

Pinedale Anticline Ground Water Data Summary



Data collected by the Sublette County Conservation District
January 1, 2013 through December 31, 2013

Annual Report To the Bureau of Land Management, Pinedale Field Office, February 2014

Volume 1 of 6



*Sublette County
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Introduction

The Pinedale Anticline Project Area (PAPA), which is currently undergoing gas exploration and development, is located south of Pinedale, WY and north of the Jonah gas field. It is bordered by the Green River to the west and Highway 191 to the east. The Record of Decision (ROD) for the Environmental Impact Statement for the Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County Wyoming, was released by the Bureau of Land Management (BLM) in July of 2000. The Conditions of Approval within this ROD states, "...the operators will conduct a survey and a complete water analysis (ex. static water level, alkalinity, salinity, benzene, oil, etc.) of all water wells within a one mile radius of existing and proposed development, and annually monitor and maintain a complete record of water analysis of all new water supply wells drilled in the project area to evaluate the quality of source options in the event some mitigation is required." (section 3, p. 25). See Map 1.

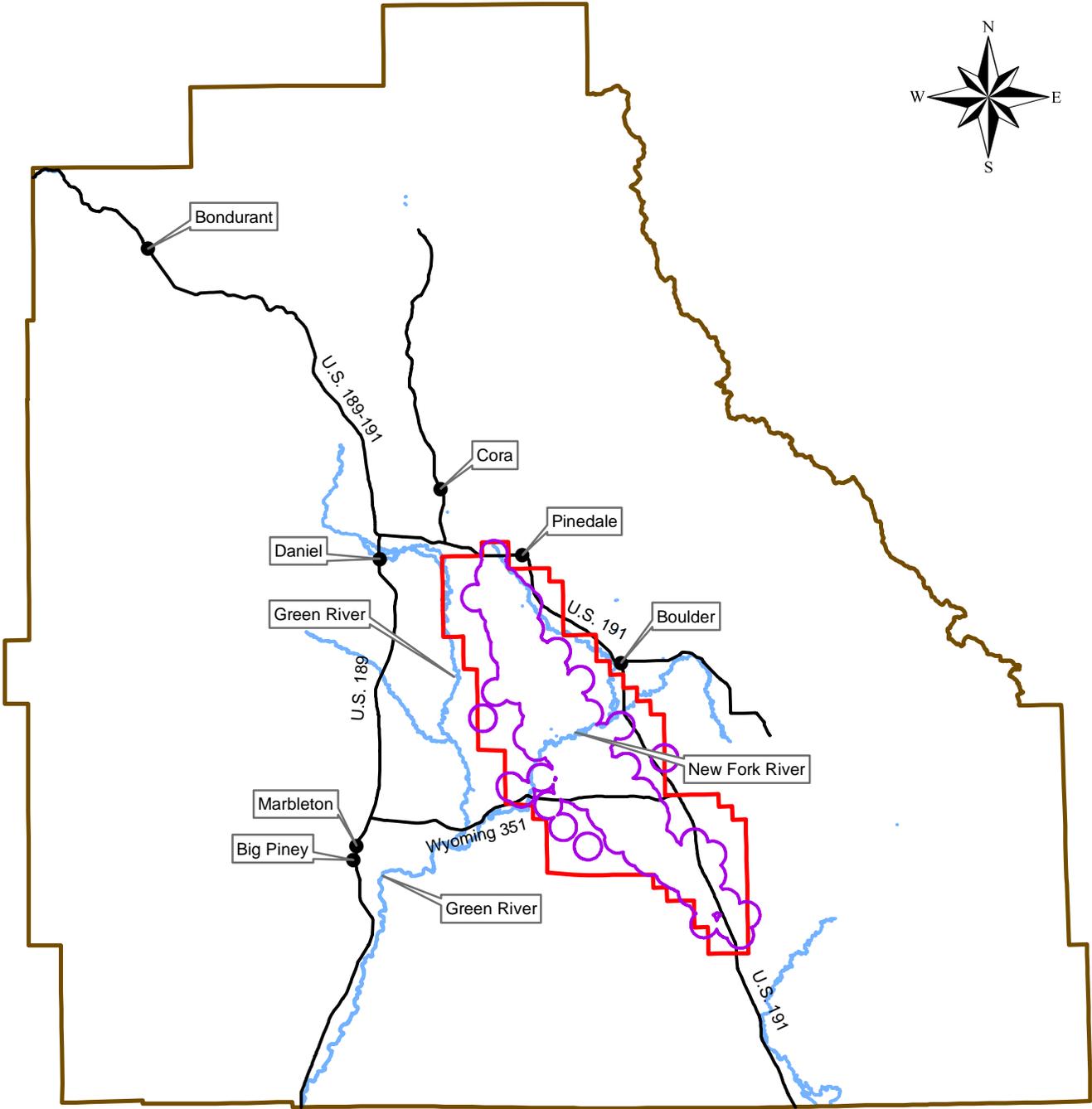
The Sublette County Conservation District (SCCD) was selected to perform the above requirements. The ground water monitoring program began development in 2001 and ground water sampling began in 2004. As of December 31, 2013, the SCCD has collected 2,589 ground water samples from 387 water wells within one mile of an existing or proposed gas well within the PAPA.

