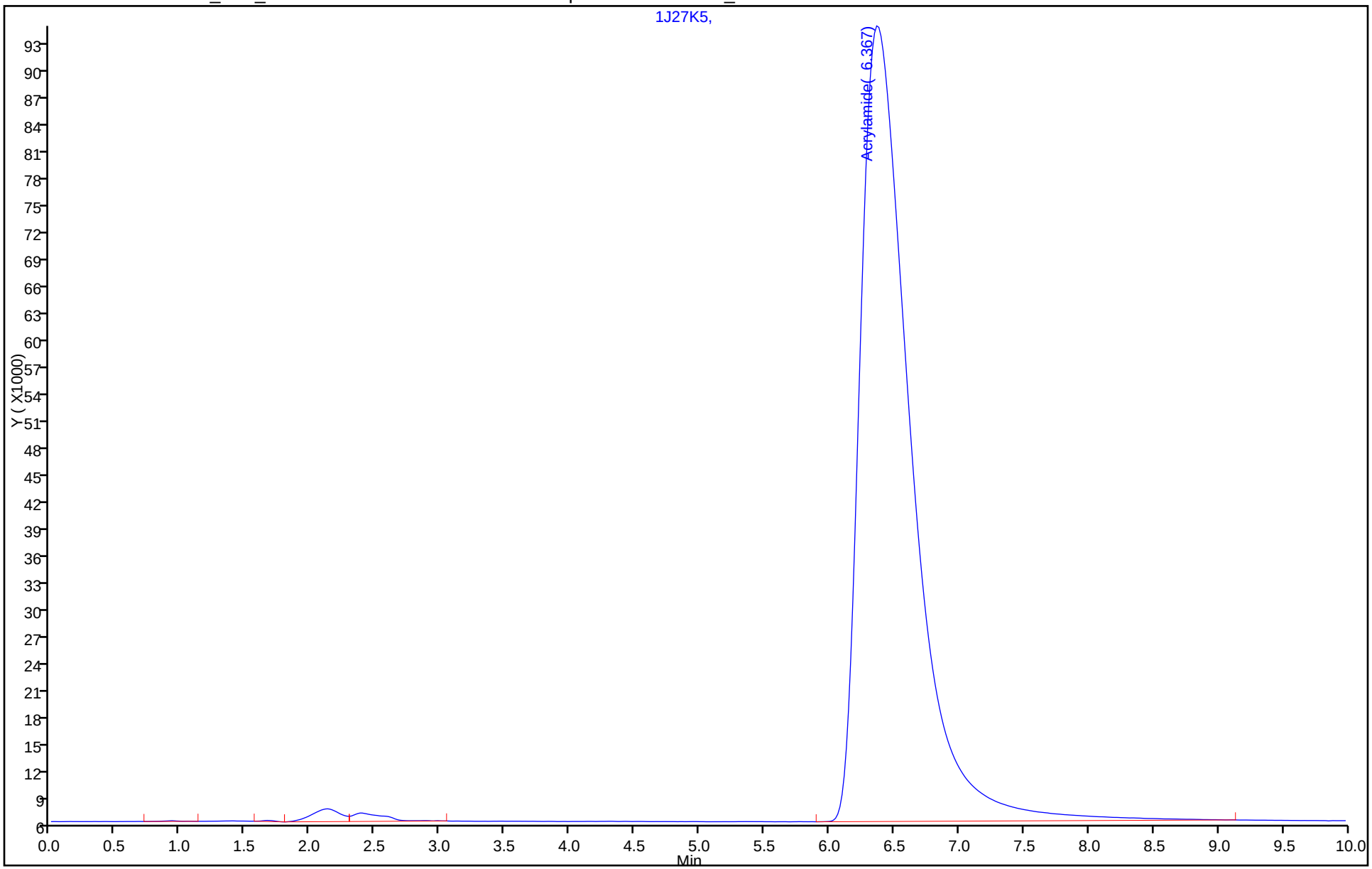
Report Date: 28-Oct-2014 12:27:32 Chrom Revision: 2.2 07-Oct-2014 12:16:06

TestAmerica Tallahassee

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K5.d				
Injection Date:	27-Oct-2014 14:40:46	Instrument ID:	CHLCK	Operator ID:	RD
Lims ID:	IC			Worklist Smp#:	5
Client ID:					
Injection Vol:	1.0 ul	Dil. Factor:	1.0000	ALS Bottle#:	0
Method:	8316_C18_CHLCK	Limit Group:	LC-8316_ICAL		



TestAmerica Tallahassee
Target Compound Quantitation Report

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K6.d				
Lims ID:	IC				
Client ID:					
Sample Type:	IC	Calib Level:	5		
Inject. Date:	27-Oct-2014 14:52:04	ALS Bottle#:	0	Worklist Smp#:	6
Injection Vol:	1.0 ul	Dil. Factor:	1.0000		
Sample Info:	C5_00087				
Misc. Info.:	FFFFFF				
Operator ID:	RD	Instrument ID:	CHLCK		
Sublist:	chrom-8316_C18_CHLCK*sub1				
Method:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\8316_C18_CHLCK.m				
Limit Group:	LC-8316_ICAL				
Last Update:	28-Oct-2014 12:27:33	Calib Date:	27-Oct-2014 14:52:04		
Integrator:	Falcon				
Quant Method:	External Standard	Quant By:	Initial Calibration		
Last ICal File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K6.d				
Column 1 :			Det: 1G25I18		
Process Host:	XAWRK024				

Compound	RT (min.)	Exp RT (min.)	Dlt RT (min.)	Response	Cal Amt ug/ml	OnCol Amt ug/ml	Flags
1 Acrylamide	6.300	6.383	-0.083	338445H	10.0	9.72	

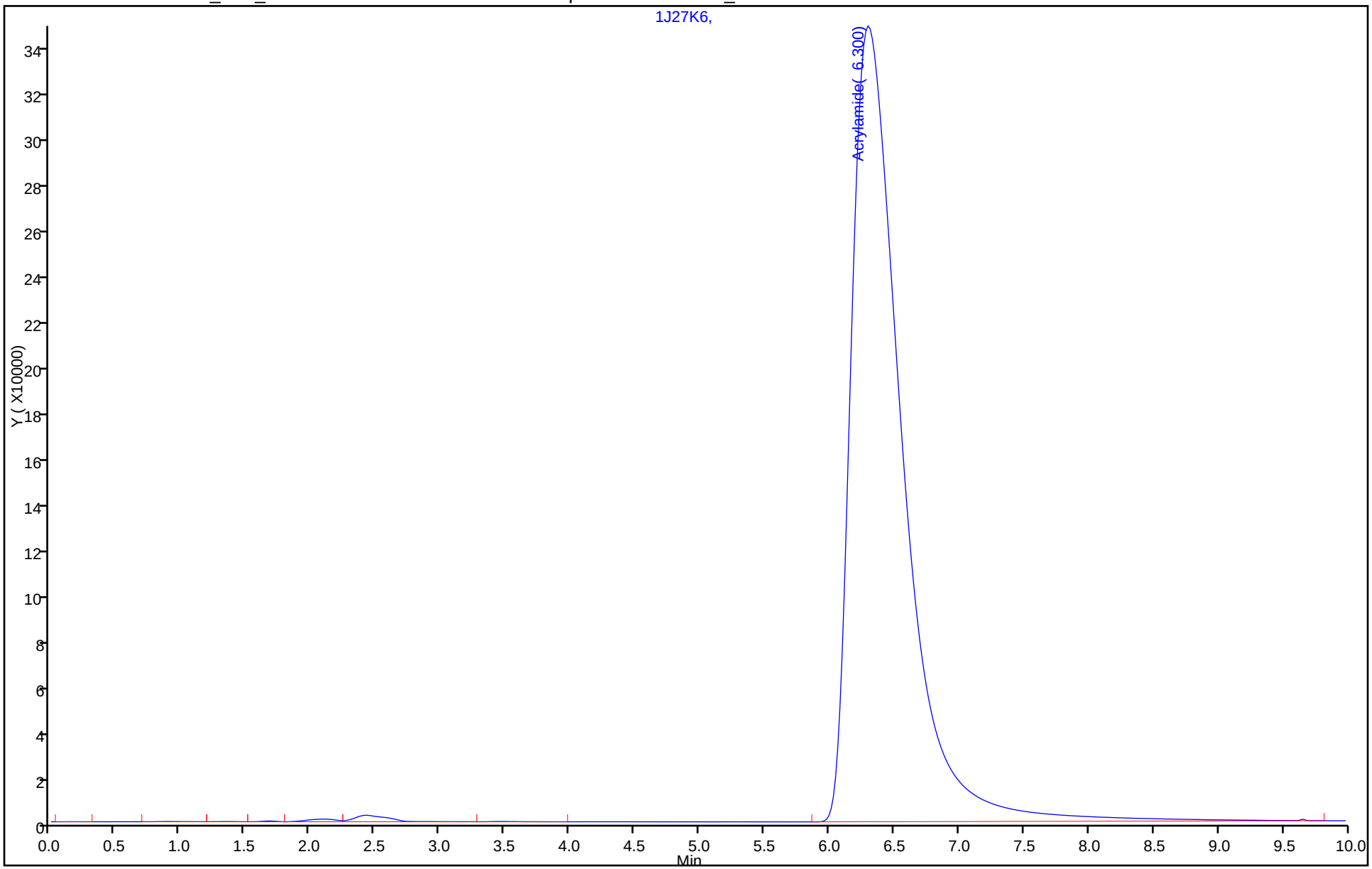
Reagents:

LCI_8316_C5_00087 Amount Added: 1.00 Units: mL

Report Date: 28-Oct-2014 12:27:33 Chrom Revision: 2.2 07-Oct-2014 12:16:06

TestAmerica Tallahassee

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K6.d				
Injection Date:	27-Oct-2014 14:52:04	Instrument ID:	CHLCK	Operator ID:	RD
Lims ID:	IC			Worklist Smp#:	6
Client ID:					
Injection Vol:	1.0 ul	Dil. Factor:	1.0000	ALS Bottle#:	0
Method:	8316_C18_CHLCK	Limit Group:	LC-8316_ICAL		



FORM VII
HPLC/IC CONTINUING CALIBRATION DATA

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Lab Sample ID: ICV 640-112716/7 Calibration Date: 10/28/2014 10:31

Instrument ID: CHLCI Calib Start Date: 10/28/2014 09:35

GC Column: LC-CN ID: 4.60(mm) Calib End Date: 10/28/2014 10:15

Lab File ID: 1J28I7.d Conc. Units: ug/mL

ANALYTE	CURVE TYPE	AVE CF	CF	MIN CF	CALC AMOUNT	SPIKE AMOUNT	%D	MAX %D
Acrylamide	Ave	54590	60978		2.79	2.50	11.7	30.0

FORM VII 8316

FORM VII
HPLC/IC CONTINUING CALIBRATION RETENTION TIME SUMMARY

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Lab Sample ID: ICV 640-112716/7 Calibration Date: 10/28/2014 10:31

Instrument ID: CHLCI Calib Start Date: 10/28/2014 09:35

GC Column: LC-CN ID: 4.60(mm) Calib End Date: 10/28/2014 10:15

Lab File ID: 1J28I7.d

Analyte	RT	RT WINDOW	
		FROM	TO
Acrylamide	4.30	4.17	4.43

Form VII 8316

TestAmerica Tallahassee
Target Compound Quantitation Report

Data File:	\\TALCHROM\ChromData\CHLCI\20141028-718.b\1J28I7.d				
Lims ID:	ICV				
Client ID:					
Sample Type:	ICV				
Inject. Date:	28-Oct-2014 10:31:03	ALS Bottle#:	0	Worklist Smp#:	7
Injection Vol:	50.0 ul	Dil. Factor:	1.0000		
Sample Info:	ICV_00067				
Misc. Info.:	FFFFFF				
Operator ID:	DS	Instrument ID:	CHLCI		
Sublist:					
Method:	\\TALCHROM\ChromData\CHLCI\20141028-718.b\8316_CN_1_CHLCI.m				
Limit Group:	LC-8316_ICAL				
Last Update:	28-Oct-2014 12:28:36	Calib Date:	28-Oct-2014 10:15:21		
Integrator:	Falcon				
Quant Method:	External Standard	Quant By:	Initial Calibration		
Last ICal File:	\\TALCHROM\ChromData\CHLCI\20141028-718.b\1J28I6.d				
Column 1 :			Det: 1G25I18		
Process Host:	XAWRK024				

Compound	RT (min.)	Exp RT (min.)	Dlt RT (min.)	Response	Cal Amt ug/ml	OnCol Amt ug/ml	Flags
1 Acrylamide	4.300	4.300	0.000	152446H	2.50	2.79	

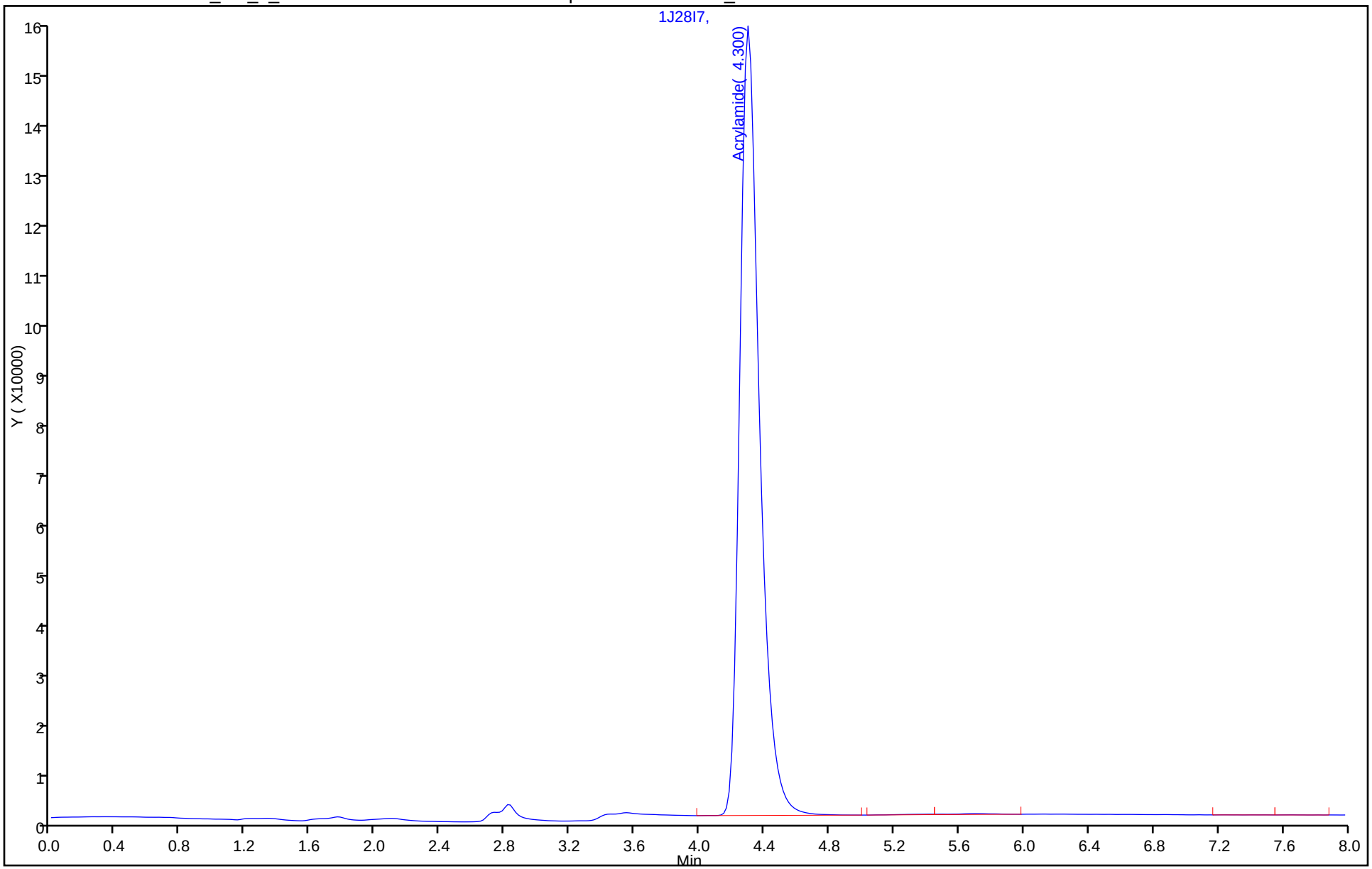
Reagents:

LCI_8316_ICV_00067 Amount Added: 1.00 Units: mL

Report Date: 28-Oct-2014 12:28:36 Chrom Revision: 2.2 07-Oct-2014 12:16:06

TestAmerica Tallahassee

Data File:	\\TALCHROM\ChromData\CHLCI\20141028-718.b\1J28I7.d				
Injection Date:	28-Oct-2014 10:31:03	Instrument ID:	CHLCI	Operator ID:	DS
Lims ID:	ICV			Worklist Smp#:	7
Client ID:					
Injection Vol:	50.0 ul	Dil. Factor:	1.0000	ALS Bottle#:	0
Method:	8316_CN_1_CHLCI	Limit Group:	LC-8316_ICAL		



FORM VII
HPLC/IC CONTINUING CALIBRATION DATA

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Lab Sample ID: CCV 640-112716/13 Calibration Date: 10/28/2014 11:40

Instrument ID: CHLCI Calib Start Date: 10/28/2014 09:35

GC Column: LC-CN ID: 4.60(mm) Calib End Date: 10/28/2014 10:15

Lab File ID: 1J28I13.d Conc. Units: ug/mL

ANALYTE	CURVE TYPE	AVE CF	CF	MIN CF	CALC AMOUNT	SPIKE AMOUNT	%D	MAX %D
Acrylamide	Ave	54590	55962		1.03	1.00	2.5	15.0

FORM VII 8316

FORM VII
HPLC/IC CONTINUING CALIBRATION RETENTION TIME SUMMARY

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Lab Sample ID: CCV 640-112716/13 Calibration Date: 10/28/2014 11:40

Instrument ID: CHLCI Calib Start Date: 10/28/2014 09:35

GC Column: LC-CN ID: 4.60(mm) Calib End Date: 10/28/2014 10:15

Lab File ID: 1J28I13.d

Analyte	RT	RT WINDOW	
		FROM	TO
Acrylamide	4.30	4.17	4.43

Form VII 8316

TestAmerica Tallahassee
Target Compound Quantitation Report

Data File: \\TALCHROM\ChromData\CHLCI\20141028-718.b\1J28I13.d
Lims ID: CCV
Client ID:
Sample Type: CCV
Inject. Date: 28-Oct-2014 11:40:37 ALS Bottle#: 0 Worklist Smp#: 13
Injection Vol: 50.0 ul Dil. Factor: 1.0000
Sample Info: M3_00099
Misc. Info.: FFFFFF
Operator ID: DS Instrument ID: CHLCI
Sublist: chrom-8316_CN_1_CHLCI*sub1

Method: \\TALCHROM\ChromData\CHLCI\20141028-718.b\8316_CN_1_CHLCI.m
Limit Group: LC-8316_ICAL
Last Update: 28-Oct-2014 12:28:38 Calib Date: 28-Oct-2014 10:15:21
Integrator: Falcon
Quant Method: External Standard Quant By: Initial Calibration
Last ICal File: \\TALCHROM\ChromData\CHLCI\20141028-718.b\1J28I6.d

Column 1 : Det: 1G25I18
Process Host: XAWRK024

Compound	RT (min.)	Exp RT (min.)	Dlt RT (min.)	Response	Cal Amt ug/ml	OnCol Amt ug/ml	Flags
1 Acrylamide	4.300	4.300	0.000	55975H	1.00	1.03	

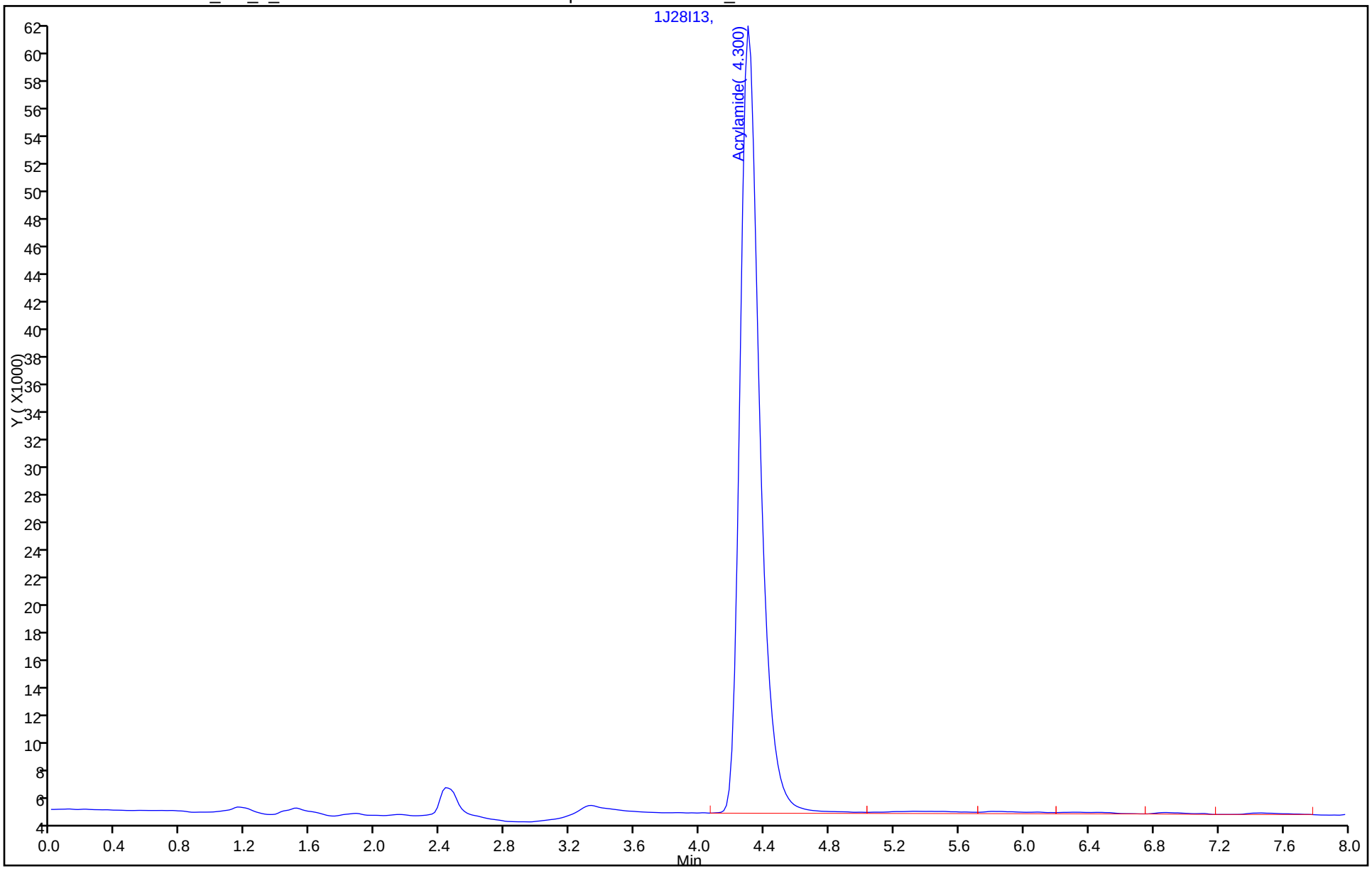
Reagents:

LCI_8316_C3_00099 Amount Added: 1.00 Units: mL

Report Date: 28-Oct-2014 12:28:38 Chrom Revision: 2.2 07-Oct-2014 12:16:06

TestAmerica Tallahassee

Data File:	\\TALCHROM\ChromData\CHLCI\20141028-718.b\1J28I13.d				
Injection Date:	28-Oct-2014 11:40:37	Instrument ID:	CHLCI	Operator ID:	DS
Lims ID:	CCV			Worklist Smp#:	13
Client ID:					
Injection Vol:	50.0 ul	Dil. Factor:	1.0000	ALS Bottle#:	0
Method:	8316_CN_1_CHLCI	Limit Group:	LC-8316_ICAL		



FORM VII
HPLC/IC CONTINUING CALIBRATION DATA

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Lab Sample ID: ICV 640-112706/7 Calibration Date: 10/27/2014 15:03

Instrument ID: CHLCK Calib Start Date: 10/27/2014 14:06

GC Column: LC-C18 ID: 4.60(mm) Calib End Date: 10/27/2014 14:52

Lab File ID: 1J27K7.d Conc. Units: ug/mL

ANALYTE	CURVE TYPE	AVE CF	CF	MIN CF	CALC AMOUNT	SPIKE AMOUNT	%D	MAX %D
Acrylamide	Lin2		36340		2.62	2.50	4.6	30.0

FORM VII 8316

FORM VII
HPLC/IC CONTINUING CALIBRATION RETENTION TIME SUMMARY

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Lab Sample ID: ICV 640-112706/7 Calibration Date: 10/27/2014 15:03

Instrument ID: CHLCK Calib Start Date: 10/27/2014 14:06

GC Column: LC-C18 ID: 4.60(mm) Calib End Date: 10/27/2014 14:52

Lab File ID: 1J27K7.d

Analyte	RT	RT WINDOW	
		FROM	TO
Acrylamide	6.35	6.19	6.58

Form VII 8316

TestAmerica Tallahassee
Target Compound Quantitation Report

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K7.d				
Lims ID:	ICV				
Client ID:					
Sample Type:	ICV				
Inject. Date:	27-Oct-2014 15:03:23	ALS Bottle#:	0	Worklist Smp#:	7
Injection Vol:	1.0 ul	Dil. Factor:	1.0000		
Sample Info:	ICV_00067				
Misc. Info.:	FFFFFF				
Operator ID:	RD	Instrument ID:	CHLCK		
Sublist:					
Method:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\8316_C18_CHLCK.m				
Limit Group:	LC-8316_ICAL				
Last Update:	28-Oct-2014 12:27:33	Calib Date:	27-Oct-2014 14:52:04		
Integrator:	Falcon				
Quant Method:	External Standard	Quant By:	Initial Calibration		
Last ICal File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K6.d				
Column 1 :			Det: 1G25I18		
Process Host:	XAWRK024				

Compound	RT (min.)	Exp RT (min.)	Dlt RT (min.)	Response	Cal Amt ug/ml	OnCol Amt ug/ml	Flags
1 Acrylamide	6.350	6.383	-0.033	90851H	2.50	2.62	

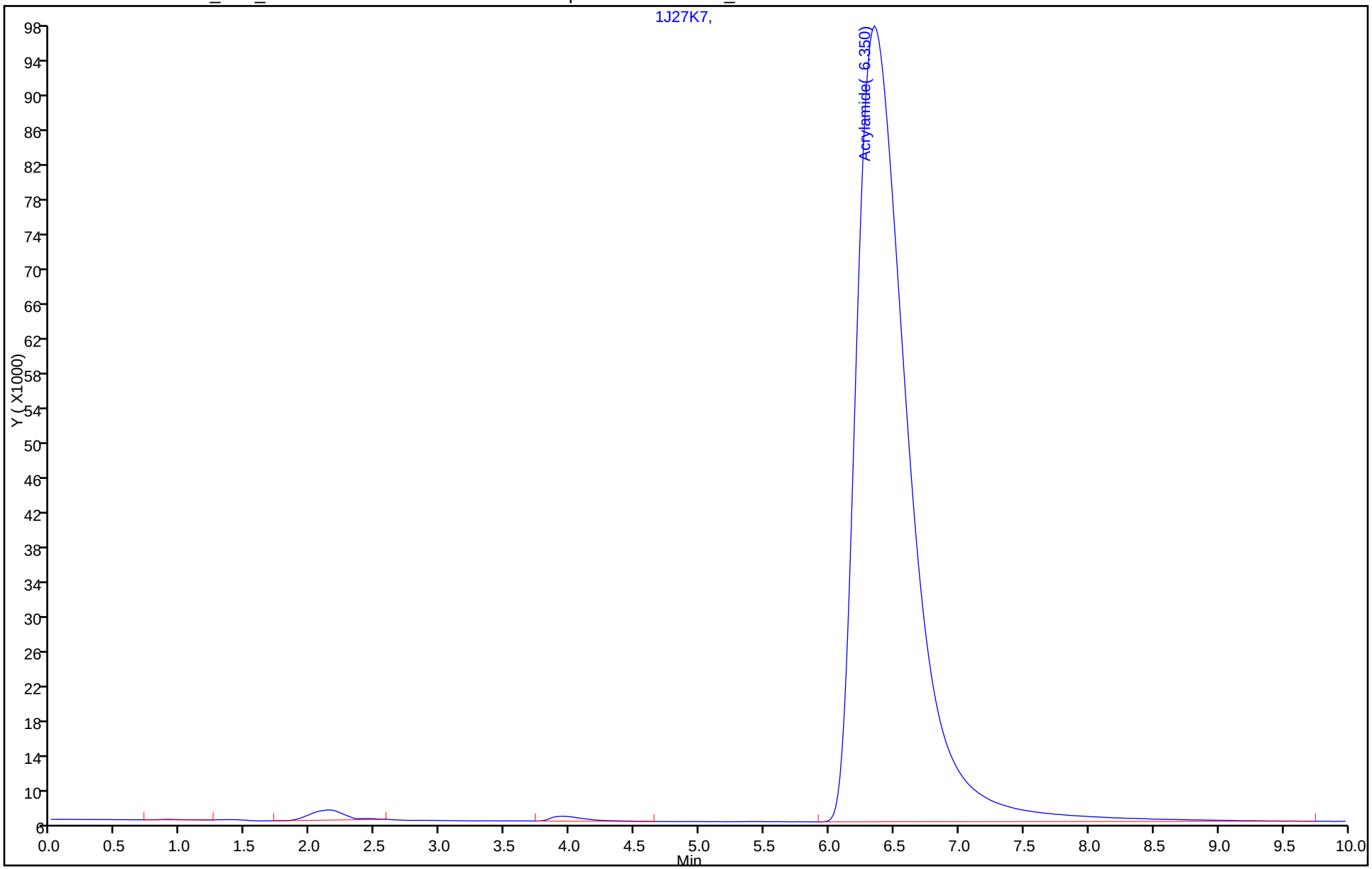
Reagents:

