West Peetz Field - Nearby Water Well Sampling and Analysis Summary
Logan County, Colorado

Prepared for Ron Richards, Midstream Energy Holdings

COGCC Remediation Project # 9425

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VERSION 1.2

dig
Dolan Integration Group
Geochemistry for Energy™

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Summary and Principal Conclusions

- Due to similarities in the thermogenic hydrocarbon gas in the West Peetz storage field and the dissolved hydrocarbon gas found in the Nelson Water Well (NWW), East Cheyenne Gas Storage, LLC. coordinated a sampling and analysis plan as outlined in the Colorado Oil and Gas Conservation Commission (COGCC) Form 27 to re-sample the NWW and groundwater wells within an approximate 1 mile radius of the NWW. Sampling took place in March and April of 2016.

- The sampling of the NWW occurred after the construction of an aeration type methane mitigation system on the NWW. Samples were collected both upstream and downstream of the system to quantify the effectiveness of the treatment system. Upstream and downstream samples were collected during 3 separate sampling events, the third supplementary set being collected after modifications were made to the system to improve its efficiency. Although the treatment system is removing a significant amount of methane, ethane and propane from the water, there are still elevated dissolved gas concentrations post treatment. East Cheyenne is in the process of installing additional equipment that should lower the post treatment concentration of methane to below 10 mg L^{-1}.

- The nearby water wells - the Michaels water well (MWW), Wood water well (WWW) and Williams Shallow water well (WSWW) all contained either very small amounts of methane or the concentration was below detection limits. No ethane or propane was detected in these samples. Comparison of these data with previous baseline samples collected by ECGS in 2010-2015 show that the dissolved gas concentrations have remained relatively constant or declined throughout time. Methane concentrations were not sufficient for isotopic analysis.

- Though not originally requested, an additional water well that was not found in the CO DWR water well database, the Williams Deep water well (WDWW), was sampled because it was within a 1 mile radius of the NWW. This well had also been sampled multiple times for baseline purposes from 2010-2015 and the dissolved gas concentration has decreased significantly in the latest April 2016 result. The stable carbon and hydrogen isotope composition of the methane indicates the gas in the WDWW is predominantly of microbial origin.

- A full list Volatile Organic Compound (VOC) and Semi-Volatile Organic Compound (SVOC) analysis was carried out on samples collected from each water well. No

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VOC's or SVOC's were detected in any of the nearby water wells. There were several low level VOC's detected in the NWW, however, these compounds were all detected at concentrations near the detection limit and below the applicable EPA maximum contaminant levels (MCL's) and health advisory levels (HAL's). 5 of the 10 detected VOC's may be originating from either 1) well disinfection processes utilizing chlorine or chloramine 2) PVC cement products used to construct the methane aeration system on the NWW.

- As requested, all analytical data from the March – April 2016 sampling campaign has been uploaded to the COGCC database through the COGCC's Electronic Data Deliverable (EDD) process.

- A review of the geochemical results of the March and April 2016 sampling events supports the conclusion that the nearby water wells in the area have not been impacted in the same manner as the NWW. Due to the lack of thermogenic gas in the nearby samples and the lack of detectable VOC's and SVOC's, quarterly monitoring of these wells may not be necessary. In addition, the full suite SVOC analysis may also not be necessary on future quarterly NWW sampling events.

Introduction

Ron Richards from Midstream Energy Holdings requested that the Dolan Integration Group (DIG) provide a summary of the sampling and analytical results obtained from water wells sampled near the West Peetz gas storage field in Logan County, Colorado in March and April of 2016. This sampling and analytical program was implemented as part of the plan of action outlined in the COGCC Form 27 and is in reference to COGCC Remediation Project Number 9425 – Peetz West Field (Ron Nelson Water Well). Specifically, the COGCC recommended the following actions:

