Appendix M

Monitored Natural Attenuation Evaluation for 100-F/IU Groundwater Contaminants of Concern

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Contents

M1 Introduction M-1
M1.1 Purpose M-1
M1.2 MNA Regulatory Guidance M-1
M1.3 Criteria for Selecting MNA as a Remedy M-2
M1.4 Remediation of Groundwater Contaminant Sources M-3
M1.5 COC Plume Description M-7
M2 Natural Attenuation Processes M-9
M2.1 Degradation Processes M-11
M2.1.1 Biodegradation M-11
M2.1.2 Abiotic Degradation M-16
M2.1.3 Radioactive Decay M-20
M2.2 Non-degrading Processes M-20
M2.2.1 Dispersion M-20
M2.2.2 Diffusion M-21
M2.2.3 Sorption M-21
M2.2.4 Volatilization M-22
M2.2.5 Groundwater-Surface Water Mixing M-23
M3 Natural Attenuation Assessment for 100-F/IU Groundwater M-27
M3.1 Natural Attenuation Evaluation Data Set M-27
M3.2 Evidence for Declining COC Concentrations M-27
M3.2.1 Types of Attenuation Rates M-28
M3.2.2 Point Decay Calculation Approach M-28
M3.2.3 Cr(VI) Point Attenuation Rates M-30
M3.2.4 Nitrate Point Attenuation Rates M-34
M3.2.5 Trichloroethene Point Attenuation Rates M-40
M3.2.6 Strontium-90 Point Attenuation Rates M-45
M3.2.7 Uncertainties in Point Decay Rate Estimation M-47
M3.3 Evidence for Type(s) of Natural Attenuation Processes M-47
M3.3.1 Oxidation-Reduction Potential M-47
M3.3.2 Dissolved Oxygen M-48
M3.3.3 Nitrate M-48
M3.3.4 Iron M-48
M3.3.5 Sulfate M-52
M3.3.6 Trichloroethene Daughter Products M-52
M3.3.7 Carbon Sources M-52

M3.4 Non-degrading Processes (all COCs) M-53
M3.5 Evaluation of Potentially Toxic and/or Mobile Transformation Products M-54
M3.6 Uncertainties and Data Gaps M-54
M4 Summary and Conclusions M-55
M5 References M-61

Tables

Table M1-1. 100-F/IU Groundwater Contaminant Source Remedial Action Summary M-5
Table M1-2. Groundwater Contaminant Plume Evaluated in the 100-F/IU RI/FS M-8
Table M2-1. Natural Attenuation Processes M-9
Table M2-2. Initial Dispersivity Values used for 100 Area Groundwater Transport Model M-21
Table M2-3. Mobility of Vadose Zone Contaminants for 100-F/IU Groundwater COCs M-22
Table M3-1. Cr(VI) and Total Chromium Attenuation Rates Estimated Using Point Decay Method . M-29
Table M3-2. Nitrate Attenuation Rates Estimated Using Point Decay Method M-40
Table M3-3. Trichloroethene Attenuation Rates Estimated Using Point Decay Method M-42
Table M3-4. Strontium-90 Attenuation Rates Estimated Using Point Decay Method M-45
Table M3-5. Input Parameter Values for Saturated Zone Groundwater Transport Simulations M-53
Table M4-1. Remedial Action Timeframes Estimated Using Numerical Modeling vs Decay Factors M-56

Figures

Figure M1-1. Location of Waste Sites with Groundwater COC Contaminated Soil M-4
Figure M1-2. 100-F/IU Groundwater Contaminant Plume Distribution Evaluated in the 100-F/IU RI/FS M-7
Figure M2-1. Aquifer Redox Zones in a Plume Containing an Organic Carbon Source M-12
Figure M2-2. Reductive Dechlorination Pathway for Trichloroethene M-14
Figure M2-3. Potential Chloroethene Abiotic Degradation Pathways M-19
Figure M2-4. Schematic of Principal Features of Groundwater-Surface Water Mixing Zone M-24
Figure M2-5. Hexavalent Chromium in 100-F Aquifer Tubes M-25
Figure M3-1. Location of Monitoring Wells Used for Cr(VI) Point Decay Attenuation Rate M-30
Figure M3-2. Cr(VI) Concentration Trends for Point Decay Attenuation Rate Monitoring Wells ... M-31
Figure M3-3. Ln Transformed Cr(VI) Concentration Trends for Point Decay Attenuation Rate Monitoring Wells M-33
Figure M3-4. Location of Monitoring Wells Used for Nitrate Point Decay Attenuation Rate M-34
Figure M3-5. Nitrate Concentration Trends for Point Decay Attenuation Rate – East to West Monitor Well Transect M-36
Figure M3-6. Ln Transformed Nitrate Concentration Trends for Point Decay Attenuation Rate – East to West Monitor Well Transect M-37

Figure M3-7. Nitrate Concentration Trends for Point Decay Attenuation Rate – North to South Monitor Well Transect M-38
Figure M3-8. Ln Transformed Nitrate Concentration Trends for Point Decay Attenuation Rate – North to South Monitor Well Transect M-39
Figure M3-9. Location of Monitoring Wells used for Trichloroethene Point Decay Attenuation Rate M-41
Figure M3-10. Trichloroethene Concentration Trends for Point Decay Attenuation Rate M-43
Figure M3-11. Ln Transformed Trichloroethene Concentration Trends for Point Decay Attenuation Rate M-44
Figure M3-12. Location of Monitoring Well Used for Strontium-90 Point Decay Attenuation Rate M-45
Figure M3-13. Strontium-90 Concentration Trends for Point Decay Attenuation Rate M-46
Figure M3-14. Groundwater ORP in Vicinity of Cr(VI) Plume M-49
Figure M3-15. Groundwater ORP in Vicinity of Nitrate Plume M-50
Figure M3-16. Groundwater ORP in Vicinity of Trichloroethene Plume M-51
Figure M4-1. Cr(VI) Concentration Statistics – All Alternatives M-57
Figure M4-2. Nitrate: Concentration Statistics – All Alternatives M-58
Figure M4-3. Trichloroethene: Concentration Statistics – All Alternatives M-59
Figure M4-4. Strontium-90: Concentration Statistics – All Alternatives M-60

Attachments

1. Natural Attenuation Evaluation Data Set
2. Decay Regression Analysis

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Terms

ac	acre
BSZ	bank storage zone
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
Cis-DCE	Cis 1,2-dichloroethene
COC	Contaminant of Concern
Cr(VI)	hexavalent chromium
CSIA	Compound specific isotope analysis
DO	Dissolved oxygen
EPA	U.S. Environmental Protection Agency
Fe	iron
Fe(II)	Ferrous iron
Fe(III)	Ferric iron
FS	Feasibility Study
ft	Foot or feet
GPM	gallons per minute
GW	groundwater
Ha	Hectare
HEIS	Hanford Environmental Information System
IC	Institutional Controls
ISS	Interim safe storage
K_d	Soil:water distribution coefficient
L	liter
Ln	Natural logarithm
M	meter
mg	milligram
Mn	manganese
MNA	Monitored Natural Attenuation
mV	millivolt
NA	Natural attenuation

NCP	National Contingency Plan
ORP	Oxidation-reduction potential
OU	Operable Unit
pCi	Picocuries
PNNL	Pacific Northwest National Laboratory
PRG	Preliminary remediation goal
Sr-90	Strontium-90
SW	Surface water
TCE	Trichloroethene
Trans-DCE	Trans 1,2-dichlorethene
VC	Vinyl chloride

M1 Introduction

This appendix provides additional information on the natural attenuation (NA) processes affecting the fate and transport of contaminants of concern (COCs) present in 100-F/IU groundwater. This information supplements the monitored natural attenuation (MNA) remedial technology screening and the detailed evaluation of Alternative GW-2 – Institutional Controls (ICs) and MNA presented in Section 8.3 and Section 9.2, respectively, of *Remedial Investigation and Feasibility Study for the 100-FR-1, 100-FR-2, 100-IU-2, 100-IU-6, and 100-FR-3 Operable Units* (DOE/RL-2010-98), hereinafter called 100-F/IU RI/FS.

The COCs present in 100-F/IU groundwater include: hexavalent chromium [Cr(VI)], nitrate, trichloroethene, and strontium-90. The NA processes discussed in this appendix include: biodegradation, abiotic degradation, radioactive decay, adsorption, diffusion, and dispersion. Direct and indirect evidence presented in this appendix shows that each of these processes are occurring in the 100-F/IU unconfined aquifer, and collectively provide an important contribution to the overall reduction of COC concentrations in groundwater.

M1.1 Purpose

The purpose for this assessment is to present the results of a site-specific analysis that has been conducted for evaluation of Alternative GW-2: ICs and MNA as a viable remedial action alternative for 100-F/IU groundwater. Alternative GW-2 uses ICs to prevent exposure to contaminated groundwater until NA processes reduce COC concentrations to preliminary remedial goals (PRGs). A comprehensive groundwater monitoring, data evaluation and reporting program would also be implemented under Alternative GW-2, if selected, to confirm that NA processes are reducing COC concentrations in accordance with expectations.

M1.2 MNA Regulatory Guidance

The information presented in this appendix was prepared using the following guidance:

1. OSWER Directive 9200.4-17P, *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*
2. EPA/600/R-07/139, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 1 – Technical Basis for Assessment*
3. EPA/600/R-07/140, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 2 – Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium*
4. EPA/600/R-10/093, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 3 – Assessment for Radionuclides Including Tritium, Radon, Strontium, Technetium, Uranium, Iodine, Radium, Thorium, Cesium, and Plutonium-Americium*
5. EPA/540/S-02/500, *Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies*
6. ITRC, 2010, *A Decision Framework for Applying Monitored Natural Attenuation Processes to Metals and Radionuclides in Groundwater*
7. EPA 600/R-11/204, *An Approach for Evaluating the Progress of Natural Attenuation in Groundwater*

8. EPA 600/R-09/115, *Identification and Characterization Methods for Reactive Minerals Responsible for Natural Attenuation of Chlorinated Organic Compounds in Ground Water*

M1.3 Criteria for Selecting MNA as a Remedy

According to OSWER Directive 9200.4-17P, three types of site-specific information or "evidence" should be assessed before selecting MNA as a stand-alone or component of a broader sitewide remedy. The three lines of evidence include the following:

1. Historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points. In the case of a groundwater plume, decreasing concentrations should not be solely the result of plume migration. In the case of inorganic contaminants, the primary attenuating mechanism should also be understood.

2. Hydrogeologic and geochemical data that can be used to demonstrate **indirectly** the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels. For example, characterization data may be used to quantify the rates of contaminant sorption, dilution, or volatilization, or to demonstrate and quantify the rates of biological degradation processes occurring at the site.

3. Data from field or microcosm studies (conducted in or with actual contaminated site media) which **directly** demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern (typically used to demonstrate biological degradation processes only).

Unless EPA or the implementing state agency determines that historical data (Number 1 above) are of sufficient quality and duration to support a decision to use monitored natural attenuation, EPA expects that data characterizing the nature and rates of natural attenuation processes at the site (Number 2 above) should be provided. Where the latter are also inadequate or inconclusive, data from microcosm studies (Number 3 above) may also be necessary.

In general, more supporting information may be required to demonstrate the efficacy of MNA at those sites with contaminants that do not readily degrade through biological processes (e.g. inorganics), at sites with contaminants that transform into more toxic and/or mobile forms than the parent contaminant, or at sites where monitoring has been performed for a relatively short period of time. The amount and type of information needed for such a demonstration will depend upon a number of site-specific factors, such as the size and nature of the contamination problem, the proximity of receptors and the potential risk to those receptors, and other physical characteristics of the environmental setting (e.g., hydrogeology, ground cover, or climatic conditions).

Monitored natural attenuation is appropriate as a remedy: 1) where it is protective of human health and the environment (e.g., no complete exposure pathways), 2) when it can be shown that it is capable of achieving a site's remedial action objectives (RAOs) within a timeframe that is reasonable compared to other alternatives, and 3) where it meets the applicable *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedy selection criteria.

Selection of MNA as a sole remedy or as a component of a broader alternative may be appropriate under the following circumstances (OSWER Directive 9200.4-17P):

- When the contaminants present in soil or groundwater can be effectively remediated by NA processes.

- When the resulting transformation products do not pose a greater risk than the parent contaminants.
- When the nature and distribution of contaminant sources have been or can be adequately controlled.
- When the plume is relatively stable, and the potential for the environmental conditions that influence plume stability and natural attenuation processes will not change over time.
- Where the impact of existing, ongoing, or proposed active remediation measures will not adversely affect NA processes.
- Where drinking water supplies, other groundwaters, surface waters, ecosystems, sediments, air, or other environmental resources would not be adversely impacted as a consequence of selecting MNA as a remediation option.
- When the estimated remediation timeframe is reasonable compared to that for other remedial action options.
- When the current and projected demand for the affected aquifer is commensurate with the time period that the MNA remedy will remain in effect (including the availability of other water supplies and the loss of availability of other groundwater resources as a result of contamination from other sources).
- Where site-specific vehicles for implementing, monitoring, and enforcing ICs are available.

With respect to the above factors, the most important considerations regarding the suitability of MNA as a remedy include whether the groundwater contaminant plume is growing, stable, or shrinking, and whether there are risks posed to human and environmental receptors by the contamination. MNA may not be appropriate where such an approach would result in significant contaminant migration or unacceptable risk to receptors. Sites where the contaminant plumes are no longer increasing in size (e.g., stable) or are shrinking in size are the most appropriate candidates for a MNA remedy.

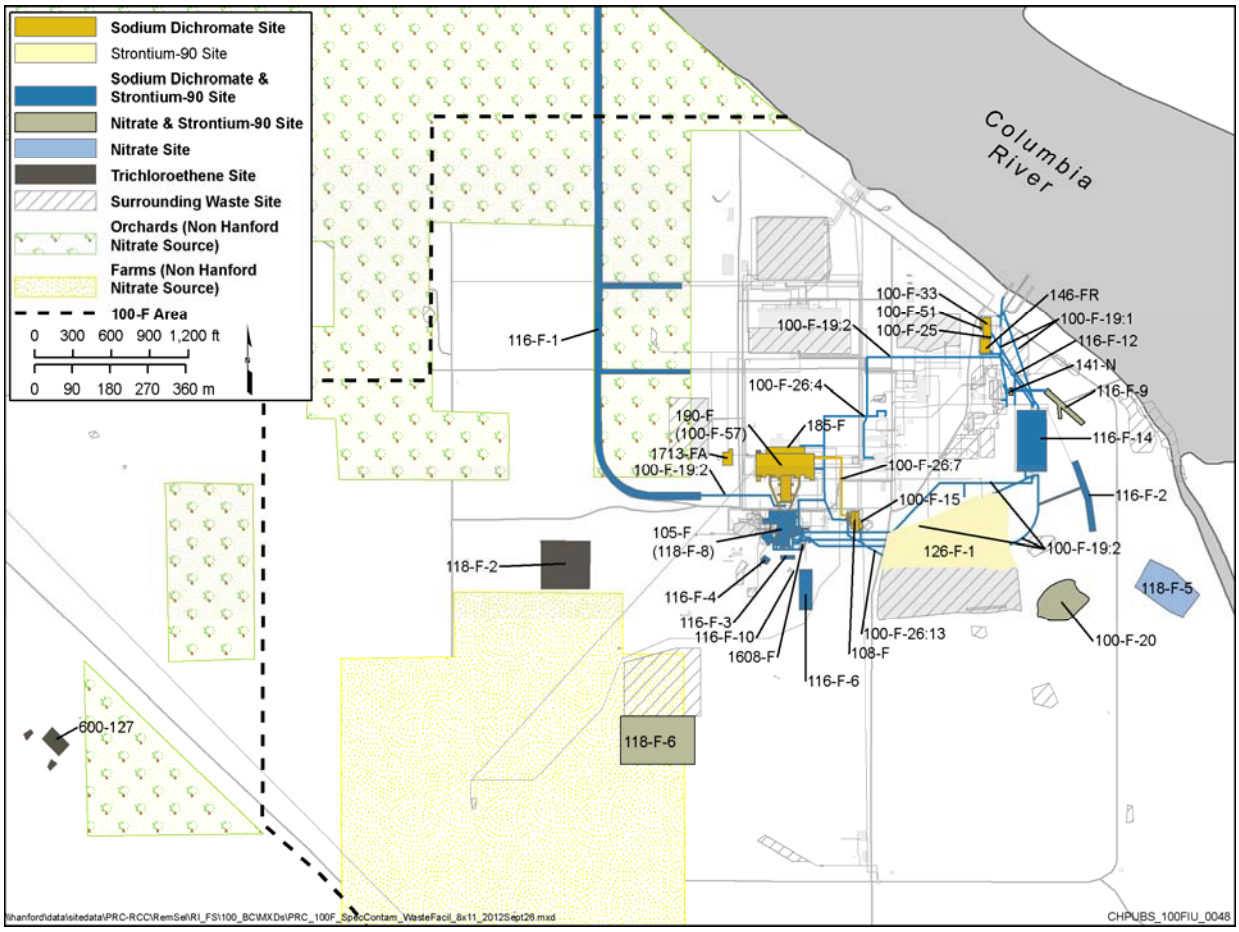
M1.4 Remediation of Groundwater Contaminant Sources

Remediation of known and potential groundwater contaminant sources is a key element of a MNA-based remedy. Remediation of groundwater contaminant sources in 100-F/IU is complete. Approximately 977 million kilograms (kg) (1.07 million tons) of contaminated soil and debris have been removed and disposed at the Environmental Restoration Disposal Facility. The remediated waste sites within 100-F/IU consist mainly of basins, trenches, ditches, cribs, ponds, burial grounds, and unplanned releases. The location of waste sites where Cr(VI), nitrate, strontium-90 and trichloroethene contaminated soil have been removed is shown on Figure M1-1. Table M1-1 summarizes remediation accomplishments.

Remediation of Cr(VI) contaminated material included excavation and disposal of 140,500 metric tons of Cr(VI) contaminated soil and 615,000 metric tons of Cr(VI) and strontium-90 contaminated soil (755,000 metric tons total) from 18 waste sites. Additionally, 200 gallons of concentrated sodium dichromate liquid from the 100-F-26:7 waste site was removed, treated and disposed. Remediation of Cr(VI) contaminated waste sites was started in 1993 and completed in 2011.

Remediation of strontium-90 contaminated material included excavation and disposal of 116,200 metric tons of strontium-90 contaminated soil, 615,000 metric tons of strontium-90 and Cr(VI) contaminated soil, and 112,000 metric tons of strontium-90 and nitrate contaminated soil (843,200 metric tons total) from 21 waste sites. Remediation of strontium-90 contaminated waste sites started in 1993 and was completed in 2011.

Remediation of nitrate contaminated material included excavation and disposal of 78,500 metric tons of nitrate contaminated soil and 112,000 metric tons of nitrate and strontium-90 contaminated soil (190,500 metric tons total) from five waste sites. Remediation of nitrate-contaminated sites started in 2001 and was completed in 2007.



Source: *Remedial Investigation/Feasibility Study for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (Chapter 1, Figure 1-5).

Figure M1-1. Location of Waste Sites with Groundwater COC Contaminated Soil

Remediation of trichloroethene-contaminated material included excavation and disposal of 80,000 metric tons of soil from two waste sites. Remediation of these two waste sites was performed between 2006 and 2007, and in 2010.

Table M1-1. 100-F/IU Groundwater Contaminant Source Remedial Action Summary

Waste Site	Cr (VI)	Strontium-90	Nitrate	Trichloro-ethene	Excavation Mass (metric tons)	Remediation Start Date	Remediation End Date	WSRF	CVP
100-F-25	√				809	12-Apr-03	12-Apr-03	2003-021	CVP-2003-00010
100-F-26:7	√				2,221*	12-Jan-11	13-Apr-11	2011-088	N/A
100-F-33	√				2,024	5-Aug-05	8-Aug-05	2006-021	N/A
100-F-51	√				398	20-Dec-10	20-Jan-11	2011-085	N/A
100-F-57	√				137,242	6-Dec-10	9-Apr-12	2012-010 & 2012-058	N/A
100-F-15		√			Removed with D&D of the 108-F Facility	Removed with D&D of the 108-F Facility	Removed with D&D of the 108-F Facility	2002-040	CVP-2002-00001
126-F-1		√			111,313	5-Oct-01	17-Jun-02	2002-058	CVP-2002-00004
100-F-19:1 and 116-F-12	√	√			62,099	Jul-00	7-Aug-01	2001-099	CVP-2001-00002
100-F-19:2	√	√			43,373	Aug-01	Dec-02	2003-022	CVP-2001-00003
100-F-26:4	√	√			1,980	12-Feb-07	5-Jan-11	2007-035	N/A
100-F-26:12	√	√			6,580	11-Jan-07	4-Oct-07	2007-034	N/A
100-F-26:13	√	√			1,320	5-Feb-07	24-Aug-07	2005-011	N/A
116-F-1	√	√			76,469	Jun-02	Dec-02	2003-007	CVP-2002-00009
116-F-14	√	√			233,707	27-Jul-00	16-Jan-02	2002-050	CVP-2001-00009
116-F-2	√	√			124,534	22-Nov-00	17-Apr-02	2002-057	CVP-2001-00005
116-F-3	√	√			5,738	Oct-02	Jan-03	2003-005	CVP-2002-00008
116-F-4	√	√			1,560	20-Sep-93	10-Nov-93	2001-039	CVP-2001-00006

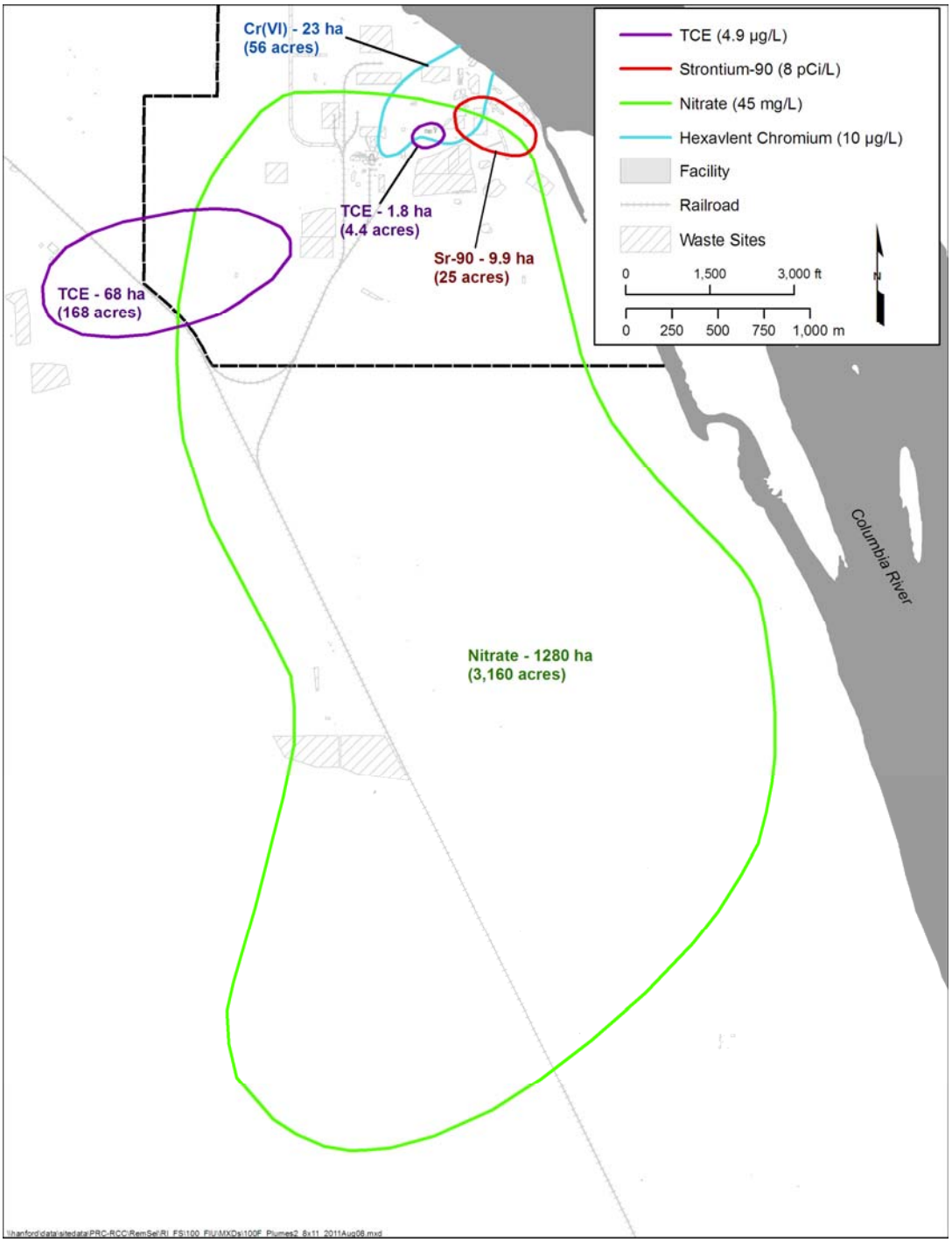
Table M1-1. 100-F/IU Groundwater Contaminant Source Remedial Action Summary

Waste Site	Cr (VI)	Strontium-90	Nitrate	Trichloro-ethene	Excavation Mass (metric tons)	Remediation Start Date	Remediation End Date	WSRF	CVP
116-F-6	√	√			32,156	Oct-02	Nov-02	2003-006	CVP-2002-00010
118-F-8:1&3	√	√			22,132	1999	Dec-03	2003-051	CVP-2003-00017
118-F-8:4	√	√			3,491	14-Mar-07	22-Jun-07	2007-027	CVP-2007-00004
132-F-1		√			1,591	9-Aug-05	12-Aug-05	2006-029	N/A
141-C		√			1,993	Not documented	Not documented	2006-027	N/A
100-F-2		√			1,269	5-Dec-01	9-Jan-02	2002-039	CVP-2001-00001
100-F-20		√	√		11,953	5-Dec-05	8-Aug-06	2006-060	CVP-2006-00009
116-F-9		√	√		49,405	4-Sep-01	25-Mar-02	2002-056	CVP-2001-00008
118-F-6		√	√		50,710	12-Dec-05	13-Dec-07	2008-018	CVP-2008-00001
116-F-10			√		848	22-Oct-02	22-Oct-02	2003-003	CVP-2003-00003
118-F-5			√		77,687	28-Nov-05	29-Aug-07	2007-022	CVP-2007-00003
118-F-2				√	36,895	17-Jan-06	8-Aug-07	2007-021	CVP-2007-00002
600-127				√	43,163	Jan-10	Jun-10	2004-064	N/A

Note: Complete citations for Cleanup Verification Packages referenced in this table are provided in Section M5.
* Includes 200 gal concentrated sodium dichromate liquid
N/A = not applicable

M1.5 COC Plume Description

Four groundwater plumes with COC concentrations above PRGs are present in 100-F/IU (Figure M1-2). Table M1-2 summarizes the area and estimated volume of contaminated groundwater associated with each plume based on the information presented in Figure M1-2.



Source: DOE/RL-2010-98, *Remedial Investigation/Feasibility Study for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units.*

Figure M1-2. 100-F/IU Groundwater Contaminant Plume Distribution Evaluated in the 100-F/IU RI/FS

Table M1-2. Groundwater Contaminant Plume Evaluated in the 100-F/IU RI/FS

COC Plume	EPC[a] (2010)	Maximum Detected (2011)	Estimated Plume			
			2011 Data	2010 Data		
			Size[b]	Size[c]	Volume[c]	COC Mass
Cr(VI) > 10 µg/L[f]	20 µg/L	41.6 µg/L	17 ha (42 acre)	23 ha (56 acre)	46 million gallons	16.5 kg[d] 12.9 kg[e]
Cr(VI) > 48 µg/L			0 ha (0 acre)	12.8 ha (31 acre)	25.5 million gallons	16.5 kg[d] 12.9 kg[e]
Strontium-90	3.3 pCi//L	285 pCi//L	7.2 ha (17.8 acre)	9.9 ha (25 acre)	21 million gallons	2.1 Ci[d] 2.0 Ci[e]
Trichloroethene	11 µg/L	14 µg/L	70 ha (173 ac)	70 ha (172.4 ac)	140 million gallons	8.0 kg[d] 2.9 kg[e]
Nitrate [g]	109,500 µg/L	201,000 µg/L	1,060 ha (2,619 ac)	1,280 ha (3,162 ac)	2.6 billion gallons	1,200,000 kg [d] 760,000 kg [e]

Source: DOE/RL-2010-98, *Remedial Investigation/Feasibility Study for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*.
a. EPC = exposure point concentration from human health risk assessment.
b. Size based on PRGs of 10 µg/L and 48 µg/L for Cr(Vi), 8 pCi/L for strontium-90, 4.9 µg/L for trichloroethene and 45,000 µg/L for nitrate.
c. Volume estimated by multiplying plume area by porosity of 0.18 and average plume thickness of 14 ft.
d. Includes all COC mass contained within the area enclosed by 0.1 * PRG.
e. Includes all COC mass contained within the area enclosed by the PRG.
f. A majority of the Cr(VI plume lies inland of the river where cleanup actions are not required to meet the 10 µg/L PRG except where groundwater discharges to surface water.
g. Although a 45,000 µg/L PRG was used to estimate the volume of nitrate contaminated groundwater present, the Model Toxics Control Act-Cleanup risk thrhold for nitrate is 113,600 µg/L.

M2 Natural Attenuation Processes

Natural attenuation processes include degradation and non-degrading processes (Table M2-1) that reduce risk to human health and the environment as follows (OSWER Directive 9200.4-17P):

1. Transformation of contaminants to a less toxic form.
2. Reduction of contaminant concentrations whereby exposure levels are reduced.
3. Reduction of contaminant mobility and bioavailability.

While NA processes that degrade/destroy contaminants are preferable (OSWER Directive 9200.4-17P), non-degrading processes must not be overlooked because they are frequently the dominant processes at many CERCLA sites.

For the purposes of this appendix, *degradation* processes break down an organic, inorganic, or radionuclide molecule converting the parent compound to less toxic or less mobile daughter products. Non-degrading processes do not alter the parent compound; they reduce its concentration through mixing of contaminated groundwater with uncontaminated groundwater and/or mass transfer (partitioning) of contaminants from groundwater to soil and/or groundwater to soil vapor. The degree to which a degradation or non-degrading process affects contaminant concentrations is determined by the physical and chemical properties of both the contaminant and the aquifer matrix.

The following subsections describe the degradation and non-degrading processes affecting COCs in 100-F/IU groundwater, and how the presence of these processes can be ascertained from direct or indirect evidence.

Table M2-1. Natural Attenuation Processes

Process	Description	Dependencies	Effect
Degrading Processes			
Biodegradation	Microbial mediated oxidation-reduction reactions that degrade contaminants. Generally, only organic contaminants are biodegraded; but inorganic contaminants may be transformed to other valence states during the biodegradation process, rendering them less mobile and/or toxic.	Dependent on ground-water geochemistry, microbial population and contaminant properties. Biodegradation can occur under aerobic and/or anaerobic conditions.	May ultimately result in complete degradation of contaminants. Typically the most important process acting to truly reduce contaminant mass.
Abiotic Degradation	Chemical transformations that degrade organic and inorganic contaminants without microbial facilitation.	Dependent on contaminant properties and ground-water geochemistry.	Can result in partial or complete degradation of contaminants. Rates typically much slower than for biodegradation.
Radioactive Decay	Spontaneous disintegration of a radionuclide accompanied by the emission of ionizing radiation in the form of alpha or beta particles or gamma rays	Half-life of parent radionuclide and daughter products. Half-life of strontium-90, which decays to yttrium-90, is 28.8 years.	Results in transformation and eventual destruction of radionuclide contaminants.

Table M2-1. Natural Attenuation Processes

Process	Description	Dependencies	Effect
Non-Degrading Processes			
Advection	Movement of contaminant by bulk groundwater movement.	Dependent on aquifer properties, mainly hydraulic conductivity and effective porosity, and hydraulic gradient. Independent of contaminant properties.	Primary contaminant transport mechanism that in conjunction with dispersion acts to reduce contaminant concentrations in the subsurface.
Dispersion	Fluid mixing due to groundwater movement and aquifer heterogeneities.	Dependent on aquifer properties and scale (distance from source or point-of-release). Independent of contaminant properties.	Causes longitudinal, transverse, and vertical spreading of the plume thereby reducing contaminant concentrations.
Diffusion	Spreading and dilution of contaminant due to molecular diffusion.	Dependent on contaminant properties and concentration gradients. Described by Fick's Laws.	Results in mass transfer from areas of relatively high concentration to areas of relatively low concentration. Less important, relative to dispersion, in most aquifer settings except within fine-grained zones.
Sorption	Reaction between aquifer matrix and contaminant whereby contaminant mass partitions from groundwater to soil particles comprising aquifer matrix.	Dependent on aquifer matrix properties (organic carbon and clay mineral content, bulk density, specific surface area, and porosity) and contaminant properties (solubility, hydrophobicity, octanol-water partitioning coefficient).	Reduces contaminant concentrations in groundwater while increasing concentrations on aquifer sediments. May or may not be reversible. Desorption rates are generally slower. Reduces contaminant transport rates.
Volatilization	Volatilization of contaminants dissolved in ground water into the vapor phase (soil gas).	Dependent on the chemical's vapor pressure and Henry's Law constant.	Removes contaminants from groundwater and transfers them to soil gas.
Mixing (Dilution)	Movement of water across the water table into the saturated zone. Also includes mixing with surface water in a zone of interaction.	Dependent on aquifer matrix properties, depth to ground-water, evapotranspiration, and recharge (rainfall/snowmelt, irrigation or other sources) rates or river stage relative to water table.	Causes dilution of the contaminant plume and may replenish electron acceptor concentrations, especially dissolved oxygen.

Modified from EPA/600/R-98/128, *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water*.

M2.1 Degradation Processes

The degradation processes affecting COCs in 100-F/IU groundwater include: biodegradation, abiotic degradation, and radioactive decay.

M2.1.1 Biodegradation

Microorganisms in the subsurface environment obtain energy for growth and activity by harvesting the energy that is released though coupled oxidation and reduction reactions. Under aerobic conditions (dissolved oxygen [DO] concentrations greater than 0.5 mg/L), bacteria couple the oxidation of naturally occurring or anthropogenic organic carbon with the reduction of oxygen where the organic carbon serves as the electron donor and DO as the electron acceptor. In the absence of dissolved oxygen (DO less than 0.5 mg/L), anaerobic microorganisms use naturally occurring or anthropogenic carbon as the electron donor and nitrate, manganese (IV), iron (III), sulfate, carbon dioxide, and chlorinated solvents as the electron acceptor.

The subsurface contains a diverse community (consortia) of microorganisms. In a consortium, distinct populations of organisms carry out different specialized reactions that, when combined, may lead to the complete mineralization of a contaminant. The metabolic interaction between different organisms can be complex and may be so tightly linked, under a given set of conditions, that consortia may be mistakenly identified as a single species.

The release of a soluble, degradable contaminant into groundwater initiates a series of complex and inter-related responses by the microorganism community. These communities are frequently differentiated by the dominant electron acceptor process. As electron acceptors and nutrients are depleted by microbial activity during the biodegradation process, the redox potential of a contaminated aquifer decreases. This results in a succession of microorganism communities adapted to specific redox regimes and electron acceptors.

Biodegradation causes measurable changes in groundwater chemistry. During aerobic biodegradation, oxygen is reduced to water, and dissolved oxygen concentrations decrease. During anaerobic biodegradation, there are a number of different electron acceptor processes that occur in the following order because each process is less energetically favorable to the microorganism consortium:

1. Denitrification. Under this process, nitrate is stepwise reduced to nitrite (NO_2^-), nitric oxide (N_2O), nitrous oxide (NO), and eventually nitrogen gas (N_2), resulting in decreased nitrate concentrations in groundwater.

2. Manganese Reduction. Under this process, solid phase manganeic [Mn(IV)] manganese is reduced to manganeous [Mn(II)] manganese resulting in Mn(II) concentration increases in groundwater.

3. Iron Reduction. Under this process, solid phase ferric (Fe[III]) is reduced to Fe(II), resulting in Fe(II) concentration increases in groundwater.

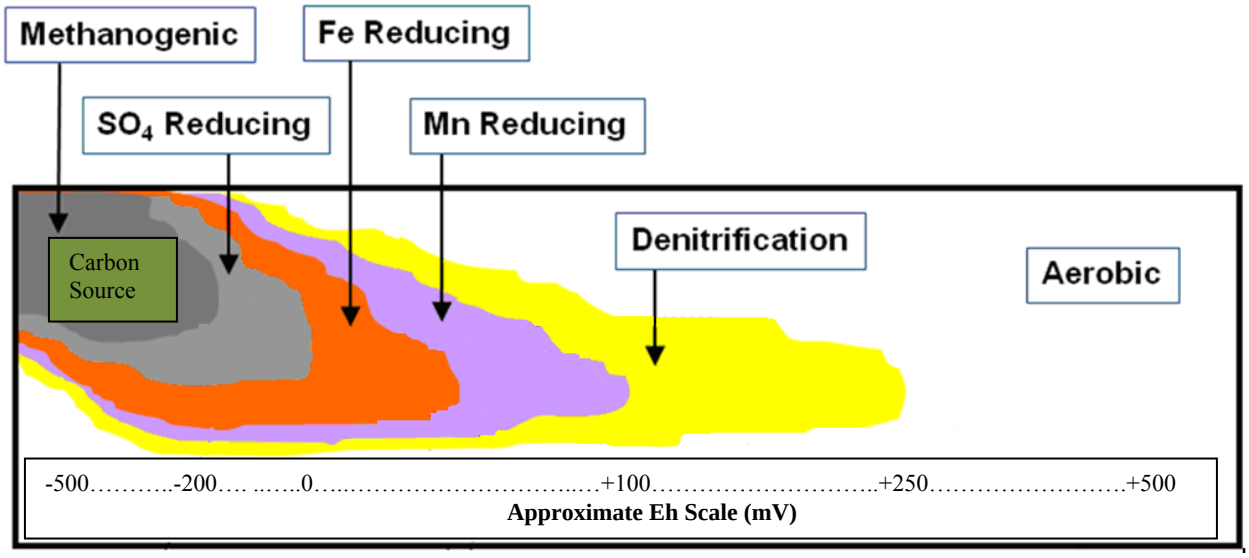
4. Sulfate Reduction. Under this process, sulfate is reduced to sulfide (HS^-)/hydrogen sulfide (H_2S), resulting in decreased sulfate concentrations and increased sulfide concentrations in groundwater.

5. Methanogenesis. Under this process, carbon dioxide, or chlorinated solvents, serve as the electron acceptor, resulting in increased methane concentrations in groundwater.

During aerobic and anaerobic (denitrification, manganese reduction, iron reduction, and sulfate reduction) biodegradation, the total alkalinity of the groundwater increases as a result of the formation of carbon dioxide.

As each subsequent electron acceptor is used, the groundwater becomes more reduced; and the redox potential of the water decreases, resulting in different oxidation-reduction (redox) zones (Figure M2-1). In reality, these zones are not defined by sharp boundaries but rather regions of transition; so within a contaminated aquifer there may be multiple redox regimes.

The primary driving force behind the redox changes are the microbial mediated oxidation-reduction reactions. Redox measured in the field, in a flow through cell while purging a monitoring well before sampling, can be used as a general indicator of which oxidation-reduction reactions are occurring at a site.



Source: Modified from *A Decision Framework for Applying Monitored Natural Attenuation Processes to Metals and Radionuclides in Groundwater* (ITRC, 2010).

Figure M2-1. Aquifer Redox Zones in a Plume Containing an Organic Carbon Source

The redox measured in the field using an oxidation reduction potential (ORP) electrode is termed the Eh. The approximate Eh values correlating to different redox zones are shown on Figure M2-1. Within these different redox zones, there is potential for transformation of Cr(VI), nitrate and trichloroethene present in 100-F/IU groundwater to less toxic compounds under favorable geochemical conditions.

M2.1.1.1 Biotransformation – Cr(VI)

Hexavalent chromium does not undergo biodegradation (e.g. chromium is not destroyed) but may experience biotransformation where Cr(VI) is reduced to trivalent chromium, which has low mobility and toxicity under typical environmental conditions. The redox conditions that favor Cr(VI) biotransformation to trivalent chromium are similar to those where nitrate, iron, and sulfate reduction occur as indicated through isolation of microbial strains (*Microbial Community Changes During Sustained Cr(VI) Reduction at the 100H Site in Hanford, WA* [Chakraborty et al., 2010]; "Physiological and Transcriptional Studies of Cr(VI) Reduction under Anaerobic and Denitrifying Conditions by an Aquifer-Derived Pseudomonad" [Han et al., 2010]).

Abiotic transformation where Cr(VI) is reduced in the presence of aqueous Fe(II), solid-phase Fe(II), aqueous and solid phase sulfide, and naturally occurring or anthropogenic carbon is expected to be a more important transformation process in most environmental settings unless conditions are enhanced via organic substrate injections. Additional information on abiotic transformation of Cr(VI) is presented in Section M2.1.2.

How Measured – Evidence

Evidence of microbial transformation of Cr(VI) to trivalent chromium may be obtained through direct and indirect means and will most likely require a multiple lines-of-evidence approach. Direct evidence includes microbial analysis to identify the presence of microorganisms capable of performing the oxidation - reduction reaction(s) and assessment of chromium stable isotope ratios ($^{53}Cr/^{52}Cr$). The presence of microorganisms capable of performing the transformation of Cr(VI) to trivalent chromium was established through testing performed on 100-H area aquifer sediments (*In Situ Long-Term Reductive Bioimmobilization of Cr(VI) in Groundwater Using Hydrogen Release Compound* [Faybishenko, 2009]). Many of these microorganisms are expected to either be dormant or operating at a low-level of activity as a result of less than favorable conditions. Relative to stable isotope ratios, Cr(VI) reduction causes an enrichment of the lighter isotopes along the transport pathway. Compound specific isotope analysis (CSIA) does not differentiate biodegradation from abiotic reduction (, *A Guide for Assessing Biodegradation and Source Identification of Organic Ground Water Contaminants using Compound Specific Isotope Analysis* (*CSIA)* [EPA 600/R-08/148]); therefore, both microbial and CSIA are necessary to establish the presence of a degradation pathway.

Measurement of Cr(VI) and total chromium concentrations in groundwater throughout the plume also provides direct evidence to calculate first-order decay rates and to determine if concentrations at a particular location are decreasing, increasing, or stable. The latter calculation is performed using the Mann-Kendall statistical test (*Non-parametric Tests Against Trend* [Mann, 1945] *Rank Correlation Methods* [Griffin, 1975]).

Indirect evidence of Cr(VI) biodegradation can be inferred from measurement and evaluation of ORP, DO, Fe(II), sulfide, and total organic carbon concentrations throughout the plume.

M2.1.1.2 Biodegradation - Nitrate

The principal biodegradation process for nitrate is denitrification, a microbial respiratory process where nitrate is used as the terminal electron acceptor and is reduced to nitrogen gas as follows:

$$2NO_3^- + 12H^+ + 10e^- \rightarrow N_2 + 6H_2O$$

The denitrification process includes four intermediate reactions where nitrate is first reduced to nitrite, then nitric oxide, nitrous oxide, and finally nitrogen gas as follows:

$$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

Denitrifying organisms cannot carry out all four intermediate reactions, therefore, a consortia of microorganisms is necessary for complete denitrification to occur.

Anaerobic conditions (DO less than 0.5 mg/L) are essential for denitrification. This correlates to a measured Eh potential of +300 to +350 mV (Reddy and Patrick, 1984). The optimum temperature range for denitrification is from 20 to 35 °C; and the optimum pH is neutral to slightly alkaline, but denitrification can occur over a pH range of 5 to 9 ("Biochemical ecology of nitrification and denitrification" [Focht and Verstraete, 1977]).

There are two distinct classes of denitrifying bacteria: heterotrophic denitrifiers, which use naturally occurring or anthropogenic organic carbon as an electron donor and carbon source; and autotrophic denitrifiers, which use inorganic compounds (e.g., minerals containing reduced sulfur and iron) as electron donors and carbon dioxide as a carbon source.

Denitrification performed by heterotrophic microorganisms (EPA/600/R-07/140) generally proceeds according to:

$$4NO_3^- + 5CH_2O \text{ (organic matter)} \rightarrow 2N_2 + 5HCO_3^- + H^+ + 2H_2O$$

$$8NO_3^- + 5CH_3COO^- \text{(acetate)} + 3H^+ \rightarrow 4N_2 + 10HCO_3^- + 4H_2O$$

Whereas autotrophic denitrification (EPA/600/R-07/140) proceeds as follows:

$$14NO_3^- + 5FeS_2 \text{ (pyrite)} + 4H^+ \rightarrow 7N_2 + 5Fe^{2+} + 10SO_4^{2-} + 2H_2O$$

$$NO_3^- + 5Fe^{2+} + 7H_2O \rightarrow 5FeOOH \text{ (goethite)} + 0.5N_2 + 9H^+$$

How Measured – Evidence

The same approach and information used for obtaining evidence of Cr(VI) reduction to trivalent chromium can be used to assess the presence of denitrifying conditions within an aquifer. This approach includes collection of samples for microbial analysis to identify the presence of heterotrophic and autotrophic microorganisms, CSIA to quantify ^{15}N to ^{14}N ratios (denitrification cause ^{15}N enrichment), and groundwater analysis for heterotrophic (bicarbonate) and autotrophic (sulfate) denitrification byproducts.

Measurement of nitrate concentrations in groundwater throughout the plume also provides direct evidence to calculate first-order decay rates and to determine if concentrations at a particular location are decreasing, increasing or stable. The latter calculation is performed using the Mann-Kendall statistical test.

Indirect evidence of denitrification can be inferred from measurement and evaluation of ORP, DO, Fe(II), sulfide, and total organic carbon concentrations throughout the plume.

M2.1.1.3 Biodegradation of Trichloroethene

Biodegradation of an organic contaminant is generally defined as the process of breaking down the molecule by converting it to cellular biomass, carbon dioxide, and water. During this process intermediate compounds, or daughter products of the parent compound, may be formed. Depending on the characteristics of the daughter products and the degradation environment, the daughter products may be more or less mobile, and more or less toxic than their parent compounds.

The biodegradation of trichloroethene, a 100-F/IU COC, through reductive dechlorination is a widely recognized process. Reductive dechlorination involves the stepwise substitution of hydrogen atoms for chlorine atoms on a chloroethene molecule, resulting in the release of electrons and transformation of trichloroethene to cis 1,2-dichlorethene, then vinyl chloride (VC) and ethene(Figure M2-2). Ethene is further degraded to ethane (CH_4) and/or carbon dioxide and water. Transformation of trichloroethene to trans 1,2-dichloroethene is also possible but less frequently observed.

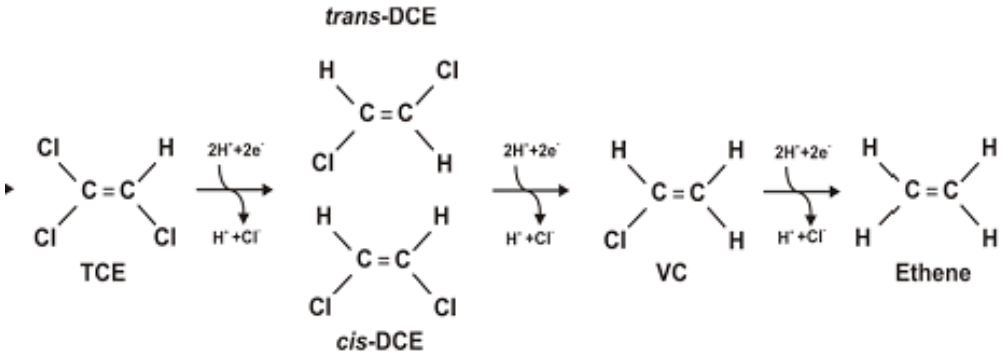


Figure M2-2. Reductive Dechlorination Pathway for Trichloroethene

The following elements are necessary for biodegradation of a chloroethene molecule:

1. A population of "niche" microorganisms to carry out the biodegradation or oxidation – reduction reactions. Microorganims derive energy from the electrons released during these reactions.
2. An adequate supply of nutrients (nitrogen, phosphorus, potassium, and organic carbon) to sustain the microbial population and to serve as electron donors in the oxidation – reduction reactions.
3. A sufficient mass of contaminants in a soluble form to serve as an electron acceptor in the oxidation – reduction reaction.
4. Tolerable variations in temperature, pH, and other geochemical conditions to minimize disruption in the biodegradation reactions.

Deficiencies in one or more of these elements may prevent the reaction, slow its rate, or stall a series of sequential reactions. Deeply anaerobic (reducing) conditions are required for reductive dechlorination of many chlorinated ethenes and competing electron acceptors such as DO, nitrate, nitrite, manganese (IV), ferric iron (III), and sulfate must be substantially depleted.

Three types of environments have generally been identified where biodegradation of chlorinated ethenes occurs (EPA/600/R-98/128, *Technical Protocol for Evaluating Natural Attenuation Of Chlorinated Solvents In Ground Water*):

- Type 1 – characterized by high concentrations of nutrients from anthropogenic sources and absence of competing electron acceptors resulting in relatively rapid reductive dechlorination rates. This type of environment is indicated by strong reducing conditions (Eh < -200 mV) and elevated concentrations of methane (greater than 0.5 mg/L).
- Type 2 – characterized by moderate concentrations of nutrients from natural sources with low concentrations of competing electron acceptors resulting in slower reductive dechlorination rates.
- Type 3 – characterized by low concentrations of nutrients from natural sources and high concentrations of competing electron acceptors (generally DO) resulting in slow rates of reductive dechlorination. DO concentrations greater than 0.5 mg/L, nitrate concentrations greater than 1 mg/L, and sulfate concentrations greater than 20 mg/L are typical of Type 3 conditions.