LCI_8316_ICV_00067 Amount Added: 1.00 Units: mL

Report Date: 28-Oct-2014 12:27:33 Chrom Revision: 2.2 07-Oct-2014 12:16:06

TestAmerica Tallahassee

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K7.d				
Injection Date:	27-Oct-2014 15:03:23	Instrument ID:	CHLCK	Operator ID:	RD
Lims ID:	ICV			Worklist Smp#:	7
Client ID:					
Injection Vol:	1.0 ul	Dil. Factor:	1.0000	ALS Bottle#:	0
Method:	8316_C18_CHLCK	Limit Group:	LC-8316_ICAL		



FORM VII
HPLC/IC CONTINUING CALIBRATION DATA

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Lab Sample ID: CCV 640-112706/21 Calibration Date: 10/27/2014 18:03

Instrument ID: CHLCK Calib Start Date: 10/27/2014 14:06

GC Column: LC-C18 ID: 4.60(mm) Calib End Date: 10/27/2014 14:52

Lab File ID: 1J27K21.d Conc. Units: ug/mL

ANALYTE	CURVE TYPE	AVE CF	CF	MIN CF	CALC AMOUNT	SPIKE AMOUNT	%D	MAX %D
Acrylamide	Lin2		31036		0.900	1.00	-10.0	15.0

FORM VII
HPLC/IC CONTINUING CALIBRATION RETENTION TIME SUMMARY

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Lab Sample ID: CCV 640-112706/21 Calibration Date: 10/27/2014 18:03

Instrument ID: CHLCK Calib Start Date: 10/27/2014 14:06

GC Column: LC-C18 ID: 4.60(mm) Calib End Date: 10/27/2014 14:52

Lab File ID: 1J27K21.d

Analyte	RT	RT WINDOW	
		FROM	TO
Acrylamide	6.23	6.05	6.42

TestAmerica Tallahassee
Target Compound Quantitation Report

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K21.d				
Lims ID:	CCV				
Client ID:					
Sample Type:	CCV				
Inject. Date:	27-Oct-2014 18:03:59	ALS Bottle#:	0	Worklist Smp#:	21
Injection Vol:	1.0 ul	Dil. Factor:	1.0000		
Sample Info:	M3_00099				
Misc. Info.:	FFFFFF				
Operator ID:	RD	Instrument ID:	CHLCK		
Sublist:	chrom-8316_C18_CHLCK*sub1				
Method:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\8316_C18_CHLCK.m				
Limit Group:	LC-8316_ICAL				
Last Update:	28-Oct-2014 12:27:37	Calib Date:	27-Oct-2014 14:52:04		
Integrator:	Falcon				
Quant Method:	External Standard	Quant By:	Initial Calibration		
Last ICal File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K6.d				
Column 1 :			Det: 1G25I18		
Process Host:	XAWRK024				

Compound	RT (min.)	Exp RT (min.)	Dlt RT (min.)	Response	Cal Amt ug/ml	OnCol Amt ug/ml	Flags
1 Acrylamide	6.233	6.233	0.000	31043H	1.00	0.9002	

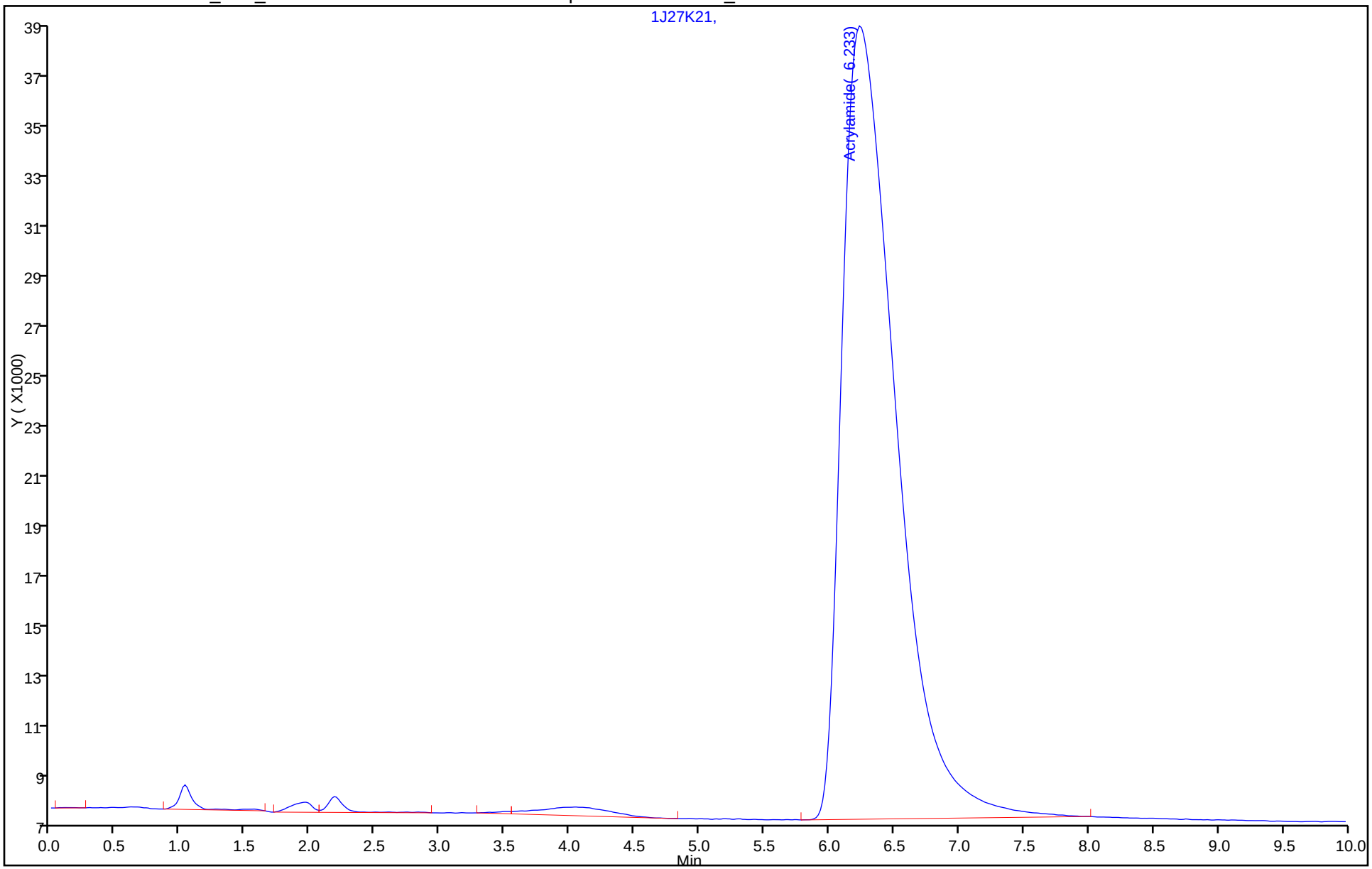
Reagents:

LCI_8316_C3_00099 Amount Added: 1.00 Units: mL

Report Date: 28-Oct-2014 12:27:37 Chrom Revision: 2.2 07-Oct-2014 12:16:06

TestAmerica Tallahassee

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K21.d				
Injection Date:	27-Oct-2014 18:03:59	Instrument ID:	CHLCK	Operator ID:	RD
Lims ID:	CCV			Worklist Smp#:	21
Client ID:					
Injection Vol:	1.0 ul	Dil. Factor:	1.0000	ALS Bottle#:	0
Method:	8316_C18_CHLCK	Limit Group:	LC-8316_ICAL		



FORM I
HPLC/IC ORGANICS ANALYSIS DATA SHEET

Lab Name: TestAmerica Tallahassee
Job No.: 640-49437-1
SDG No.: 261593
Client Sample ID:
Lab Sample ID: MB 640-112288/1-A
Matrix: Water
Lab File ID: 1J27K8.d
Analysis Method: 8316
Date Collected:
Extraction Method: Filtration
Date Extracted: 10/13/2014 08:24
Sample wt/vol: 10(mL)
Date Analyzed: 10/27/2014 15:36
Con. Extract Vol.: 10(mL)
Dilution Factor: 1
Injection Volume: 1(uL)
GC Column: LC-C18 ID: 4.6(mm)
% Moisture:
GPC Cleanup:(Y/N) N
Analysis Batch No.: 112706
Units: ug/L

CAS NO.	COMPOUND NAME	RESULT	Q	RL	MDL
79-06-1	Acrylamide	ND		100	9.5

TestAmerica Tallahassee
Target Compound Quantitation Report

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K8.d				
Lims ID:	MB 640-112288/1-A				
Client ID:					
Sample Type:	MB				
Inject. Date:	27-Oct-2014 15:36:59	ALS Bottle#:	0	Worklist Smp#:	8
Injection Vol:	1.0 ul	Dil. Factor:	1.0000		
Sample Info:	MB 640-112288/1A				
Misc. Info.:	FFFFFF				
Operator ID:	RD	Instrument ID:	CHLCK		
Method:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\8316_C18_CHLCK.m				
Limit Group:	LC-8316_ICAL				
Last Update:	28-Oct-2014 12:27:33	Calib Date:	27-Oct-2014 14:52:04		
Integrator:	Falcon				
Quant Method:	External Standard	Quant By:	Initial Calibration		
Last ICal File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K6.d				
Column 1 :			Det: 1G25I18		
Process Host:	XAWRK024				

Compound	RT (min.)	Exp RT (min.)	Dlt RT (min.)	Response	Cal Amt ug/ml	OnCol Amt ug/ml	Flags
1 Acrylamide		6.383				ND	

QC Flag Legend

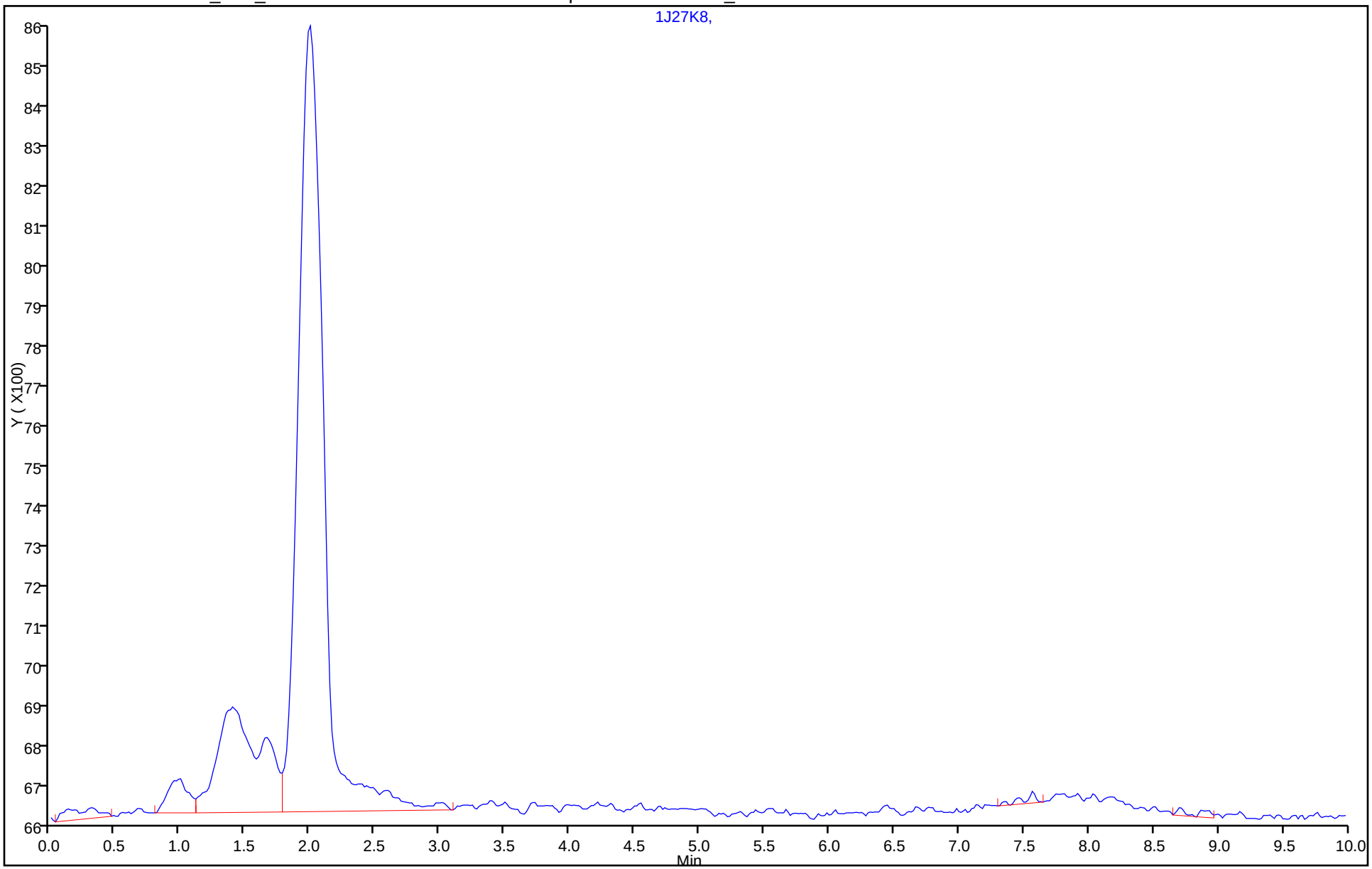
Processing Flags

ND - Not Detected or Marked ND

Report Date: 28-Oct-2014 12:27:33 Chrom Revision: 2.2 07-Oct-2014 12:16:06

TestAmerica Tallahassee

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K8.d				
Injection Date:	27-Oct-2014 15:36:59	Instrument ID:	CHLCK	Operator ID:	RD
Lims ID:	MB 640-112288/1-A			Worklist Smp#:	8
Client ID:					
Injection Vol:	1.0 ul	Dil. Factor:	1.0000	ALS Bottle#:	0
Method:	8316_C18_CHLCK	Limit Group:	LC-8316_ICAL		



FORM I
HPLC/IC ORGANICS ANALYSIS DATA SHEET

Lab Name: TestAmerica Tallahassee
Job No.: 640-49437-1
SDG No.: 261593
Client Sample ID:
Lab Sample ID: LCS 640-112288/2-A
Matrix: Water
Lab File ID: 1J27K9.d
Analysis Method: 8316
Date Collected:
Extraction Method: Filtration
Date Extracted: 10/13/2014 08:24
Sample wt/vol: 10(mL)
Date Analyzed: 10/27/2014 15:48
Con. Extract Vol.: 10(mL)
Dilution Factor: 1
Injection Volume: 1(uL)
GC Column: LC-C18 ID: 4.6(mm)
% Moisture:
GPC Cleanup:(Y/N) N
Analysis Batch No.: 112706
Units: ug/L

CAS NO.	COMPOUND NAME	RESULT	Q	RL	MDL
79-06-1	Acrylamide	537		100	9.5

TestAmerica Tallahassee
Target Compound Quantitation Report

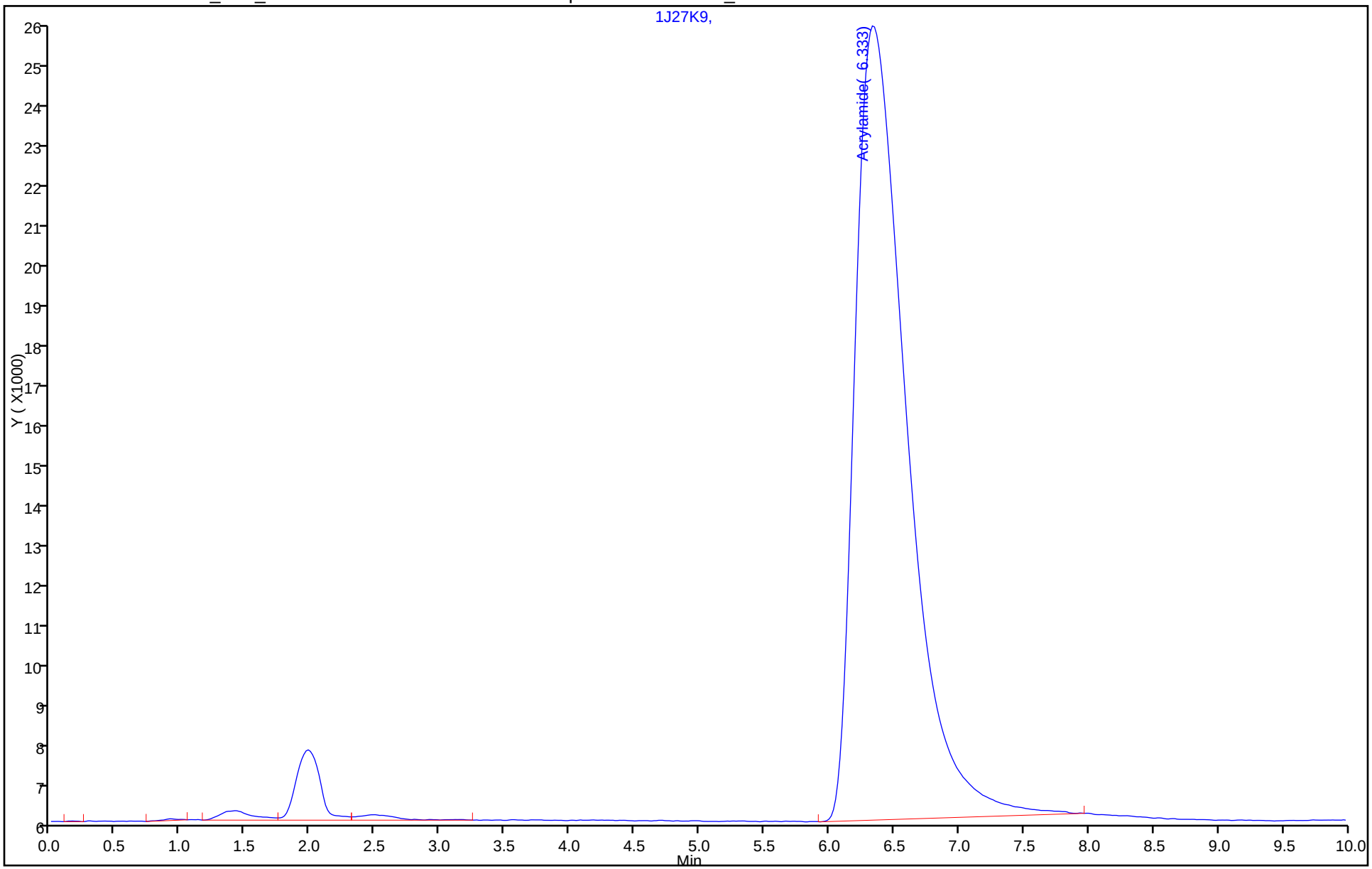
Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K9.d				
Lims ID:	LCS 640-112288/2-A				
Client ID:					
Sample Type:	LCS				
Inject. Date:	27-Oct-2014 15:48:17	ALS Bottle#:	0	Worklist Smp#:	9
Injection Vol:	1.0 ul	Dil. Factor:	1.0000		
Sample Info:	LCS 640-112288/2A				
Misc. Info.:	FFFFFF				
Operator ID:	RD	Instrument ID:	CHLCK		
Method:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\8316_C18_CHLCK.m				
Limit Group:	LC-8316_ICAL				
Last Update:	28-Oct-2014 12:27:33	Calib Date:	27-Oct-2014 14:52:04		
Integrator:	Falcon				
Quant Method:	External Standard	Quant By:	Initial Calibration		
Last ICal File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K6.d				
Column 1 :			Det: 1G25I18		
Process Host:	XAWRK024				

Compound	RT (min.)	Exp RT (min.)	Dlt RT (min.)	Response	Cal Amt ug/ml	OnCol Amt ug/ml	Flags
1 Acrylamide	6.333	6.383	-0.050	18373H	0.4999	0.5367	

Report Date: 28-Oct-2014 12:27:34 Chrom Revision: 2.2 07-Oct-2014 12:16:06

TestAmerica Tallahassee

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K9.d				
Injection Date:	27-Oct-2014 15:48:17	Instrument ID:	CHLCK	Operator ID:	RD
Lims ID:	LCS 640-112288/2-A			Worklist Smp#:	9
Client ID:					
Injection Vol:	1.0 ul	Dil. Factor:	1.0000	ALS Bottle#:	0
Method:	8316_C18_CHLCK	Limit Group:	LC-8316_ICAL		



FORM I
HPLC/IC ORGANICS ANALYSIS DATA SHEET

Lab Name: TestAmerica Tallahassee
Job No.: 640-49437-1
SDG No.: 261593
Client Sample ID:
Lab Sample ID: LCSD 640-112288/3-A
Matrix: Water
Lab File ID: 1J27K10.d
Analysis Method: 8316
Date Collected:
Extraction Method: Filtration
Date Extracted: 10/13/2014 08:24
Sample wt/vol: 10(mL)
Date Analyzed: 10/27/2014 15:59
Con. Extract Vol.: 10(mL)
Dilution Factor: 1
Injection Volume: 1(uL)
GC Column: LC-C18 ID: 4.6(mm)
% Moisture:
GPC Cleanup:(Y/N) N
Analysis Batch No.: 112706
Units: ug/L

CAS NO.	COMPOUND NAME	RESULT	Q	RL	MDL
79-06-1	Acrylamide	535		100	9.5

TestAmerica Tallahassee
Target Compound Quantitation Report

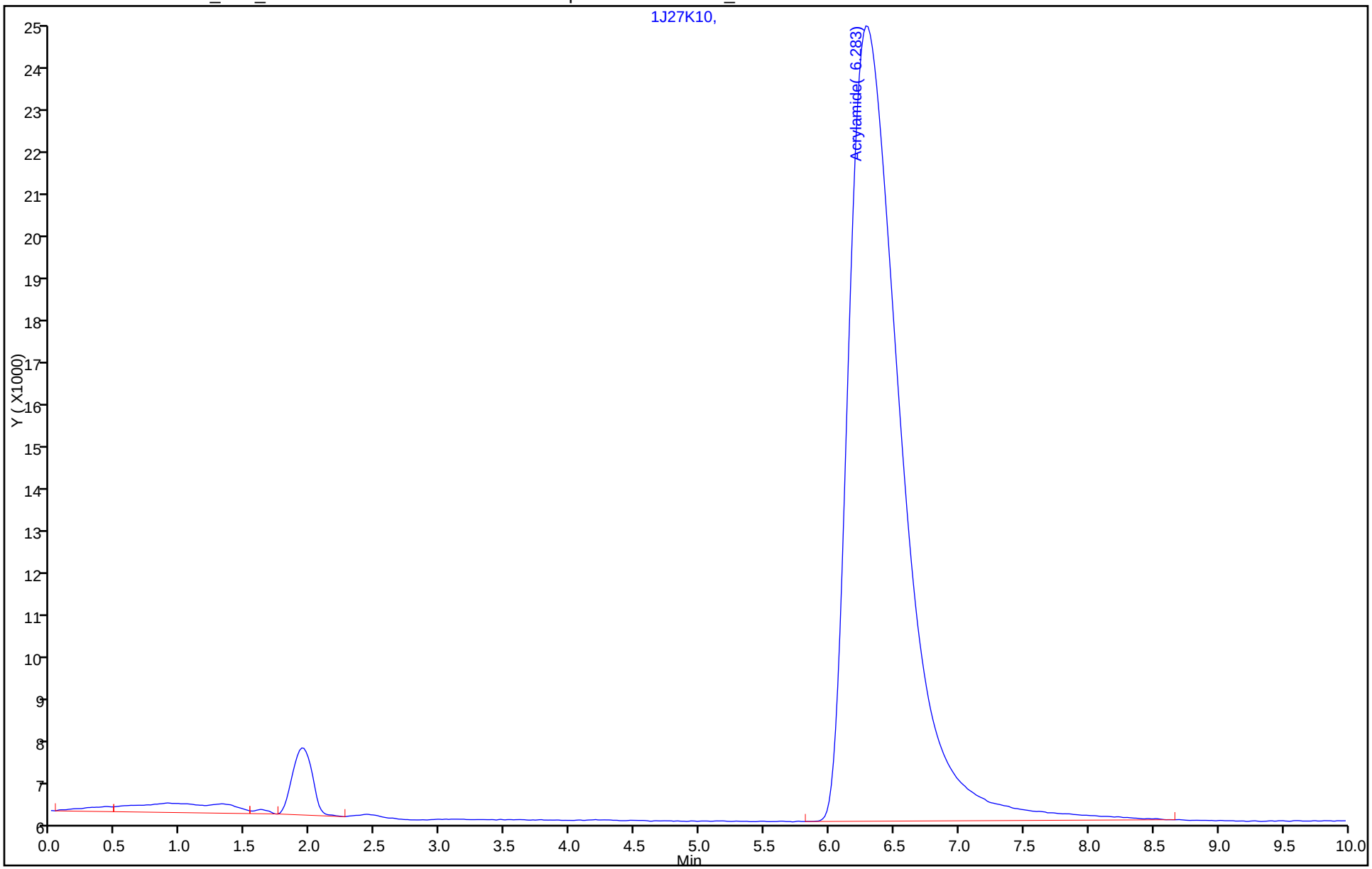
Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K10.d				
Lims ID:	LCSD 640-112288/3-A				
Client ID:					
Sample Type:	LCSD				
Inject. Date:	27-Oct-2014 15:59:35	ALS Bottle#:	0	Worklist Smp#:	10
Injection Vol:	1.0 ul	Dil. Factor:	1.0000		
Sample Info:	LCSD 640-112288/3A				
Misc. Info.:	FFFFFF				
Operator ID:	RD	Instrument ID:	CHLCK		
Method:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\8316_C18_CHLCK.m				
Limit Group:	LC-8316_ICAL				
Last Update:	28-Oct-2014 12:27:33	Calib Date:	27-Oct-2014 14:52:04		
Integrator:	Falcon				
Quant Method:	External Standard	Quant By:	Initial Calibration		
Last ICal File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K6.d				
Column 1 :			Det: 1G25I18		
Process Host:	XAWRK024				

Compound	RT (min.)	Exp RT (min.)	Dlt RT (min.)	Response	Cal Amt ug/ml	OnCol Amt ug/ml	Flags
1 Acrylamide	6.283	6.383	-0.100	18306H	0.4999	0.5348	

Report Date: 28-Oct-2014 12:27:34 Chrom Revision: 2.2 07-Oct-2014 12:16:06

TestAmerica Tallahassee

Data File:	\\TALCHROM\ChromData\CHLCK\20141027-715.b\1J27K10.d				
Injection Date:	27-Oct-2014 15:59:35	Instrument ID:	CHLCK	Operator ID:	RD
Lims ID:	LCSD 640-112288/3-A			Worklist Smp#:	10
Client ID:					
Injection Vol:	1.0 ul	Dil. Factor:	1.0000	ALS Bottle#:	0
Method:	8316_C18_CHLCK	Limit Group:	LC-8316_ICAL		



