PACIFIC groundwater GROUP

SUPPLEMENTAL REMEDIAL ACTION WORK PLAN
CASCADE NATURAL GAS SITE
SUNNYSIDE, WASHINGTON

April 2013

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CASCADE NATURAL GAS SITE
SUNNYSIDE, WASHINGTON

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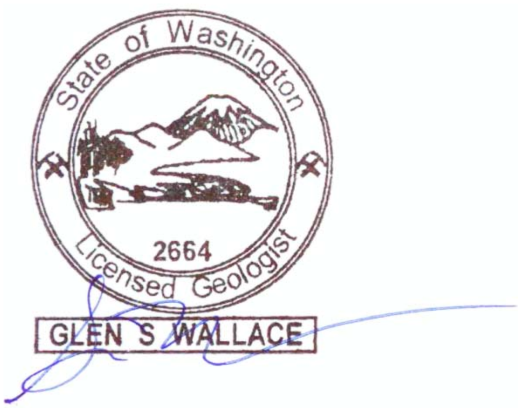
SIGNATURE

This report, and Pacific Groundwater Group's work contributing to this report, were reviewed by the undersigned and approved for release.



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1.0 INTRODUCTION

The Cascade Natural Gas cleanup site in Sunnyside, Washington (Site ID #492) (Figure 1) has been using monitored natural attenuation (MNA) to address groundwater contamination since 1999. Yakima County is conducting the MNA remediation under consent decree 98-2-01173-3. The consent decree allows Ecology to require additional remedial action if baseline concentrations are exceeded or remediation is not expected to meet the restoration timeline. On October 18, 2011 Ecology sent a letter indicating that MNA is not adequately protective of human health and the environment (Ecology, 2011a).

Baseline concentrations equal to or greater than site cleanup levels were established for each monitoring well as a metric of remediation effectiveness. Baseline and cleanup levels are listed in the cleanup action plan (consent decree Exhibit B). Baseline concentrations were set using the greatest concentration from the highest concentration observed during 1993 and 1994 monitoring events. The cleanup action plan states that, “If the baseline level has been exceeded by 1% or greater the PLPs may be required to submit an exceedance report to the Ecology Site Manager within 60 days.” Yakima County submitted an exceedance report to Ecology on December 17, 2011. Ecology requested that the approach outlined in the exceedance report be developed into this work plan for agency review.

The proposed interim remedial action described in this work plan is injection of oxygen-releasing biostimulant compounds to enhance naturally occurring biodegradation processes (Figure 2).

Our professional services were performed, our findings obtained, and our report prepared in accordance with generally accepted hydrogeologic practices. This warranty is in lieu of all other warranties, express or implied.

1.1 CONSTITUENT TRENDS

Groundwater concentrations and mass flux of contaminants have generally decreased between 1998 and 2012 (Figure 3). However, despite substantial progress for constituents at CNGMW-3, upward trends have been noted. Specifically:

- Benzene and TPH-G at CNGMW-4 and CNGMW-5
- Benzene, TPH-D and TPH-G have had ongoing exceedances of baseline concentrations at CNGMW-4 and, to a lesser extent at CNGMW-5

Analytical results for 2011 sampling events at CNGMW-5 indicate a sharp decline in TPH-G concentrations; it is unclear at this point if the decrease in concentrations is transient or represents a significant decrease in plume concentrations. Benzene concentrations do not appear to be on a trend that will achieve cleanup levels within the 30 year restoration time outlined in the consent decree.

1.2 CONCEPTUAL MODEL

Upward and steady concentration trends are likely due to the presence of residual NAPL in a source area located near and below the former UST excavation. Free product was not observed during UST removal and excavation of contaminated soil in 1990, 1991 and 1992 (Kleinfelder, 1991; SEACOR, 1992). However, light sheen is observed in purge water during sampling at CNGMW-3, CNGMW-4, and CNGMW-

5, consistent with diesel concentrations (660 to 1,600 ug/L) near the solubility limit for diesel formulations (approximately 1 to 6 mg/L).

The residual NAPL is most likely present as isolated blebs of product in soil pores in both the saturated and capillary zones. Free-product has not been observed at the site and residual NAPL is not expected to be present as free product. However, the residual NAPL is likely partitioning to groundwater and maintaining elevated groundwater concentrations.

1.3 REMEDIAL ACTON OBJECTIVE

The objective of the remedial action is contaminant mass reduction adequate to reach cleanup levels at the point of compliance within the 30 year time frame outlined in the Consent Decree for the site.

2.0 PROPOSED REMEDIAL ACTION

The primary goal of the remedial action is to reduce source area concentrations in the area immediately south of the former UST excavation. Based on a brief evaluation, injection of oxygen-releasing compounds as a biostimulant has been selected as a cost-effective approach that is likely to meet the remediation objective. These compounds are injected into the saturated and capillary zones as a slurry where they release 10 to 14% of their mass as oxygen depending on vendor and formulation. The most common oxygen releasing compounds are EHC-O and PermeOx, which are marketed by FMC Environmental Solutions, and Oxygen Release Compound (ORC), and ORC-Advanced, which are marketed by Regenesis. EHC-O is the preferred choice based on cost per pound of oxygen delivered. The final product selection will be based on the required oxygen loading and estimated injection costs.

The remediation will consist of a single application of oxygen releasing compounds in rows of injection points up-gradient and down-gradient of the former UST excavation. The UST excavation was backfilled with coarse basalt cobbles making additional drilling or other work in the foot-print of the excavation technically challenging. Injections upgradient of the excavation will increase oxygen and nutrient concentrations in and below saturated portions of the former excavation area. Injections downgradient of the excavation will target the expected residual source area directly in addition to accelerating biodegradation at down-gradient areas.