Another viable degradation pathway for trichloroethene is cometabolism where the degradation is catalyzed by an enzyme or cofactor that is fortuitously produced by the microorganism for other purposes (*Ground-water treatment for chlorinated solvents, In Handbook of Bioremediation* [McCarty and Semprini, 1994]). Cometabolism is best documented in aerobic environments, although it potentially could occur under anaerobic conditions. It has been reported that under aerobic conditions chlorinated ethenes such as trichloroethene, with the exception of perchloroethene, are susceptible to cometabolic degradation ("Progress toward the biological treatment of C1 and C2 halogenated hydrocarbons" [Murray and Richardson, 1993]; *Handbook of Bioremediation* [Vogel, 1994]; *Ground-water treatment for chlorinated solvents, In Handbook of Bioremediation* [McCarty and Semprini, 1994]). *Handbook of Bioremediation* (Vogel, 1994) further elaborates that the rate of cometabolism increases as the degree of dechlorination decreases. During cometabolism, trichloroethene is indirectly transformed by bacteria as they use another substrate to meet their energy requirements.

How Measured – Evidence

The same approach and information used for obtaining evidence of Cr(VI) reduction to trivalent chromium and denitrification can be used to assess the presence of trichloroethene reductive

dechlorination processes within an aquifer. This includes microbial and CSIA analysis, and measurement of trichloroethene concentrations in groundwater throughout the plume to calculate decay rates and to assess plume stability using the Mann-Kendall statistical test.

Additionally, the presence of trichloroethene daughter products (cis 1,2-dichloroethene, trans 1,2-dichlorethene, and VC), elevated concentrations of dissolved gases (methane, ethane, ethene, and carbon dioxide), and presence of byproducts (chloride, total alkalinity) provide direct and indirect evidence of trichloroethene biodegradation.

M2.1.2 Abiotic Degradation

Abiotic degradation includes chemical transformations that occur without microbial involvement. These processes may provide an important contribution to the transformation of Cr(VI), nitrate and trichloroethene under the conditions present at 100-F/IU.

Abiotic degradation reactions are facilitated by iron and sulfide bearing minerals. Iron sulfides (mackinawite and pyrite), iron oxides (magnetite), green rust, and iron-bearing clays have been shown to support complete or nearly complete transformation of chlorinated ethenes and carbon tetrachloride (EPA 600/R-09/115, *Identification and Characterization Methods for Reactive Minerals Responsible for Natural Attenuation of Chlorinated Organic Compounds in Ground Water*). Because the chemical reactions are similar, these same minerals are expected to support abiotic transformation of Cr(VI) to trivalent chromium, nitrate to nitrogen gas, and trichloroethene to cis 1,2-dichloroethene. These minerals are present in many environments, especially in anoxic settings, and may be important at the groundwater –surface water interface or within the fine-grained portions of the 100-F/IU aquifer. Mineral surfaces act as electron donors and/or reaction mediators to increase the rate of chemical reduction.

M2.1.2.1 Abiotic Transformation – Cr(VI)

Abiotic reduction of Cr(VI) to trivalent chromium in groundwater is promoted by the natural reductants of Fe(II) and sulfide (EPA/600/R-07/140) and dissolved organic carbon ("Adsorption and desorption of hexavalent chromium in an alluvial aquifer near Telluride, Colorado" [Stollenwerk and Grove, 1985]). Dissolved Fe(II) reduces Cr(VI) rapidly over a wide range of conditions (e.g., "Kinetics and pH dependence of chromium(VI) reduction by iron(II)" [Buerge and Hug, 1997]; "Chromate removal from aqueous wastes by reduction with ferrous iron" [Eary and Rai, 1988]). The rate of Fe(II) reduction decreases at lower temperature with the effect of temperature more pronounced at near-neutral pH ("Reduction of hexavalent chromium by ferrous iron" [Sedlak and Chan, 1997]). Dissolved sulfide (e.g., "The Reduction of Chromium(VI) by Iron(II) in Aqueous Solutions" [Pettine et al., 1998]), sulfur-containing dissolved organic compounds ("Potential transformations of chromium in natural waters" [Schroeder and Lee, 1975]), and hydrogen sulfide gas ("Hydrogen Sulfide Gas Treatment of Cr(VI)- contaminated sediment samples from a plating-waste disposal site--Implications for insitu remediation" [Thornton and Amonette, 1999]) have been shown to reduce Cr(VI) rapidly as evidenced by the calcium polysulfide pilot tests conducted at 100-K (DOE/RL-2006-17, *Treatability Test Report for Calcium Polysulfide in the 100-K Area*). Dissolved Fe(II) and sulfide are generally not present in most aerobic aquifer settings, therefore, these reductants and their availability for redox reactions is most likely to occur on aquifer solids where mineralized forms occur (EPA/540/S-94-505, *Natural Attenuation of Hexavalent Chromium in Groundwater and Soils*).

Many compounds found in soils and sediments have been shown to be capable of reducing Cr(VI). Reduction of Cr(VI) by Fe(II) associated with surfaces of oxide minerals, e.g., magnetite, ilmenite, and Fe(II)-substituted goethite ("Reduction of aqueous transition metal species on surfaces of Fe(II)-containing oxides" [White and Peterson, 1996]; "X-ray absorption spectroscopy investigation of surface redox transformations of thallium and chromium on colloidal mineral oxides" [Bidoglio et al., 1993]),

silicates ("The catalytic effect of sodium and lithium ions on coupled sorption-reduction of chromate at the biotite edge-fluid interface" [Ilton et al., 1997]; "Kinetics of chromate reduction by ferrous ions derived from hematite and biotite at 25 °C" [Eary and Rai, 1989]), and sulfides ("Reduction of hexavalent chromium by amorphous iron sulfide" [Patterson et al., 1997]) has been reported. Reduction by Fe(II) associated with minerals has been observed in the presence of dissolved oxygen in laboratory experiments (Ilton et al., 1997) and in field-scale transport experiments ("Transport of chromium and selenium in the suboxic zone of a shallow aquifer: Influence of redox and adsorption reactions" [Kent et al., 1994]).

Laboratory experiments have demonstrated that reduction of Cr(VI) by soil humic and fulvic substances occurs at an appreciable rate at pH 2 but the rate of reduction decreases with increasing pH ("Effect of temperature, ionic strength, background electrolytes, and Fe(III) on the reduction of hexavalent chromium by soil humic substances" [Wittbrodt and Palmer, 1996]), which is consistent with reduction of Cr(VI) by synthetic, substituted phenols reported in "Redox interactions of Cr(VI) and substituted phenols: kinetic investigation" (Elovitz and Fish, 1994). The rate of reduction by soil humic and fulvic substances decreases with decreasing temperature in the range 15-55 °C (Wittbrodt and Palmer, 1996). The rate of reduction of Cr(VI) by soil organic matter may decrease during the course of the reaction as a result of disappearance of more reactive components of the complex soil organic compounds (Wittbrodt and Palmer, 1996). Soil organic matter may also promote Cr(VI) reduction by enhancing the reductive dissolution of Fe(III) to produce Fe(II) (Wittbrodt and Palmer, 1996). The reduction of Cr(VI) by humic and fulvic substances present within hyporheic zone sediments is also expected to be an important Cr(VI) transformation process. These processes may be similarly influenced by pH and temperature variations within the hyporheic zone.

The reactivity of Fe(II) at mineral surfaces is subject to passivation as a result of buildup of oxidation products at the surface. Reduction of Cr(VI) by magnetite and illmenite was inhibited by build-up of Fe(III) oxides on the surface resulting from reaction between Fe(II)-containing minerals and Cr(VI) or by prolonged exposure of Fe(II) mineral to oxygen ("Surface passivation of magnetite by reaction with aqueous Cr(VI): XAFS and TEM results" [Peterson et al., 1997]; White and Peterson, 1996).

Magnetite collected from anoxic reservoir sediments reduced Cr(VI) rapidly but magnetite collected from an oxic soil profile did not reduce Cr(VI), presumably as a result of passivation by Fe(III) oxide coatings on the surface (White and Peterson, 1996). Passive oxide surface coatings can adsorb Cr(VI) but can completely inhibit its reduction ("Direct XAFS evidence for heterogeneous redox reaction at the aqueous chromium/magnetite interface. Colloids and Surfaces A." [Peterson et al., 1996]).

Oxidation of trivalent chromium to Cr(VI) is also an important process to consider for the long-term MNA performance. Oxidation of trivalent chromium by DO is too slow to be an important process at low temperatures ("Chemical speciation of chromium in sea water, Part 2, Effects of manganese oxides and reducible organic materials on the redox processes of chromium" [Nakayama et al., 1981]) but may be appreciable at elevated temperatures (Schroeder and Lee, 1975). Oxidation of trivalent chromium to Cr(VI) has been observed in some soil and sediment slurries under oxidizing conditions (EPA/540/5-94/505, *Natural Attenuation of Hexavalent Chromium in Groundwater and Soils*; "Chromium redox chemistry in a lower Mississippi Valley bottomland hardwood wetland" [Masscheleyn et al., 1992]; "Behavior of chromium in soils: III. Oxidation" [Bartlett and James, 1979]) in the presence of manganese. Various Mn(IV) and Mn(III) oxides can oxidize trivalent chromium to Cr(VI) rapidly ("Chromium(III) Oxidation by δ-MnO_2.1. Characterization" [Fendorf and Zasoski, 1992]; Eary and Rai, 1987; Manceau, and Charlet, 1992). The reaction is inhibited by precipitation of $Cr(OH)_3$ on the manganese oxide surface ("Oxidation of aqueous Cr(III) at birnessite surfaces: Constraints on reaction mechanism" [Banerjee and Nesbitt, 1999]; "Inhibitory mechanisms of Cr(III) oxidation by δ-MnO2" [Fendorf et al., 1992]). At near-neutral pH values, the oxidation is inhibited by aluminum ("Competing

metal ion influences on chromium(III) oxidation by birnessite," [Fendorf et al., 1993]), which apparently blocks oxidation sites either by surface precipitation or competitive adsorption. The oxidation reaction is also inhibited by dissolved organic compounds that form complexes with trivalent chromium ("The oxidation of chromium(III) to chromium(VI) on the surface of manganite γ-MnOOH)" [Johnson and Xyla, 1991]; Nakayama et al., 1981). These inhibitory effects suggest that oxidation requires contact between aqueous trivalent chromium and reactive sites at the manganese oxide surface. Thus, while manganese oxides are potentially important oxidants for transformation of trivalent chromium to Cr(VI), this process has not been observed at the Hanford site.

How Measured - Evidence

The same information used to assess biotransformation of Cr(VI) to trivalent chromium can also be used to assess abiotic transformation processes. Additional measurements that can be performed include sampling and analysis of aquifer and hyporheic zone sediment solids for Fe(II) and sulfide reactive minerals. However, sample collection and laboratory analysis of aquifer and sediment solids is difficult because the reactive minerals may be unstable in the presence of atmospheric oxygen and may be present at very low concentrations. More detailed information on the sampling and analysis of reactive minerals is provided in EPA 600/R-09/115.

Mineralogical studies of Ringold Formation and the Hanford formation sediments were conducted (PNNL-14202, *Mineralogical and Bulk-Rock Geochemical Signatures of Ringold and Hanford Formation Sediments*). The results of these studies suggest that both formations contain sufficient iron, mica, and other critical components capable of fostering Cr(VI) reduction as well as adsorption of the anionic Cr(VI) species to positively charged surfaces such as along the edges of mica sheets and related clay weathering products.

M2.1.2.2 Abiotic Degradation - Nitrate

Abiotic transformation of nitrate may also occur under conditions similar to that just described for Cr(VI). Chemical reduction of nitrate has been shown to occur in the presence of Fe(II) silicates (arfvedsonite and augite) but only after an oxyhydroxide precipitate had formed on the silicate surface ("Kinetics of nitrate reduction by detrital Fe(II) silicates" [Postma,1990]).

In sulfate green rust, nitrate can be reduced to ammonium. Recent thermodynamic and spectroscopic studies give direct evidence for the existence of green rusts in soils ("Evaluation of the free energy of formation of Fe(II)-Fe(III) hydroxide-sulphate (green rust) and its reduction of nitrite" [Hansen et al., 1994]; "Identification of a green rust mineral in a reductomorphic soil by Mossbauer and Raman spectroscopies" [Trolard et al., 1997]). Since microbial processes may be expected only to dominate in environments rich in organic carbon, the green rust-facilitated nitrate to ammonium reduction may be an important pathway for nitrate removal under anoxic conditions with low organic carbon concentrations.

How Measured - Evidence

The same information used to assess biotransformation of Cr(VI) to trivalent chromium, and nitrate biodegradation can also be used to assess the abiotic denitrification pathway.

M2.1.2.3 Abiotic Degradation - Trichloroethene

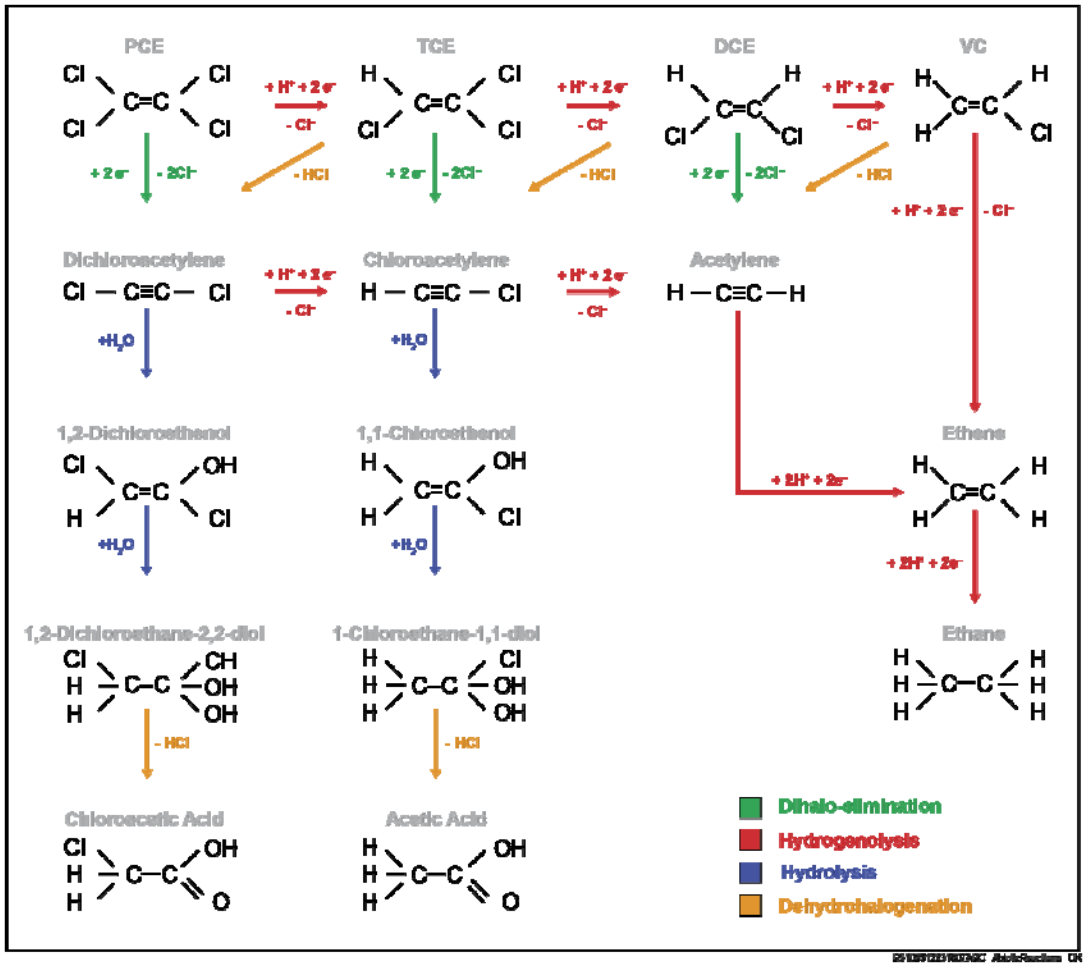
A variety of naturally occurring iron-bearing soil minerals, such as mackinawite, pyrite, magnetite, green rust, and iron-bearing clays (reactive minerals), have been shown to facilitate degradation of chlorinated ethenes (EPA 600/R-09/115). Reactive minerals support complete transformation of trichloroethene, cis 1,2-dichloroethene, and trans 1,2-dichlorethene through various reactions (Figure M2-3), which may avoid the creation of daughter products, such as VC. In these reactions, the mineral surfaces act as

electron donors and /or reaction mediators to increase the rate of transformation via one or more abiotic degradation pathways.

Natural abiotic degradation reactions for trichloroethene are slower than biodegradation reactions; however, abiotic degradation may be an important process at sites where the population of reductive dechlorination microorganisms is low (EPA/600/R-98/128). Thermodynamically stable minerals, such as pyrite and magnetite, support comparatively slower trichloroethene degradation rates than do metastable mineral phases, such as mackinawite (EPA 600/R-09/115). The rate of FeS-mediated abiotic degradation is a function of pH, with increasing pH, resulting in an increased degradation rate (EPA 600/R-09/115). Acetylene is a reaction byproduct for trichloroethene but is quickly degraded to ethene and then carbon dioxide and water (EPA/600/R-98/128).

How Measured - Evidence

As with other transformation processes, both direct and indirect lines-of-evidence are used to identify abiotic degradation processes at a site. Direct evidence that demonstrates the effects of abiotic degradation includes plume degradation patterns and CSIA. Indirect evidence includes data indicating that the site has conditions conducive to abiotic degradation, such as high concentrations of reactive minerals, which are evident though mineral equilibrium modeling and downhole magnetic susceptibility measurements.



Modified from "Monitored natural attenuation forum; the case for abiotic MNA," (Brown et al., 2007).

Figure M2-3. Potential Chloroethene Abiotic Degradation Pathways

M2.1.3 Radioactive Decay

Radioactive decay is an important degradation process for radionuclides with relatively short half-lives such as the strontium-90 present in 100-F/IU groundwater, which has a half-life of 28.8 years. Strontium-90 decays to yttrium-90 via emission of a beta particle. Yttrium-90, with a half-life of 64 hours, decays via emission of a beta particle to zirconium-90 which is stable.

M2.1.3.1 How Measured - Evidence

Indirect evidence of strontium-90 decay is inferred through periodic measurement of strontium-90 concentrations in groundwater samples.

M2.2 Non-degrading Processes

The key non-degrading processes present in the 100-F/IU groundwater include: dispersion, diffusion, sorption, volatilization, and groundwater-surface water mixing within the bank storage and hyporheic zone.

M2.2.1 Dispersion

Dispersion is the mechanical mixing of contaminated water with uncontaminated (or lower concentration) water and is caused by the tortuous flow of groundwater through aquifer materials. The result of dispersion is an elongation of the COC plume in the direction of groundwater flow (longitudinal dispersion) and perpendicular (transverse) to the groundwater flow direction causing the extent of a contaminant plume to increase and the maximum concentrations to decrease. Given a finite contaminant source and unlimited aquifer dimensions, a contaminant plume would grow in length and width and eventually disperse such that concentrations would decline to non-detect levels.

Dispersion is a relatively rapid and scale dependent process that continually reduces contaminant concentrations as the plume advances until a flow boundary is encountered. Because the 100-F/IU Cr(VI) and strontium-90 plumes lie near the river shoreline and are being transported towards the river, the effects of dispersion are expected to be low. The trichloroethene plume lies approximately 3,000 ft inland from the river; therefore, dispersion will be an important concentration reduction process. Based on its geometry, the nitrate plume is migrating somewhat parallel to the river shoreline. While dispersion will provide some reduction in nitrate concentrations, the magnitude of this reduction is not expected to be as large as that experienced by the trichloroethene plume.

M2.2.1.1 How Measured - Evidence

Longitudinal and transverse dispersion coefficients can be measured from field tracer tests but generally these coefficients are determined from published values for similar aquifer materials. Dispersivity values for the Hanford formation and Ringold Unit E were estimated during development of the 100 Area groundwater flow model (SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*). Longitudinal dispersivity for the Hanford formation and Cold Creek gravel unit is considered to generally lie within the range of 60 to 120 m (197 to 394 ft) for a sand and gravel aquifer, as determined in *Field Study of a Long and Very Narrow Contaminant Plume* (van der Kamp et al. 1994). The initial values for longitudinal dispersivity and transverse dispersivity used for groundwater transport modeling in the 100 Areas are listed in Table M2-2.

Table M2-2. Initial Dispersivity Values used for 100 Area Groundwater Transport Model

Formation Type	Longitudinal Dispersivity (m)	Transverse Dispersivity (m)
Hanford formation	62.5	12.5
Ringold Unit E gravels	30	6

M2.2.2 Diffusion

Diffusion is the movement of a contaminant in groundwater from a zone of higher concentration toward a zone of lower concentration. Diffusion occurs as long as a concentration gradient exists, even if the water is not moving. This process alone causes a contaminant plume to increase in size and the maximum concentrations to decrease. Given a finite contaminant source and unlimited aquifer dimensions, a contaminant plume would eventually diffuse such that concentrations would decline below laboratory detection limits. However, diffusion does not rapidly reduce contaminant concentrations and its significance is generally limited to aquifer settings with low hydraulic conductivities and to multi-layer aquifers with interbedded coarse and fine-grained zones. Under these conditions, diffusion transports contaminant mass from the coarse-grained zone to the fine-grained zones. Once concentrations are reduced in the coarse-grained zoned, back-diffusion transports contaminant mass from the fine-grained zone to the coarse-grained zone.

M2.2.2.1 How Measured - Evidence

Relative to dispersion, diffusion is expected to be an insignificant process for the 100-F/IU unconfined aquifer. Therefore, approaches for measuring and assessing the significance of diffusion are not considered in this appendix.

M2.2.3 Sorption

Sorption (adsorption and absorption) plays an important role in transferring contaminant mass from the aqueous to the solid phase and in retarding overall plume transport rates. Adsorption is the attachment of a contaminant to a solid surface. Adsorption processes include electrostatic attraction, chemical reaction, and physical bonding of the contaminant to the aquifer solids. Adsorption results in the removal of contaminants from groundwater. Inorganic compounds such as Cr(VI) and strontium-90 and organic compounds (such as trichloroethene) adsorb to organic carbon and clay particles in the aquifer materials and river sediments and to a lesser extent to mineral surfaces. Adsorption results in the retardation, or slowing down, of a plume's movement. Absorption is similar except the contaminant penetrates the interior portions of the aquifer and sediment solids.

Sorption is quantified using the soil-water partition coefficient (K_d), which is the ratio of a contaminant's concentration in soil to its concentration in water at equilibrium. This coefficient has units of mL/g or L/kg. While there is potential for sorption coefficients to change over time, given the small ratio of contaminant mass to aquifer mass, they are expected to remain relatively constant in the future. For constituents other than strontium, sorption is not considered to be a significant contaminant removal process for assessing the effectiveness of NA processes in 100-F/IU groundwater.

Another use of K_d is to estimate the coefficient of retardation, which is calculated from:

$$R = 1 + (p_b * K_d / n)$$

Where:

R = coefficient of retardation (dimensionless)

p_b = bulk density of aquifer (g/mL) = 1.72 (Table 3-1, ECF-100FR311-0116, *Modeling of RI/FS Design Alternatives for 100-FR-3*)

K_d = distribution coefficient [mL/g] = varies by COC (Table 5-2, 100-F/IU RI/FS [DOE/RL-2010-98])

n = porosity (dimensionless) = 0.225 ((Table 3-1, ECF-100FR311-0116)

The coefficient of retardation is related to the groundwater flow velocity and contaminant transport velocity by:

$$v_c = v_w/R$$

Where:

v_c = retarded contaminant transport velocity (m/day)

v_w = advective ground-water velocity (m/yr) = 0.19 m/day (Table 3-11, 100-F/IU RI/FS [DOE/RL-2010-98])

R = coefficient of retardation (dimensionless)

The range of K_d, retardation, and transport velocities for the 100-F/IU COCs is summarized in Table M2-3.

Table M2-3. Mobility of Vadose Zone Contaminants for 100-F/IU Groundwater COCs

COC	K_d	R	V_c (m/day)	Relative Mobility
Cr(VI)	0.8	7.1	0.03	Moderate
Trivalent chromium	200	1529	0.0001	Low
Nitrate	0	0	0.19	High
Trichloroethene	0.094	1.7	0.11	Moderate
Strontium-90	25	43	0.0044	Slight

Source: ECF-HANFORD-10-0442, *Calculation of Nonradiological Preliminary Remediation Goals Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the Protection of Groundwater for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

M2.2.3.1 How Measured - Evidence

Sorption coefficients are contaminant specific and were estimated using batch leaching tests. These tests were conducted for the 100-F/IU remedial investigation or for other River Corridor OU remedial investigations. The vadose zone K_d values for the 100-F/IU groundwater COCs are listed in Table M2-3.

M2.2.4 Volatilization

Like sorption, volatilization is a mass transfer process that moves contaminant mass from groundwater to soil vapor and potentially the atmosphere where photodegradation may occur. Volatilization is applicable to trichloroethene only in the 100-F/IU groundwater OU. Volatilization rates are controlled by the volatile

organic compound's physical properties, groundwater and subsurface soil temperatures and soil vapor exchange with the atmosphere.

Volatilization or partitioning of a contaminant between the liquid phase and the gaseous phase is governed by Henry's Law. Thus, the Henry's Law constant of a chemical determines the tendency of a contaminant to volatilize from groundwater into the soil gas. Henry's Law states that the concentration of a contaminant in the gaseous phase is directly proportional to the compound's concentration in the liquid phase and is a constant characteristic of the compound. Stated mathematically, Henry's Law is given by *Mobility and Degradation of Organic Contaminants in Subsurface Environments* (Lyman et al., 1992):

$$C_a = H*C_l$$

Where:

H = Henry's Law Constant (atm*m^3/mole)

C_a = concentration in air (atm)

C_l = concentration in water (mol/m3)

The Henry's Law constant for trichloroethene is 0.0091 atm*m^3/mole or 0.4027 in dimensionless units.

Volatilization is not considered to be a significant contaminant removal process for this NA assessment. However, it's reasonable to expect that some trichloroethene mass transfer between groundwater and soil gas and soil gas and groundwater will continue to occur as long as the groundwater and soil gas plumes are present.

M2.2.4.1 How Measured - Evidence

Volatilization from groundwater to soil gas can be assessed using a soil gas survey or flux chamber. A soil gas study performed in 1995 in the area of the 100-F/IU trichloroethene plume identified a region of soil gas containing trichloroethene concentrations up to 77 parts per billion by volume overlying a region of groundwater contamination with trichloroethene concentrations up to 52 µg/L. Exclusive of the temperature effects, this is in reasonable agreement with the concentration predicted by Henry's Constant and demonstrates the existence of this mass transfer process. The highest observed trichloroethene concentration detected in the 2011 groundwater samples was 14 µg/L.

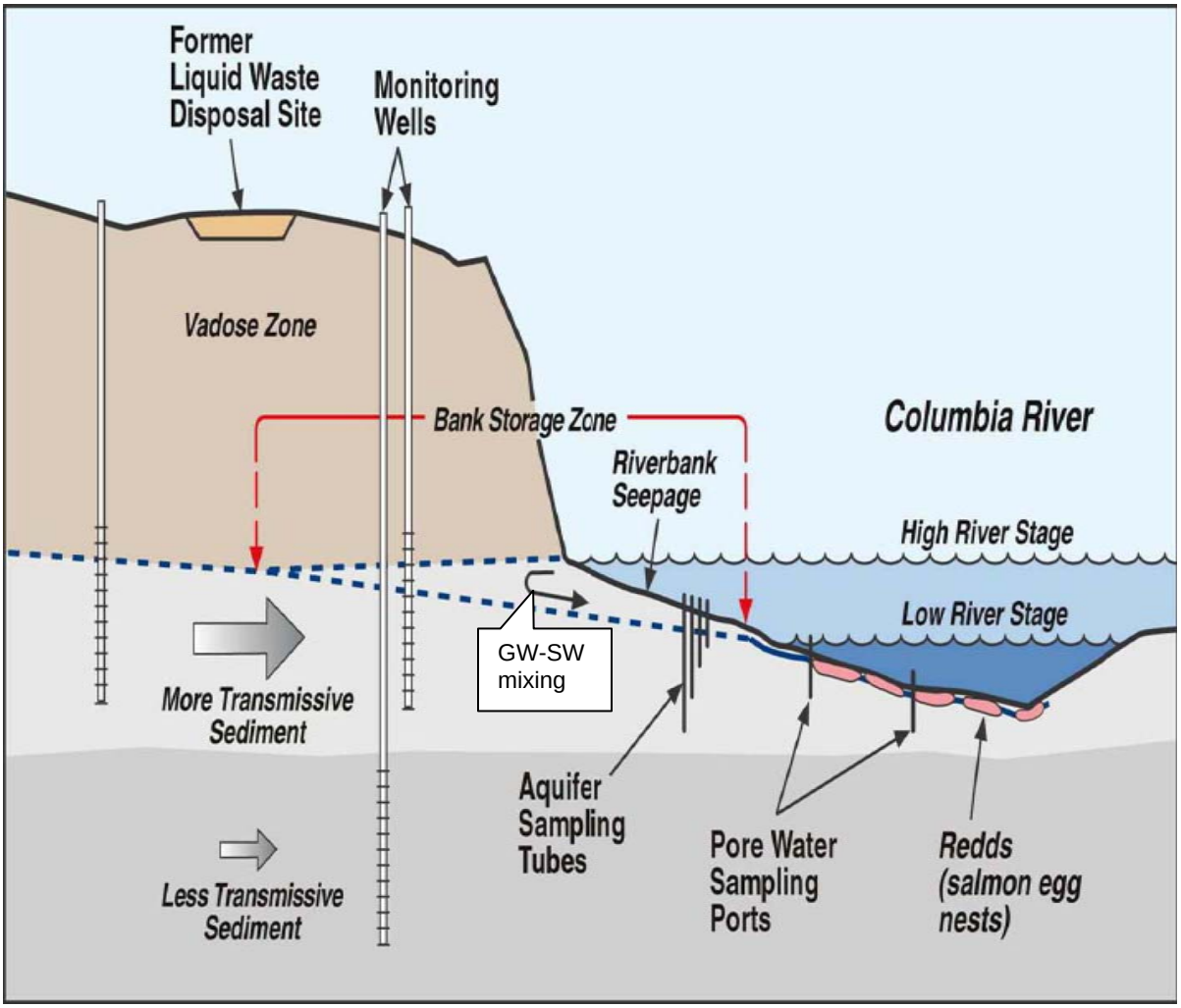
M2.2.5 Groundwater-Surface Water Mixing

Near the Columbia River river shore, contaminant concentrations are reduced by the continuous mixing of contaminated groundwater with surface water and the chemical and biological processes that are expected to be more active in this zone. Current information suggests that physical processes are responsible for the largest fraction of the total concentration reduction that occurs (PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task, Science and Technology Groundwater/Vadose Zone Integration Project*). Physical processes include (1) layering and mixing of groundwater and river water, which infiltrates the banks and riverbed sediments; and (2) varying fluxes attributed to dynamic hydraulic gradients associated with daily and seasonal river stage fluctuations.

The conceptual site model for the groundwater-surface water zone of interaction (Figure M2-4) describes groundwater flow in the aquifer and the mixing that occurs within the bank storage zone (BSZ). Flow paths and gradients in the BSZ vary with daily and seasonal fluctuations in river stage. River water infiltrates the BSZ during high river stages, moves inland mixing with groundwater, then reverses flow as the river stage subsides and the groundwater-surface water mixture is drawn back through the BSZ.

Aquifer tube monitoring and groundwater flow modeling suggests back-and-forth motion of groundwater and river water is very cyclical in response to the diurnal river stage cycle, which typically includes two high stages and two low stages in response to peak electrical power generation schedules.

An individual contaminant molecule travels a very tortuous path through the BSZ experiencing numerous reversals in flow direction as it moves from the aquifer to the river. Modeling studies (PNNL-13674) indicate that the movement of groundwater in response to river stage is predominantly piston-type flow. This flow mechanism is very significant because it allows for rejuvenation of the geochemical conditions in the BSZ that promote contaminant concentration reductions through the degradation processes described in Section M2.1.

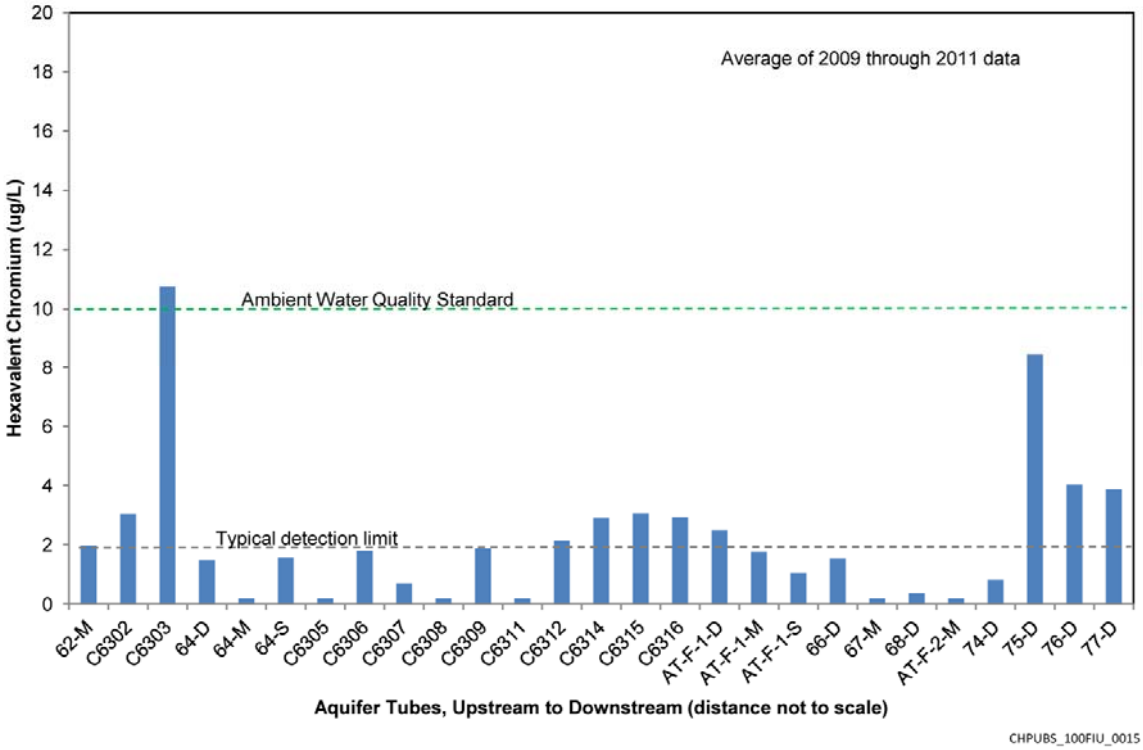


Source: PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project.*

Figure M2-4. Schematic of Principal Features of Groundwater-Surface Water Mixing Zone

Although the Cr(VI) and strontium-90 plumes lie near the river, they are not expected to measurably affect surface water quality because of their moderate to slight mobility and low mass inventory (Table M1-2). Cr(VI) concentrations measured in aquifer tubes along the river shoreline (Figure M2-5) show average concentrations for the 2009 to 2010 period at levels near the typical detection limit. The

fate and transport simulations presented in DOE/RL-2010-98 show Cr(VI) concentrations in groundwater along the shoreline averaging between 2 µg/L and 8 µg/L for the next 20 years before concentrations begin to decline. Strontium-90 concentrations in groundwater samples collected from the aquifer tubes ranged from 0 to 1.7 pCi/L in 2011. The fate and transport model simulations presented in the 100-F/IU RI/FS (DOE/RL-2010-98) project that average strontium-90 concentrations in groundwater along the shoreline will decline from the current estimated level of about 2 pCi/L to 1 pCi/L in about 20 years.



Source: DOE/RL-2010-98, *Remedial Investigation/Feasibility Study for 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (Chapter 4, Figure 4-23).

Figure M2-5. Hexavalent Chromium in 100-F Aquifer Tubes

The primary trichloroethene plume is located about 3,000 ft west (upgradient) of the river and not expected to reach the shoreline for about 30 years based on the groundwater fate and transport model simulations presented in the 100-F/IU RI/FS (DOE/RL-2010-98). The average trichloroethene concentration in groundwater along the shoreline is not expected to rise above 1 µg/L. This concentration would not pose a threat to surface water quality.

For nitrate, which has a mass inventory of 1.2 million kg, the flux rate to the river varies with river stage but is estimated to average about 40 kg/day based on the 100-F/IU groundwater flow and contaminant transport model simulations (ECF-100FR3-11-0116). While the flux of nitrate entering the river is relatively large, compared to the other 100-F/IU COCs, it represents about 1.1 percent of the average 2,700 kg/day that enters the Columbia River from upstream irrigation return flows during the May through August irrigation season (WA-36-1010, *Irrigation Return Flow Quality, South Columbia Basin Irrigation District*[1], *May-August 1980*). Groundwater studies in the Yakima Valley have identified agriculture-related nitrate contamination in private wells (Ecology Publication No. 10-10-009, *Lower*

[1] The South Columbia Irrigation District is generally the region bounded by the Columbia River to the west and the Snake River to the east, extending northward to a east-west boundary approximately five miles south of Othello, WA.

Yakima Valley Groundwater Quality: Preliminary Assessment and Recommendations Document). Concentrations two to three times the 45,000 µg/L 100-F/IU PRG have been observed in shallow wells.

M3 Natural Attenuation Assessment for 100-F/IU Groundwater

Per the three lines of evidence specified in OSWER Directive 9200.4-17P, a MNA assessment was performed using Step 1 of the two step approach described in EPA 600/R-11/204. This evaluation was conducted to support retention of MNA as a groundwater remedial action technology and to support the detailed evaluation of Alternative GW-2: ICs and MNA against the CERCLA threshold and balancing criteria.

In Step 1, existing groundwater quality monitoring data were evaluated to determine if there is a clear and meaningful trend of decreasing contaminant concentrations at appropriate sampling points. The information obtained from this evaluation was also used to assess whether NA processes are capable of achieving remedial goals within a reasonable timeframe; thus providing an independent check of the contaminant transport modeling results presented in ECF-100FR3-11-0116. This portion of the evaluation is designed to meet the first line of evidence specified in OSWER Directive 9200.4-17P (see #1 in Section M1.3).

This assessment also reviews existing geochemical data to indirectly identify the types of NA processes active in 100-F/IU groundwater. As described in Section M2, the presence of many NA processes can be inferred from measurements of other parameters. This portion of the evaluation was performed per the second line of evidence specified in OSWER Directive 9200.4-17P (see #2 in Section M1.3).

M3.1 Natural Attenuation Evaluation Data Set

The data used for this evaluation were extracted from the HEIS database and included the following: total chromium, Cr(VI), nitrate, trichloethene and strontium-90 concentrations; trichloroethene degradation products cis-DCE and vinyl chloride; dissolved oxygen; ORP; and total iron, manganese and sulfate for all monitoring wells and aquifer tubes (Attachment 1). For sampling events where field duplicate/triplicate results were reported, the average concentration was calculated and used for the evaluation. Use of the average concentration ensures that each sampling event is weighted equally in the regression analysis.

From the set of all 100-F/IU monitoring wells, a subset of appropriate locations was selected for each COC plume. This included six monitoring wells spanning the Cr(VI) plume's west to east axis, 11 wells spanning the nitrate plume's west to east and north to south axes, seven wells spanning the two trichloroethene plume's west to east axes, and one strontium-90 monitoring well. Additional information on the well selection rationale is presented in Section M3.2.

M3.2 Evidence for Declining COC Concentrations

The overall effectiveness of all NA processes at a site can be assessed by evaluating the rate at which contaminant concentrations are decreasing temporally or spatially. Guidance issued by the EPA (OSWER Directive 9200.4-17) and the American Society for Testing and Materials (ASTM E1943, *Standard Guide for Remediation of Ground Water by Natural Attenuation at Petroleum Release Sites*) has endorsed the use of site-specific attenuation rate constants for evaluating NA processes in groundwater. OSWER Directive 9200.4-17P includes several references to the application of attenuation rates as follows:

- Once site characterization data have been collected and a conceptual model developed, the next step is to evaluate the potential efficacy of MNA as a remedial alternative. This involves collection of site-specific data sufficient to estimate with an **acceptable level of confidence both the rate of attenuation processes and the anticipated time** required to achieve remediation objectives.

- At a minimum, the monitoring program should be sufficient to enable a determination of the **rate(s) of attenuation** and how that rate is changing with time.
- Site characterization (and monitoring) data are typically used for estimating **attenuation rates**.

M3.2.1 Types of Attenuation Rates

In general, there are three different types of attenuation rates (EPA/540/S-02/500, *Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies*) as follows:

1. Point Attenuation Rate. A first-order rate constant, in units of 1/day, derived from the slope of the natural log concentration vs. time curve measured at a representative monitoring well location(s). This type of rate constant provides an indication of a plume's longevity at a specific location.
2. Bulk Attenuation Rate. A first-order rate constant, in units of 1/day, derived from the slope of the natural log of the concentration vs. distance (along a groundwater flow path extending downgradient from the presumed source) multiplied by the groundwater seepage velocity. This type of rate constant is used to assess whether the plume is expanding, stable or shrinking.
3. Biodegradation Rate Constant. A rate constant, in units of 1/day, derived from a tracer test, a microcosm test or through calibration of a solute transport model.

M3.2.2 Point Decay Calculation Approach

As recommended in EPA 600/R-11/204, point attenuation rates were used in this evaluation to determine if there is a clear and meaningful trend of decreasing contaminant concentrations. **The point decay rate reflects concentration changes attributed to all degradation and non-degrading processes**, and therefore, will provide a less conservative prediction of plume restoration timeframes than a contaminant fate and transport model which assumes a value of zero for the decay input parameter as was done for the 100-F/IU remedial alternatives simulation presented in ECF-100FR3-11-0116.

First-order decay is described by the following:

$$Ln\ (C_t) = kt + Ln\ (C_0)$$

Where:

Ln = natural logarithm

C_0 = initial contaminant concentration (µg/L)

C_t = contaminant concentration (µg/L) at time *t*

t = time in decimal years

k = first-order decay rate constant (1/year)

Regression analysis was performed on the Ln transformed concentration vs time data to derive the first-order decay rate constant (k) for Cr(VI), nitrate, trichloroethene, and strontium-90. For each data set, the best estimate of the decay rate is the slope of the mean regression line, which defines the mean point decay rate. The 95-percent upper confidence interval estimates the slowest point decay rate at 95 percent confidence. The regression analysis statistics are provided in Attachment 2 for each of the monitoring wells where the regression analysis was completed. As described in Appendix A of EPA 600/R-11/204, the appropriateness of using the regression analysis method was evaluated by comparing the standard residuals to a normal distribution (Attachment 2). The plot of standard residuals derived from the

regression analysis against the normal probability distribution (Attachment 2) indicates that the natural log transformed data are normally distributed and suitable for regression analysis use.

An estimate of the time required to achieve the PRG at a specific location can be made by rearranging the first order decay equation as follows:

$$t = \frac{Ln\,(C_t) - Ln\,(C_0)}{k}$$

Point decay rates for Cr(VI), nitrate, trichloroethene and strontium-90, and the time required to achieve the PRG for each at representative monitoring well locations, are summarized in Table M3-1, and the results contrasted with the contaminant transport model projected timeframes in Section M4. All of the calculations presented in this section were performed in Microsoft Excel (MS Excel)™ spreadsheets using the Data Analysis Tool Pack. Detailed information on the steps used to perform the regression analysis with the Data Analysis ToolPack are described in Appendix A of EPA 600/R-11/204). Potential uncertainties associated with calculation of the point decay rate are discussed in Section M3.2.7.

Table M3-1. Cr(VI) and Total Chromium Attenuation Rates Estimated Using Point Decay Method

Well	Number of Data Points - Date Range for Regression Analysis	Point Decay Rate k = 1/year		COC Concentration (Most Recent)		Time for COC Concentration to Decay to Surface Water Protection PRG (yrs)	
		Mean	Slowest	µg/L or pCi/L	Ln (µg/L of pCi/L)	Mean Rate	Slowest Rate
199-F5-48	6 – 5/10 to 4/12	-0.1272	-0.0077	12.1	2.49	1.5	24.3
199-F5-45	3 – 5/10 to 9/10	Not calculated, only three Cr(VI) data points					
199-F5-45[a]	10 – 12/99 to 9/10	-0.1587	-0.0616	15.7	2.75	2.8	7.3
199-F5-46	26 –10/97 to 12/11	-0.0868	-0.0329	22.3	3.10	9.2	24.2
199-F5-46[a]	26 –10/97 to 12/11	-0.0977	-0.0604	22.3	3.10	8.2	13.2
199-F5-6	5 – 12/05 to 11/10	-0.1883	+0.1644	1 U	Not calculated, most recent value was non-detect		
199-F5-53	6 – 8/10 to 9/11	Not calculated, too few Cr(VI) and total chromium detections.					
199-F5-44[a]	6 – 10/07 to 12/11	-0.3355	+0.1877	14.7	2.69	1.2	Not Estimated[b]
	Average Cr(VI)	**-0.1649**	**+0.0316**	23.9 (2011)	3.17	5.3	Not Estimated[b]

Notes:
a. Regression analysis performed using total chromium concentration data.
b. Remediation timeframe not estimated because decay factor is positive (e.g. concentrations not decreasing).

™ Microsoft Excel (MS Excel) is a trademark of Microsoft Corporation.

M3.2.3 Cr(VI) Point Attenuation Rates

Point attenuation rates were calculated for six different monitoring well locations (Figure M3-1) located along a groundwater flow path transect. From a southwest (upgradient) to northeast (downgradient) direction, the wells include: 199-F5-48, 199-F5-45, 199-F5-46, 199-F5-6, 199-F5-53, and 199-F5-44. These monitoring wells are located in the vicinity of known 100-F Cr(VI) sources (Figure 1-1, 100-F/IU RI/FS [DOE/RL-2010-98]). These wells are were selected for the regression analysis because they span the Cr(VI) plume's longitudinal axis.

Monitoring well 199-F5-46, which is located just west of the 116-F-14 Retention Basin (a known source), has the longest monitoring history of the six wells evaluated with analytical results available for the 1997 through 2012 (Figure M3-2) timeframe. The time-series plot for 199-F5-46 shows Cr(VI) concentrations declining steadily, except for upward spikes in April 2004 and March 2010, from a peak concentration of 208 µg/L in 2000 to 22 µg/L in September 2011. The total chromium time-series plot for 199-F5-46 shows a similar trend except for the 2003 to 2010 period where hexavalent chromium was not measured. The monitoring data sets for the remaining five wells are shorter, ranging from 2010 to 2012 (199-F5-48), 1999 to 2010 (199-F5-45), 2005 to 2010 (199-F5-6), and 2007 to 2011 (199-F5-44).

The regression analysis also considered total chromium concentration data in addition to hexavalent chromium concentration data at Wells 199-F5-45, 199-F5-46 and 199-F5-44 because total chromium was measured more frequently than hexavalent chromium. Use of the total chromium concentration data set allowed for regression analysis at Wells 199-F5-45 and 199-F5-44, which had only four Cr(VI) measurements each.