HPLC/IC ANALYSIS RUN LOG

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Instrument ID: CHLCI Start Date: 10/28/2014 09:35

Analysis Batch Number: 112716 End Date: 10/28/2014 11:40

LAB SAMPLE ID	CLIENT SAMPLE ID	DATE ANALYZED	DILUTION FACTOR	LAB FILE ID	COLUMN ID
IC 640-112716/2		10/28/2014 09:35	1	1J28I2.d	LC-CN 4.6(mm)
IC 640-112716/3		10/28/2014 09:45	1	1J28I3.d	LC-CN 4.6(mm)
IC 640-112716/4		10/28/2014 09:55	1	1J28I4.d	LC-CN 4.6(mm)
IC 640-112716/5		10/28/2014 10:05	1	1J28I5.d	LC-CN 4.6(mm)
IC 640-112716/6		10/28/2014 10:15	1	1J28I6.d	LC-CN 4.6(mm)
ICV 640-112716/7		10/28/2014 10:31	1	1J28I7.d	LC-CN 4.6(mm)
MB 640-112288/1-A		10/28/2014 10:50	1	1J28I8.d	LC-CN 4.6(mm)
ZZZZZ		10/28/2014 11:00	1		LC-CN 4.6(mm)
ZZZZZ		10/28/2014 11:10	1		LC-CN 4.6(mm)
640-49437-1	FB-2-10092014	10/28/2014 11:20	1	1J28I11.d	LC-CN 4.6(mm)
ZZZZZ		10/28/2014 11:30	1		LC-CN 4.6(mm)
CCV 640-112716/13		10/28/2014 11:40	1	1J28I13.d	LC-CN 4.6(mm)

8316

HPLC/IC ANALYSIS RUN LOG

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Instrument ID: CHLCK Start Date: 10/27/2014 14:06

Analysis Batch Number: 112706 End Date: 10/27/2014 18:03

LAB SAMPLE ID	CLIENT SAMPLE ID	DATE ANALYZED	DILUTION FACTOR	LAB FILE ID	COLUMN ID
IC 640-112706/2		10/27/2014 14:06	1	1J27K2.d	LC-C18 4.6(mm)
IC 640-112706/3		10/27/2014 14:18	1	1J27K3.d	LC-C18 4.6(mm)
IC 640-112706/4		10/27/2014 14:29	1	1J27K4.d	LC-C18 4.6(mm)
IC 640-112706/5		10/27/2014 14:40	1	1J27K5.d	LC-C18 4.6(mm)
IC 640-112706/6		10/27/2014 14:52	1	1J27K6.d	LC-C18 4.6(mm)
ICV 640-112706/7		10/27/2014 15:03	1	1J27K7.d	LC-C18 4.6(mm)
MB 640-112288/1-A		10/27/2014 15:36	1	1J27K8.d	LC-C18 4.6(mm)
LCS 640-112288/2-A		10/27/2014 15:48	1	1J27K9.d	LC-C18 4.6(mm)
LCSD 640-112288/3-A		10/27/2014 15:59	1	1J27K10.d	LC-C18 4.6(mm)
ZZZZZ		10/27/2014 16:10	1		LC-C18 4.6(mm)
ZZZZZ		10/27/2014 16:22	1		LC-C18 4.6(mm)
ZZZZZ		10/27/2014 16:33	1		LC-C18 4.6(mm)
640-49437-1	FB-2-10092014	10/27/2014 16:44	1	1J27K14.d	LC-C18 4.6(mm)
ZZZZZ		10/27/2014 16:56	1		LC-C18 4.6(mm)
ZZZZZ		10/27/2014 17:07	1		LC-C18 4.6(mm)
ZZZZZ		10/27/2014 17:18	1		LC-C18 4.6(mm)
ZZZZZ		10/27/2014 17:30	1		LC-C18 4.6(mm)
ZZZZZ		10/27/2014 17:41	1		LC-C18 4.6(mm)
ZZZZZ		10/27/2014 17:52	1		LC-C18 4.6(mm)
CCV 640-112706/21		10/27/2014 18:03	1	1J27K21.d	LC-C18 4.6(mm)

8316

HPLC/IC BATCH WORKSHEET

Lab Name: TestAmerica Tallahassee Job No.: 640-49437-1

SDG No.: 261593

Batch Number: 112288 Batch Start Date: 10/13/14 08:24 Batch Analyst: Smith, Daniel N

Batch Method: Filtration Batch End Date: 10/13/14 09:16

Lab Sample ID	Client Sample ID	Method Chain	Basis	InitialAmount	FinalAmount	LCI8316SPK 00188			
MB 640-112288/1		Filtration, 8316		10 mL	10 mL				
LCS 640-112288/2		Filtration, 8316		10 mL	10 mL	50 uL			
LCSD 640-112288/3		Filtration, 8316		10 mL	10 mL	50 uL			
640-49437-A-1	FB-2-10092014	Filtration, 8316	T	10 mL	10 mL				

Batch Notes	
Batch Comment	8316
Person's name who witnessed reagent drop	DS

Basis	Basis Description
T	Total/NA

The pound sign (#) in the amount added field denotes that the reagent was used undiluted. All calculations are performed using the stated concentration for this reagent.

Shipping and Receiving Documents

Curtis & Tompkins, Ltd.
Analytical Laboratories, Since 1878
2323 Fifth Street
Berkeley, CA 94710
(510) 486-0900
(510) 486-0532

640-49437

Project Number: 261593
Site: Pavillion, WY

Subcontract Laboratory:
TA Tallahassee
2846 Industrial Plaza Drive
Tallahassee, FL 32301
(850) 878-3994

Results due: Report Level: III

Please send report to: Will S Rice (will.rice@ctberk.com)
*** Please report using Sample ID rather than C&T Lab #.

Sample ID	Sampled	Matrix	Analysis	C&T Lab #	Comments
FB-2-10092014	10/09 11:15	Water	ACRYLAMIDE	261593-001	

640-49437 Chain of Custody

Notes:	Relinquished By:	Received By:
	Date/Time: 10/10/14 @ 1530	Date/Time: 10-11-2014 0915
3.4°C	Date/Time:	Date/Time:

Signature on this form constitutes a firm Purchase Order for the services requested above.

Login Sample Receipt Checklist

Client: Curtis & Tompkins, Ltd.

Job Number: 640-49437-1
SDG Number: 261593

Login Number: 49437
List Number: 1
Creator: Carpenter, Jonnie T

List Source: TestAmerica Tallahassee

Question	Answer	Comment
Radioactivity wasn't checked or is </= background as measured by a survey meter.	N/A	
The cooler's custody seal, if present, is intact.	True	
Sample custody seals, if present, are intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the containers received and the COC.	True	
Samples are received within Holding Time.	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified.	N/A	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
Containers requiring zero headspace have no headspace or bubble is <6mm (1/4").	N/A	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	N/A	
Residual Chlorine Checked.	N/A	

PRECISION ANALYSIS

Laboratory • Gas Measurement
Emissions Testing • Sample Collection

29 Country Acres Rd, Riverton, WY 82501 • Phone: (307) 856-0866 • E-mail: Admin@Precision-Labs.com • Online: www.Precision-Labs.com

CASE NARRATIVE

Client:	Acton Mickelson Environmental, Inc.	**Lab Order:**	14100912
Project:	90081.07s	**Report Date:**	10/20/2014

This data package consists of the following:
Case Narrative - 1 Page
Sample Analysis Reports -3 Pages
Quality Control Data- 2 Pages
Chain of Custody and Sample Log-in Report - 2 Pages

No extra sample was provided for any total coliform or E. coli tests, therefore there was no sample available to run a duplicate. After evaluating the remainder of the quality parameters, we concluded that there was no contamination in our process and that the conditions of the test are conducive to incubating an accurate number of bacteria."

Also, we updated our BART methods and now we can report "<1", rather than "not aggressive".

PRECISION ANALYSIS

Gas Measurement • Emissions Testing
Laboratory • Sample Collection
Phone: (307)-856-0866 • Toll Free: (866)-985-0866

Laboratory Analytical Report

Customer Name:	Acton Mickelson Environmental, Inc.	Order ID:	14100912
Project ID:	90081.07s	Report Date:	10/20/2014

			Date	Time
Lab Sample ID:	14100912-01			
Customer Sample ID:	FB-2-10092014	Collection:	10/9/2014	11:15 AM
Matrix:	Aqueous	Received:	10/9/2014	1:15 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time	Analyst
						Prep Date: 10/9/2014 2:30:00 PM	
E. Coli	<1	cfu/100ml	1		SM 9223 B	10/10/2014 2:40:00 PM	KF
						Prep Date: 10/9/2014 2:30:00 PM	
Total Coliform	<1	cfu/100ml	1		SM 9223 B	10/10/2014 2:40:00 PM	KF

			Date	Time
Lab Sample ID:	14100912-02			
Customer Sample ID:	FB-2-10092014	Collection:	10/9/2014	11:15 AM
Matrix:	Aqueous	Received:	10/9/2014	1:15 PM
Notes:				

Analyses	Result	Units	RL	Qual.	Method	Analysis Date/Time	Analyst
Iron Related Bacteria	<1	cfu/ml			BART	10/9/2014 3:15:00 PM	KF
Sulfate Reducing Bacteria	<1	cfu/ml			BART	10/9/2014 3:15:00 PM	KF

Definitions:

ND-Not Detected at the reporting limit
RL-Analyte Reporting Limit
H-Holding times for preparation or analysis exceeded
S-Spike Recovery outside accepted recovery limits
J-Analyte detected below quantitation limits
M-Matrix Effect
D-Diluted out of recovery limits
L-Analyzed by a contract laboratory

Documentation will be kept for five (5) years.

PRECISION ANALYSIS GAS MEASUREMENT EMISSIONS TESTING LABORATORY
307.856.0866
www.precision-labs.com

QUALITY CONTROL DATA

Customer Name:	Acton Mickelson Environmental, Inc.	Site:	PGDW49; QAQC
Customer Sample Number:	PGDW49-08192014; Dupe-2-08192014	Project ID:	Pavillion WY 90081.01
Customer Contact:	Michael Acton	Project Manager:	Jeff Heglie
Laboratory ID:	14081912	Matrix:	Aqueous

Test: E. coli Method: SM 9223 B QC Batch ID: Benchsheet 81814

QC Type / Parameter	Units	RL	Results	Percent Recovery	% Recovery Limits	RPD	Max RPD	Qualifiers
Duplicate								
E. coli	cfu/100mL	1	<1	N/A	N/A	0	< 20	
Sample Results			<1					
Method Blank								
E. coli	cfu/100mL	1	<1	N/A	N/A	N/A		
Residual Chlorine								
E. coli	Present/Absent		Absent	N/A	N/A	N/A		

Test: Total Coliform Method: SM 9223 B QC Batch ID: Benchsheet 81814

QC Type / Parameter	Units	RL	Results	Percent Recovery	% Recovery Limits	RPD	Max RPD	Qualifiers
Duplicate								
Total Coliform	cfu/100mL	1	<1	N/A	N/A	0	< 20	
Sample Results			<1					
Method Blank								
Total Coliform	cfu/100mL	1	<1	N/A	N/A	N/A		
Residual Chlorine								
E. coli	Present/Absent		Absent	N/A	N/A	N/A		

Test: Sulfate Reducing Bacteria Method: Hach Bart System QC Batch ID: Benchsheet 81914

QC Type / Parameter	Units	RL	Results	Percent Recovery	% Recovery Limits	RPD	Max RPD	Qualifiers
Duplicate								
Sulfate Reducing Bacteria	cfu/100mL	1	200.00	N/A	N/A	0	< 20	
Sample Results			200.00					
Method Blank								
Sulfate Reducing Bacteria	cfu/100mL	1	Not Aggr.	N/A	N/A	N/A		

Test: Iron Related Bacteria Method: Hach BART System QC Batch ID: Benchsheet 81914

QC Type / Parameter	Units	RL	Results	Percent Recovery	% Recovery Limits	RPD	Max RPD	Qualifiers
Duplicate								
Iron Reducing Bacteria	cfu/100mL	1	500.00	N/A	N/A	0	< 20	
Sample Results			500.00					
Method Blank								
Iron Reducing Bacteria	cfu/100mL	1	Not Aggr.	N/A	N/A	N/A		

Test: Monthly Tests Method: SM 9223 B

QC Type / Parameter	Units	Results	Pass/Fail	QC ID
Sterility				Document 30111-60414
Sample Bottles	+/-	-	Pass	
Dilution Water	+/-	-	Pass	
Growth Media	+/-	-	Pass	
Air Quality	+/-	-	Pass	Benchsheet 70814
Controls				Document 30110-50514
E. coli (+ and +)	+/-	+,+	Pass	
Klebsilla (+ and -)	+/-	+,-	Pass	
Pseudomonas (- and -)	+/-	-,-	Pass	

29 Country Acres Rd.
Riverton, WY 82501
(307) 856-0866

Login Report

Customer Name: Acton Mickelson Environmental, Inc.

Order ID: 14100912

Project ID: 90081.07s

Order Date: 10/9/2014

Comment:

SAMPLE CONDITION RECORD

Number of cooler/packages received:	1
Number of bottles received:	3
Were the samples received intact? (no broken bottles, leaks, etc.)	Yes
Were the samples received with custody seals?	N/A
Were custody seals intact?	N/A
Did signature match?	N/A
Is the COC properly completed, legible, and signed?	Yes
Were all samples received accounted for on the COC?	Yes
Were all requested analyses understood and appropriate?	Yes
Did the bottle labels correspond with the COC information?	Yes
Were Samples collected in proper containers?	Yes
Were all containers properly preserved?	Yes
Do VOA vials have <6mm headspace?	N/A
Was a trip blank present?	N/A
Were all analyses within holding time at time of receipt?	Yes
Have rush or project due dates been checked and accepted?	Yes
Login verification: Client Name:	Yes
Login verification: Project Name:	Yes
Login Verification: Matrix:	Yes
Sample/Cooler Temperature(s):	15.8

Acton Mi[illegible]son Environmental, Inc.
1107 Investment Blvd, Suite 290
El Dorado Hills, CA 95762
Phone: (916) 939-7550 Fax: (916) 939-7570

Invoice To: Ellen Frosch	
(916) 939-7550	Email: efrosch@ameinc.net
Project Name	Pavillion, Wy

CHAIN OF CUSTODY RECORD

DATE: 10/9/2014

PAGE: 1 OF 1

LABORATORY CLIENT: **Precision Analysis, LLC**

ADDRESS: **29 Country Acres Rd**

CITY: **Riverton, Wyoming 82501**

TEL: **(307) 856-0866** FAX: Contact: **Preston Richardson**

Project Number: **90081.07s**

PROJECT CONTACT: **Michael Acton**

SAMPLER(S): Dennis Jones, Michael Acton

P.O.

LAB USE ONLY

COOLER RECEIPT Temp = 15.8 °C

TURNAROUND TIME

☐ SAME DAY ☐ 24 HR ☐ 48 HR ☐ 72 HR ☐ 5 DAYS ☐ 10 DAYS

SPECIAL REQUIREMENTS (ADDITIONAL COSTS MAY APPLY)

☐ RWQCB REPORTING ☐ ARCHIVE SAMPLES UNTIL ____/____/____

SPECIAL INSTRUCTIONS:

Note 1: FB-1-10062014 matrix is laboratory-grade organic-free reagant water.
WQ=water quality control matrix, blank water
Note 2: 30-hour holding time

REQUESTED ANALYSIS

14100912

LAB USE ONLY	SAMPLE ID	Field Point Name	SAMPLING DATE	SAMPLING TIME	MATRIX	PRESERVE	NO. OF CONT.	E. Coli SM 9223B*2	Total Coliform SM9223B*2	IRB, SRB (bacteria) BART*2	CONTAINER TYPE/NOTES
01	FB-2-10 09 2014	QAQC	10/9/2014	1115	WQ[1]	$Na_2S_2O_3$	2	X	X		125 mL POLY/30-HOUR HOLD
02	FB-2-10 09 2014	QAQC	10/9/2014	1115	WQ[1]	C	1			X	1L Poly/30-HOUR HOLD

Relinquished by: (Signature)	Received by: (Signature)	Date, & Time:
		10-9-14 1315
Relinquished by: (Signature)	Received by: (Signature)	Date, & Time: 10/9/14 1315
Relinquished by: (Signature)	Received by: (Signature) Mary Hines	Date, & Time: 10/9/14 13:15

APPENDIX F

Well Owner Interviews

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW05

Well Owner: Louis, Donna Meeks

Interviewee: Louis, Donna Meeks

Interviewer: M. Acton, M. Thiesse

Date: October 6, 2014

1. General Considerations

a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation
Personal Hygiene: Currently for showering.
Domestic Purposes: Washing dishes; previously for all domestic uses.

b. Number of Well Users
Currently 2
Previously 4

c. Length of Time at Current Residence
Since 1976
VA loan water test conducted at time of move in, however, the Meeks' don't have the results.

d. Previous Experience using Well Water
Yes. Lived on 8-Mile Road with a well.

e. Piping Material, e.g., Copper or PVC
Currently PVC
Pipe was changed from galvanized to PVC in 2000

2. Well Maintenance

a. Well Maintenance Frequency
1976-2004 new well house, pitless adapter

b. Who Conducted Maintenance
Ward
Campbell

c. Licensed Water Well Service Provider
Yes, Ward

d. Service/Maintenance Conducted

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
Pump replaced in 2000
Ward chlorinated well many times
Well chlorinated and acidized in summer 2005

ii. Is Well Vented?
Yes

iii. Inspection of Surface and Downhole Well Equipment
As needed

iv. Date, Service Provider, Results, etc.
2005-2008 multiple services done

v. Previous Downhole Video
2007/2008-Ward and Carol Septic conducted video paid by Encana.

e. Well Cleaning/Disinfection, Mechanical or Chemical
Mechanical and chemical disinfection was conducted 2005-2008.

i. Materials used, e.g., Acids, Caustics, Polymers
Chlorinated and acidized
Flush/fracking

f. Permits and Permitting Records from State Engineers Office
Keith and Cindy Huelle Permit
UW.32161, 1976; 210 ft. TD, pump at 189 ft.

g. Records from Service and Testing Professionals
Ward should have records
M. Thiesse to contact Ward to obtain records

i. Construction Report, Well System Maintenance, and Water Testing
Construction report in permit
DEQ has water test records
EPA and DEQ (D. Harris) has original Meeks testing results from 2003/2004.

3. Historical Changes to Well

a. Pump Replacement
Pump was replaced in 2000.
Pump replaced in 2005 and was paid by Encana.

b. Casing Changes
Casing was changed from galvanized to PVC in 2000.

c. Borehole Changes
No

d. Other
N/A

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
In 2005, well yield was OK, but there was a decline in quality and in 2006, the yield declined.

b. Flow Testing Results if Performed
Ward did work
Owner did not have records and suggested they could be obtained from Ward.
2006/2007-Well pumped dry during sampling

5. Palatability Issues with Well Water

a. Identify issue
In February 2005, there was gas odor in the water.
Donna brought 1-gallon jug of water to the school.

i. Staining, Water Appearance, Odor, Taste, Ignitable, Other
Staining: Yellow/brown
Odor: Gas
Taste: Bad
Other: Floating/suspended material in water
Inconsistent good/bad for staining, odor, and taste
In 2005, there was no sheen on water
August 2014 well sampling-sheen on water in bucket

b. Suspected Source of Issue
Not identified

c. Date Issue Identified
Early 2005

d. Date Issue Reported to WDEQ or Other State/Federal Agency
Early 2005-notified DEQ
Late 2007-notified EPA

e. Reported to Any Other Party? e.g., County Health Agency
No

f. Mitigation Measures Undertaken By Owner or Agency, if Any
DEQ sampled well
Encana paid and collected for sample
Energy Lab and Engberg Miller, paid by Encana
EPA conducted 10-12 sampling events
Meeks had to obtain a permit for a new well and Encana provided water during this period
A well blow-out occurred in December 2004

6. Contamination in Well Water

a. Identify Contaminant(s)
10-12 sampling events
Sodium, phenol, GRO/DRO reported

b. How was Contaminant Confirmed and Documented
Analytical results from 10-12 sampling events

c. Previous Private (not WDEQ or EPA) testing
DEQ has analytical results from privately collected samples from PGDW05
DEQ did not sample well prior to June 2014

i. Analytical Method(s) and Result(s)
See reports in DEQ file

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)

There are five gas wells within 1,420 feet of PGDW05.

24-02	578 ft.
21-11B	827 ft.
14-2	986 ft.
11-11B	1,118 ft.
11-11	1,389 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)

There is one pit within 1,420 feet of PGDW05.

14-2	1,174 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)

Owner states there is a pipeline that runs E from 14-2

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.

There are four ASTs approximately 100 ft. SE of PGDW05, along E side of entrance driveway. One AST contains unleaded gas and a second contains diesel fuel. The remaining two ASTs are empty and not used, but were previously used for unleaded gas and diesel fuel storage before the currently used tanks were brought in.
No specific spot for equipment cleaning

ii. Agricultural Chemical Spraying, Including Aerial

Weed spraying in yard
No recent field spraying
Field spray 4-5 years ago to kill alfalfa in field S of house (across W. Powerline Road)

iii. Proximity of Livestock, Manure

Some livestock have been approximately 150 feet N of PGDW05

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

The septic system is located on the W/SW side of the house, and the drainage system extends to the SW from there.
Septic is for domestic purposes, no chemicals or other materials are disposed in the septic.

v. If Irrigation, Flood or Sprinkler

Sprinklers around house
Sprinkler irrigation of yard around/near well
Flood irrigation of adjacent fields

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW14

Well Owner: Marvin, Evelyn Griffin

Interviewee: Evelyn Griffin

Interviewer: M. Acton, J. O'Connor

Date: October 9, 2014

1. General Considerations

a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation
Well is used for drinking, cooking, and personal hygiene.
RO filter

b. Number of Well Users
Two Current
Four previous

c. Length of Time at Current Residence
Approximately 40 years

d. Previous Experience using Well Water
Yes

e. Piping Material, e.g., Copper or PVC
White PVC

2. Well Maintenance

a. Well Maintenance Frequency
As needed

b. Who Conducted Maintenance
Ward

c. Licensed Water Well Service Provider
Ward, yes

d. Service/Maintenance Conducted

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
The pump was pulled many years ago.

ii. Is Well Vented?
Not known by owner

iii. Inspection of Surface and Downhole Well Equipment
Unknown

iv. Date, Service Provider, Results, etc.
Unknown

v. Previous Downhole Video
No

e. Well Cleaning/Disinfection, Mechanical or Chemical
Unknown

i. Materials used, e.g., Acids, Caustics, Polymers
Unknown

f. Permits and Permitting Records from State Engineers Office
Records are on file at agency offices

g. Records from Service and Testing Professionals
No

i. Construction Report, Well System Maintenance, and Water Testing
Owner thinks they may be on file at SEO

3. Historical Changes to Well

1980s-Halliburton in the field
Well water turned black
Ward said this was due to oil and gas development-diesel
Filters clogged with tar globs
New well installed in 1995 due to decreased water quality in original well

a. Pump Replacement
   Unknown

b. Casing Changes
   Unknown

c. Borehole Changes
   Unknown

d. Other
   Unknown

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
   No

b. Flow Testing Results if Performed
   No

5. Palatability Issues with Well Water

See Section 3 above.

a. Identify issue

   i. Staining, Water Appearance, Odor, Taste, Ignitable, Other

b. Suspected Source of Issue
Owner suspects oil and gas development

c. Date Issue Identified
1980s

d. Date Issue Reported to WDEQ or Other State/Federal Agency
Unknown

e. Reported to Any Other Party? e.g., County Health Agency
Unknown

f. Mitigation Measures Undertaken Owner or Agency, if Any
Installed new well in 1995

6. Contamination in Well Water

a. Identify Contaminant(s)
May be identified in EPA sample analysis

b. How was Contaminant Confirmed and Documented
Unknown

c. Previous Private (not WDEQ or EPA) testing
Encana, Tom Brown Inc.
Owner will check if she has records

i. Analytical Method(s) and Result(s)

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)

There are 11 gas wells within 1,420 feet of PGDW14.

32-10C	249 ft.
33X-10	740 ft.
32-10B	826 ft.
32-10	958 ft.
33-10W	1,042 ft.
33-10	1,092 ft.
23-10B	1,098 ft.
33-10B	1,101 ft.
31-10B	1,263 ft.
22-10	1,302 ft.
23-10	1,307 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)

There are seven pits located within 1,420 feet of PGDW14.

33X-10	650 ft.
32-10	958 ft.
33-10	1,092 ft.
23-10B	1,098 ft.
33-10B	1,101 ft.
23-10	1,307 ft.
22-10	1, 474 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)
Unknown by owner

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.

No pesticides
Herbicides: Used years ago
Gasoline AST approximately 250 feet SSE of PGDW14, near house
Diesel AST approximately 500 feet SE of PGDW14, at shop
Used motor oil taken to recycler

ii. Agricultural Chemical Spraying, Including Aerial

Chemical spraying with tractor of adjacent fields
Previous aerial spraying of adjacent fields for alfalfa weevil

iii. Proximity of Livestock, Manure
None current
Horses to SW of well previously

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

Household use of septic only
Septic located approximately 175 feet SSW of PGDW14

v. If Irrigation, Flood or Sprinkler
Hose irrigation of landscaping
Flood irrigation of adjacent fields

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW23

Well Owner: John & Katherine Fenton

Interviewee: John Fenton

Interviewer: Deb Harris

Date: November 3, 2014

1. **General Considerations**
   a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation

      Personal Hygiene: Showering, doing laundry, and pet use.
      Irrigation: Ornamental plant (trees and bushes) irrigation around the house.

      Bottled water has been used for cooking/culinary uses since the bottled water delivery service began on an unknown date. Discontinued drinking the water ~3 years ago.

   b. Number of Well Users
      3-6

   c. Length of Time at Current Residence
      Approximately 12-13 years

   d. Previous Experience using Well Water
      They have always lived on numerous ranches with private wells, but briefly lived in Hudson, WY on municipal system.

   e. Piping Material, e.g., Copper or PVC
      PVC

2. Well Maintenance

a. Well Maintenance Frequency
   None

b. Who Conducted Maintenance
   N/A

c. Licensed Water Well Service Provider
   Mike Abbey with Wind River Drilling installed the well.

d. Service/Maintenance Conducted
   i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment

      In 2001/2002 the well was chlorinated after well development. Ward's Well Service came and bailed the well to determine production yield ~1 year after pump installation.

   ii. Is Well Vented?
      Yes, passive venting through a broken/missing fitting.

   iii. Inspection of Surface and Downhole Well Equipment
      No

   iv. Date, Service Provider, Results, etc.
      No

   v. Previous Downhole Video
      None

e. Well Cleaning/Disinfection, Mechanical or Chemical
Refer to #2.d. above.

i. Materials used, e.g., Acids, Caustics, Polymers
Chlorinated

f. Permits and Permitting Records from State Engineers Office

Installed in 2001/2002 under an SEO permit called 'Griffin #2'. Permit and construction records may exist and will provide if JF can locate them.

g. Records from Service and Testing Professionals

i. Construction Report, Well System Maintenance, and Water Testing

3. Historical Changes to Well

a. Pump Replacement
Original pump

b. Casing Changes
Original casing

c. Borehole Changes
None

d. Other
None

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
No changes in well yield

b. Flow Testing Results if Performed
Well has always had good production. 1¼ HP pump with yield of 22/23 gpm. The well has never been pumped dry since it was developed.

5. Palatability Issues with Well Water

a. Identify Issue

i. Staining, Water Appearance, Odor, Taste, Ignitable, Other

Staining: No Fe staining, but began observing a 'white staining' around 2005/2006 when watering the trees by the house.