Water wells sampled through the program include wells permitted through the Wyoming State Engineer's Office as domestic, domestic/stock, stock and miscellaneous-use. Wells used for industrial purposes within the PAPA are permitted for miscellaneous-use. Well owners whose well is located on private lands or Wyoming State lands can participate in the program but are not required to do so.

Report Objective

The purpose of this report is to provide a summary of the data collection procedures, field data and the lab analysis results from January 1, 2013 through December 31, 2013 as required by the ROD discussed above. For reference purposes, historical results have been included in Appendix A, Table 1 and Table 2, as well as Appendix B, Table 3 and Table 4.

Map 1. PAPA Boundary Within Sublette County



- Sublette County boundary
- Pinedale Anticline Project Area
- Main highways
- One mile sampling area
- Main cities



Sublette County Conservation District / Pinedale Anticline Ground Water Data / Created by Delsa Allen / February 2014

Report Structure

This report in its entirety consists of six documents (Volumes 1 through 6):

Volume 1: Pinedale Anticline Ground Water Data Summary

This document contains summary information from results collected January 1, 2013 through December 31, 2013. Included are ranges of results from each well type, organized by parameter; listings of wells with hydrocarbon-related detections by analytical tests and/or compound; and maps showing the locations of water wells visited, sampled and those with hydrocarbon-related detections.

Volume 2: Appendix A, Table 1. Water Well Field Data, 01/01/13 – 12/31/13 Plus Historical Results 01/01/04 – 12/31/13: Wells Permitted for Domestic-use and Stock-use

Volume 3: Appendix A, Table 2. Water Well Field Data, 01/01/13 – 12/31/13 Plus Historical Results 01/01/04 – 12/31/13: Wells Permitted for Miscellaneous-use

These documents contain the complete data set collected from January 1, 2013 through December 31, 2013. All of the recorded field data from each well visit in 2013 is contained within these tables, followed by historical laboratory and field results. The order in which the data is presented within these documents is by Well ID, then date.

Volume 4: Appendix B, Table 3. Historical Hydrocarbon-Related Data From Water Wells With Detections: Primary Results, 01/01/04 – 12/31/13

Volume 5: Appendix B, Table 4. Historical Hydrocarbon-Related Data From Water Wells With Detections: Complete BTEX Method SW8260B Results, 01/01/04 – 12/31/13

These documents are dedicated to the results of hydrocarbon-related parameters from water wells with any level of historic detections. Table 3 includes data for benzene, ethylbenzene, m+p-Xylenes, o-Xylene and toluene (commonly known as BTEX) using method SW8021B, Gasoline Range Organics (GRO), Diesel Range Organics (DRO) and Non-Polar. Primary BTEX results are also listed using method SW8260B. Table 4 includes all of the SW8260 BTEX results when this method was analyzed. The order in which the data is presented within these documents is by Well ID, then date.

Volume 6: Appendix C: Order of Well Visits, 01/01/13 – 12/31/13

This document lists the order in which field visits and sample collection, if applicable, took place from January 1, 2013 through December 31, 2013. The listing is by date, then time.

Methods

Water wells that become part of the SCCD ground water monitoring program are monitored annually. Sampling procedures are followed in accordance with the Sublette County Conservation District's Ground Water Monitoring Manual and Protocol (April 2013), and the Water Quality Monitoring Sampling and Analysis Plan for the PAPA (March 2008). The data collected includes water level, GPS coordinates, field parameters and laboratory analysis data.