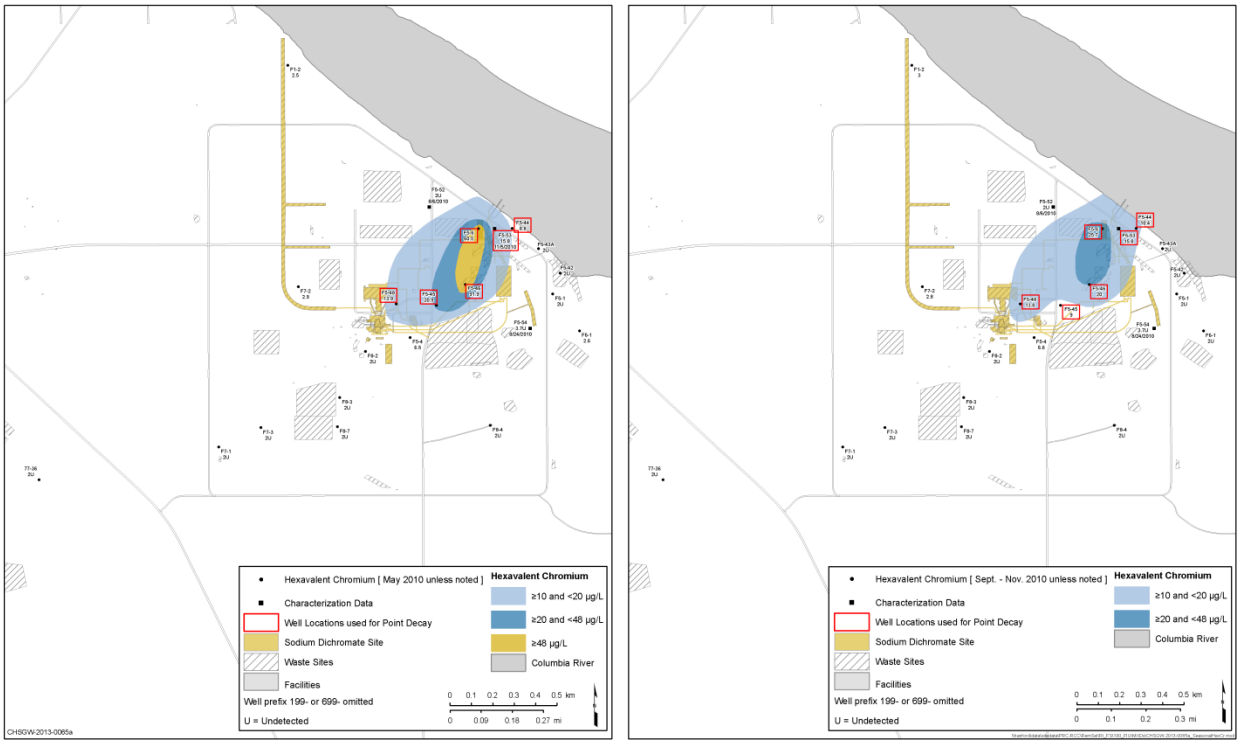


Figure M3-1. Location of Monitoring Wells Used for Cr(VI) Point Decay Attenuation Rate

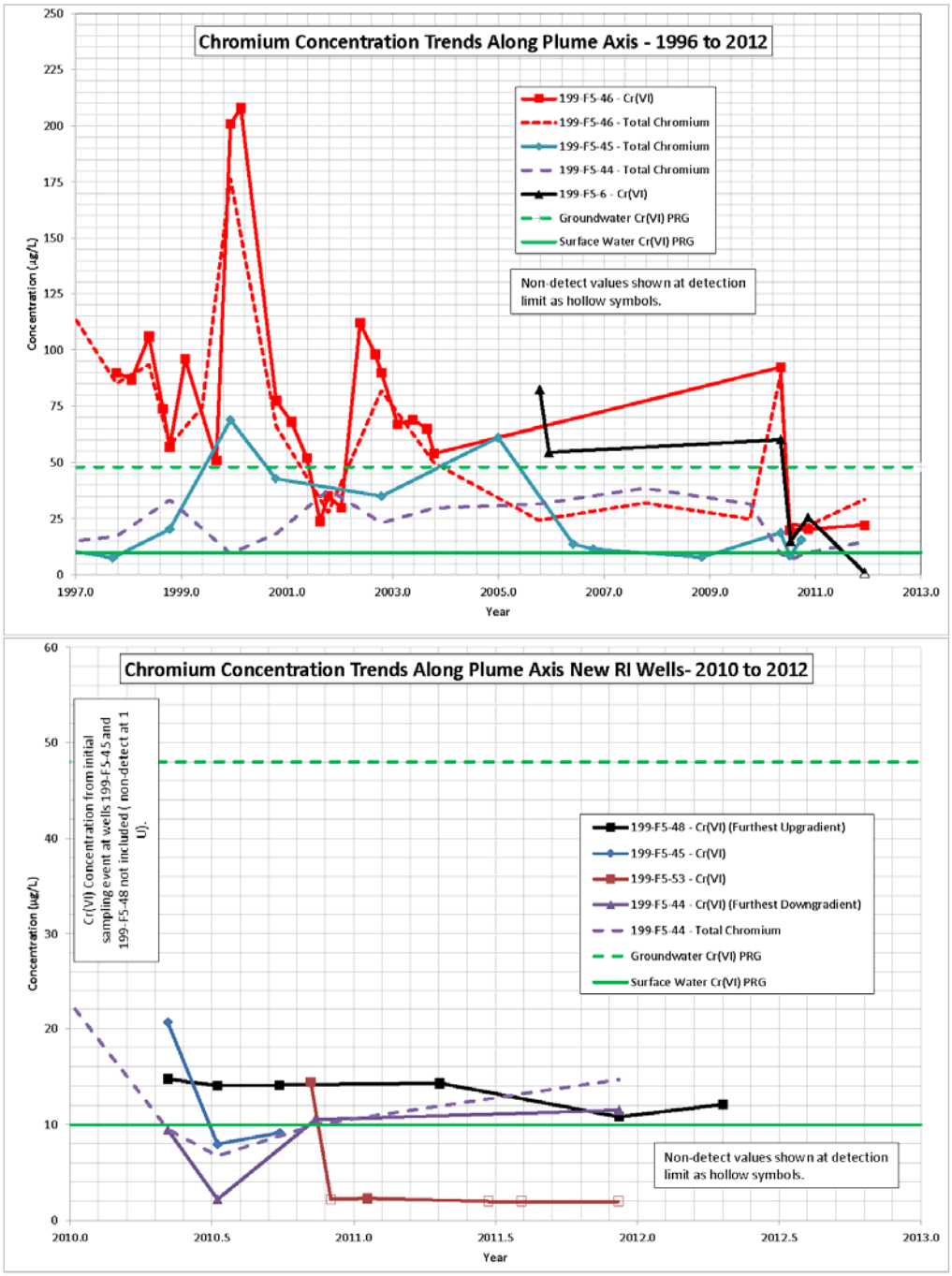


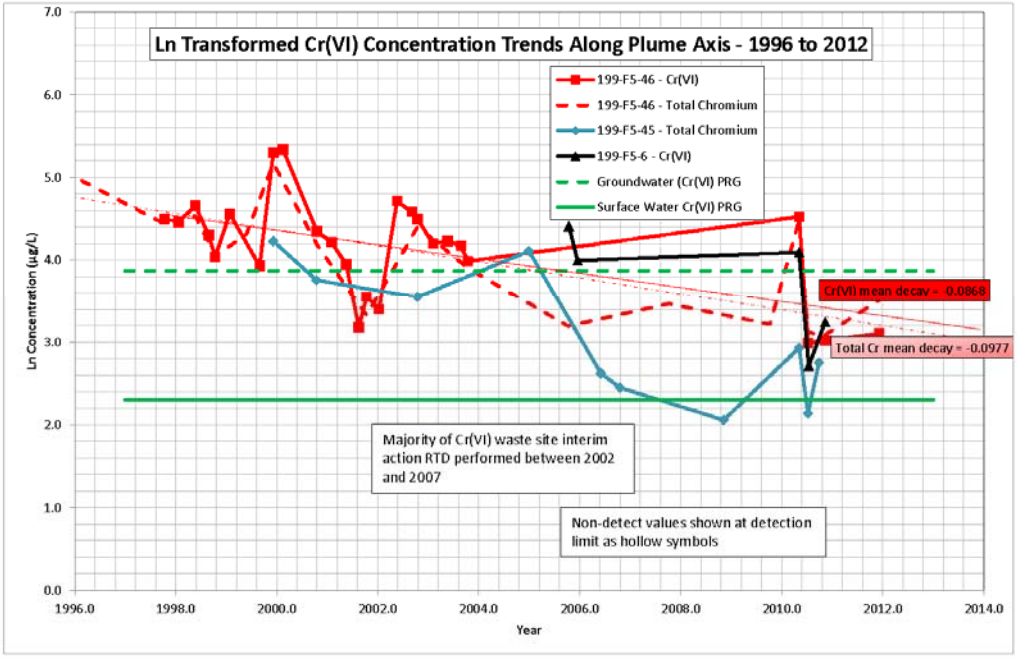
Figure M3-2. Cr(VI) Concentration Trends for Point Decay Attenuation Rate Monitoring Wells

Another important consideration, in addition to selecting appropriate or representative well locations, is the regression analysis time period. Waste site remediation in 100-F/IU was performed between 1993 and 2012, with the largest number of waste site remediations completed between 2002 and 2007. Therefore, the regression analysis period focused primarily on use of post-2007 data. However, based on interpretation of the Cr(VI) and total chromium time-series charts, earlier data was also included in the regression analysis for Wells 199-F5-45 and 199-F5-46.

The regression analysis for the natural log (Ln) of Cr(VI) concentration vs. time (Figure M3-3) yields a best-fit line with a slope of k. A negative value of k indicates a declining concentration whereas a positive k value indicates an increasing concentration. For the Cr(VI) regression analysis, all Cr(VI) concentration data were used unless noted.

The *mean point decay rates* for Cr(VI) varied from -0.1833/year to -0.0868/year while the mean total chromium decay rates ranged from -0.0977/year to -0.3355/year. The average mean decay rate for all of the Cr(VI) and total chromium concentration data evaluated was -0.1649/year (Table M3-1). The *slowest point decay rates* at 95 percent confidence for Cr(VI) and total chromium varied from +0.1877/year to -0.0077/year, averaging +0.0316/year. Calculation of a mean decay factor using Cr(VI) and total chromium at well 199-F5-46 yielded similar mean decay values of -0.0868/year and -0.0977/year respectively. A Cr(VI) decay rate of -0.0621/year (-0.00017/day) was calculated previously in the 100-H area at well 699-99-43 using data for the 1993 to 2002 period (*In Situ Long-Term Reductive Bioimmobilization of Cr(VI) in Groundwater Using Hydrogen Release Compound* [Faybishenko, 2009]). Decay rates were not calculated for well 199-F5-45 because there were too few Cr(VI) and total chromium concentration data points (minimum of five detected values deemed necessary for meaningful regression analysis). Because well 199-F5-46 has 26 data points upon which the regression analysis is based, it is expected to yield a more reliable decay rate than that estimated at wells 199-F5-48 or 199-F5-6.

The estimated timeframe to achieve the 10 µg/L surface water protection PRG for Cr(VI) using the 199-F5-46 mean Cr(VI) point decay rate is 9.2 years and 24.2 years based on the slowest decay rate. Because 199-F5-46 currently has the highest observed Cr(VI) concentration in 100-F/IU groundwater, 24.2 years is expected to represent a “worst-case” remedial action timeframe estimate. Additionally, because the mean/slowest point decay rates include both degradation and non-degrading processes, the remedial action timeframe estimates will be shorter than those estimated using the fate and transport model (see Section M4), which includes non-degrading processes only.



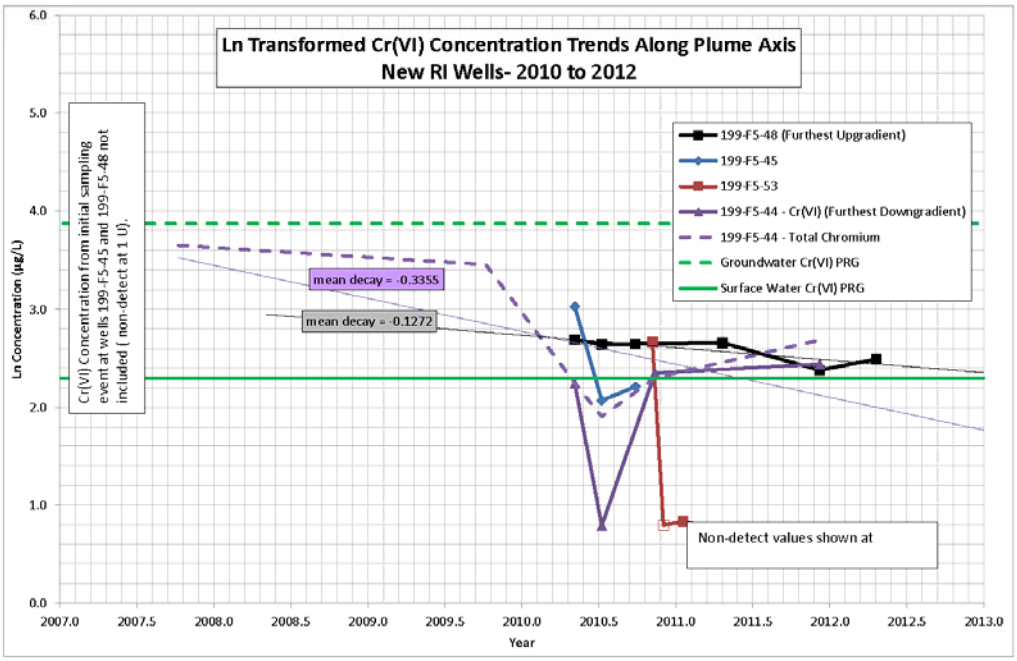


Figure M3-3. Ln Transformed Cr(VI) Concentration Trends for Point Decay Attenuation Rate Monitoring Wells

M3.2.4 Nitrate Point Attenuation Rates

Point attenuation rates were calculated at 11 different monitoring well locations (Figure M3-4) aligned on two different transects spanning the nitrate plume's lateral (west – east) and longitudinal (north – south) axis. A multiple axis approach was used given the nitrate plume's larger size. Along the plume's west – east axis, five wells were selected (199-F7-2, 199-F5-48, 199-F5-45, 199-F5-54, and 199-F6-1), and along the plumes' north – south axis six wells (199-F5-6, 199-F5-46, 199-F5-4, 199-F8-7, 699-71-30, and 699-62-31) were selected. The primary source of nitrate present in 100-F/IU groundwater is believed to be the 116-F-9 animal waste leaching trench, which is located in the vicinity of monitoring well 199-F5-54. Additionally, pre-Hanford nitrate sources may also exist. The highest observed nitrate concentrations in 100-F/IU groundwater were detected at wells 699-71-30 (169,000 µg/L – July 1998) and 199-F5-54 (145,000 µg/L – January 2011). The July 1998 value for 699-71-30 is unusual high because nitrate concentrations in the two bounding events (November 1995 and January 1999) were notably lower at 73,900 µg/L and 68,600 µg/L.

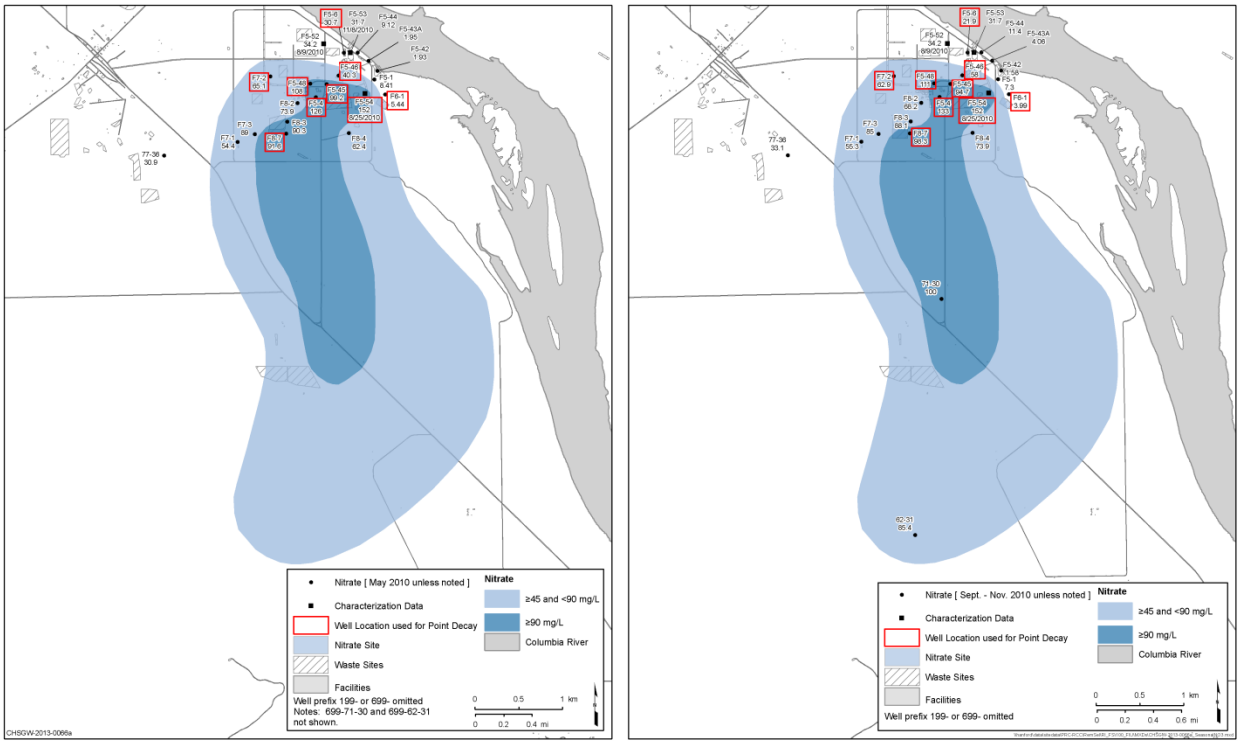


Figure M3-4. Location of Monitoring Wells Used for Nitrate Point Decay Attenuation Rate

The nitrate data set in 100-F/IU is more extensive than the other COCs with several monitoring wells having laboratory analysis results dating back to 1980. Because of the longer timeframe, this data set shows both the evolution and migration of the nitrate plume over time. Relative to the other groundwater COCs, nitrate concentrations in 100-F/IU groundwater have been slow to reverse the upward trend that prevailed at many of the well locations evaluated in this appendix between 1990 and 2005. Between 2005 and 2010, nitrate concentrations appear to have peaked at most locations and have since begun to decline. The proximity (e.g. greater distance) of these monitoring wells relative to historic primary sources and recently remediated secondary sources is the likely cause for this time lag.

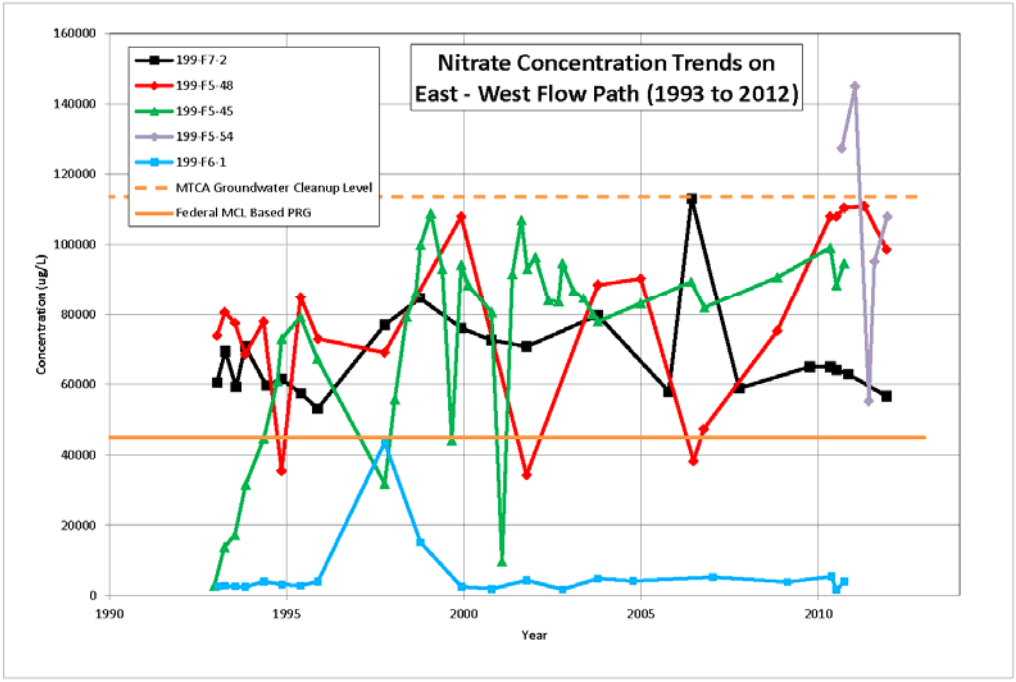
To establish a timeframe for calculating the decay rate, the 2003 to 2012 period was selected because this period corresponds to the timeframe that follows completion of the 116-F-9 animal waste leaching trench

interim remedial action (CVP-2001-00008, *Cleanup Verification Package for the 116-F-9 Animal Waste Leaching Trench*), which was completed in March 2002. Four other waste sites with nitrate contamination were remediated in 2002, 2006 and 2007.

The time-series charts for the five wells spanning the plume's west – east axis (Figure M3-5) show decreasing concentrations at three (199-F7-2, 199-F5-54 and 199-F6-1) of the five locations. The Ln concentration vs time transformed data yield a best-fit line (Figure M3-6) with *mean point decay rates* ranging from -0.2949/year to +0.0673/year. The *slowest point decay rates* at 95 percent confidence varied from +0.0233/year to +0.9704/year (Table M3-2). The mean and slowest decay rates for wells 199-F5-48 and 199-F5-45 were positive for the 2003 to 2011 period indicating increasing concentration trends.

The time-series charts for the six wells spanning the plume's north – south axis (Figure M3-7) show declining concentration trends at five of the six well locations with increasing concentrations present at well 199-F5-4. The Ln concentration vs time transformed data (Figure M3-8) yield a best-fit line with *mean point decay rates* ranging from -0.0031/year to +0.0397/year (Table M3-2). The *slowest point decay rates* at 95 percent confidence varied from -0.0067/year to +0.0786/year. The positive decay rate for well 199-F5-4 indicates an increasing concentration trend for the 2003 to 2011 period. The average mean decay for all 11 wells is -0.0474/year and the average slowest decay rate +0.1206/year.

The estimated timeframe to achieve a 45,000 µg/L PRG for nitrate, using the range of mean and slowest point decay rates at the eight locations where declining nitrate concentrations were observed, ranged from 3 to 208 years with the longest timeframe occurring at well 699-71-30, where a nitrate concentration of 99,000 µg/L was observed in 2011.



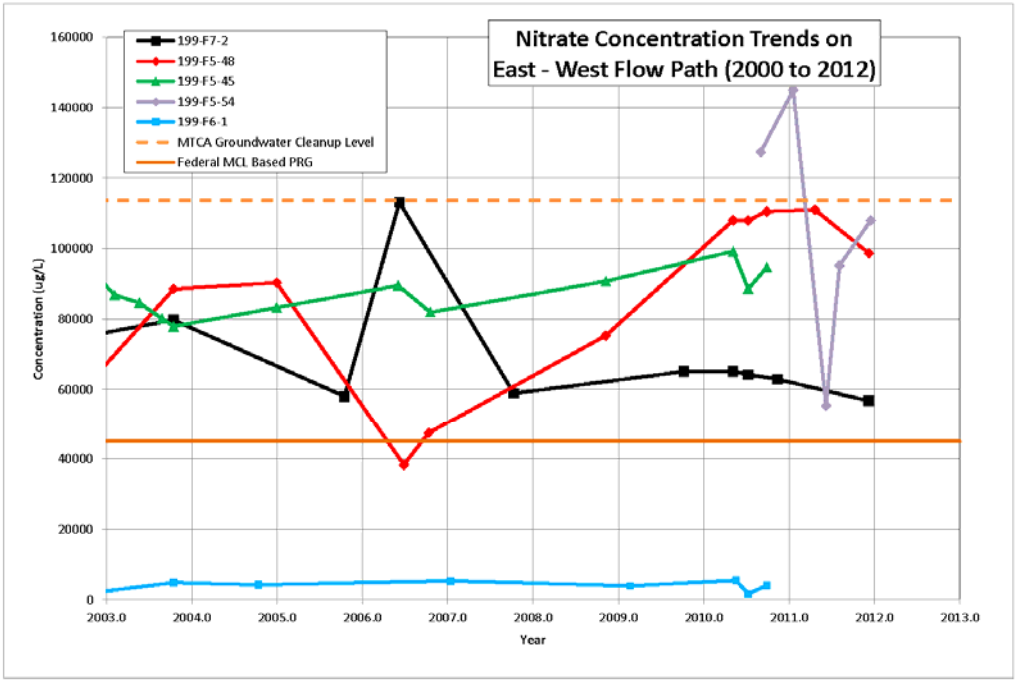
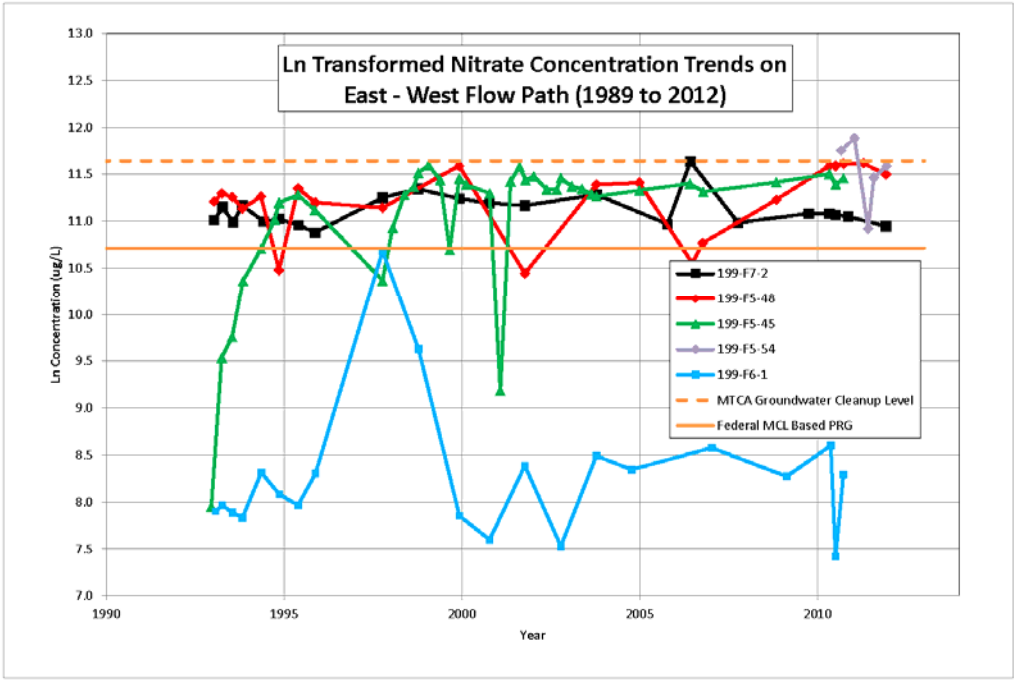


Figure M3-5. Nitrate Concentration Trends for Point Decay Attenuation Rate – East to West Monitor Well Transect



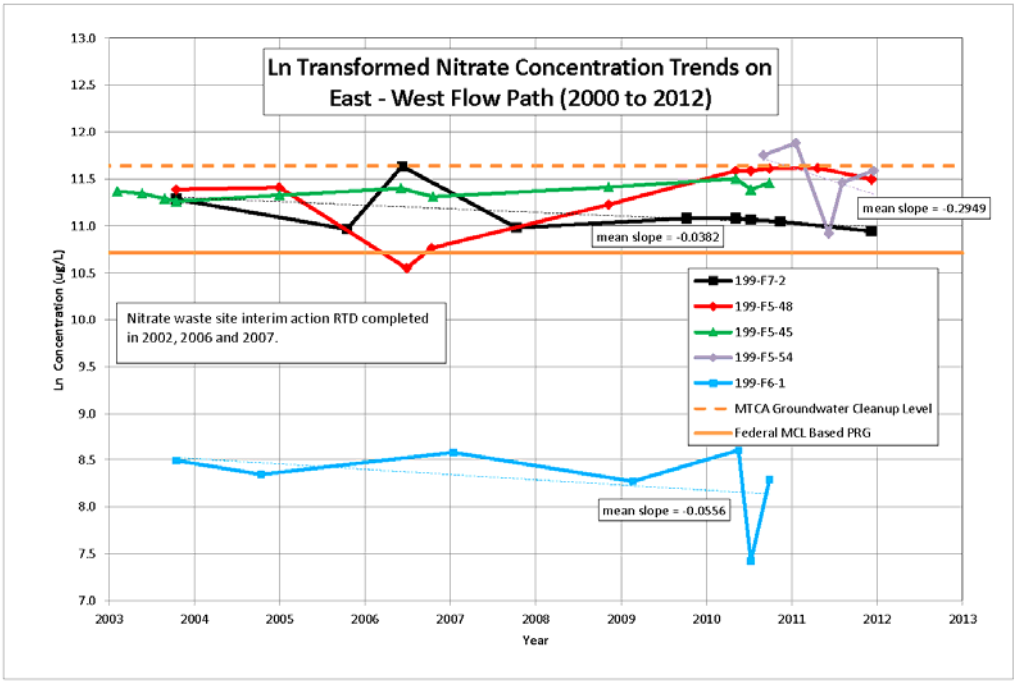
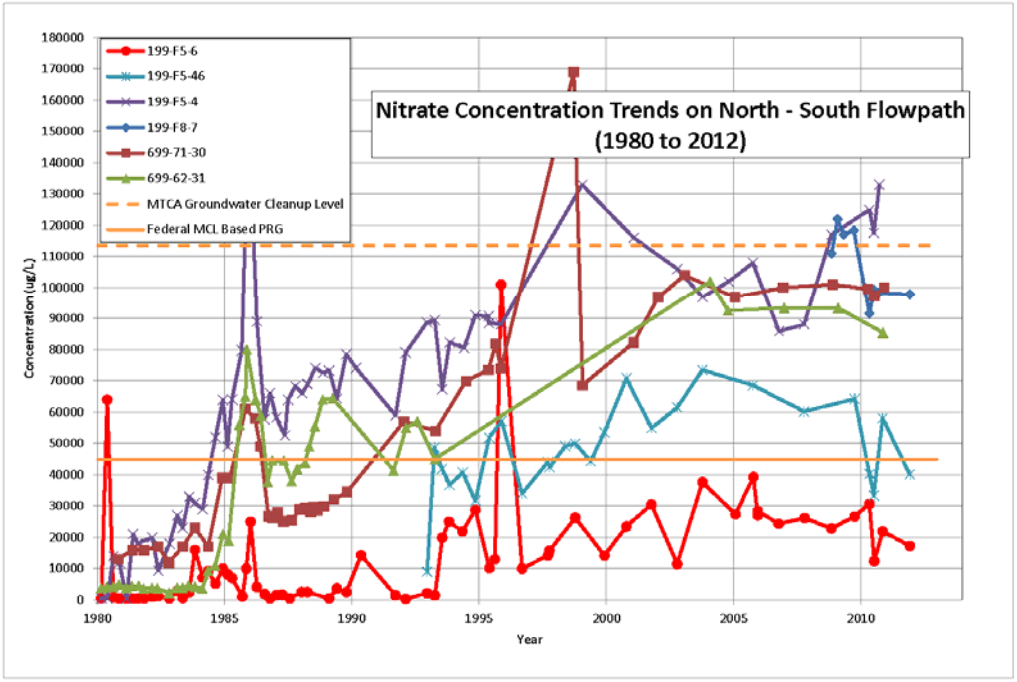


Figure M3-6. Ln Transformed Nitrate Concentration Trends for Point Decay Attenuation Rate – East to West Monitor Well Transect



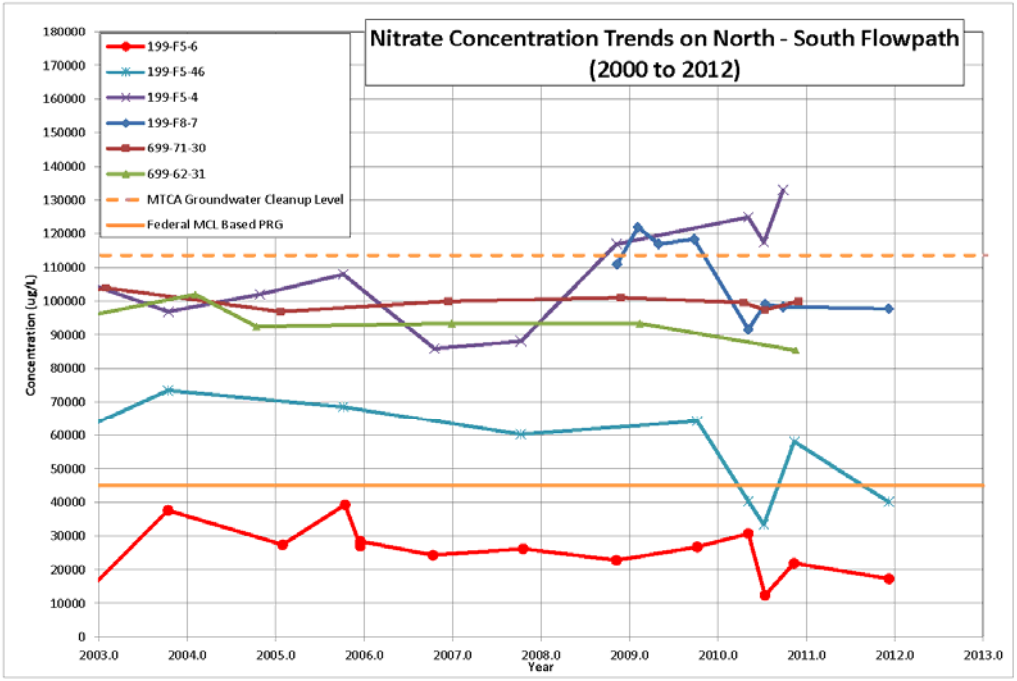
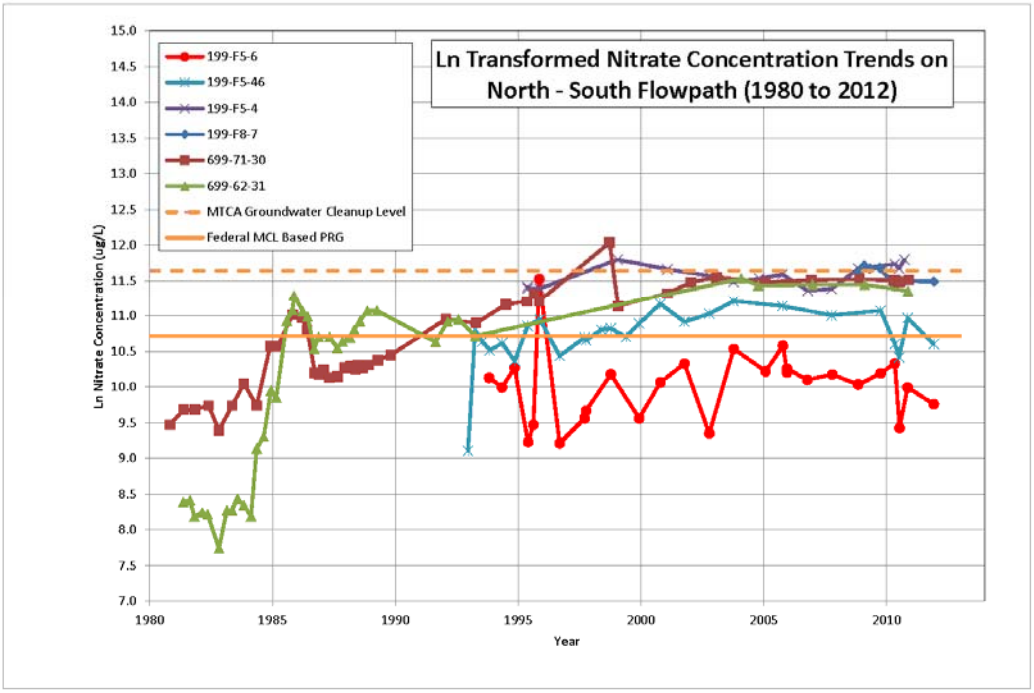


Figure M3-7. Nitrate Concentration Trends for Point Decay Attenuation Rate – North to South Monitor Well Transect



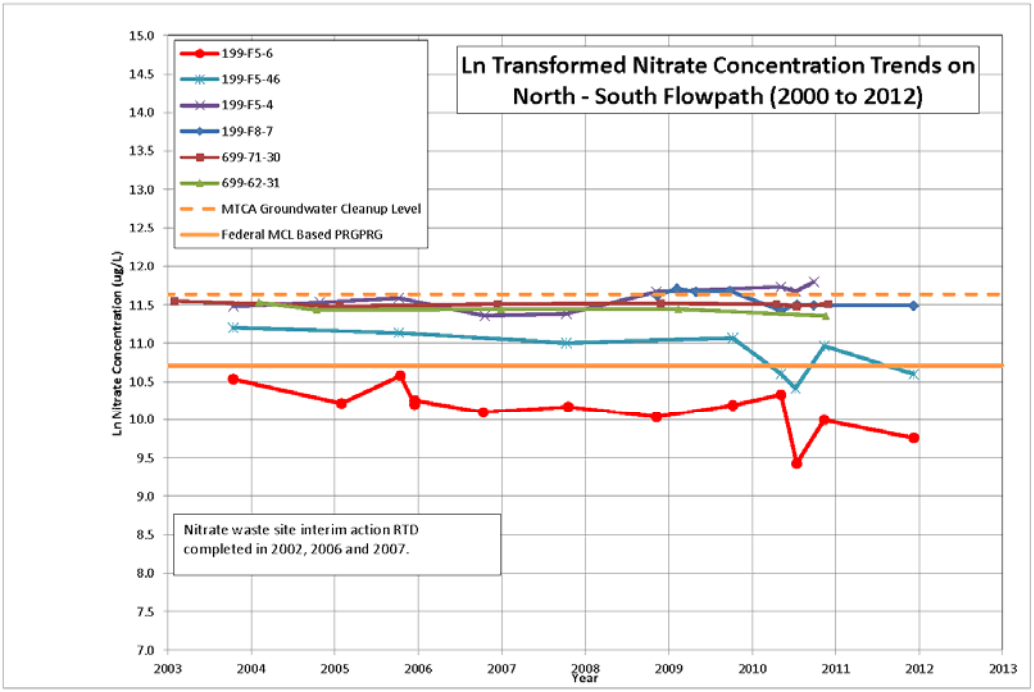


Figure M3-8. Ln Transformed Nitrate Concentration Trends for Point Decay Attenuation Rate – North to South Monitor Well Transect

Table M3-2. Nitrate Attenuation Rates Estimated Using Point Decay Method

Well	Number of Data Points - Date Range for Regression Analysis	Point Decay Rate k = 1/year		COC Concentration (Most Recent)		Time for COC Concentration to Decay to PRG (yrs)	
		Mean	Slowest	µg/L or pCi/L	Ln (µg/L of pCi/L)	Mean Rate	Slowest Rate
Nitrate – West to East Transect (use post-2003 data only)							
199-F7-2	9-10/03 to12/11	-0.0382	+0.0233	56,700	10.95	6.1	Not Estimated [a]
199-F5-48	10-10/03 to 12/11	+0.0673	+0.1591	98,700	11.50	Not Estimated [a]	Not Estimated [a]
199-F5-45	11- 2/03 to 9/10	+0.0183	+0.0297	94,700	11.46	Not Estimated [a]	Not Estimated [a]
199-F5-54	5-8/10 to 12/11	-0.2949	+0.9704	108,000	11.59	3.0	Not Estimated [a]
199-F6-1	7-10/03 to 9/10	-0.0556	+0.0924	3,990	8.29	Below PRG	Below PRG
Nitrate – North to South Transect (use post-2003 data only)							
199-F5-6	13-10/03 to 12/11	-0.0803	-0.0238	17,300	9.76	Below PRG	Below PRG
199-F5-46	8-10/03 to 12/11	-0.0766	-0.0067	40,100	10.60	Below PRG	Below PRG
199-F5-4	9-10/03 to 9/10	+0.0397	0.0786	133,000	11.80	Not Estimated [a]	Not Estimated [a]
199-F8-7	8-11/08 to 12/11	-0.0789	-0.0083	97,800	11.49	9.8	93.4
699-71-30	7-1/03 to 11/10	-0.0031	+0.0052	85,400	11.36	208.3	Not Estimated [a]
699-62-31	5 – 2/04 to 11/10	-0.0177	+0.0062	100,000	11.51	45.1	Not Estimated [a]
Average Nitrate		-0.0473	0.1206	133,000	11.80	23	Not Estimated [a]

a. Remediation timeframe not estimated because decay factor is positive (e.g. concentrations not decreasing).

M3.2.5 Trichloroethene Point Attenuation Rates

There are three 100-F/IU trichloroethene plumes identified informally in this appendix as the west, east and south plumes. Point attenuation rates were calculated for six different monitoring well locations (Figure M3-9) with three wells (699-77-36, 199-F7-1, and 199-F7-3) spanning the longitudinal axis of the west plume and three wells (199-F7-2, 199-F5-45, and 199-F5-46) spanning the longitudinal axis of the east plume. A decay rate for the single well (199-F8-4) defining the south plume was not calculated because the current trichloroethene concentration does not exceed the 4.9 µg/L PRG. The presumed

source of trichloroethene observed in 100-F/IU groundwater is the 600-127 waste site located in the vicinity of monitoring well 699-77-36 and the 118-F-2 Burial Ground located just upgradient of the east plume. Interim remedial action of these two waste sites as completed in 2010 and 2007, respectively.

Laboratory analysis results dating back to 1987 show the existence of a trichloroethene plume at well 699-77-36, migration of the plume past 199-F7-1 in 1990, and appearance of the plume's leading edge at 199-F7-3 in 1998. It's presumed interim remedial action in 100-F/IU resulted in a temporary concentration rebound with trichloroethene concentrations rising between 2007 and 2010 (Figure M3-10) at these three locations before resuming a downward trend. trichloroethene concentrations in the eastern plume have fluctuated between about 2 µg/L and 8 µg/L.

The regression analysis for the Ln of trichloroethene concentration vs. time (Figure M3-11) transformed data yields a best-fit line with *mean point decay rates* varying from -0.0131/year to -0.0539/year (Table M3-3). The *slowest point decay rates* at 95 percent confidence ranged from +0.0459/year to -0.0486/year.

The estimated timeframe to achieve a 4.9 µg/L PRG for trichloroethene using the mean point decay rates ranges from 13.2 to 39.3 years with an average of 33.6 years. The estimated timeframe to achieve the PRG based on the slowest calculated decay rate ranges from 14.7 to 82 years.

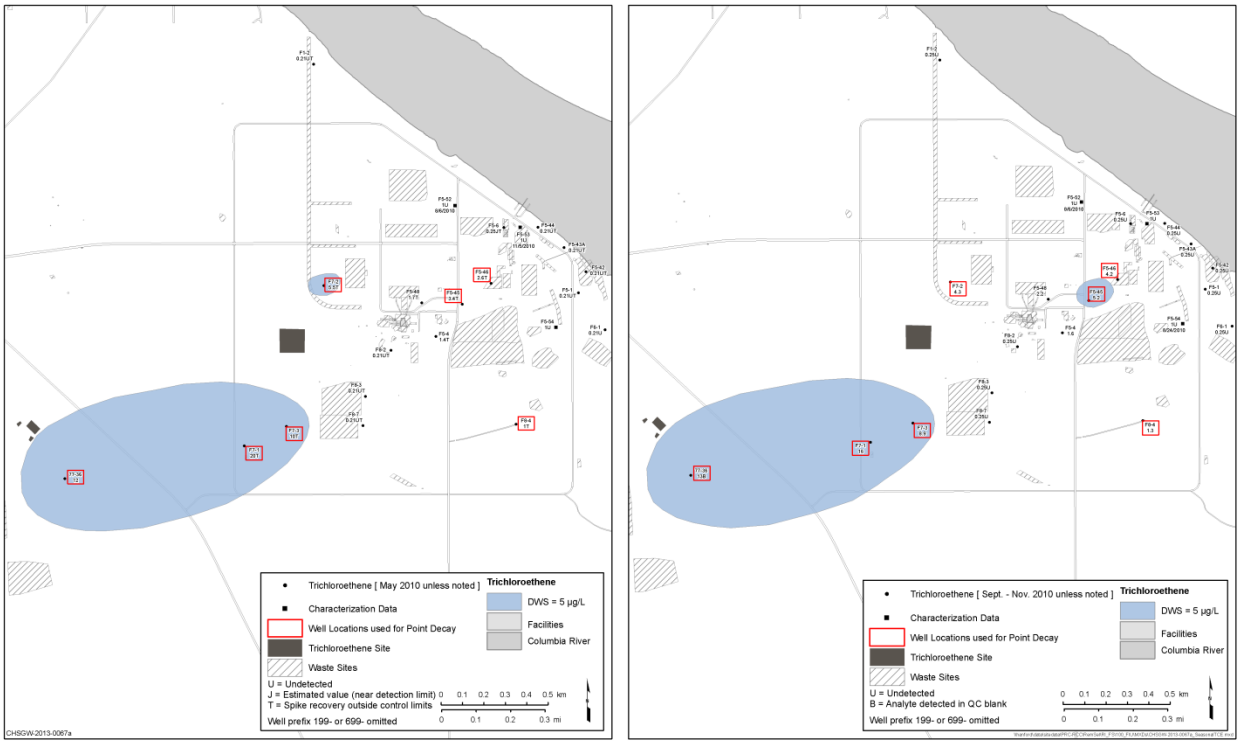


Figure M3-9. Location of Monitoring Wells used for Trichloroethene Point Decay Attenuation Rate

Table M3-3. Trichloroethene Attenuation Rates Estimated Using Point Decay Method

Well	Number of Data Points - Date Range for Regression Analysis	Point Decay Rate k = 1/year		COC Concentration (Most Recent)		Time for COC Concentration to Decay to PRG (yrs)	
		Mean	Slowest	µg/L or pCi/L	Ln (µg/L of pCi/L)	Mean Rate	Slowest Rate
699-77-36	30-12/87 to 11/11	-0.0539	-0.0486	10	1.3	13.2	14.7
199-F7-1	26-2/90 to 12/11	-0.0267	-0.0128	14	2.6	39.3	82
199-F7-3	9- 10/02 to 12/11	-0.0131	+0.0459	7.7	2.0	34.5	Not Estimated*
199-F8-4	18-1/93 to 9/10	No detection above PRG					
199-F7-2	22-1/93 to 12/11	Not calculated, most recent values are generally non-detect					
199-F5-45	21-12/92 to 9/10	Not calculated, most recent values are generally non-detect					
199-F5-46	21-12/92 to 12/11	Not calculated, most recent values are generally non-detect					
Average Trichloroethene		-0.0312	-0.0052	14	2.64	34	200

*Remediation timeframe not estimated because decay factor is positive (e.g. concentrations not decreasing).

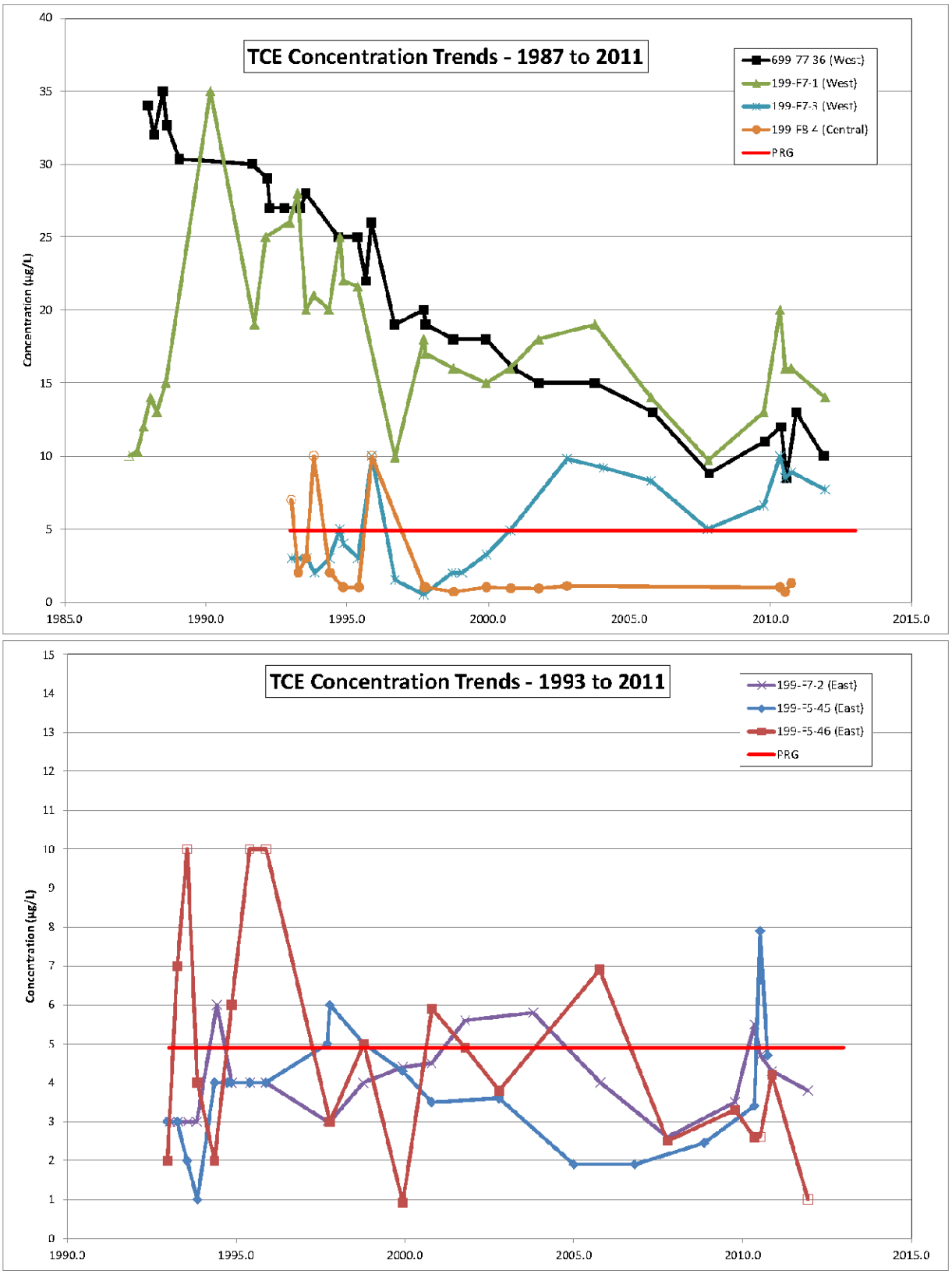


Figure M3-10. Trichloroethene Concentration Trends for Point Decay Attenuation Rate

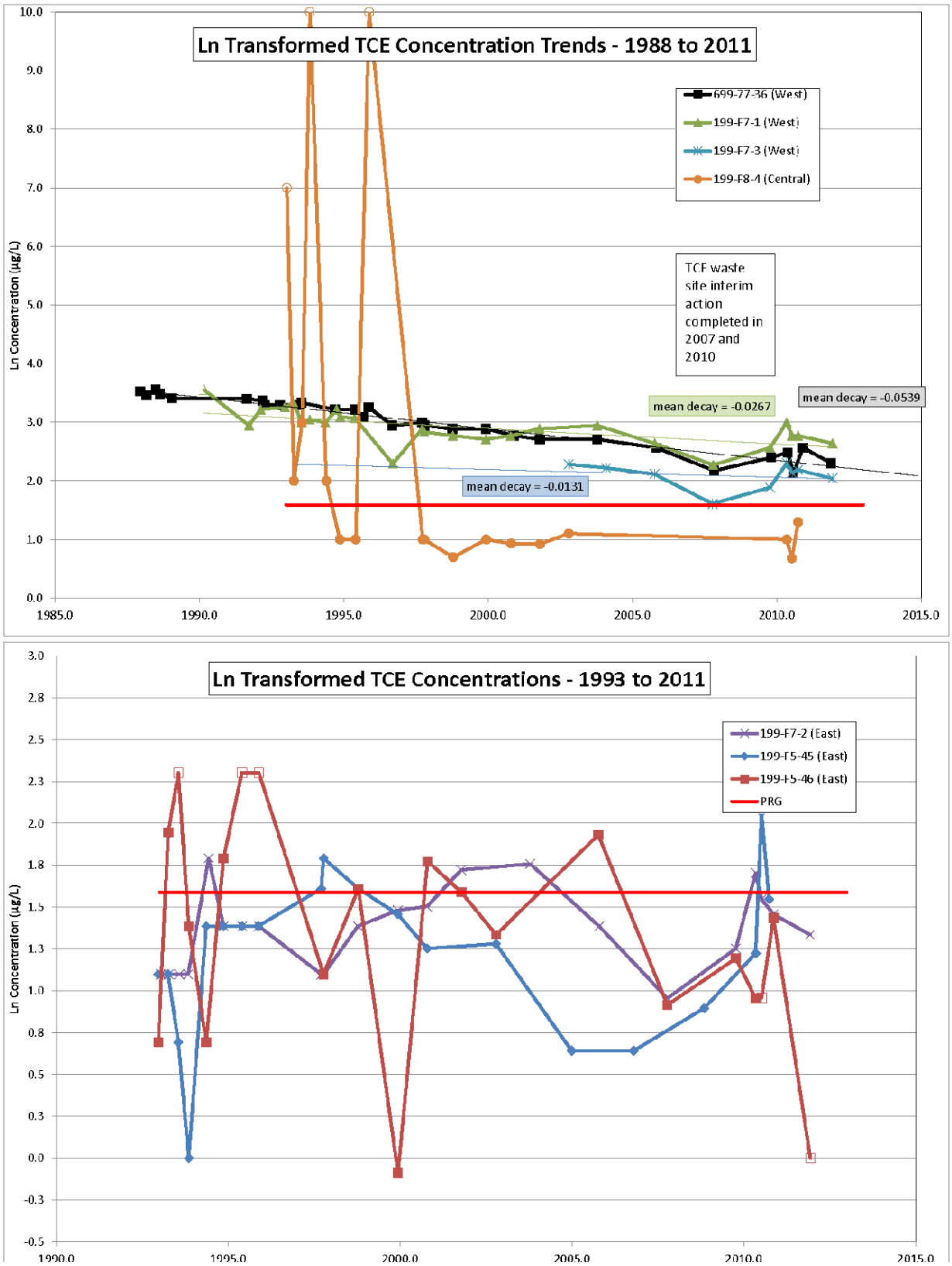


Figure M3-11. Ln Transformed Trichloroethene Concentration Trends for Point Decay Attenuation Rate

M3.2.6 Strontium-90 Point Attenuation Rates

A point attenuation rate was calculated at the one monitoring well location (Figure M3-12) that defines the strontium-90 plume. The strontium-90 concentration trend for this well is portrayed on Figure M3-13. There were a number of waste sites that contained strontium-90 that were remediated between 1993 and 2011 with a majority of the waste site remediation work completed in the 2002 to 2003 and 2007 timeframe.