Appearance/Odor: In 2005/2006, owners also noticed a 'fizzing' or effervescence that JF said was 'CO_2 or methane'. The water had a 'weird oily smell'. Didn't notice it initially, but the changes came on gradually and about the same time. JF thought that the fizzing/effervescence may have increased during the winter months due to a lack of usage and limited times the pump is cycled, as opposed to the higher volumes extracted during the summer months.

b. Suspected Source of Issue
The changes were associated with the drilling activity all around the house. Gradual change in WQ ~2005/2006. Has a photo of 6-7 drill rigs operating in close proximity to the house at the same time. Supposed that this time was ~2003. Also, had concerns about the 'rat and mouse holes' from the drilling operations on the ridge above the house. JF's concern was that the 'rat and mouse holes' were filled with all sorts of drilling and waste fluids and could have served as conduits for contaminants to the subsurface. When the drilling was completed, the 'rat and mouse holes' were filled with gravel and abandoned.

c. Date Issue Identified
   Refer to #5.b. above

d. Date Issue Reported to WDEQ or Other State/Federal Agency
   Did not comment specifically as to the date(s) reported to regulatory agencies.

e. Reported to Any Other Party? e.g., County Health Agency
   Did not comment specifically as to the date(s) reported to regulatory agencies.

f. Mitigation Measures Undertaken By Owner or Agency, if Any
   Began drinking bottled from water delivery service; stopped drinking water 3 years ago.

6. Contamination in Well Water

a. Identify Contaminant(s)
   Mentioned the EPA report findings

b. How was Contaminant Confirmed and Documented
   Mentioned the EPA report findings

c. Previous Private (not WDEQ or EPA) testing

   Basic 'UW' WQ test performed in conjunction with the original well development process.

   i. Analytical Method(s) and Result(s)
      May be in JF's records and he will forward a copy if located.

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)

There are eight gas wells within 1,420 feet of PGDW23.

43-10	409 ft.
33-10B	549 ft.
43-10B	584 ft.
44-10	833 ft.
33X-10	909 ft.
33-10	1,030 ft.
34-10	1,040 ft.
33-10W	1,124 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)

There are six pits within 1,420 feet of PGDW23.

43-10	409 ft.
33-10B	549 ft.
43-10B	584 ft.
44-10	723 ft.
33-10	1,030 ft.
33X-10	1,111 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)

There is a large pipeline trending N/S ~800 feet W of the Fenton well with a valve located near his shop. And there is a pipeline to a well pad ~300 feet NE from the residence.

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.

Pesticides: No pesticides used or stored on the property.
Herbicides: Roundup/glycophosate used for spot application. 2, 4 D used in the past.
Gasoline: AST on the Griffin property some distance to the W.
Diesel: AST at the shop ~1,000 feet to the W.
Vehicle maintenance performed by owner in the shop building. All used oil and chemicals stored in the shop. Recycle the used oils in Riverton upon filling a five-gallon bucket.

ii. Agricultural Chemical Spraying, Including Aerial

Have mowed all weeds for the past 5 to 6 years. Some spot application of herbicide around a well location to the N of the house. No chemical fertilizer application for ~10 years.

iii. Proximity of Livestock, Manure

~1,000 feet to the W in the corrals by the shop during the winter months.

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

There are two small septic systems for the house. One is a 'graywater' system for the kitchen water and the 'blackwater' system for the toilets. Both are located to the N of the house. No chemicals are disposed of in the septic system.

v. If Irrigation, Flood or Sprinkler

Irrigation is drip system around the house on the ornamental trees and bushes. Previously used a sprinkler system on a small garden. Flood irrigates the hayfields.

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

John Fenton did not have any additional information.

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW30

Well Owner: Zoe Randall

Interviewee: Rich Randall (son), Zoe Randall

Interviewer: M. Acton

Date: October 8, 2014

1. General Considerations

a. How is Well Utilized, e.g., Drinking, Cooking, Personal Hygiene, Irrigation
Currently on cistern
Well is currently used for animals (meat goats) and yard irrigation, but was previously used as a house well.

b. Number of Well Users
Three current
Three previous

c. Length of Time at Current Residence
17 years

d. Previous Experience using Well Water
Yes, ranching

e. Piping Material, e.g., Copper or PVC
PVC current
Poly was replaced 1.5 years ago in early 2013
New pump

2. Well Maintenance

a. Well Maintenance Frequency
As needed

b. Who Conducted Maintenance
Atnip Well Service

c. Licensed Water Well Service Provider
Yes

d. Service/Maintenance Conducted
Not specified

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
Pump replaced 1.5 years ago in early 2013

ii. Is Well Vented?
No

iii. Inspection of Surface and Downhole Well Equipment
Early 2013

iv. Date, Service Provider, Results, etc.
Early 2013
No other information

v. Previous Downhole Video
EPA may have conducted downhole video

e. Well Cleaning/Disinfection, Mechanical or Chemical
Unknown

i. Materials used, e.g., Acids, Caustics, Polymers
Unknown

f. Permits and Permitting Records from State Engineers Office
On file with the state

g. Records from Service and Testing Professionals
No

i. Construction Report, Well System Maintenance, and Water Testing
On file with the state

3. Historical Changes to Well

a. Pump Replacement
Early 2013

b. Casing Changes
Poly casing replaced with PVC in early 2013

c. Borehole Changes
No

d. Other
No

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
No change
No encrustations

b. Flow Testing Results if Performed
No, but DEQ may have conducted a drawdown test

5. Palatability Issues with Well Water
Interviewer reported water exhibited weathered gas/diesel like odor.

a. Identify issue
In approximately 2004, water had a purple/black color for 6-8 months.
Water had pumpkin orange color during installation of EPA monitoring well.

i. Staining, Water Appearance, Odor, Taste, Ignitable, Other
For all 17 years, water taste and smell like hydraulic fluid.

b. Suspected Source of Issue
Unknown

c. Date Issue Identified
Specified above

d. Date Issue Reported to WDEQ or Other State/Federal Agency
Owner could not recall dates reported to DEQ and EPA

e. Reported to Any Other Party? e.g., County Health Agency
Owner reported to County Health Agency, but does not recall the date.

f. Mitigation Measures Undertaken Owner or Agency, if Any
Cistern installed; owner stopped using well for household purposes.

6. Contamination in Well Water

a. Identify Contaminant(s)
Not specified by owner

b. How was Contaminant Confirmed and Documented
Not specified by owner

c. Previous Private (not WDEQ or EPA) testing
Not specified by owner

i. Analytical Method(s) and Result(s)
Not specified by owner

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)

There are 10 gas wells within 1,420 feet of PGDW30.

41-10B	670 ft.
41-10	755 ft.
44-03	792 ft.
31-10	811 ft.
41X-10	898 ft.
W.E. Lloyd1	1,185 ft.
34-03	1,234 ft.
34-03R	1,234 ft.
44-03C	1,393 ft.
42-10	1,281 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)

There are four pits within 1,420 feet of PGDW30.

44-03	792 ft.
41X-10	1,003 ft.
42-10	1,281 ft.
W.E. Lloyd1	1,342 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)
Owner states there is a pipeline S of PGDW30, running SSW to NNE.

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.

No use of pesticides, herbicides, gas, or diesel other than in vehicles.
No storage

ii. Agricultural Chemical Spraying, Including Aerial
No spraying
No aerial spraying

iii. Proximity of Livestock, Manure
Goats near well house

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

Septic for household only
Septic is located approximately 100 feet NW of PGDW30

v. If Irrigation, Flood or Sprinkler
Flood irrigate adjacent field with gated pipe

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW32

Well Owner: Joe & Hope Dennis

Interviewee: Joe Dennis

Interviewer: Deb Harris

Date: November 3, 2014

1. **General Considerations**
   a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation
      Well is used for all of the above, including ice cubes, cooking and all household culinary uses.

   b. Number of Well Users
      2 total average users

   c. Length of Time at Current Residence
      30 years (land purchased in 1984)

   d. Previous Experience using Well Water
      Previously lived in Riverton and San Antonio on municipal systems, but raised and lived on numerous ranches with private wells.

   e. Piping Material, e.g., Copper or PVC
      PVC

2. Well Maintenance

a. Well Maintenance Frequency
No regular periodic maintenance. No chlorination.

b. Who Conducted Maintenance
Owner

c. Licensed Water Well Service Provider
Loren Walrod installed the original well prior to licensure requirements. The original well, installed by cable tool, sloughed off before the casing could be installed. A replacement well was installed by rotary method. The location of the replacement well offset the original well by a few feet.

d. Service/Maintenance Conducted

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
Pump and casing replaced approximately 5 years ago by Doyle Ward, which is Ward's Well Service.

ii. Is Well Vented?
Not vented

iii. Inspection of Surface and Downhole Well Equipment
No

iv. Date, Service Provider, Results, etc.
No

v. Previous Downhole Video
No

e. Well Cleaning/Disinfection, Mechanical or Chemical
None performed

i. Materials used, e.g., Acids, Caustics, Polymers
None used

f. Permits and Permitting Records from State Engineers Office
Original well permitted by SEO, but replacement well not permitted. Refer to 2.c. (above)

g. Records from Service and Testing Professionals

i. Construction Report, Well System Maintenance, and Water Testing
The owner may have the well log and construction details in his records, but does not know where they are located.

3. Historical Changes to Well

a. Pump Replacement
Pump was replaced about 5 years ago by Doyle Ward with Ward's Well Service.

b. Casing Changes
Casing replaced approximately 5 years ago by Doyle Ward with Ward's Well Service.

c. Borehole Changes
Not aware of any

d. Other
Not aware of any

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
No

b. Flow Testing Results if Performed
N/A

5. Palatability Issues with Well Water

a. Identify issue
No particular issue

i. Staining, Water Appearance, Odor, Taste, Ignitable, Other
Staining: Fe removal by means of a bubbler system installed at the time of the well construction in 1984.

b. Suspected Source of Issue
N/A

c. Date Issue Identified
The Fe staining has been present since the time that the well was installed. Has not observed any change from the initial quality.

d. Date Issue Reported to WDEQ or Other State/Federal Agency
None reported to any agency

e. Reported to Any Other Party? e.g., County Health Agency
None reported

f. Mitigation Measures Undertaken Owner or Agency, if Any
Fe removal by means of a bubbler system installed at the time of the well construction in 1984.

6. Contamination in Well Water

a. Identify Contaminant(s)
None identified

b. How was Contaminant Confirmed and Documented
N/A

c. Previous Private (not WDEQ or EPA) testing
Basic WQ test performed after the well was installed and developed in 1984. The records may still exist, but not sure where they are stored.

i. Analytical Method(s) and Result(s)
Not available

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)
Oil and gas operations on the property have not impacted the water quality; however, there are two gas wells within 1,420 feet of PGDW32.

12-13	576 ft.
21-13	1,100 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)
There is one pit within 1,420 ft. of PGDW32.

12-13	495 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)
Refer to #7.a.i. above

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.

There is an AST for diesel and there are irregular small spills during refueling. Vehicle maintenance performed by owner. Recycle the used oils

ii. Agricultural Chemical Spraying, Including Aerial
Pesticides: Applied by Rocky Mountain Ag- a licensed applicator.
Herbicides: Aerially applied by a licensed applicator.

iii. Proximity of Livestock, Manure
During the winter months, i.e. December thru February, cows are corralled approximately 300 feet S of the well during the day and rounded up and put in the barn at night. The barn is located more than 300 feet S of the well.

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

There are two septic systems approximately 250-300 feet from the well. The septic system for the house is to the NW and a small system used for the shop is to the E.

v. If Irrigation, Flood or Sprinkler
Irrigation is primarily from the ditch and not the well.

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

Joe Dennis did not have any additional information.

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW33

Well Owner: Dennis Ranch Limited, LLC

Interviewee: Joe Dennis

Interviewer: Deb Harris

Date: November 3, 2014

1. General Considerations

a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation
Livestock: 99% of the use is for livestock (approximately 350 cows and some horses)
Small apartment in the barn with infrequent bathing/personal hygiene use.
This well was the original source for the first ranch prior to 1984 but was discontinued sometime prior to that date.

b. Number of Well Users
Occasional visitor and numerous livestock

c. Length of Time at Current Residence
30 years

d. Previous Experience using Well Water
Previously lived in Riverton and San Antonio on municipal systems, but raised and lived on numerous ranches with private wells.

e. Piping Material, e.g., Copper or PVC
PVC

2. Well Maintenance

a. Well Maintenance Frequency
No regular periodic maintenance. No chlorination. ~6 years ago the pump and pressure tank replaced.

b. Who Conducted Maintenance
Owner

c. Licensed Water Well Service Provider
No

d. Service/Maintenance Conducted

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
Approximately 6 years ago the pump and pressure tank replaced

ii. Is Well Vented?
No well cap- vented

iii. Inspection of Surface and Downhole Well Equipment
No

iv. Date, Service Provider, Results, etc.
No

v. Previous Downhole Video
No

e. Well Cleaning/Disinfection, Mechanical or Chemical
None performed

   i. Materials used, e.g., Acids, Caustics, Polymers
   N/A

f. Permits and Permitting Records from State Engineers Office
Installed by previous owner; no information or records available.

g. Records from Service and Testing Professionals

   i. Construction Report, Well System Maintenance, and Water Testing
   No information.

3. Historical Changes to Well

a. Pump Replacement
Pump replaced 2 times during the previous 30 years; the last time was roughly 6 years ago.

b. Casing Changes
None

c. Borehole Changes
Not aware of any

d. Other
Not aware of any

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
None

b. Flow Testing Results if Performed
N/A

5. Palatability Issues with Well Water

a. Identify issue
Has not observed any changes

i. Staining, Water Appearance, Odor, Taste, Ignitable, Other
Taste: Fe and sulfates have been present since the property was purchased in 1984.

b. Suspected Source of Issue
N/A

c. Date Issue Identified
The taste issue has been present since the property was purchased. Has not observed any change from the initial quality.

d. Date Issue Reported to WDEQ or Other State/Federal Agency
None reported to any agency

e. Reported to Any Other Party? e.g., County Health Agency
None reported

f. Mitigation Measures Undertaken Owner or Agency, if Any
No measures taken to resolve the issue

6. Contamination in Well Water

a. Identify Contaminant(s)
None identified

b. How was Contaminant Confirmed and Documented
N/A

c. Previous Private (not WDEQ or EPA) testing
Basic water quality test performed when the property was purchased in 1984, but not sure if they still exist and not sure where they are stored.
Joe Dennis thought that the sulfate, sodium, and iron levels are higher in this well (i.e. PGDW33) than the house well (PGDW32).

i. Analytical Method(s) and Result(s)
Not available

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)
Oil and gas operations on the property have not impacted the water quality. There is only one gas well within 1,420 ft. of PGDW33.
12-13 462 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)
There is one pit within 1,420 ft. of PGDW33.
12-13 577 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)
Refer to #7.a.i. above

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.

   There is an AST for gasoline and there irregular small spills during refueling. Vehicle maintenance performed by owner. Recycle the used oils.

ii. Agricultural Chemical Spraying, Including Aerial
   Pesticides: Applied by Rocky Mountain Ag—a licensed applicator.
   Herbicides: Aerially applied by a licensed applicator.

iii. Proximity of Livestock, Manure
   During the winter months, i.e. December thru February, livestock is pastured in adjacent fields >100 feet away from the well.

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

   There is a small septic system for the barn apartment ~450 feet from the well.

v. If Irrigation, Flood or Sprinkler
   Irrigation is primarily from the ditch and not the well.

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

Joe Dennis did not have any additional information.

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW41A

Well Owner: Leon, Amie Toyne

Interviewee: Leon, Amie Toyne

Interviewer: M. Thiesse, M. Acton

Date: October 7, 2014

1. General Considerations

a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation
   Historically for domestic, e.g. bathroom
   Never for drinking/cooking
   Owners use cistern currently

b. Number of Well Users
   Two

c. Length of Time at Current Residence
   Two years. Since fall 2012.

d. Previous Experience using Well Water
   Yes

e. Piping Material, e.g., Copper or PVC
   PVC

2. Well Maintenance

a. Well Maintenance Frequency
   Replaced switches

b. Who Conducted Maintenance
Self-maintained

c. Licensed Water Well Service Provider
No.

d. Service/Maintenance Conducted
No

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
N/A

ii. Is Well Vented?
No

iii. Inspection of Surface and Downhole Well Equipment
No

iv. Date, Service Provider, Results, etc.)
N/A

v. Previous Downhole Video
Uncertain; EPA may have conducted downhole video.

e. Well Cleaning/Disinfection, Mechanical or Chemical
No

i. Materials used, e.g., Acids, Caustics, Polymers
N/A

f. Permits and Permitting Records from State Engineers Office
No

g. Records from Service and Testing Professionals
N/A

i. Construction Report, Well System Maintenance, and Water Testing
No

3. Historical Changes to Well

a. Pump Replacement
No

b. Casing Changes
No

c. Borehole Changes
No

d. Other
No

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
Decrease in water quality after pumping
Large holding tank, cattle tanks

b. Flow Testing Results if Performed
None

5. Palatability Issues with Well Water

a. Identify issue

i. Staining, Water Appearance, Odor, Taste, Ignitable, Other
White film – alkali?

b. Suspected Source of Issue
Unknown

c. Date Issue Identified
N/A

d. Date Issue Reported to WDEQ or Other State/Federal Agency
N/A

e. Reported to Any Other Party? e.g., County Health Agency
No

f. Mitigation Measures Undertaken Owner or Agency, if Any
Cistern installed

6. Contamination in Well Water

a. Identify Contaminant(s)
Sodium at 3500 mg/L
Nitrates
Three cattle died
Bull became blind

b. How was Contaminant Confirmed and Documented
Encana testing
Toyne private testing
EPA testing

c. Previous Private (not WDEQ or EPA) testing
Yes

i. Analytical Method(s) and Result(s).
Unknown

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)

There are eight gas wells within 1,420 ft. of PGDW41A.

13-03W	480 ft.
43-04	652 ft.
14-03W	761 ft.
Mae H. Rhodes 1	1,028 ft.
13X-3	1,076 ft.
44-04	1,125 ft.
14-03B	1,372 ft.
Blankenship 4-8	1,385 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)
There are three pits within 1,420 ft. of PGDW41A.

Mae Rhodes 1	1,028 ft.
13X-3	1,076 ft.
Blankenship 4-8	1,486 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.
Household pesticides
Herbicides
One gasoline AST and one diesel AST are located approximately 200 feet NE of PGDW41A.

ii. Agricultural Chemical Spraying, Including Aerial
Weed spray by tractor/machine

iii. Proximity of Livestock, Manure
No

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

The septic system is located at the SE corner of the house and the drainage system extends to the SE from there.

v. If Irrigation, Flood or Sprinkler
Flood irrigation of nearby fields

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW41B

Well Owner: Leon, Amie Toyne

Interviewee: Leon, Amie Toyne

Interviewer: M. Thiesse, M. Acton

Date: October 7, 2014

1. General Considerations

a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation
Historically for domestic, e.g. bathroom
Never for drinking/cooking
Owners use cistern currently

b. Number of Well Users
Two

c. Length of Time at Current Residence
Two years; since fall 2012.

d. Previous Experience using Well Water
Yes

e. Piping Material, e.g., Copper or PVC
PVC

2. Well Maintenance

a. Well Maintenance Frequency
Replaced switches

b. Who Conducted Maintenance
Self-maintained

c. Licensed Water Well Service Provider
No

d. Service/Maintenance Conducted
No

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
N/A

ii. Is Well Vented?
No

iii. Inspection of Surface and Downhole Well Equipment
No

iv. Date, Service Provider, Results, etc.)
N/A

v. Previous Downhole Video
Uncertain; EPA may have conducted downhole video.

e. Well Cleaning/Disinfection, Mechanical or Chemical
No

i. Materials used, e.g., Acids, Caustics, Polymers
N/A

f. Permits and Permitting Records from State Engineers Office
No

g. Records from Service and Testing Professionals
N/A

i. Construction Report, Well System Maintenance, and Water Testing
No

3. Historical Changes to Well

a. Pump Replacement
No

b. Casing Changes
No

c. Borehole Changes
No

d. Other
No

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
Decrease in water quality after pumping
Large holding tank, cattle tanks

b. Flow Testing Results if Performed
None

5. Palatability Issues with Well Water

a. Identify issue

i. Staining, Water Appearance, Odor, Taste, Ignitable, Other
White film – alkali?

b. Suspected Source of Issue
Unknown

c. Date Issue Identified
N/A

d. Date Issue Reported to WDEQ or Other State/Federal Agency
N/A

e. Reported to Any Other Party? e.g., County Health Agency
No

f. Mitigation Measures Undertaken Owner or Agency, if Any
Cistern installed

6. Contamination in Well Water

a. Identify Contaminant(s)
Sodium at 3500 mg/L
Nitrates
Three cattle died
Bull became blind

b. How was Contaminant Confirmed and Documented
Encana testing
Toyne: private testing
EPA testing

c. Previous Private (not WDEQ or EPA) testing
Yes

i. Analytical Method(s) and Result(s)
Unknown

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)
There are eight gas wells within 1,420 ft. of PGDW41B.

13-03W	474 ft.
43-04	654 ft.
14-03W	761 ft.

Mae H. Rhodes 1	1,029 ft.
13X-3	1,071 ft.
44-04	1,131 ft.
14-03B	1,373 ft.
Blankenship 4-8	1,383 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)
There are three pits within 1,420 ft. of PGDW41B.

Mae Rhodes 1	1,029 ft.
13X-3	1,071 ft.
Blankenship 4-8	1,484 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.
Household pesticides
Herbicides
One gasoline AST and one diesel AST are located approximately 200 feet NE of PGDW41B.

ii. Agricultural Chemical Spraying, Including Aerial
Weed spray by tractor/machine

iii. Proximity of Livestock, Manure
No

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

The septic system is located at the SE corner of the house and the drainage system extends to the SE from there.

v. If Irrigation, Flood or Sprinkler
Flood irrigation of nearby fields

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW44

Well Owner: Marvin, Evelyn Griffin

Interviewee: Marvin, Evelyn Griffin

Interviewer: M. Acton, J. O'Connor

Date: October 9, 2014

1. General Considerations

a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation
Currently stock well

b. Number of Well Users
Horses

c. Length of Time at Current Residence
Approximately 40 years

d. Previous Experience using Well Water
Yes

e. Piping Material, e.g., Copper or PVC
Cast-iron casing

2. Well Maintenance

a. Well Maintenance Frequency
As needed

b. Who Conducted Maintenance
Ward

c. Licensed Water Well Service Provider
Ward, yes

d. Service/Maintenance Conducted

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
None

ii. Is Well Vented?
No

iii. Inspection of Surface and Downhole Well Equipment
Unknown

iv. Date, Service Provider, Results, etc.
Unknown

v. Previous Downhole Video
No

e. Well Cleaning/Disinfection, Mechanical or Chemical
Unknown

i. Materials used, e.g., Acids, Caustics, Polymers
Unknown

f. Permits and Permitting Records from State Engineers Office
Unknown

g. Records from Service and Testing Professionals
No

i. Construction Report, Well System Maintenance, and Water Testing
Unknown

3. Historical Changes to Well

a. Pump Replacement
   Twice in 40 years

b. Casing Changes
   None

c. Borehole Changes
   None

d. Other
   None

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

None

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
   No

b. Flow Testing Results if Performed
   No

5. Palatability Issues with Well Water

a. Identify issue

   i. Staining, Water Appearance, Odor, Taste, Ignitable, Other
      Appearance: Brackish
      Odor: Others have said water has an odor.

b. Suspected Source of Issue
   Unknown

c. Date Issue Identified
   Unknown

d. Date Issue Reported to WDEQ or Other State/Federal Agency
Unknown

e. Reported to Any Other Party? e.g., County Health Agency
Unknown

f. Mitigation Measures Undertaken Owner or Agency, if Any
None

6. Contamination in Well Water

a. Identify Contaminant(s)
May be identified in EPA sample analysis.

b. How was Contaminant Confirmed and Documented
Unknown

c. Previous Private (not WDEQ or EPA) testing
Unknown

i. Analytical Method(s) and Result(s).
Unknown

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)
There are 10 gas wells within 1,420 feet of PGDW44.

33X-10	311 ft.
33-10W	582 ft.
33-10	607 ft.
33-10B	639 ft.
32-10C	758 ft.
32-10B	1,130 ft.
23-10C	1,187 ft.

23-10	1,237 ft.
23-10B	1,275 ft.
34-10	1,384 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)
There are six pits located within 1,420 feet of PGDW44.

33X-10	505 ft.
33-10	607 ft.
33-10B	639 ft.
23-10C	1,187 ft.
23-10	1,237 ft.
23-10B	1,275 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)
Unknown by owner.

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.
No pesticides.
Herbicides used years ago.
Gasoline AST approximately 250 feet NW of PGDW44, near house.
Diesel AST approximately 250 feet NE of PGDW44, at shop.
Used motor oil taken to recycler.

ii. Agricultural Chemical Spraying, Including Aerial
Chemical spraying with tractor of adjacent fields.
Previous aerial spraying of adjacent fields for alfalfa weevil.

iii. Proximity of Livestock, Manure
None current
Horses to N of well previously.

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other
Household use of septic only
Septic located approximately 500 feet NW of PGDW44.

v. If Irrigation, Flood or Sprinkler
Hose irrigation of landscaping; flood irrigation of adjacent fields.

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW45

Well Owner: Louis, Donna Meeks

Interviewee: Louis, Donna Meeks

Interviewer: M. Acton, M. Thiesse

Date: October 6, 2014

1. General Considerations

a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation
Currently used for yard irrigation.

b. Number of Well Users
Currently 2

c. Length of Time at Current Residence
Since 1976

d. Previous Experience using Well Water
Yes. Lived on 8-Mile Road with a well.

e. Piping Material, e.g., Copper or PVC
Black PVC

2. Well Maintenance

a. Well Maintenance Frequency
Periodic chlorine pellets

b. Who Conducted Maintenance
Ward

c. Licensed Water Well Service Provider
Yes, ward

d. Service/Maintenance Conducted

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
Chlorinated in approximately 2010.

ii. Is Well Vented?
No

iii. Inspection of Surface and Downhole Well Equipment
No

iv. Date, Service Provider, Results, etc.
N/A

v. Previous Downhole Video
No

e. Well Cleaning/Disinfection, Mechanical or Chemical

i. Materials used, e.g., Acids, Caustics, Polymers
Chlorine pellets

f. Permits and Permitting Records from State Engineers Office
No

g. Records from Service and Testing Professionals
No

i. Construction Report, Well System Maintenance, and Water Testing
No

3. Historical Changes to Well

a. Pump Replacement
Pump replaced approximately in 2012; Cowboy Well Service permit.

b. Casing Changes
No

c. Borehole Changes
No

d. Other
N/A

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
Cannot pump well dry. Yield drops until fields are irrigated.

b. Flow Testing Results if Performed
No.

5. Palatability Issues with Well Water

a. Identify issue

i. Staining, Water Appearance, Odor, Taste, Ignitable, Other
Staining: Hard water staining on windows, which has become worse over the last 5 years. Water also leaves a white film on bucket.

b. Suspected Source of Issue
Unknown

c. Date Issue Identified
Unknown

d. Date Issue Reported to WDEQ or Other State/Federal Agency
Not reported

e. Reported to Any Other Party? e.g., County Health Agency
No

f. Mitigation Measures Undertaken Owner or Agency, if Any
None

6. Contamination in Well Water

a. Identify Contaminant(s)
EPA-identified DRO

b. How was Contaminant Confirmed and Documented
EPA sample analysis

c. Previous Private (not WDEQ or EPA) testing
No

i. Analytical Method(s) and Result(s)
No

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)

There are five gas wells within 1,420 feet of PGDW45.

24-02	650 ft.
21-11B	894 ft.
14-2	895 ft.
11-11B	1,048 ft.
11-11	1,383 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)

There is one pit within 1,420 feet of PGDW45.
14-2 1,079 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)

According to owner, pipeline runs E from 14-2.

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.

Four ASTs are approximately 175 ft. SE of PGDW45 along E side of entrance driveway. One AST contains unleaded gas and a second contains diesel fuel. The remaining two ASTs are empty and not used, but were previously used for unleaded gas and diesel fuel storage before the currently used tanks were brought in.
No specific spot for equipment cleaning.

ii. Agricultural Chemical Spraying, Including Aerial

Weed spraying in yard
No recent field spraying
Field spray 4-5 years ago to kill alfalfa in field S of house (across W. Powerline Road).

iii. Proximity of Livestock, Manure

Some livestock have been approximately 150 feet NE of PGDW45.

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

The septic system is located on the W/SW side of the house, and the drainage system extends to the SW from there.