2.1 DATA GAPS

Existing downgradient groundwater data suggest conditions favorable for application of oxygen releasing compounds as a remedial technology. However, there is insufficient data from the source area adjacent to the UST excavation to calculate biostimulant application rates, and natural attenuation parameters have not been monitored in over a decade. Application rates are calculated from the contaminant mass estimates derived from soil and groundwater sampling. The most recent observations of subsurface conditions in this area are from the UST excavation in 1992, at which time petroleum-impacted soils were noted in the south sidewall of the excavation, but free-product was not observed. Data needs from the source/application area include:

- Groundwater TPH concentrations, and biological and chemical oxygen demand
- Soil TPH concentrations to estimate sorbed phase oxygen demand
- Test for presence/absence of LNAPL above residual saturation (free-product)

Natural attenuation parameters provide information on the occurrence of biodegradation processes. COC concentrations, pH, dissolved oxygen and redox potential are well-constrained by recent quarterly/annual monitoring. An additional round of natural attenuation parameter measurements at select wells will provide a pre-remediation snapshot of biodegradation processes. This information will be used to confirm that biodegradation processes indicated by data collected in 1998 are still occurring as expected, and will provide a reference point should additional action be required after the initial injection. Chemical oxygen demand and dissolved iron were measured in 1998 at the beginning of the MNA program; however, the data are now more than a decade old and should be sampled again to evaluate current conditions. Free product has not been observed in wells or excavations at the site. The presence of free-product significantly reduces the effectiveness of EHC-O remediation. If free-product is observed, then EHC-O should be reconsidered as the presumptive source reduction approach (Section 3.1).

Groundwater transport times from the source area to CNGMW-5 are approximately 6 to 8 months based on observed time lag between water level and groundwater concentration variations. An additional monitoring well immediately down gradient of the former UST excavation would provide more direct and timely indication source area concentrations and effectiveness of the remedial action.

3.0 WORK PLAN

The Supplemental Remedial Action will be conducted in three phases:

- Source area characterization
- Biostimulant/ oxygen releasing compound injection
- Monitoring

3.1 SOURCE AREA CHARACTERIZATION

An additional well will be installed and supplemental groundwater sampling will be conducted to fill data gaps regarding biodegradation conditions, oxygen demand, and presence of free-product.

3.1.1 Soil Characterization

Continuous core will be collected between the ground surface and 16 feet bgs at the location of CNGMW-12 prior to well installation. Core will be logged for lithology and visual indication of petroleum hydrocarbons. Soils will be tested with dye color indicator field test kits for the presence of LNAPL. Soil samples will be sent to Analytical Resources Inc. for quantitative TPH-G and TPH-D analysis if visible petroleum saturation is observed.

3.1.2 Well Installation

The new well will be installed downgradient of the proposed line of injection points, and will be designated CNGMW-12. The location of CNGMW-12 is shown on Figure 1. A 4-inch well will be installed with a 10-foot screen between 6 and 16 feet and standard flush-mount monument.

CNGMW-12 is intended as an operational well to track remediation progress, and identify aquifer and chemical characteristics it the source area.

3.1.3 Groundwater Sampling

Monitoring wells CNGMW-1, CNGMW-3, CNGMW-4, CNGMW-5, and CNGMW-12 will be sampled for the constituents listed below following the procedures in the Sampling and Analysis Plan (PGG, 1998):

- COCs: TPH-D, TPH-G, BTEX compounds, 1,2-dichloroethane
- Dissolved oxygen (DO)
- pH
- Redox potential (Eh)
- Dissolved iron and manganese
- Biological and chemical oxygen demand (BOD,COD)
- Presence-absence of measureable free-product in CNGMW-12
- Alkalinity

Groundwater sampling at CNGMW-1, CNGMW-3, CNGMW-4, and CNGMW-5 may be conducted at a different time than CNGMW-12 to coordinate with a quarterly monitoring event. CNGMW-12 will be allowed to sit for a minimum of 12 hours to allow free product to enter the well (if present) before checking for measurable product thickness with an interface probe, and followed by a check with a clear PVC bailer if not LNAPL is detected with the interface probe.

3.1.4 Oxygen Demand Estimation

Source area oxygen demand will be calculated based on the source area groundwater concentration (CNGMW-12). Oxygen loading will be calculated based on a stoichiometric oxygen demand of 3.5 grams of oxygen per gram of petroleum compound degraded. Example compound-specific stoichiometric oxygen demands are (EPA, 2004):

- Benzene: 3.1 g/g
- Toluene: 3.1 g/g
- Ethylbenzene: 3.2 g/g
- Xylenes: 3.2 g/g
- Naphthalene: 3.0 g/g
- Hexane: 3.5 g/g

Oxygen releasing compounds release between 10% and 14% of their mass as dissolved oxygen. A safety factor of 2 will be applied to loading calculations to account for additional oxygen demand from other compounds present in the aquifer. For example, degradation of 1kg of TPH would require 3.5 kg of oxygen, provided by 50 kg (110 lbs) of oxygen releasing compound (at 14% by mass with factor of safety 2).

Preliminary design calculations based on an estimated source area are presented in Table 1 and Appendix A. The preliminary design based on an assumed dissolved phase concentration of 4,000 ug/L total TPH and average soil concentration of 30 mg/kg indicate use of approximately 7,000 lbs oxygen releasing compound with a loading rate of 117 lbs per hole at 60 injection borings. The preliminary treatment interval would extend from 6 to 16 feet bgs (final interval will be based on soil core observations described in

Section 3.1.1). This injection rate would cause approximately 4% dilution of groundwater concentrations in the treatment interval.

An alternate design may be presented if oxygen demand calculations indicate that use of oxygen releasing compounds alone will not be a feasible alternative to meet supplemental remedial action goals.