The plot of the natural log (Ln) of concentration vs. time can be approximated by a straight line with a slope of k (Figure M3-13). The *mean point decay rate* for strontium-90 was -0.0832/year with a *slowest point decay rate* at 95 percent confidence of -0.0546/year (Table M3-4). The estimated timeframe to achieve the strontium-90 PRG of 8 pCi/L is approximately 43 and 65 years, respectively.

Table M3-4. Strontium-90 Attenuation Rates Estimated Using Point Decay Method

Well	Number of Data Points - Date Range for Regression Analysis	Point Decay Rate k = 1/year		COC Concentration (Most Recent)		Time for COC Concentration to Decay to PRG (yrs)	
		Mean	Slowest	µg/L or pCi/L	Ln (µg/L of pCi/L)	Mean Rate	Slowest Rate
199-F5-1	13-10/00 to 12/11	-0.0832	-0.0546	285*	5.65	43	65

* Although 11 pCi/L is the highest recent strontium-90 concentration presented in this appendix, a value of 285 pCi/L was used to reflect 2012 groundwater monitoring results.

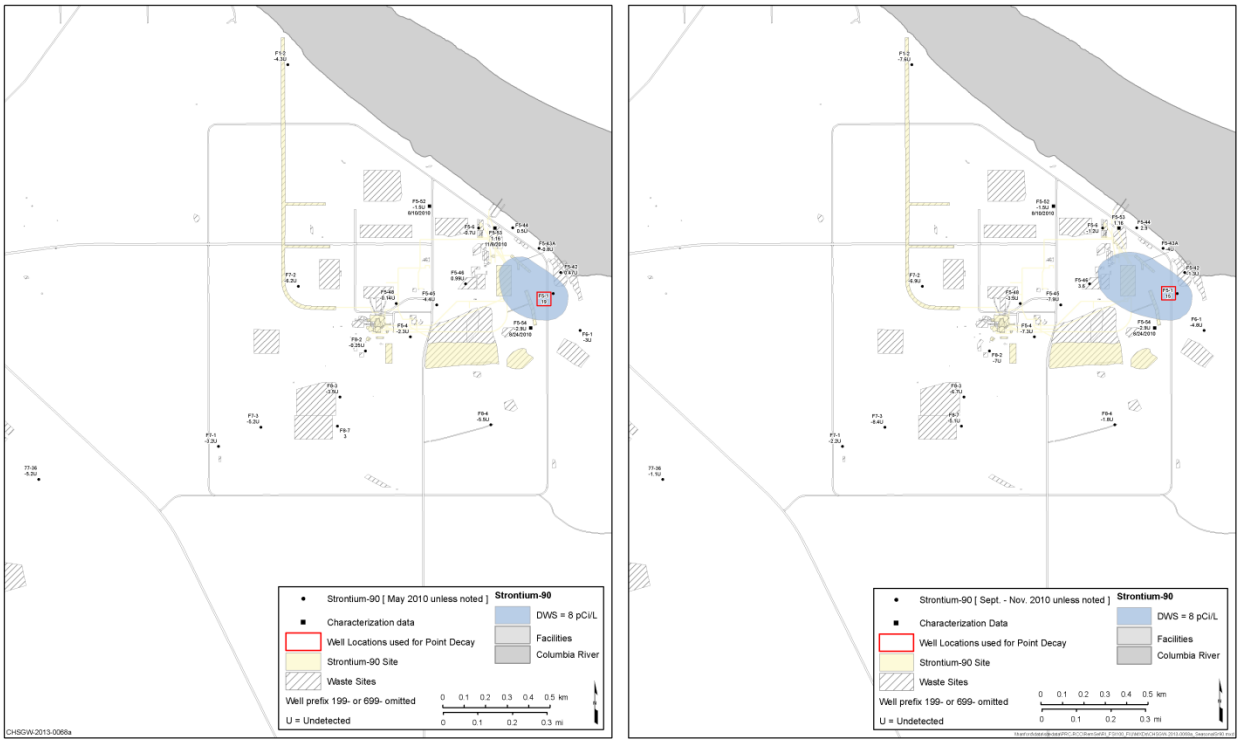
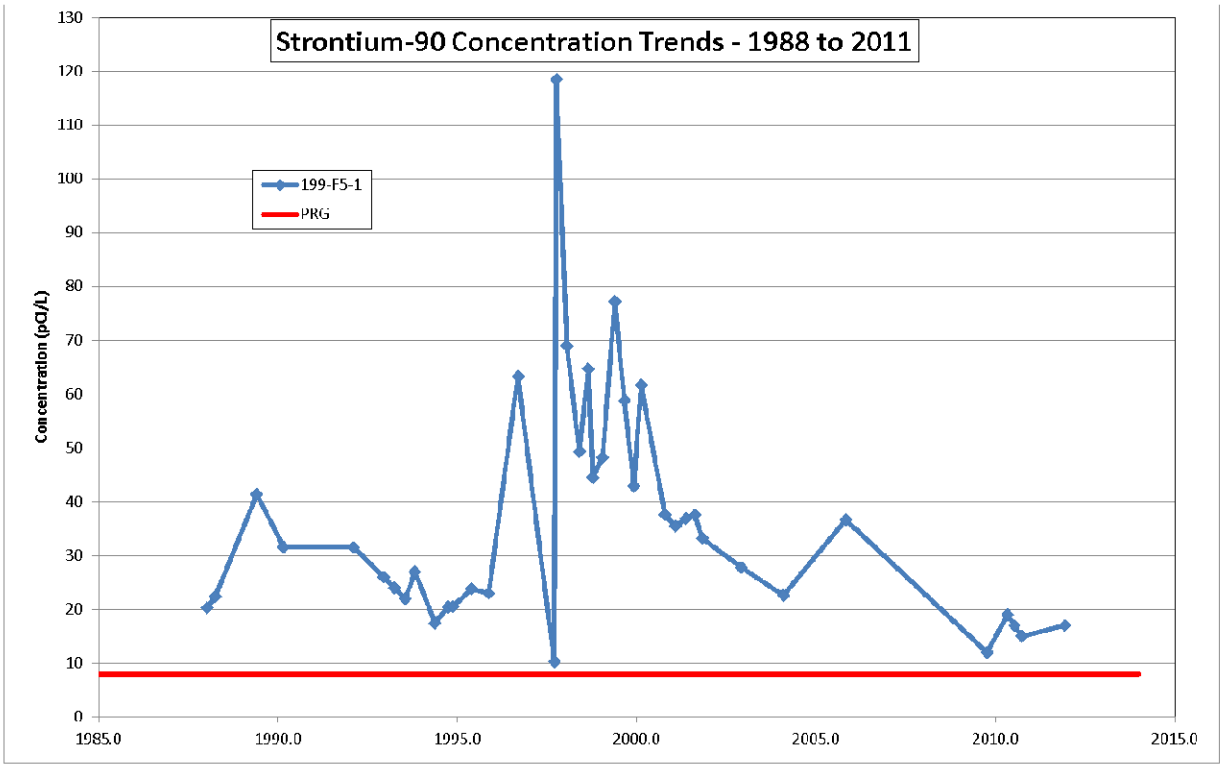


Figure M3-12. Location of Monitoring Well Used for Strontium-90 Point Decay Attenuation Rate



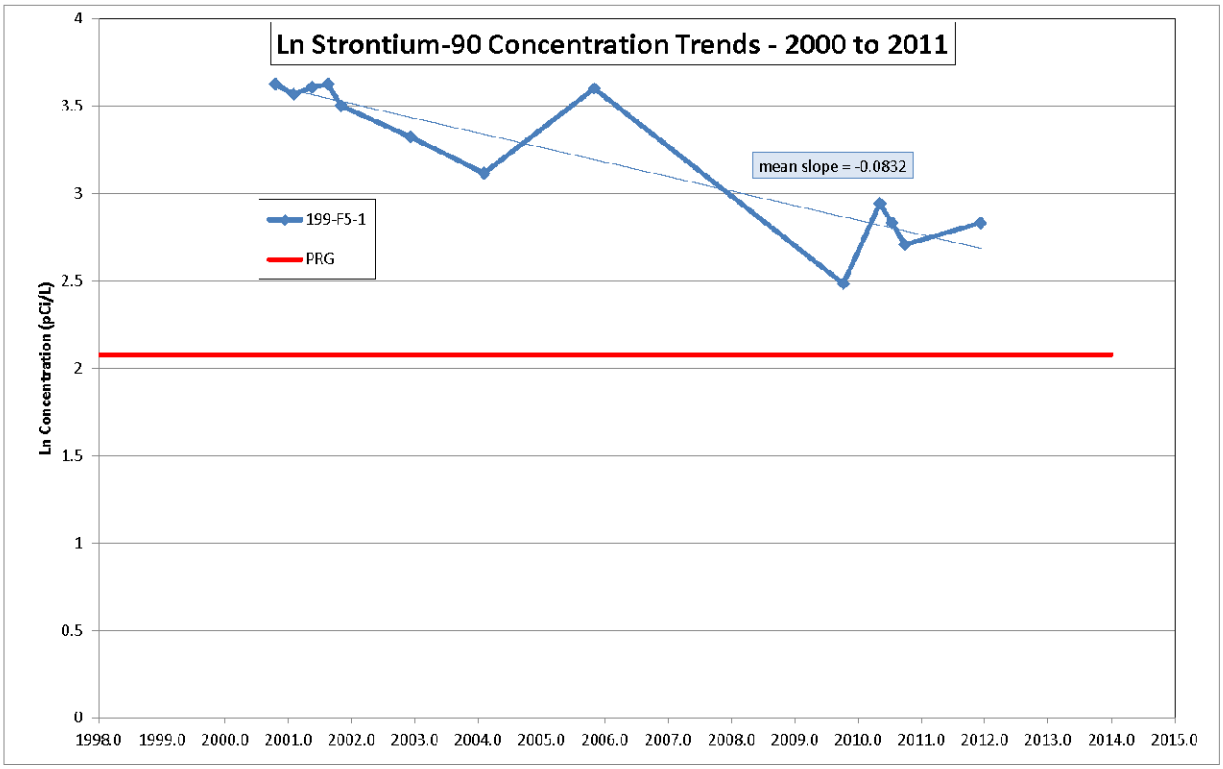


Figure M3-13. Strontium-90 Concentration Trends for Point Decay Attenuation Rate

M3.2.7 Uncertainties in Point Decay Rate Estimation

Point decay rates estimated using Ln transformed concentration versus time data are expected to provide reasonable estimates of remediation timeframes because they are based on historical observations. These estimates can be influenced by several factors with the period duration (e.g., begin and end) and number of data points used in the regression analysis expected to exert the greatest influence. Decay factors may also be influenced by measurements collected during primary source discharge events or when primary/secondary source remedial action is underway. This influence may be reduced if a longer regression analysis timeframe is used. Decay factors estimated using concentration measurements collected under steady-state conditions following remediation of primary and secondary sources are expected to yield the most representative results.

As shown in Table M3-2, the mean decay factors for 3 of the 11 nitrate monitoring well locations evaluated were positive, which indicates an increasing concentration trend. These three wells (199-F5-4, 199-F5-45, and 199-F5-48) are located in the core region of the plume, near historic remediated sources, where concentrations are currently higher relative to other locations. Within this portion of the aquifer, nitrate levels at Wells 199-F5-45 and 199-F5-48 appear to have stabilized only recently. At 199-F5-4, nitrate concentrations have fluctuated widely. This portion of the nitrate plume appears to be transitioning from an unstable to stable condition. Therefore, as the aquifer system recovers from the effects of historical primary source discharges and remediation of secondary sources, decay rates should approach values reflective of long-term conditions.

M3.3 Evidence for Type(s) of Natural Attenuation Processes

As described in Section M2.1, ORP, DO, nitrate, manganese, iron, sulfate, carbon dioxide, and alkalinity can provide indirect evidence on the presence of biodegradation and abiotic degradation processes. To evaluate this line of evidence, the HEIS database was queried and historic concentration data downloaded for many of these parameters. The following subsections summarize the results and describe their significance relative to potential COC transformation processes in 100-F/IU groundwater.

M3.3.1 Oxidation-Reduction Potential

As shown on Figure M2-1, ORP measurements provide a general measure of the oxidation-reduction reactions that may be occurring at a site. ORP measurements at 100-F/IU were first implemented in 2010 and have continued through 2012. The HEIS 100-F/IU summary for ORP shows 221 measurements with values ranging from 0 mV to +476 mV with the lowest values of 0 mV observed in depth discrete groundwater samples collected from wells 199-F5-52 and 199-F5-54 in August 2010. The range of values observed indicates that the groundwater is generally oxidizing with some potential for denitrification, manganese and iron reduction in specific areas.

Mapping of average 2010 ORP values within the boundaries of Cr(VI) plume (Figure M3-14) shows oxidizing conditions (greater than +250 mV) at all locations except 199-F5-52 (+29.3 mV) and 199-F5-54 (+6.9 mV). These conditions are not conducive to widespread reduction of Cr(VI) to trivalent chromium.

Within the nitrate plume (Figure M3-15), ORP values are greater than +250 mV at all locations except 199-F5-52 and 199-F5-54 indicating oxidizing conditions are prevalent. As indicated in Figure M2-1, ORP values between +100 mV and +250 mV are more favorable for denitrification processes.

In the vicinity of the trichloroethene plume (Figure M3-16), ORP values are also greater than +250 mV at all locations except 199-F5-52 and 199-F5-54. Although reductive dechlorination can occur across a broad range of redox conditions, ORP values less than -200 mV are more favorable.

The ORP measurements were made in the field with a dedicated probe and flow though cell as the monitoring well is purged prior to sampling. Many of the monitoring wells have screen lengths greater than 3 m (10 ft), and therefore, the ORP measurements provide an integrated value for a broad portion of the aquifer opposite the well screen. Additionally, under pumping conditions, groundwater is preferentially drawn through the well screen from the more transmissive zones, with the less transmissive zones providing only a limited contribution to the total flow and ORP measurement. Many of oxidation-reduction reactions of interest are expected to take place in the less transmissive zones. Therefore, the ORP measurements may not be representative for all portions of the aquifer. Vertical ORP profiling across the well screen interval under static (non-pumping) conditions may provide more representative information to identify the presence and vertical extent of these fine-grained zones.

M3.3.2 Dissolved Oxygen

Dissolved oxygen concentrations greater than 0.5 mg/L are indicative of aerobic conditions while concentrations less than 0.5 mg/L indicate anaerobic conditions. Many of the biologically mediated redox reactions affecting 100-F/IU groundwater COCs occur under anaerobic conditions; therefore, mapping of DO concentrations in groundwater can identify areas where aerobic and anaerobic conditions occur. Although chemical reduction reactions may occur at DO concentrations greater than 0.5 mg/L, many of the species (ferrous iron and sulfide minerals) that participate in these reactions are expected to be present in groundwater only when the DO concentrations are low.

The HEIS database query for DO showed 226 measurements for the 2006 to 2011 period. DO concentrations in this data set ranged from 0.3 mg/L to 15.29 mg/L with only one measurement less than the anaerobic threshold level of 0.5 mg/L. This measurement was taken in April 2010 at well 699-74-44 and subsequent measurements performed in July and November 2010 showed DO concentrations of 1.05 and 1.09 mg/L, respectively. The range of DO concentrations observed indicates that aerobic conditions prevail; however, as described for the ORP measurements, the DO measurements may not be representative of the fine-grained portions of the aquifer where anaerobic conditions may occur. In well vertical profiling of DO and ORP may be helpful in identifying the presence of zones where chemical or biologically mediated reduction is occurring.

M3.3.3 Nitrate

Nitrate is a competing electron acceptor, and when present at concentrations greater than 1 mg/L, it may preclude the evolution of more reducing conditions required for widespread reduction of Cr(VI) and trichloroethene. Based on the levels of nitrate present, and its widespread distribution, it is believed that nitrate is a significant inhibitor to degradation processes in 100-F/IU groundwater.

M3.3.4 Iron

As described in Section M2.1, aqueous and mineral phase Fe(II) is an important Cr(VI) and nitrate reductant. Additionally, where Fe(II) concentrations exceed 1 mg/L (iron-reducing conditions), a trichloroethene-reductive dechlorination pathway is possible. Additionally, although it has not been detected, VC, which is a trichloroethene degradation product, may be oxidized to carbon dioxide.

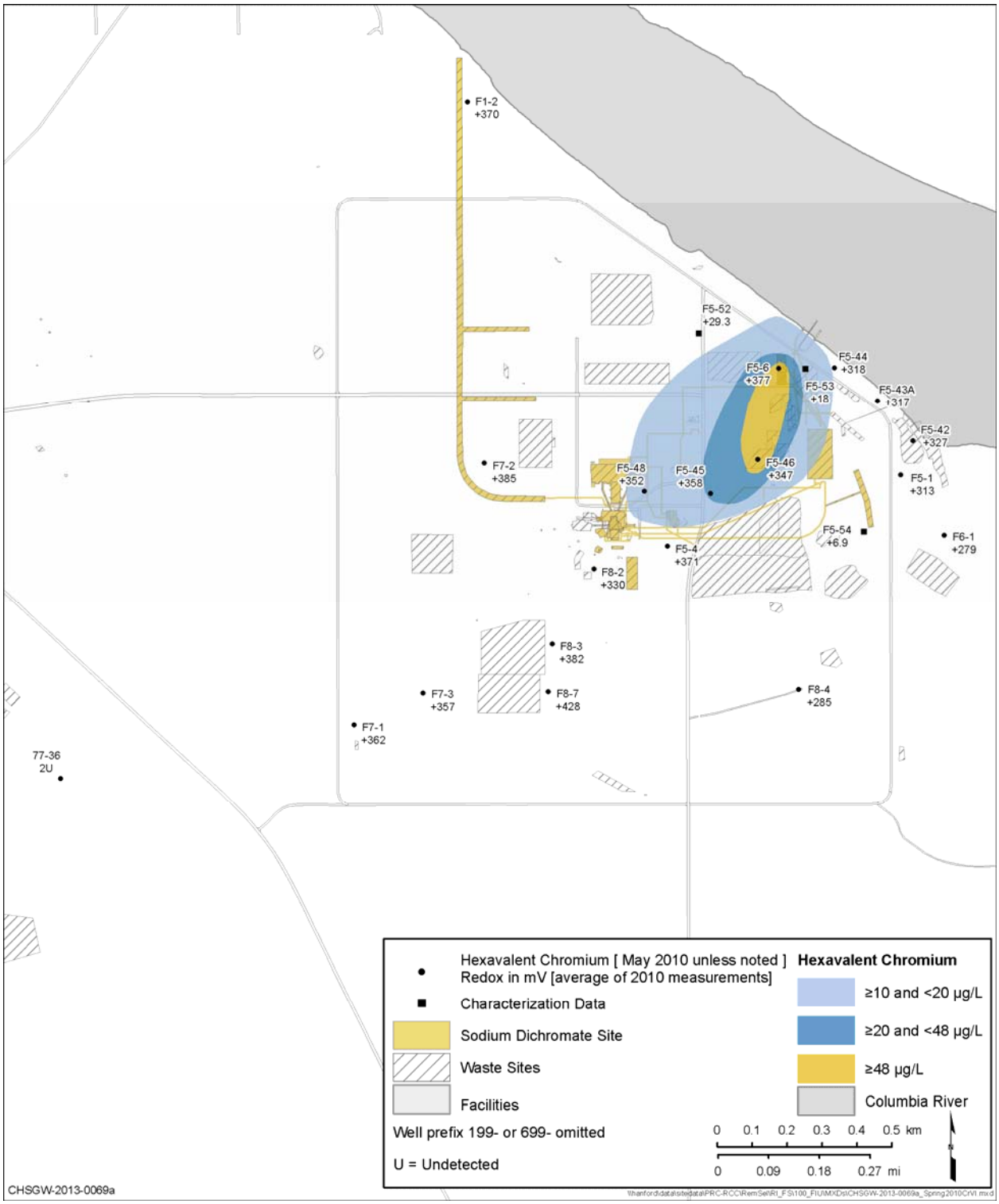


Figure M3-14. Groundwater ORP in Vicinity of Cr(VI) Plume

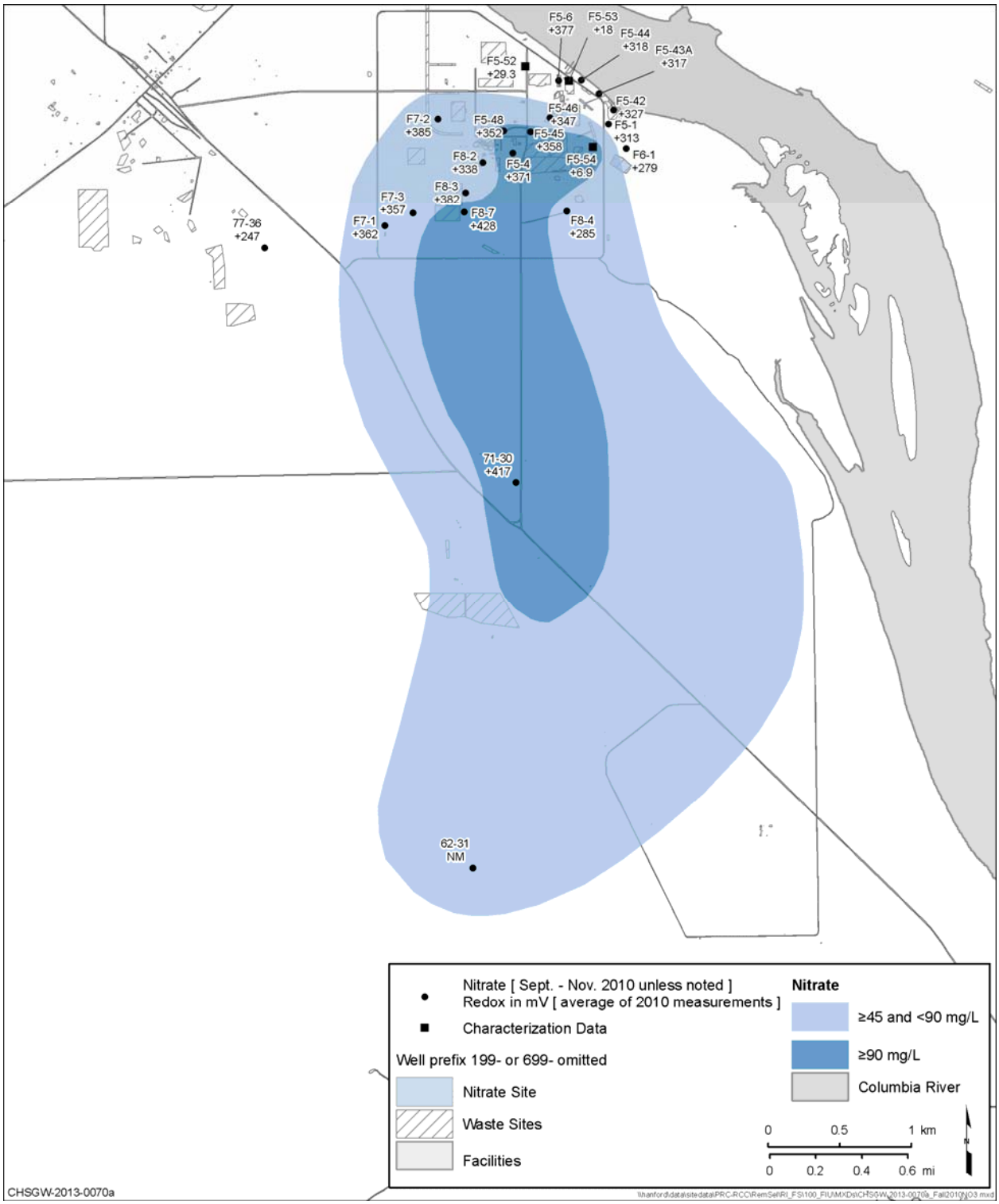


Figure M3-15. Groundwater ORP in Vicinity of Nitrate Plume

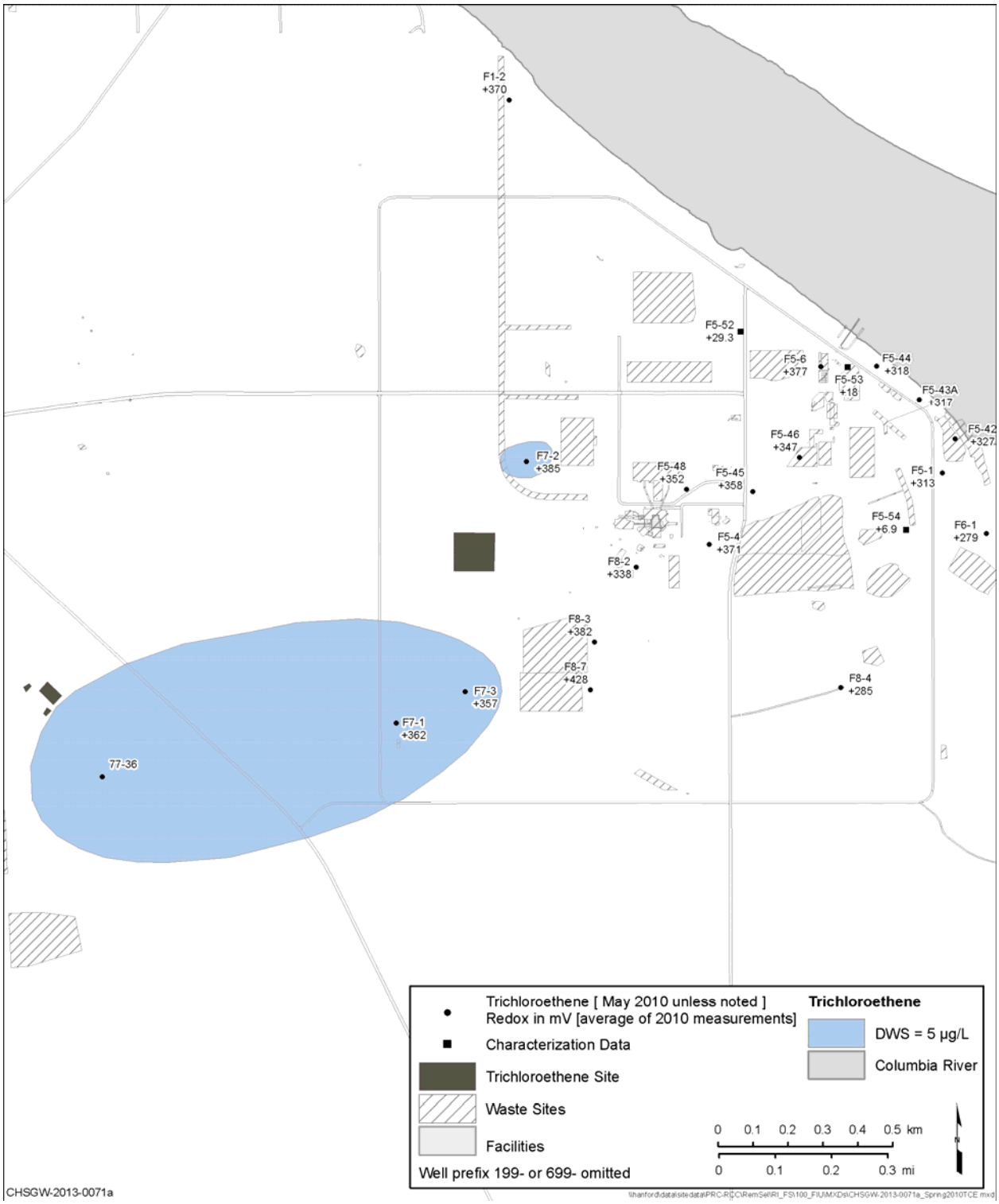


Figure M3-16. Groundwater ORP in Vicinity of Trichloroethene Plume

The HEIS database query for iron showed 522 measurements for the 2006 to 2011 period. The results are for total iron and do not differentiate Fe(II) from Fe(III). Because groundwater is aerobic across most of the 100-F/IU area, the analysis results most likely reflect Fe(III) concentrations. Iron concentrations in the data set ranged from less than 0.009 mg/L to 9.38 mg/L, with concentrations greater than 1 mg/L observed in unfiltered samples from aquifer tubes 62-M and 74-D, monitor well 699-74-44, and borehole groundwater samples C6309 and C6315. The corresponding filtered samples contained much lower concentrations of iron, indicating the unfiltered samples contained particulate matter from the aquifer or well screen, and therefore, are not representative of groundwater conditions.

The absence of total iron concentrations greater than 1 mg/L within the area covered by the 100-F/IU monitoring well network is consistent with the ORP and DO measurements and indicates that iron-reducing conditions are not prevalent. Therefore, Cr(VI), nitrate, and trichloroethene degradation is not expected under these conditions, however, this conclusion should be confirmed with field Fe(II) measurements and vertical profiling to identify discrete iron reducing zones that may be present but are no evident with the current sampling protocol.

M3.3.5 Sulfate

If sulfate concentrations are low (generally less than 20 mg/L) and sulfide concentrations are high (generally greater than 1 mg/L), sulfate-reducing conditions are present, and a Cr(VI), nitrate and trichloroethene reduction pathway is possible. When sulfide is present, DO concentrations are generally less than 0.5 mg/L.

The HEIS database query for sulfate showed 318 measurements for the 2006 to 2011 period. Sulfate concentrations in the data set ranged from less than 0.13 mg/L to 2,110 mg/L with the highest concentration detected at aquifer tube AT-F-2-M. However, this result was flagged as a suspected error, and a duplicate sample had a sulfate concentration two orders of magnitude lower. The next highest observed sulfate concentration was 234 mg/L at Well 199-F5-56 (December 2011). Sulfide was not reported in this data set.

Based on the sulfate concentrations, and ORP and DO concentrations observed, sulfate reducing concentrations are not expected to be widespread in 100-F/IU groundwater.

M3.3.6 Trichloroethene Daughter Products

As shown on Figure M2-2, reductive dechlorination of trichloroethene results in the formation of cis 1,2-dichloroethene and vinyl chloride. The year 2006 to 2012 data set used for this NA assessment contains laboratory analysis results for 160 samples where cis 1,2-dichloroethene was tested and 174 samples where VC was tested. Cis-DCE was not detected at concentrations above the 0.083 to 5 µg/L reporting limit. Similarly, VC was not detected at concentrations above the 0.084 µg/L to 10 µg/L reporting limit. The absence of these daughter products suggests that a reductive dechlorination pathway does not occur in 100-F/IU groundwater.

M3.3.7 Carbon Sources

Testing for total and dissolved organic carbon, which is an important component for a biodegradation pathway, has not been performed. However, based on the observed distribution of other electron acceptors, the nature of contaminants released in 100-F/IU, and the arid-semiarid site setting, the absence of naturally occurring organic carbon in groundwater is expected to be a limiting factor affecting degradation processes in 100-F/IU groundwater.

M3.4 Non-degrading Processes (all COCs)

The effect of non-degrading NA processes on the fate and transport of 100-F/IU COCs is illustrated in the numerical modeling simulations presented in ECF-100FR3-11-0116 for remedial action alternatives GW-1: No Action/GW-2: ICs and MNA. These simulations include input parameters (Table M3-5) for dispersion, sorption and radioactive decay only, and therefore, do not account for any degradation that may occur via biological or abiotic means, mass transfer through volatilization, or concentration reductions resulting from groundwater-surface water mixing in the hyporheic zone. Consequently, the distribution and estimated timeframe to achieve the PRGs for the alternative GW-1/GW-2 model simulations will be greater than estimates made using the mean point decay rates presented in Table M3-1. A comparison of the remedial action timeframes estimated with the fate and transport model versus those estimated using the decay factors is presented in Section M4.

Table M3-5. Input Parameter Values for Saturated Zone Groundwater Transport Simulations

Parameter	Cr(VI)		Nitrate		Strontium		Trichloroethene	
	Mobile Domain	Immobile Domain	Mobile Domain	Immobile Domain	Mobile Domain	Immobile Domain	Mobile Domain	Less Mobile Domain
Porosity	0.18	0.045	0.18	0.045	0.18	0.045	0.18	0.045
Bulk density (g/cc)	1.72		1.72		1.72		1.72	
K_d (cc/g)	0.0[b]	0.3[a]	0.0[2]	0.0[b]	7.0[c]	39.0[c]	0.0[d]	0.025[d]
Decay in water (1/day)	0.0		0.0		6.59E-05		0.0	
Decay on soil (1/day)	0.0		0.0		6.59E-05		0.0	
Radioactive Decay (years)[e]	-		-		28.8		-	
Mass transfer rate (1/day) between mobile and immobile domains	0.01		0.01		0.01		0.01	

[a] Recent leach tests conducted on vadose zone sediment samples indicate that a higher-valued distribution coefficient (kd) of 0.8 may be appropriate as a conservative lower limit when representing residual hexavalent chromium that is present in fine sediment after several pore-volume flushes of contaminated sediments have occurred (ECF-HANFORD-11-0165, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area*). Future revisions of the groundwater fate and transport models will incorporate this new information. Model parameters will also be calibrated to match observed conditions and available information for hexavalent chromium plumes across the River Corridor.

[b] PNNL-18564, *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report*, Table 6.9, Sandy Gravel sediment type

[c] Based on a value of 12 cc/g (PNNL-18564, Table 6.9, Sandy Gravel sediment type) and distributed in the mobile and immobile domains based on the approximate ratio of the corresponding porosities.

[d] Based on empirical calculation (PNNL-13560, *Assessment of Carbon Tetrachloride Groundwater Transport in Support of the Hanford Carbon Tetrachloride Innovative Technology Demonstration Program* (Equations 1 & 2, p. C.16), assuming foc = 0.00027, solubility of trichloroethene of 1,100 mg/L).

[e] Decay values in water/soil correspond to the half-life represented by the radioactive decay.

M3.5 Evaluation of Potentially Toxic and/or Mobile Transformation Products

As described in Section M2.1, for the conditions present in 100-F/IU, Cr(VI) is transformed to trivalent chromium, nitrate to nitrogen gas, trichloroethene to cis 1,2-dichloroethene, and strontium-90 to yttrium. While there is potential for formation of intermediates between the parent and final transformation products, the intermediates identified in Section M2.1 are not expected to be stable or persist in groundwater.

M3.6 Uncertainties and Data Gaps

The key uncertainties associated with NA evaluation include the following:

- Point decay rates – for the Cr(VI) and trichloroethene plumes were estimated at several monitoring well locations using limited data sets (too few detections or too few data points), at locations where concentrations only recently have trended down (nitrate) or where data sets where a temporary concentration trend reversal (trichloroethene) recently occurred. Future groundwater monitoring at the Cr(VI), nitrate and trichloroethene plume monitoring wells will provide additional data that are expected to provide improved decay rate estimates.
- Post waste site interim remedial effects are likely influencing nitrate concentrations at the three monitoring well locations where an increasing concentration was indicated based on the current data set. As groundwater quality begins to stabilize in this portion of the plume, nitrate concentrations are expected to trend down at rates comparable to that observed at other locations.
- NA processes - affecting Cr(VI), nitrate and trichloroethene degradation processes are influenced by the aquifer's redox conditions. One or more NA processes may be acting within different portions of the plume. Improved methods for measuring redox across the well screen under static conditions will allow for greater confidence in identifying the predominant NA process.
- CSIA offers an additional line of evidence to differentiate degradation (biological and abiotic) from non-degrading processes. Periodic CSIA measurements coupled with geochemical indicator parameters provide an important line of evidence for assessing NA degradation processes.
- Microbiology analysis can provide an additional line of evidence for identifying specific microorganisms associated with known NA processes.

M4 Summary and Conclusions

Before selecting MNA as a standalone or component of a broader remedial action alternative, EPA guidance (OSWER Directive 9200.4-17P) specifies that existing site characterization data be compiled to demonstrate:

1. A clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points. In the case of a groundwater plume, decreasing concentrations should not be solely the result of plume migration. In the case of inorganic contaminants, the primary attenuating mechanism should also be understood.

2. Directly or indirectly the type(s) of NA processes that are active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels.

Existing groundwater quality data collected from representative 100-F/IU monitoring wells was used to calculate NA rates, using the methods described in EPA 600/R-11/204, and to identify the likely processes responsible for NA of the Cr(VI), nitrate, trichloroethene and strontium-90 plumes. Based on evaluation of the available information the following conclusions are drawn:

- Waste site remediation completed under the interim action ROD has removed nearly 1 billion kg of Cr(VI), nitrate, trichloroethene and strontium-90 contaminated soil. These actions have removed known and potential groundwater contaminant sources.

- Cr(VI). The average NA rate within the Cr(VI) plume is -0.1649/year. The estimated timeframe to achieve the 10 µg/L surface water protection PRG based on this NA rate and the highest observed Cr(VI) concentration of 23.9 µg/L in 2012 is about 5 years. Because of spatial variations in NA rates, actual remediation timeframes at other monitoring well locations may be shorter or longer. Cr(VI) transformation to trivalent chromium most likely occurs through an abiotic – iron reduction pathway where Cr(VI) is reduced to trivalent chromium in the presence of aqueous or solid phase Fe(II) minerals. Non-degrading processes are also reducing Cr(VI) concentrations in groundwater.

- Nitrate. The average NA rate within the nitrate plume is -0.0473/year. The estimated timeframe to achieve a 45,000 µg/L PRG based on this NA rate and the highest observed nitrate concentration of 133,000 µg/L in 2011 is about 23 years. Due to spatial variations in NA rates, actual remediation timeframes at other monitoring well locations may be shorter or longer. Nitrate transformation to nitrogen gas most likely occurs through the denitrifiction pathway. Non-degrading processes are also reducing nitrate concentrations in groundwater.

- Trichloroethene. The average NA rate within the trichloroethene plume is -0.0312/year. The estimated timeframe to achieve a 4.9 µg/L PRG is about 34 years. Trichloroethene transformation to cis-DCE with direct oxidation to ethene/ethane and carbon dioxide is expected to occur via low-level biological and/or abiotic pathway. Because of spatial variations in NA rates, actual remediation timeframes at other locations within the plume may be shorter or longer. Non-degrading processes are also reducing trichloroethene concentrations in groundwater.

- Strontium-90. The calculated NA rate for strontium-90 based on concentration trends observed at a single monitoring well is -0.0832/year, which is greater than its radioactive half-life of -0.0347/year. Due to strontium-90's high affinity for aquifer solids, mass transfer from the aqueous phase to aquifer solids (sorption) is most likely responsible for the increased NA rate. The estimated timeframe to achieve an 8 pCi/L PRG based on this NA rate and the highest observed strontium-90 concentration

of 285 pCi/L is 43 years. As a result of spatial variations in NA rates, actual remediation timeframes at other locations within the plume may be shorter or longer.

A comparison of remedial action timeframes estimated using the NA rates calculated from existing COC concentration trends versus that estimated from a numerical fate and transport model (Figures M4-1 to M4-4) shows that remedial action timeframes estimated using the calculated NA rates are lower (Table M4-1). This is not unexpected because the fate and transport modeling does not include degradation. Additionally, this is consistent with the determination that degradation (biological and abiotic) processes are acting in concert with non-degrading processes to reduce COC concentration in 100-F/IU groundwater.

Table M4-1. Remedial Action Timeframes Estimated Using Numerical Modeling vs Decay Factors

COC	PRG (µg/L or pCi/L)	Numerical Model - GW-1/GW-2 (years)		Decay Factor (years)
		C90	Cmax	Mean
Cr(VI)	48	10	20	2011 Cr(VI) concentrations are less than 48 µg/L
	10	25	35	5.3
Nitrate	45,000	30	80	23
Trichloroethene	4.9	0	45.	34
Strontium-90	8	90	150	43

Note:

Remediation timeframe not estimated because decay factor is positive (e.g. concentrations not decreasing).