In 2013, field notes were recorded regarding procedures used to sample, and other field observations as applicable. Field parameters were measured just prior to bottles being filled for laboratory analysis. The parameters measured in the field included pH, conductivity, total dissolved solids (TDS) and temperature (reported in Celsius). Water level was also measured when well access was possible and active pumping had not recently taken place.

Field data results were taken with an Oakton PC 300 multi-parameter field meter and a Ravensgate Sonic Water Level Meter. If a pump was in place, multiple readings were taken per well visit for conductivity, TDS, temperature and pH. The last set of recordings per visit are used for ranges reported within this report. If no pump was in place, the use of dedicated polyethylene bailers were used to collect grab samples from a specific depth below water level (typically the center of the main water-bearing zone). One set of field parameters was measured when samples were collected using this method.

Samples were then tested further for alkalinity, calcium, chloride, fluoride, magnesium, potassium, sodium, sulfate and TDS by Energy Laboratories Inc. in Casper, Wyoming. In addition, all samples were tested for hydrocarbon presence using Diesel Range Organics (DRO) and Gasoline Range Organics (GRO), method SW8015B, as indicators. Confirmation samples were collected if DRO and/or GRO analysis indicated the presence of hydrocarbons with additional analysis of benzene, ethylbenzene, m+p-Xylenes, o-Xylene and toluene (commonly known as BTEX) using method SW8021B. BTEX analysis using method SW8260B was also added for comparative purposes.

The Quality Assurance Manual for Energy Laboratories, Inc. is located at the following web address in PDF format:

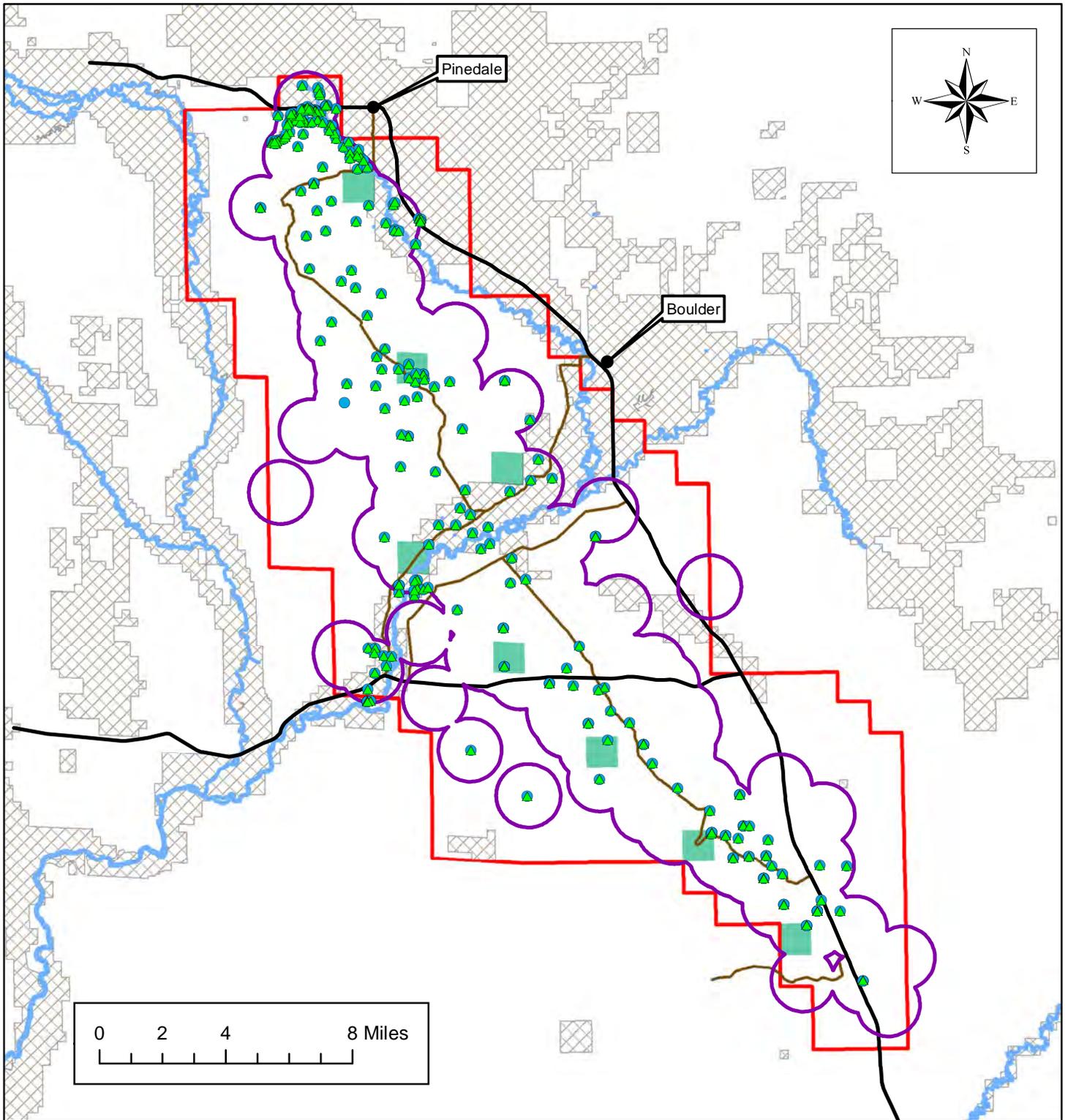
<http://www.energylab.com/QualityControlList.asp?branch=Casper>