3.2 BIOSTIMULANT INJECTION

Biostimulant oxygen releasing compounds will be applied in a single round of injections at the locations shown in Figure 1. Injections are tentatively estimated at approximately 100 to 120 lbs of material between 6 and 16 feet bgs. The specific injection interval will be based on soil core observations described in Section 3.1.1 and will exclude areas that are not part of the source contaminant mass. Injections will be completed using a direct push rig and grout pump.

3.3 MONITORING

The effects of the injections will be tracked through monitoring at wells CNGMW-3, CNGMW-4, CNGMW-5, and CNGMW-12. Groundwater monitoring at CNGMW-3, CNGMW-4, CNGMW-5 will follow the ongoing quarterly monitoring schedule. CNGMW-12 will be monitored twice per quarter for six months, followed by quarterly monitoring up to two years from the completion of injections. Groundwater samples will be analyzed for TPH-G, TPH-Dx, and BTEX. Dissolved oxygen, and oxidation-reduction potential will be measured in the field.

4.0 CONTINGENCY

An alternate strategy will be recommended in consultation with Ecology if data from the source area characterization (Section 3.1) indicate that oxygen releasing compounds will not be a feasible or efficient remediation method. Oxygen releasing compounds will not be an appropriate method if free product accumulates in CNGMW-12, or if source area TPH concentrations exceed 10 mg/L (Regnesis, 2012).

The alternate strategy will be developed based on available site data. The most likely alternate strategy would combine in-situ chemical oxidation with biostimulation. Oxidants would be injected into the source area to directly degrade TPH compounds to less toxic or non-toxic compounds. Reaction products from in-situ chemical oxidation can result in desorption of petroleum compounds from soil particles and increase in aqueous solubility. Therefore, oxygen releasing compounds would be concurrently injected down gradient from the oxidant injections to control potential increases in dissolved phase TPH concentrations. Injectable oxidizing compounds that would be considered include potassium permanganate, RegenOx[1], peroxide, or other proven commercially-available oxidants.

If an alternate remedial strategy is adopted, the revised approach will be provided as an addendum to this work plan to replace Section 3.2.

[1] RegenOx is a proprietary trademark of Regensis. The reference here is not an endorsement of the product.

5.0 SCHEDULE

Monitoring well installation and supplemental groundwater sampling will be conducted within 90 days of work plan approval.

Oxygen releasing compound injection will be evaluated for feasibility and required injection volumes upon receipt of groundwater sampling results. A technical memorandum outlining the results of the groundwater sampling and final remediation design will be submitted to Ecology within 60 days of receipt of final groundwater data from the analytical laboratory.

Yakima County will proceed with contracting for injections upon approval of the final remediation design to Ecology. Injections will begin within 60 days of contract award.

6.0 REFERENCES

Ecology, 2005. Guidance on Remediation of Petroleum-Contaminated Ground Water By Natural Attenuation. July 2005. Publication No. 05-09-091 (Version 1.0).

Ecology, 2011a. Periodic Review, Cascade Natural Gas Cleanup Site, Sunnyside, Wash-ington. June, 2011.

Ecology, 2011b. Letter to Mr. Terry Austin from Mr. Norm Peck, Re: letter October 18, 2011.

Kleinfelder, 1991. Report Review and Former Property Use Assessment, Cascade Natu-ral Gas Property, 512 Decatur Avenue, Sunnyside, Washington. June 17, 1991.

Regenesis, 2012. Product Selection Guide. http://www.regonlinesoft.com/calculator/product_selection_guide. Webpage accessed August, 2012.

SEACOR, 1992. Soil Remediation Status Report, Cascade Natural Gas Facility, Sunny-side, Washington. February 11, 1992.