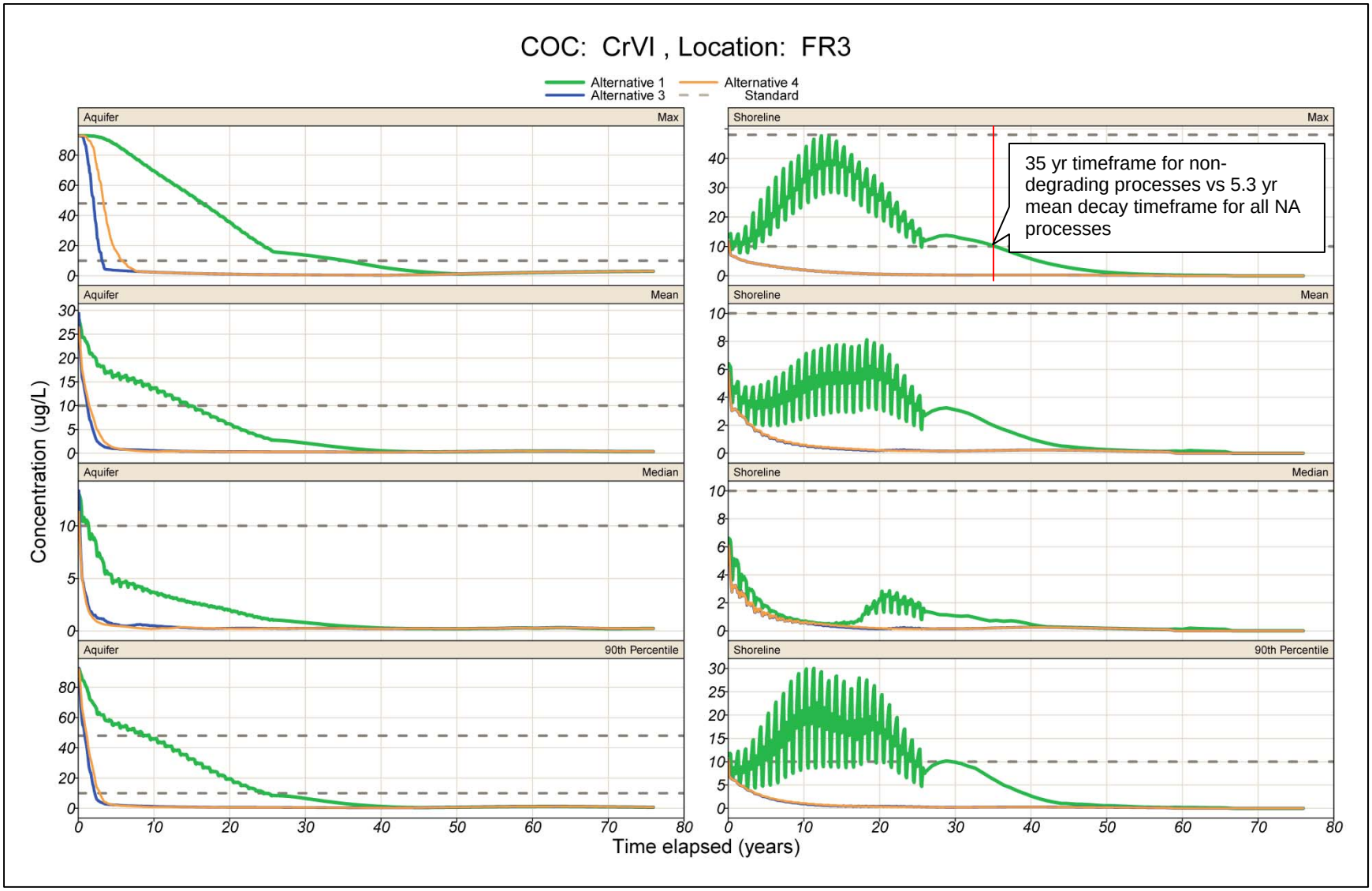


Figure M4-1. Cr(VI) Concentration Statistics – All Alternatives

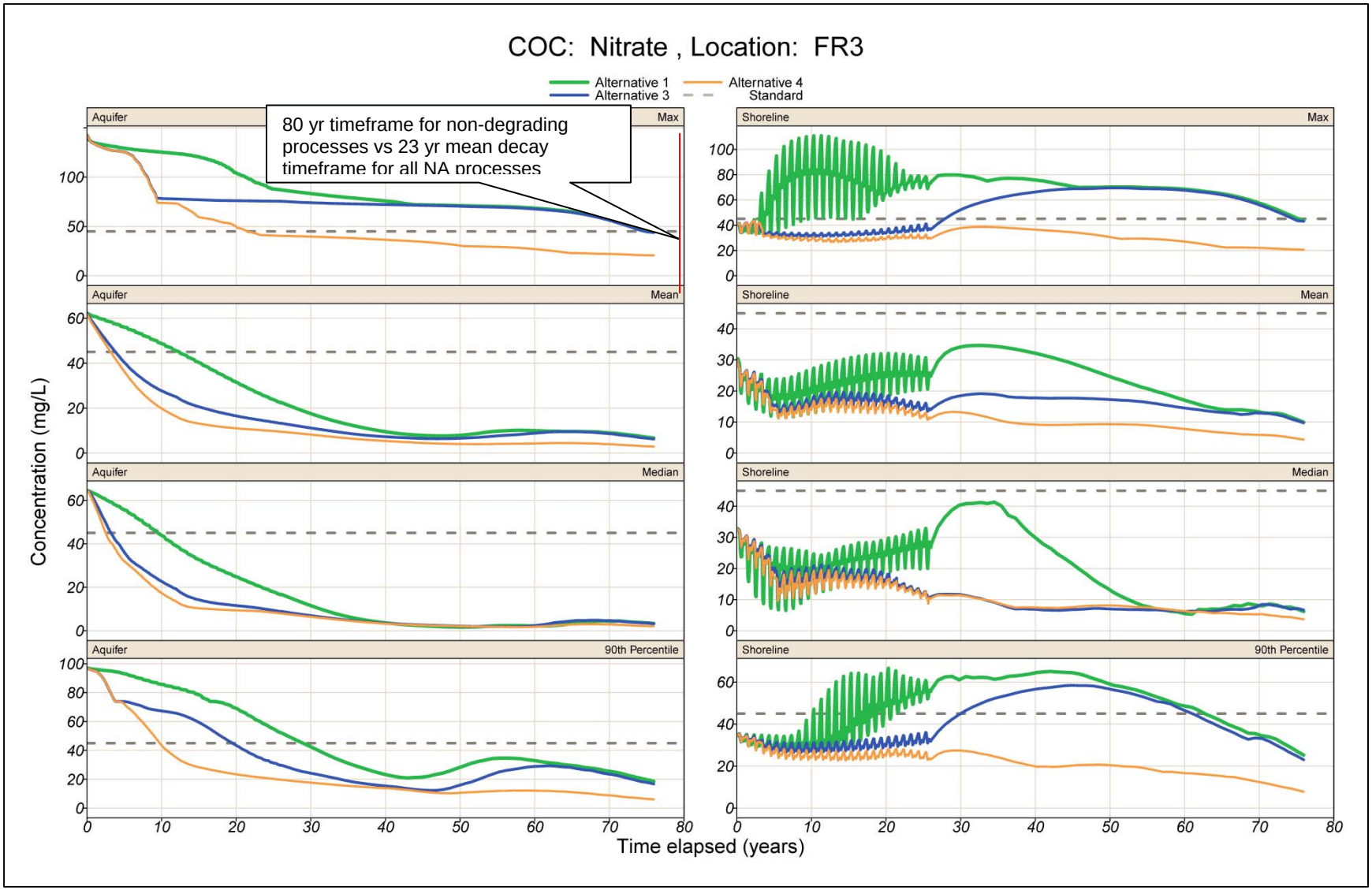


Figure M4-2. Nitrate: Concentration Statistics – All Alternatives

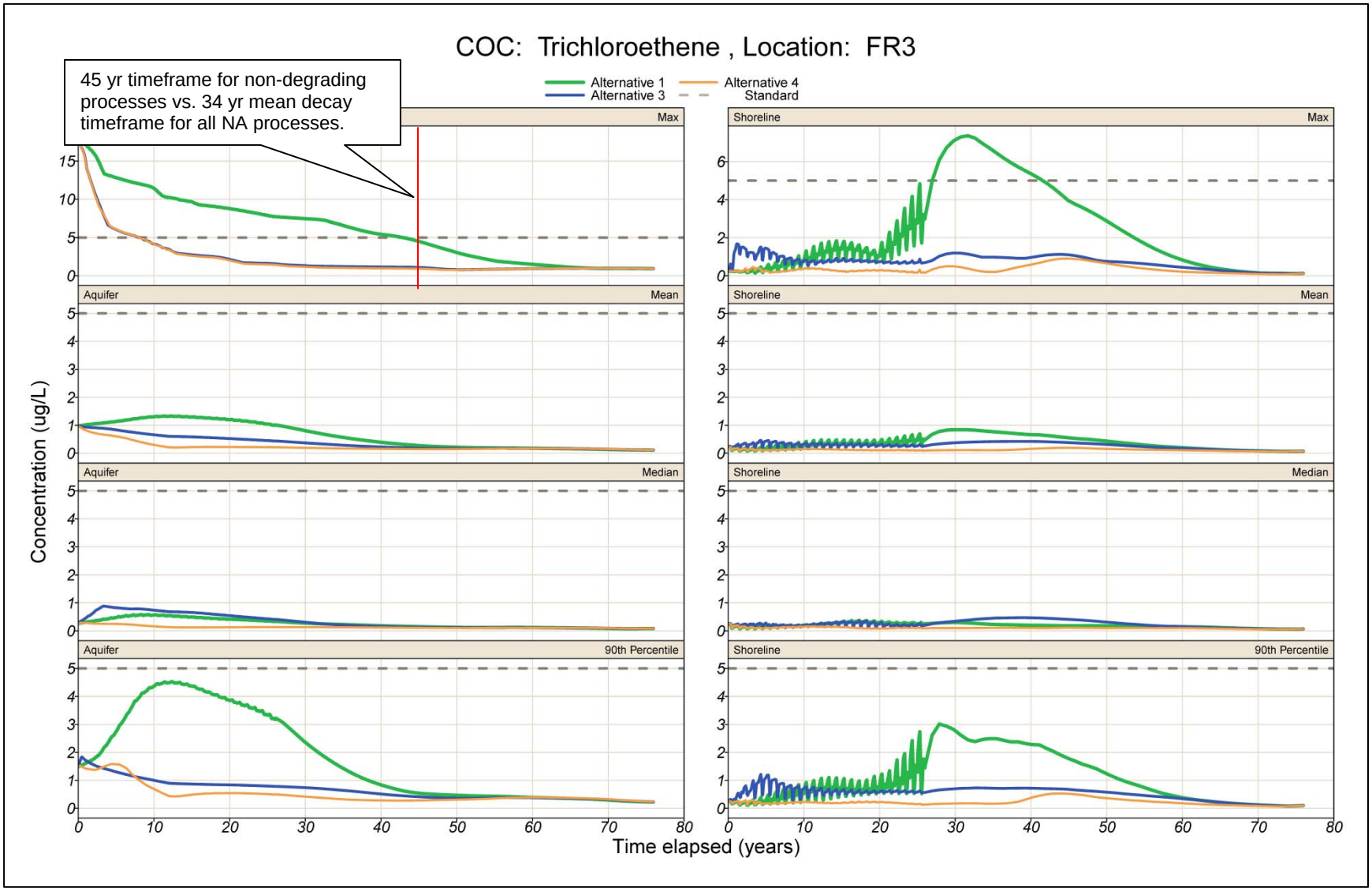


Figure M4-3. Trichloroethene: Concentration Statistics – All Alternatives

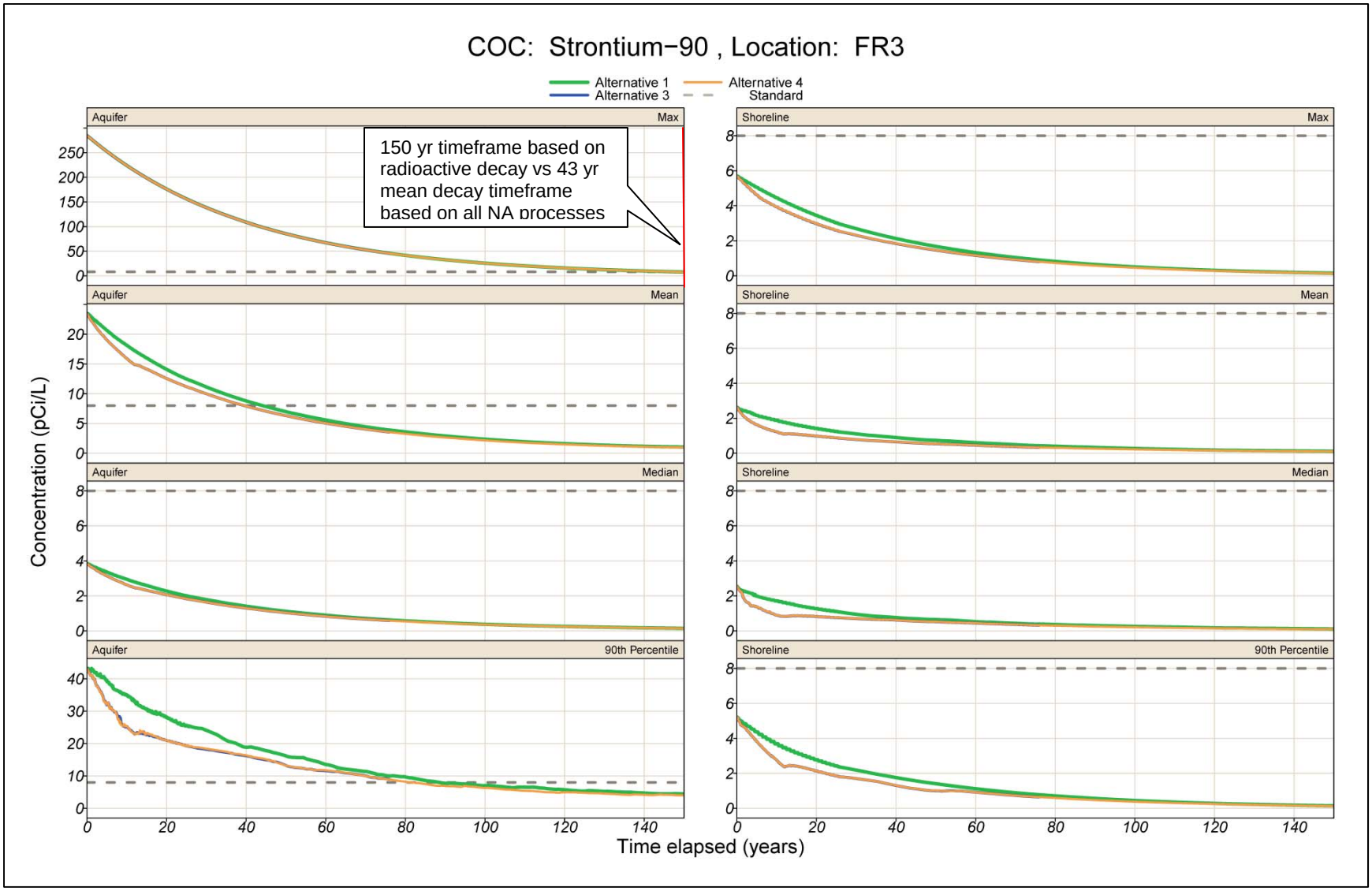


Figure M4-4. Strontium-90: Concentration Statistics – All Alternatives

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Attachment 1

Natural Attenuation Evaluation Data

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Well	Date Decimal Year	Date Number	Date	Cr (VI) ug/L	Units	LabQ	ValQ	Ln Cr (VI) ug/L	
	2010.3	40304	5/5/2010	9.45				2.246	
	2010.5	40368	7/8/2010	2.2	B			0.788	
	2010.9	40493	11/11/2010	10.5				2.351	
199-F5-44	2011.9	40885	12/7/2011	11.5		Q		2.442	
	2006.4	38870	6/1/2006	1	U			0.000	Not used
	2010.3	40303	5/5/2010	20.65				3.028	
	2010.5	40367	7/8/2010	7.95				2.073	
199-F5-45	2010.7	40447	9/26/2010	9.15				2.214	
	1997.8	35711	10/8/1997	90				4.500	
	1998.1	35816	1/21/1998	87				4.466	
	1998.4	35937	5/21/1998	106				4.663	
	1998.7	36033	8/26/1998	74				4.304	
	1998.8	36080	10/12/1998	57				4.043	
	1999.1	36187	1/26/1999	96				4.564	
	1999.7	36402	8/30/1999	51				3.932	
	1999.9	36501	12/7/1999	201		G		5.303	
	2000.1	36571	2/15/2000	208				5.338	
	2000.8	36816	10/17/2000	77.5				4.350	
	2001.1	36922	1/30/2001	68				4.220	
	2001.4	37028	5/17/2001	52				3.951	
	2001.6	37119	8/16/2001	24				3.178	
	2001.8	37175	10/11/2001	35				3.555	
	2002.0	37265	1/9/2002	30				3.401	
	2002.4	37396	5/20/2002	112				4.718	
	2002.7	37502	9/3/2002	98				4.585	
	2002.8	37544	10/15/2002	90				4.500	
	2003.1	37657	2/4/2003	67				4.205	
	2003.4	37761	5/20/2003	69				4.234	
	2003.7	37858	8/25/2003	65				4.174	
	2003.8	37907	10/13/2003	54		H		3.989	
	2010.3	40304	5/5/2010	92.4				4.526	
	2010.5	40367	7/8/2010	20.0				2.994	
	2010.9	40493	11/11/2010	20.45				3.018	
199-F5-46	2011.9	40884	12/7/2011	22.3		Q		3.105	
	2006.5	38895	6/26/2006	1	U			0.000	
	2010.3	40303	5/5/2010	14.75				2.691	
	2010.5	40368	7/8/2010	14.05				2.643	
	2010.7	40447	9/26/2010	14.125				2.648	
	2011.3	40653	4/20/2011	14.3				2.660	
	2011.9	40885	12/7/2011	10.8		Q		2.380	
199-F5-48	2012.3	41018	4/19/2012	12.1				2.493	
	2010.8	40487	11/5/2010	14.4				2.667	
	2010.9	40514	12/1/2010	2.2125	U			0.794	
	2011.0	40560	1/17/2011	2.3	B			0.833	
	2011.5	40716	6/22/2011	2	U			0.693	
	2011.6	40759	8/3/2011	2	U			0.693	
199-F5-53	2011.9	40883	12/6/2011	2	U			0.693	
	2005.8	38638	10/13/2005	82.5				4.413	
	2006.0	38701	12/15/2005	54.5				3.998	
	2010.3	40304	5/5/2010	60.15				4.097	
	2010.5	40373	7/13/2010	15.1				2.715	
	2010.9	40493	11/10/2010	25.6				3.243	
199-F5-6	2011.9	40884	12/7/2011	1	U	FQ		0.000	

Data not used
Average of duplicate/triplicate value

Well	Date	Date	Date	Chromium	LabQ	RvwQ	ValQ	Ln Chromium	Sample No.	Lab	Method
199-F5-44	1993.0	33955	12/16/1992	5.5	B			1.7047	B07R66	SKINER	CLP METALS ICP
199-F5-44	1993.3	34060	4/1/1993	29.3				3.3776	B088V1	SKINER	CLP METALS ICP
199-F5-44	1993.6	34170	7/20/1993	11.45	B			2.4380	B08Y47	SKINER	CLP_METALS_ICP
199-F5-44	1993.8	34272	10/30/1993	18.55				2.9205	B09D94	SKINER	CLP_METALS_ICP
199-F5-44	1994.4	34465	5/11/1994	5	U			1.6094	B0BMR9	ITSTU	CLP METALS ICP
199-F5-44	1994.9	34649	11/11/1994	25.95				3.2562	B0D810	QTESSL	CLP METALS ICP
199-F5-44	1995.4	34845	5/25/1995	4.75	B			1.5581	B0FK75	QTESSL	CLP METALS ICP
199-F5-44	1995.9	35018	11/14/1995	11.95				2.4807	B0GS89	QTESSL	CLP_METALS_ICP
199-F5-44	1997.8	35712	10/9/1997	17.3				2.8507	B0M5D2	QTESSL	6010_METALS_ICP
199-F5-44	1998.8	36080	10/12/1998	33.4				3.5086	B0R1P4	QTESSL	6010 METALS ICP
199-F5-44	1999.9	36500	12/6/1999	9.5	B			2.2513	B0WHT1	QTESSL	6010 METALS ICP
199-F5-44	2000.8	36816	10/16/2000	18.4				2.9124	B10DB6	STLSL	6010 METALS ICP
199-F5-44	2001.8	37179	10/15/2001	38				3.6376	B13034	STLSL	6010_METALS_ICP
199-F5-44	2002.8	37544	10/15/2002	23.2				3.1442	B15M39	STLSL	6010_METALS_ICP
199-F5-44	2003.8	37907	10/13/2003	29.7				3.3911	B17L41	STLSL	6010_METALS_ICP
199-F5-44	2005.8	38631	10/6/2005	31.6				3.4532	B1F140	STLSL	6010 METALS ICP
199-F5-44	2007.8	39363	10/8/2007	38.55	C			3.6520	B1PVF9	WSCF	6010 METALS ICP
199-F5-44	2009.8	40092	10/6/2009	31.6	B			3.4532	B220R7	WSCF	6010 METALS ICP
199-F5-44	2010.3	40304	5/5/2010	9.5	D			2.2513	B258P7	WSCF	200.8_METALS_ICPMS
199-F5-44	2010.5	40368	7/8/2010	6.7375	B, U			1.9077	B264J2	WSCF	6010_METALS_ICP
199-F5-44	2010.9	40493	11/11/2010	10	U, D			2.3026	B27T29	WSCF	200.8 METALS ICPMS
199-F5-44	2011.9	40885	12/7/2011	14.7	B			2.6878	B2HKH2	WSCF	6010 METALS ICP
199-F5-45	1993.0	33954	12/16/1992	4.05	B			1.3987	B07R72	SKINER	CLP METALS ICP
199-F5-45	1993.2	34059	3/31/1993	3.642	U			1.2924	B08911	SKINER	CLP_METALS_ICP
199-F5-45	1993.5	34167	7/17/1993	4.8	J			1.5686	B08Y51	SKINER	CLP_METALS_ICP
199-F5-45	1993.9	34279	11/6/1993	10.25				2.3273	B09D98	SKINER	CLP METALS ICP
199-F5-45	1994.4	34464	5/10/1994	33.4				3.5086	B0BMS3	ITSTU	CLP METALS ICP
199-F5-45	1994.9	34648	11/10/1994	57.9	*			4.0587	B0D814	QTESSL	CLP METALS ICP
199-F5-45	1995.4	34844	5/25/1995	18.3				2.9069	B0FK78	QTESSL	CLP_METALS_ICP
199-F5-45	1995.9	35017	11/14/1995	15				2.7081	B0GS91	QTESSL	CLP_METALS_ICP
199-F5-45	1997.7	35686	9/12/1997	7.6	B			2.0281	B0LX94	QTESSL	6010 METALS ICP
199-F5-45	1998.8	36080	10/12/1998	20.425				3.0168	B0R0P7	QTESSL	6010 METALS ICP
199-F5-45	1999.9	36500	12/6/1999	68.9				4.2327	B0WHP6	QTESSL	6010 METALS ICP
199-F5-45	2000.8	36812	10/13/2000	42.9				3.7589	B10DF2	STLSL	6010_METALS_ICP
199-F5-45	2002.8	37543	10/14/2002	35				3.5553	B15M42	STLSL	6010_METALS_ICP
199-F5-45	2005.0	38350	12/28/2004	61.1				4.1125	B1BTP3	STLSL	6010_METALS_ICP
199-F5-45	2006.4	38870	6/1/2006	13.8				2.6247	J12698	RLNP	6010 METALS ICP
199-F5-45	2006.8	39007	10/17/2006	11.6				2.4510	B1KPH4	STLSL	6010 METALS ICP
199-F5-45	2008.9	39758	11/6/2008	7.85	B, U			2.0605	B1X721	WSCF	6010 METALS ICP
199-F5-45	2010.3	40303	5/5/2010	18.75	D			2.9312	B258R2	WSCF	200.8_METALS_ICPMS
199-F5-45	2010.5	40367	7/8/2010	8.4975	U			2.1398	B264J8	WSCF	6010_METALS_ICP
199-F5-45	2010.7	40447	9/26/2010	15.7	D			2.7537	B27T34	WSCF	200.8 METALS ICPMS
199-F5-46	1993.0	33954	12/16/1992	297				5.69373	B07R77	SKINER	CLP METALS ICP
199-F5-46	1993.3	34062	4/3/1993	106.5				4.66814	B088W1	SKINER	CLP METALS ICP
199-F5-46	1993.5	34168	7/18/1993	201.5				5.30579	B08Y56	SKINER	CLP_METALS_ICP
199-F5-46	1993.9	34279	11/6/1993	72.65				4.28565	B09DB2	SKINER	CLP_METALS_ICP
199-F5-46	1994.4	34464	5/10/1994	350				5.85793	B0BMS6	ITSTU	CLP METALS ICP
199-F5-46	1994.9	34648	11/10/1994	52.15	*			3.95412	B0D817	QTESSL	CLP METALS ICP
199-F5-46	1995.4	34844	5/25/1995	200				5.29832	B0FK79	QTESSL	CLP METALS ICP
199-F5-46	1995.9	35023	11/20/1995	155				5.04343	B0GS94	QTESSL	CLP_METALS_ICP
199-F5-46	1997.8	35711	10/8/1997	85.1				4.44383	B0M5D6	QTESSL	6010_METALS_ICP
199-F5-46	1998.4	35937	5/21/1998	93.5				4.53796	B0NMM7	QTESSL	6010 METALS ICP
199-F5-46	1998.8	36080	10/12/1998	57.75				4.05612	B0R1P6	QTESSL	6010 METALS ICP
199-F5-46	1999.4	36304	5/24/1999	74.5				4.31080	B0VC02	QTESSL	6010 METALS ICP
199-F5-46	1999.9	36501	12/7/1999	176.5				5.17332	B0WHP4	QTESSL	6010_METALS_ICP
199-F5-46	2000.8	36816	10/17/2000	66.1				4.19117	B10DF0	STLSL	6010_METALS_ICP
199-F5-46	2001.8	37175	10/11/2001	27.8				3.32504	B13031	STLSL	6010_METALS_ICP
199-F5-46	2002.8	37544	10/15/2002	82				4.40672	B15M64	STLSL	6010 METALS ICP
199-F5-46	2003.8	37907	10/13/2003	49.8				3.90801	B17L46	STLSL	6010 METALS ICP
199-F5-46	2005.8	38632	10/6/2005	24.4				3.19458	B1F0X3	STLSL	6010 METALS ICP
199-F5-46	2007.8	39364	10/9/2007	32.05	C			3.46730	B1PVH3	WSCF	6010_METALS_ICP
199-F5-46	2009.8	40093	10/6/2009	24.9	B			3.21487	B220T1	WSCF	6010_METALS_ICP
199-F5-46	2010.3	40304	5/5/2010	89				4.48864	B258R7	WSCF	6010 METALS ICP
199-F5-46	2010.5	40367	7/8/2010	22.52	D			3.11440	B264K3	WSCF	200.8 METALS ICPMS
199-F5-46	2010.9	40493	11/11/2010	22	D			3.09104	B27T39	WSCF	200.8 METALS ICPMS
199-F5-46	2011.9	40884	12/7/2011	33.55				3.51304	B2HKH9	WSCF	6010_METALS_ICP
199-F5-48	1993.0	33983	1/14/1993	22.9					B07R87	SKINER	CLP_METALS_ICP
199-F5-48	1993.0	33983	1/14/1993	24.5					B07R86	SKINER	CLP METALS ICP
199-F5-48	1993.3	34062	4/3/1993	23.4					B088X1	SKINER	CLP METALS ICP
199-F5-48	1993.3	34062	4/3/1993	29.4					B088X0	SKINER	CLP METALS ICP
199-F5-48	1993.5	34167	7/17/1993	44.1					B08Y66	SKINER	CLP_METALS_ICP
199-F5-48	1993.5	34167	7/17/1993	20.5					B08Y67	SKINER	CLP_METALS_ICP
199-F5-48	1993.8	34273	10/31/1993	17.4					B09DC1	SKINER	CLP METALS ICP
199-F5-48	1993.8	34273	10/31/1993	19.6					B09DC0	SKINER	CLP METALS ICP
199-F5-48	1994.4	34464	5/9/1994	27.1					B0BMT4	ITSTU	CLP METALS ICP
199-F5-48	1994.4	34464	5/9/1994	21.8					B0BMT5	ITSTU	CLP METALS ICP
199-F5-48	1994.9	34648	11/10/1994	11.6	J*				B0D822	QTESSL	CLP_METALS_ICP
199-F5-48	1994.9	34648	11/10/1994	8.4	B*				B0D823	QTESSL	CLP_METALS_ICP
199-F5-48	1995.4	34844	5/25/1995	21.1					B0FK84	QTESSL	CLP METALS ICP
199-F5-48	1995.4	34844	5/25/1995	24.6					B0FK83	QTESSL	CLP METALS ICP
199-F5-48	1995.9	35023	11/20/1995	16.3					B0GS98	QTESSL	CLP METALS ICP

Well	Date	Date	Date	Chromium	LabQ	RvwQ	ValQ	Ln Chromium	Sample No.	Lab	Method
199-F5-48	1995.9	35023	11/20/1995	13.7					B0GS97	QTESSL	CLP METALS ICP
199-F5-48	1997.7	35685	9/12/1997	12.7					B0LX99	QTESSL	6010 METALS ICP
199-F5-48	1997.8	35712	10/8/1997	18.7					B0M5F0	QTESSL	6010_METALS_ICP
199-F5-48	1997.8	35712	10/8/1997	11.2					B0M3D1	QTESSL	6010_METALS_ICP
199-F5-48	1999.9	36500	12/6/1999	14					B0WHN4	QTESSL	6010 METALS ICP
199-F5-48	2001.8	37174	10/10/2001	0.65	U				B12YY2	STLSL	6010 METALS ICP
199-F5-48	2001.8	37174	10/10/2001	3.1	U	Q			B13029	STLSL	6010 METALS ICP
199-F5-48	2001.8	37174	10/10/2001	0.65	U				B13028	STLSL	6010_METALS_ICP
199-F5-48	2001.8	37174	10/10/2001	0.65	U	Q			B12YY3	STLSL	6010_METALS_ICP
199-F5-48	2003.8	37908	10/14/2003	21					B17L54	STLSL	6010 METALS ICP
199-F5-48	2003.8	37908	10/14/2003	15.8					B17L53	STLSL	6010 METALS ICP
199-F5-48	2005.0	38350	12/28/2004	20.9					B1BTP9	STLSL	6010 METALS ICP
199-F5-48	2006.5	38895	6/26/2006	19.2					J126B0	RLNP	6010_METALS_ICP
199-F5-48	2006.8	39000	10/10/2006	12.4					B1KPJ3	STLSL	6010_METALS_ICP
199-F5-48	2008.9	39759	11/6/2008	13.1	B				B1X730	WSCF	6010_METALS_ICP
199-F5-48	2008.9	39759	11/6/2008	13.1	B				B1X729	WSCF	6010 METALS ICP
199-F5-48	2010.3	40303	5/5/2010	15.3					B258T2	WSCF	200.8 METALS ICPMS
199-F5-48	2010.3	40303	5/5/2010	15.8	D				B258T3	WSCF	200.8 METALS ICPMS
199-F5-48	2010.3	40303	5/5/2010	13	U	G			B258T3	WSCF	6010_METALS_ICP
199-F5-48	2010.3	40303	5/5/2010	13.6	B				B258T2	WSCF	6010_METALS_ICP
199-F5-48	2010.5	40368	7/8/2010	2.51	BD				B264K9	WSCF	200.8 METALS ICPMS
199-F5-48	2010.5	40368	7/8/2010	24	B	Y			B264K9	WSCF	6010 METALS ICP
199-F5-48	2010.5	40368	7/8/2010	18	B	Y			B264L0	WSCF	6010 METALS ICP
199-F5-48	2010.5	40368	7/8/2010	5.4	BD				B264L0	WSCF	200.8_METALS_ICPMS
199-F5-48	2010.7	40447	9/26/2010	32	B	Y			B284N1	WSCF	6010_METALS_ICP
199-F5-48	2010.7	40447	9/26/2010	35	B	Y			B284N0	WSCF	6010 METALS ICP
199-F5-48	2010.7	40447	9/26/2010	19.5	D				B27T44	WSCF	200.8 METALS ICPMS
199-F5-48	2010.7	40447	9/26/2010	18.8	D				B27T50	WSCF	200.8 METALS ICPMS
199-F5-48	2010.7	40447	9/26/2010	23.7	D				B27T45	WSCF	200.8_METALS_ICPMS
199-F5-48	2010.7	40447	9/26/2010	22.4	D				B27T51	WSCF	200.8_METALS_ICPMS
199-F5-48	2010.7	40447	9/26/2010	29	B	Y			B284N2	WSCF	6010 METALS ICP
199-F5-48	2010.7	40447	9/26/2010	19	B				B284M9	WSCF	6010 METALS ICP
199-F5-48	2011.3	40653	4/20/2011	16	B				B2CJ77	WSCF	6010 METALS ICP
199-F5-48	2011.3	40653	4/20/2011	17	B				B2CJ74	WSCF	6010_METALS_ICP
199-F5-53	2010.8	40487	11/5/2010	21.4					B273B1	LVL	6010_METALS_ICP_TR
199-F5-53	2010.8	40487	11/5/2010	23.6	D				B273C8	WSCF	200.8_METALS_ICPMS
199-F5-53	2010.9	40491	11/8/2010	4.74	BD				B273C9	WSCF	200.8 METALS ICPMS
199-F5-53	2010.9	40491	11/8/2010	4.7	B				B273D7	TASL	6010 METALS ICP TR
199-F5-53	2010.9	40514	12/1/2010	1	UD				B273D6	WSCF	200.8 METALS ICPMS
199-F5-53	2010.9	40514	12/1/2010	1	UD				B273D1	WSCF	200.8_METALS_ICPMS
199-F5-53	2011.0	40560	1/17/2011	14	U				B2B3L9	WSCF	6010_METALS_ICP
199-F5-53	2011.0	40560	1/17/2011	14	U				B2B3L8	WSCF	6010 METALS ICP
199-F5-53	2011.5	40716	6/22/2011	5.1	U				B2CJ86	WSCF	6010 METALS ICP
199-F5-53	2011.5	40716	6/22/2011	5.1	U				B2CJ89	WSCF	6010 METALS ICP
199-F5-53	2011.6	40759	8/3/2011	5	U				B2F3D8	WSCF	6010_METALS_ICP
199-F5-53	2011.6	40759	8/3/2011	5	U				B2F3F1	WSCF	6010_METALS_ICP
199-F5-53	2011.9	40883	12/6/2011	5	U				B2HKM6	WSCF	6010 METALS ICP
199-F5-53	2011.9	40883	12/6/2011	5	U				B2HKM0	WSCF	6010 METALS ICP
199-F5-6	1987.3	31877	4/10/1987	10	U				H00074Y4F	USTEST	6010 METALS ICP
199-F5-6	1987.6	31985	7/27/1987	10	U				H00074Y6F	USTEST	6010_METALS_ICP
199-F5-6	1989.1	32548	2/9/1989	10	U				H00074Z0F	USTEST	6010_METALS_ICP
199-F5-6	1992.1	33645	2/11/1992	0	U				B05WN3	DATACH	6010 METALS ICP
199-F5-6	1993.0	33955	12/16/1992	2.7	U				B07RD7	SKINER	CLP METALS ICP
199-F5-6	1993.0	33955	12/16/1992	8.2	B				B07RD6	SKINER	CLP METALS ICP
199-F5-6	1993.3	34066	4/7/1993	5.8	U				B088S6	SKINER	CLP_METALS_ICP
199-F5-6	1993.3	34066	4/7/1993	6.3	B				B088S5	SKINER	CLP_METALS_ICP
199-F5-6	1993.6	34171	7/21/1993	26.8					B08Y31	SKINER	CLP_METALS_ICP
199-F5-6	1993.6	34171	7/21/1993	17.4					B08Y32	SKINER	CLP METALS ICP
199-F5-6	1993.8	34268	10/26/1993	48.3					B09D83	SKINER	CLP METALS ICP
199-F5-6	1993.8	34268	10/26/1993	55.9					B09DH0	WESTON	CLP METALS ICP
199-F5-6	1993.8	34268	10/26/1993	42.5					B09DH1	WESTON	CLP_METALS_ICP
199-F5-6	1993.8	34269	10/26/1993	49.7					B09DG3	SKINER	CLP_METALS_ICP
199-F5-6	1993.8	34269	10/26/1993	53.2					B09D82	SKINER	CLP METALS ICP
199-F5-6	1993.8	34269	10/26/1993	61.1					B09DG2	SKINER	CLP METALS ICP
199-F5-6	1994.3	34460	5/6/1994	47.3					B0BMY4	SKINER	CLP METALS ICP
199-F5-6	1994.3	34460	5/6/1994	47.6					B0BMQ7	ITSTU	CLP_METALS_ICP
199-F5-6	1994.3	34460	5/6/1994	54					B0BMQ6	ITSTU	CLP_METALS_ICP
199-F5-6	1994.3	34460	5/6/1994	43.8					B0BMY5	SKINER	CLP METALS ICP
199-F5-6	1994.3	34460	5/6/1994	44.8					B0BMX6	ITSTU	CLP METALS ICP
199-F5-6	1994.3	34460	5/6/1994	48.7					B0BMX7	ITSTU	CLP METALS ICP
199-F5-6	1994.9	34647	11/9/1994	71.8	*				B0D802	QTESSL	CLP_METALS_ICP
199-F5-6	1994.9	34647	11/9/1994	69.2	J*				B0D801	QTESSL	CLP_METALS_ICP
199-F5-6	1995.4	34849	5/30/1995	7	B				B0FK68	QTESSL	CLP METALS ICP
199-F5-6	1995.4	34849	5/30/1995	34.6					B0FK67	QTESSL	CLP METALS ICP
199-F5-6	1995.9	35016	11/13/1995	40.9					B0GS82	QTESSL	CLP METALS ICP
199-F5-6	1995.9	35016	11/13/1995	42.6					B0GS81	QTESSL	CLP METALS ICP
199-F5-6	1997.7	35689	9/16/1997	33.8					B0LXB3	QTESSL	6010_METALS_ICP
199-F5-6	1997.7	35689	9/16/1997	33.3					B0LXB1	QTESSL	6010_METALS_ICP
199-F5-6	1997.8	35712	10/8/1997	32.6					B0M388	QTESSL	6010 METALS ICP
199-F5-6	1997.8	35712	10/8/1997	33.1					B0M5J5	QTESSL	6010 METALS ICP
199-F5-6	1998.8	36080	10/12/1998	66					B0R1P9	QTESSL	6010 METALS ICP

Well	Date	Date	Date	Chromium	LabQ	RvwQ	ValQ	Ln Chromium	Sample No.	Lab	Method
199-F5-6	1998.8	36080	10/12/1998	71					B0R1R0	QTESSL	6010 METALS ICP
199-F5-6	1999.9	36501	12/7/1999	27.2					B0WHN1	QTESSL	6010 METALS ICP
199-F5-6	2000.8	36816	10/17/2000	44.5					B10DC2	STLSL	6010_METALS_ICP
199-F5-6	2001.8	37175	10/10/2001	58.6					B12YV7	STLSL	6010_METALS_ICP
199-F5-6	2002.8	37545	10/15/2002	35.9					B15M48	STLSL	6010 METALS ICP
199-F5-6	2003.8	37907	10/13/2003	97.8					B17L56	STLSL	6010 METALS ICP
199-F5-6	2005.1	38381	1/28/2005	53.7					B1BY75	STLSL	6010 METALS ICP
199-F5-6	2005.8	38638	10/13/2005	80.1					J10891	RLNP	6010_METALS_ICP
199-F5-6	2005.8	38638	10/13/2005	83.3					B1F0X7	STLSL	6010_METALS_ICP
199-F5-6	2006.0	38701	12/15/2005	58					B1F867	STLSL	6010 METALS ICP
199-F5-6	2006.8	39001	10/11/2006	60.3					B1KPN0	STLSL	6010 METALS ICP
199-F5-6	2007.8	39373	10/18/2007	49.7					B1PVJ1	WSCF	6010 METALS ICP
199-F5-6	2007.8	39373	10/18/2007	41					B1PVJ0	WSCF	6010_METALS_ICP
199-F5-6	2008.9	39759	11/6/2008	32.9					B1X732	WSCF	6010_METALS_ICP
199-F5-6	2008.9	39759	11/6/2008	21.2					B1X733	WSCF	6010_METALS_ICP
199-F5-6	2009.8	40092	10/6/2009	53.7	B				B220T6	WSCF	6010 METALS ICP
199-F5-6	2009.8	40092	10/6/2009	56	B				B220T7	WSCF	6010 METALS ICP
199-F5-6	2010.3	40304	5/5/2010	56	D				B258T8	WSCF	200.8 METALS ICPMS
199-F5-6	2010.3	40304	5/5/2010	58.5	D				B258T7	WSCF	200.8_METALS_ICPMS
199-F5-6	2010.3	40304	5/5/2010	52.4	B				B258T7	WSCF	6010_METALS_ICP
199-F5-6	2010.3	40304	5/5/2010	53.2	B				B258T8	WSCF	6010 METALS ICP
199-F5-6	2010.5	40373	7/13/2010	18.5	D	Q			B264L4	WSCF	200.8 METALS ICPMS
199-F5-6	2010.5	40373	7/13/2010	17	B	Q			B264L5	WSCF	6010 METALS ICP
199-F5-6	2010.5	40373	7/13/2010	13	U	Q			B264L4	WSCF	6010_METALS_ICP
199-F5-6	2010.5	40373	7/13/2010	17.8	D	Q			B264L5	WSCF	200.8_METALS_ICPMS
199-F5-6	2010.9	40493	11/10/2010	34	B				B284N5	WSCF	6010 METALS ICP
199-F5-6	2010.9	40493	11/10/2010	23	B				B284N4	WSCF	6010 METALS ICP
199-F5-6	2010.9	40493	11/10/2010	25.9	D				B27T54	WSCF	200.8 METALS ICPMS
199-F5-6	2010.9	40493	11/10/2010	27.1	D				B27T53	WSCF	200.8_METALS_ICPMS
199-F5-6	2011.9	40884	12/7/2011	25.4					B2HKP7	WSCF	6010_METALS_ICP
199-F5-6	2011.9	40884	12/7/2011	23.8	B				B2HKR0	WSCF	6010 METALS ICP

Well	Date Decimal Year	Date Number	Date	Nitrate	Units LabQ	RvwQ	ValQ	Nitrate Ln	Samp	Lab	Method	
199-F5-4	1980.2	29279	2/28/1980	500	ug/L					H00074N2	USTEST	UNKNOWN_GENCHEM
199-F5-4	1980.4	29363	5/22/1980	500	ug/L					H00074N3	USTEST	UNKNOWN_GENCHEM
199-F5-4	1980.6	29452	8/19/1980	14000	ug/L					H00074N4	USTEST	UNKNOWN_GENCHEM
199-F5-4	1980.9	29536	11/11/1980	12000	ug/L					H00074N5	USTEST	UNKNOWN_GENCHEM
199-F5-4	1981.2	29643	2/26/1981	500	ug/L					H00074N6	USTEST	UNKNOWN_GENCHEM
199-F5-4	1981.4	29736	5/30/1981	21000	ug/L					H00074N7	USTEST	UNKNOWN_GENCHEM
199-F5-4	1981.6	29801	8/3/1981	18000	ug/L					H00074N8	USTEST	UNKNOWN_GENCHEM
199-F5-4	1982.2	30011	3/1/1982	20000	ug/L					H00074P0	USTEST	UNKNOWN_GENCHEM
199-F5-4	1982.4	30095	5/24/1982	9300	ug/L					H00074P1	USTEST	UNKNOWN_GENCHEM
199-F5-4	1982.8	30257	11/2/1982	18000	ug/L					H00074P2	USTEST	UNKNOWN_GENCHEM
199-F5-4	1983.2	30371	2/24/1983	27000	ug/L					H00074P3	USTEST	UNKNOWN_GENCHEM
199-F5-4	1983.4	30447	5/11/1983	23000	ug/L					H00074P4	USTEST	UNKNOWN_GENCHEM
199-F5-4	1983.6	30539	8/11/1983	33000	ug/L					H00074P5	USTEST	UNKNOWN_GENCHEM
199-F5-4	1983.8	30622	11/2/1983	31000	ug/L					H00074P6	USTEST	UNKNOWN_GENCHEM
199-F5-4	1984.1	30734	2/22/1984	29000	ug/L					H00074P7	USTEST	UNKNOWN_GENCHEM
199-F5-4	1984.4	30813	5/11/1984	40000	ug/L					H00074P8	USTEST	UNKNOWN_GENCHEM
199-F5-4	1984.6	30917	8/23/1984	52000	ug/L					H00074P9	USTEST	UNKNOWN_GENCHEM
199-F5-4	1984.9	31022	12/6/1984	64000	ug/L					H00074Q0	USTEST	UNKNOWN_GENCHEM
199-F5-4	1985.1	31092	2/14/1985	49000	ug/L					H00074Q1	USTEST	UNKNOWN_GENCHEM
199-F5-4	1985.3	31155	4/18/1985	64000	ug/L					H00074Q2	USTEST	UNKNOWN_GENCHEM
199-F5-4	1985.7	31294	9/4/1985	79700	ug/L					H00074Q4	USTEST	300.0_ANIONS_IC
199-F5-4	1985.9	31360	11/9/1985	130000	ug/L					H00074Q5	USTEST	UNKNOWN_GENCHEM
199-F5-4	1986.0	31421	1/9/1986	140000	ug/L					H00074Q6	PNL-KI	UNKNOWN_GENCHEM
199-F5-4	1986.3	31511	4/9/1986	89000	ug/L					H00074Q7	PNL-KI	UNKNOWN_GENCHEM
199-F5-4	1986.6	31622	7/29/1986	57700	ug/L					H00074Q8	USTEST	300.0_ANIONS_IC
199-F5-4	1986.8	31701	10/16/1986	66100	ug/L					H00074R0	USTEST	300.0_ANIONS_IC
199-F5-4	1987.0	31791	1/14/1987	58300	ug/L					H00074R2	USTEST	300.0_ANIONS_IC
199-F5-4	1987.4	31914	5/17/1987	52500	ug/L					H00074R3	USTEST	300.0_ANIONS_IC
199-F5-4	1987.5	31960	7/2/1987	64000	ug/L					H00074R4	USTEST	300.0_ANIONS_IC
199-F5-4	1987.8	32065	10/15/1987	68350	ug/L					H00074R6	USTEST	300.0_ANIONS_IC
199-F5-4	1988.1	32162	1/20/1988	66000	ug/L					H00074R7	USTEST	300.0_ANIONS_IC
199-F5-4	1988.3	32239	4/6/1988	68950	ug/L					H00074R9	USTEST	300.0_ANIONS_IC
199-F5-4	1988.6	32353	7/29/1988	74150	ug/L					H00074S2	USTEST	300.0_ANIONS_IC
199-F5-4	1988.9	32461	11/14/1988	72500	ug/L					H00074S3	USTEST	300.0_ANIONS_IC
199-F5-4	1989.1	32548	2/9/1989	73300	ug/L					H00074S4	USTEST	300.0_ANIONS_IC
199-F5-4	1989.4	32661	6/2/1989	64300	ug/L					H00074S6	USTEST	300.0_ANIONS_IC
199-F5-4	1989.8	32797	10/16/1989	78500	ug/L					H00074S7	USTEST	300.0_ANIONS_IC
199-F5-4	1990.2	32937	3/5/1990	74100	ug/L					H00074S8	USTEST	300.0_ANIONS_IC
199-F5-4	1991.7	33500	9/19/1991	59000	ug/L					B00LY7	PNL2	300.0_ANIONS_IC
199-F5-4	1992.1	33645	2/11/1992	79000	ug/L					B05WN0	DATACH	D4327_ANIONS_IC
199-F5-4	1993.0	33953	12/14/1992	88683.56	ug/L					B07RH6	SKINER	353.2_NO3/NO2
199-F5-4	1993.3	34064	4/5/1993	89421.36	ug/L					B088R5	SKINER	353.2_NO3/NO2
199-F5-4	1993.6	34172	7/21/1993	67300	ug/L		Z			B08Y26	FIELD	353.3_NO3/NO2_FLD
199-F5-4	1993.9	34279	11/6/1993	82338.48	ug/L					B09D78	SKINER	353.2_NO3/NO2
199-F5-4	1994.4	34486	6/1/1994	80567.76	ug/L					B0BMQ2	ITAS	353.2_NO3/NO2
199-F5-4	1994.9	34647	11/9/1994	91033.33333	ug/L	J	Z			B0D7Z8	QTESSL	300.0_ANIONS_IC
199-F5-4	1995.4	34843	5/23/1995	90750	ug/L	J		11.42		B0FK65	QTESSL	300.0_ANIONS_IC
199-F5-4	1995.4	34843	5/23/1995	88500	ug/L		Z	11.39		B0FKD3	LASLV	300.0_ANIONS_IC
199-F5-4	1995.9	35018	11/15/1995	88100	ug/L	J		11.39		B0GS79	QTESSL	300.0_ANIONS_IC
199-F5-4	1999.1	36181	1/21/1999	133000	ug/L	D		11.8		B0TD22	QTESSL	300.0_ANIONS_IC
199-F5-4	2001.1	36921	1/30/2001	116000	ug/L	D		11.66		B116B0	STLSL	300.0_ANIONS_IC
199-F5-4	2002.8	37547	10/17/2002	106000	ug/L	D		11.57		B15M34	STLSL	300.0_ANIONS_IC
199-F5-4	2003.8	37908	10/14/2003	96900	ug/L	D		11.48		B17L27	STLSL	300.0_ANIONS_IC
199-F5-4	2004.8	38286	10/26/2004	102000	ug/L	D	H	11.53		B1B8T6	STLSL	300.0_ANIONS_IC
199-F5-4	2005.8	38631	10/6/2005	108000	ug/L	D	H	11.59		B1F0X1	STLSL	300.0_ANIONS_IC
199-F5-4	2006.8	39008	10/17/2006	85900	ug/L	D	H	11.36		B1KPJ0	STLSL	300.0_ANIONS_IC
199-F5-4	2007.8	39364	10/9/2007	88100	ug/L	D		11.39		B1PVD8	WSCF	300.0_ANIONS_IC
199-F5-4	2008.9	39758	11/6/2008	117000	ug/L	D		11.67		B1X714	WSCF	300.0_ANIONS_IC
199-F5-4	2010.3	40303	5/5/2010	125000	ug/L	D		11.74		B25B07	WSCF	300.0_ANIONS_IC
199-F5-4	2010.5	40367	7/8/2010	117500	ug/L	D		11.67		B26825	WSCF	300.0_ANIONS_IC
199-F5-4	2010.7	40448	9/26/2010	133000	ug/L	D		11.8		B285M6	WSCF	300.0_ANIONS_IC
199-F5-45	1993.0	33954	12/16/1992	2833.152	ug/L			7.949		B07R71	SKINER	353.2_NO3/NO2
199-F5-45	1993.2	34059	3/31/1993	13855.884	ug/L			9.536		B088P6	WESTON	353.2_NO3/NO2
199-F5-45	1993.5	34167	7/17/1993	17290.548	ug/L	J		9.758		B08Y51	SKINER	353.2_NO3/NO2
199-F5-45	1993.9	34279	11/6/1993	31607.352	ug/L			10.36		B09D98	SKINER	353.2_NO3/NO2
199-F5-45	1994.4	34464	5/10/1994	44710.68	ug/L			10.71		B0BMS2	ITAS	353.2_NO3/NO2
199-F5-45	1994.7	34605	9/28/1994	61000	ug/L	D		11.02		B0D075	DATACH	D4327_ANIONS_IC
199-F5-45	1994.9	34648	11/10/1994	73000	ug/L	J	Z	11.2		B0D813	QTESSL	300.0_ANIONS_IC
199-F5-45	1995.4	34844	5/25/1995	79200	ug/L	J		11.28		B0FK77	QTESSL	300.0_ANIONS_IC
199-F5-45	1995.9	35017	11/14/1995	67300	ug/L	J		11.12		B0GS91	QTESSL	300.0_ANIONS_IC
199-F5-45	1997.8	35711	10/8/1997	31800	ug/L	D		10.37		B0M5D3	QTESSL	300.0_ANIONS_IC
199-F5-45	1998.1	35817	1/21/1998	55800	ug/L	D		10.93		B0MP65	QTESSL	300.0_ANIONS_IC
199-F5-45	1998.4	35937	5/21/1998	79200	ug/L	D	H	11.28		B0NPK7	QTESSL	300.0_ANIONS_IC
199-F5-45	1998.7	36034	8/26/1998	86300	ug/L	D		11.37		B0PCN4	QTESSL	300.0_ANIONS_IC
199-F5-45	1998.8	36080	10/12/1998	100000	ug/L	D		11.51		B0R1P5	QTESSL	300.0_ANIONS_IC
199-F5-45	1999.1	36186	1/26/1999	109000	ug/L	D		11.6		B0TD38	QTESSL	300.0_ANIONS_IC
199-F5-45	1999.4	36304	5/24/1999	93000	ug/L	D		11.44		B0VBT3	QTESSL	300.0_ANIONS_IC
199-F5-45	1999.7	36402	8/30/1999	44100	ug/L	D		10.69		B0W377	QTESSL	300.0_ANIONS_IC
199-F5-45	1999.9	36500	12/6/1999	94300	ug/L	D		11.45		B0WHP7	QTESSL	300.0_ANIONS_IC