All laboratory and field data have been entered into the SCCD-managed database and quality control measures have been applied to ensure accuracy of the data entry process.

Results

From January 1, 2013 through December 31, 2013, 243 field visits took place with 247 samples being collected. Some of these were duplicate samples taken as a quality control measure; others were second samples, typically collected due to previous hydrocarbon-related detections. See Map 2.

Map 2. Water Wells Visited vs Sampled



- | | | | |
|------------------------|-----------------------------|---------------------------------|-----------------------|
| State land within PAPA | Main rivers | Pinedale Anticline Project Area | Wells sampled in 2013 |
| Private lands | Main highways | One mile sampling area | Wells visited in 2013 |
| Main cities | Secondary roads within PAPA | | |

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Water Wells Permitted Through the Wyoming State Engineer's Office for Domestic, Stock and Domestic/Stock Use

Field Data

The following field results are from 120 sample sets collected from 79 domestic water wells, 14 domestic/stock wells and 24 stock wells. Multiple field samples are typically collected per well visit (one sample set). The following results represent the last field sample collected during a well visit and are presented to represent the range of data collected from a specific well-use group.

<i>Field Data Collected</i>	<i>Range</i>
<i>Conductivity (us/cm)</i>	
Domestic	232 to 1815
Domestic/Stock	305 to 1152
Stock	377 to 2540
<i>TDS (mg/L)</i>	
Domestic	116 to 907
Domestic/Stock	153 to 575
Stock	189 to 1270
<i>Temperature (Celsius)</i>	
Domestic	6.7 to 17
Domestic/Stock	8.3 to 15
Stock	7.4 to 18
<i>pH</i>	
Domestic	7.4 to 9.75
Domestic/Stock	7.56 to 9.61
Stock	7.23 to 9.69
<i>Water Level (feet from top of well casing)</i>	
Domestic	0 to 100.4
Domestic/Stock	10.3 to 99.2
Stock	0 to 528.3

The Wyoming Department of Environmental Quality (WDEQ) and Environmental Protection Agency (EPA) have established drinking water and livestock water quality standards. Some of these parameters are analyzed through the SCCD Groundwater Monitoring Program, both in the field and subsequent lab analysis. The standards for these parameters are given below:

- *Drinking Water Standards:* chloride, 250 mg/L; fluoride, 4 mg/L; sulfate, 250 mg/L; and total dissolved solids, 500 mg/L.
- *Livestock Standards:* chloride, 2000 mg/L; sulfate, 3000 mg/L; and total dissolved solids, 5000 mg/L.

When comparing TDS results from field analysis with the above standards, 11 domestic wells (AD016, AD017, AD018, AD057, AD063, AD145, AD194, AD213, AD222, AD234 and AD251) exceeded the drinking water standard, 1 domestic/stock well (ADS028) exceeded the drinking water standard, and 0 stock wells exceeded the livestock standard. All of these wells have had historical levels at or above the drinking water standard without significant changes when compared to SCCD’s prior data.

The complete field data, including details regarding sampling methods, is provided in Appendix A, Table 1. Water Well Field Data, 01/01/13 – 12/31/13 Plus Historical Results 01/01/04 – 12/31/13: Wells Permitted for Domestic-use and Stock-use.

Laboratory Data

The following laboratory results are from 132 samples collected from 79 domestic water wells, 14 domestic/stock wells and 24 stock wells. They represent the range of data collected from the specific well-use group. “ND” represents non-detectible.