Table 1. Soil and Groundwater Loading Summary

Cascade Natural Gas Site, Sunnyside, Washington

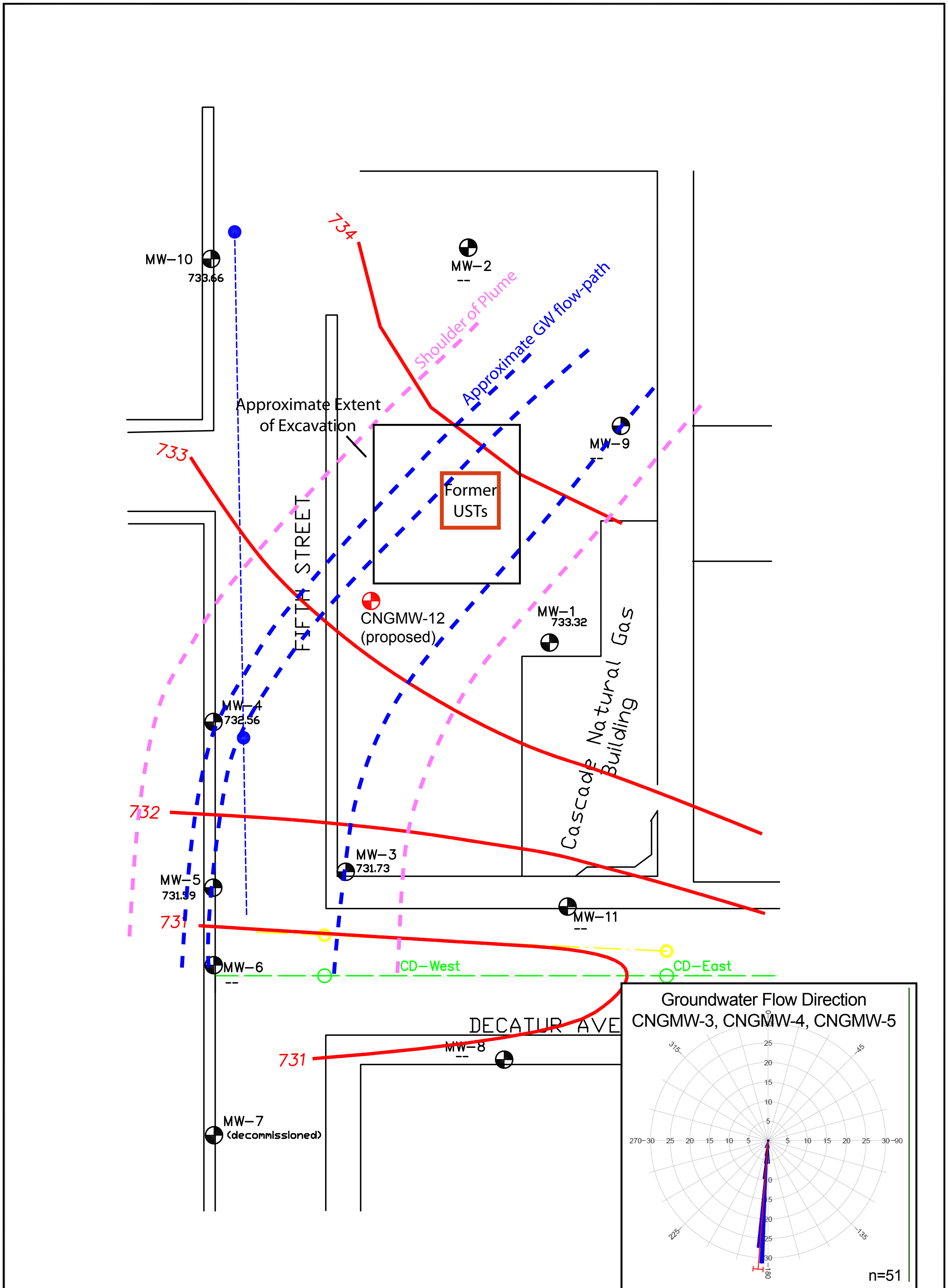
Parameter	Units	Baseline Case	Preliminary Design Case	High Case	Threshold Case
Groundwater Demand Per Hole	lb	10	10	19	25
Soil Demand Per Hole	lb	52	105	175	350
Total Demand Per Hole	**lb**	**62**	**115**	**193**	**374**
Number of Injection Borings	--	60	60	60	60
Total Biostimulant Demand	**lb**	**3,741**	**6,887**	**11,602**	**22,461**
Slurry Concentration	%	20%	20%	20%	20%
Slurry Volume	gallons	2,241	4,126	6,952	13,457
Slurry Volume	m3	8.5	15.6	26.3	50.9
Injection Area Pore Volume	m3	378	378	378	378
Injected Slurry Pore Volume	%	2%	4%	7%	13%

Soil and groundwater demand is expressed as pounds of injected biostimulant assuming 14% oxygen release by mass.

See Appendix A for soil and groundwater oxygen demand calculations.

The Threshold Case calculation results in an impractical loading per boring and additional borings would be required. A typical upper limit per boring is approximatley 200 lb/hole. A constant number of borings is used for simpler comparison between scenarios.

Injected slurry pore volume is an indicator of the expected dilution due to the biostimulant injection in the treatment area.