Well	Date Decimal Year	Date Number	Date	Nitrate	Units LabQ	RvwQ	ValQ	Nitrate Ln	Samp	Lab	Method	
199-F5-45	2000.1	36571	2/15/2000	88500	ug/L	D		11.39		B0X6R0	QTESSL	300.0_ANIONS_IC
199-F5-45	2000.8	36812	10/13/2000	80600	ug/L	D		11.3		B10DF3	STLSL	300.0_ANIONS_IC
199-F5-45	2001.1	36922	1/30/2001	9740	ug/L	D	Y	9.184		B11697	STLSL	300.0 ANIONS IC
199-F5-45	2001.4	37028	5/16/2001	91600	ug/L	D		11.43		B11VR6	STLSL	300.0 ANIONS IC
199-F5-45	2001.6	37119	8/16/2001	107000	ug/L	D		11.58		B12JR0	STLSL	300.0 ANIONS IC
199-F5-45	2001.8	37180	10/16/2001	93000	ug/L	D		11.44		B12YV3	STLSL	300.0_ANIONS_IC
199-F5-45	2002.0	37265	1/9/2002	96500	ug/L	D		11.48		B13R67	STLSL	300.0_ANIONS_IC
199-F5-45	2002.4	37398	5/22/2002	84100	ug/L	D		11.34		B14FF5	STLSL	300.0 ANIONS IC
199-F5-45	2002.7	37502	9/3/2002	83700	ug/L	D		11.33		B151F1	STLSL	300.0 ANIONS IC
199-F5-45	2002.8	37543	10/14/2002	94700	ug/L	D		11.46		B15M43	STLSL	300.0 ANIONS IC
199-F5-45	2003.1	37657	2/4/2003	86800	ug/L	D		11.37		B16B49	STLSL	300.0_ANIONS_IC
199-F5-45	2003.4	37761	5/20/2003	84600	ug/L	D		11.35		B16VW1	STLSL	300.0_ANIONS_IC
199-F5-45	2003.7	37858	8/25/2003	80100	ug/L	D		11.29		B17841	STLSL	300.0_ANIONS_IC
199-F5-45	2003.8	37908	10/14/2003	77900	ug/L	D		11.26		B17L44	STLSL	300.0 ANIONS IC
199-F5-45	2005.0	38350	12/28/2004	83200	ug/L	D		11.33		B1BTP4	STLSL	300.0 ANIONS IC
199-F5-45	2006.4	38870	6/1/2006	89466.76	ug/L	D		11.4		J12698	RLNP	353.2 NO3/NO2
199-F5-45	2006.8	39007	10/17/2006	81900	ug/L	D	H	11.31		B1KPH5	STLSL	300.0_ANIONS_IC
199-F5-45	2008.9	39758	11/6/2008	90700	ug/L	D		11.42		B1X722	WSCF	300.0_ANIONS_IC
199-F5-45	2010.3	40303	5/5/2010	99200	ug/L	D		11.5		B25B11	WSCF	300.0 ANIONS IC
199-F5-45	2010.5	40367	7/8/2010	88500	ug/L	D		11.39		B26520	WSCF	300.0 ANIONS IC
199-F5-45	2010.7	40447	9/26/2010	94700	ug/L	D		11.46		B285M8	WSCF	300.0 ANIONS IC
199-F5-46	1993.0	33954	12/16/1992	9030.672	ug/L			9.108		B07R76	SKINER	353.2_NO3/NO2
199-F5-46	1993.3	34062	4/3/1993	48694.8	ug/L			10.79		B088W0	SKINER	353.2_NO3/NO2
199-F5-46	1993.5	34168	7/18/1993	41854.1	ug/L		Z	10.64		B08Y56	FIELD	353.3 NO3/NO2 FLD
199-F5-46	1993.9	34279	11/6/1993	36786.708	ug/L			10.51		B09DB2	SKINER	353.2 NO3/NO2
199-F5-46	1994.4	34464	5/10/1994	40726.56	ug/L			10.61		B0BMS6	ITAS	353.2 NO3/NO2
199-F5-46	1994.9	34648	11/10/1994	31700	ug/L	J	Z	10.36		B0D816	QTESSL	300.0_ANIONS_IC
199-F5-46	1995.4	34844	5/25/1995	51800	ug/L	J		10.86		B0FK79	QTESSL	300.0_ANIONS_IC
199-F5-46	1995.9	35023	11/20/1995	57100	ug/L	J		10.95		B0GS93	QTESSL	300.0 ANIONS IC
199-F5-46	1996.7	35318	9/10/1996	34000	ug/L	D		10.43		B0J8Q8	DATACH	D4327 ANIONS IC
199-F5-46	1997.7	35689	9/16/1997	44100	ug/L	D	H	10.69		B0LX95	QTESSL	300.0 ANIONS IC
199-F5-46	1997.8	35711	10/8/1997	42450	ug/L	D		10.66		B0M5D5	QTESSL	300.0_ANIONS_IC
199-F5-46	1998.4	35937	5/21/1998	49100	ug/L	D	H	10.8		B0NMM8	QTESSL	300.0_ANIONS_IC
199-F5-46	1998.8	36080	10/12/1998	50000	ug/L	D		10.82		B0R1P7	QTESSL	300.0_ANIONS_IC
199-F5-46	1999.4	36304	5/24/1999	44300	ug/L	D		10.7		B0VC03	QTESSL	300.0 ANIONS IC
199-F5-46	1999.9	36501	12/7/1999	53600	ug/L	D		10.89		B0WHP5	QTESSL	300.0 ANIONS IC
199-F5-46	2000.8	36816	10/17/2000	70850	ug/L	D		11.17		B10DF1	STLSL	300.0 ANIONS IC
199-F5-46	2001.8	37175	10/11/2001	54900	ug/L	D		10.91		B13032	STLSL	300.0_ANIONS_IC
199-F5-46	2002.8	37544	10/15/2002	61500	ug/L	D		11.03		B15M65	STLSL	300.0_ANIONS_IC
199-F5-46	2003.8	37907	10/13/2003	73500	ug/L	D		11.21		B17L47	STLSL	300.0 ANIONS IC
199-F5-46	2005.8	38632	10/6/2005	68600	ug/L	D	H	11.14		B1F0X4	STLSL	300.0 ANIONS IC
199-F5-46	2007.8	39364	10/9/2007	60200	ug/L	D		11.01		B1PVH3	WSCF	300.0 ANIONS IC
199-F5-46	2009.8	40093	10/6/2009	64200	ug/L	D		11.07		B220T1	WSCF	300.0_ANIONS_IC
199-F5-46	2010.3	40304	5/5/2010	40300	ug/L	D		10.6		B25B12	WSCF	300.0_ANIONS_IC
199-F5-46	2010.5	40367	7/8/2010	33400	ug/L	D		10.42		B26532	TASL	300.0 ANIONS IC
199-F5-46	2010.9	40493	11/11/2010	58000	ug/L	D		10.97		B28369	WSCF	300.0 ANIONS IC
199-F5-46	2011.9	40884	12/7/2011	40100	ug/L	D		10.6		B2HKH7	WSCF	300.0 ANIONS IC
199-F5-48	1993.0	33983	1/14/1993	73927.56	ug/L			11.21		B07R86	SKINER	353.2_NO3/NO2
199-F5-48	1993.3	34062	4/3/1993	80567.76	ug/L			11.3		B088X0	SKINER	353.2_NO3/NO2
199-F5-48	1993.5	34167	7/17/1993	77481.4	ug/L	J		11.26		B08Y66	SKINER	353.2 NO3/NO2
199-F5-48	1993.8	34273	10/31/1993	68615.4	ug/L			11.14		B09DC0	SKINER	353.2 NO3/NO2
199-F5-48	1994.4	34464	5/9/1994	77911.68	ug/L			11.26		B0BMT4	ITAS	353.2 NO3/NO2
199-F5-48	1994.9	34648	11/10/1994	35500	ug/L	J	Z	10.48		B0D822	QTESSL	300.0_ANIONS_IC
199-F5-48	1995.4	34844	5/25/1995	85000	ug/L	J		11.35		B0FK83	QTESSL	300.0_ANIONS_IC
199-F5-48	1995.9	35023	11/20/1995	73000	ug/L	J		11.2		B0GS97	QTESSL	300.0_ANIONS_IC
199-F5-48	1997.8	35712	10/8/1997	69100	ug/L	D		11.14		B0M5F0	QTESSL	300.0 ANIONS IC
199-F5-48	1999.9	36500	12/6/1999	108000	ug/L	D		11.59		B0WHN5	QTESSL	300.0 ANIONS IC
199-F5-48	2001.8	37174	10/10/2001	34300	ug/L	D	H	10.44		B13029	STLSL	300.0 ANIONS IC
199-F5-48	2003.8	37908	10/14/2003	88500	ug/L	D		11.39		B17L54	STLSL	300.0_ANIONS_IC
199-F5-48	2005.0	38350	12/28/2004	90300	ug/L	D		11.41		B1BTR0	STLSL	300.0_ANIONS_IC
199-F5-48	2006.5	38895	6/26/2006	38284.62	ug/L	D		10.55		J126B0	RLNP	353.2 NO3/NO2
199-F5-48	2006.8	39000	10/10/2006	47400	ug/L	DN		10.77		B1KPJ4	STLSL	300.0 ANIONS IC
199-F5-48	2008.9	39759	11/6/2008	75300	ug/L	D		11.23		B1X730	WSCF	300.0 ANIONS IC
199-F5-48	2010.3	40303	5/5/2010	108000	ug/L	D		11.59		B25B13	WSCF	300.0_ANIONS_IC
199-F5-48	2010.5	40368	7/8/2010	108000	ug/L	D		11.59		B26522	WSCF	300.0_ANIONS_IC
199-F5-48	2010.7	40447	9/26/2010	110500	ug/L	D		11.61		B285N0	WSCF	300.0 ANIONS IC
199-F5-48	2011.3	40653	4/20/2011	111000	ug/L	D		11.62		B2CJ75	WSCF	300.0 ANIONS IC
199-F5-48	2011.9	40885	12/7/2011	98700	ug/L	D		11.5		B2HKK4	WSCF	300.0 ANIONS IC
199-F5-54	2010.7	40421	8/31/2010	127366.6667	ug/L	D		11.75		B26YY2	WSCF	300.0_ANIONS_IC
199-F5-54	2011.0	40560	1/17/2011	145000	ug/L	D		11.88		B2B5P0	WSCF	300.0_ANIONS_IC
199-F5-54	2011.4	40702	6/7/2011	55300	ug/L	D		10.92		B2CJ93	WSCF	300.0 ANIONS IC
199-F5-54	2011.6	40759	8/3/2011	95200	ug/L	D		11.46		B2F3F4	WSCF	300.0 ANIONS IC
199-F5-54	2012.0	40892	12/15/2011	108000	ug/L	D		11.59		B2HKM9	WSCF	300.0 ANIONS IC
199-F5-6	1980.2	29279	2/28/1980	500	ug/L					H00074V3	USTEST	UNKNOWN_GENCHEM
199-F5-6	1980.4	29363	5/22/1980	64000	ug/L					H00074V4	USTEST	UNKNOWN_GENCHEM
199-F5-6	1980.6	29452	8/19/1980	790	ug/L					H00074V5	USTEST	UNKNOWN_GENCHEM
199-F5-6	1980.9	29536	11/11/1980	500	ug/L					H00074V6	USTEST	UNKNOWN_GENCHEM
199-F5-6	1981.2	29643	2/26/1981	500	ug/L					H00074V7	USTEST	UNKNOWN_GENCHEM
199-F5-6	1981.4	29724	5/18/1981	500	ug/L					H00074V8	USTEST	UNKNOWN_GENCHEM

Well	Date Decimal Year	Date Number	Date	Nitrate	Units LabQ	RvwQ	ValQ	Nitrate Ln	Samp	Lab	Method	
199-F5-6	1981.6	29801	8/3/1981	500	ug/L					H00074V9	USTEST	UNKNOWN_GENCHEM
199-F5-6	1981.8	29892	11/2/1981	500	ug/L					H00074W0	USTEST	UNKNOWN_GENCHEM
199-F5-6	1982.2	30011	3/1/1982	960	ug/L					H00074W1	USTEST	UNKNOWN_GENCHEM
199-F5-6	1982.4	30095	5/24/1982	1200	ug/L					H00074W2	USTEST	UNKNOWN_GENCHEM
199-F5-6	1982.8	30257	11/2/1982	500	ug/L					H00074W3	USTEST	UNKNOWN_GENCHEM
199-F5-6	1983.2	30371	2/24/1983	2900	ug/L					H00074W4	USTEST	UNKNOWN_GENCHEM
199-F5-6	1983.4	30447	5/11/1983	640	ug/L					H00074W5	USTEST	UNKNOWN_GENCHEM
199-F5-6	1983.6	30539	8/11/1983	2400	ug/L					H00074W6	USTEST	UNKNOWN_GENCHEM
199-F5-6	1983.8	30622	11/2/1983	16000	ug/L					H00074W7	USTEST	UNKNOWN_GENCHEM
199-F5-6	1984.1	30734	2/22/1984	7100	ug/L					H00074W8	USTEST	UNKNOWN_GENCHEM
199-F5-6	1984.4	30813	5/11/1984	9200	ug/L					H00074W9	USTEST	UNKNOWN_GENCHEM
199-F5-6	1984.6	30917	8/23/1984	5200	ug/L					H00074X0	USTEST	UNKNOWN_GENCHEM
199-F5-6	1984.9	31022	12/6/1984	10000	ug/L					H00074X1	USTEST	UNKNOWN_GENCHEM
199-F5-6	1985.1	31092	2/14/1985	8200	ug/L					H00074X2	USTEST	UNKNOWN_GENCHEM
199-F5-6	1985.3	31155	4/18/1985	7000	ug/L					H00074X3	USTEST	UNKNOWN_GENCHEM
199-F5-6	1985.7	31304	9/14/1985	1100	ug/L					H00074X4	USTEST	UNKNOWN_GENCHEM
199-F5-6	1985.9	31360	11/9/1985	10000	ug/L					H00074X5	USTEST	UNKNOWN_GENCHEM
199-F5-6	1986.0	31421	1/9/1986	25000	ug/L					H00074X6	PNL-KI	UNKNOWN_GENCHEM
199-F5-6	1986.3	31511	4/9/1986	4100	ug/L					H00074X7	PNL-KI	UNKNOWN_GENCHEM
199-F5-6	1986.6	31622	7/29/1986	1890	ug/L					H00074X8	USTEST	300.0_ANIONS_IC
199-F5-6	1986.8	31701	10/16/1986	500	ug/L	U				H00074Y0	USTEST	300.0_ANIONS_IC
199-F5-6	1987.0	31791	1/14/1987	1520	ug/L					H00074Y2	USTEST	300.0_ANIONS_IC
199-F5-6	1987.3	31877	4/10/1987	1640	ug/L					H00074Y3	USTEST	300.0_ANIONS_IC
199-F5-6	1987.6	31985	7/27/1987	500	ug/L	U				H00074Y6	USTEST	300.0_ANIONS_IC
199-F5-6	1988.0	32153	1/11/1988	2500	ug/L	U				H00074Y8	USTEST	300.0_ANIONS_IC
199-F5-6	1988.3	32239	4/6/1988	2500	ug/L	U				H00074Y9	USTEST	300.0_ANIONS_IC
199-F5-6	1989.1	32548	2/9/1989	500	ug/L	U				H00074Z0	USTEST	300.0_ANIONS_IC
199-F5-6	1989.4	32661	6/2/1989	3700	ug/L					H00074Z1	USTEST	300.0_ANIONS_IC
199-F5-6	1989.8	32797	10/16/1989	2500	ug/L	U				H00074Z2	USTEST	300.0_ANIONS_IC
199-F5-6	1990.4	33007	5/14/1990	14300	ug/L					H00074Z3	USTEST	300.0_ANIONS_IC
199-F5-6	1991.7	33500	9/19/1991	1480	ug/L					B00LW7	PNL1	ANIONS_IC
199-F5-6	1992.1	33645	2/11/1992	300	ug/L					B05WN2	DATACH	D4327_ANIONS_IC
199-F5-6	1993.0	33955	12/16/1992	2169.132	ug/L					B07RD6	SKINER	353.2_NO3/NO2
199-F5-6	1993.3	34066	4/7/1993	1460.844	ug/L					B088S5	SKINER	353.2_NO3/NO2
199-F5-6	1993.6	34171	7/21/1993	19900	ug/L		Z			B08Y31	FIELD	353.3_NO3/NO2_FLD
199-F5-6	1993.8	34269	10/26/1993	25040.932	ug/L			10.13		B09D82	SKINER	353.2_NO3/NO2
199-F5-6	1994.3	34460	5/6/1994	21912.66	ug/L			9.995		B0BMY4	TMANC	353.2_NO3/NO2
199-F5-6	1994.9	34647	11/9/1994	28800	ug/L	J	Z	10.27		B0D801	QTESSL	300.0_ANIONS_IC
199-F5-6	1995.4	34849	5/30/1995	10200	ug/L	J		9.23		B0FK67	QTESSL	300.0_ANIONS_IC
199-F5-6	1995.6	34929	8/17/1995	13000	ug/L	D		9.473		B0G9C8	DATACH	D4327_ANIONS_IC
199-F5-6	1995.9	35016	11/13/1995	101000	ug/L	J	Y	11.52		B0GS81	QTESSL	300.0_ANIONS_IC
199-F5-6	1996.7	35318	9/10/1996	10000	ug/L	D		9.21		B0J8Q9	DATACH	D4327_ANIONS_IC
199-F5-6	1997.7	35689	9/16/1997	14200	ug/L	D	H	9.561		B0LXB0	QTESSL	300.0_ANIONS_IC
199-F5-6	1997.8	35712	10/8/1997	15800	ug/L	D		9.668		B0M5J5	QTESSL	300.0_ANIONS_IC
199-F5-6	1998.8	36080	10/12/1998	26300	ug/L	D		10.18		B0R1R0	QTESSL	300.0_ANIONS_IC
199-F5-6	1999.9	36501	12/7/1999	14200	ug/L	D		9.561		B0WHN2	QTESSL	300.0_ANIONS_IC
199-F5-6	2000.8	36816	10/17/2000	23500	ug/L	D		10.06		B10DC3	STLSL	300.0_ANIONS_IC
199-F5-6	2001.8	37175	10/10/2001	30500	ug/L	D		10.33		B12YV8	STLSL	300.0_ANIONS_IC
199-F5-6	2002.8	37545	10/15/2002	11500	ug/L	D		9.35		B15M49	STLSL	300.0_ANIONS_IC
199-F5-6	2003.8	37907	10/13/2003	37600	ug/L	D		10.53		B17L57	STLSL	300.0_ANIONS_IC
199-F5-6	2005.1	38381	1/28/2005	27400	ug/L	D		10.22		B1BY76	STLSL	300.0_ANIONS_IC
199-F5-6	2005.8	38638	10/13/2005	39262.468	ug/L	D		10.58		B1F0X8	STLSL	300.0_ANIONS_IC
199-F5-6	2006.0	38701	12/15/2005	27000	ug/L	D		10.2		B1F868	STLSL	300.0_ANIONS_IC
199-F5-6	2006.0	38702	12/15/2005	28425	ug/L	D	H	10.26		B1F898	STLSL	300.0_ANIONS_IC
199-F5-6	2006.8	39001	10/11/2006	24300	ug/L	DN		10.1		B1KPN1	STLSL	300.0_ANIONS_IC
199-F5-6	2007.8	39373	10/18/2007	26200	ug/L			10.17		B1PVJ1	WSCF	300.0_ANIONS_IC
199-F5-6	2008.9	39759	11/6/2008	22800	ug/L	D		10.03		B1X733	WSCF	300.0_ANIONS_IC
199-F5-6	2009.8	40092	10/6/2009	26700	ug/L	D		10.19		B220T7	WSCF	300.0_ANIONS_IC
199-F5-6	2010.3	40304	5/5/2010	30700	ug/L	D		10.33		B25B14	WSCF	300.0_ANIONS_IC
199-F5-6	2010.5	40373	7/13/2010	12400	ug/L	D	GQ	9.425		B26523	WSCF	300.0_ANIONS_IC
199-F5-6	2010.9	40493	11/10/2010	21900	ug/L	D		9.994		B285N1	WSCF	300.0_ANIONS_IC
199-F5-6	2011.9	40884	12/7/2011	17300	ug/L	D		9.758		B2HKP6	WSCF	300.0_ANIONS_IC
199-F6-1	1993.1	33997	1/28/1993	2700.348	ug/L			7.901		B07R91	SKINER	353.2_NO3/NO2
199-F6-1	1993.3	34065	4/6/1993	2877.42	ug/L			7.965		B088X5	SKINER	353.2_NO3/NO2
199-F6-1	1993.6	34171	7/21/1993	2660	ug/L		Z	7.886		B08Y71	FIELD	353.3_NO3/NO2_FLD
199-F6-1	1993.8	34272	10/30/1993	2523.276	ug/L			7.833		B09DC4	SKINER	353.2_NO3/NO2
199-F6-1	1994.4	34466	5/12/1994	4072.656	ug/L			8.312		B0BMT8	ITAS	353.2_NO3/NO2
199-F6-1	1994.9	34652	11/14/1994	3230	ug/L	J	Z	8.08		B0D825	QTESSL	300.0_ANIONS_IC
199-F6-1	1995.4	34845	5/26/1995	2880	ug/L	J		7.966		B0FK85	QTESSL	300.0_ANIONS_IC
199-F6-1	1995.9	35024	11/20/1995	4030	ug/L	J		8.302		B0GS99	QTESSL	300.0_ANIONS_IC
199-F6-1	1997.8	35712	10/8/1997	43500	ug/L	D		10.68		B0M5H0	QTESSL	300.0_ANIONS_IC
199-F6-1	1998.8	36081	10/13/1998	15200	ug/L	D	Q	9.629		B0R1R2	QTESSL	300.0_ANIONS_IC
199-F6-1	1999.9	36501	12/7/1999	2570	ug/L			7.852		B0WHM9	QTESSL	300.0_ANIONS_IC
199-F6-1	2000.8	36812	10/13/2000	1990	ug/L			7.596		B10DC0	STLSL	300.0_ANIONS_IC
199-F6-1	2001.8	37174	10/10/2001	4380	ug/L			8.385		B12YY0	STLSL	300.0_ANIONS_IC
199-F6-1	2002.8	37544	10/15/2002	1860	ug/L			7.528		B15M61	STLSL	300.0_ANIONS_IC
199-F6-1	2003.8	37908	10/14/2003	4870	ug/L	D		8.491		B17L60	STLSL	300.0_ANIONS_IC
199-F6-1	2004.8	38271	10/11/2004	4210	ug/L	D		8.345		B1B8X0	STLSL	300.0_ANIONS_IC
199-F6-1	2007.0	39093	1/11/2007	5310	ug/L	D		8.577		B1KPM8	STLSL	300.0_ANIONS_IC

Well	Date Decimal Year	Date Number	Date	Nitrate	Units LabQ	RvwQ	ValQ	Nitrate Ln	Samp	Lab	Method
199-F6-1	2009.1	39862	2/18/2009	3910	ug/L	D		8.271		B1X736	WSCF 300.0_ANIONS_IC
199-F6-1	2010.4	40316	5/17/2010	5440	ug/L	D		8.602		B25B15	WSCF 300.0_ANIONS_IC
199-F6-1	2010.5	40368	7/8/2010	1670	ug/L	D		7.421		B26524	WSCF 300.0 ANIONS IC
199-F6-1	2010.7	40447	9/26/2010	3990	ug/L	D		8.292		B285N2	WSCF 300.0 ANIONS IC
199-F7-2	1993.0	33984	1/14/1993	60647.16	ug/L			11.01		B07R61	SKINER 353.2 NO3/NO2
199-F7-2	1993.3	34067	4/8/1993	69500.76	ug/L			11.15		B088Y5	SKINER 353.2_NO3/NO2
199-F7-2	1993.6	34178	7/28/1993	59300	ug/L		Z	10.99		B08Y81	FIELD 353.3_NO3/NO2_FLD
199-F7-2	1993.8	34272	10/30/1993	70828.8	ug/L			11.17		B09DD2	SKINER 353.2 NO3/NO2
199-F7-2	1994.4	34491	6/6/1994	59761.8	ug/L			11		B0BMV6	ITAS 353.2 NO3/NO2
199-F7-2	1994.9	34649	11/11/1994	61500	ug/L	J	Z	11.03		B0D831	QTESSL 300.0 ANIONS IC
199-F7-2	1995.4	34850	5/30/1995	57500	ug/L	J		10.96		B0FK89	QTESSL 300.0_ANIONS_IC
199-F7-2	1995.9	35020	11/17/1995	53100	ug/L	J		10.88		B0GSB3	QTESSL 300.0_ANIONS_IC
199-F7-2	1997.8	35712	10/9/1997	77000	ug/L	D		11.25		B0M5H4	QTESSL 300.0_ANIONS_IC
199-F7-2	1998.8	36076	10/8/1998	84600	ug/L	D		11.35		B0R0M5	QTESSL 300.0 ANIONS IC
199-F7-2	1999.9	36501	12/7/1999	76100	ug/L	D		11.24		B0WHM6	QTESSL 300.0 ANIONS IC
199-F7-2	2000.8	36812	10/12/2000	72600	ug/L	DN		11.19		B10D89	STLSL 300.0 ANIONS IC
199-F7-2	2001.8	37175	10/11/2001	70800	ug/L	D		11.17		B12YX7	STLSL 300.0_ANIONS_IC
199-F7-2	2003.8	37909	10/14/2003	79700	ug/L	D		11.29		B17L66	STLSL 300.0_ANIONS_IC
199-F7-2	2005.8	38640	10/14/2005	58000	ug/L	D		10.97		B1F0Y2	STLSL 300.0 ANIONS IC
199-F7-2	2006.4	38876	6/7/2006	113127.8	ug/L	D		11.64		J126B2	RLNP 353.2 NO3/NO2
199-F7-2	2007.8	39364	10/9/2007	58900	ug/L	D		10.98		B1PVJ8	WSCF 300.0 ANIONS IC
199-F7-2	2009.8	40093	10/6/2009	65074	ug/L	D		11.08		B220V3	WSCF 300.0_ANIONS_IC
199-F7-2	2010.3	40304	5/5/2010	65100	ug/L	D		11.08		B25B17	WSCF 300.0_ANIONS_IC
199-F7-2	2010.5	40368	7/8/2010	64200	ug/L	D		11.07		B26526	WSCF 300.0 ANIONS IC
199-F7-2	2010.9	40493	11/10/2010	62900	ug/L	D		11.05		B28370	WSCF 300.0 ANIONS IC
199-F7-2	2011.9	40883	12/6/2011	56700	ug/L	D		10.95		B2HKT0	WSCF 300.0 ANIONS IC
199-F8-7	2008.9	39761	11/9/2008	111000	ug/L	D		11.62		B1XMN7	WSCF 300.0_ANIONS_IC
199-F8-7	2009.1	39847	2/3/2009	122000	ug/L	D		11.71		B1Y5P3	WSCF 300.0_ANIONS_IC
199-F8-7	2009.3	39933	4/29/2009	117000	ug/L	D		11.67		B203B3	WSCF 300.0 ANIONS IC
199-F8-7	2009.7	40079	9/23/2009	118417	ug/L	D		11.68		B20Y33	WSCF 300.0 ANIONS IC
199-F8-7	2010.3	40303	5/5/2010	91600	ug/L	D		11.43		B25B23	WSCF 300.0 ANIONS IC
199-F8-7	2010.5	40373	7/13/2010	99200	ug/L	D	Q	11.5		B26531	WSCF 300.0_ANIONS_IC
199-F8-7	2010.7	40447	9/26/2010	98300	ug/L	D		11.5		B285N4	WSCF 300.0_ANIONS_IC
199-F8-7	2011.9	40883	12/6/2011	97800	ug/L	D		11.49		B2HKW8	WSCF 300.0_ANIONS_IC
699-62-31	1980.2	29277	2/26/1980	3800	ug/L					H000F7C1	USTEST UNKNOWN GENCHEM
699-62-31	1980.4	29355	5/14/1980	4100	ug/L					H000F7C2	USTEST UNKNOWN GENCHEM
699-62-31	1980.6	29451	8/18/1980	4200	ug/L					H000F7C3	USTEST UNKNOWN GENCHEM
699-62-31	1980.9	29531	11/6/1980	4900	ug/L					H000F7C4	USTEST UNKNOWN_GENCHEM
699-62-31	1981.1	29636	2/19/1981	3800	ug/L					H000F7C5	USTEST UNKNOWN_GENCHEM
699-62-31	1981.4	29719	5/13/1981	4400	ug/L			8.389		H000F7C6	USTEST UNKNOWN GENCHEM
699-62-31	1981.6	29818	8/20/1981	4500	ug/L			8.412		H000F7C7	USTEST UNKNOWN GENCHEM
699-62-31	1981.8	29886	10/27/1981	3600	ug/L			8.189		H000F7C8	USTEST UNKNOWN GENCHEM
699-62-31	1982.1	30005	2/23/1982	3800	ug/L			8.243		H000F7C9	USTEST UNKNOWN_GENCHEM
699-62-31	1982.4	30084	5/13/1982	3700	ug/L			8.216		H000F7D0	USTEST UNKNOWN_GENCHEM
699-62-31	1982.8	30250	10/26/1982	2300	ug/L			7.741		H000F7D1	USTEST UNKNOWN GENCHEM
699-62-31	1983.1	30369	2/22/1983	3900	ug/L			8.269		H000F7D2	USTEST UNKNOWN GENCHEM
699-62-31	1983.4	30445	5/9/1983	3900	ug/L			8.269		H000F7D3	USTEST UNKNOWN GENCHEM
699-62-31	1983.6	30529	8/1/1983	4600	ug/L			8.434		H000F7D4	USTEST UNKNOWN_GENCHEM
699-62-31	1983.8	30622	11/2/1983	4200	ug/L			8.343		H000F7D5	USTEST UNKNOWN_GENCHEM
699-62-31	1984.1	30728	2/16/1984	3600	ug/L			8.189		H000F7D6	USTEST UNKNOWN GENCHEM
699-62-31	1984.4	30812	5/10/1984	9300	ug/L			9.138		H000F7D7	USTEST UNKNOWN GENCHEM
699-62-31	1984.6	30916	8/22/1984	11000	ug/L			9.306		H000F7D8	USTEST UNKNOWN GENCHEM
699-62-31	1984.9	31023	12/7/1984	21000	ug/L			9.952		H000F7D9	USTEST UNKNOWN_GENCHEM
699-62-31	1985.2	31104	2/26/1985	19000	ug/L			9.852		H000F7F0	USTEST UNKNOWN_GENCHEM
699-62-31	1985.6	31262	8/3/1985	56000	ug/L			10.93		H000F7F1	USTEST UNKNOWN_GENCHEM
699-62-31	1985.8	31346	10/26/1985	65000	ug/L			11.08		H000F7F2	USTEST UNKNOWN GENCHEM
699-62-31	1985.9	31367	11/16/1985	80000	ug/L			11.29		H000F7F3	USTEST UNKNOWN GENCHEM
699-62-31	1986.2	31495	3/24/1986	64000	ug/L			11.07		H000F7F4	PNL-KI UNKNOWN GENCHEM
699-62-31	1986.4	31569	6/6/1986	59000	ug/L			10.99		H000F7F5	PNL-KI UNKNOWN_GENCHEM
699-62-31	1986.7	31668	9/13/1986	37700	ug/L			10.54		H000F7F6	USTEST 300.0_ANIONS_IC
699-62-31	1986.9	31733	11/17/1986	44500	ug/L			10.7		H000F7F7	USTEST 300.0 ANIONS IC
699-62-31	1987.3	31897	4/30/1987	44500	ug/L			10.7		H000F7F8	USTEST 300.0 ANIONS IC
699-62-31	1987.6	32012	8/23/1987	37900	ug/L			10.54		H000F7F9	USTEST 300.0 ANIONS IC
699-62-31	1987.9	32089	11/8/1987	41800	ug/L			10.64		H000F7G0	USTEST 300.0_ANIONS_IC
699-62-31	1988.2	32206	3/4/1988	43800	ug/L			10.69		H000F7G1	USTEST 300.0_ANIONS_IC
699-62-31	1988.3	32262	4/29/1988	49000	ug/L			10.8		H000F7G2	USTEST 300.0 ANIONS IC
699-62-31	1988.6	32346	7/22/1988	55400	ug/L			10.92		H000F7G3	USTEST 300.0 ANIONS IC
699-62-31	1988.9	32458	11/11/1988	64100	ug/L			11.07		H000F7G4	USTEST 300.0 ANIONS IC
699-62-31	1989.3	32601	4/3/1989	64400	ug/L			11.07		H000F7G5	USTEST 300.0_ANIONS_IC
699-62-31	1991.6	33472	8/22/1991	41400	ug/L			10.63		B00L62	PNL1 ANIONS_IC
699-62-31	1992.1	33652	2/18/1992	55000	ug/L			10.92		B05X93	DATACH D4327 ANIONS IC
699-62-31	1992.6	33815	7/30/1992	57000	ug/L			10.95		B073N1	DATACH D4327 ANIONS IC
699-62-31	1993.3	34064	4/5/1993	45000	ug/L			10.71		B08CX6	DATACH D4327 ANIONS IC
699-62-31	2004.1	38019	2/2/2004	102000	ug/L	D		11.53		B18577	STLSL 300.0 ANIONS IC
699-62-31	2004.8	38273	10/12/2004	92500	ug/L	D		11.43		B1B8Y2	STLSL 300.0_ANIONS_IC
699-62-31	2007.0	39078	12/27/2006	93400	ug/L	D		11.44		B1KPK6	STLSL 300.0_ANIONS_IC
699-62-31	2009.1	39855	2/10/2009	93400	ug/L	D		11.44		B1X7D6	WSCF 300.0 ANIONS IC
699-62-31	2010.9	40500	11/17/2010	85400	ug/L	D		11.36		B28632	WSCF 300.0 ANIONS IC
699-71-30	1980.8	29523	10/29/1980	13000	ug/L			9.473		H000FFH5	USTEST UNKNOWN GENCHEM

Well	Date Decimal Year	Date Number	Date	Nitrate	Units LabQ	RvwQ	ValQ	Nitrate Ln	Samp	Lab	Method	
699-71-30	1981.4	29724	5/18/1981	16000	ug/L			9.68		H000FFH6	USTEST	UNKNOWN_GENCHEM
699-71-30	1981.8	29892	11/2/1981	16000	ug/L			9.68		H000FFH7	USTEST	UNKNOWN_GENCHEM
699-71-30	1982.4	30095	5/24/1982	17000	ug/L			9.741		H000FFH8	USTEST	UNKNOWN_GENCHEM
699-71-30	1982.8	30250	10/26/1982	12000	ug/L			9.393		H000FFH9	USTEST	UNKNOWN_GENCHEM
699-71-30	1983.4	30447	5/11/1983	17000	ug/L			9.741		H000FFJ0	USTEST	UNKNOWN_GENCHEM
699-71-30	1983.8	30622	11/2/1983	23000	ug/L			10.04		H000FFJ1	USTEST	UNKNOWN_GENCHEM
699-71-30	1984.4	30813	5/11/1984	17000	ug/L			9.741		H000FFJ2	USTEST	UNKNOWN_GENCHEM
699-71-30	1984.9	31014	11/28/1984	39000	ug/L			10.57		H000FFJ3	USTEST	UNKNOWN_GENCHEM
699-71-30	1985.2	31127	3/21/1985	39000	ug/L			10.57		H000FFJ4	USTEST	UNKNOWN_GENCHEM
699-71-30	1985.8	31346	10/26/1985	61000	ug/L			11.02		H000FFJ5	USTEST	UNKNOWN_GENCHEM
699-71-30	1986.2	31485	3/14/1986	58000	ug/L			10.97		H000FFJ6	PNL-KI	UNKNOWN_GENCHEM
699-71-30	1986.4	31562	5/30/1986	49000	ug/L			10.8		H000FFJ7	PNL-KI	UNKNOWN_GENCHEM
699-71-30	1986.7	31678	9/23/1986	26800	ug/L			10.2		H000FFJ8	USTEST	300.0_ANIONS_IC
699-71-30	1986.9	31735	11/19/1986	26200	ug/L			10.17		H000FFK0	USTEST	300.0_ANIONS_IC
699-71-30	1987.1	31810	2/2/1987	28000	ug/L			10.24		H000FFK2	USTEST	300.0_ANIONS_IC
699-71-30	1987.3	31894	4/27/1987	25100	ug/L			10.13		H000FFK3	USTEST	300.0_ANIONS_IC
699-71-30	1987.6	32014	8/25/1987	25500	ug/L			10.15		H000FFK4	USTEST	300.0_ANIONS_IC
699-71-30	1988.0	32124	12/13/1987	28900	ug/L			10.27		H000FFK6	USTEST	300.0_ANIONS_IC
699-71-30	1988.2	32204	3/2/1988	29449.5	ug/L			10.29		H000FFK7	USTEST	300.0_ANIONS_IC
699-71-30	1988.4	32283	5/20/1988	28200	ug/L			10.25		H000FFK9	USTEST	300.0_ANIONS_IC
699-71-30	1988.5	32318	6/24/1988	29700	ug/L			10.3		H000FFL0	USTEST	300.0_ANIONS_IC
699-71-30	1988.7	32385	8/30/1988	28700	ug/L			10.26		H000FFL2	USTEST	300.0_ANIONS_IC
699-71-30	1988.9	32475	11/28/1988	29900	ug/L			10.31		H000FFL3	USTEST	300.0_ANIONS_IC
699-71-30	1989.3	32618	4/20/1989	32100	ug/L			10.38		H000FFL4	USTEST	300.0_ANIONS_IC
699-71-30	1989.8	32807	10/26/1989	34500	ug/L			10.45		H000FFL5	USTEST	300.0_ANIONS_IC
699-71-30	1992.1	33624	1/21/1992	57000	ug/L			10.95		B00NL6	DATACH	D4327_ANIONS_IC
699-71-30	1993.3	34075	4/16/1993	54000	ug/L			10.9		B08D08	DATACH	D4327_ANIONS_IC
699-71-30	1994.5	34515	6/30/1994	70000	ug/L	D		11.16		B0C225	DATACH	D4327_ANIONS_IC
699-71-30	1995.4	34835	5/16/1995	73500	ug/L	J		11.21		B0FKB1	QTESSL	300.0_ANIONS_IC
699-71-30	1995.7	34941	8/30/1995	82000	ug/L	D		11.31		B0GCG4	DATACH	D4327_ANIONS_IC
699-71-30	1995.9	35014	11/10/1995	73900	ug/L	J		11.21		B0GSC5	QTESSL	300.0_ANIONS_IC
699-71-30	1998.7	36060	9/22/1998	169000	ug/L	D	Q	12.04		B0PT39	QTESSL	300.0_ANIONS_IC
699-71-30	1999.1	36188	1/27/1999	68600	ug/L	D		11.14		B0TD16	QTESSL	300.0_ANIONS_IC
699-71-30	2001.1	36921	1/30/2001	82300	ug/L	D		11.32		B11692	STLSL	300.0_ANIONS_IC
699-71-30	2002.0	37272	1/16/2002	96900	ug/L	D		11.48		B13R64	STLSL	300.0_ANIONS_IC
699-71-30	2003.1	37649	1/28/2003	104000	ug/L	D		11.55		B16B51	STLSL	300.0_ANIONS_IC
699-71-30	2005.1	38372	1/20/2005	96900	ug/L	CD		11.48		B1BY81	STLSL	300.0_ANIONS_IC
699-71-30	2006.9	39063	12/12/2006	100000	ug/L	D		11.51		B1KPP0	STLSL	300.0_ANIONS_IC
699-71-30	2008.9	39777	11/25/2008	101000	ug/L	D		11.52		B1X751	WSCF	300.0_ANIONS_IC
699-71-30	2010.3	40284	4/15/2010	99600	ug/L	D		11.51		B24M71	WSCF	300.0_ANIONS_IC
699-71-30	2010.5	40372	7/13/2010	97400	ug/L	D	Q	11.49		B26685	WSCF	300.0_ANIONS_IC
699-71-30	2010.9	40512	11/29/2010	100000	ug/L	D		11.51		B28656	WSCF	300.0_ANIONS_IC

Data not used
Average of duplicate/triplicate value

Well	Date Decimal	Date Number	Date	TCE ug/L	Units	LabQ	RvwQ	ValQ	Ln TCE	Method
199-F5-45	1993.0	33954	12/16/1992	3	ug/L	J			1.1	CLP_VOA_GCMS
199-F5-45	1993.2	34059	3/31/1993	3	ug/L	J			1.1	CLP_VOA_GCMS
199-F5-45	1993.5	34167	7/17/1993	2	ug/L	J			0.69	CLP_VOA_GCMS
199-F5-45	1993.9	34279	11/6/1993	1	ug/L	J			0	CLP_VOA_GCMS
199-F5-45	1994.4	34464	5/10/1994	4	ug/L	J			1.39	CLP_VOA_GCMS
199-F5-45	1994.7	34605	9/28/1994	4	ug/L				1.39	502.2_VOA_GC
199-F5-45	1994.9	34648	11/10/1994	4	ug/L	J			1.39	CLP_VOA_GCMS
199-F5-45	1995.4	34844	5/25/1995	4	ug/L	J			1.39	CLP_VOA_GCMS
199-F5-45	1995.9	35017	11/14/1995	4	ug/L	J			1.39	CLP_VOA_GCMS
199-F5-45	1997.7	35686	9/12/1997	5	ug/L				1.61	8260_VOA_GCMS
199-F5-45	1997.8	35711	10/8/1997	6	ug/L				1.79	8260_VOA_GCMS
199-F5-45	1998.8	36080	10/12/1998	5	ug/L	J			1.61	8260_VOA_GCMS
199-F5-45	1999.9	36500	12/6/1999	4.3	ug/L	J			1.46	8260_VOA_GCMS
199-F5-45	2000.8	36812	10/13/2000	3.5	ug/L				1.25	8260_VOA_GCMS
199-F5-45	2002.8	37543	10/14/2002	3.6	ug/L				1.28	8260_VOA_GCMS
199-F5-45	2005.0	38350	12/28/2004	1.9	ug/L	J			0.64	8260_VOA_GCMS
199-F5-45	2006.8	39007	10/17/2006	1.9	ug/L				0.64	8260_VOA_GCMS
199-F5-45	2008.9	39758	11/6/2008	2.45	ug/L	J			0.9	8260_VOA_GCMS
199-F5-45	2010.3	40303	5/5/2010	3.4	ug/L	T			1.22	8260_VOA_GCMS
199-F5-45	2010.5	40367	7/8/2010	7.9	ug/L	T			2.07	8260_VOA_GCMS
199-F5-45	2010.7	40447	9/26/2010	4.7	ug/L	J	G		1.55	8260_VOA_GCMS
199-F5-46	1993.0	33954	12/16/1992	2	ug/L	J			0.69	CLP_VOA_GCMS
199-F5-46	1993.3	34062	4/3/1993	7	ug/L	J			1.95	CLP_VOA_GCMS
199-F5-46	1993.5	34168	7/18/1993	10	ug/L	U			2.3	CLP_VOA_GCMS
199-F5-46	1993.9	34279	11/6/1993	4	ug/L	J			1.39	CLP_VOA_GCMS
199-F5-46	1994.4	34464	5/10/1994	2	ug/L	J			0.69	CLP_VOA_GCMS
199-F5-46	1994.9	34648	11/10/1994	6	ug/L	J			1.79	CLP_VOA_GCMS
199-F5-46	1995.4	34844	5/25/1995	10	ug/L	U			2.3	CLP_VOA_GCMS
199-F5-46	1995.9	35023	11/20/1995	10	ug/L	U			2.3	CLP_VOA_GCMS
199-F5-46	1997.8	35711	10/8/1997	3	ug/L	J			1.1	8260_VOA_GCMS
199-F5-46	1998.8	36080	10/12/1998	5	ug/L	J			1.61	8260_VOA_GCMS
199-F5-46	1999.9	36501	12/7/1999	0.915	ug/L	J			-0.1	8260_VOA_GCMS
199-F5-46	2000.8	36816	10/17/2000	5.9	ug/L				1.77	8260_VOA_GCMS
199-F5-46	2001.8	37175	10/11/2001	4.9	ug/L	J			1.59	8260_VOA_GCMS
199-F5-46	2002.8	37544	10/15/2002	3.8	ug/L				1.34	8260_VOA_GCMS
199-F5-46	2005.8	38632	10/6/2005	6.9	ug/L				1.93	8260_VOA_GCMS
199-F5-46	2007.8	39364	10/9/2007	2.5	ug/L	J			0.92	8260_VOA_GCMS
199-F5-46	2009.8	40093	10/6/2009	3.3	ug/L	J			1.19	8260_VOA_GCMS
199-F5-46	2010.3	40304	5/5/2010	2.6	ug/L	T			0.96	8260_VOA_GCMS
199-F5-46	2010.5	40367	7/8/2010	2.605	ug/L	U			0.96	8260_VOA_GCMS
199-F5-46	2010.9	40493	11/11/2010	4.2	ug/L				1.44	8260_VOA_GCMS
199-F5-46	2011.9	40884	12/7/2011	1	ug/L	U			0	8260_VOA_GCMS
199-F7-1	1987.3	31877	4/10/1987	10	ug/L	U				8240_VOA_GCMS
199-F7-1	1987.6	31985	7/27/1987	10.3	ug/L					8240_VOA_GCMS
199-F7-1	1987.8	32065	10/15/1987	12	ug/L					8240_VOA_GCMS
199-F7-1	1988.0	32156	1/14/1988	14	ug/L					8240_VOA_GCMS
199-F7-1	1988.3	32239	4/6/1988	13	ug/L					8240_VOA_GCMS
199-F7-1	1988.6	32353	7/29/1988	15	ug/L					8240_VOA_GCMS
199-F7-1	1990.2	32932	2/28/1990	35	ug/L				3.56	8240_VOA_GCMS
199-F7-1	1991.7	33500	9/19/1991	19	ug/L				2.94	502.2_VOA_GC
199-F7-1	1992.1	33646	2/12/1992	25	ug/L				3.22	502.2_VOA_GC
199-F7-1	1993.0	33954	12/15/1992	26	ug/L				3.26	CLP_VOA_GCMS
199-F7-1	1993.2	34059	3/31/1993	28	ug/L				3.33	CLP_VOA_GCMS
199-F7-1	1993.6	34170	7/19/1993	20	ug/L				3	CLP_VOA_GCMS
199-F7-1	1993.8	34269	10/27/1993	21	ug/L				3.04	CLP_VOA_GCMS
199-F7-1	1994.4	34464	5/10/1994	20	ug/L				3	CLP_VOA_GCMS
199-F7-1	1994.7	34607	9/29/1994	25	ug/L				3.22	502.2_VOA_GC
199-F7-1	1994.9	34654	11/15/1994	22	ug/L				3.09	CLP_VOA_GCMS
199-F7-1	1995.4	34838	5/18/1995	21.6	ug/L				3.07	CLP_VOA_GCMS
199-F7-1	1996.7	35319	9/11/1996	9.9	ug/L				2.29	8010_VOA_GC
199-F7-1	1997.7	35691	9/18/1997	18	ug/L				2.89	8260_VOA_GCMS
199-F7-1	1997.8	35717	10/13/1997	17	ug/L				2.83	8260_VOA_GCMS

Well	Date Decimal	Date Number	Date	TCE ug/L	Units	LabQ	RvwQ	ValQ	Ln TCE	Method
199-F7-1	1998.8	36076	10/8/1998	16	ug/L				2.77	8260_VOA_GCMS
199-F7-1	1999.9	36497	12/3/1999	15	ug/L				2.71	8260_VOA_GCMS
199-F7-1	2000.8	36811	10/12/2000	16	ug/L		H		2.77	8260_VOA_GCMS
199-F7-1	2001.8	37175	10/11/2001	18	ug/L				2.89	8260_VOA_GCMS
199-F7-1	2003.8	37907	10/13/2003	19	ug/L				2.94	8260_VOA_GCMS
199-F7-1	2005.8	38632	10/7/2005	14	ug/L				2.64	8260_VOA_GCMS
199-F7-1	2007.8	39373	10/18/2007	9.7	ug/L				2.27	8260_VOA_GCMS
199-F7-1	2009.8	40092	10/6/2009	13	ug/L				2.56	8260_VOA_GCMS
199-F7-1	2010.3	40303	5/5/2010	20	ug/L	T			3	8260_VOA_GCMS
199-F7-1	2010.5	40367	7/8/2010	16	ug/L	T			2.77	8260_VOA_GCMS
199-F7-1	2010.7	40448	9/26/2010	16	ug/L				2.77	8260_VOA_GCMS
199-F7-1	2011.9	40885	12/7/2011	14	ug/L		Q		2.64	8260_VOA_GCMS
199-F7-2	1993.0	33984	1/14/1993	3	ug/L	J			1.1	CLP_VOA_GCMS
199-F7-2	1993.3	34067	4/8/1993	3	ug/L	J			1.1	CLP_VOA_GCMS
199-F7-2	1993.6	34178	7/28/1993	3	ug/L	J			1.1	CLP_VOA_GCMS
199-F7-2	1993.8	34272	10/30/1993	3	ug/L	J			1.1	CLP_VOA_GCMS
199-F7-2	1994.4	34491	6/6/1994	6	ug/L	J			1.79	CLP_VOA_GCMS
199-F7-2	1994.9	34649	11/11/1994	4	ug/L	J			1.39	CLP_VOA_GCMS
199-F7-2	1995.4	34850	5/30/1995	4	ug/L	J			1.39	CLP_VOA_GCMS
199-F7-2	1995.9	35020	11/17/1995	4	ug/L	J			1.39	CLP_VOA_GCMS
199-F7-2	1997.7	35685	9/12/1997	3	ug/L	J			1.1	8260_VOA_GCMS
199-F7-2	1997.8	35712	10/9/1997	3	ug/L	J			1.1	8260_VOA_GCMS
199-F7-2	1998.8	36076	10/8/1998	4	ug/L	J			1.39	8260_VOA_GCMS
199-F7-2	1999.9	36501	12/7/1999	4.4	ug/L	J			1.48	8260_VOA_GCMS
199-F7-2	2000.8	36812	10/12/2000	4.5	ug/L		H		1.5	8260_VOA_GCMS
199-F7-2	2001.8	37175	10/11/2001	5.6	ug/L				1.72	8260_VOA_GCMS
199-F7-2	2003.8	37909	10/14/2003	5.8	ug/L				1.76	8260_VOA_GCMS
199-F7-2	2005.8	38640	10/14/2005	4	ug/L				1.39	8260_VOA_GCMS
199-F7-2	2007.8	39364	10/9/2007	2.6	ug/L	J			0.96	8260_VOA_GCMS
199-F7-2	2009.8	40093	10/6/2009	3.5	ug/L	J			1.25	8260_VOA_GCMS
199-F7-2	2010.3	40304	5/5/2010	5.5	ug/L	T			1.7	8260_VOA_GCMS
199-F7-2	2010.5	40368	7/8/2010	4.7	ug/L	T			1.55	8260_VOA_GCMS
199-F7-2	2010.9	40493	11/10/2010	4.3	ug/L				1.46	8260_VOA_GCMS
199-F7-2	2011.9	40883	12/6/2011	3.8	ug/L	J			1.34	8260_VOA_GCMS
199-F7-3	1993.0	33983	1/13/1993	3	ug/L	J				CLP_VOA_GCMS
199-F7-3	1993.3	34068	4/9/1993	3	ug/L	J				CLP_VOA_GCMS
199-F7-3	1993.6	34178	7/28/1993	3	ug/L	J				CLP_VOA_GCMS
199-F7-3	1993.9	34280	11/6/1993	2	ug/L	J				CLP_VOA_GCMS
199-F7-3	1994.4	34473	5/19/1994	3	ug/L	J				CLP_VOA_GCMS
199-F7-3	1994.7	34605	9/28/1994	5	ug/L					502.2_VOA_GC
199-F7-3	1994.9	34648	11/10/1994	4	ug/L	J				CLP_VOA_GCMS
199-F7-3	1995.4	34842	5/23/1995	3	ug/L	J				CLP_VOA_GCMS
199-F7-3	1995.9	35020	11/17/1995	10	ug/L	UJ				CLP_VOA_GCMS
199-F7-3	1996.7	35319	9/11/1996	1.5	ug/L					8010_VOA_GC
199-F7-3	1997.7	35691	9/18/1997	0.5	ug/L	J				8260_VOA_GCMS
199-F7-3	1998.7	36060	9/22/1998	2	ug/L	J				8260_VOA_GCMS
199-F7-3	1999.1	36186	1/26/1999	2	ug/L	J				8260_VOA_GCMS
199-F7-3	1999.9	36502	12/8/1999	3.25	ug/L	J				8260_VOA_GCMS
199-F7-3	2000.8	36811	10/12/2000	4.9	ug/L		H			8260_VOA_GCMS
199-F7-3	2002.8	37544	10/15/2002	9.8	ug/L				2.28	8260_VOA_GCMS
199-F7-3	2004.1	38020	2/3/2004	9.2	ug/L	N			2.22	8260_VOA_GCMS
199-F7-3	2005.8	38631	10/6/2005	8.3	ug/L				2.12	8260_VOA_GCMS
199-F7-3	2007.8	39364	10/9/2007	5	ug/L	J			1.61	8260_VOA_GCMS
199-F7-3	2009.8	40092	10/6/2009	6.6	ug/L				1.89	8260_VOA_GCMS
199-F7-3	2010.3	40303	5/5/2010	10	ug/L	T			2.3	8260_VOA_GCMS
199-F7-3	2010.5	40367	7/8/2010	8.5	ug/L	T			2.14	8260_VOA_GCMS
199-F7-3	2010.7	40447	9/26/2010	8.9	ug/L				2.19	8260_VOA_GCMS
199-F7-3	2011.9	40883	12/6/2011	7.7	ug/L		Q		2.04	8260_VOA_GCMS
199-F8-4	1993.0	33977	1/8/1993	7	ug/L	U				CLP_VOA_GCMS
199-F8-4	1993.3	34068	4/8/1993	2	ug/L	J				CLP_VOA_GCMS
199-F8-4	1993.6	34172	7/22/1993	3	ug/L	J				CLP_VOA_GCMS
199-F8-4	1993.8	34271	10/29/1993	10	ug/L	U				CLP_VOA_GCMS