1. Perform quarterly monitoring of the Nelson Water Well for the duration of the source area investigation. Collect water well samples prior to the treatment system for the following laboratory analyses:
    a. 8260 VOCs full list, 8270 SVOC full list, pH, specific conductance, total dissolved solids, dissolved (methane, ethane, propane, butane, iso-butane, pentane, iso-pentane, hexane), total bicarbonate as CaCO3, carbonate as CaCO3, bromide, fluoride, sulfate, nitrate and nitrite as N, phosphorus, calcium, iron, magnesium, manganese, potassium, sodium, barium, boron, selenium, strontium and iron related bacteria. If the full list VOC constituents are not detected during the initial sampling event, only BTEX analysis shall be required during subsequent monitoring events. SVOC analysis shall not be required beyond the initial sampling event if the results are below the detection limits.
2. If access can be obtained, collect groundwater samples from surrounding water wells within an approximate 1 mile radius of the Nelson (Langness) water well and analyze for the same constituents requested for 1.a. Follow up sampling of the water wells will be determined based on the analytical results.
    a. Specific water wells include Hugh Williams Permit No. 82501; Kevin & Peggy Michaels Permit No. 235877; U.S. Air Force Permit No. 11499-A. If the US Air Force well is not available to sample, the David Davis Permit No. 15889-A should be pursued as an alternate.
3. Upload all groundwater sample results via the EDD process into the COGCC database.
4. Collect pre and post methane treatment system water samples from the Ron Nelson Water Well for dissolved methane analysis in order to confirm the effectiveness of the treatment system. Collect the samples upon completion of the methane treatment system installation, and again within 5 days of the system startup. After the two initial sampling events, continue the post system sampling and analysis during the ongoing quarterly monitoring events.
5. If not already completed, offer to provide a methane monitoring and alarm system to the residence and/or the ground water treatment system building.

As requested by the COGCC, samples were collected from the water wells listed in Table 1. Though permission to sample the Air Force Permit No. 11499A well was requested, permission was not obtained and the David Davis Permit No. 158889A well was subsequently sampled as an alternate. Colorado Department of Water Resources (DWR) information has not been updated to reflect the present ownership of the David Davis

Permit No. 158889A well; this property and well is currently owned by Mr. Frank Wood and will henceforth be referred to as the Wood Water Well (WWW). Also of note, the Williams Deep Water Well (WDWW) was sampled while field personnel were in the area and submitted for the full analytical suite, though it was not requested by the COGCC in the list of nearby water wells. This may be due to the fact that the Williams Deep water well was not in the Colorado DWR permit database. A map of the area in Figure 1 shows the WDWW is located inside the 1 mile radius from the Nelson Water Well that was specified.

Well ID	CO DWR Receipt #	CO DWR Permit #	Field Sample ID	Lat	Long	Sec.	Twn	Rng.	Well Depth (ft)
Nelson Water Well (NWW)	3638023B	280327A	18852	40.961583	-103.212912	6	11N	52W	1020
Williams Shallow Water Well (WSWW)	9045346	82501	17956-N	40.962312	-103.230001	1	11N	53W	500
Williams Deep Water Well (WDWW)			17956-S	40.961580	-103.230420	1	11N	53W	1160
Michaels Water Well (MWW)	480219	235877	18250	40.976627	-103.224838	31	12N	52W	435
Wood Water Well (WWW)	0319388B	158889A	19973	40.965008	-103.194840	32	12N	52W	300

Table 1: Nearby water wells sampled as part of the March-April 2016 West Peetz Field study.

Samples from the water wells listed in Table 1 were collected by Tasman Geosciences and submitted for the analyses listed in Table 2, per COGCC guidance. Care was taken to strictly follow the COGCC Model Sampling and Analysis Plan as dictated in COGCC Rule 609 – Statewide Groundwater Baseline Sampling and Monitoring. Tasman Geosciences also used a Trimble Global Positioning System (GPS) to survey the Wood's and Michael's well casings per COGCC Rule 215, as there were not existing facility ID's in the COGCC database for these sites. Results from the analyses were uploaded via the EDD process into the COGCC database under the respective COGCC facility ID's listed in Table 2.

Well ID	Lab Batch	COGCC Facility ID	Field Sample ID	Sample Date	Analysis	Notes
Michaels Water Well (MWW)	1603534	754716	18250	3/30/2016	Full Suite*	
Williams Shallow Water Well (WSWW)	1604018	754159	17956-N	3/30/2016	Full Suite*	
Williams Deep Water Well (WDWW)	1604017	754160	17956-S	3/30/2016	Full Suite*	
Nelson Water Well (NWW)	1604253	707193	18852-Post	3/30/2016	Dissolved methane only	Post-treatment system
Nelson Water Well (NWW)	1603533	707193	18852-Pre	3/30/2016	Full Suite*	Pre-treatment system
Nelson Water Well (NWW)	1603535	707193	Dup of 18852-Pre	3/30/2016	Full Suite*	Pre-treatment system
Trip Blank	1603536	707193	Trip Blank	3/30/2016	VOC's	
Nelson Water Well (NWW)	1604019	707193	18852-Post	4/1/2016	Dissolved methane only	Post-treatment system
Nelson Water Well (NWW)	1604020	707193	18852-Pre	4/1/2016	Dissolved methane only	Pre-treatment system
Trip Blank	1604021	707193	Trip Blank	4/1/2016	VOC's	
Wood Water Well (WWW)	1604445	754715	19973	4/22/2016	Full Suite*	
Nelson Water Well (NWW)	1604448	707193	18852-Post	4/22/2016	Dissolved methane only	Post-treatment system
Nelson Water Well (NWW)	1604447	707193	18852-Pre	4/22/2016	Dissolved methane only	Pre-treatment system
Trip Blank	1604446	707193	Trip Blank	4/22/2016	VOC's	