Septic is for domestic purposes, no chemicals or other materials disposed in septic.

v. If Irrigation, Flood or Sprinkler

Sprinklers around house
Sprinkler irrigation of yard around/near well; Flood irrigation of adjacent fields

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

PAVILLION 2014 GROUNDWATER INVESTIGATION WELL OWNER INTERVIEW QUESTIONNAIRE

Wyoming Department of Environmental Quality
Acton • Mickelson • Environmental, Inc.

WELL OWNER INTERVIEW QUESTIONNAIRE

Well Number: PGDW49

Well Owner: Louis, Donna Meeks

Interviewee: Louis, Donna Meeks

Interviewer: M. Acton, M. Thiesse

Date: October 6, 2014

1. General Considerations

a. How is Well Utilized? e.g., Drinking, Cooking, Personal Hygiene, Irrigation
Not currently used; stopped in 2009/2010. Well was used for stock.

b. Number of Well Users
Previously livestock

c. Length of Time at Current Residence
Before 1976

d. Previous Experience using Well Water
Yes. Lived on 8-Mile Road with a well.

e. Piping Material, e.g., Copper or PVC
PVC

2. Well Maintenance

a. Well Maintenance Frequency
None

b. Who Conducted Maintenance
N/A

c. Licensed Water Well Service Provider
N/A

d. Service/Maintenance Conducted

i. Date Pump Last Pulled, Well Chlorinated and/or Other Water Treatment
N/A

ii. Is Well Vented?
No

iii. Inspection of Surface and Downhole Well Equipment
No

iv. Date, Service Provider, Results, etc.
N/A

v. Previous Downhole Video
No

e. Well Cleaning/Disinfection, Mechanical or Chemical
None

i. Materials used, e.g., Acids, Caustics, Polymers
None

f. Permits and Permitting Records from State Engineers Office
No

g. Records from Service and Testing Professionals
No

i. Construction Report, Well System Maintenance, and Water Testing
No

3. Historical Changes to Well

a. Pump Replacement
No

b. Casing Changes
No

c. Borehole Changes
No

d. Other
No

4. Operational Issues or Events Potentially Affecting the Well or Water Quality

a. Change in Well Yield Due to Equipment, Bacteria, or Encrustation
No

b. Flow Testing Results if Performed
None

5. Palatability Issues with Well Water

a. Identify issue
None

i. Staining, Water Appearance, Odor, Taste, Ignitable, Other
None

b. Suspected Source of Issue
N/A

c. Date Issue Identified
N/A

d. Date Issue Reported to WDEQ or Other State/Federal Agency
N/A

e. Reported to Any Other Party? e.g., County Health Agency
N/A

f. Mitigation Measures Undertaken Owner or Agency, if Any
N/A

6. Contamination in Well Water

a. Identify Contaminant(s)
Sodium, uranium, and manganese

b. How was Contaminant Confirmed and Documented
EPA sample analysis

c. Previous Private (not WDEQ or EPA) testing
No

i. Analytical Method(s) and Result(s)
EPA sampling

7. Survey and Observations of Surface Issues Potentially Affecting the Well or Water Quality

a. Oil and Gas Operations

i. Wells on Property or Nearby (Number and Distance from Well)

There are 10 gas wells within 1,420 ft. of PGDW49.

12-11B	643 ft.
41-10	799 ft.
42-10	814 ft.
41-10B	874 ft.
11-11B	898 ft.
41X-10	1,040 ft.
11-11	1,172 ft.

42-10B	1,191 ft.
12-11	1,346 ft.
12-11W	1,412 ft.

ii. Pits on Property or Nearby (Number and Distance from Well)
There are three pits within 1,420 feet of PGDW49.

42-10	814 ft.
41X-10	1,140 ft.
12-11	1,346 ft.

iii. Pipelines on Property or Nearby (Number and Distance from Well)
Unknown at time of interview

b. Farming/Ranching Operations

i. Hazardous Chemicals, e.g., Pesticides, Herbicides, Gasoline, Diesel, Motor Oil, Cleaning Supplies, etc.

Herbicide: weed spray

ii. Agricultural Chemical Spraying, Including Aerial

Herbicide: weed spray

iii. Proximity of Livestock, Manure

Manure in area of wellhead
Water is hauled in from Pavillion for the horse
Sheep in 2010
Cattle in 2014

iv. Septic System Use Other than Domestic Such as Hobbies or Activities that Discharge Chemicals to Septic, e.g., Leather Work/Tanning, Hunting Related, Model Airplane Assembly, Auto Refurbishing/Repair, Other

No septic

v. If Irrigation, Flood or Sprinkler

Flood irrigation of adjacent fields

WELL OWNER INTERVIEW QUESTIONNAIRE SUPPLEMENTAL SHEET

APPENDIX G

MBDCI Evaluation of the WOGCC's Well Integrity Review Report

DRAFT

Pavillion, Wyoming Shallow Gas: Sources, Well Integrity, Options

Maurice B. Dusseault, Ph.D., PEng

MBDCI, Waterloo Ontario Canada

December 2, 2015

Maurice B. Dusseault Consulting Inc.
246 Shakespeare Drive
Waterloo Ontario Canada N2L 2T6

Brief Summary

Bradenhead Annulus Gas

- Bradenhead gas reported in the analyses provided for Pavillion Field is thermogenic. It seems quite consistent in composition, indicating a generally common source.
- Most of the Bradenhead annulus pressure data comes from wells completed in the mid-2000s time period, and there is no substantial evidence that older wells (pre-2000) present a greater risk of gas migration than younger wells (post-2000).
- The Bradenhead gas composition is not greatly different from the tubing gas.
- Bradenhead gas may or may not come from the production zone; more likely, it is sourced from a shallower intermediate depth zone that contains thermogenic gas.
- There is no evidence that production casing impairment exists in the existing active production wells in Pavillion Field.

Risks of Hydraulic Fracture Communication with Shallow Groundwater

- No evidence exists that fracture fluids have ever risen from depth to interact with the groundwater protection zone.
- The probability that the small hydraulic fracture well stimulation treatments used in Pavillion Field wells have led to fracture fluids rising and interacting with the groundwater protection zone is negligibly small.

Gas Seepage and Energy Well Integrity

- The presence or absence of sustainable gas pressure in the Bradenhead annular space of a number of energy wells neither proves nor disproves the hypothesis that there is large-scale active gas migration taking place from great depth along Pavillion Field wells.
- However, based on experience elsewhere, it is highly probable that some energy wells are experiencing slow gas seepage from non-producing intermediate depth zones to the groundwater protection zone, evidenced in part as Bradenhead gas.
- Evidence exists that gas seepage in this area was happening naturally before energy well development. Thus, deep-sourced gas in the shallow groundwater zones is almost certain to exist, and proving its general source (natural or recent) may be difficult.
- No information exists as to the possibility of outside-the-casing gas migration frequency or rates (as opposed to Bradenhead annulus gas presence). But, given expected fluid gradients and the high probability that gas columns were generated in some cases behind the outermost casing, it is almost certain that vertical fluids migration has occurred in some energy wells.
- Water-supply wells are not scientific instruments that can be used to quantitatively address gas migration issues; they are suitable for reconnaissance level surveys and are not suitable for use in arriving at reliable conclusions as to the source and pathways of gases that may be present in the waters produced from such wells.

Detection, Delineation, Rectification

- The reliable quantification of gas sources, seepage rates, and pathways is challenging, with no guarantee that specific issues can be resolved with a high degree of certainty.
- The geological complexity of the Upper Wind River Formation (lenses, isolated sand bodies, local seals, no regional seals, no continuous regional aquifer…) means that any attempt to develop areal distribution maps of issues such as the presence of free gas in aquifers will be costly and difficult.
- Multi-level groundwater well installations or multiple groundwater wells completed at different depths with sampling and compositional and isotopic gas analysis over time, surface gas migration measurements in the vicinity of energy wells (including abandoned wells), extensive wellbore measurements (noise logs for example) in existing energy wells and perhaps even re-entry into abandoned wells, isotopic soil and well gas analysis, and other activities as well, would be required to further assess the sources and rates of gas seepage associated with gas well development.
- There is no certainty that specific sources and pathways of fluid migration can be identified using existing techniques because of the number of energy wells, the complex pathways arising from the geological complexity in the shallow strata, and the uncertain gas provenance (deep, intermediate, mixed).

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APPENDIX MD-I Hydraulic Fracturing Mechanisms at Shallow Depth

Symbols and Abbreviations Used

BGPZ The **B**ase of the **G**roundwater **P**rotection **Z**one (either rigorously defined, or taken as the base of potable or usable water). This is defined differently in different jurisdictions; the limits set by the State of Wyoming are listed later in the report (footnote 15). Specific to this study, the groundwater protection zone can be considered in the context of the depths of the water-supply wells in the vicinity of the Pavillion gas field. One defined area referred to as the "cistern area" encompasses 23 sections of land and most of the Pavillion gas field. Of the 88 water-supply wells (with non-zero values for the total depth) within the cistern area, the reported well depth ranges from 10 to 1,055 feet. A majority of the water-supply wells is less than 200 feet deep; also, relatively few (seven total) are more than 700 feet deep.

E&P **E**xploration and **P**roduction – as in "…all local E&P activity…" – a generic abbreviation for that part of the upstream O&G industry that deals with drilling, operating and decommissioning energy wellbores, whether for exploration or production or both.

HF **H**ydraulic **F**racture (or **H**ydraulic **F**racturing) – a well stimulation technique involving the injection of fluids with chemicals and proppant into prospective producing strata under conditions of high pressures and high rates to create discrete high permeability flow paths to enhance the well productivity.

O&G **O**il and **G**as – as in "the O&G industry…"– a generic abbreviation for the industry.

WSW **W**ater-**S**upply **W**ell – a private well used to supply potable water for humans and animals, or water suitable for agricultural use.

Extended Summary of Conclusions

The set of conclusions is further delineated in this extended summary. These conclusions are based on the materials provided to the author, several emails, teleconference meetings with members of the WDEQ – Wyoming Department of Environmental Quality – and the consulting company Acton Mickelson Environmental, Inc. of El Dorado Hills, California 95762 (USA), and other scientific materials and analysis that the author has consulted. These conclusions are made under conditions of substantial uncertainty: there are lacunae in the data available; pre-drilling baseline data was not obtained for later comparison; there is a high level of fundamental uncertainty in the geoscience of gas migration; the shallow subsurface geology in the Pavillion Field area is extremely complex; and, there are few studies in the general area of wellbore integrity with respect to long-term slow gas seepage or gas entry into aquifers. Conclusions and comments in this analysis must be viewed in the context of this uncertainty.

Gas Origins and Water-Supply Wells (WSWs) Issues

- There is thermogenic gas in the Bradenhead annulus – the annulus between the surface casing and the production casing – in a substantial percentage of the energy wells in the Pavillion Field study area around the WSWs that have been identified as potentially having poorer quality groundwater (quality and palatability issues). When this gas pressure is released, gas and often water are produced through the Bradenhead valve until the pressure is depleted. Apparently, there are no cases of large-scale fully free-flowing fluid from the Bradenhead annulus, although pressure recovery takes place once the valve is closed, indicating recharge is occurring from some source.
    - This is not an unusual circumstance; Bradenhead annulus pressure or gas flow (or gas and liquid co-flow) is common in the Oil and Gas (O&G) industry, affecting perhaps 5-10 percent of active producing wells.
    - The presence of Bradenhead gas with a thermogenic signature indicates that there is thermogenic gas present as dissolved and free gas in the region of the surface casing shoe.
    - Thus, the presence of Bradenhead gas in some energy wells is also almost certain confirmation that there is gas present in some groundwater zones and perhaps also as free gas in at least some of the shallow permeable (coarse-grained) groundwater zones used for WSW development.
    - The Bradenhead gas verifies the presence of gas below the casing shoe of the energy wells, but it is extremely likely that there is also free gas and dissolved gas in groundwater zones above the surface casing shoe depth as well. This will be the case if upward gas migration is taking place, either from energy well leakage or naturally over geological time, because gas is buoyant and tends to migrate to shallower depth, given a viable pathway.
    - Such pathways may have existed over geological time in the Pavillion Field area, but the drilling and completion of energy wells opens the possibility of new pathways along the production casing.

  - The presence of sustainable pressure in the Bradenhead annulus (i.e. pressure that can be re-established after some time) has been identified decades ago as a potential source of natural gas contamination of aquifers near energy wells.[1]
  - There is no evidence to suggest that wells in the Pavillion Field are not susceptible to the development of slow gas seepage from intermediate depth gassy zones; hence, it must be concluded that there is a high probability that some gas migration has occurred from depth (intermediate zone below the surface casing shoe) along wellbores in the Pavillion Field area.
  - It is not possible at the present time to specify the source (or sources) of the thermogenic gas in the Bradenhead annulus, except to say that it has migrated into the shallower strata, either naturally over long times before O&G E&P activity (geological time), or as the result of O&G E&P activity in the last 60 years, but likely some combination of the two.
  - The nature of the thermogenic gases in the Upper Wind River Formation is not greatly different than the gases below the Wind River Formation in the Fort Union Formation, therefore chemical or isotopic discrimination of the specific Bradenhead gas source will remain a challenging task. It is not clear if this issue can be successfully resolved in the Pavillion Field case.[2]
- The absence of pre-development baseline data on water quality and isotopic composition of free or dissolved gas in the groundwater makes it exceedingly difficult to verify if WSW quality is linked explicitly to gas migration associated with O&G development; there is reported information, albeit anecdotal and incomplete, indicating that gas was present in the groundwater protection zone before O&G E&P activity.
  - Useful pre-development data would include WSW yield and aqueous geochemistry, including chemical and isotopic composition of free and dissolved gas.[3]
  - Corporate data collected on drilling mud gas analysis that is performed during E&P drilling to build up a composition and isotopic fingerprint of the formation gases with depth would aid in interpretation of data. (Such data are proprietary.)
- The presence of Bradenhead gas does not necessarily prove or disprove that there is gas migrating from depth toward the surface along O&G wells at the present time or in the recent past.
  - The Bradenhead gas may have entered the annulus between the surface casing and the production casing from shallow zones (below the casing shoe) that contained thermogenic gas before O&G E&P activity, as the result of natural upward gas seepage.
  - The Bradenhead gas may have been sourced from intermediate depth zones that are gassy but uncommercial, leading to slow seepage from depths above the highest

[1] Harrison, S. S., 1985, Contamination of aquifers by overpressuring the annulus of oil and gas wells: Groundwater, v. 23, no. 3, p. 317–324

[2] Rowe, D. and Muehlenbachs, K. 1999. Low-temperature thermal generation of hydrocarbon gases in shallow shales. *Nature* **398** (4 March), 61-63

[3] Wilson, B., 2014, Geologic and baseline groundwater evidence for naturally occurring, shallowly sourced, thermogenic gas in northeastern Pennsylvania: AAPG Bulletin, v. 98, no. 2, p. 373–394, doi: 10.1306/08061312218.

perforated interval, but below the surface casing shoe. (This is widely reported in jurisdictions such as Pennsylvania, Alberta, British Columbia and Texas.)

- Energy well cementation and completion approaches have improved substantially over the last 60 years of O&G E&P activity in the Pavillion area. Recent wells (<15 yr.) are almost certainly less likely to evidence long-term integrity issues compared to older wells (>30 yr.).
- Nevertheless, in other jurisdictions (e.g. Horn River Basin in British Columbia), a small percentage of recent wells have shown early Bradenhead gas that is unequivocally sourced from strata much deeper than the casing shoe, dominantly from the intermediate depth zone.[4]
- Therefore, occurrences of slow gas seepage along energy well pathways remain a widespread phenomenon in the O&G industry, and have been observed even in recent wells completed with high quality methods.
- Given the range of completion quality over the last 60 years and the existence of Bradenhead pressure build-up in some of the wells, it is likely that in the Pavillion Field, there has been some gas seepage from depths below the base of the groundwater protection zone (BGPZ) along energy well pathways, and that this gas seepage is continuing.
- Gas seepage along the exterior of the casing means that there are three possible fates for the gas: it enters the Bradenhead annulus (negligible volumes but easily detectable), it is vented slowly to surface along the casing pathway (slow seepage to surface, high soil gas contents), or it enters into permeable zones with a low capillary entry pressure somewhere between the source and the surface or is geochemically consumed (possibly affecting groundwater quality if the gas percolates into a shallow aquifer that is a potential WSW completion zone).
- Unless some strong discriminatory procedure is identified, given the lenticular nature of many of the groundwater zones (isolated one from the other, not aerially continuous), it will be difficult to: **A**: Demonstrate if gas migration from O&G E&P activity has affected specific zones used for WSW, or **B**: If such cases are found, to specify with reasonable accuracy (such as ±10 percent) what proportion of the existing shallow gas existed before O&G development, or what proportion has seeped into the groundwater protection zone since O&G development began.
- If the shallow gas in the groundwater protection zone that existed before O&G E&P activity is of thermogenic origin, which seems likely because of the lack of a regional cap rock that provides a strong seal, it will be difficult to differentiate this gas from any gas that may currently be entering the groundwater protection zone as the result of slow seepage along energy wells (i.e., diagnostic differences may be small, and local effects of groundwater chemistry, mixing with shallow gas sources in the groundwater protection zone, differential dissolution of gases into water as a function of pressure and residence

[4] Muehlenbachs, K., 2013, Determining the source depth of migrating problem gases along wellbores: Presented at the North American Wellbore Integrity Workshop, Petroleum Technology Research Centre (Regina, Saskatchewan), Denver, Colorado, October 16–17, 2013, 30 p.

time, and different local rates of biologically mediated decomposition will have altered the chemical signature, and created more local and varied isotopic characteristics that make source identification more challenging).

  - Absent careful fingerprinting of gas through the Wind River and Fort Union Formations, identifying specific sources is difficult. However, it may still remain problematic if such fingerprinting becomes available, as there appears not to be a great deal of difference reported in gas compositions from different depths, thus even careful isotopic fingerprinting may be inadequate to specify a source with confidence.
  - Even if there is some component of upward gas migration along the outside of O&G wells that is contributing to the claimed deterioration of quality and palatability in local WSWs, identifying the specific pathway (the actual leaking energy well or wells) is an expensive activity, and there is no guarantee that a specific answer will be found, or that all wells with behind-the-casing gas seepage pathways can be identified.

- The quality of cement seals between the outermost casing and the sedimentary strata in wells is an issue that remains of concern. This, combined with cases of partial cementing of the production casing, gives a high probability that gas seepage pathways exist and have led to vertical gas migration along some fraction of the O&G wells in Pavillion Field.
  - Bradenhead annulus gas observed to be under pressure can easily re-establish pressure after pressure is released temporarily at the wellhead, proving that the cement seal between the surface casing and the production casing is either absent (cement did not rise into the surface casing) or was not 100 percent effective in all wells, and that gas migration pathways exist in some wells.
  - In some older wells, it was common to have a production casing that was not fully cemented to surface or even into the surface casing; such an open annulus between the casing and the rock can lead to the accumulation of gas from intermediate depth zones, followed by upward migration along the outside of the surface casing because of buoyancy and pressure development.
  - Incomplete production casing cementation was still common in the 2004-2005 drilling campaign in Pavillion Field, though the use of low density cements became more common in an effort to obtain cement-to-surface conditions.
  - The most likely reason for gas migration in the more modern wells is cement shrinkage or other causes for channelling behind the production casing, as gas pressure in the Bradenhead annulus is observed even in recent wells (2004) with cement-to-surface.
  - If there is cement shrinkage or channeling sufficient to allow a pathway permitting slow gas seepage and pressure build-up to develop in the wellbore and to have this pressure invade the Bradenhead annulus, it is logical to surmise that cement shrinkage or some other form of challenging has (or could have) taken place in the cement annulus between the production casing and the rock formations below the surface casing shoe. This is also the case even if the production casing was cemented to surface.
  - Just because an energy well exhibits no gas migration evidence at the time the well is decommissioned is no guarantee that slow gas seepage cannot develop at some time in the future because of the buoyancy of gas and because of the existence of pathways, as

demonstrated by the presence of Bradenhead gas under pressure in wells that had reasonably high quality primary cement installations.
  - There is no evidence that older wells are showing a higher incidence of Bradenhead gas occurrence, compared to the large number of wells installed in the mid-2000s.

Hydraulic Fracturing and Potential for Groundwater Contamination

Hydraulic fracturing (HF) has been used in a number of Pavillion area energy wells to stimulate production by improving the flow capacity of low permeability gas zones. The process involves high-pressure injection, sufficient to part the zone being stimulated, followed by placement of a coarse-grained granular proppant (quartz sand) to create a permanent increase in permeability in the zone affected by the fracturing. The issue discussed below relates to the mechanisms of possible deep HF interaction with the shallow groundwater protection zones being exploited by WSWs.

- Providing that a wellbore being stimulated using HF possesses and maintains pressure integrity throughout hydraulic fracture stimulation and injection processes (always the case in the Pavillion wells, given the data provided), it is unlikely that HF fluids or chemicals can migrate upward to the BGWZ by WSWs either during or subsequent to HF treatments.
  - In the data available, there was no evidence of large-scale inadequate casing integrity or reports of incidents of loss of integrity during HF stimulation of the O&G energy wells. Incidents of loss of injection well integrity during HF operations are typically quite rare.
  - The volumes used in the HF stimulation treatment of the gas-producing zones in the Pavillion Field are small compared to current HF practices in the O&G industry.
  - The CO_2 added in some HF stimulations ("energized fracturing") can give additional energy to rise, but even then the volumes are small, and the pressures are relieved by lateral flow into the reservoir (see a more extensive discussion in **Appendix MD-I**).
  - Relative to the depth of these HF stimulated zones below the groundwater protection zone, at least 700 feet for the shallowest HF (about 1,400 feet deep) in the area of study (i.e., within 1,420 feet of the 14 WSWs included in the study), the small volumes do not provide adequate potential for HF rise to anywhere close to the BGPZ. Much larger volumes and longer injection times would be needed to make this a possibility.
  - The presence of overlying permeable leak-off zones, found throughout the Wind River Formation between the HF depth and the base of the surface casing shoe, would inhibit HF rise through diminution of the energy and the fluid content in the active fracture.
  - In the Pavillion area, there is a stress rotation, such that the propagation orientation of hydraulic fractures changes from vertical at depth to horizontal somewhere in the upper 800-1,500 feet. This is characteristic of uplifted and eroded basins, and constitutes a barrier to upward HF propagation.
  - The Wind River Formation strata are mainly sands and clayey fine-grained sediments, and these contain clay minerals which would tend to strongly absorb and therefore immobilize most chemicals that might be injected during HF stimulation.
  - Finally, once fractured, the HF stimulated zone is placed on production, and it becomes a pressure sink (depleted pressure compared to the surroundings), rather than a pressure source. Liquids and chemicals dissolved in the liquids cannot flow away from the pressure sink, and the liquids and chemicals that are not retained or adsorbed by

the clay minerals in the strata tend to return to the wellbore to be co-produced along with the produced formation water.

- The comments above are intended to indicate why the chances of HF interaction with the potable groundwater zone are small.[5] These comments do not pertain to issues such as surface spills, seepage of fracture flowback fluids from surface retention ponds (lagoons), surface pits used for drilling wastes, produced water or other surface wastes, and other potential pathways involving surface-to-groundwater interaction. The comments above refer to pathways involving subsurface-to-groundwater flow.

Wyoming Oil and Gas Conservation Commission Report

The WOGCC has assembled a great deal of information pertinent to the basic question of whether the Pavillion area WSWs where groundwater quality and palatability issues have been noted or claimed have been affected by the O&G E&P activity in the Pavillion area. The October 8, 2014 WOGCC Report[6] has been reviewed, and an annotated PDF copy that includes several comments by this author has been provided to the WDEQ. The comments are all of a clarification nature or related to the use of a word, or a grammar comment. Some errors of fact or interpretation have been found in the WOGCC Report, and the ones of concern are listed below.

- The Report contains available information on the array of energy wells surrounding the WSWs having noted or claimed quality and palatability issues. This information includes all available well reports including drilling and casing completion reports, Bradenhead gas analyses (along with tubing and production casing gas analyses) from energy wells where Bradenhead gas was noted, and other valuable information.
- The Report and associated data show that there has been a range of well completion quality over the years, but that the tendency has been more and more toward better cementing operations, using low-density cement in an effort to obtain cement returns to the surface, and better overall quality control.
- The Report shows that the data from the WSWs cannot be considered complete in that older WSWs have incomplete drilling, screening and cementing records, often there is no information allowing one to judge quality control on the effectiveness of the casing sealing, and other, similar issues. These issues are common to all WSWs, particularly when dealing with an array of older WSWs, and this makes it difficult to carry out forensic analysis to identify sources of groundwater gas that might be associated with gas migration from O&G activity.
- Page 9 of the Report contains the Principal Conclusions. The author has concern with the implicit conclusion in the final clause of Conclusion 5: "…and adequately isolate potential gas zones from domestic water sources."

[5] Dusseault, M.B. and Jackson, R. 2014. Seepage pathway assessment for natural gas to shallow groundwater during well stimulation, in production, and after abandonment. *Environmental Geosciences* **21(3)**, 107–126

[6] Wyoming Oil and Gas Conservation Commission, Oct 14, 2014 Report. *Pavillion Field Well Integrity Review*, 95 numbered pages plus appendices and Responses to Public Comments. Issued by the WOGCC, 2211 King Blvd., Casper, WY 82602

- Although all energy wells were decommissioned according to state or federal guidelines, for several reasons this fact is not sufficient to provide the guarantee implicit in the quoted clause.
- Pathways for slow gas seepage may currently exist or may develop over time outside of the exterior-most casing (the surface casing for the first several hundred feet, then the production casing below that depth). These pathways are not closed by standard plugging methods where bridge plugs and cement dump bailing intervals are installed "within the casing" before decommissioning.
- No verification in the field has been undertaken (nor is it practical to do so) to show that isolation has been effective in all cases of energy well decommissioning.
- It is recommended that the wording be altered to reflect these facts, or that the phrase be dropped.

- Conclusion 6 from page 9 of the Report contains the assertion "…the bradenhead (annulus) gas likely did not result from behind-the-pipe migration of gas from the producing intervals, but rather from shallow gas-bearing Wind River Sands penetrated by drilling after surface casing was set." The author agrees fully with this assertion, but wishes to amplify somewhat, as this is an important point that is pertinent to the attempts to determine source, timing, and pathway for the natural gas that is known to exist in the shallow groundwater protection zones in the Pavillion area.
  - The differences between the tubing gas (produced gas) and the Bradenhead gas are not large, both are thermogenically dominated, and the Bradenhead gas almost certainly has come from a different horizon than the (mixed) production gas.
  - The presence or absence of CO_2 is not a good indicator of differences in gases sampled from different locations because CO_2 is easily absorbed by cement (carbonation) and dissolved into water.
  - Because the production zone gases are pressure-depleted during exploitation, it is almost certain that the Bradenhead gas cannot be sourced from the production horizon (the perforated zones). Many studies show that Bradenhead gas (Surface Casing Vent Flow gas in Canada) is usually not sourced from the deep production horizon, but comes largely from shallower sources.[7]
  - Because during production the pressure in the production casing and the tubing is maintained below the hydrostatic pressure in the fluids in the surrounding formations behind the production casing all the way from the uppermost perforated interval to the surface casing shoe, the Bradenhead gas of active producing wells could not have come from leaking threads or casing impairment, so therefore it almost certainly cannot be from the same source as the production gas.
  - The fairly rapid repressurization behavior of the Bradenhead gas in a number of wells indicates that the proximal source (not the original source) of the gas is local (in the general vicinity of the surface casing shoe) and is apparently under a limited pressure

[7] Chatellier, J-Y.D., Rioux, R., Molgat, M., Goodall, C. and Smith, R. 2012. Applied Organic Geochemistry and Best Practices to Address a Surface Casing Vent Flow - Lessons from Remediation Work of a Shale Gas Well in Quebec Search and Discovery Article #40976 (2012), Posted July 16, 2012

head that is generally less than the hydrostatic pressure one would expect at the bottom of the casing shoe.