<i>Laboratory Data</i>	<i>Range</i>
<i>Alkalinity (mg/L)</i>	
Domestic	119 to 490
Domestic/Stock	133 to 257
Stock	64 to 254
<i>Calcium (mg/L)</i>	
Domestic	ND to 88
Domestic/Stock	ND to 58
Stock	ND to 90
<i>Chloride (mg/L)</i>	
Domestic	ND to 73
Domestic/Stock	ND to 13
Stock	1 to 61
<i>Fluoride (mg/L)</i>	
Domestic	ND to 9.2
Domestic/Stock	ND to 5.5
Stock	0.1 to 7.9
<i>Magnesium (mg/L)</i>	
Domestic	ND to 28
Domestic/Stock	ND to 11
Stock	ND to 15
<i>Potassium (mg/L)</i>	
Domestic	ND to 4
Domestic/Stock	ND to 2
Stock	ND to 3

<i>Sodium (mg/L)</i>	
Domestic	5 to 381
Domestic/Stock	18 to 257
Stock	9 to 506
<i>Sulfate (mg/L)</i>	
Domestic	ND to 501
Domestic/Stock	ND to 307
Stock	ND to 1020
<i>TDS (mg/L)</i>	
Domestic	135 to 1200
Domestic/Stock	153 to 695
Stock	232 to 1680
<i>Conductivity (umhos/cm)</i>	
Domestic	228 to 1800
Domestic/Stock	272 to 1110
Stock	369 to 2450

When comparing chloride results from laboratory analysis with the standards listed earlier in this summary, there were no drinking or livestock water exceedances for domestic, domestic/stock or stock water wells.

When comparing fluoride results from laboratory analysis with the standards listed earlier in this summary, 4 domestic wells (AD021, AD022, AD197 and AD203) exceeded the drinking water standard and 1 domestic/stock well (ADS004) exceeded the drinking water standard. All of these wells have had historical levels at or above the drinking water standard without significant changes when compared to SCCD's prior data.

When comparing sulfate results from laboratory analysis with the standards listed earlier in this summary, 11 domestic wells (AD016, AD017, AD018, AD057, AD063, AD145, AD194, AD213, AD222, AD234 and AD251) exceeded the drinking water standard, 1 domestic/stock well exceeded the drinking water standard (ADS028), and there were no stock wells that exceeded the livestock standard. All of these wells have had historical levels at or above the drinking water standard without significant changes when compared to SCCD's prior data.

When comparing TDS results from laboratory analysis with the standards listed earlier in this summary, 14 domestic wells (AD016, AD017, AD018, AD046, AD057, AD063, AD137, AD145, AD174, AD194, AD213, AD222, AD234 and AD251) exceeded the drinking water standard, 1 domestic/stock well exceeded the drinking water standard (ADS028), and there were no stock wells that exceeded the livestock standard. All of these wells have had historical levels at or above the drinking water standard without significant changes when compared to SCCD's prior data.

The complete laboratory analysis data is provided in Appendix A, Table 1. Water Well Field Data, 01/01/13 – 12/31/13 Plus Historical Results 01/01/04 – 12/31/13: Wells Permitted for Domestic-use and Stock-use.

Water Wells Permitted Through the Wyoming State Engineer's Office for Miscellaneous Use

Field Data

The following results are from 108 samples collected from 94 wells. Multiple field samples are typically collected per well visit (one sample set). The following results represent the last field sample collected during a well visit.

<i>Field Data Collected</i>	<i>Range</i>
<i>Conductivity (us/cm)</i>	285 to 2650
<i>TDS (ppm)</i>	143 to 1320
<i>Temperature (Celsius)</i>	8.0 to 31.8
<i>pH</i>	7.16 to 10.30
<i>Water Level (feet from top of well casing)</i>	0 to 685.5

The complete field data, including details regarding sampling methods, is provided in Appendix A, Table 2. Water Well Field Data, 01/01/13 – 12/31/13 Plus Historical Results 01/01/04 – 12/31/13: Wells Permitted for Miscellaneous-use.

Laboratory Data

The following results are from 115 samples collected from 95 wells. “ND” represents non-detectable.