Table 2: COGCC facility ID's, sample dates and analyses for the water wells sampled in this study.

***Full Suite includes the following laboratory analyses: 8260 VOCs full list, 8270 SVOC full list, pH, specific conductance, total dissolved solids, dissolved (methane, ethane, propane, butane, iso-butane, pentane, iso-pentane, hexane), total bicarbonate as CaCO3, carbonate as CaCO3, bromide, fluoride, sulfate, nitrate and nitrite as N, phosphorus, calcium, iron, magnesium, manganese, potassium, sodium, barium, boron, selenium, strontium and iron related bacteria.**

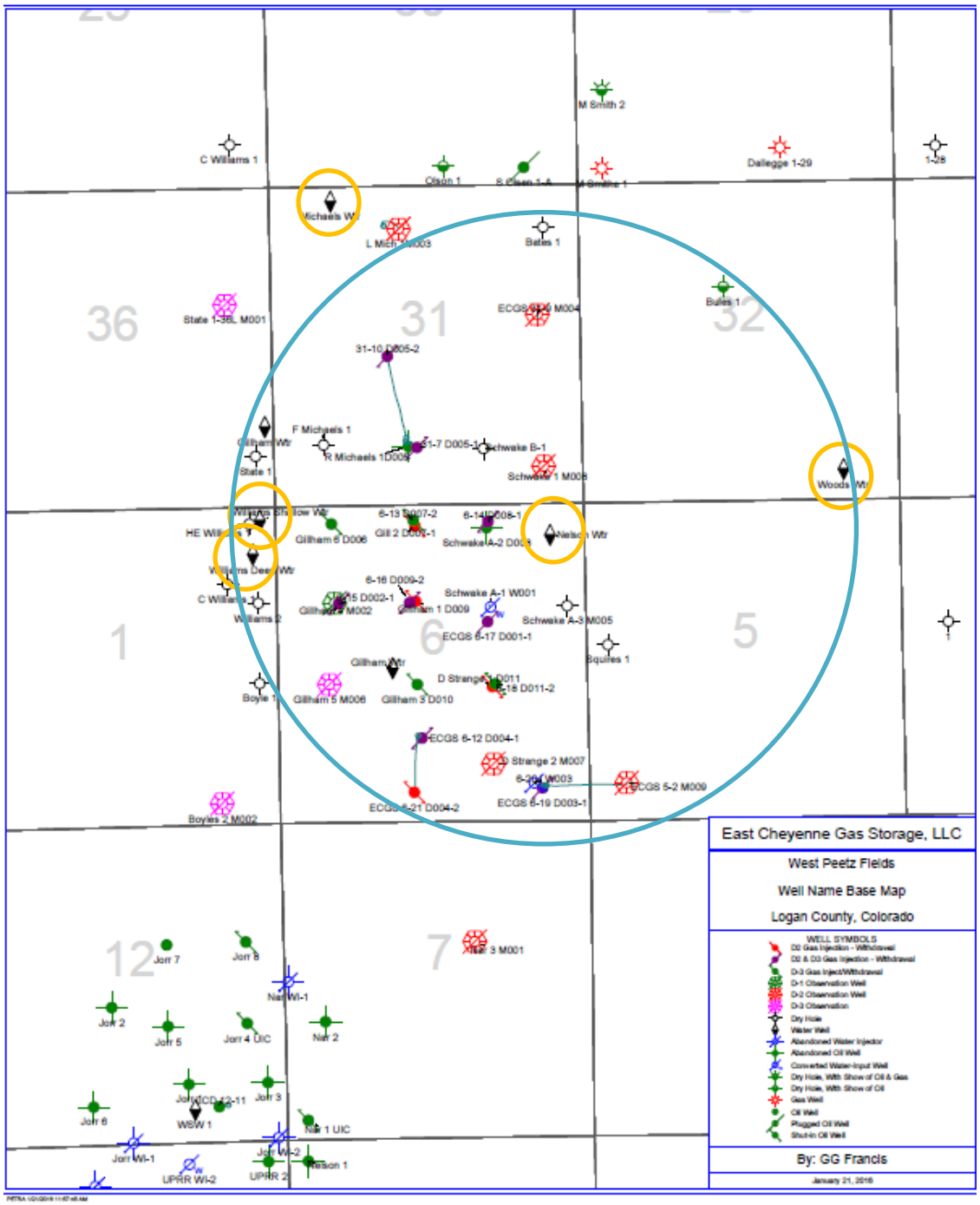

Figure 1: Well name base map for West Peetz field portion of the East Cheyenne Gas Storage project from Greg Francis. Orange circles indicate water well locations that were sampled in March – April of 2016. Blue circle indicates a 1 mile radius from the NWW specified by the COGCC when selecting nearby wells.

Analytical Results – VOC's and SVOC's

No volatile organic compounds (VOC's) or Semi-volatile Organic Compounds (SVOC's) in the EPA method 8260 or 8270 full list specified by the COGCC were detected in the nearby MWW, WSWW, WDWW or WWW samples collected in March and April of 2016. As documented in the Form 27 action plan, any subsequent quarterly sampling and analyses on these water wells should only require BTEX analysis due to the absence of detectable full list VOC and SVOC compounds.

In the Nelson pre-treatment sample collected on March 30, 2016, low levels of the following VOC's shown in Table 3 were detected.

Compound	Result	Method Code	Report Limits	Units	US EPA MCL	US EPA HAL
Chloromethane	1.2	SW8260_25	1	ug/l		3
Bromomethane	1.5	SW8260_25	1	ug/l		10
Chloroethane	3.8	SW8260_25	1	ug/l		
Iodomethane	1.4	SW8260_25	1	ug/l		
2-butanone	56	SW8260_25	10	ug/l		4000
Chloroform	2.4	SW8260_25	1	ug/l	80	
Bromodichloromethane	1.5	SW8260_25	1	ug/l	80	
Dibromochloromethane	1.5	SW8260_25	1	ug/l	80	
M&P-Xylene	1.7	SW8260_25	1	ug/l	10000	
Bromoform	1	SW8260_25	1	ug/l	80	

Table 3: Results of the VOC analysis on the NWW sample collected pre-treatment on March 30, 2016. HAL (Health Advisory Level) and MCL (Maximum Contaminant Level) data from US EPA, 2012.

The US Environmental Protection Agency (EPA) publishes a Table of Regulated Drinking Water Contaminants, which is based upon the legally enforceable National Primary Drinking Water Regulations (NPDWRs). Included in this standard are maximum contaminant levels (MCL's) for five of the compounds identified in the NWW: Chloroform, Bromodichloromethane, Dibromochloromethane, Bromoform and M&P-Xylene. Chloroform, Bromodichloromethane, Dibromochloromethane and Bromoform are designated as Trihalomethanes and are known to occur when naturally-occurring organic and inorganic materials in the water react with the disinfectants, chlorine and chloramine (US EPA, 2012). The 80 µg L^{-1} MCL designated for these four compounds is a total trihalomethanes (TTHMs) MCL, i.e., the sum of all four compounds detected. The detected amounts in the NWW sample are well below the MCL for TTHMs. The MCL of

10,000 µg L^{-1} is for Total Xylene concentrations, and the M&P-Xylene detected in this sample is well below that particular MCL.

The US EPA also publishes health advisories for contaminants, but these are not formal regulations and are subject to change as new data and analyses become available. Health Advisory Levels (HAL's) shown in Table 3 are considered to be without appreciable health risk, assuming a 70 kg adult consuming 2 liters of water per day over a 70 year lifetime (US EPA, 2012). The three compounds which have HAL's are chloromethane, bromomethane and 2-butanone and all three are below the respective HAL. There are no known MCL's or HAL's for two of the detected compounds – Chloroethane and Iodomethane.