- However, departures from a hydrostatic head in WSWs in the Pavillion area appear common and irregular, and it is a reasonable assumption that the groundwater pressure at the casing shoes in the examined area is not hydrostatic (i.e. less than 0.433 pound per square inch per foot or psi/ft.).
- Most Bradenhead pressures equilibrated in the range 150-185 psi (one showed a value of 20 psi, and another a value of 120 psi). These pressures correspond to a column of free gas of approximately 375 feet (for 150 psi) to 450 feet (for 185 psi) assuming a column of near-surface fresh water is balanced by gas. Example calculations are found on pages 41 and 42 of the Report.
- Furthermore, because most of the Bradenhead pressure tests show a re-equilibration pressure that is similar, it is likely that most of the Bradenhead annular spaces of the wells showing Bradenhead pressurization are hydraulically connected to the same source of pressurization and that the gas is at shallow depth, within the groundwater protection zone.
- The proximal source of the gas responsible for the Bradenhead annulus repressurization is not necessarily a continuous zone with full lateral connectivity. However, given the similar equilibration pressures, it may be a single shallow stratigraphic horizon which has provided accumulation sites for migrating thermogenic gas. This horizon likely has lenses of sand with low capillary entry pressure that have allowed naturally occurring gas accumulations over time, the entry of seepage gas from energy wells, or both.
- There is no evidence of an existing active pressure connection to a gas source at greater depth below the groundwater protection zone; otherwise, a higher equilibration pressure would have been expected for the Bradenhead gas, at least in some cases.
- The thermogenic gases in the deep formations being exploited have been reported to be very similar in chemical composition over large vertical distances, and there are no systematically collected isotope data for the wells during drilling (mud gas analysis), therefore the specific source of the Bradenhead gas cannot be identified in a straightforward manner.
- Because of vertical gas migration in this region over geological time, even if such data were available, it would not necessarily resolve the issue of gas source and pathway in shallow groundwater zones.
- The possibility remains that the Bradenhead gas is not from pre-existing shallow gas in the Pavillion area that seeped upward from the source rocks over geological time, but that the gas has seeped toward the surface along energy well pathways (behind-the-casing gas migration) more recently. As discussed above, proving where the Bradenhead gas came from and when it migrated to the groundwater protection zone is not likely to be feasible.

Potential Future Actions for Well Integrity Assessment

There is a large number of actions that could be taken or commissioned by WDEQ and WOGCC personnel, or by other agencies or companies active in the Pavillion case involving claims of quality and palatability issues in private water wells, to address well integrity and the possibility that gas migration is

occurring along energy well pathways. However, there is a lack of good baseline data collected before any O&G E&P activity for the general groundwater regimes in the Pavillion area and there is a lack of sufficient history of analysis results from WSWs (time-series geochemical and gas occurrence data taken on WSWs over a period of several years). Therefore, further reduction of uncertainty is a challenging undertaking, it would incur large costs, and there is no guarantee that the results would be unequivocal, much less satisfying to all parties. It is again emphasized that because of the great uncertainty and the history, combined with the very real possibility that thermogenic gas (from deep sources) is in the shallow groundwater in the Pavillion region naturally, a satisfactory outcome is unlikely.

The following points are not recommendations: they are a listing of some actions that could be undertaken to support the efforts of the State of Wyoming in their attempts to further assess and quantify the issue, to see if further action should be forthcoming. Inaction may, in the Pavillion Field case, be the most acceptable approach, unless it can be demonstrated by further analyses and assessment that there is a reasonable chance that further investigations would significantly reduce uncertainty. Not all WSW contamination cases related to gas migration can be satisfactorily resolved.

Studying O&G Energy Wells for Gas Migration

- After a large rainfall, when the ground is wet, visual examination around active or decommissioned wellhead sites may indicate whether there is gas migration taking place, as some gas may be bubbling slowly up to surface, or vegetative distress may be noted. The presence of pressurized thermogenic Bradenhead gas in some energy wells is proof that there is thermogenic gas in some shallow aquifers, whether or not the source was natural geological seepage or associated with the O&G energy wells.
- Gas trapping rings and tents might be considered if there is a concern that gas migration is occurring and that methane is escaping to the atmosphere through slow seepage around O&G wells. These sampling exercises can be deployed at varying distances from a wellhead of interest, and sampled over an extended time period to assess the localization and any periodicity[8] in the gas migration behavior. (http://www.epa.gov/oust/cat/pvi/soil_gas.htm)
- Soil gas sampling using careful protocols and new devices such as the GasClam™ around active and decommissioned energy wells may give more insight into regional conditions and perhaps allow some inferences to be made about gas migration. (http://www.gasclam.com/). For example, soil gas samples could be systematically collected near to and also more than perhaps 500 feet from active wellheads with or without Bradenhead gas, as well as old abandoned wells, to detect if there are compositional and quantity differences that are spatially related to the presence of energy wells. (Note that this still is not sufficient to prove that the gas is seeping from depth because of poor wellbore integrity; additional data is needed.)[9]

[8] Jackson, R.E. and Dusseault, M.B. 2014. Gas Release Mechanisms from Energy Wellbores. *Proc. 48th U.S. Rock Mechanics Symposium*, Minneapolis, Paper ARMA 14-7753, 5 p. (Available on OnePetro)

[9] It is beyond the remit of this assessment of well integrity and the competencies of the author to recommend details of the design of a shallow groundwater and soil gas evaluation program, if a decision to do so is made. Great care is needed in the design and execution of any such program because of the geological complexity in the Wind River Formation, regional groundwater flow patterns, irrigation, the presence and exploitation rates of WSWs, and other factors.

- If WSW gas samples are to be collected, careful protocols should be followed to obtain representative dissolved gas samples, the dissolution pressures, and so on. The work of Cathy Ryan at the University of Calgary with respect to soil gas sampling in O&G regions is seminal in this area. (http://www.ucalgary.ca/ryan/Publications)
- Positive identification of surface emissions of gas can be achieved, but techniques for the positive identification of gas in deeper aquifers around O&G energy wells are costly and involve multi-level groundwater wells or multiple wells completed at different depths. There is no known remote-sensing method that is sufficiently reliable to detect small amounts of free gas in aquifers at depth.
- If there are concerns over the integrity of O&G energy wells triggered by evidence of significant gas migration, to rectify the problem (if it is deemed appropriate) it is necessary to re-enter the wellbore, and this is a highly expensive undertaking. Some of the actions that might be undertaken at that point include the following:
    - Pressure integrity tests on the casing can be performed.
    - Noise logs may be used to assess if there are gas entry points behind the casing that are emitting enough noise to be detected.
    - Casing bond logs in the production casing interval or perhaps even the surface casing interval may give some indication of poor cementing or incomplete sealing, but such logs are difficult to interpret consistently and quantitatively.
- It is important to remember that inaction is an option if the problem is minor, considering that there is evidence of natural gas migration in the area. Nevertheless, if it is considered necessary, well remedial sealing can be undertaken using conventional “perf-and-squeeze” cementation, or the use of a more effective sealing resin to intersect the pathway. Although such actions may improve the seal of a particular well, there is no guarantee that such actions will result in an improvement in the general groundwater quality in the region because of the naturally occurring presence of thermogenic gas in some shallow strata.

Source of Shallow (Bradenhead) Gas in the Pavillion Area

The *Pavillion Field Well Integrity Review* reports gas analyses from a group of energy wells surrounding a group of WSWs for which claims and concerns have been expressed over water quality. These comments are intended to address these issues in more detail. The pages that follow are intended to clarify certain issues and processes. There are three possibilities:

1. Natural gas from depth (thermogenic gas) may be common in the shallow sediments above the BGPZ in the Pavillion Field area as the result of seepage over geological times.
2. Thermogenic gas in shallow Pavillion Field area sediments may have entered into the groundwater zones as the result of pathways created by O&G exploration and development.
3. Gases present in shallow Pavillion Field area sediments may be a mixture of naturally occurring thermogenic gases and new thermogenic gas arising from O&G exploration and development activity.

Possible subsurface pathways associated with O&G activity are shown on Figure 1.

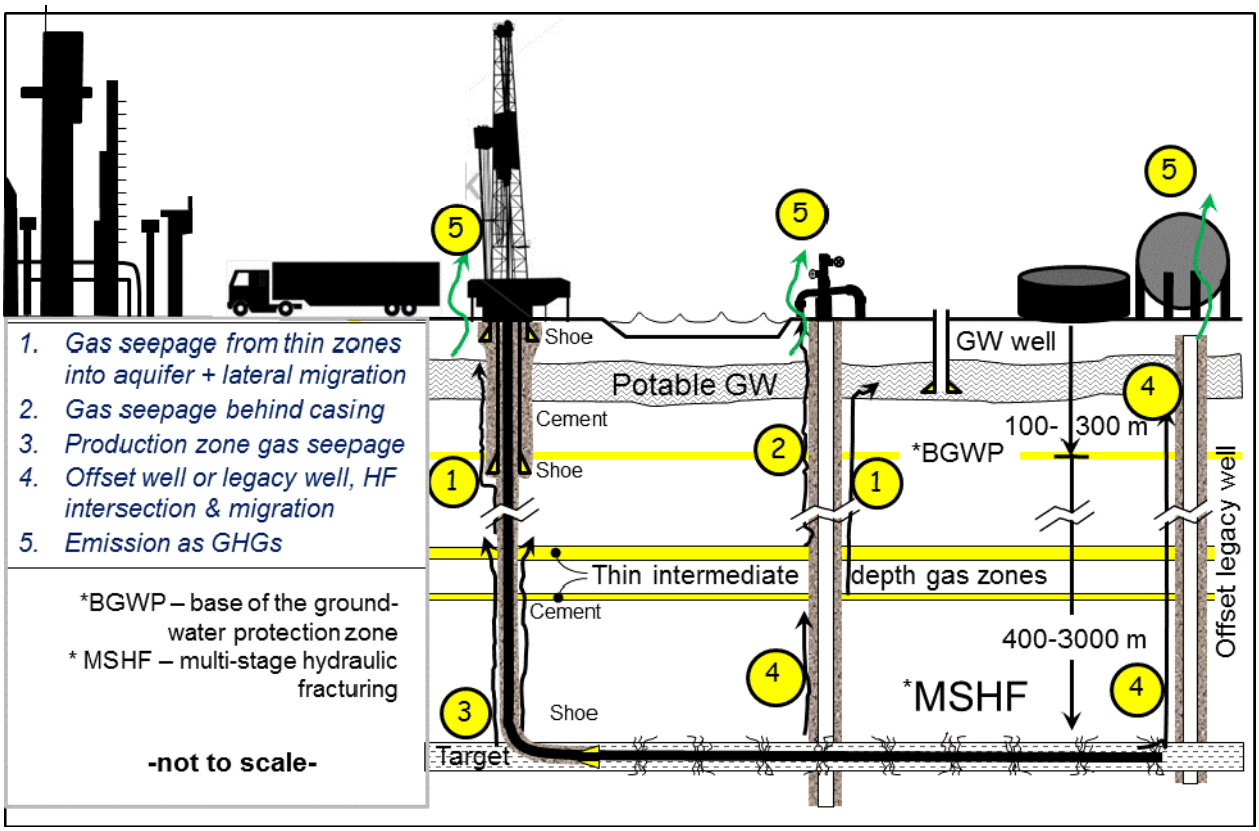

Figure 1: Possible Subsurface Pathways for Contaminant Migration (GW = Groundwater, GHG = Green House Gases)

In general, one may sample gas from energy wells in the following locations:

- Gas from the gas production tubing
- Gas from the casing head, outside the tubing, but not in the surface casing annulus
- Gas from the surface casing annulus ("Bradenhead" gas)
- Soil gas in the vicinity of the energy well (gas found outside the surface casing)

The following comments address the issues of understanding where sampling can take place and the meaning of terms used. Furthermore, this section begins to address some of the issues related to potential fluid seepage in and around energy wells.

Production Tubing Gas

Production tubing gas is sampled from the well flow, and it comes from depth along a tubing string anchored above the producing perforations with a tubing packer. The production tubing contains gases from the formations behind the opened perforations, without additional sources of gas (assuming good packer seals). Because wellhead pressure is low in the Pavillion energy wells and the weight of the column of gas in the production tubing is small, the pressure at the casing perforations is also small, far below any original pressure in the beds that have been perforated. This means that the gas sampled is a mixture of gas from various zones, each of which is contributing some amount of gas to the bulk production. It is not common practice in such wells that are perforated in several zones to differentiate the production sources chemically or isotopically. Thus, although it is certain that the production tubing gas is being sourced from the perforated production zones open to the tubing, it is not known what percentage of the gas comes from which specific zone at depth. During production, some wells may become liquid loaded near the base if a liquid lifting system (a "water jack" or similar device) is not installed, impeding deeper gas production, and allowing gas from the higher perforations to dominate production. Wells in which there is no water ingress or where the water levels in the bottom of the hole are kept low yield gas production from all of the perforated intervals.

It is important to realize that the production tubing gas, because it comes from a mixing of the gas from a group of producing production horizons, should not be expected to be "identical" to the gas collected from the Bradenhead annular space. The source of the gas in the Bradenhead annular space is more likely to be from one shallow gas-charged zone, rather than mixed, thus it is highly unlikely to be the same gas compositionally. The production tubing pressure is at or somewhat less than the pressure in the annular space between the production casing and the production tubing.

Casing Head Gas

Gas from the casing head is sampled from the annular space between the tubing and the production casing. This gas that is outside the tubing also more-or-less reflects the composition of the production gas, but because the casing head annular space may be inactive (static, non-flowing, and not connected directly to the tubing gas because of the tubing packer) for long periods of time during continuous production through the tubing, the gas that is sampled may not represent the specific chemical composition of the gas that is being produced from the tubing at the sampling time. There also may be slow seepage into the production casing from a packer that is not fully sealing, or through improperly sealed threads in the production tubing (if pressures are different), and it is also feasible that there is some slow seepage from improperly or inadequately sealed threads in the production casing. It is highly improbable that deeper formation gas can escape to the region outside of the production casing

because the pressure in the casing head annulus will always be far less than the pressure in the strata outside of the production casing once wells have been on production for some time (wellhead pressures are now very low in Pavillion Field). However, slow influx of natural gas from unperforated thin gassy zones outside the production casing into the casing head space is a definite possibility because the pressure in the casing head space is lower than the pressure in the strata. Such slow influx, for example, might take place through threaded casing connections that have not achieved a full positive seal.

Therefore, although great compositional similarity would be expected between tubing and casing gas, there are good reasons why this might not be the case if there are improperly sealing casing threads.

Bradenhead Gas (Surface Casing Annulus Gas)

Gas from the surface casing annulus (Bradenhead Gas) is taken from a valve accessing annular space between the surface and production casings. In modern well completion practice, this space is intended to be cemented to the surface, or at least cemented a substantial distance above the surface casing shoe so that an effective flow seal exists between the two casings. Data from Pavillion Field reports show that primary cementing operations in many wells failed to lead to cement rising into the surface casing. It seems that regulatory practices in Wyoming allow a non-cemented space to be left in place below the surface casing. In some jurisdictions, such practices are allowed with the caveat that the energy company be responsible for making sure that the cement around the production casing rose to above the shallowest gas-bearing zone, or some similar set of conditions (different regulatory jurisdictions have different rules in place, some of them explicitly directive, some of them performance-based). In general, leaving an open annular space between the top of the production casing cement and the bottom (shoe) of the surface casing is not considered good practice (annum 2015), but wells drilled in the 2004-2005 campaign in Pavillion were not all cemented to above the surface casing shoe.

Because the Bradenhead annulus is not connected to the production horizons that are being depleted, it is not expected that the Bradenhead gas will be identical to the production gas. The pressure inside the production casing is maintained less than the pressure of the fluids in the surrounding geological strata, so there is no mechanism for gas to escape from inside the production casing into the Bradenhead annulus, even if there are threaded connection quality issues. Furthermore, because gas from the Bradenhead valve has been exposed to water and to the cement along the wellbore and in the annular space between the surface casing and the production casing, there will have been adsorption of gases that are somewhat reactive. For example, cement adsorbs CO_2, a process leading to cement carbonation, well-studied in the context of well design for possible CO_2-sequestration projects.[10] Therefore, if there are CO_2 traces in production gas, and if the Bradenhead annulus gas does not have any CO_2, it is not proof that the gases are of different provenance: The cement may have adsorbed the small amount of CO_2 in the fugitive gas as it passed up through the Bradenhead annular space.

Gas Migration

Gas migration is the term used to describe the process of gas seepage into the shallow strata associated with energy wells, and this gas may dominate or contribute to the presence of aquifer gas and soil gas if

[10] Kutchko, B.G., Strazisar, B.R., Lowry, G.V., Dzombak, D.A., Thaulow, N. 2007. Rate of CO_2 Attack on Hydrated Class H Well Cement under Geologic Sequestration Conditions. *Environmental Science and Tech.* **42**, 6237–6242

it is occurring. Such gas is most commonly understood to be shallow gas that is considered to be "fugitive" gas that is seeping upward from depth, rather than sourced directly *in situ* – such as marsh gas that is dominantly methane from the anaerobic decomposition of plant matter. It is found in soil samples, but there is no accepted defining depth above which it would be called soil gas, and some use the term soil gas for all naturally occurring gas found at shallow depth. Soil gas is not generally sourced from deep gas production horizons, although in many areas underlain by deep thermogenic gas strata, soil gas can have a strongly thermogenic signature. It is perhaps more commonly sourced from relatively shallow biogenic gas formation processes (e.g. from the top 1,500-3,000 feet) that lead to soil gas presence through slow upward seepage, but it can also originate from intermediate-depth gas zones through slow upward migration. It is rarely sourced entirely from the deep formation being produced from the local oil and gas fields; more often, it is of mixed provenance, with multiple sources.

Because the perforated and open horizons are pressure-depleted during production, gas migrating upward to the soil from the production horizon because of the gas production development is actually unlikely. In some oil and gas regions, exploration for reservoirs using soil gas sampling has been quite successful,[11] using various indicators such as the frequency and concentrations of gas occurrences, as well as the isotopic and chemical composition of the gas. Thus, natural gas found in soil (and even found naturally in shallow aquifers used for WSWs) may be thermogenic in origin, biogenic in origin, or of mixed provenance. The presence of thermogenic or mixed-source gas near the surface is generally proof that there has been some seepage of thermogenic gas from depth, but it is challenging, indeed often impossible, to identify the specific pathway. If there have been no baseline gas occurrence surveys in shallow aquifers and soil before O&G development, identifying when the gas invaded the soil is difficult, and pinpointing the source is challenging and costly.

A significant issue in gas migration understanding is that the process is almost never quantified unless there is a clear presence of gas at the surface, such as bubbling in the vicinity of a wellhead, the presence of dead or clearly distressed vegetation around a well location, gassy water arriving in shallow aquifers where the gas can be shown to be of thermogenic origin, and so on.

[11] Philp, P. and Crisp, P.T. 1982. Surface geochemical methods used for oil and gas prospecting — a review. *Journal of Geochemical Exploration* **17(1)**, 1-34.

Figure 2: Consequences of Gas Migration in a Field in Saskatchewan. (Courtesy of K. Muehlenbachs and S. Arkadakskiy, University of Alberta, Edmonton AB, 2015)

On Figure 2, distressed vegetation in a canola field in Canada has been tied to the presence of gas migration associated with abandoned wellheads, apparently through soil gas sampling and isotopic analysis. This type of direct evidence of gas migration appears to be absent in the Pavillion Field area (or else such data have not been collected).

Figure 3: Gas Bubbling up Around an Old Wellhead in Southwestern Ontario (Courtesy of the Oil and Gas Laboratory, Ontario Ministry of Natural Resources website, downloaded in 2013).

This well on Figure 3 is showing an exceptional rate of gas migration that is also lifting deep formation brine to the surface in a process akin to "gas lift" in oil wells (gas is injected to reduce the density of the column of fluid, and the buoyancy of the gas bubbles help "lift" the oil to the surface).

In comparison to Bradenhead gas and the evidence in repressurizing of the Bradenhead gas seepage that has been identified in Pavillion, the occurrence of gas migration appears not to have been verified or carefully assessed in the Pavillion WSW study. This is not intended to be a criticism: answering questions as to occurrence, provenance and pathways of fugitive gas through the deliberate scientific assessment of the occurrence and rate of gas migration in complex geological conditions (as in the Wind River Formation) is extremely challenging. Doing this using only WSWs is not realistic; confirmation of well integrity, identification of leaking wells, and quantification of rates of gas flux into aquifers and into the atmosphere require a large effort. To the writer's knowledge, even though there are some recent studies that have addressed these issues, there has not yet been an integrated study of gas migration associated with energy wells in a mature field such as Pavillion Field. Therefore, there is no significant experience base or database in the public domain that can be addressed in this regard.

There are many reasons to believe that different geographical and geological regions will have different controlling factors that may impact the development of gas migration processes along the outside of the outermost cemented casing. For example, in some jurisdictions gas migration around energy wells is well known, and may be associated with particular geological conditions. In other regions, such as very dry areas where there is no standing water or significant vegetation that can be distressed through plant root gas exposure, there may be no surface evidence of gas migration. In yet other areas (e.g. where there are no intermediate gas zones), gas migration may be exceedingly rare.

Similarly, geological conditions can be variable even within an area such as the Pavillion Field area. The Pavillion area geology in the Wind River Basin is an assemblage of sandstones, siltstones and some shales, laid down in conditions dominated by streams and continental deltas. River channel deposits consist of sand that varies from fine-grained to coarse-grained, often truncated by later erosion and new sedimentation episodes. If an energy well passes through such a sand body at a depth of 1,200 feet, for example, and slow gas migration develops from gassy sandstones at greater depth, it is quite possible that the gas never reaches the surface casing shoe to be noted (perhaps) as Bradenhead gas. On the other hand, there are different local sources for observed gas. Bradenhead gas observed at one well may be occurring naturally in the shallow Wind River Formation sediments, it may have seeped up slowly along the energy well, or it may have arrived through a more complex pathway such as migration from an offset well. Undoubtedly, the latter scenario is far less probable that the other two, but long distance gas migration along permeable zones is well known.

Although the geological disposition is quite different, an example of long distance migration of escaping gas from a breached gas storage facility in Hutchinson, Kansas is perhaps the most notorious example of lateral gas migration known in the world at this time, Figure 4.[12]

[12] Nissen, S.E., Watney, W.L., Bhattacharya, S., Byrnes, A.P, Young, D. 2004. Geologic Factors Controlling Natural Gas Distribution Related to the January 2001 Gas Explosions, in Hutchinson, Kansas. Kansas Geological Survey Open-File Report 2004-21. http://www.kgs.ku.edu/PRS/publication/2004/AAPG/NG_Migration/P1-02.html

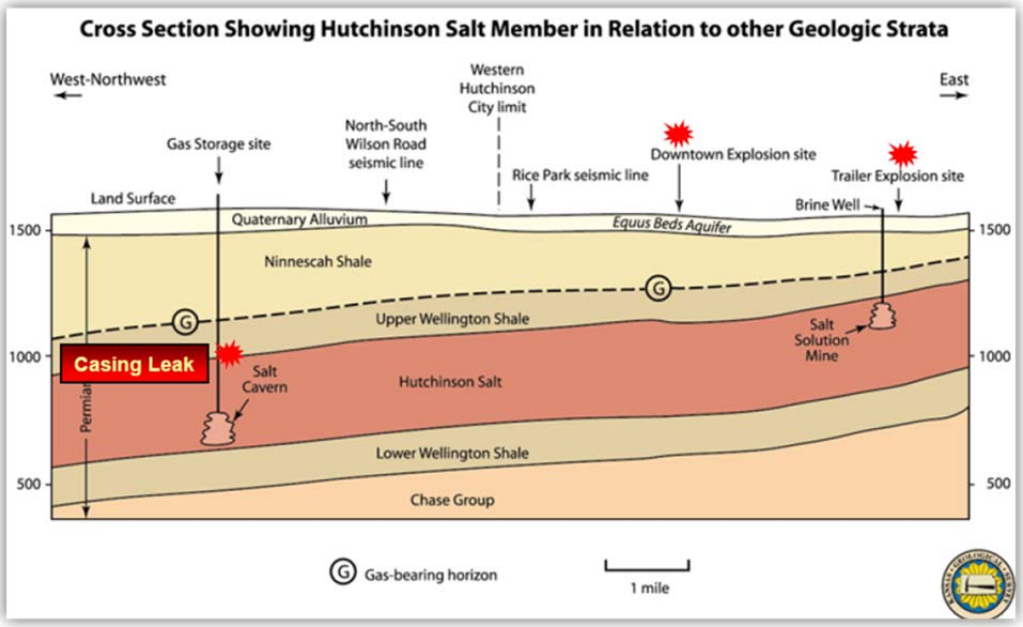

Figure 4: Lateral Migration of Natural Gas along a Small Geological Feature

To emphasize that geological conditions are different, note that Pavillion Field is in layered clastics with only small amounts of carbonates, whereas the Hutchinson geology is layered and relatively flat-lying carbonates and evaporates such as limestone, dolomites, salt and marls. The gas under pressure that escaped from a ruptured casing in the salt storage facility migrated 13-14 km (8-9 miles) from its source to the village of Hutchinson, where it led to several explosions, fires and deaths. The migration occurred along a thin permeable bed of dolomitized micrite only a foot or two thick that was under a shale caprock, so that the gas pressure could not be dissipated upward. This bed is shown on Figure 5.

Figure 5: A Thin Dolomicrite Bed Served as a Gas Pathway for Lateral Migration

The technical point that deserves emphasis is that identifying the source of gas that is detected in the soil, in aquifers, or even in the Bradenhead annulus is not a straightforward task. The Hutchinson, Kansas case also triggered a great deal of ancillary research ranging from multiple groundwater wells to trials of shallow seismic and geochemical identification, and the conclusions as to the feasibility of pathway identification for this very clear case (the source was known, the exit points were known) were not highly positive. The specific sources of the Pavillion Field Bradenhead annulus gas accumulations would be challenging to identify.

One would expect a substantially greater incidence of gas migration in older wells completed when cementing practices were less developed than today. Some of the issues in these cases may include:

- Incomplete cementing of production casing between the surface casing shoe and the top of cement (recorded in some Pavillion wells). Modern practice is generally to take the production casing cement to the surface, although many of the wells in the 2004-2005 drilling campaign did not achieve cement-to-surface conditions.
- Poor cement quality control such that significant autogenous shrinkage takes place during set and cure, leading to conditions of microannular space development.
- Poor hole cleaning and mud cake removal, leading to the development of continuous vertical channels which can accumulate a free gas column, leading to enhanced buoyancy effects.

To assess this, the ages of the reported cases of Bradenhead annulus pressurization were studied to see if common conditions existed. Specifically, age appears not to be a factor. If further assessments of conditions of wells in the Pavillion Field are considered valuable, it is suggested that a careful evaluation of the condition of the cement in energy wells be undertaken to see if there are commonalities that are associated with the presence or absence of Bradenhead annulus repressurization. This might involve cement bond logs that are available, cementing reports, the density and type of cement used, examination of the region surrounding energy wells to see if there is evidence of gas migration outside the surface casing, perhaps soil gas sampling and more comprehensive WSW sampling for free and dissolved methane. Such an assessment is beyond the scope of this report.

Table 1: Wells with Bradenhead Annulus Gas Repressurization Noted[13] (gas contents reported as percentage of total gas)

Well	N2	N2	CO2	CO2	Pressure	Year	
	Tubing	Braden	Tubing	Braden			
Fee 13-3W	0.3936	0.5851	0.0502	0	120	2005	
Fee 43-4	0.3936	0.5851	0.0295	0	150	2005	
Fee 44-4	0.3952	0.7962	0.0295	0	185	2005	
Fee 31-10	0.3529	0.8255	0.0006	0.0005	160	1994/2002	reperforated and fracked
Tribal 32-10C	0.4696	1.4023	0.1336	0	165	2005	
Fee 41-10B	0.5704	0.7897	0.0467	0	165	2005	
Tribal 42-10B	0.4577	1.1921	0.0592	0	20	2005	
Unit 44-10	0.358	1.3997	0.209	0	150	1978/2004	reperforated and fracked
Unit 12-11	0.3545	0.7963	0.3991	0	150	1993/2004	reperforated and fracked
Fee 12-11W	0.46991	0.9415	0.0575	0	150	2001	

Another issue in cementing may arise because of the use of low density cement; light-weight cement with density less than 10 pounds per gallon (ppg) is recorded for some of the Pavillion energy wells. Low density cement is used to avoid cement losses in areas where the horizontal stresses are low and lost circulation can take place during primary cementation, leading to an inability to bring the production casing cement up into the surface casing. The low horizontal stress is often the result of the partial depletion effect from previous production – a reduction of reservoir pressure leads to a significant reduction in the horizontal stress as well, such that a column of cement of typical density 2.05 cannot be sustained all the way to the surface. Some of the fracture gradients reported by EnCana are as low as 0.7 psi/ft. This cannot sustain a column of cement to the surface, so low density cement is used to guarantee that cement fully fills the Bradenhead annulus to the surface. As mentioned above, this was not achieved in all of the Pavillion wells, even in the most recent drilling campaigns. Furthermore, the shrinkage characteristics of this low-density cement are not known.

