
Parker	80138	146	308	0.77	2/13/2008
Parker	80134	70	191.2	0.78	1/30/2008
Parker	80134	75	169.2	0.78	1/30/2008
Parker	80138	97	260	0.79	2/21/2008
Parker	80134	74	220	0.81	2/21/2008
Parker	80138	0	252	0.81	1/10/2008
Parker	80138	98	246	0.81	2/7/2008
Parker	80134	80	208	0.87	1/30/2008
Parker	80138	88	226	0.87	2/20/2008
Parker	80138	107	290	0.91	10/16/2007
Parker	80138	100	233	0.91	2/7/2008
Parker	80138	125	297	0.94	3/6/2008
Parker	80138	190	424	0.97	2/7/2008
Parker	80138	129	355	0.98	2/20/2008
Parker	80138	116	296	1.0	2/20/2008
Parker	80138	120	295	1.0	1/30/2008
Parker	80134	65	168.2	1.1	1/30/2008
Parker	80138	120	255	1.1	2/7/2008
Parker	80138	128	333	1.1	1/10/2008
Parker	80138	116	293	1.2	10/16/2007
Parker	80138	116	299	1.2	2/7/2008
Parker	80138	Not Taken	Not Taken	1.2	10/8/2007
Parker	80134	71	139.5	1.3	1/16/2008
Parker	80134	73	167	1.3	3/13/2008
Parker	80138	112	282	1.3	1/10/2008
Parker	80138	175	351	1.3	1/10/2008
Parker	80138	102	244	1.4	2/7/2008

Location	Zip	Hardness (mg/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Sample Date
Parker	80138	462	986	1.4	1/15/2008
Parker	80138	110	283	1.4	1/16/2008
Parker	80134	94	231	1.5	2/7/2008
Parker	80134	240	695	1.5	2/21/2008
Parker	80138	115	284	1.5	2/13/2008
Parker	80138	134	344	1.5	1/15/2008
Parker	80138	157	367	1.6	1/24/2008
Parker	80138	134	310	1.7	2/12/2008
Parker	80138	149	371	1.7	1/24/2008
Parker	80134	74	188	1.8	1/30/2008
Parker	80138	128	290	1.9	2/20/2008
Parker	80138	66	355	2.0	1/30/2008
Parker	80138	146	356	2.0	2/20/2008
Parker	80138	147	333	2.1	2/12/2008
Parker	80134	134	335	2.2	2/7/2008
Parker	80138	340	768	2.2	1/15/2008
Parker	80138	150	358	2.2	1/24/2008
Parker	80138	77	205	2.3	2/13/2008
Parker	80138	149	372	2.4	2/20/2008
Parker	80138	182	443	2.4	1/24/2008
Parker	80138	210	434	2.4	3/26/2008
Parker	80138	143	345	2.6	2/13/2008
Parker	80138	148	388	2.6	1/30/2008
Parker	80138	160	394	2.7	1/10/2008
Parker	80138	96	252	2.7	2/20/2008
Parker	80138	167	397	2.7	3/27/2008
Parker	80138	196	485	2.9	10/16/2007
Parker	80138	170	316	3.1	1/24/2008
Parker	80138	135	359	3.3	2/20/2008
Parker	80138	144	376	3.3	2/20/2008
Parker	80138	188	419	3.3	2/20/2008
Parker	80138	197	410	3.3	2/21/2008
Parker	80138	219	403	3.3	3/26/2008
Parker	80134	373	858	3.5	3/12/2008
Parker	80138	104	253	3.5	2/7/2008
Parker	80138	124	256	3.5	3/13/2008
Parker	80138	294	740	3.8	2/7/2008
Parker	80138	304	694	3.8	2/12/2008
Parker	80138	204	500	4.0	2/7/2008
Parker	80138	366	893	4.2	1/16/2008
Parker	80138	257	600	4.4	2/28/2008
Parker	80138	139	332	4.6	2/13/2008
Parker	80138	225	556	4.6	1/24/2008
Parker	80138	332	715	4.7	2/13/2008
Parker	80138	151	276	5.0	2/7/2008
Parker	80138	258	607	5.2	1/30/2008
Parker	80138	217	563	5.3	1/10/2008
Parker	80138	73	197.2	5.5	2/7/2008
Parker	80138	238	639	5.6	1/10/2008
Parker	80134	367	929	5.7	1/10/2008

Location	Zip	Hardness (mg/L)	Conductivity (µS/cm)	Nitrate (NO_3) (mg/L)	Sample Date
Parker	80138	169	386	5.9	2/20/2008
Parker	80138	224	529	5.9	1/30/2008
Parker	80138	327	759	6.3	3/13/2008
Parker	80138	230	560	7.2	2/13/2008
Parker	80138	176	444	8.1	2/12/2008
Parker	80138	461	948	8.5	1/10/2008
Parker	80138	368	857	8.8	2/28/2008
Parker	80138	212	557	9.1	2/20/2008
Parker	80138	214	509	9.6	2/20/2008
Parker	80138	276	752	10.1	1/16/2008
Parker	80138	324	737	11	2/12/2008
Parker	80138	286	634	12	1/15/2008
Parker	80134	365	803	16	3/26/2008
Parker	80138	175	444	17	3/6/2008
Parker	80138	315	775	25	2/28/2008
Parker	80138	864	2100	75	2/20/2008
Sedalia	80135	49	146	Non-Detect	10/9/2007
Sedalia	80135	103	249	Non-Detect	10/9/2007
Sedalia	80135	109	261	Non-Detect	10/9/2007
Sedalia	80135	114	293	Non-Detect	10/9/2007
Sedalia	80135	124	292	Non-Detect	10/9/2007
Sedalia	80135	171	395	Non-Detect	10/9/2007
Sedalia	80135	2300	3490	Non-Detect	10/9/2007
Sedalia	80135	1	199.6	Non-Detect	12/4/2007
Sedalia	80135	72	231	Non-Detect	12/4/2007
Sedalia	80135	107	202	Non-Detect	12/4/2007
Sedalia	80135	111	228	Non-Detect	12/4/2007
Sedalia	80135	123	274	Non-Detect	12/4/2007
Sedalia	80135	125	320	Non-Detect	3/20/2008
Sedalia	80135	126	280	Non-Detect	3/20/2008
Sedalia	80135	140	747	Non-Detect	12/4/2007
Sedalia	80135	178	1014	Non-Detect	12/4/2007
Sedalia	80135	252	596	Non-Detect	12/4/2007
Sedalia	80135	421	1773	Non-Detect	3/14/2008
Sedalia	80135	930	4070	Non-Detect	1/9/2008
Sedalia	80135	23	109	0.41	10/18/2007
Sedalia	80135	103	226	0.43	10/18/2007
Sedalia	80135	40	103.1	0.49	12/4/2007
Sedalia	80135	43	116.1	0.55	12/4/2007
Sedalia	80135	86	225	0.59	2/19/2008
Sedalia	80135	81	208	0.65	10/18/2007
Sedalia	80135	51	119.0	1.3	12/4/2007
Sedalia	80135	122	270	1.5	1/9/2008
Sedalia	80135	99	239	2.1	10/9/2007
Sedalia	80135	72	169.8	3.4	1/9/2008
Sedalia	80135	242	538	7.9	12/4/2007

E.2 Frequency Distribution of Nitrate Samples in Douglas County, n=295

Figure 3 **Frequency Distribution of Nitrate Samples, Douglas County, n = 295**



Appendix F

F.1 Map of Well Sample Locations and Nitrate Concentrations