A review of the relevant scientific literature discovered that 2-butanone, also known as methyl ethyl ketone (MEK), which was detected at 56 µg L^{-1}, is a constituent in PVC solvent or cement products used to form a seal on PVC pipe and fittings. The Material Safety Data Sheet (MSDS) for a low-VOC PVC cement product shows methyl ethyl ketone as a main ingredient, varying from 10-25% by weight (PVC Cement MSDS, 2009). PVC cement was used in the construction of the methane mitigation system installed by East Cheyenne Gas Storage and the cement is a probable source of the contaminant, given the overall lack of other VOC contaminants and the documentation in the scientific literature of PVC cements causing similar results in both field and laboratory settings (Sosebee, 1983 and Wang, 1979). In these studies, the concentration of 2-butanone increased with longer residence time in the PVC pipe, with samples collected at a residence time of zero showing no detectable 2-butanone (Wang, 1979).

Analytical Results – Dissolved Gases

In addition to the analysis of the recent water well samples collected in March – April 2016, baseline environmental surveys of the groundwater wells in the vicinity of the West Peetz gas storage field were conducted by Vista Geosciences in 2010 – 2015. These geochemical data are incorporated in this report to distinguish potential temporal changes. In figure 2, the dissolved methane concentration in micrograms per liter is plotted against sample date for samples collected from the NWW, showing a significant increase in the dissolved gas concentration prior to the November 2015 sampling campaign. As part of the remediation action plan, ECGS installed a methane treatment system on the NWW to reduce the concentration of dissolved gas prior to use by the homeowner. The data from samples collected both upstream and downstream of the treatment system are included from the March – April 2016 sampling campaign are included as well, showing a significant decrease in the dissolved methane concentration post-treatment, with samples ranging from 14,050–16,330 µg L^{-1}.