MW–3 (731.80) Monitoring Well with groundwater elevation in feet

730 Equipotential

Assumed location of county drain

Assumed location of storm drain

Assumed location of sanitary sewer

CD–West

County drain manhole

Storm drain manhole

Sanitary sewer manhole

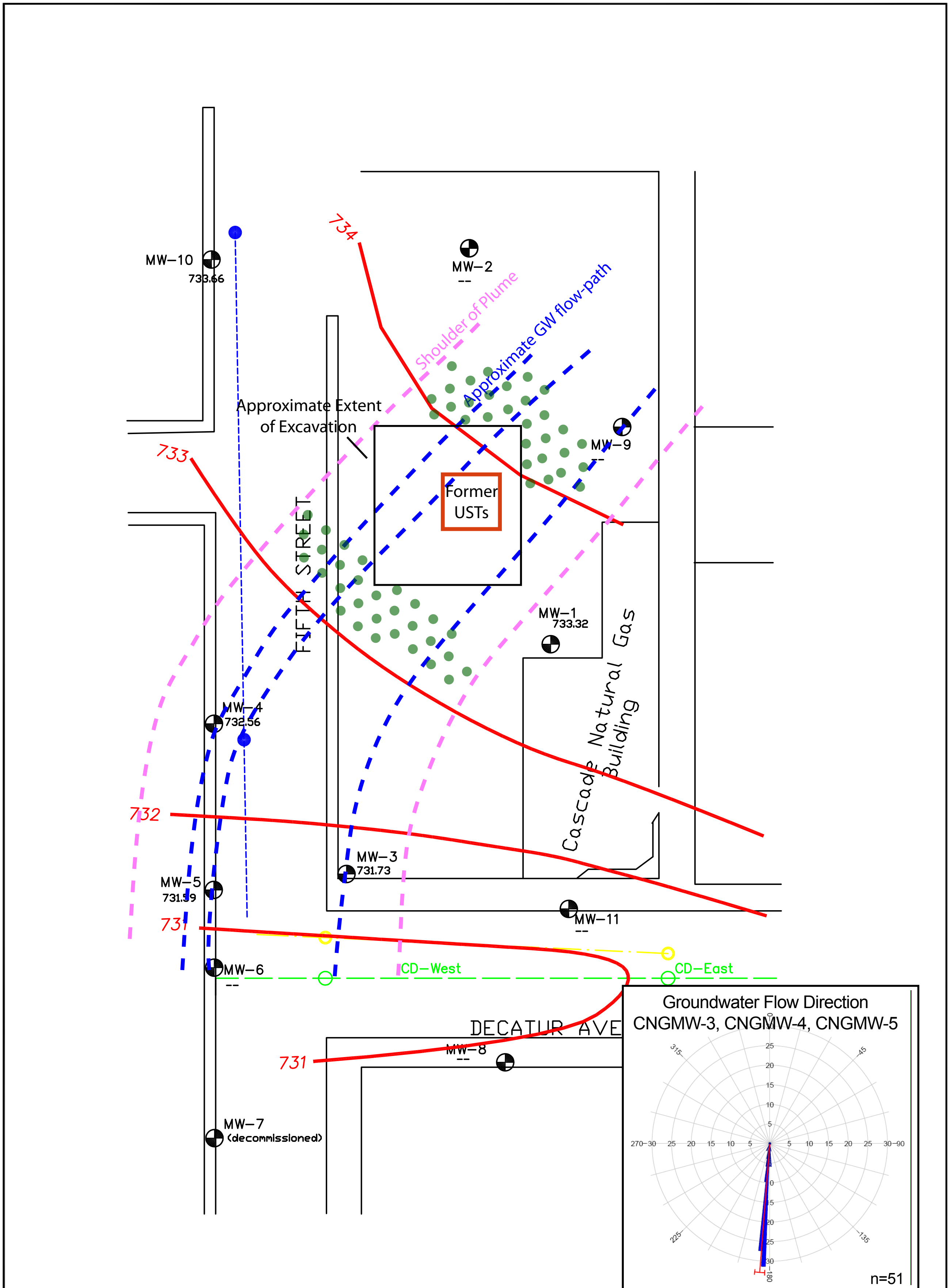
0 30 60

Approx. Scale in Feet

Figure 1. Site Map and CNMW-12 Location

Cascade Natural Gas Company
Sunnyside, Washington

PGG



MW–3 (731.80)	Monitoring Well with groundwater elevation in feet
730	Equipotential
	Assumed location of county drain
	Assumed location of storm drain
	Assumed location of sanitary sewer

CD–West

- County drain manhole
- Storm drain manhole
- Sanitary sewer manhole
- Biostimulant Injection Point Location