Well	Date Decimal	Date Number	Date	TCE ug/L	Units	LabQ	RvwQ	ValQ	Ln TCE	Method
199-F8-4	1994.4	34477	5/23/1994	2	ug/L	J				CLP_VOA_GCMS
199-F8-4	1994.9	34649	11/11/1994	1	ug/L	J				CLP_VOA_GCMS
199-F8-4	1995.4	34850	5/31/1995	1	ug/L	J				CLP_VOA_GCMS
199-F8-4	1995.9	35018	11/15/1995	10	ug/L	U				CLP_VOA_GCMS
199-F8-4	1997.7	35699	9/25/1997	1	ug/L	J				8260_VOA_GCMS
199-F8-4	1997.8	35716	10/13/1997	1	ug/L	J				8260_VOA_GCMS
199-F8-4	1998.8	36082	10/13/1998	0.7	ug/L	J				8260_VOA_GCMS
199-F8-4	1999.9	36501	12/7/1999	1	ug/L	J				8260_VOA_GCMS
199-F8-4	2000.8	36818	10/19/2000	0.93	ug/L	J				8260_VOA_GCMS
199-F8-4	2001.8	37179	10/15/2001	0.92	ug/L	J				8260_VOA_GCMS
199-F8-4	2002.8	37544	10/15/2002	1.1	ug/L					8260_VOA_GCMS
199-F8-4	2010.3	40303	5/5/2010	1	ug/L	T				8260_VOA_GCMS
199-F8-4	2010.5	40367	7/8/2010	0.68	ug/L	JT				8260_VOA_GCMS
199-F8-4	2010.7	40447	9/26/2010	1.3	ug/L					8260_VOA_GCMS
699-77-36	1988.0	32124	12/13/1987	34	ug/L				3.53	8240_VOA_GCMS
699-77-36	1988.2	32203	3/1/1988	32	ug/L				3.47	8240_VOA_GCMS
699-77-36	1988.5	32318	6/24/1988	35	ug/L				3.56	8240_VOA_GCMS
699-77-36	1988.6	32370	8/15/1988	32.67	ug/L				3.49	8240_VOA_GCMS
699-77-36	1989.1	32528	1/20/1989	30.33	ug/L				3.41	8240_VOA_GCMS
699-77-36	1991.6	33472	8/22/1991	30	ug/L				3.4	502.2_VOA_GC
699-77-36	1992.2	33668	3/4/1992	29	ug/L				3.37	502.2_VOA_GC
699-77-36	1992.3	33697	4/3/1992	27	ug/L				3.3	502.2_VOA_GC
699-77-36	1992.8	33891	10/14/1992	27	ug/L				3.3	502.2_VOA_GC
699-77-36	1993.3	34094	5/5/1993	27	ug/L				3.3	8010_VOA_GC
699-77-36	1993.5	34166	7/16/1993	28	ug/L				3.33	502.2_VOA_GC
699-77-36	1994.7	34585	9/7/1994	25	ug/L				3.22	502.2_VOA_GC
699-77-36	1995.4	34835	5/16/1995	25	ug/L				3.22	CLP_VOA_GCMS
699-77-36	1995.7	34941	8/30/1995	22	ug/L				3.09	8010_VOA_GC
699-77-36	1995.9	35014	11/10/1995	26	ug/L				3.26	CLP_VOA_GCMS
699-77-36	1996.7	35313	9/5/1996	19	ug/L				2.94	8010_VOA_GC
699-77-36	1997.7	35691	9/17/1997	20	ug/L				3	8260_VOA_GCMS
699-77-36	1997.8	35716	10/13/1997	19	ug/L				2.94	8260_VOA_GCMS
699-77-36	1998.8	36075	10/7/1998	18	ug/L				2.89	8260_VOA_GCMS
699-77-36	1999.9	36497	12/3/1999	18	ug/L				2.89	8260_VOA_GCMS
699-77-36	2000.9	36847	11/17/2000	16	ug/L				2.77	8260_VOA_GCMS
699-77-36	2001.8	37180	10/16/2001	15	ug/L				2.71	8260_VOA_GCMS
699-77-36	2003.8	37904	10/9/2003	15	ug/L				2.71	8260_VOA_GCMS
699-77-36	2005.8	38652	10/27/2005	13	ug/L				2.56	8260_VOA_GCMS
699-77-36	2007.8	39385	10/29/2007	8.8	ug/L		Q		2.17	8260_VOA_GCMS
699-77-36	2009.8	40104	10/18/2009	11	ug/L				2.4	8260_VOA_GCMS
699-77-36	2010.4	40315	5/17/2010	12	ug/L				2.48	8260_VOA_GCMS
699-77-36	2010.6	40385	7/26/2010	8.5	ug/L				2.14	8260_VOA_GCMS
699-77-36	2010.9	40511	11/29/2010	13	ug/L	B			2.56	8260_VOA_GCMS
699-77-36	2011.9	40864	11/17/2011	10	ug/L				2.3	8260_VOA_GCMS

Data not used
Average of duplicate/triplicate value

Well	Date	Date	Date	Strontium-90	LabQ	RvwQ	Sr-90	ValQ	Sample No.	Lab	Method
199-F5-1	1988.0	32153.00	1/11/1988	20.3			3.0106		H0007405	USTEST	UST_RAD_CNT_LSC
199-F5-1	1988.3	32239.00	4/6/1988	22.4			3.1091		H0007406	USTEST	UST_RAD_CNT_LSC
199-F5-1	1989.4	32660.00	6/1/1989	41.4			3.7233		H0007408	USTEST	UST_RAD_CNT_LSC
199-F5-1	1990.2	32932.00	2/28/1990	31.6			3.4532		H0007409	USTEST	UST_RAD_CNT_LSC
199-F5-1	1992.1	33645.40	2/11/1992	31.5			3.45		B05WM8	ITASRL	SRTOT_SEP_PRECIP_GPC
199-F5-1	1993.0	33953.48	12/15/1992	26			3.2581		B07RG6	TMANC	SAS_COUNT_LSC
199-F5-1	1993.2	34059.54	3/31/1993	24			3.1781		B088Q5	TMANC	SAS_COUNT_LSC
199-F5-1	1993.6	34173.41	7/23/1993	22		R	3.091	R	B08Y16	TMANC	SAS_COUNT_LSC
199-F5-1	1993.8	34270.37	10/28/1993	27			3.2958		B09D70	TMANC	SAS_COUNT_LSC
199-F5-1	1994.4	34472.50	5/18/1994	17.433			2.8584		B0BMY8	TMANC	SAS_COUNT_LSC
199-F5-1	1994.7	34606.69	9/29/1994	20.5			3.0204		B0D099	ITASRL	SRTOT_SEP_PRECIP_GPC
199-F5-1	1994.9	34655.34	11/17/1994	20.533			3.022		B0D7Z2	QTESRL	SRTOT_SEP_PRECIP_GPC
199-F5-1	1995.4	34845.41	5/26/1995	23.8			3.1697		B0FK63	QTESRL	SRTOT_SEP_PRECIP_GPC
199-F5-1	1995.9	35020.53	11/17/1995	22.967			3.134		B0GSD9	QTESRL	SRTOT_SEP_PRECIP_GPC
199-F5-1	1996.7	35318.38	9/10/1996	63.312			4.1481		B0J691	ITASRL	SRTOT_SEP_PRECIP_GPC
199-F5-1	1997.7	35688.60	9/15/1997	10.3			2.3321		B0LX89	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	1997.8	35711.40	10/8/1997	118.5			4.7749		B0M5F6	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	1998.1	35816.44	1/21/1998	69			4.2341		B0MP63	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	1998.4	35943.51	5/28/1998	49.3			3.8979		B0NPK5	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	1998.7	36033.49	8/26/1998	64.7			4.1698		B0PCN1	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	1998.8	36081.40	10/13/1998	44.5			3.7955		B0R1N5	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	1999.1	36181.42	1/21/1999	48.3			3.8774		B0TD17	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	1999.4	36304.43	5/24/1999	77.3			4.3477		B0VBX7	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	1999.7	36402.45	8/30/1999	58.8			4.0741		B0W373	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	1999.9	36497.51	12/3/1999	42.9			3.7589		B0WHX9	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2000.1	36571.51	2/15/2000	61.7			4.1223		B0X6P9	QTESRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2000.8	36816.52	10/17/2000	37.6			3.627		B10DB2	STLRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2001.1	36921.43	1/30/2001	35.5			3.5695		B11690	STLRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2001.4	37028.47	5/17/2001	36.9			3.6082		B11VH1	STLRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2001.6	37119.45	8/16/2001	37.6			3.627		B12JR3	STLRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2001.8	37195.45	10/31/2001	33.2			3.5025		B12YT9	STLRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2002.9	37593.42	12/3/2002	27.8			3.325		B15M38	STLRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2004.1	38020.43	2/3/2004	22.6			3.1179		B18596	STLRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2005.8	38656.40	10/31/2005	36.675			3.6021		B1F0W5	STLRL	SRISO_SEP_PRECIP_GPC
199-F5-1	2009.8	40092.52	10/6/2009	12			2.4849		B220P7	WSCF	SRTOT_SEP_PRECIP_GPC
199-F5-1	2010.3	40303.42	5/5/2010	19			2.9444		B25917	WSCF	SRTOT_SEP_PRECIP_GPC
199-F5-1	2010.5	40372.31	7/13/2010	17	U	QY	2.8332		B264D4	WSCF	SRTOT_SEP_PRECIP_GPC
199-F5-1	2010.7	40447.45	9/26/2010	15			2.7081		B27T10	WSCF	SRTOT_SEP_PRECIP_GPC
199-F5-1	2011.9	40884.43	12/7/2011	17			2.8332		B2HKD0	WSCF	SRTOT_SEP_PRECIP_GPC

Data not used
Average of duplicate/triplicate value

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Attachment 2

Regression Analysis Statistics

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SUMMARY OUTPUT - Well 199-F5-48

Regression Statistics	
Multiple R	0.828090258
R Square	0.685733475
Adjusted R Squar	0.607166844
Standard Error	0.07669493
Observations	6

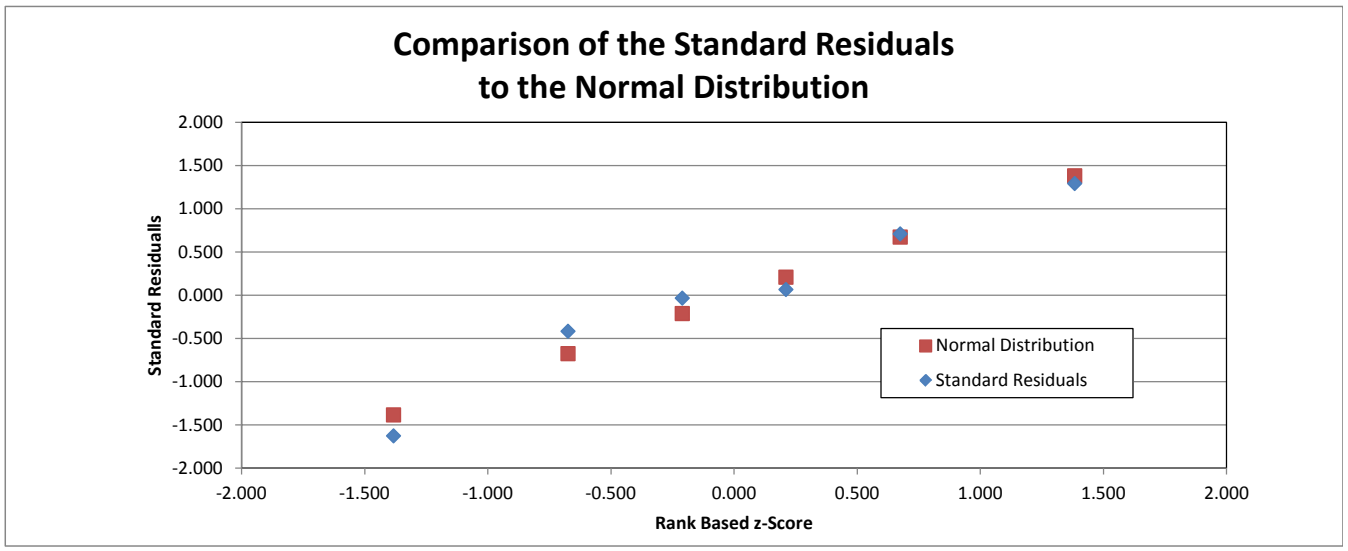
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.051339369	0.051339369	8.72805	0.041789218
Residual	4	0.023528449	0.005882112		
Total	5	0.074867818			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	258.4339277	86.60114927	2.98418589	0.040571	17.99059072	498.877265	17.99059072	498.8772647
X Variable 1	-0.1272	0.043059635	-2.954327313	0.041789	-0.246764969	-0.0077	-0.246764969	-0.007659543

RESIDUAL OUTPUT

						Normal Distribution
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
5	2.491052821	-0.111506687	-1.625508579	1	0.08	-1.383
2	2.671109826	-0.028487431	-0.415280591	2	0.25	-0.674
1	2.693430503	-0.00218742	-0.031887508	3	0.42	-0.210
3	2.643303369	0.004642908	0.067682815	4	0.58	0.210
6	2.444416067	0.048789385	0.711235949	5	0.75	0.674
4	2.571510292	0.088749245	1.293757914	6	0.92	1.383



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Cr (VI) ug/L	LabQ	Ln Cr(VI) ug/L
199-F5-48	2010.3	40303	5/5/2010	14.75		2.691
	2010.5	40368	7/8/2010	14.05		2.643
	2010.7	40447	9/26/2010	14.125		2.648
	2011.3	40653	4/20/2011	14.3		2.660
	2011.9	40885	12/7/2011	10.8		2.380
	2012.3	41018	4/19/2012	12.1		2.493

SUMMARY OUTPUT - 199-F5-45 Total Chromium

Regression Statistics	
Multiple R	0.799678274
R Square	0.639485342
Adjusted R Square	0.594421009
Standard Error	0.508297153
Observations	10

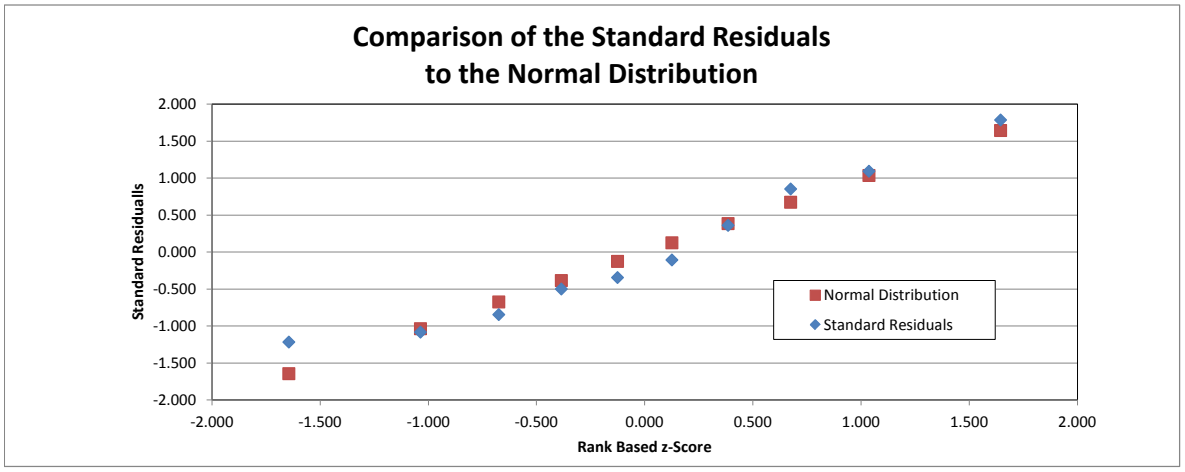
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.666342292	3.666342292	14.19049854	0.005488906
Residual	8	2.066927969	0.258365996		
Total	9	5.733270262			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	321.4632118	84.52333862	3.803247921	0.005212495	126.5520436	516.3743801	126.5520436	516.3743801
X Variable 1	-0.1587	0.042130617	-3.767027813	0.005488906	-0.255860585	-0.0616	-0.255860585	-0.06155383

RESIDUAL OUTPUT

					Normal Distribution	
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
7	2.643809019	-0.583295487	-1.217158678	1	0.05	-1.645
6	2.970131628	-0.51912653	-1.083257757	2	0.15	-1.036
5	3.029900902	-0.40523231	-0.845595473	3	0.25	-0.674
9	2.379192602	-0.239420599	-0.499597316	4	0.35	-0.385
2	3.923927364	-0.165055538	-0.344420255	5	0.45	-0.126
3	3.606301122	-0.050953061	-0.106323401	6	0.55	0.126
1	4.059498672	0.173157506	0.361326577	7	0.65	0.385
10	2.344438511	0.409222201	0.85392115	8	0.75	0.674
8	2.406988089	0.524205664	1.093856351	9	0.85	1.036
4	3.256013712	0.856498154	1.787248803	10	0.95	1.645



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Total Chromium ug/L	LabQ	Ln Total Chromium ug/L
199-F5-45	1999.9	36500	12/6/1999	68.9		4.2327
	2000.8	36812	10/13/2000	42.9		3.7589
	2002.8	37543	10/14/2002	35		3.5553
	2005.0	38350	12/28/2004	61.1		4.1125
	2006.4	38870	6/1/2006	13.8		2.6247
	2006.8	39007	10/17/2006	11.6		2.4510
	2008.9	39758	11/6/2008	7.85	B, U	2.0605
	2010.3	40303	5/5/2010	18.75	D	2.9312
	2010.5	40367	7/8/2010	8.4975	U, B, D	2.1398
	2010.7	40447	9/26/2010	15.7	D	2.7537

SUMMARY OUTPUT - 199-F5-46 - Cr(VI)

Regression Statistics	
Multiple R	0.561563376
R Square	0.315353426
Adjusted R Square	0.286826485
Standard Error	0.532692431
Observations	26

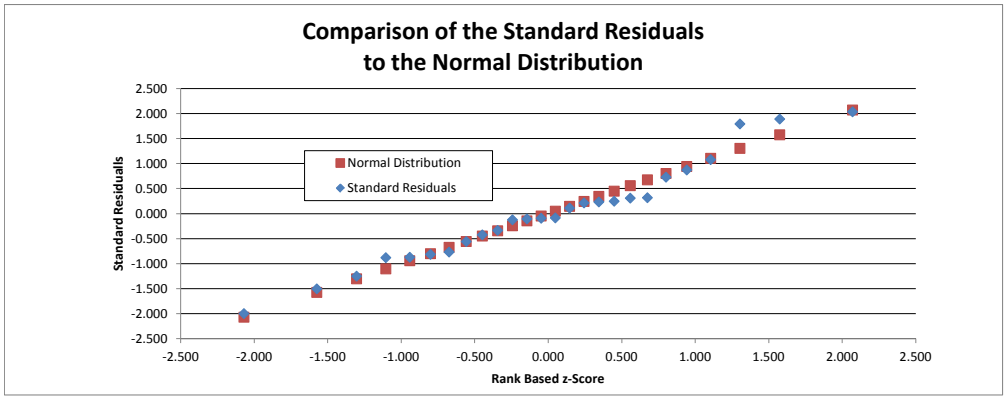
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.136861956	3.136861956	11.05458275	0.002834564
Residual	24	6.810269426	0.283761226		
Total	25	9.947131382			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	177.9694864	52.28006462	3.404155822	0.002333631	70.06873695	285.8702358	70.06873695	285.8702358
X Variable 1	-0.0868	0.02610755	-3.324843268	0.002834564	-0.140686848	-0.0329	-0.140686848	-0.032920178

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	Normal Distribution *Z-Score*
13	4.221196565	-1.043142734	-1.998626286	1	0.02	-2.070
15	4.186486382	-0.785289	-1.504587231	2	0.06	-1.574
14	4.207898608	-0.652550547	-1.250264832	3	0.10	-1.304
7	4.391574452	-0.459748819	-0.880863227	4	0.13	-1.105
24	3.449296047	-0.45523183	-0.872208829	5	0.17	-0.942
5	4.468123974	-0.425072706	-0.814424964	6	0.21	-0.801
25	3.419356295	-0.401373412	-0.769017917	7	0.25	-0.674
12	4.24281905	-0.291575331	-0.558648497	8	0.29	-0.558
26	3.32643564	-0.221848961	-0.425055125	9	0.33	-0.448
4	4.47928518	-0.175220087	-0.335715775	10	0.37	-0.344
2	4.530844941	-0.064936823	-0.124416762	11	0.40	-0.243
1	4.555803179	-0.055993509	-0.107281674	12	0.44	-0.145
11	4.268216949	-0.048709244	-0.093325269	13	0.48	-0.048
22	4.033936256	-0.044952209	-0.086126916	14	0.52	0.048
10	4.2932077	0.057070236	0.109344648	15	0.56	0.145
19	4.093550543	0.111142076	0.212944468	16	0.60	0.243
6	4.4429025	0.121445692	0.232685848	17	0.63	0.344
21	4.045548181	0.128839089	0.246851347	18	0.67	0.448
3	4.502315936	0.161123158	0.308706535	19	0.71	0.558
20	4.068612605	0.165493899	0.317080728	20	0.75	0.674
18	4.120200258	0.379609412	0.727318826	21	0.79	0.801
17	4.130172859	0.45479462	0.871371148	22	0.83	0.942
16	4.155374033	0.563124838	1.078928191	23	0.87	1.105
8	4.368056503	0.935248405	1.791904392	24	0.90	1.304
9	4.351431541	0.986106539	1.88934686	25	0.94	1.574
23	3.46447973	1.061647249	2.034080311	26	0.98	2.070



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Cr (VI) ug/L	LabQ	Ln Cr(VI) ug/L
199-F5-46	1997.8	35711	10/8/1997	90		4.500
	1998.1	35816	1/21/1998	87		4.466
	1998.4	35937	5/21/1998	106		4.663
	1998.7	36033	8/26/1998	74		4.304
	1998.8	36080	10/12/1998	57		4.043
	1999.1	36187	1/26/1999	96		4.564
	1999.7	36402	8/30/1999	51		3.932
	1999.9	36501	12/7/1999	201	G	5.303
	2000.1	36571	2/15/2000	208		5.338
	2000.8	36816	10/17/2000	77.5		4.350
	2001.1	36922	1/30/2001	68		4.220
	2001.4	37028	5/17/2001	52		3.951
	2001.6	37119	8/16/2001	24		3.178
	2001.8	37175	10/11/2001	35		3.555
	2002.0	37265	1/9/2002	30		3.401
	2002.4	37396	5/20/2002	112		4.718
	2002.7	37502	9/3/2002	98		4.585
	2002.8	37544	10/15/2002	90		4.500
	2003.1	37657	2/4/2003	67		4.205
	2003.4	37761	5/20/2003	69		4.234
	2003.7	37858	8/25/2003	65		4.174
	2003.8	37907	10/13/2003	54	H	3.989
	2010.3	40304	5/5/2010	92.4		4.526
	2010.5	40367	7/8/2010	20.0		2.994
	2010.9	40493	11/11/2010	20.45		3.018
	2011.9	40884	12/7/2011	22.3	Q	3.105

SUMMARY OUTPUT - 199-F5-46 - Total Chromium

Regression Statistics	
Multiple R	0.756746433
R Square	0.572665165
Adjusted R Square	0.553240854
Standard Error	0.554164676
Observations	24

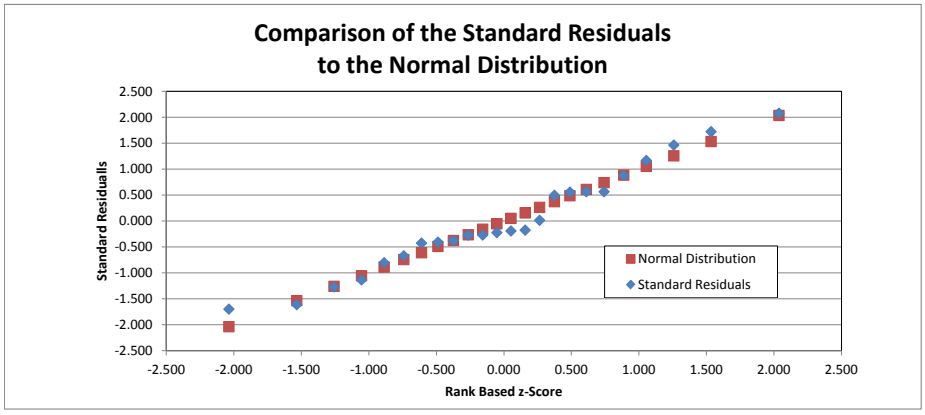
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9.053840257	9.053840257	29.48187832	1.87344E-05
Residual	22	6.756166737	0.307098488		
Total	23	15.81000699			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	199.7987157	36.01050374	5.548345483	1.41203E-05	125.1175022	274.4799293	125.1175022	274.4799293
X Variable 1	-0.0977	0.017995966	-5.429721754	1.87344E-05	-0.135034437	-0.0604	-0.135034437	-0.060391739

RESIDUAL OUTPUT

						Normal Distribution
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
6	4.874585283	-0.920461102	-1.698318649	1	0.02	-2.037
15	4.198551758	-0.873515737	-1.611700988	2	0.06	-1.534
4	4.973398191	-0.687744801	-1.268939904	3	0.10	-1.258
18	3.80899188	-0.614408748	-1.133629475	4	0.15	-1.054
11	4.491482577	-0.435359227	-0.803269897	5	0.19	-0.887
2	5.031344044	-0.363199059	-0.670129063	6	0.23	-0.742
22	3.344607067	-0.230203263	-0.424742007	7	0.27	-0.610
23	3.310904449	-0.219861995	-0.405661604	8	0.31	-0.489
20	3.418128939	-0.203261135	-0.375031792	9	0.35	-0.374
9	4.590181416	-0.14635438	-0.27003463	10	0.40	-0.264
19	3.612926062	-0.145628879	-0.268696027	11	0.44	-0.157
12	4.431557233	-0.120758108	-0.222807619	12	0.48	-0.052
14	4.294582604	-0.103413857	-0.190806197	13	0.52	0.052
17	4.002725597	-0.094710613	-0.174748068	14	0.56	0.157
10	4.529971828	0.007989608	0.014741417	15	0.60	0.264
8	4.774243401	0.269181715	0.496660127	16	0.65	0.374
3	5.002991903	0.302797478	0.558683689	17	0.69	0.489
24	3.206305408	0.306731455	0.565942167	18	0.73	0.610
16	4.099831368	0.306887879	0.56623078	19	0.77	0.742
7	4.822119025	0.476198342	0.878621077	20	0.81	0.887
1	5.060217114	0.633515025	1.168881966	21	0.85	1.054
13	4.378838499	0.794482377	1.465878607	22	0.90	1.258
5	4.923773445	0.934159709	1.723593591	23	0.94	1.534
21	3.361699054	1.126937315	2.079282498	24	0.98	2.037



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Total Chromium ug/L	LabQ	Ln Total Chromium ug/L
199-F5-46	1993.0	33954	12/16/1992	297		5.69373
	1993.3	34062	4/3/1993	106.5		4.66814
	1993.5	34168	7/18/1993	201.5		5.30579
	1993.9	34279	11/6/1993	72.65		4.28565
	1994.4	34464	5/10/1994	350		5.85793
	1994.9	34648	11/10/1994	52.15	*	3.95412
	1995.4	34844	5/25/1995	200		5.29832
	1995.9	35023	11/20/1995	155		5.04343
	1997.8	35711	10/8/1997	85.1		4.44383
	1998.4	35937	5/21/1998	93.5		4.53796
	1998.8	36080	10/12/1998	57.75		4.05612
	1999.4	36304	5/24/1999	74.5		4.31080
	1999.9	36501	12/7/1999	176.5		5.17332
	2000.8	36816	10/17/2000	66.1		4.19117
	2001.8	37175	10/11/2001	27.8		3.32504
	2002.8	37544	10/15/2002	82		4.40672
	2003.8	37907	10/13/2003	49.8		3.90801
	2005.8	38632	10/6/2005	24.4		3.19458
	2007.8	39364	10/9/2007	32.05	C	3.46730
	2009.8	40093	10/6/2009	24.9	B	3.21487
	2010.3	40304	5/5/2010	89		4.48864
	2010.5	40367	7/8/2010	22.52	D	3.11440
	2010.9	40493	11/11/2010	22	D	3.09104
	2011.9	40884	12/7/2011	33.55		3.51304

SUMMARY OUTPUT - 199-F5-6

Regression Statistics	
Multiple R	0.700337854
R Square	0.49047311
Adjusted R Square	0.320630813
Standard Error	0.573170827
Observations	5

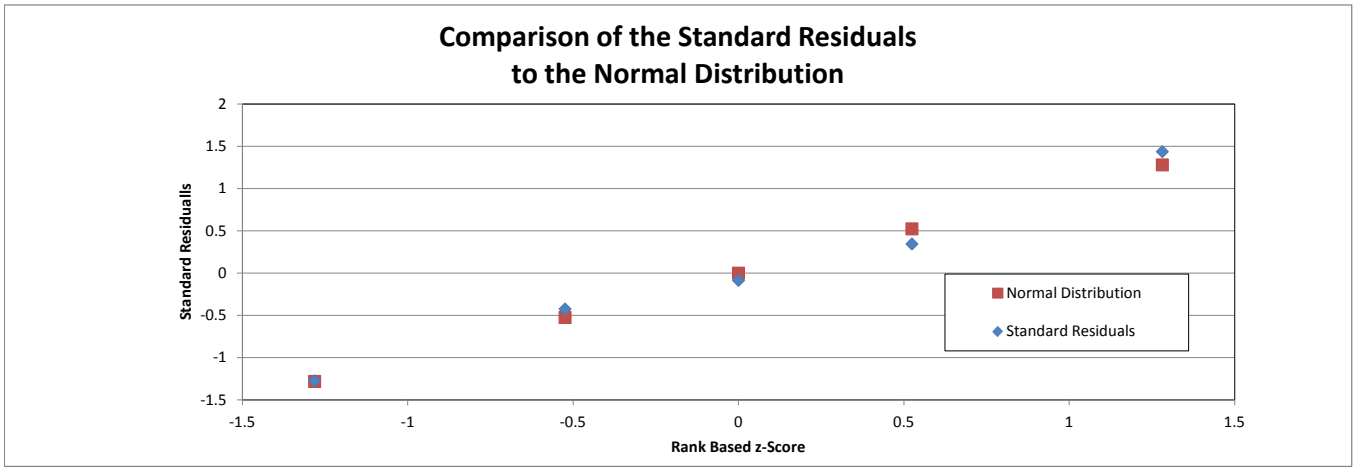
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.948718793	0.948718793	2.887814871	0.187813273
Residual	3	0.98557439	0.328524797		
Total	4	1.934293183			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	381.9731333	222.6020286	1.715946327	0.184677425	-326.4458701	1090.392137	-326.4458701	1090.392137
X Variable 1	-0.1883	0.110819027	-1.699357194	0.187813273	-0.540996712	0.1644	-0.540996712	0.164354492

RESIDUAL OUTPUT

						Normal Distribution
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
4	3.347140181	-0.632445437	-1.274114196	1	0.1	-1.281551566
2	4.208783735	-0.210583033	-0.424237121	2	0.3	-0.524400513
5	3.285271634	-0.042679282	-0.085980981	3	0.5	-1.39214E-16
1	4.241220395	0.171577898	0.345658017	4	0.7	0.524400513
3	3.382711588	0.714129854	1.438674281	5	0.9	1.281551566



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Cr (VI) ug/L	LabQ	Ln Cr(VI) ug/L
199-F5-6	2005.8	38638	10/13/2005	82.5		4.413
	2006.0	38701	12/15/2005	54.5		3.998
	2010.3	40304	5/5/2010	60.15		4.097
	2010.5	40373	7/13/2010	15.1		2.715
	2010.9	40493	11/10/2010	25.6		3.243
	2011.9	40884	12/7/2011	1	U	0.000

Notes

This data not used because it appears anamolous relative to previous results

SUMMARY OUTPUT - 199-F5-44 Total Chromium

Regression Statistics	
Multiple R	0.664925162
R Square	0.442125471
Adjusted R Square	0.302656838
Standard Error	0.58575945
Observations	6

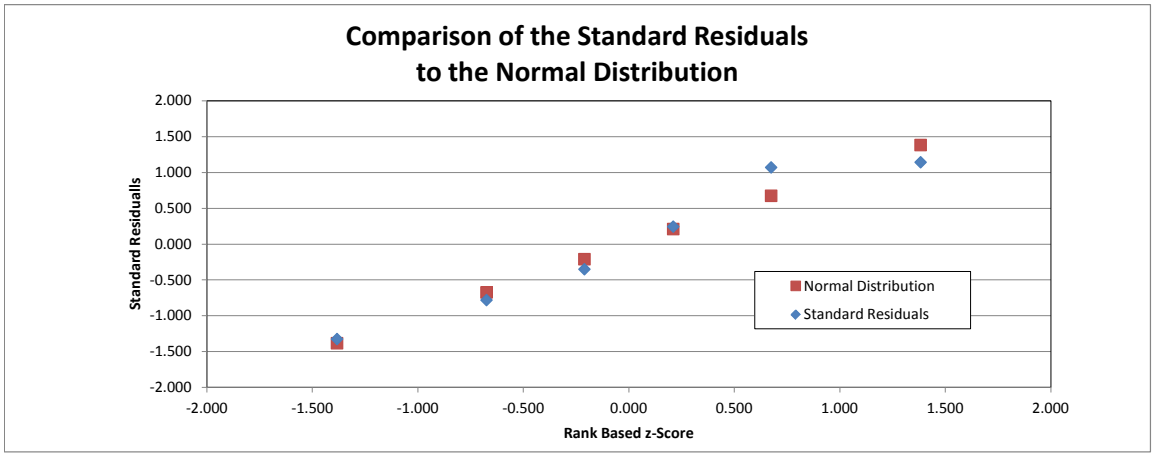
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.087696172	1.087696172	3.170071026	0.149602432
Residual	4	1.372456532	0.343114133		
Total	5	2.460152704			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	677.0824183	378.7616302	1.78762146	0.148361034	-374.5284558	1728.693292	-374.5284558	1728.693292
X Variable 1	-0.3355	0.188419768	-1.780469327	0.149602432	-0.85861276	0.1877	-0.85861276	0.187661525

RESIDUAL OUTPUT

					Normal Distribution	
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
4	2.601910879	-0.694221943	-1.32505541	1	0.08	-1.383
3	2.660687998	-0.4093962	-0.78141098	2	0.25	-0.674
5	2.486247183	-0.18366209	-0.35055424	3	0.42	-0.210
1	3.524082937	0.127873163	0.244070398	4	0.58	0.210
6	2.127005201	0.560842293	1.070474827	5	0.75	0.674
2	2.854592344	0.598564777	1.142475405	6	0.92	1.383



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Total Chromium ug/L	LabQ	Ln Total Chromium ug/L
199-F5-44	2007.8	39363	10/8/2007	38.55	C	3.6520
	2009.8	40092	10/6/2009	31.6	B	3.4532
	2010.3	40304	5/5/2010	9.5	D	2.2513
	2010.5	40368	7/8/2010	6.7375	B, U	1.9077
	2010.9	40493	11/11/2010	10	U, D	2.3026
	2011.9	40885	12/7/2011	14.7	B	2.6878

SUMMARY OUTPUT-199-F7-2 Nitrate

Regression Statistics	
Multiple R	0.485402075
R Square	0.235615175
Adjusted R Square	0.126417342
Standard Error	0.202711959
Observations	9

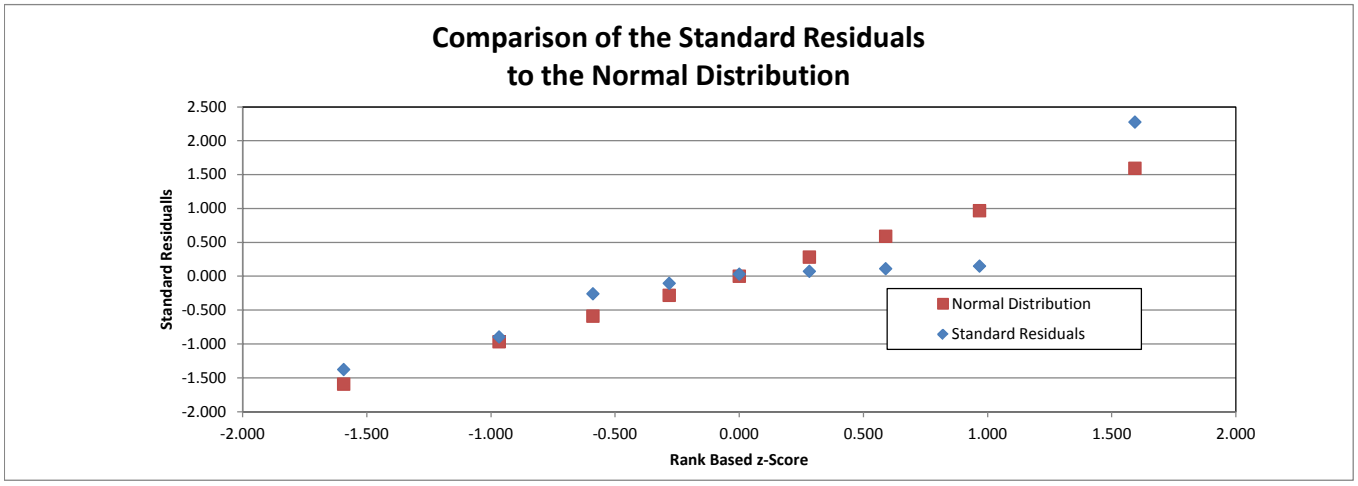
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.088664135	0.088664135	2.157690953	0.185309922
Residual	7	0.287644968	0.041092138		
Total	8	0.376309103			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	87.86012331	52.24107572	1.681820715	0.136485998	-35.67039123	211.3906378	-35.67039123	211.3906378
X Variable 1	-0.03820	0.026008946	-1.468908082	0.185309922	-0.099706134	0.0233	-0.099706134	0.023296633

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	Normal Distribution *Z-Score*
2	11.22944836	-0.261250075	-1.377758271	1	0.06	-1.593
4	11.15362317	-0.170026795	-0.896672752	2	0.17	-0.967
9	10.99472973	-0.049200238	-0.259468002	3	0.28	-0.589
1	11.30591016	-0.0198853	-0.104869391	4	0.39	-0.282
5	11.07746594	0.005814426	0.030663622	5	0.50	0.000
8	11.03561671	0.013684729	0.072169352	6	0.61	0.282
7	11.04870051	0.021057978	0.111053763	7	0.72	0.589
6	11.05538721	0.028292614	0.149207164	8	0.83	0.967
3	11.20476077	0.431512661	2.275674515	9	0.94	1.593



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
199-F7-2	2003.8	37909	10/14/2003	79700	D		11.28602486
	2005.8	38640	10/14/2005	58000	D		10.96819829
	2006.4	38876	6/7/2006	113127.8	D		11.63627343
	2007.8	39364	10/9/2007	58900	D		10.98359637
	2009.8	40093	10/6/2009	65074	D		11.08328036
	2010.3	40304	5/5/2010	65100	D		11.08367983
	2010.5	40368	7/8/2010	64200	D		11.06975849
	2010.9	40493	11/10/2010	62900	D		11.04930144
	2011.9	40883	12/6/2011	56700	D		10.94552949

SUMMARY OUTPUT - 199-F5-48 Nitrate

Regression Statistics	
Multiple R	0.512796256
R Square	0.26296
Adjusted R Square	0.17083
Standard Error	0.341837964
Observations	10

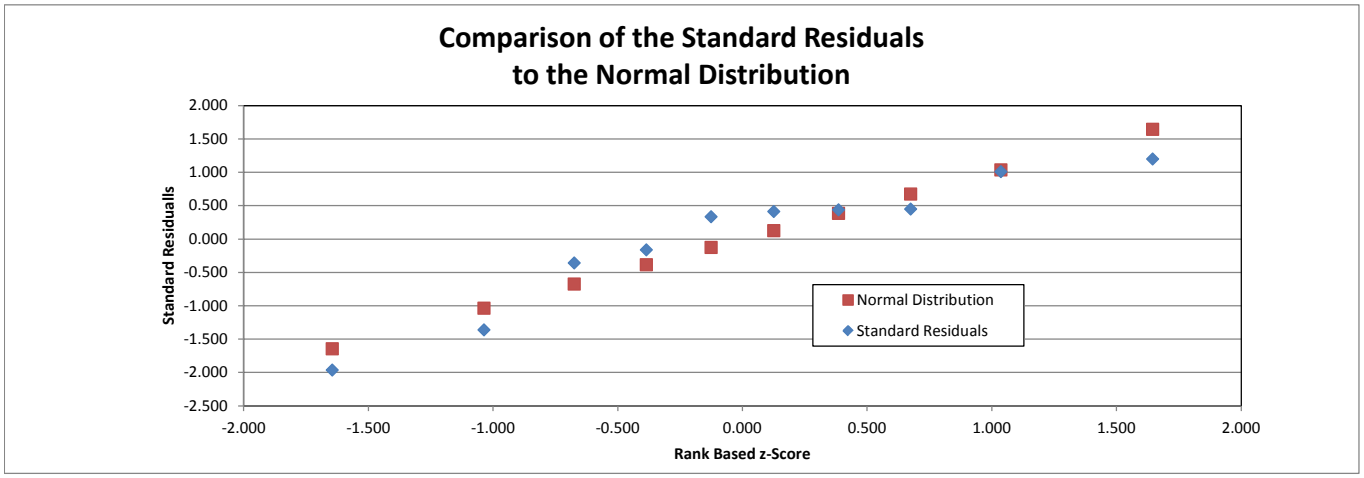
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.333525625	0.333525625	2.854227722	0.129605545
Residual	8	0.934825549	0.116853194		
Total	9	1.268351173			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-123.7624434	79.96026039	-1.547799405	0.160259858	-308.1511344	60.62624752	-308.1511344	60.62624752
X Variable 1	0.0673	0.039809424	1.689445981	0.129605545	-0.024544825	0.1591	-0.024544825	0.159056566

RESIDUAL OUTPUT

						Normal Distribution
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
3	11.1856116	-0.632808073	-1.963486769	1	0.05	-1.645
4	11.20512419	-0.438746684	-1.361350061	2	0.15	-1.036
5	11.34470838	-0.115472969	-0.358291331	3	0.25	-0.674
10	11.55204114	-0.052200912	-0.161969806	4	0.35	-0.385
9	11.50950406	0.107781417	0.334425864	5	0.45	-0.126
7	11.45684677	0.133039739	0.412797779	6	0.55	0.126
8	11.47154777	0.141223032	0.438189028	7	0.65	0.385
6	11.44504604	0.144840461	0.449413245	8	0.75	0.674
2	11.08526422	0.325628519	1.010365253	9	0.85	1.036
1	11.00404236	0.38671547	1.199906799	10	0.95	1.645



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
199-F5-48	2003.8	37908	10/14/2003	88500	D		11.39075783
	2005.0	38350	12/28/2004	90300	D		11.41089274
	2006.5	38895	6/26/2006	38284.62	D		10.55280353
	2006.8	39000	10/10/2006	47400	DN		10.76637751
	2008.9	39759	11/6/2008	75300	D		11.22923541
	2010.3	40303	5/5/2010	108000	D		11.58988651
	2010.5	40368	7/8/2010	108000	D		11.58988651
	2010.7	40447	9/26/2010	110500	D		11.6127708
	2011.3	40653	4/20/2011	111000	D		11.61728548
	2011.9	40885	12/7/2011	98700	D		11.49984023

SUMMARY OUTPUT - 199-F5-45 Nitrate

Regression Statistics	
Multiple R	0.771280376
R Square	0.594873418
Adjusted R Square	0.549859353
Standard Error	0.048672305
Observations	11

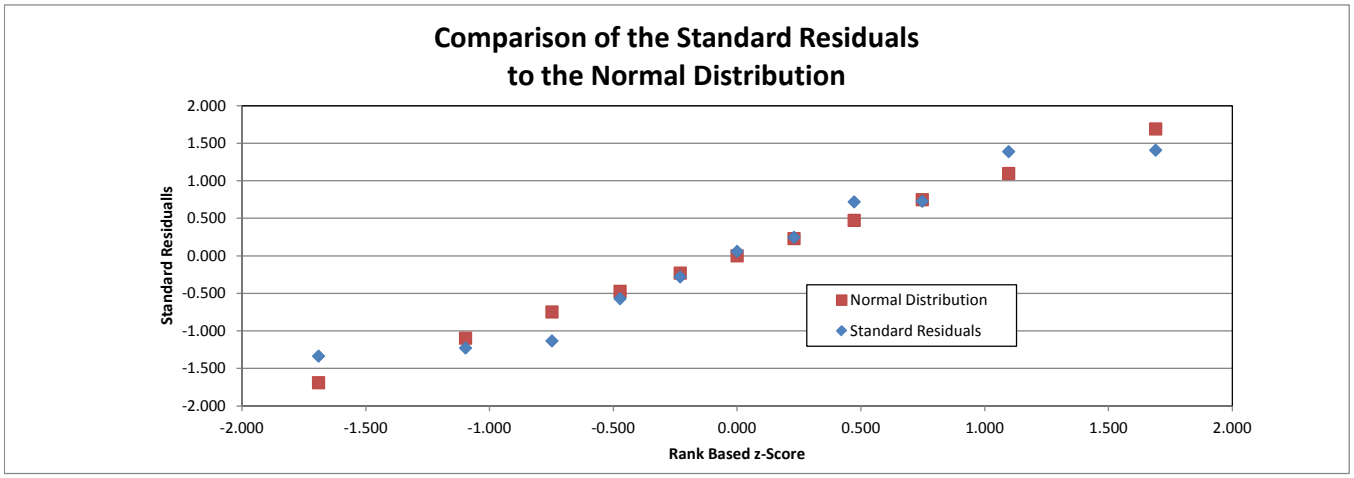
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.031306907	0.031306907	13.21527887	0.005440688
Residual	9	0.02132094	0.002368993		
Total	10	0.052627847			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-25.35621247	10.10308726	-2.509748934	0.033324481	-48.21098362	-2.501441313	-48.21098362	-2.501441313
X Variable 1	0.0183	0.005034925	3.635282503	0.005440688	0.006913584	0.0297	0.006913584	0.029693168

RESIDUAL OUTPUT

						Normal Distribution
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
7	11.37493972	-0.061685451	-1.335917293	1	0.05	-1.691
4	11.31986269	-0.05668146	-1.227546239	2	0.14	-1.097
10	11.4430915	-0.052333673	-1.133386519	3	0.23	-0.748
3	11.31736242	-0.026331288	-0.570254776	4	0.32	-0.473
5	11.34196953	-0.012966901	-0.280823219	5	0.41	-0.230
8	11.41257384	0.0027388	0.059313988	6	0.50	0.000
11	11.44709962	0.011369658	0.246231847	7	0.59	0.230
2	11.31250146	0.033188085	0.718751919	8	0.68	0.473
6	11.36804665	0.033575786	0.727148333	9	0.77	0.748
1	11.30724284	0.064119058	1.388621756	10	0.86	1.097
9	11.43988591	0.065007386	1.407860204	11	0.95	1.691



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
199-F5-45	2003.1	37657	2/4/2003	86800	D		11.3713619
	2003.4	37761	5/20/2003	84600	D		11.34568955
	2003.7	37858	8/25/2003	80100	D		11.29103113
	2003.8	37908	10/14/2003	77900	D		11.26318123
	2005.0	38350	12/28/2004	83200	D		11.32900263
	2006.4	38870	6/1/2006	89466.76	D		11.40162244
	2006.8	39007	10/17/2006	81900	D		11.31325427
	2008.9	39758	11/6/2008	90700	D		11.41531264
	2010.3	40303	5/5/2010	99200	D		11.50489329
	2010.5	40367	7/8/2010	88500	D		11.39075783
	2010.7	40447	9/26/2010	94700	D		11.45846928

SUMMARY OUTPUT - 199-F5-54 **Nitrate**

Regression Statistics	
Multiple R	0.393696192
R Square	0.154996692
Adjusted R Square	-0.126671078
Standard Error	0.395513974
Observations	5

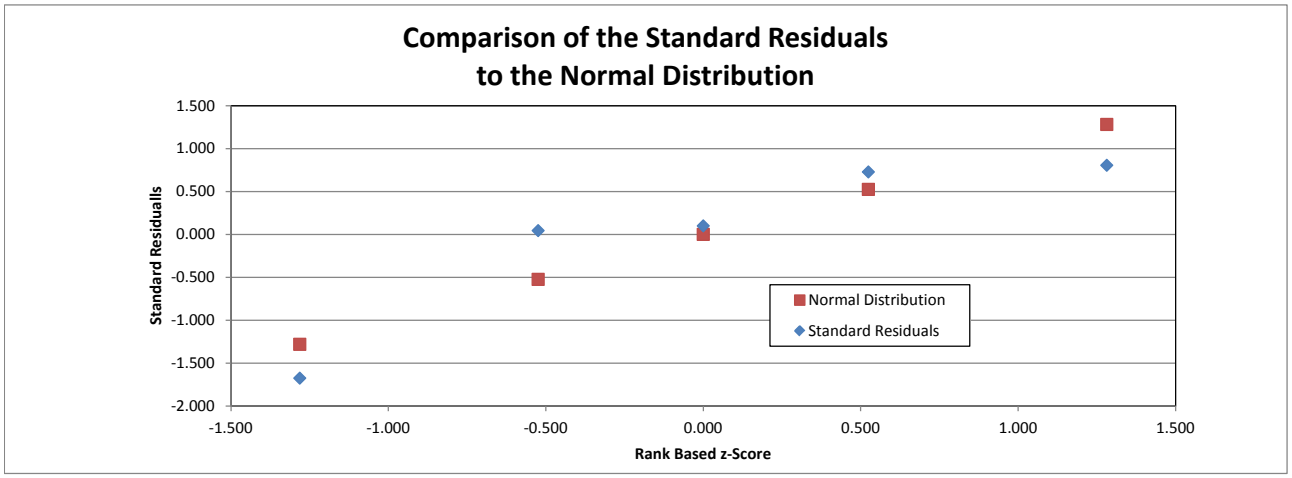
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.086081324	0.086081324	0.550281957	0.511998734
Residual	3	0.469293911	0.156431304		
Total	4	0.555375235			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	604.7527138	799.7062584	0.756218558	0.504481375	-1940.269513	3149.774941	-1940.269513	3149.774941
X Variable 1	-0.2949	0.39759877	-0.74180992	0.511998734	-1.560279448	0.9704	-1.560279448	0.970394024