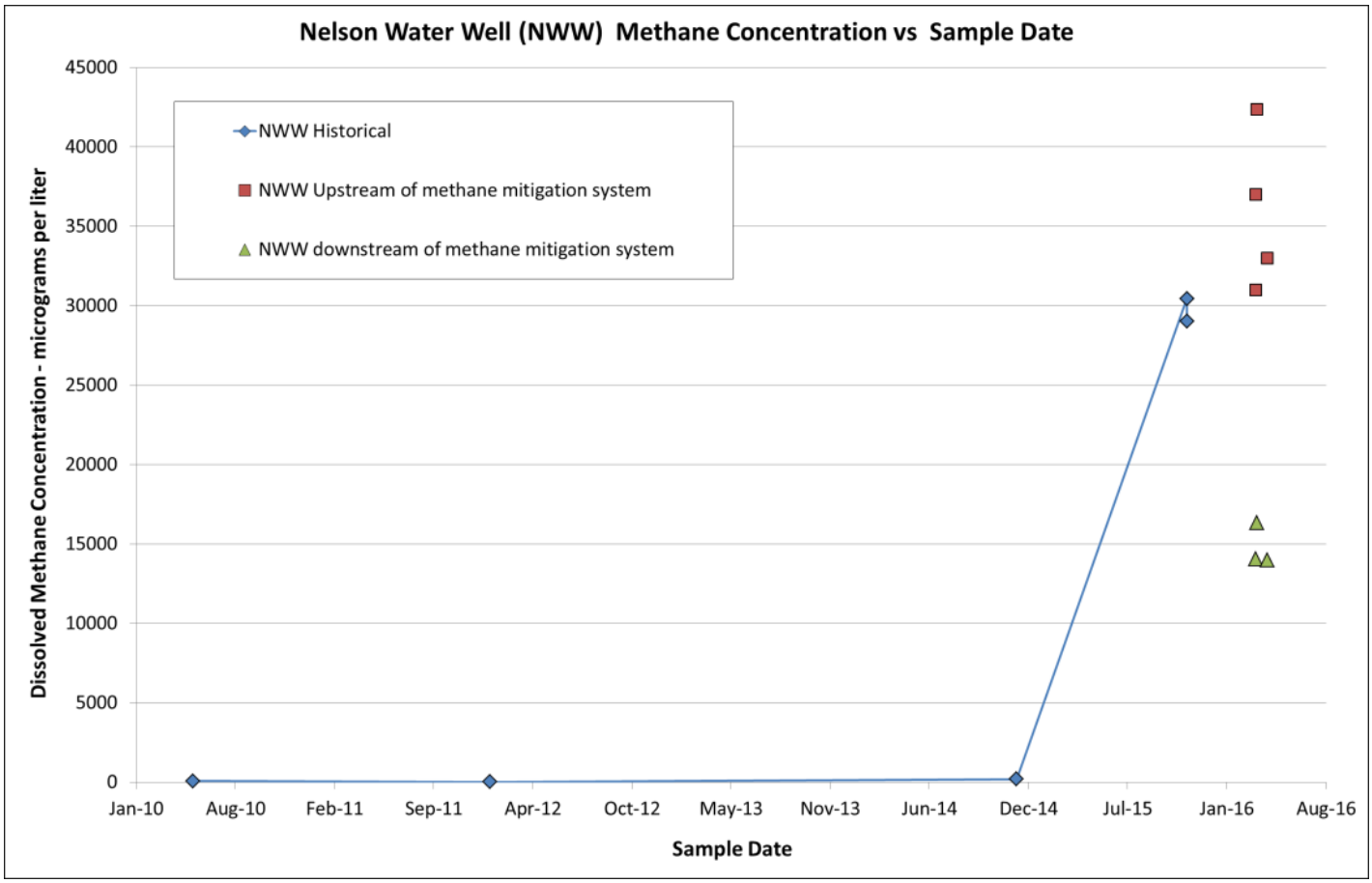

Figure 2: Dissolved methane concentration data from the NWW from historical baseline studies done by Vista Geoscience and the samples collected both upstream and downstream of the methane mitigation system installed on the NWW.

For the nearby WSWW, WWW, MWW and WDWW, data was compiled and plotted in a similar manner in Figure 3. The dissolved methane