0 30 60
Approx. Scale in Feet

Figure 2. Site Map and Injection Locations

Cascade Natural Gas Company
Sunnyside, Washington

PGG

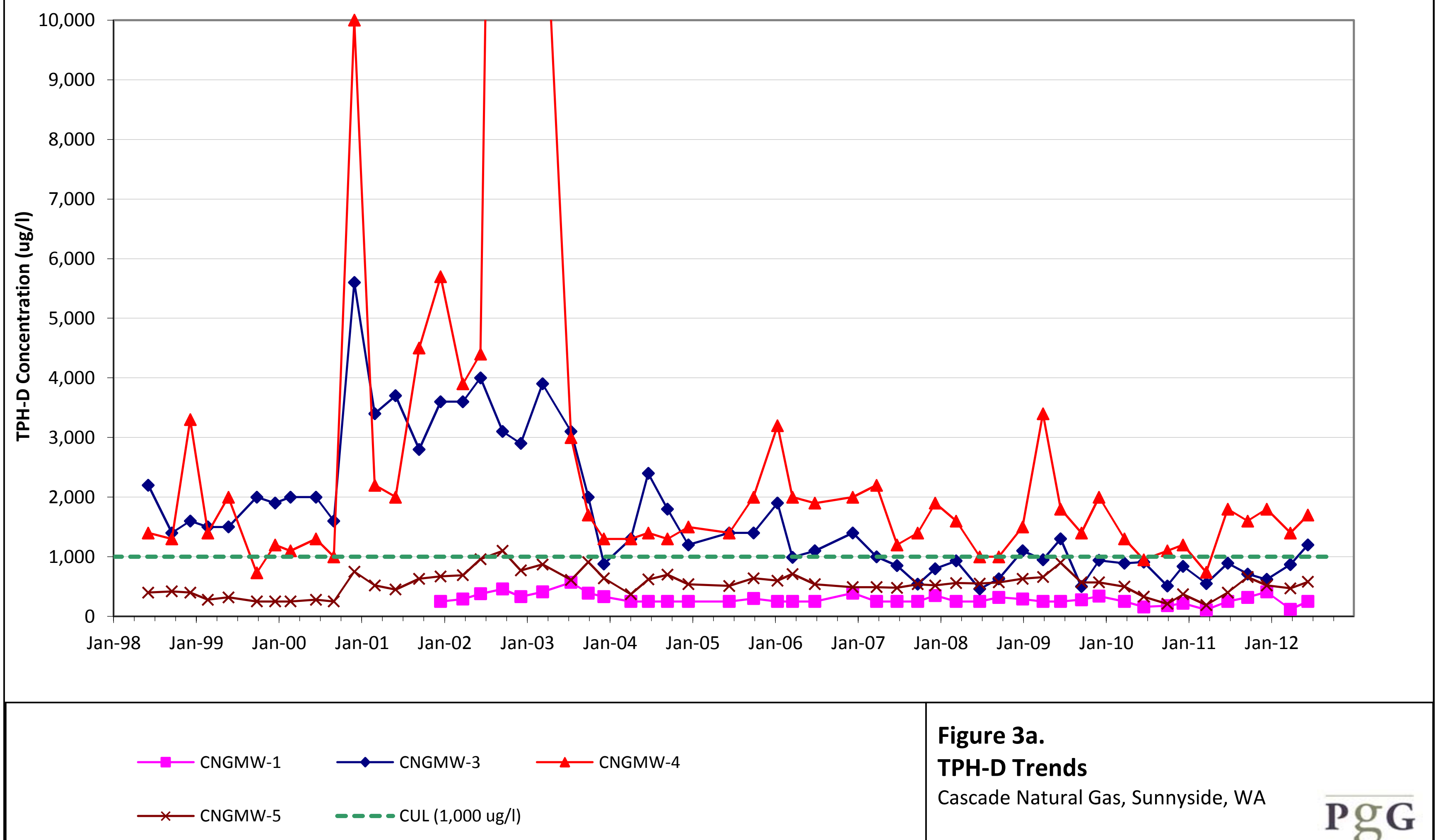


Figure 3a.
TPH-D Trends
Cascade Natural Gas, Sunnyside, WA

PgG

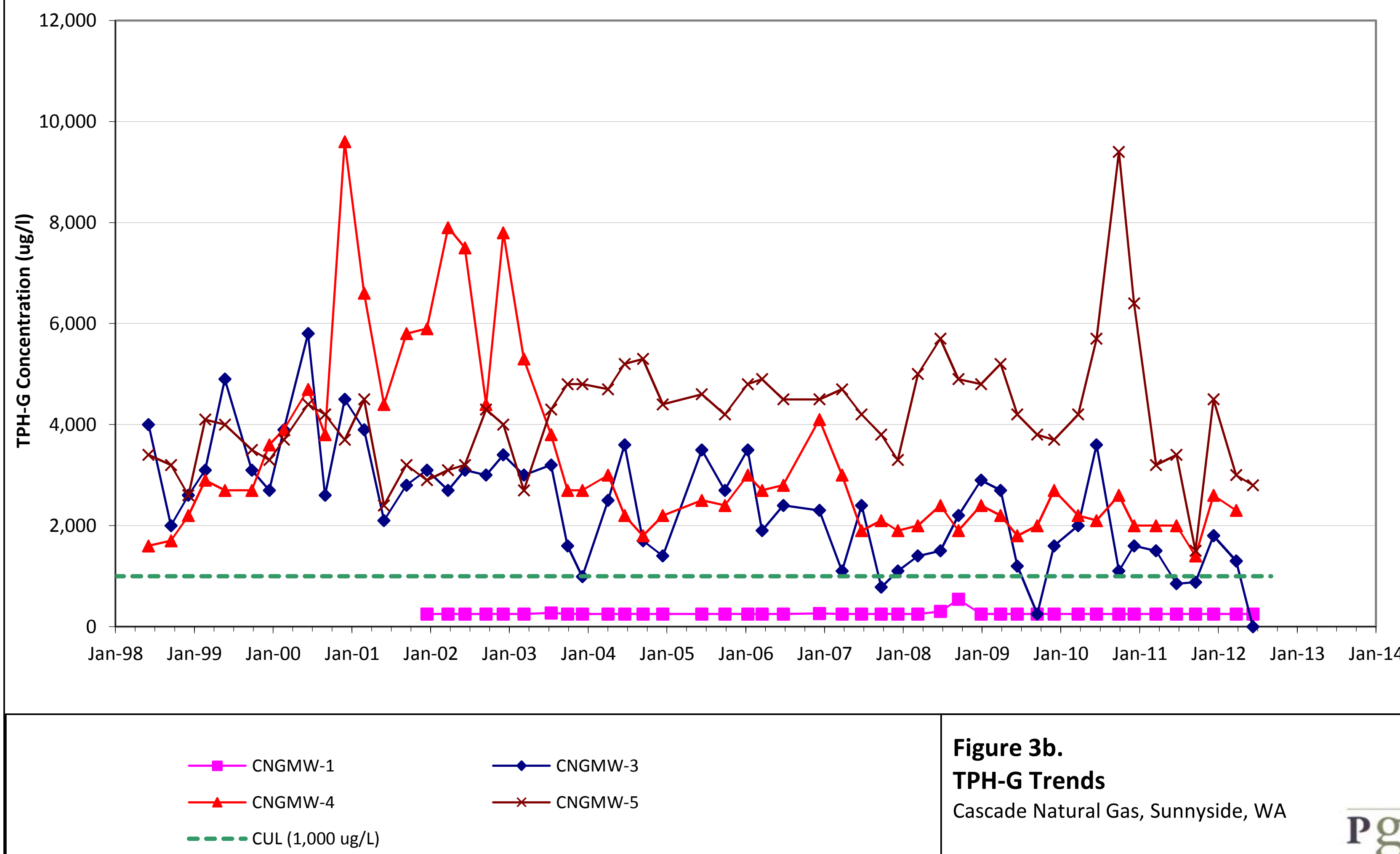


Figure 3b.
TPH-G Trends
Cascade Natural Gas, Sunnyside, WA

PgG

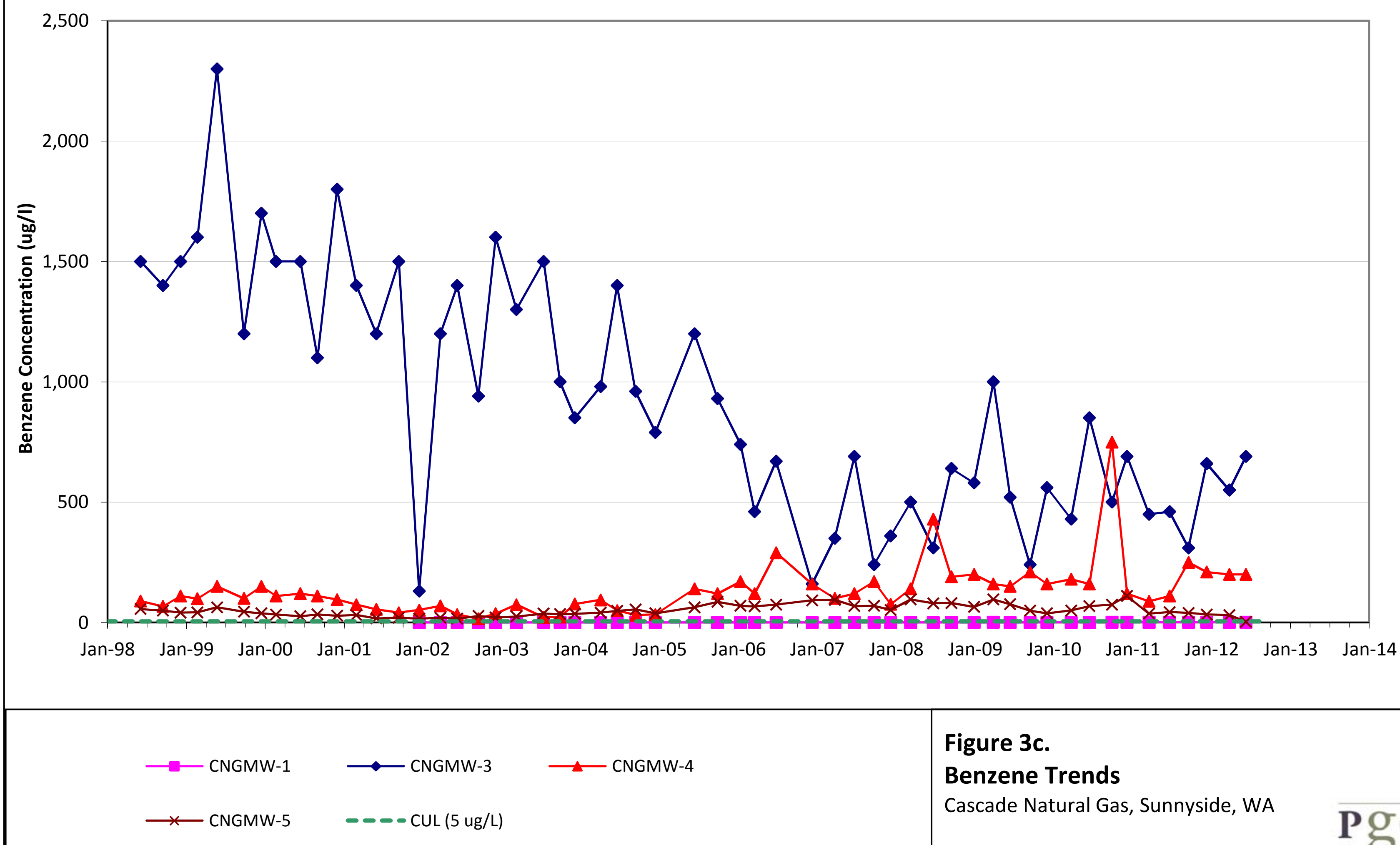


Figure 3c.
Benzene Trends
Cascade Natural Gas, Sunnyside, WA

PgG

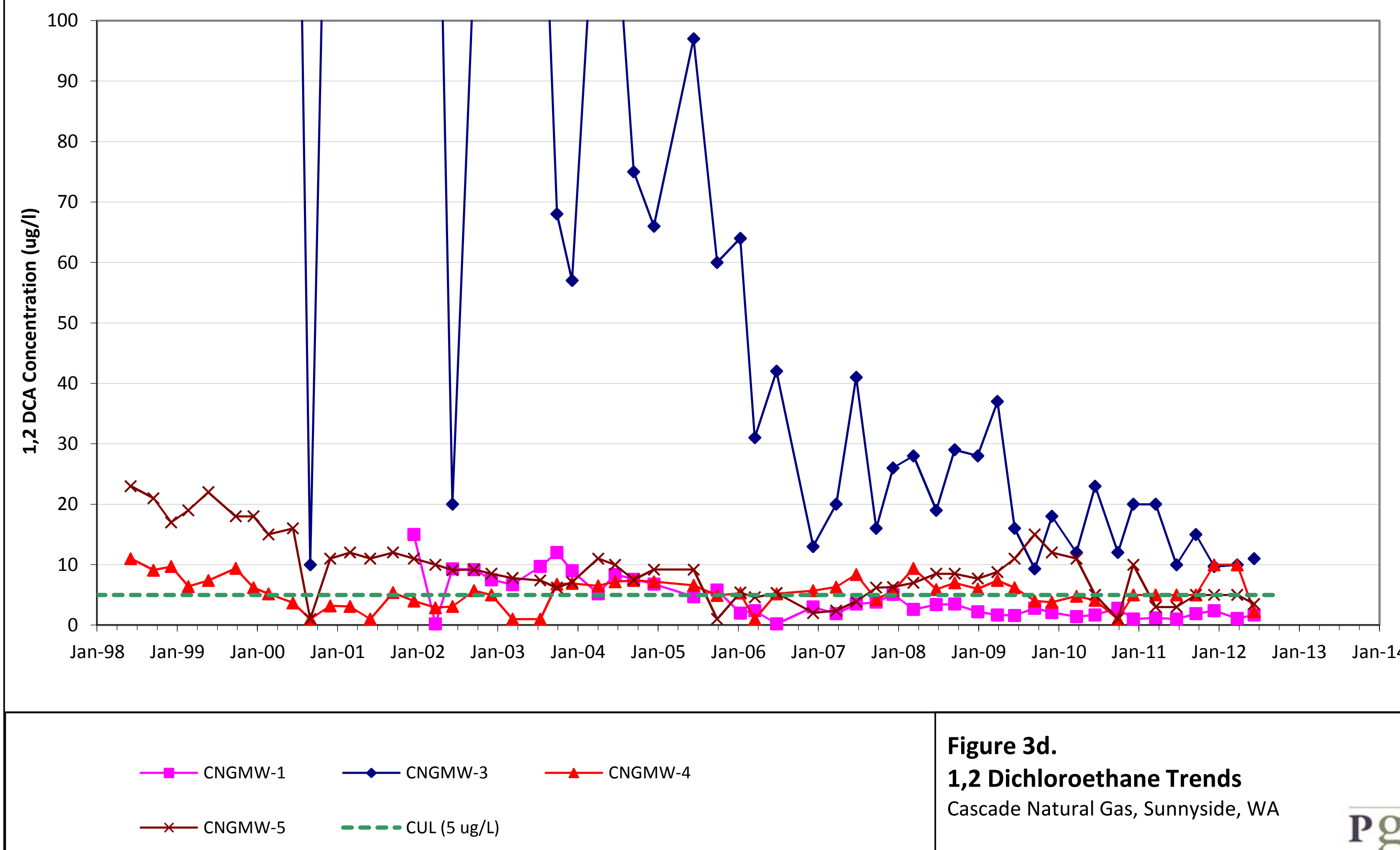


Figure 3d.
1,2 Dichloroethane Trends
Cascade Natural Gas, Sunnyside, WA

APPENDIX A
BIOSTIMULANT DEMAND CALCULATIONS

Table A-1. Groundwater Biostimulant Demand Calculations

Cascade Natural Gas Site, Sunnyside, Washington

Parameter	Units	Baseline Case	Preliminary Design Case	High Case	Threshold Case
Width	m	60	60	60	60
Seepage Velocity	m/yr	50	50	50	50
Thickness	m	3	3	3	3
Volume	m3	9,000	9,000	9,000	9,000
Porosity	--	0.3	0.3	0.3	0.3
Fluid Volume per year [1]	m3/yr	2,700	2,700	2,700	2,700
Average TPH Concentration	mg/L	2	4	8	10
Contaminant Mass	**g**	5,400	10,800	20,250	27,000
Contaminant Mass	kg	5.4	10.8	20.3	27.0
Product Oxygen Demand					
Benzene	g O_2/g contaminant	3.1	3.1	3.1	3.1
Toluene	g O_2/g contaminant	3.1	3.1	3.1	3.1
Ethylbenzene	g O_2/g contaminant	3.2	3.2	3.2	3.2
Xylenes	g O_2/g contaminant	0.2	0.2	0.2	0.2
Cumene	g O_2/g contaminant	3.2	3.2	3.2	3.2