Intermediate Gas Zones

Intermediate depth gas zones are defined as gas zones – containing thermogenic, biogenic or mixed gas – lying between the top of the uppermost perforated producing horizon and the shoe of the surface casing. These zones may simply be too thin to be commercial, or the production license may exclude them. In the Pavillion area, there are many intermediate gas zones, and in the absence of detailed sampling of these zones followed by geochemical analyses of the profile, something that might be performed by an oil and gas company during exploratory drilling, it is not possible to specify what the source of the gas in intermediate zones might be. In some regions of the world, where plant matter has been rapidly buried in geological history before it could decompose entirely, biogenic gas may dominate the profile to depths as large as 6,000-7,000 ft. The molecular compositions and isotopic analysis results acquired from intermediate gas zones during drilling (mud gas sampling) with depth would give some insight into the provenance and mixing of biogenic and thermogenic gases in the intermediate zone.

Figure 6 shows an older type of completion that is common where the regulatory agencies do not insist that the production casing cement be brought to surface. This is becoming a far less common practice,

[13] Only Tribal 42-10B had casing (and tubing) pressures higher than the Bradenhead equilibration pressure. Furthermore, the lack of CO_2 in the Bradenhead gas is likely because CO_2 is highly soluble in groundwater, in contrast to hydrocarbon gases, and it is also reactive with cement (carbonation of cementitious minerals)

and low-weight cements are often used to enable cement to return to surface. The figure also specifies the locations of Bradenhead, casing, and tubing gases.

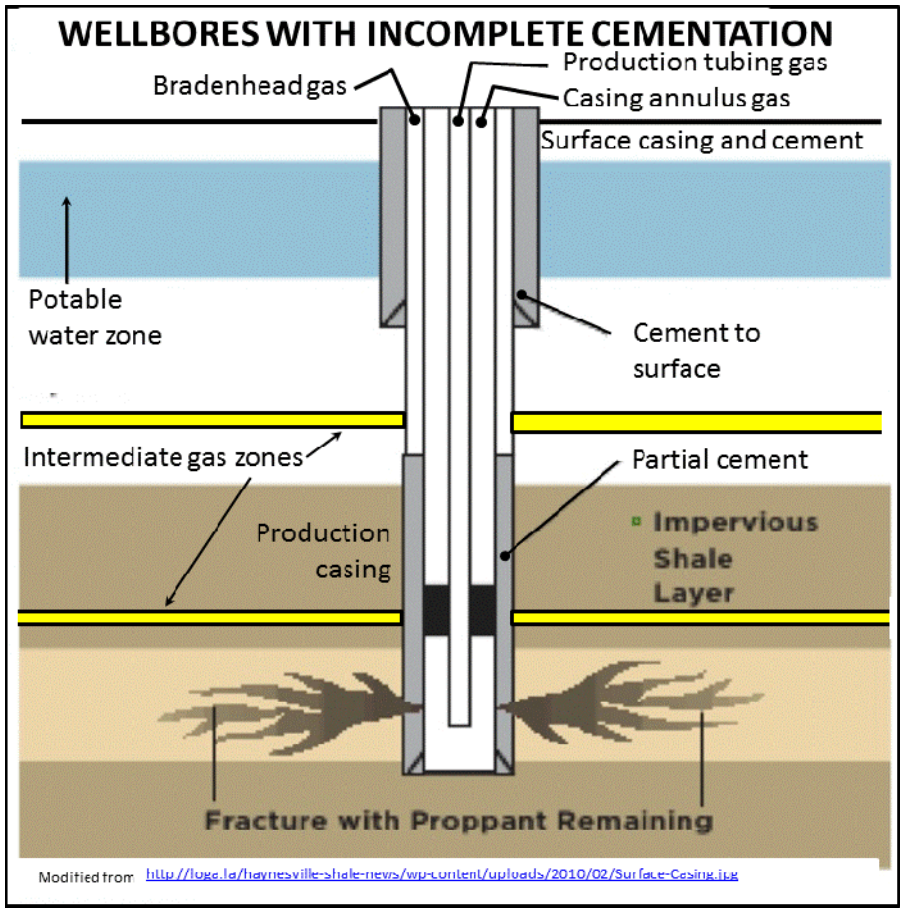

Figure 6: Well Completion Showing the Location of Bradenhead, Casing and Tubing Gases, along with Intermediate Depth Gas Zones and a Production Casing not Cemented to Surface

Naturally Occurring Shallow Gas

Naturally occurring shallow gas may be defined as free or dissolved gas that is naturally present in the potable water aquifers (the groundwater protection zone) and is also present as dissolved or sometimes free gas in the less permeable porous horizons within the zone defined as "groundwater." Some jurisdictions (e.g. Alberta) use a definition of 4,000 ppm[14] total dissolved salts as the BGPZ, to differentiate it from the deeper saline formation water zone.[15] In most petroleum-prone regions such as

[14] Other jurisdictions may use somewhat higher numbers, such as 10,000 ppm, and various other conditions may apply to specify a definition of the groundwater protection zone. See for example U.S. Environmental Protection Agency (US EPA), 2011. *Glossary of Underground Injection Control Terms* http://www.epa.gov/r5water/uic/glossary.htm

[15] The State of Wyoming and also the US EPA use different TDS concentrations as a basis for classifying groundwater uses. Wyoming recognizes three classes of groundwater: Class 1 Domestic (TDS <500 mg/L), Class II

eastern Ohio, Pennsylvania, and Texas, naturally occurring shallow gas may be found in a substantial percentage of WSWs, and regional frequencies of 10 percent to over 30 percent have been reported.[16,17] The gas may be largely or entirely dissolved in the groundwater, but as the pressure is reduced, the gas may come out of solution as free gas, where there was none previously. It is likely that the Pavillion Field area where the WSWs are being studied had shallow gas in the groundwater protection zone, and partly of a thermogenic nature, based on experience in other parts of the world. Regional groundwater pressure decline may have led to gas exsolution.

Thermogenic Gas

Deep-sourced **thermogenic gas** is formed by slow thermally-induced degradation of larger hydrocarbon molecules into smaller molecules, a process that is considered to happen only at depths where the temperatures are sufficiently high, below perhaps 8,000 ft. (depending on the geothermal gradient). The larger hydrocarbon molecules came from the diagenetic modification of kerogen, a semi-solid organic substance usually of algal origin (kerogen is mainly the lipid-rich cell walls and other large organic molecules found in cells). This process generates not only CH_4, but some amount of many other aliphatic hydrocarbons, C_2H_6, C_3H_8, C_4H_{10}…, called alkanes, and more complex hydrocarbons such as trace amounts of benzene. It is generally accepted that the presence of significant percentages of the larger gaseous alkane molecules such as ethane and propane (C2, C3…) is evidence of a thermogenic origin for the gas, or at least a partial thermogenic origin. Furthermore, gas can be analyzed for the presence of different stable isotope ratios for various elements such as carbon ($^{13}C/^{12}C$) and hydrogen (H/D), and also the noble gases (Xe, Ar, Ne, Darrah *et al*. 2014).

Biogenic Gas

Biogenic gas, generally shallow-sourced in comparison to thermogenic gas, is methane-dominated (dry gas) and is formed by methanogenic bacteria that work in the absence of oxygen, similar to the bacteria (rumen) in the stomach of ruminants (ruminants emit methane; apparently, a head of cattle emits about 105 kg of CH_4 per year). These methanogenic bacteria break down plant matter, largely cellulose and lignin, into gaseous products (CH_4 and CO_2) as well as H_2O and some other secondary products, usually leaving behind carbon as the final product (coal, peat or coaly fragments for example). Swamp gas produced from the anoxic mud in the bottom of an organic-rich water body (peat bogs, swamps, perennial ponds) is an example of locally-sourced methane of shallow, fully biogenic origin. Coal is an example of a natural material that is formed biogenically from plant matter biodegradation, and many non-metamorphosed higher porosity coals have large amounts of methane absorbed on the surfaces of pores in the coal. If the coal seams are thick enough and at the right depths, this gas may be commercially exploitable and is called CBM – coal-bed methane. The San Juan Basin, the Powder River Basin, and the Four Corners region are well-known areas that are rich in coal seams and therefore in biogenic methane – CBM. In Wyoming and in eastern Alberta, shallow biogenic gas at depths from 1,000

Agriculture (TDS <2,000 mg/L), and Class III Livestock (TDS <5,000 mg/L). Thus, for Wyoming the equivalent value is 5,000 mg/L. The US EPA definition of "Underground Sources of Drinking Water" includes TDS <10,000 mg/L.

[16] Moritz, A., Hélie, J.F., Pinti, D.L., Larocque, M., Barnetche, D., Retailleau, S., Lefebvre, R., Gélinas, Y. 2015. Methane baseline concentrations and sources in shallow aquifers from the shale gas-prone region of the St. Lawrence lowlands (Quebec, Canada). *Environ Science and Technology* **49(7)**: 4765-71.

[17] Molofsky, L.J., Connor, J.A., Wylie, A.S., Wagner, T., Farhat, S.K. 2013. Evaluation of Methane Sources in Groundwater in Northeastern Pennsylvania. *Groundwater* **51(3)**, 333–349.

feet to perhaps 2,800 feet in the Colorado Group strata has been widely exploited through small vertical wells. Biogenic gas is close to pure CH_4 (dry gas), usually with a minor component of CO_2. The methanogenic bacteria that decompose cellulose do not excrete much C_2H_6 or other, larger molecular weight alkanes; significant quantities of these larger molecules are associated only with thermogenic gas, and the presence of ethane, propane and butane (C_2H_6, C_3H_8 and C_4H_{10}) is considered diagnostic of thermogenic gas, or at least the presence of a thermogenic component in the case of a mixed-source gas.

The following figure shows the concept of natural gas fingerprinting and gas source discrimination in a sedimentary sequence, in this case, the Western Canada Sedimentary Basin in the vicinity of Lloydminster, Alberta.[18]

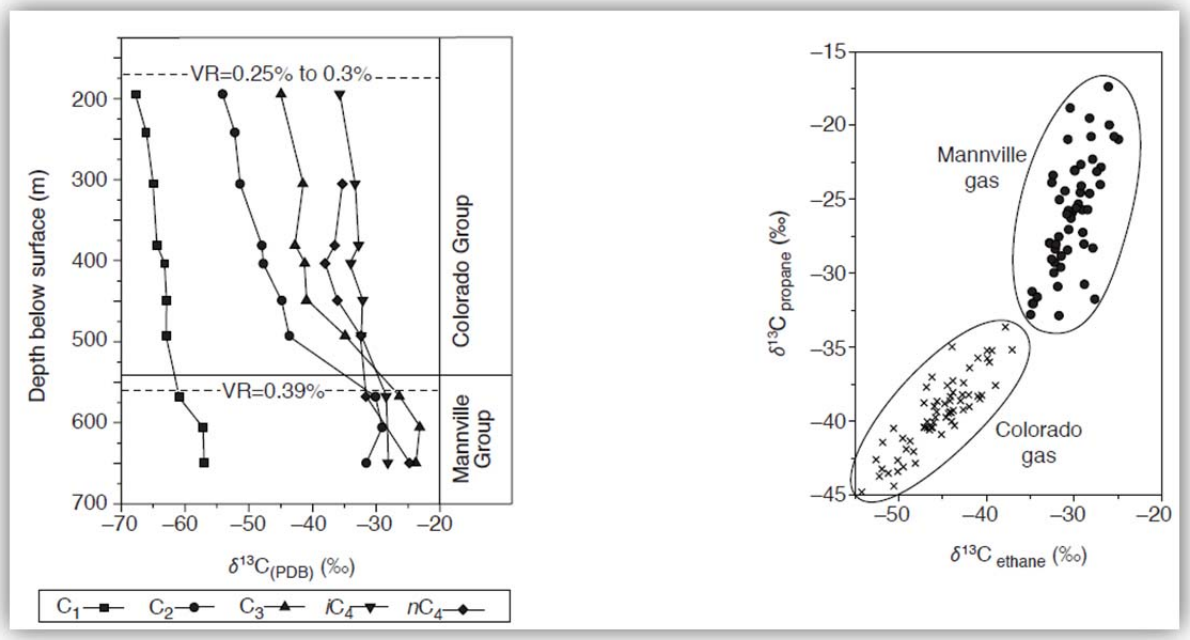

Figure 7: Discrimination of Gas Sources in a Late Cretaceous Arenaceous Sequence (Rowe and Muehlenbachs 1999)

These data are based on 20 wells from which mud gas samples were collected and analyzed for composition (various gas molecules) and carbon isotope ratios. A quote from the abstract to this article is pertinent:

> "We can distinguish between gases of shallow and deep origin by using the carbon-isotope compositions of the non-methane components (ethane, propane and butane); the shallow gases have isotopic compositions consistent with a thermal origin, whereas the deep gases—although of abiogenic origin—bear isotopic signatures that have been biologically altered. These findings have

[18] Rowe, D. and Muehlenbachs, K. 1999. Low-temperature thermal generation of hydrocarbon gases in shallow shales. *Nature* **398** (4 March), 61-63

allowed the development of a successful tool for detecting the source of leaking gases around oil wells in this basin, enabling cheaper and more effective remediation." (*Ibid*.)

The figure indicates several important points that are relevant to the Pavillion gas occurrences at shallow depth:

- Source discrimination between the shallower Colorado Group gases and the deeper Mannville Group gases on the basis of composition alone is not easy, given the fact that gases can be generated at different conditions.
- Isotopic analysis proved to be an extremely strong discriminator between the Colorado gas and the deeper Mannville Group gas.

With respect to Pavillion, it is reasonable to say:

- Gas source discrimination between the Wind River and the Fort Union Formations on the basis of composition alone is not likely to lead to strong results, and the Bradenhead/tubing gas analysis results confirm this.
- If it is deemed that source identification is important, it will be necessary to:
    - Execute isotopic analyses on gas collected in WSWs, in Bradenhead and tubing gas, in wellhead (behind the tubing) gas and other gas sources (such as soil gas or gas seeps observed outside of the surface casing) that might become available if additional investigations are undertaken.
    - Have some "fingerprinting" data with depth based not on composition alone, but on the isotopic composition of the various gas molecules. This might be difficult in the absence of additional drilling, but all energy companies that have drilled wells in the Pavillion area in the last 15-20 years could be asked if such data are available, and some agreement established to examine the data (perhaps in a confidential mode).
- Given the lack of a thick shale sequence that served as a regional seal to upward movement of gas in the Pavillion area, even a detailed mud gas data base may not provide a strong ability to discriminate source of shallow gas in the Pavillion area.

Baseline Soil Gas and WSW Gas

It is widely acknowledged that **baseline soil gas and WSW gas data** acquired before large-scale energy well development takes place in a region are needed to more rigorously identify if development activity has led to increased natural gas occurrence in the groundwater protection zone. Baseline data aid in addressing questions such as:

- How many WSWs have naturally occurring gas in them, in dissolved form, or as free gas that may be liberated as the water pressure is reduced?
- What proportion of the gas found in the defined groundwater protection zone is from a deep thermogenic source, and what proportion was generated by shallower biogenic processes? (In general, this would require isotopic analysis and some knowledge of the isotopic signatures of the naturally occurring gases in the intermediate zone.)
- From what strata in the defined groundwater protection zone is water being withdrawn, and are there different water-quality issues in different zones related to migration from deeper gas sources? (For example, chlorides increase naturally with depth, and aggressive groundwater

withdrawal may lead to ingress of more chloride-rich or sulphate-rich water, or to the generation of free methane as the pressure is reduced.)

Baseline data from a limited number of WSWs are generally inadequate to address these questions appropriately because of a number of issues, including uncertainty of well completion quality, of recent contamination from other sources such as surface facilities, of groundwater withdrawal from multiple zones (mixing), and so on. To overcome these uncertainties, purpose-installed monitor wells would be required, in addition to an exhaustive sampling of all available WSWs, using appropriate isotopic and compositional indices. Even then, as suggested before, there is no guarantee that a specific source or sources of the gas in the groundwater could be conclusively identified and localized.

Baseline soil sampling is, to date, even more rarely available than adequate groundwater baseline data. This general lack of baseline data in areas with energy well development confound analysis and interpretation of data, giving a level of uncertainty that is unfortunate, as it reduces the possibility that the actual source of groundwater contamination by intermediate depth or deep formation gas can be verified as to source and pathway. There are no baseline data available for Pavillion with respect to the presence of gas in the permeable subsurface strata used for potable water.

Mud Gas Analysis Data

Mud gas analysis involves collection of gas samples from the drilling fluid of an advancing energy well during the primary drilling phase, followed by analysis of the isotope signature with depth. The small amounts of gas dissolved in the natural interstitial fluids or trapped in the rocks being drilled are liberated by the granulation of the rocks into drill chips, and this gas evolves in the mud tanks. Therefore, drilling fluids are collected at the flow line to the tanks and subjected to a bit of vacuum extraction to collect the gas. Typically, this is done by O&G companies as part of their exploration program in any area where the company lacks such data, but the analyses are not repeated on all wells, only on the first several wells in a new area. This is because the companies know that the isotopic signature with depth is relatively consistent over an area, and repeating the assessments on each well is not economically defensible in practice. In petroleum-prone areas such as Pavillion, one would generally expect to see the following trends from mud gas analysis in a virgin well (before extensive energy well drilling):

- Isotopic analysis perhaps indicating biogenic gas dominance at shallow depth.
- An increasing thermogenic gas isotopic signature with depth.
- Increasing amounts of higher molecular weight alkanes with depth.
- The presence of traces of cyclic (aromatic) molecules with depth.
- The gradual disappearance of a biogenic gas component such that below some depth (e.g. 3,000-4,000 feet) there is only thermogenic gas. (This depth is quite dependent on the geological history of the sedimentary basin, the depth to the last coal seam, the amount of uplift and erosion, etc.)
- A definite isotopic signature shift with depth for various natural gas molecules (CH_4, C_2H_6, C_3H_8) indicating a greater thermogenic component.

Bradenhead Gas Analyses in Pavillion Field

Excerpt from Page 42, *Pavillion Field Well Integrity Review*:

> A chemical analysis of the bradenhead gas was obtained on 10 wells showing continually high bradenhead pressures. This gas analysis indicates the bradenhead gas is from a different source than the producing Ft. Union or lower Wind River Formations. The mole % for nitrogen and carbon dioxide is substantially different between produced gas and bradenhead gas in almost all samples. This difference in gas analysis indicates the bradenhead gas is from a different and separate source than the produced gas and is not just gas that has migrated from a deeper horizon. The difference between produced gas from the Fort Union and Lower Wind River formations and the gas found during bradenhead testing is shown in the table below:

The gas analysis shows that the Bradenhead gas is not "pure Ft. Union or Wind River gas." However, referring to the analyses in Appendix B of the report, the chemical content of the Bradenhead gas shows percentages of C2, C3 and C4+ that indicate that the gas is almost certainly not from shallow biogenic sources. A typical Bradenhead gas analysis is replicated here from page 5 of Appendix B for Well Tribal Pavillion 43-04.

Method	S2_BTEX,C10		
Operator	User1	**Analysis Date**	4/4/2012
Client:	ENCANA	**Date Sampled:**	4/4/2012
Sample Identification:	PAV 43-04 BH	**Purpose:**	
Unique #:		**Pressure:**	118 PSI
Sample Temperature:	64 DEG F	**Type Sample:**	ON-SITE
Sample by:	ANDY FONTAINE	**County:**	FREMONT

Component	Mole %	BTU	GPM
Nitrogen (N2)	1.0322	0.0000	0.0000
Carbon Dioxide	0.0000	0.0000	0.0000
Methane (CH4)	92.4099	935.4994	0.0000
Ethane (C2)	4.3012	76.2952	1.1500
Propane (C3)	1.4523	36.6264	0.4000
iso-Butane (i-C4)	0.3484	11.3559	0.1140
Butane (C4)	0.2765	9.0419	0.0872
iso-Pentane (i-C5)	0.0858	3.4416	0.0314
Pentane (C5)	0.0434	1.7429	0.0157
Hexanes (C6+)	0.0251	1.2781	0.0108
Heptanes (C7)	0.0129	0.7110	0.0059
Octanes (C8)	0.0072	0.4519	0.0037
Nonanes (C9)	0.0010	0.0713	0.0006
Decanes+	0.0002	0.0134	0.0001
Benzene	0.0017	0.0655	0.0005
Toluene	0.0011	0.0485	0.0004
Ethylbenzene	0.0008	0.0410	0.0003
Xylenes	0.0002	0.0085	0.0001

Purely biogenic gas usually has ethane and C3+ molecules content less than 1-2 percent, sometimes only in trace quantities. Typical Bradenhead gas analyses from Pavillion wells show C_2H_6 contents of typically 4.2 to 4.6 percent, with C3-C9 of 1.5-3 percent. This is consistent with thermogenic gases, as biogenic methane tends to have a value of C1/(C1 to C5) of greater than 0.98, rather than the 0.92-0.95 values in the Pavillion wells Bradenhead gas analyses in Appendix B of the report.

There is a remarkable consistency in the ethane and propane contents of the Bradenhead gas for the analyses in Appendix B, indicating a common source or similar sources.

The pressure measurements in the Bradenhead cases where pressures were detected show that eight of the pressured wells tend toward a relatively high stable shut-in pressure of around 150-185 psi (one showed a value of 20 psi, and another a value of 120 psi). This corresponds to a column of free gas of approximately 375 feet (for 150 psi) to 450 feet (for 185 psi) inside the annulus between the surface casing and the production casing assuming a column of fresh water is balanced. (The shallowest surface casing shoe depth is reported as 362 feet depth, but the fact that this number is close to the value of 375 feet is not likely to be relevant.)

Source of Shallow Methane

The history of HF in the Pavillion Field is far different from the current view of HF for the development of unconventional gas using horizontal wells and multi-stage HF, and the unique characteristics of massive shale gas development are different from Pavillion, therefore the concerns are different.

- Pavillion was developed using vertical wells on single sites.
- Wells were often small diameter (6¼-inch boreholes is common for more recent wells).
- Thin gas zones from the bottom around 5,600 feet to a minimum depth of about 1,400 feet in the area of study were stimulated with small volume HF treatments to improve the flow of gas to the wellbore.
- Fracture stimulation was generally done with slickwater fluids, charged with CO_2, and conventional proppant. Slickwater is of low viscosity, and fracture fluid leak off rates are therefore high, suggesting that substantial fracture migration out-of-zone did not occur.
- The wells produced from many zones simultaneously and in a short time so the pressures in the wellbores dropped to where the internal pressure in the production casing remained far lower than the pore pressure in the formations outside the production casing.

Tests of well pressure integrity demonstrated that the production casing is intact in the five cases where casing integrity tests were requested and reported. Given the data and the small size of the fracture treatments, it is a reasonable conclusion that little wellbore impairment has arisen from the hydraulic fracturing itself. Later, it will be shown that during the high-pressure injection phase, direct interaction of hydraulic fracture fluids with the shallow groundwater protection zone is extremely improbable.

Suppose that it has been demonstrated that there is natural gas in a WSW, and by inference, that there is natural gas in the dominant aquifer in which the WSW is completed. Biogenic, thermogenic or mixed natural gas entering aquifers is common in many areas of the world,[19] and by no means exclusively over sedimentary basins known to contain petroleum. In recent regional studies in places such as New Brunswick (study currently underway) or North-Central Pennsylvania (especially in the coal-bearing regions, but also elsewhere), percentages of WSWs containing naturally occurring methane can exceed 30 percent. Recent studies in Pennsylvania show that, although individual cases of loss of well integrity or gas escape into shallow sediments have occurred, there is no significant link between oil and gas activity and the presence of methane in the groundwater.[20]

To be fair, the study by Seigel et al. (2015) seems to contradict a group of far smaller previous studies,[21,22] which indicated a statistical link between O&G well proximity and the presence of methane

[19] Barker, J.F., Fritz, P. 1981. The occurrence and origin of methane in some groundwater flow systems. *Canadian Journal of Earth Sciences* **18(12)**, 1802-1816

[20] Siegel, D.I., Azzolina, N.A., Smith, B.J., Perry, A.E., Bothun, R.L. 2015. Methane Concentrations in Water Wells Unrelated to Proximity to Existing Oil and Gas Wells in Northeastern Pennsylvania. *Environmental Science and Technology* **49**, 4106–4112

[21] Osborn, S. G., Vengosh, A., Warner, N. R., Jackson, R. B. 2011. Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. *Proceedings of the US National Academy of Sciences* **108**, 8172–8176.

in the groundwater sampled from WSWs, although these studies do not identify a mechanism nor a pathway. The geology of Pennsylvania is dominated by stiff, often cemented and low-porosity naturally fractured rocks, whereas Pavillion Field is in a basin with softer, higher porosity sediments that are not intensely naturally fractured.

In the case of the Pavillion Field, previous authors have noted that there is not a great deal of isotopic differentiation (C and H isotopes) from the Fort Union Formation to the much shallower Upper Wind River Formation. This is evidence that there are slow natural seepage pathways whereby the deeper thermogenic gases are gradually working their way to the surface. During this transit, these gases will have been chemically modified from the deep gases because of differential solubility in formation waters, so the ethane and propane ratios may be quite different than those at depth. Furthermore, there may be mixing with shallower biogenic gas that has been generated by shallow organic material that underwent anaerobic decomposition, contributing dry methane (no C2++) of different isotopic composition to the gas that is found at shallow depths.

So, thermogenic gas can be expected to be found at relatively shallow depths in the Wind River Basin, but perhaps with a composition different from that at depth because of mixing with shallower biogenic gas and even some gas slowly washed in by groundwater mixing (nitrogen for example).

Nevertheless, gas seepage along energy wellbores remains an issue, and the wells with open sections between the surface casing and the top of cement could have served, and may still serve, as conduits for deeper gas to have entered the shallower upper Wind River Formation permeable zones that may also serve as WSW aquifers.

What is the effect of, for example, CH_4 getting into an aquifer? Apparently, souring of the water, giving a faint sulfur smell is very common, even if there is no CH_4 detectable. In the presence of bacteria that can metabolize CH_4, and if some sulphates (e.g. gypsum) are present, small amounts of H_2S can be generated. This is not new to recent O&G development areas: smelly groundwater is widely known. Sulphate-rich areas like SW Saskatchewan have odoriferous and bad-tasting water.

There are some components in the gas that could be used as “tracers” to identify the “chemical hangover” associated with methane contamination. For example, argon dissolved in the groundwater is conservative, it does not get biodegraded, so it may serve as a proxy for CH_4 that has been bio-consumed. If argon is present in unusual amounts, it may indicate that CH_4 has entered, but been quickly consumed. Other trace gases, such as the noble gases (including argon), have recently been used to help identify provenance of gases at shallow depths as free gas or dissolved in groundwater.[23]

It is wise not to be optimistic about the use of WSW to pin down this issue. Multi-level groundwater monitoring wells, properly developed to seal off individual zones, would have to be installed and monitored. If it can be shown that, dissolved or present as free gas in the groundwater protection zone,

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[22] Jackson, R. B., Vengosh, A., Darrah, T. H., Warner, N. R., Down, A., Poredac, R. J., Osborn, S. G., Zhao, K., Karra, J. D. 2013. Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. *Proceedings of the US National Academy of Science* **110**, 11250−11255

[23] Darrah, T.H., Vengosh, A., Jackson, R.B., Warner, N.R. and Poreda R.J. 2014. Noble gases identify the mechanisms of fugitive gas contamination in drinking-water wells overlying the Marcellus and Barnett Shales. Proc. Of the National Academy of Sciences of the United States of America, 111(39), p 14076–14081

there is indeed natural gas that bears a thermogenic signature, this is not proof that the gas is associated with energy development wells. This would take a considerable effort in regional evaluation and access to additional data such as mud gas logging information and detailed isotopic analysis. Also, even if it can be demonstrated with a high degree of certainty that the natural gas found in the groundwater protection zone is associated with energy well development, finding the specific source or sources, and proving that a particular wellbore is the culprit (or one of several culprits) would be extremely costly. A number of multi-level groundwater monitor wells would have to be installed to increase the probability of identifying the source (or sources), wellbores would have to be relogged and technologies such as noise detection logs[24] used to identify gas migration and source behind casing. Old decommissioned wellbores would probably have to be re-entered and logged. And finally, even with a great deal of such activity, it may not be possible to pin down the specific source, if there is one associated with the region's energy wells.