concentrations are very low in the MWW, WSWW and WWW samples both in the historical Vista analyses and the more recent March-April 2016 analyses. The WDWW contains significant amounts of dissolved methane, though the concentration has declined significantly as of the most recent sample to 1,500 µg L^{-1}.

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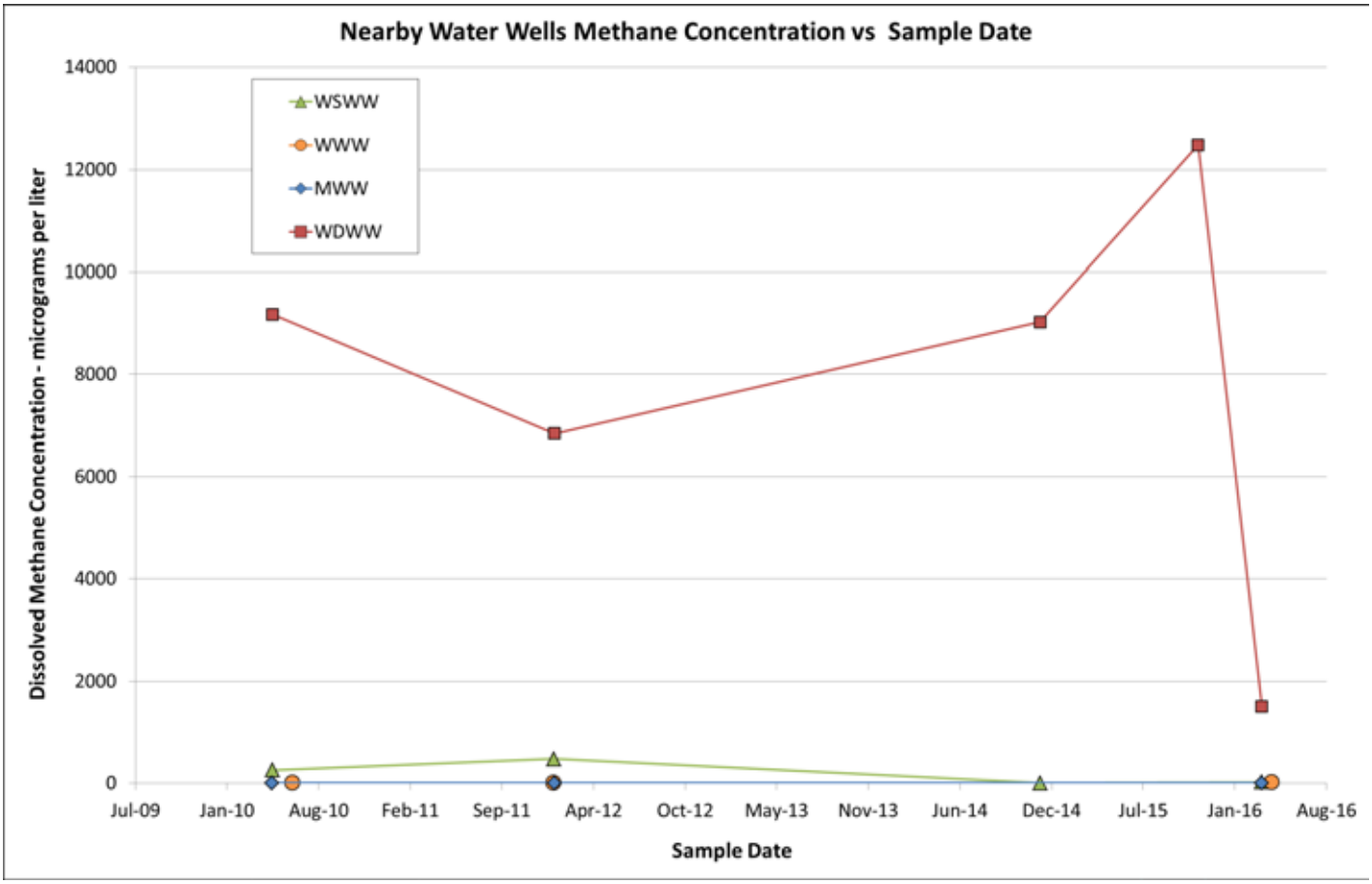