Napthalene	g O_2/g contaminant	3	3	3	3
Fluorene	g O_2/g contaminant	3	3	3	3
Phenanthrene	g O_2/g contaminant	3	3	3	3
Hexane	g O_2/g contaminant	3.5	3.5	3.5	3.5
Value for Calculation	g O_2/g contaminant	3.5	3.5	3.5	3.5
Stoichiometric Oxygen Demand	g	18,900	37,800	70,875	94,500
Stoichiometric Oxygen Demand	kg	19	38	71	95
Safety Factor	--	2	2	2	2
Final Oxygen Demand	kg	38	76	142	189
Oxygen Loading Demand					
Product % oxygen by mass	%	14%	14%	14%	14%
Groundwater Injectable Demand	kg	270	270	506	675
Groundwater Injectable Demand	lb	595	595	1,116	1,488
Est. Number of borings [2]	holes	60	60	60	60
Product per hole	**lb**	**10**	**10**	**19**	**25**

[1] Calculation assumes loading based on pore volumes in one year, the maximum expected release-time for oxygen releasing injectables

[2] Number of borings is based on two rows spanning the width of the treatment area and nominal 10-foot interval between borings.

Product oxygen demand from *EPA Exhibit XII-9 Organic Compound Oxidation Stoichiometry* .

Table A-2. Soil Biostimulant Demand Calculations

Cascade Natural Gas Site, Sunnyside, Washington

Parameter	Units	Baseline Case	Preliminary Design Case	High Case	Threshold Case
Width	m	60	60	60	60
Length	m	7	7	7	7
Thickness	m	3	3	3	3
Volume	m^3	1,260	1,260	1,260	1,260
Bulk Density	kg/m^3	1,510	1,510	1,510	1,510
Average TPH Concentration [1]	mg/kg	15	30	50	100