<i>Laboratory Data</i>	<i>Range</i>
<i>Alkalinity (mg/L)</i>	85 to 317
<i>Calcium (mg/L)</i>	ND to 69
<i>Chloride (mg/L)</i>	2 to 260
<i>Fluoride (mg/L)</i>	0.1 to 13.6
<i>Magnesium (mg/L)</i>	ND to 12
<i>Potassium (mg/L)</i>	ND to 3
<i>Sodium (mg/L)</i>	6 to 586
<i>Sulfate (mg/L)</i>	ND to 1070
<i>TDS (mg/L)</i>	151 to 1700
<i>conductivity (umhos/cm)</i>	253 to 2570

The complete laboratory analysis data is provided in Appendix A, Table 2. Water Well Field Data, 01/01/13 – 12/31/13 Plus Historical Results 01/01/04 – 12/31/13: Wells Permitted for Miscellaneous-use.

Hydrocarbon Results

Hydrocarbons reported as DRO, GRO or BTEX using method SW8021B, have been detected in a total of 16 wells from January 1, 2013 through December 31, 2013. All of these water wells are permitted for miscellaneous-use. See Map 3.

To address hydrocarbons in water wells, WDEQ uses a set of ground water clean-up levels to help guide them in the decision making process of whether a well should be recommended for the voluntary remediation program:

- *Ground Water Cleanup Levels:* DRO, 1.1 mg/L or 10 mg/L; GRO, 7.3 mg/L; benzene, 5 ug/L; ethylbenzene, 700 ug/L; m+p-Xylenes, 10,000 ug/L; o-Xylene, 10,000 ug/L; and toluene, 1,000 ug/L.

The cleanup level for DRO can be either 1.1 mg/L or 10 mg/L depending on the results of other parameters, some of which are not tested for by SCCD.

The following laboratory results are from samples collected from January 1, 2013 through December 31, 2013. BTEX was tested for when previous results showed hydrocarbon related detections or when field observations prompted the analysis. When BTEX was tested, an additional method of SW8260B was used for comparative purposes.

A number of documents have been published that discuss the differences and reliability of the two different BTEX methods tested for (SW8021B and SW8260B). When reviewing the following data it should be noted that misidentification, or false-positives, using method SW8021B can occur.

- *DRO* was detected in a total of 4 wells with results ranging from 1.4 mg/L to 68.0 mg/L (AMI182, AMI187, AMI228, and AMI258). It cannot be determined from SCCD's data set how many of the 4 wells have levels over the cleanup level.
- *GRO* was detected in a total of 11 wells with results ranging from 0.022 mg/L to 0.53 mg/L (AMI018, AMI117, AMI146, AMI159, AMI163, AMI182, AMI187, AMI228, AMI237, AMI240 and AMI258). All levels were under the cleanup level.
- *Benzene using method SW8021B* was detected in a total of 6 wells with results ranging from 0.75 ug/L to 100 ug/L (AMI146, AMI182, AMI187, AMI214, AMI228 and AMI237), with 5 having levels over the cleanup level (AMI146, AMI182, AMI187, AMI228 and AMI237).
- *Benzene using method SW8260B* was detected in 2 wells with results ranging from 1.4 ug/L to 64 ug/L (AMI228 and AMI237), with 1 having levels over the cleanup level (AMI237).
- *Ethylbenzene using method SW8021B* was detected in 3 wells with results ranging from 0.76 ug/L to 4.9 ug/L (AMI228, AMI237 and AMI258), all with levels under the cleanup level.
- *Ethylbenzene using method SW8260B* was detected in 2 wells with results ranging from 1.1 ug/L to 4.7 ug/L (AMI237 and AMI258), both with levels under the cleanup level.
- *m+p-Xylenes using method SW8021B* was detected in a total of 3 wells with results ranging from 1.0 ug/L to 37 ug/L (AMI134, AMI237 and AMI258), all with levels under the cleanup level.

- *m+p-Xylenes using method SW8260B* was detected in a total of 3 wells with results ranging from 1.1 ug/L to 50 ug/L (AMI134, AMI237 and AMI258), all with levels under the cleanup level.
- *o-Xylene using method SW8021B* was detected in 2 wells with results ranging from 3.1 ug/L to 4.6 ug/L (AMI237 and AMI258), both with levels under the cleanup level.
- *o-Xylene using method SW8260B* was detected in a total of 2 wells with results ranging from 3.5 ug/L to 4.8 ug/L (AMI237 and AMI258), both with levels under the cleanup level.
- *Toluene using method SW8021B* was detected in a total of 10 wells with results ranging from 0.61 ug/L to 140 ug/L (AMI134, AMI146, AMI162, AMI186, AMI187, AMI189, AMI228, AMI237, AMI240 and AMI258), all with levels under the cleanup level.
- *Toluene using method SW8260B* was detected in a total of 8 wells with results ranging from 1.0 ug/L to 140.0 ug/L (AMI146, AMI162, AMI186, AMI189, AMI228, AMI237, AMI240 and AMI258), all with levels under the cleanup level.