Figure 3: Dissolved methane concentration data from the nearby water wells, from both historical baseline studies done by Vista Geoscience and the samples during the March-April 2016 sampling campaign.

At the request of East Cheyenne Gas Storage, the Dolan Integration Group (DIG) proceeded with the gas composition analysis of C_1-C_6+ and the stable isotope analysis of dissolved hydrocarbon gas that was present in sufficient concentrations, though this was not originally specified in the Form 27 action plan. There were not sufficient concentrations of gas for isotopic analysis in the WWW, MWW or WSWW samples. Shown in Figures 4A-C are the Whiticar, Schoell and Bernard genetic characterization plots from the stable isotope geochemistry literature. Each of the three characterization plots show the WDWW as exhibiting a signature consistent with a microbial origin of the gas, while the NWW exhibits a signature indicative of a thermogenic source of the gas. Also of note, the most recent NWW samples are slightly wetter (% C_2+) and slightly more enriched in the stable carbon isotope composition of the methane than those samples collected in November of 2015.

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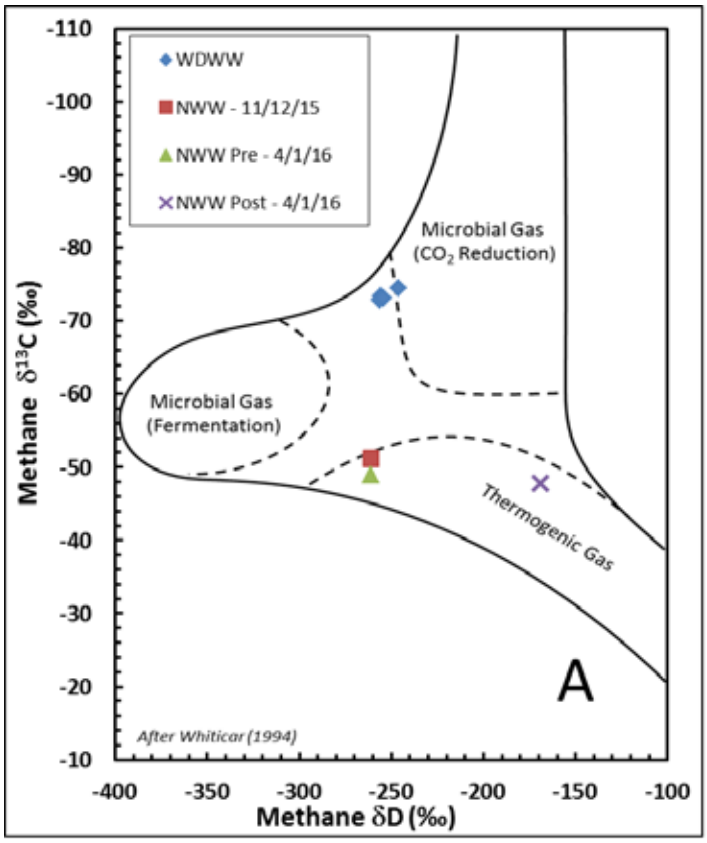