Contaminant Mass	g	28,539	57,078	95,130	190,260
Contaminant Mass	kg	29	57	95	190
Product Oxygen Demand					
Benzene	g O_2/g contaminant	3.1	3.1	3.1	3.1
Toluene	g O_2/g contaminant	3.1	3.1	3.1	3.1
Ethylbenzene	g O_2/g contaminant	3.2	3.2	3.2	3.2
Xylenes	g O_2/g contaminant	0.2	0.2	0.2	0.2
Cumene	g O_2/g contaminant	3.2	3.2	3.2	3.2
Napthalene	g O_2/g contaminant	3	3	3	3
Fluorene	g O_2/g contaminant	3	3	3	3
Phenanthrene	g O_2/g contaminant	3	3	3	3
Hexane	g O_2/g contaminant	3.5	3.5	3.5	3.5
Maximum	g O_2/g contaminant	3.5	3.5	3.5	3.5
Stoichiometric Oxygen Demand	g	99,887	199,773	332,955	665,910
Stoichiometric Oxygen Demand	kg	100	200	333	666
Safety Factor	--	2	2	2	2
Final Oxygen Demand	kg	200	400	666	1,332
Oxygen Loading Demand					
Product % oxygen by mass	%	14%	14%	14%	14%
Mass of Product	kg	1,427	2,854	4,757	9,513
Mass of Product	lb	3,146	6,292	10,486	20,973
Est. Number of borings [2]	holes	60	60	60	60
Product per hole	lb	52	105	175	350

Product oxygen demand from *EPA Exhibit XII-9 Organic Compound Oxidation Stoichiometry* .

[1] Average concentration over treatment depth interval. Concentrations are expected to be variable over that interval.

[2] Number of borings is based on two rows spanning the width of the treatment area and nominal 10-foot interval between borings.

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