Details of water wells with new hydrocarbon related detections since last reported (Pinedale Anticline Ground Water Data Summary, February, 2013)

AMI117 / Mesa 9-16 / QEP

This well has been sampled annually since 2004 using polyethylene bailers with no hydrocarbon-related detections until 2013. Results from the 08/15/13 sample showed a GRO detection of 0.34 mg/L. Confirmation samples were collected on 09/19/13 with all hydrocarbon-related parameters showing ND, including BTEX analysis.

AMI159 / Mesa 11-28 / Shell

This well has been sampled annually since 2004 mostly using polyethylene bailers with no hydrocarbon-related detections until 2013. Results from the 06/18/13 sample showed a GRO detection of 0.22 mg/L. Confirmation samples were collected on 07/10/13 with all hydrocarbon-related parameters showing ND, including BTEX analysis.

AMI163 / Rainbow 15-32 / Linn Energy

This well has been sampled annually since 2005 mostly using polyethylene bailers with no hydrocarbon-related detections until 2013. Results from the 08/01/13 sample showed a GRO detection of 0.11 mg/L. Confirmation samples were collected on 09/04/13. Results from that sample showed a GRO detection of 0.096 mg/L and a carbon disulfide detection of 2.1 ug/L using BTEX method SW8260B.

Status of wells with hydrocarbon detections

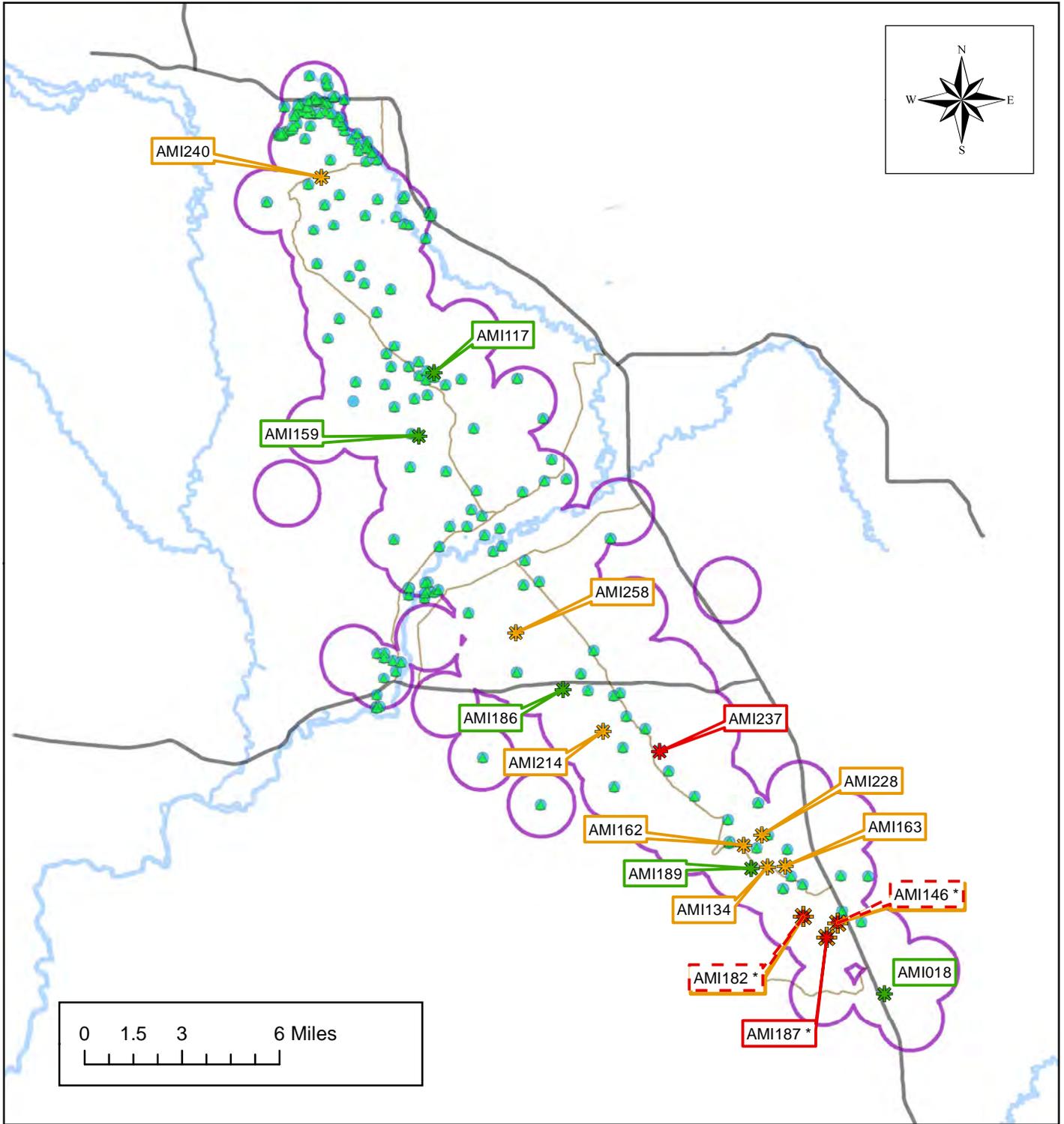
Based on the results of the last set of samples collected from wells with past hydrocarbon detections in 2013, the following wells currently have some level of primary* hydrocarbon presence (see Map 3), some below the cleanup levels listed earlier in this summary and some at or above.