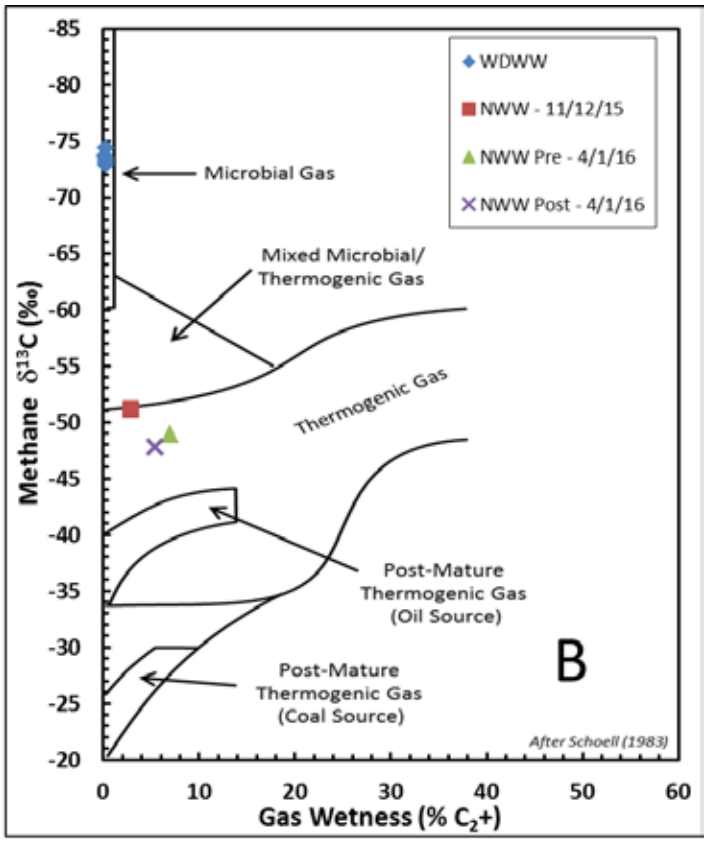

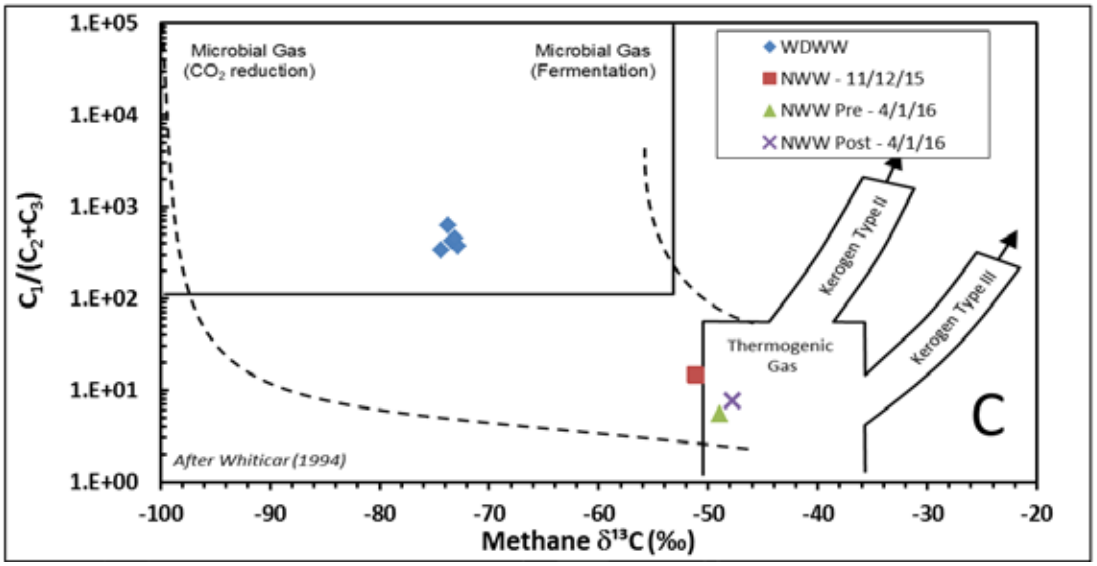

Figure 4A: Whiticar (1994) genetic classification plot showing the stable carbon and hydrogen isotope composition of methane. Figure 4B: Schoell (1983) genetic classification plot showing the methane stable carbon isotope composition and the wetness (% C_2+) of the gas sample. Figure 4C: Genetic classification plot after Bernard and others showing the methane carbon isotope composition vs the ratio of $C_1/(C_2-C_3)$.

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