RESIDUAL OUTPUT

					Normal Distribution	
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
3	11.49468889	-0.5741607	-1.676258523	1	0.10	-1.282
4	11.44870012	0.0150351	0.043894878	2	0.30	-0.524
1	11.72086939	0.033955952	0.099134186	3	0.50	0.000
5	11.3405825	0.249304007	0.727841468	4	0.70	0.524
2	11.60862338	0.275865641	0.80538799	5	0.90	1.282



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
199-F5-54	2010.7	40421	8/31/2010	127366.67	D		11.75482534
	2011.0	40560	1/17/2011	145000	D		11.88448902
	2011.4	40702	6/7/2011	55300	D		10.92052819
	2011.6	40759	8/3/2011	95200	D		11.46373522
	2012.0	40892	12/15/2011	108000	D		11.58988651

SUMMARY OUTPUT - 199-F6-1 Nitrate

Regression Statistics	
Multiple R	0.396279602
R Square	0.157037523
Adjusted R Square	-0.011554972
Standard Error	0.406289616
Observations	7

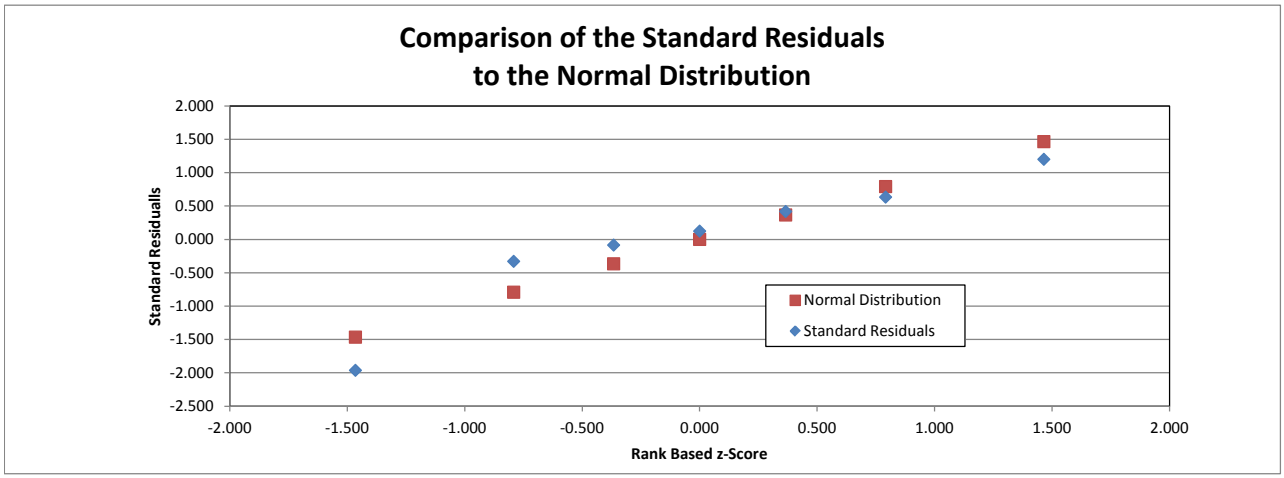
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.153757619	0.153757619	0.931462121	0.378809285
Residual	5	0.825356261	0.165071252		
Total	6	0.97911388			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	119.8388462	115.5847293	1.036805181	0.347343066	-177.2811593	416.9588517	-177.2811593	416.9588517
X Variable 1	-0.0556	0.057560527	-0.965122853	0.378809285	-0.203517025	0.0924	-0.203517025	0.092411065

RESIDUAL OUTPUT

					Normal Distribution	
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
6	8.148448246	-0.727869341	-1.962493951	1	0.07	-1.465
2	8.467261893	-0.122043967	-0.329057061	2	0.21	-0.792
1	8.522471601	-0.031622385	-0.085260824	3	0.36	-0.366
4	8.225270341	0.046022312	0.124086156	4	0.50	0.000
7	8.136308258	0.155238252	0.41855607	5	0.64	0.366
3	8.342242128	0.235104986	0.633894145	6	0.79	0.792
5	8.156364197	0.445170142	1.200275465	7	0.93	1.465



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
199-F6-1	2003.8	37908	10/14/2003	4870	D		8.490849216
	2004.8	38271	10/11/2004	4210	D		8.345217927
	2007.0	39093	1/11/2007	5310	D		8.577347114
	2009.1	39862	2/18/2009	3910	D		8.271292653
	2010.4	40316	5/17/2010	5440	D		8.60153434
	2010.5	40368	7/8/2010	1670	D		7.420578905
	2010.7	40447	9/26/2010	3990	D		8.29154651

SUMMARY OUTPUT - 199-F5-6 Nitrate

Regression Statistics	
Multiple R	0.685916107
R Square	0.470480906
Adjusted R Square	0.422342806
Standard Error	0.230330218
Observations	13

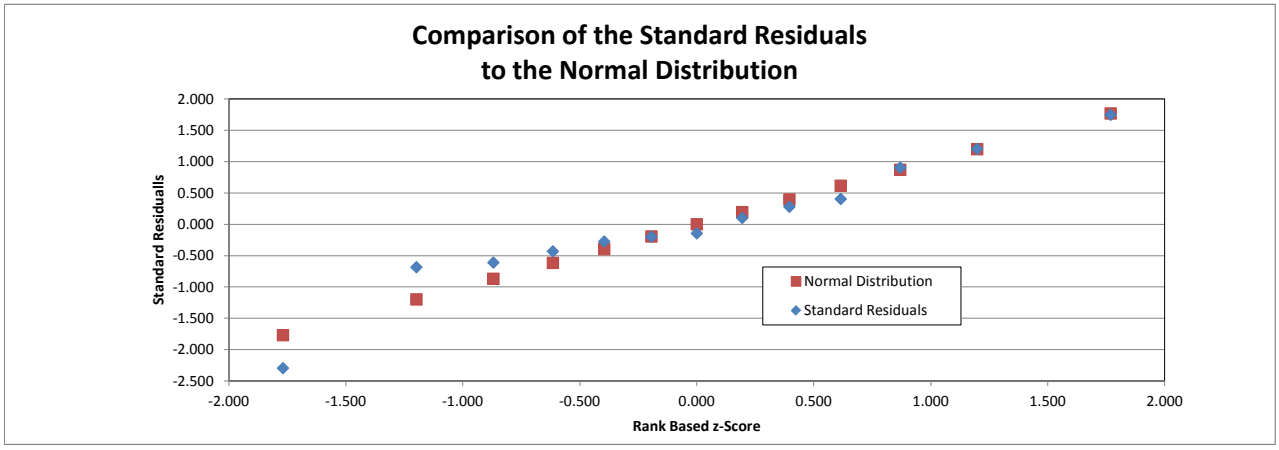
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.51850733	0.51850733	9.773566271	0.009641567
Residual	11	0.583572103	0.053052009		
Total	12	1.102079433			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	171.3059336	51.55270955	3.322927835	0.006795923	57.83918495	284.7726822	57.83918495	284.7726822
X Variable 1	-0.0803	0.025674187	-3.126270345	0.009641567	-0.136772954	-0.0238	-0.136772954	-0.023755945

RESIDUAL OUTPUT

						Normal Distribution
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
11	9.931529352	-0.5060776	-2.294882618	1	0.04	-1.769
2	10.3692839	-0.150985609	-0.684666243	2	0.12	-1.198
6	10.23284242	-0.134610796	-0.610412267	3	0.19	-0.869
4	10.29877095	-0.095178805	-0.431602162	4	0.27	-0.615
13	9.819045889	-0.060584108	-0.274727467	5	0.35	-0.396
5	10.29874073	-0.043716416	-0.198238458	6	0.42	-0.194
8	10.0664521	-0.031936282	-0.144819723	7	0.50	0.000
7	10.15109617	0.022418515	0.101660023	8	0.58	0.194
1	10.47324663	0.0615127	0.278938301	9	0.65	0.396
12	9.905160322	0.089081594	0.403953467	10	0.73	0.615
9	9.99309824	0.199320605	0.903848325	11	0.81	0.869
3	10.3125958	0.26542853	1.203624347	12	0.88	1.198
10	9.946690262	0.385327672	1.747324475	13	0.96	1.769



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
199-F5-6	2003.8	37907	10/13/2003	37600	D		10.53475933
	2005.1	38381	1/28/2005	27400	D		10.21829829
	2005.8	38638	10/13/2005	39262.47	D		10.57802433
	2006.0	38701	12/15/2005	27000	D		10.20359214
	2006.0	38702	12/15/2005	28425	D		10.25502432
	2006.8	39001	10/11/2006	24300	DN		10.09823163
	2007.8	39373	10/18/2007	26200			10.17351469
	2008.9	39759	11/6/2008	22800	D		10.03451581
	2009.8	40092	10/6/2009	26700	D		10.19241884
	2010.3	40304	5/5/2010	30700	D		10.33201793
	2010.5	40373	7/13/2010	12400	D		9.425451752
	2010.9	40493	11/10/2010	21900	D		9.994241916
	2011.9	40884	12/7/2011	17300	D		9.75846178

SUMMARY OUTPUT - 199-F5-46 - Nitrate

Regression Statistics	
Multiple R	0.738279383
R Square	0.545056447
Adjusted R Square	0.469232521
Standard Error	0.213397286
Observations	8

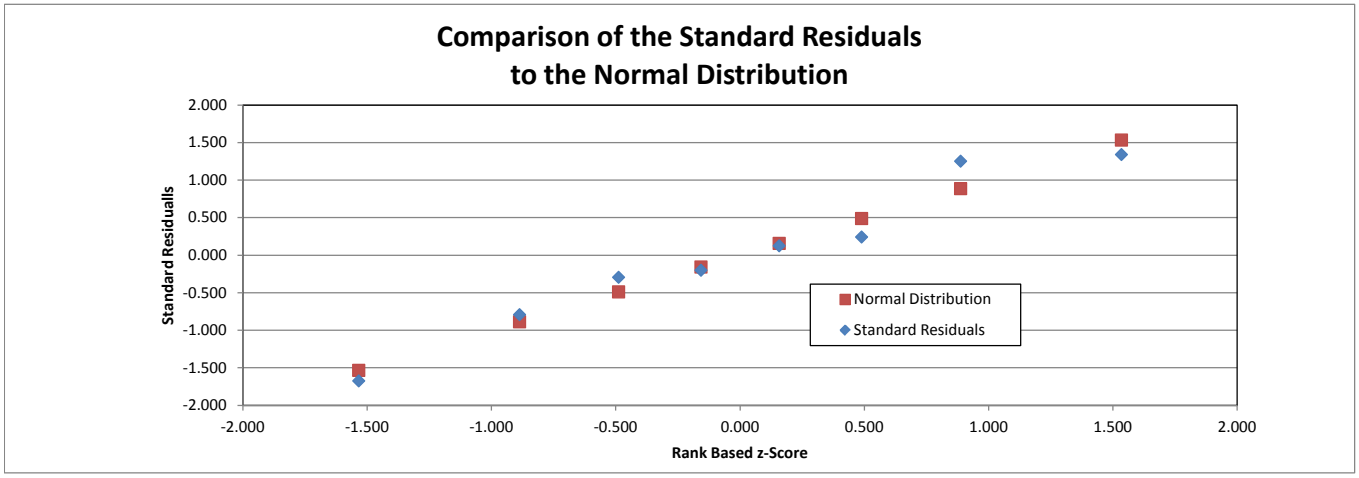
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.327350494	0.327350494	7.18844933	0.036481256
Residual	6	0.273230411	0.045538402		
Total	7	0.600580905			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	164.7921228	57.4074538	2.870570143	0.028405891	24.32114407	305.2631016	24.32114407	305.2631016
X Variable 1	-0.0766	0.028577322	-2.681128369	0.036481256	-0.146545655	-0.0067	-0.146545655	-0.006693281

RESIDUAL OUTPUT

					Normal Distribution	
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
6	10.7471577	-0.330846516	-1.674599929	1	0.06	-1.534
5	10.76055998	-0.156453236	-0.791897647	2	0.19	-0.887
1	11.26320618	-0.058165499	-0.294408242	3	0.31	-0.489
8	10.63871163	-0.039580021	-0.200336705	4	0.44	-0.157
2	11.11129435	0.024753461	0.125291161	5	0.56	0.157
3	10.95755386	0.047873775	0.242316046	6	0.69	0.489
7	10.72073056	0.247467726	1.252573069	7	0.81	0.887
4	10.80480818	0.264950312	1.341062248	8	0.94	1.534



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
199-F5-46	2003.8	37907	10/13/2003	73500	D		11.20504069
	2005.8	38632	10/6/2005	68600	D		11.13604781
	2007.8	39364	10/9/2007	60200	D		11.00542763
	2009.8	40093	10/6/2009	64200	D		11.06975849
	2010.3	40304	5/5/2010	40300	D		10.60410675
	2010.5	40367	7/8/2010	33400	D		10.41631118
	2010.9	40493	11/11/2010	58000	D		10.96819829
	2011.9	40884	12/7/2011	40100	D		10.59913161

SUMMARY OUTPUT - 199-F5-4 Nitrate

Regression Statistics	
Multiple R	0.673675544
R Square	0.453838739
Adjusted R Square	0.375815701
Standard Error	0.120615665
Observations	9

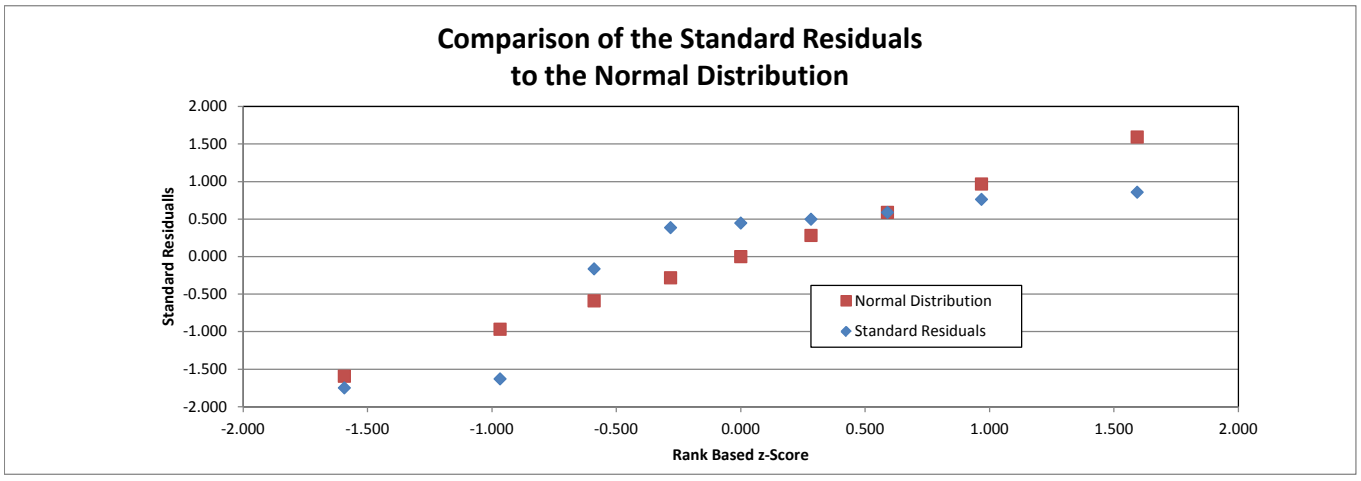
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.084622556	0.084622556	5.816727394	0.046651243
Residual	7	0.10183697	0.014548139		
Total	8	0.186459527			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-68.15141565	33.0594937	-2.0614779	0.078194319	-146.3246962	10.02186487	-146.3246962	10.02186487
X Variable 1	0.0397	0.016466244	2.411789252	0.046651243	0.00077663	0.0786	0.00077663	0.078649588

RESIDUAL OUTPUT

					Normal Distribution	
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
5	11.58353654	-0.19730873	-1.748793618	1	0.06	-1.593
4	11.54472656	-0.183787451	-1.628951348	2	0.17	-0.967
8	11.69259182	-0.018398212	-0.163067671	3	0.28	-0.589
6	11.62636827	0.04356094	0.386090844	4	0.39	-0.282
7	11.68562142	0.050447599	0.447128922	5	0.50	0.000
1	11.42521816	0.05621664	0.498261284	6	0.61	0.282
2	11.46632095	0.066407138	0.588582061	7	0.72	0.589
3	11.50383646	0.086050043	0.762681743	8	0.83	0.967
9	11.70129237	0.096812032	0.858067782	9	0.94	1.593



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
199-F5-4	2003.8	37908	10/14/2003	96900	D		11.4814348
	2004.8	38286	10/26/2004	102000	D		11.53272809
	2005.8	38631	10/6/2005	108000	D		11.58988651
	2006.8	39008	10/17/2006	85900	D		11.36093911
	2007.8	39364	10/9/2007	88100	D		11.38622781
	2008.9	39758	11/6/2008	117000	D		11.66992921
	2010.3	40303	5/5/2010	125000	D		11.73606902
	2010.5	40367	7/8/2010	117500	D		11.67419361
	2010.7	40448	9/26/2010	133000	D		11.79810441

SUMMARY OUTPUT - 199-F8-7 Nitrate

Regression Statistics	
Multiple R	0.74498499
R Square	0.555002636
Adjusted R Square	0.480836409
Standard Error	0.07783892
Observations	8

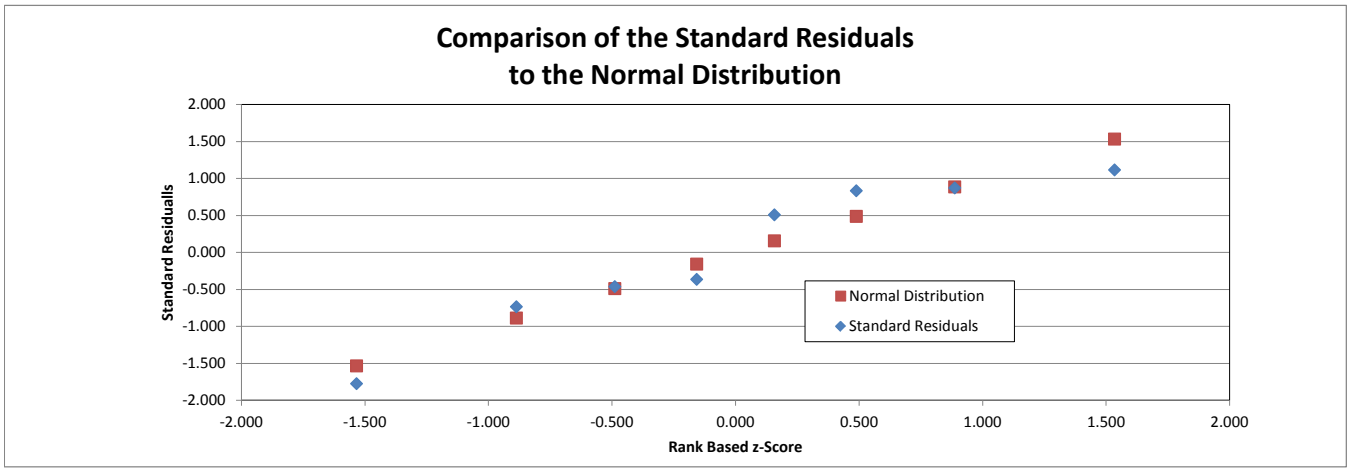
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.045340099	0.045340099	7.483225938	0.033935367
Residual	6	0.036353385	0.006058897		
Total	7	0.081693484			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	170.1945794	57.98468074	2.93516455	0.026111181	28.31117717	312.0779816	28.31117717	312.0779816
X Variable 1	-0.0789	0.028847076	-2.735548563	0.033935367	-0.149498831	-0.0083	-0.149498831	-0.008326325

RESIDUAL OUTPUT

						Normal Distribution
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
5	11.55307804	-0.127891493	-1.774672618	1	0.06	-1.534
1	11.67018766	-0.052902184	-0.734091494	2	0.19	-0.887
6	11.53816228	-0.033268989	-0.461653561	3	0.31	-0.489
7	11.52199598	-0.02621667	-0.363792813	4	0.44	-0.157
3	11.63321911	0.036710103	0.509403819	5	0.56	0.157
2	11.65160354	0.060172785	0.834981212	6	0.69	0.489
8	11.42777664	0.062903212	0.87286969	7	0.81	0.887
4	11.60147434	0.080493235	1.116955766	8	0.94	1.534



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
199-F8-7	2008.9	39761	11/9/2008	111000	D		11.61728548
	2009.1	39847	2/3/2009	122000	D		11.71177632
	2009.3	39933	4/29/2009	117000	D		11.66992921
	2009.7	40079	9/23/2009	118417	D		11.68196757
	2010.3	40303	5/5/2010	91600	D		11.42518655
	2010.5	40373	7/13/2010	99200	D		11.50489329
	2010.7	40447	9/26/2010	98300	D		11.49577931
	2011.9	40883	12/6/2011	97800	D		11.49067986

SUMMARY OUTPUT - 699-71-30 Nitrate

Regression Statistics	
Multiple R	0.393099813
R Square	0.154527463
Adjusted R Square	-0.014567045
Standard Error	0.023679708
Observations	7

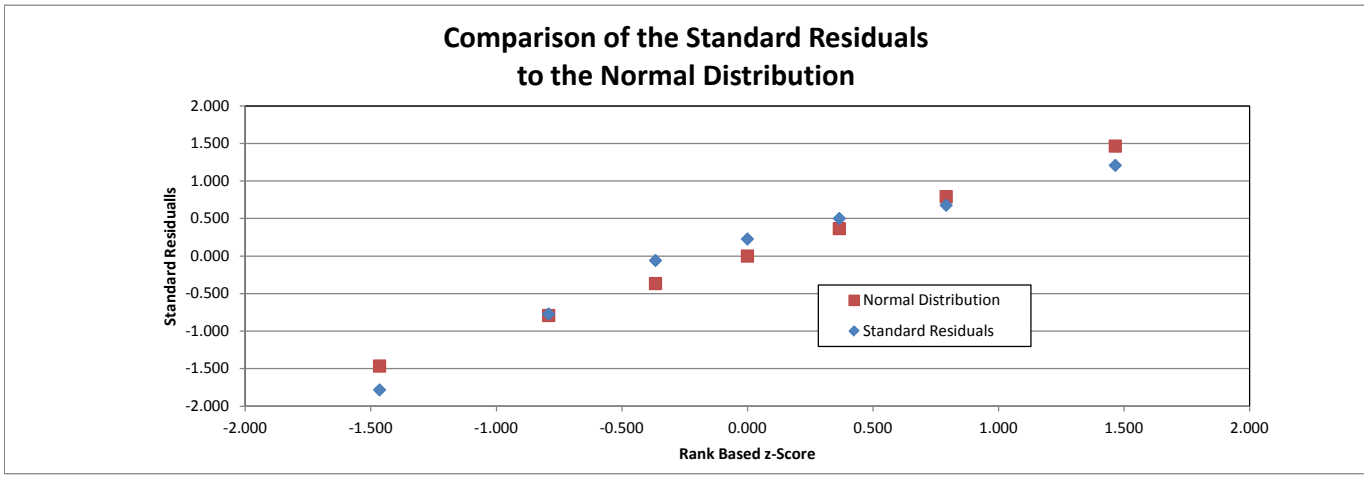
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000512423	0.000512423	0.913852644	0.382996548
Residual	5	0.002803643	0.000560729		
Total	6	0.003316066			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	17.6429465	6.414348204	2.750543927	0.040284195	1.154339526	34.13155348	1.154339526	34.13155348
X Variable 1	-0.0031	0.003194455	-0.955956403	0.382996548	-0.011265367	0.0052	-0.011265367	0.005157848

RESIDUAL OUTPUT

					Normal Distribution	
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
2	11.51998154	-0.038546745	-1.783207911	1	0.07	-1.465
6	11.50325936	-0.016677874	-0.771533809	2	0.21	-0.792
3	11.51420434	-0.001278877	-0.059162039	3	0.36	-0.366
5	11.50400322	0.004914224	0.227336523	4	0.50	0.000
7	11.50209684	0.010828621	0.500941996	5	0.64	0.366
4	11.50823483	0.014640968	0.677304684	6	0.79	0.792
1	11.5260265	0.026119682	1.208320556	7	0.93	1.465



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L	LabQ	Ln Nitrate ug/L
699-71-30	2003.1	37649	1/28/2003	104000	D	11.55214618
	2005.1	38372	1/20/2005	96900	CD	11.4814348
	2006.9	39063	12/12/2006	100000	D	11.51292546
	2008.9	39777	11/25/2008	101000	D	11.5228758
	2010.3	40284	4/15/2010	99600	D	11.50891744
	2010.5	40372	7/13/2010	97400	D	11.48658149
	2010.9	40512	11/29/2010	100000	D	11.51292546

SUMMARY OUTPUT - 699-62-31 Nitrate

Regression Statistics	
Multiple R	0.805512278
R Square	0.64885003
Adjusted R Square	0.53180004
Standard Error	0.043066548
Observations	5

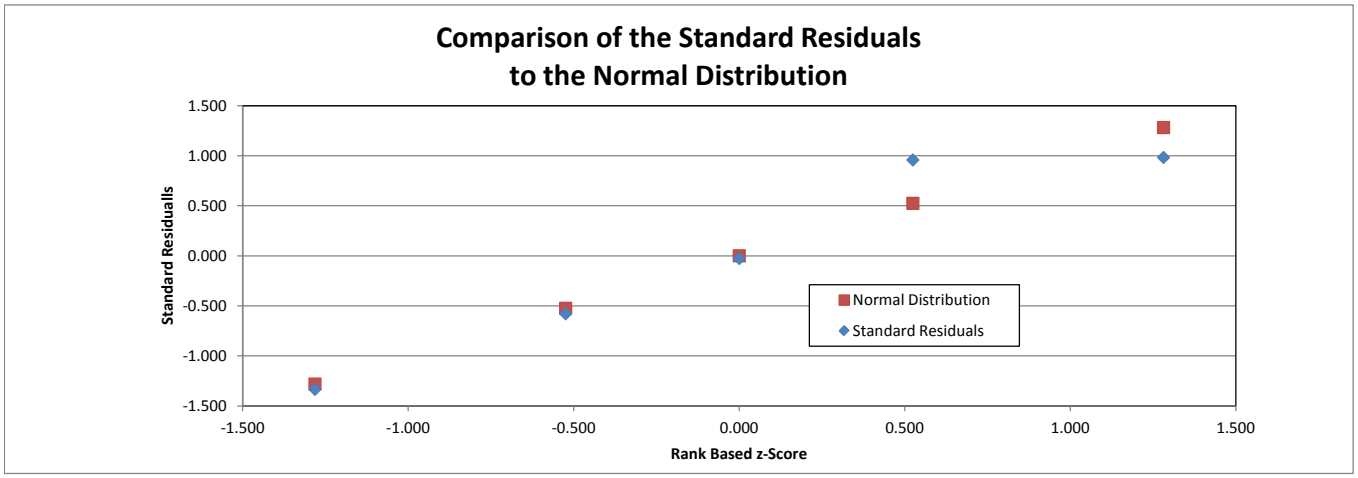
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.010281419	0.010281419	5.543358268	0.099902926
Residual	3	0.005564183	0.001854728		
Total	4	0.015845602			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	46.99868873	15.10184789	3.112115091	0.052794466	-1.062131292	95.05950876	-1.062131292	95.05950876
X Variable 1	-0.0177	0.007523934	-2.354433747	0.099902926	-0.041659117	0.0062	-0.041659117	0.006229911

RESIDUAL OUTPUT

					Normal Distribution	
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
2	11.48472857	-0.049764645	-1.334289967	1	0.10	-1.282
5	11.37671732	-0.021615937	-0.579566626	2	0.30	-0.524
3	11.44564008	-0.000993451	-0.026636427	3	0.50	0.000
1	11.49700296	0.035725132	0.957862459	4	0.70	0.524
4	11.40799772	0.036648901	0.982630562	5	0.90	1.282



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Nitrate ug/L		LabQ	Ln Nitrate ug/L
699-62-31	2004.1	38019	2/2/2004	102000	D		11.53272809
	2004.8	38273	10/12/2004	92500	D		11.43496392
	2007.0	39078	12/27/2006	93400	D		11.44464662
	2009.1	39855	2/10/2009	93400	D		11.44464662
	2010.9	40500	11/17/2010	85400	D		11.35510138

SUMMARY OUTPUT - 699-77-36 Trichloroethene

Regression Statistics	
Multiple R	0.969587771
R Square	0.940100446
Adjusted R Square	0.937961176
Standard Error	0.105584683
Observations	30

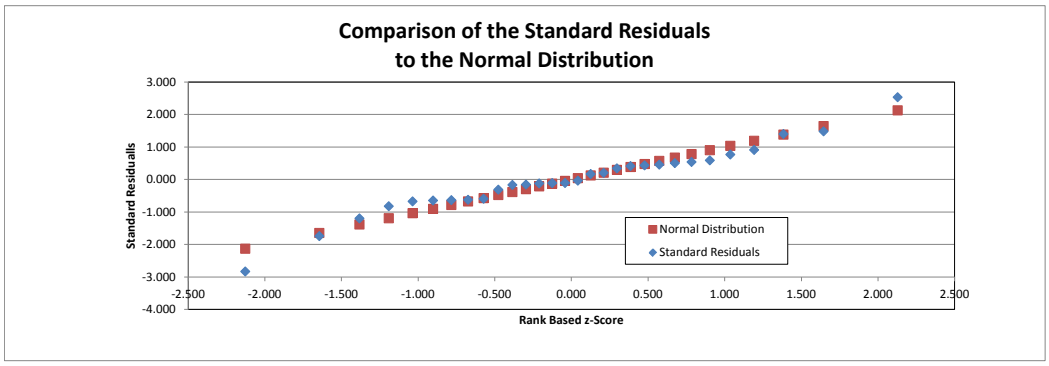
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.899034999	4.899034999	439.4492221	1.17736E-18
Residual	28	0.312147509	0.011148125		
Total	29	5.211182508			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	110.5913901	5.132936394	21.54544331	5.70804E-19	100.0770467	121.1057335	100.0770467	121.1057335
X Variable 1	-0.0539	0.002568841	-20.9630442	1.17736E-18	-0.059112766	-0.0486	-0.059112766	-0.048588701

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	Normal Distribution *Z-Score*
25	2.46833027	-0.293578549	-2.829719458	1	0.02	-2.128
28	2.320763534	-0.180697371	-1.741690147	2	0.05	-1.645
16	3.068545204	-0.124106225	-1.196224321	3	0.08	-1.383
22	2.793286109	-0.085235908	-0.821564482	4	0.12	-1.192
21	2.842386867	-0.069798145	-0.67276431	5	0.15	-1.036
5	3.479222061	-0.066974843	-0.645551314	6	0.18	-0.903
19	2.956200243	-0.065828485	-0.634501894	7	0.22	-0.784
18	3.009129301	-0.064690322	-0.623531467	8	0.25	-0.674
2	3.527138525	-0.061402622	-0.591842271	9	0.28	-0.573
14	3.123387645	-0.032345191	-0.311766025	10	0.32	-0.477
17	3.012950025	-0.017217751	-0.165956968	11	0.35	-0.385
4	3.502516834	-0.016161644	-0.155777457	12	0.38	-0.297
1	3.538785912	-0.012425387	-0.119764742	13	0.42	-0.210
24	2.576269169	-0.011319812	-0.109108418	14	0.45	-0.126
8	3.306808796	-0.01097193	-0.105755287	15	0.48	-0.042
20	2.893989418	-0.00361766	-0.034869585	16	0.52	0.042
9	3.278218639	0.017618227	0.169817036	17	0.55	0.126
23	2.686680578	0.021369623	0.205975669	18	0.58	0.210
26	2.36218701	0.035708263	0.34418171	19	0.62	0.297
12	3.175986612	0.042889213	0.41339683	20	0.65	0.385
3	3.510183469	0.045164593	0.435328562	21	0.68	0.477
10	3.248280064	0.047556802	0.458386377	22	0.72	0.573
30	2.250136919	0.052448174	0.505532912	23	0.75	0.674
7	3.311219568	0.056076262	0.540503013	24	0.78	0.784
6	3.339984804	0.061212578	0.590010487	25	0.82	0.903
13	3.13901865	0.079857175	0.76972041	26	0.85	1.036
11	3.237664725	0.094539786	0.911241888	27	0.88	1.192
15	3.11277036	0.145326178	1.400757368	28	0.92	1.383
27	2.331076017	0.153830633	1.482729365	29	0.95	1.645
29	2.302175018	0.26277434	2.532806522	30	0.98	2.128



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	TCE ug/L	LabQ	Ln TCE ug/L
699-77-36	1988.0	32124	12/13/1987	34		3.526360525
	1988.2	32203	3/1/1988	32		3.465735903
	1988.5	32318	6/24/1988	35		3.555348061
	1988.6	32370	8/15/1988	32.67		3.48635519
	1989.1	32528	1/20/1989	30.33		3.412247218
	1991.6	33472	8/22/1991	30		3.401197382
	1992.2	33668	3/4/1992	29		3.36729583
	1992.3	33697	4/3/1992	27		3.295836866
	1992.8	33891	10/14/1992	27		3.295836866
	1993.3	34094	5/5/1993	27		3.295836866
	1993.5	34166	7/16/1993	28		3.33220451
	1994.7	34585	9/7/1994	25		3.218875825
	1995.4	34835	5/16/1995	25		3.218875825
	1995.7	34941	8/30/1995	22		3.091042453
	1995.9	35014	11/10/1995	26		3.258096538
	1996.7	35313	9/5/1996	19		2.944438979
	1997.7	35691	9/17/1997	20		2.995732274
	1997.8	35716	10/13/1997	19		2.944438979
	1998.8	36075	10/7/1998	18		2.890371758
	1999.9	36497	12/3/1999	18		2.890371758
	2000.9	36847	11/17/2000	16		2.772588722
	2001.8	37180	10/16/2001	15		2.708050201
	2003.8	37904	10/9/2003	15		2.708050201
	2005.8	38652	10/27/2005	13		2.564949357
	2007.8	39385	10/29/2007	8.8		2.174751721
	2009.8	40104	10/18/2009	11		2.397895273
	2010.4	40315	5/17/2010	12		2.48490665
	2010.6	40385	7/26/2010	8.5		2.140066163
	2010.9	40511	11/29/2010	13	B	2.564949357
	2011.9	40864	11/17/2011	10		2.302585093

SUMMARY OUTPUT - 199-F7-1 Trichloroethene

Regression Statistics	
Multiple R	0.628732126
R Square	0.395304086
Adjusted R Square	0.370108423
Standard Error	0.234597229
Observations	26

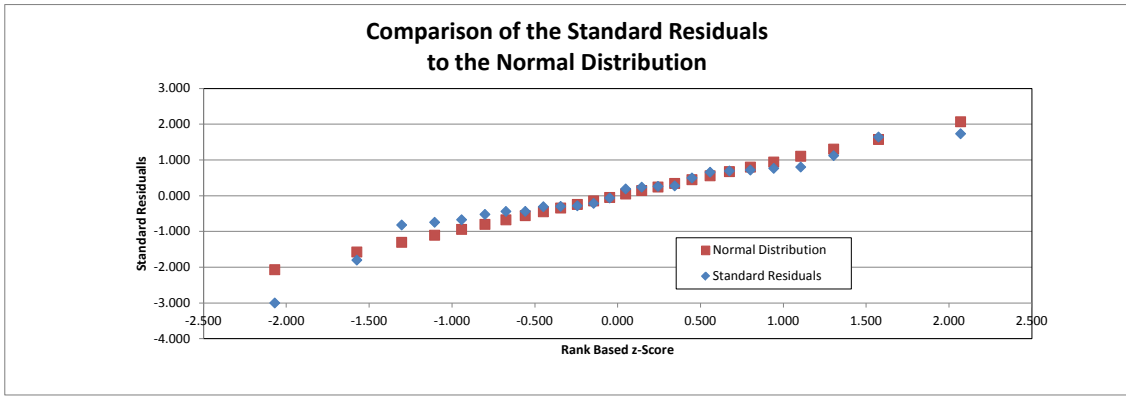
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.863477984	0.863477984	15.68937023	0.000581474
Residual	24	1.320860641	0.05503586		
Total	25	2.184338624			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	56.28042129	13.47579176	4.176409246	0.000337089	28.46775426	84.09308832	28.46775426	84.09308832
X Variable 1	-0.0267	0.006739013	-3.960980968	0.000581474	-0.040601744	-0.0128	-0.040601744	-0.012784464

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	Normal Distribution *Z-Score*
12	2.982316618	-0.689781861	-3.0009121	1	0.02	-2.070
21	2.686040522	-0.413914637	-1.800745296	2	0.06	-1.574
16	2.89622674	-0.188176539	-0.818666428	3	0.10	-1.304
2	3.115253056	-0.170814077	-0.743130633	4	0.13	-1.105
15	2.92699547	-0.154406748	-0.671750164	5	0.17	-0.942
14	2.953295455	-0.120082111	-0.52242003	6	0.21	-0.801
20	2.740197945	-0.101140616	-0.440014611	7	0.25	-0.674
17	2.873281917	-0.100693195	-0.438068097	8	0.29	-0.558
6	3.066357315	-0.070625042	-0.307255894	9	0.33	-0.448
22	2.633502875	-0.068553517	-0.298243678	10	0.37	-0.344
13	2.955131076	-0.064759318	-0.281736924	11	0.40	-0.243
8	3.044801198	-0.049068924	-0.213475501	12	0.44	-0.145
7	3.059060967	-0.014538529	-0.063250211	13	0.48	-0.048
18	2.846679709	0.043692049	0.19008328	14	0.52	0.048
11	3.017531408	0.055161907	0.239983164	15	0.56	0.145
10	3.030985958	0.060056495	0.261277184	16	0.60	0.243
26	2.57561336	0.063443969	0.27601447	17	0.63	0.344
3	3.104588959	0.114286865	0.497207677	18	0.67	0.448
19	2.793185401	0.151253578	0.658032225	19	0.71	0.558
24	2.613404636	0.159184086	0.692534084	20	0.75	0.674
25	2.607546831	0.165041892	0.718018605	21	0.79	0.801
4	3.082142209	0.175954329	0.765493419	22	0.83	0.942
9	3.03440461	0.184471215	0.802546328	23	0.87	1.105
5	3.074397778	0.257806732	1.12159421	24	0.90	1.304
23	2.618082121	0.377650152	1.64297581	25	0.94	1.574
1	3.156796217	0.398551845	1.73390911	26	0.98	2.070



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	TCE ug/L	LabQ	Ln TCE ug/L
199-F7-1	1990.2	32932	2/28/1990	35		3.555348061
	1991.7	33500	9/19/1991	19		2.944438979
	1992.1	33646	2/12/1992	25		3.218875825
	1993.0	33954	12/15/1992	26		3.258096538
	1993.2	34059	3/31/1993	28		3.33220451
	1993.6	34170	7/19/1993	20		2.995732274
	1993.8	34269	10/27/1993	21		3.044522438
	1994.4	34464	5/10/1994	20		2.995732274
	1994.7	34607	9/29/1994	25		3.218875825
	1994.9	34654	11/15/1994	22		3.091042453
	1995.4	34838	5/18/1995	21.6		3.072693315
	1996.7	35319	9/11/1996	9.9		2.292534757
	1997.7	35691	9/18/1997	18		2.890371758
	1997.8	35717	10/13/1997	17		2.833213344
	1998.8	36076	10/8/1998	16		2.772588722
	1999.9	36497	12/3/1999	15		2.708050201
	2000.8	36811	10/12/2000	16		2.772588722
	2001.8	37175	10/11/2001	18		2.890371758
	2003.8	37907	10/13/2003	19		2.944438979
	2005.8	38632	10/7/2005	14		2.63905733
	2007.8	39373	10/18/2007	9.7		2.272125886
	2009.8	40092	10/6/2009	13		2.564949357
	2010.3	40303	5/5/2010	20	T	2.995732274
	2010.5	40367	7/8/2010	16	T	2.772588722
	2010.7	40448	9/26/2010	16		2.772588722
	2011.9	40885	12/7/2011	14		2.63905733

SUMMARY OUTPUT - 199-F7-3 Trichloroethene

Regression Statistics	
Multiple R	0.194603483
R Square	0.037870515
Adjusted R Square	-0.099576554
Standard Error	0.230259774
Observations	9

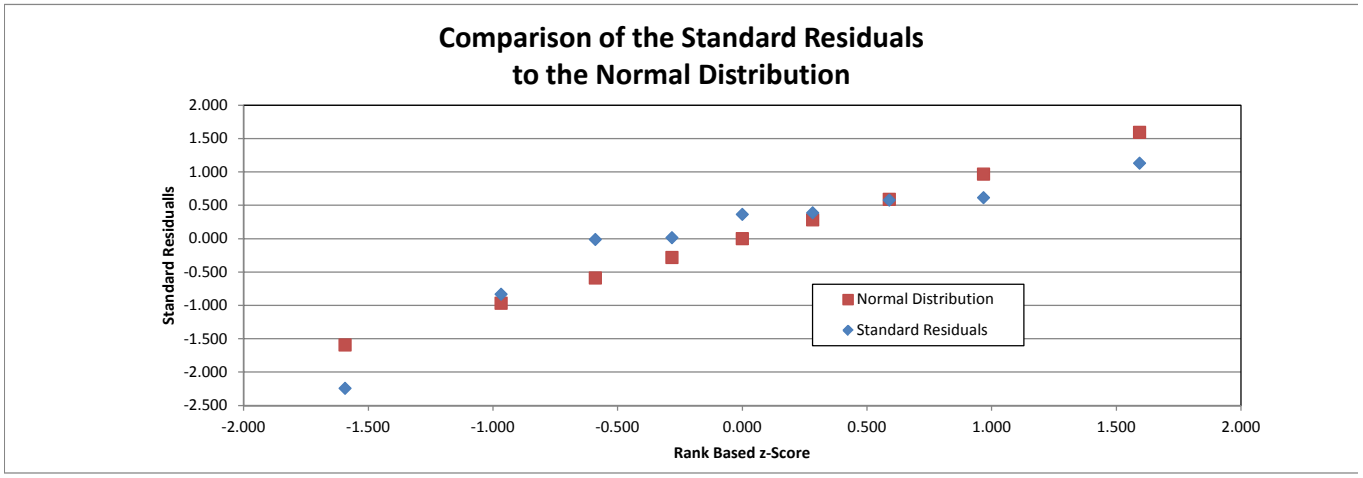
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.014608374	0.014608374	0.275527995	0.615856042
Residual	7	0.371136946	0.053019564		
Total	8	0.38574532			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	28.40909116	50.14593116	0.566528341	0.588729597	-90.16719375	146.9853761	-90.16719375	146.9853761
X Variable 1	-0.0131	0.024970653	-0.524907606	0.615856042	-0.072153498	0.0459	-0.072153498	0.045938926

RESIDUAL OUTPUT

					Normal Distribution	
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
4	2.092622983	-0.483185071	-2.243320918	1	0.06	-1.593
5	2.066499546	-0.179429897	-0.833053144	2	0.17	-0.967
3	2.118926198	-0.002670683	-0.012399387	3	0.28	-0.589
9	2.038116177	0.003104152	0.014411887	4	0.39	-0.282
2	2.140852691	0.078350793	0.363765321	5	0.50	0.000
7	2.056630256	0.083435908	0.38737438	6	0.61	0.282
1	2.157938291	0.124444095	0.57776628	7	0.72	0.589
8	2.05375842	0.132292856	0.614206336	8	0.83	0.967
6	2.058927245	0.243657848	1.131249245	9	0.94	1.593



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	TCE ug/L	LabQ	Ln TCE ug/L
199-F7-3	2002.8	37544	10/15/2002	9.8		2.282382386
	2004.1	38020	2/3/2004	9.2	N	2.219203484
	2005.8	38631	10/6/2005	8.3		2.116255515
	2007.8	39364	10/9/2007	5	J	1.609437912
	2009.8	40092	10/6/2009	6.6		1.887069649
	2010.3	40303	5/5/2010	10	T	2.302585093
	2010.5	40367	7/8/2010	8.5	T	2.140066163
	2010.7	40447	9/26/2010	8.9		2.186051277
	2011.9	40883	12/6/2011	7.7		2.041220329

SUMMARY OUTPUT - 199-F5-1 Strontium-90

Regression Statistics	
Multiple R	0.88832696
R Square	0.789124788
Adjusted R Square	0.769954314
Standard Error	0.197203841
Observations	13

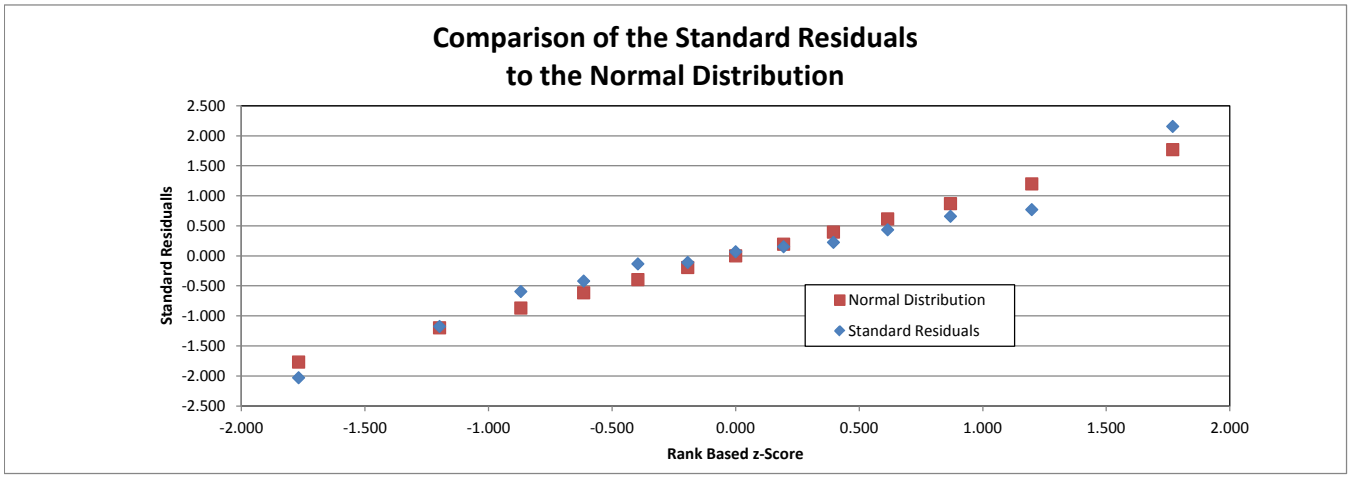
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.600823962	1.600823962	41.16355147	4.97034E-05
Residual	11	0.427782904	0.038889355		
Total	12	2.028606865			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	170.0096142	25.99734083	6.539500149	4.19509E-05	112.7898529	227.2293756	112.7898529	227.2293756
X Variable 1	-0.0832	0.012962297	-6.415882751	4.97034E-05	-0.111694404	-0.0546	-0.111694404	-0.054634756

RESIDUAL OUTPUT

						Normal Distribution
Observation	*Predicted Y*	*Residuals*	*Standard Residuals*	*Rank*	*Quantile*	*Z-Score*
9	2.868158252	-0.383251603	-2.029845067	1	0.04	-1.769
7	3.339955331	-0.222005425	-1.175824479	2	0.12	-1.198
6	3.437183384	-0.112147363	-0.593974743	3	0.19	-0.869
12	2.787342697	-0.079292496	-0.41996297	4	0.27	-0.615
5	3.527798085	-0.025248209	-0.13372404	5	0.35	-0.396
2	3.590190653	-0.020657956	-0.109412329	6	0.42	-0.194
1	3.61407604	0.01292801	0.06847162	7	0.50	0.000
11	2.804450604	0.02876274	0.152338321	8	0.58	0.194
3	3.565816676	0.042394875	0.224539253	9	0.65	0.396
4	3.545100954	0.081903097	0.433789697	10	0.73	0.615
10	2.820136858	0.124302121	0.658350925	11	0.81	0.869
13	2.687844995	0.145368349	0.769925615	12	0.88	1.198
8	3.195151465	0.406943859	2.155328196	13	0.96	1.769



Data Used for Regression Analysis

Well	Date Decimal Year	Date Number	Date	Sr-90 ug/L	LabQ	Ln Sr-90 ug/L
199-F5-1	2000.8	36816.52	10/17/2000	37.6		3.62700405
	2001.1	36921.43	1/30/2001	35.5		3.569532696
	2001.4	37028.47	5/17/2001	36.9		3.608211551
	2001.6	37119.45	8/16/2001	37.6		3.62700405
	2001.8	37195.45	10/31/2001	33.2		3.502549876
	2002.9	37593.42	12/3/2002	27.8		3.325036021
	2004.1	38020.43	2/3/2004	22.6		3.117949906
	2005.8	38656.40	10/31/2005	36.675		3.602095324
	2009.8	40092.52	10/6/2009	12		2.48490665
	2010.3	40303.42	5/5/2010	19		2.944438979
	2010.5	40372.31	7/13/2010	17	U	2.833213344
	2010.7	40447.45	9/26/2010	15		2.708050201
	2011.9	40884.43	12/7/2011	17		2.833213344