Well ID	DRO or GRO		BTEX Method SW8021B		BTEX Method SW8260B	
	Below	At or above	Below	At or above	Below	At or above
AMI134	None	None	m+p-Xylene Toluene Total Xylenes	None	None	None
AMI146	GRO	None	None	Benzene	None	None
AMI162	None	None	Toluene	None	Toluene	None
AMI163	GRO	None	None	None	None	None
AMI182	GRO	None	None	Benzene	None	None
AMI187	GRO	DRO	Toluene	Benzene	None	None
AMI214	None	None	Benzene	None	None	None
AMI228	DRO GRO	None	Toluene	None	Toluene	None
AMI237	GRO	None	Ethylbenzene m+p-Xylene o-Xylene Toluene Total Xylenes	Benzene	Ethylbenzene m+- Xylene o-Xylene Toluene Total Xylenes	Benzene
AMI240	GRO	None	Toluene	None	Toluene	None
AMI258	GRO	None	Ethylbenzene m+p-Xylene o-Xylene Toluene Total Xylenes	None	m+p-Xylene o-Xylene Total Xylenes	None

**Primary hydrocarbons include those that have clean-up levels set by WYDEQ.
The cleanup level of 10 mg/L for DRO is being used for the above determinations.*

The complete hydrocarbon analysis data is provided in Appendix B, Table 3. Historical Hydrocarbon-Related Data From Water Wells With Detections: Primary Results, 01/01/04 – 12/31/13 and Table 4. Historical Hydrocarbon-Related Data From Water Wells With Detections: Complete BTEX Method SW8260B Results, 01/01/04 – 12/31/13.

Map 3. Water Wells With Recent Hydrocarbon Detections



- | | | |
|--|---|--|
|  State land within PAPA |  Secondary roads within PAPA | Status of wells (last time sampled by SCCD) |
|  Private lands |  Pinedale Anticline Project Area |  Hydrocarbon detections over WYDEQ clean-up levels |
|  Main rivers |  One mile sampling area |  Hydrocarbon detections under WYDEQ clean-up levels |
|  Main highways |  Wells visited in 2013 |  Hydrocarbons non-detectible |

* Benzene result discrepancies between BTEX methods

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Literature Cited

- The Record of Decision for the Environmental Impact Statement for the Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County, Wyoming, Bureau of Land Management, Pinedale Field Office, July 2000
- Water Quality Rules and Regulations, Chapter 8, Wyoming Department of Environmental Quality, 2003
- Voluntary Remediation Program, Fact Sheet #12, Soil Cleanup Level Look-Up Table, Appendix A: Cleanup Levels for Total Petroleum Hydrocarbons in Soil and Groundwater, Wyoming Department of Environmental Quality, 2008
- Pinedale Anticline Ground Water Data Summary, Sublette County Conservation District, February 2013
- Sublette County Conservation District's Ground Water Monitoring Manual and Protocol, April 2013
- Water Quality Monitoring Sampling and Analysis Plan for the PAPA, March 2008