[24] McKinley, R.M., Bower, F.M. 1979. Specialized Applications of Noise Logging, *Journal of Petroleum Technology*, SPE#6784, 1387-1395. Also Boone, K., Ridge, A., Crickmore, R. Onen, D. 2014. Detecting leaks in Abandoned Gas Wells with Fibre-Optic Distributed Acoustic Sensing. Proceedings International Petroleum Conference, Qatar,

Potential Environmental Impact of Hydraulic Fracturing in Pavillion Field

In the non-technical literature, there exists a widespread and persistent perception that HFs can rise to great heights above the stimulated (injected) zone, allowing HF fluids to interact with shallow groundwater. Except in the case of very shallow fracturing, close to the base of the GWPZ, this perception is false: in well stimulation practice there is no evidence of fractures rising from considerable depth to interact with potable shallow water, and there are a number of strong arguments based in physics and geology that one may levy against this misconception. In the last two decades, a great deal has been learned about HF behavior through the advent of three monitoring technologies: improved downhole pressure monitoring methods, microseismic monitoring, and tiltmeter measurements.[25] Articles giving a broad and deep understanding of HF physics and HF operations have emerged in the last decade.[26,27,28] From the referenced literature, the conclusions that can be drawn and that apply to the Pavillion Field are:

- Direct groundwater contamination associated with HF rise from stimulation depths in Pavillion Field has not occurred.
- There is a small but remote possibility that HF fluids during treatment of a well could have migrated up along the wellbore outside of the production casing if the well had an extremely poor cement completion. There is no evidence in the records of this having happened and, because of the nature of the HF stimulation operations (low-viscosity fluids, small treatment volumes), this scenario has almost certainly not occurred.
- There is a small but remote possibility that during active HF, the HF fluids could have intersected an offset legacy wellbore and migrated toward the groundwater protection zone. There is no evidence in the records that this has happened and, as above, because of the nature of the HF stimulation operations (low-viscosity fluids, small treatment volumes), this scenario has almost certainly not occurred.

It is important to discriminate clearly among different mechanisms. Herein, a clear separation between issues related to HF itself and wellbore integrity is made. The first bullet point above refers explicitly to the behavior of a HF; the second is purely an issue of treatment wellbore integrity during the short-term high-pressure HF operation; the third is a combination of potential HF lateral propagation to an offset well possessing inferior integrity.

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[25] Fisher, K., Warpinski, N. 2012, Hydraulic-fracture-height growth: Real data: *SPE Production & Operations* **27(1)**, 8-19.

[26] Burch, D.N. and 12 others. 2009. Live Hydraulic Fracture Monitoring and Diversion. *Schlumberger Oilfield Review* **21(3)** (unrefereed), Autumn 2009, 18–31

[27] King, G.E. 2012. Hydraulic fracturing 101: What every representative, environmentalist, regulator, reporter, investor, university researcher, neighbor and engineer should know about estimating frac risk and improving frac performance in unconventional gas and oil wells. Proc SPE Hydraulic Fracturing Technology Conference, The Woodlands, TX, SPE#152596, 80 pp

[28] Ajayi, B. and 14 others. 2013. Stimulation Design for Unconventional Resources. *Schlumberger Oilfield Review* **25(2)** (unrefereed), Summer 2013, 34-46

Hydraulic Fracture Rise

The major points concerning the first bullet point above, in brief, are:

- Significant fracture height rise requires huge volumes, far more than used in typical HF operations. In particular, the HF volumes in the uppermost stimulated zones (about 1,400 feet deep) in the area of study gas wells are small, and thus cannot rise substantially.
- In many geological environments where vertical fractures are predicated (i.e. $\sigma_3 = \sigma_{hmin}$), the bounding strata to the zone to be stimulated have somewhat higher lateral stresses than the zone to be stimulated, and this forms a stress barrier to upward fracture propagation.
- In cases of HF stimulation of a partially depleted zone to increase productivity (well restimulation), a stress barrier to upward migration exists because of stress redistribution related to partial depletion of pressures.
- Fractures experience fluid leak-off to the permeable strata being fractured, especially if the fracture fluid is a low viscosity fluid such as "slickwater," and this reduces the volume available to generate fracture growth, thereby suppressing fracture rise.
- Fractures may rise out of zone somewhat, but excessive rise is wasted money, so HF designs include information about rock properties and fracture gradients (*in situ* stresses) so as not to have waste through massive fracture rise through non-productive horizons.
- As fractures rise, huge additional fluid volumes are needed to sustain the rise; approximately 8 times the volume injected is required to double the fracture height, assuming no leak-off of fluid.
- Additional permeable beds are encountered as fractures rise above the target zone, thus leaking off fracture fluid and reducing the fluid volumes for stimulation and further vertical growth.
- Near the ground surface in uplifted and eroded basins such as the Wind River Basin, the vertical stress is the minimum stress ($\sigma_3 = \sigma_v$). In this region, induced fractures become horizontal (or sub-horizontal), and cannot rise significantly above that level.
- Finally, production implies a diminution of pressure in the fractured zone. HF fluids emplaced during stimulation soon become massively underpressured with respect to the regional pressures because of production and cannot flow upward against the pressure gradient.

Most of these points, such as leak-off of HF fluids during fracturing and the small volumes involved in the HF stimulations at the Pavillion Field, also apply to the issues of wellbore integrity and lateral fracture migration.

Fracture Volume

The sizes of the hydraulic fractures emplaced in wells in the Pavillion Field are small compared to recent hydraulic fracturing practice, and in particular, are much smaller than the stimulation volumes used in Multi-Stage Hydraulic Fracturing (MSHF) for shale gas or shale oil wells. In large part, this is because the zones are thin, and large volumes would not be cost effective. For example, in the well records, fracture volumes of several tens of thousands of gallons or less were reported. More typically, the fracture volumes reported for stimulating the occasional thin upper zones that were completed at depths between 2,000 and 1,400 feet tend to be as small as 75-100 barrels (bbl). These treatments are single injection episodes at that depth in the vertical wells that are used at Pavillion. Assume, for simplicity, a treatment volume of 200 bbl, about 30 m^3; then, compare this to treatment volumes of 300 to 1,500 m^3 in each of 20-30 stages along a 2 km long horizontal well that is 2 to 3 km deep. Clearly, the stimulation

volumes using modern completion methods for MSHF wells are usually over 100 times as large as the small stimulation volumes used in the upper gas zones of the Pavillion Field wells.

Figure 8 is a representation of a fracture in a homogeneous medium. The volume of the assumed regular ellipsoid is given by the equation V = ¾π·L·H·W. Several models are available to calculate the expected width in a vertical fracture (Valko and Economides 1995; Yew1998)[29]. A simple version of the maximum fracture width ("W" in the figure, "w_{max}" in the equation) at the midpoint is

$$w_{max} = \frac{4(1-\nu^2)\mathrm{L}}{E} \cdot p^{net},$$

where L is the maximum fracture length for a roughly axisymmetric fracture, ν is Poisson's ratio, E is the formation Young's modulus (formation rigidity), and p^{net} is the difference between the minimum stress in the ground (σ_3) and the injection pressure in the fracture.

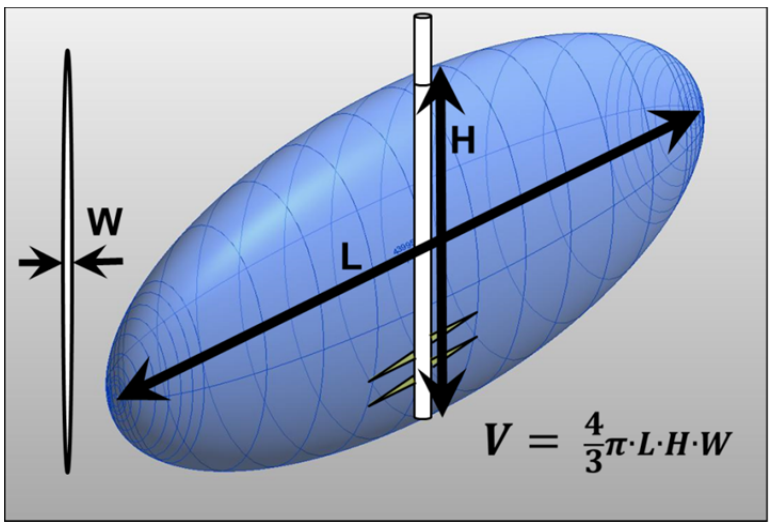

Figure 8: The Volume of a Fracture in a Completely Impermeable Rock is Approximately the Shape of an Ellipsoid (W greatly exaggerated)

These fracture models require knowledge of the formation properties and stresses, but there are some key observations that can be made. The most important is that if the length (L) doubles, the aperture doubles. This means that if fracture height were to be doubled, then the length and the width would both double as well. So, the volume equation for a doubling of height, compared to the base case, would look like V = ¾π·(2L)·(2H)·(2W), or eight times (2×2×2) the volume. Another way of saying this is that if the fracture fluid volume injected is doubled, it would only increase the height by $\sqrt[3]{2}$, or by about 26 percent.

If a 100 bbl fracture were approximately circular (H = L), and 0.4 inches (10 mm) maximum aperture at its center, it would be approximately 60 inches in radius. So, if the zone that is being stimulated is 15-

[29] Valko, P., & Economides, M. (1995). *Hydraulic Fracture Mechanics.* John Wiley & Sons Ltd.; Yew, C. (1997). *Mechanics of Hydraulic Fracturing.* Houston, Texas: Gulf Publication Company.

inch thick and the fracture rises about twice as much as it drops (water fractures tend to rise because of buoyancy), one might expect a 100 bbl fracture to rise a maximum of 20-30 feet above the top of the interval, if 100 percent of the fluid remains in the fracture. These are reasonable assumptions for relatively soft rocks such as the Wind River sediments, but this calculated fracture rise is almost certainly too large because of other factors discussed below.

These modest heights are the major reason why the concept of upward propagation of hydraulic fractures from well stimulation and intersecting the potable water zones is not a realistic concern. Furthermore, there are a number of other reasons why significant HF vertical growth is undoubtedly well-constrained.

Fracture Containment by a Stress Barrier or a Higher Caprock Stiffness

In many geological environments, the sediments overlying the fine-grained sand productive horizon that is being fractured are shales (caprock), and these may have a slightly larger horizontal stress than within the reservoir. In such a case, an induced fracture will not propagate upward easily because of the higher energy (pressure × volume) involved, and lateral propagation within the productive horizon will take precedence. Clearly, this is a desirable condition, as it gives a much better fracture treatment for a given volume of injection compared to the case where substantial vertical propagation takes place. There appear to be no data on this for the Pavillion Field wells, although it is likely to be the case. Figure 9 shows the effect of a somewhat higher value of σ_{hmin} (horizontal minimum stress) in the caprock. Lateral extension is favored, and vertical growth suppressed.

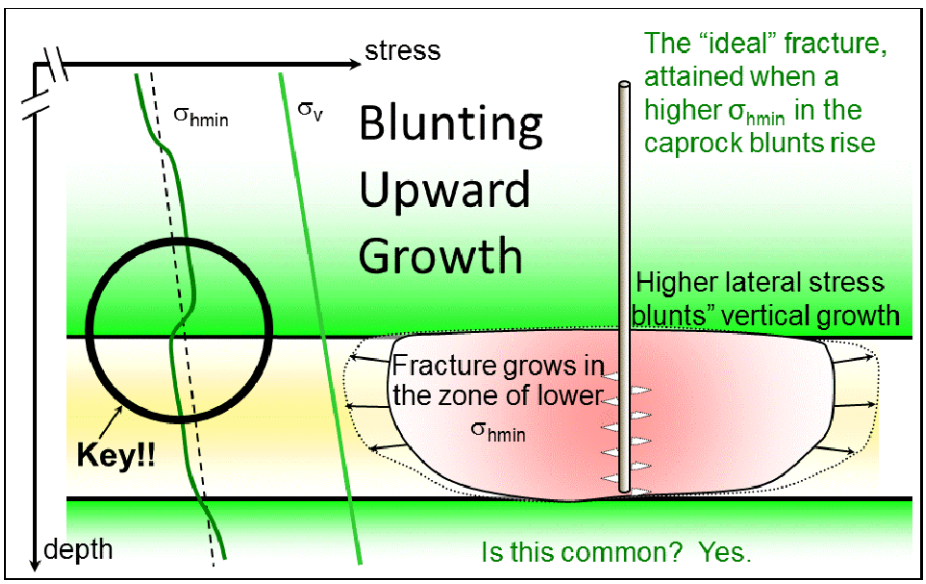

Figure 9: A Slightly Higher Lateral Stress in the Caprock Suppresses Vertical Growth

A similar constraint on vertical growth of an induced fracture occurs when the stiffness of the caprock is greater than the stiffness of the rocks comprising the underlying gas reservoir, although in the study area the contrast is not expected to be large. This is also common because shale caprocks are often denser and have a horizontal elastic modulus (stiffness) greater than the elastic modulus of the reservoir, so from the previous equation, the potential fracture aperture is smaller. This restriction

creates an impediment to vertical flow, compared to that part of the fracture perimeter that is extending in the reservoir, thereby favoring lateral extension of the fracture. Sometimes, there is a well-cemented bed at the top of the target zone that is being fractured, and the high stiffness helps keep the fracture within the zone.

The Barnett Shale in Texas is an example of a zone where little vertical fracture growth takes place because of a highly cemented caprock, and there may be an additional effect of a stress barrier. The combination of these two factors means it is rare for a fracture to extend much above the top of the reservoir, even for fluid volumes per fracture stage that are 10 times the volumes used in the uppermost Pavillion Field HFs.[30] In the case of the Barnett Shale, the barrier to vertical rise is exceptionally large, such that HF design and operations must try and suppress excessive downward fracture growth, an unusual case.

It is probable that vertical fracture growth in the Pavillion Field HF stimulation of the uppermost zones is inhibited by the presence of stiffer or slightly more highly-stressed caprock.

[30] King, G.E., Haile, L., Shuss, J.A., Dobkins, T. 2008. Increasing Fracture Path Complexity and Controlling Downward Fracture Growth in the Barnett Shale. *Proc. SPE Shale Gas Production Conference*, 16-18 November, Fort Worth, Texas, SPE#119896, 8 p.

Depletion Effect

If the HF treatment takes place in a zone already partly depleted (pressure reduction) as the result of previous production from the well or some production from that zone through offset wells, there will have been a reduction in horizontal stress in the target zone, and a concomitant increase in the horizontal stress in the caprock.[31] This creates a stress barrier if one did not previously exist, as shown on Figure 10, and HF stimulation of depleted zones in practice is characterized by excellent containment.

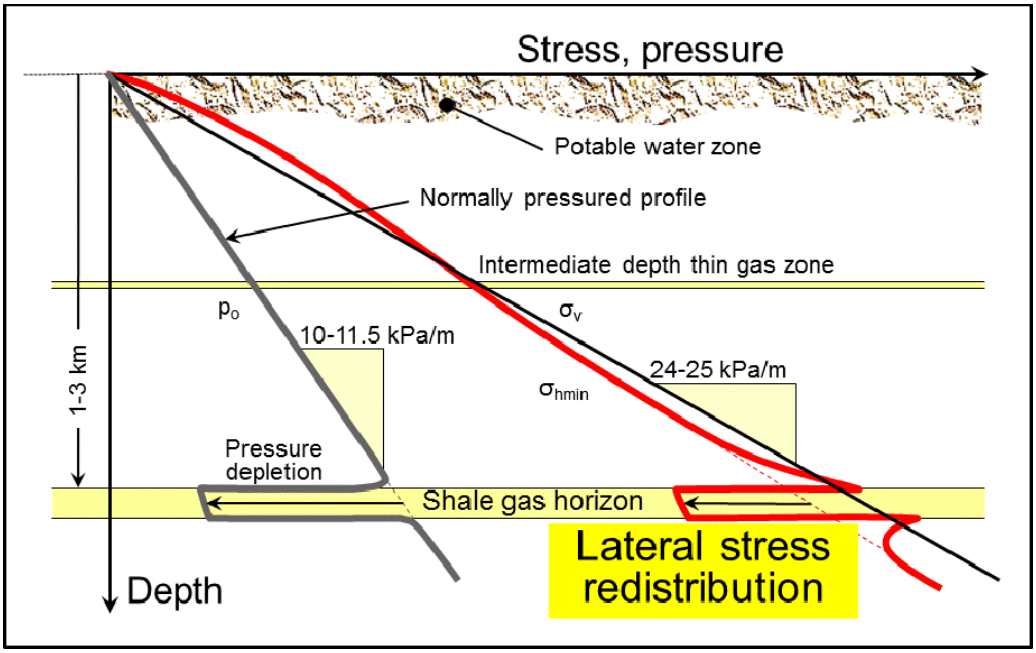

Figure 10: Depletion Decreases Lateral Stresses, Favoring Lateral Fracture Growth in the Depleted Zone when Restimulation Takes Place

In Pavillion Field, the strata all seem to be normally pressured, and it is not known if the previous production episodes had a significant effect on the pressures in the upper thin gas sands. However, there are no known cases of significant overpressuring, and one may assume that this is not a large effect. If this has happened in the field development, it restricts the height of fracture growth.

Placement of cement of low density (as low as 9.5 ppg) during cementation of the production casing in recent wells suggests that lost circulation of dense cement has been a persistent problem, and this may be the result of low horizontal stresses from depletion, or perhaps because of generally low horizontal stresses in the deepest part of the boreholes because of tectonic relaxation.

Leak-Off in the Formation and Overlying Permeable Zones

Not all injected fluid goes to propagate a fracture. Because pressure in the fracture is far higher than the pore pressure in the surrounding rocks, there is a significant outward pressure gradient at all points around the propagating HF. Because the reservoir rock itself has permeability, fluid is lost to the surrounding reservoir rocks. Furthermore, if fractures rise out of zone, they will encounter other

[31] Warpinski, N.R., Schmidt R.A., Northrop D.A. 1982. In-Situ Stresses: The Predominant Influence on Hydraulic Fracture Containment. *Journal of Petroleum Technology* **34(03)**, 653-665.

permeable streaks that will also drain fluid from the propagating fracture, a process some call blunting. This situation is encountered in all sedimentary basins, and it restricts vertical fracture growth even in massive hydraulic fractures. Note that at the extreme limits of well stimulation, HF treatments of more than 25,000 bbl for a single fracture stage have been used (300 times larger than the uppermost Pavillion Field fractures), with no unequivocal evidence of fracture growth greater than 500-1,000 feet).

The HF fluids used in the modern wells in Pavillion are reported on the records to be slickwater charged with gas, with proppant added to maintain an open aperture in the HF near the wellbore.

Stress Conditions at Shallow Depths

A final comment is now made on fracturing in uplifted and eroded basins, such as the Wind River Basin, where the current stress conditions are a function of the unloading of the vertical stress as the result of millions of years of erosion. In all such basins, it appears that there is a surface layer, from perhaps 600 to 2,000 feet in thickness, where horizontal stresses are greater than the vertical stress ($\sigma_v = \sigma_3$, $\sigma_{hmin} > \sigma_v$).

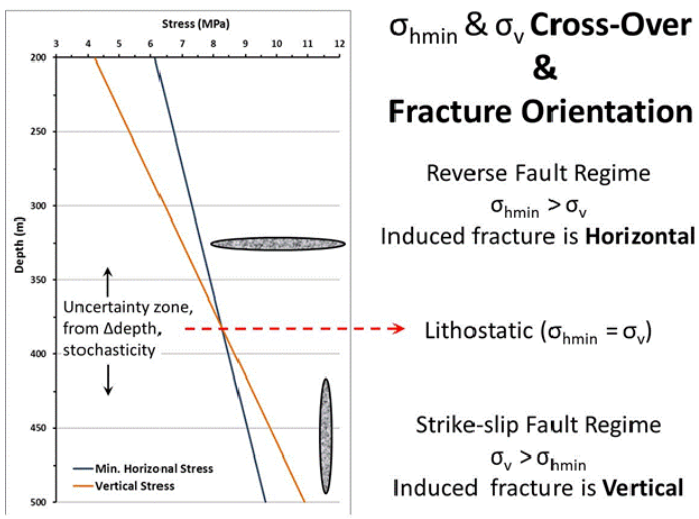

Figure 11: Fracture Orientation in an Uplifted, Eroded Basin, N of Medicine Hat, Alberta

Figure 11 shows such a case north of Medicine Hat, Alberta, where there is transition about 380 m deep (≈1,250 feet) above which induced HFs propagate in a horizontal attitude, and show no upward growth. The consequence of such a stress condition, which has been confirmed in the Pavillion Field, is that above some depth fractures cannot propagate vertically, and the fluids in the fracture cannot interact with the overlying strata.

The following text is taken from a State of Wyoming WOGCC "Sundry Notices and Reports of Wells" Form for Well Pavillion 31-10 (EnCana well) filed as a report of the Bradenhead pressure tests performed early in 2012.

> Fort Union - ISIP data shows the Fort Union to have an average frac gradient of approximately 0.7 psi per foot of depth and can range from 0.45 psi/ft to 0.9 psi/ft. This gradient is fairly constant throughout the Fort Union.
>
> Wind River – ISIP data tells a significantly different story for the Wind River Formation where frac gradients are increasing as depth decreases. Average values start at 0.85 psi/ft at 3000 ft and increase to 1.1 psi/ft at 1300 ft.
>
> Leak off data is extremely rare in this field, however, one data point was found for the Tribal Pavillion 15-21X where a leak off test was performed out from under the surface casing and resulted in a leak off frac gradient of 1.15 psi/ft at 849 ft.

The horizontal stress is estimated by the fracture gradient. In strata such as the Fort Union and Wind River Formations, the rock bulk density is on the order of 2.3 - 2.4, so the vertical stress gradient ($d\sigma_v/dz$) is in the range of 1.0-1.05 psi/ft. (the gradient of fresh water is 0.43 psi/ft., and fresh water has a density of 1.0). If the fracture gradient (σ_{hmin}) is greater than 1.05 psi/ft., horizontal fracturing would be predicated because, from the point of view of energy conservation and work minimization principles in mechanics, more energy would be expended in forcing a unit mass of water vertically than forcing it horizontally if the minimum stress is vertical. This is a fracture propagation principle that is fundamental in fracture mechanics for those reasons: the tip of a propagating fracture will orient itself so that the fracture plane is normal (at 90°) to the smallest compressive stress. One must therefore assume that above a depth of ≈1,300 feet, propagating fractures would be in a horizontal attitude, not vertical, because the minimum compressive strength is vertical above a depth of about 1,300 feet.

The following diagram (Figure 12) has also been captured from the WOGCC Report referred to above. In this diagram, the operating company has collected all of the known estimates of the fracture gradient, determined in different ways, such as using the shut-in pressures from hydraulic fracture stimulations, from leak-off tests, and from fracture screen-out occurrences. A number of significant points deserve explicit emphasis.

- The fracture gradients at depth in the Fort Union Formation are low, sufficiently so that it would be challenging to properly execute a high-quality cementation of the production casing to the surface if regular density cement (2.0-2.05) were used; hence, low-density cements were commonly used for the recent drilling campaign to bring cement to surface. Not all wells used low-density cement.
- The fracture gradients in the upper part of the strata, in the Wind River Formation, are greater than the vertical stress gradient (the weight of the overburden), therefore $\sigma_v = \sigma_{min}$, and induced fractures will propagate more-or-less horizontally.
- The transition point is ill-defined, so a number of about 1,300 feet depth to the transition point can be taken, and is a conservative estimate (it could be deeper).
- This depth can be compared to the typical depth of surface casings, and it is clear that there is a distance on the order of 550-650 feet between the casing shoe depth and the transition point.

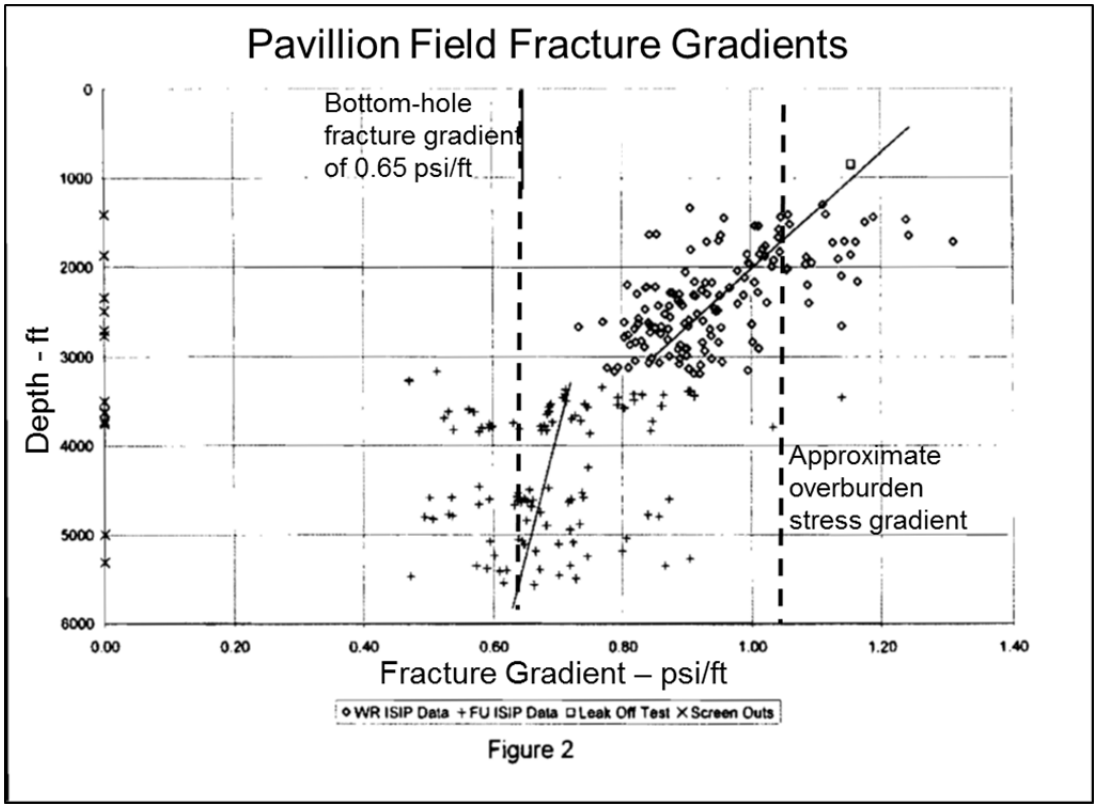

Figure 12: Measured Fracture Gradients in Pavillion Field (from Encana Report)

Above 1,000 feet depth, $\sigma_{hmin} > \sigma_v$, just as in the previous figure, therefore it is essentially physically impossible for hydraulic fractures to migrate vertically into the groundwater protection zone.

Lateral Fracture Migration during HF and Offset Well Intersection

Incidents where HF fluids have propagated laterally to offset wellbores during active injection and interacted with shallow sediments appear to be extremely rare, but several cases have been reported.[32] Figure 10 showed the effect of pressure depletion on the lateral stresses within the reservoir. This reduced lateral stress aids fracture containment within the reservoir, but it also means that if large HF injection is taking place relatively nearby within the reservoir, there is a tendency for the fractures to propagate toward the low stresses around the old production well. This possibility will be reduced by:

- Increased distance between the wells.
- Small volume fracture treatments (as in Pavillion Field).
- Low viscosity fluid so that leak-off suppresses lateral propagation tendency. (Note that the lowered pressure from depletion also increases the leak-off rate from a propagating HF).

There is no report of any interaction with adjacent wellbores in the Pavillion Field, and this would have been noted by changes in behavior in adjacent wells, increased liquid production, and perhaps other

[32] ERCB Energy Resources Conservation Board, 2012. *Midway Energy Ltd. Hydraulic Fracturing Incident: Interwellbore Communication January 13, 2012*. ERCB Investigation Report filed Dec 2012, 11 p, available on the Alberta Energy Regulator website. https://www.aer.ca/documents/reports/IR_20121212_Midway.pdf

effects. There have been wells stimulated in proximity to previous wells, noted below,[33] but as mentioned previously, the small stimulation volumes make it improbably that HF fluids could have travelled laterally, then upward, to intersect the groundwater protection zone.

Of interest perhaps are several documents that have been posted since the well intersection event described in the ERCB (2012) report took place. First, is a new set of regulatory requirements to reduce the probability of offset well intersection,[34] second is an industry consortium document on recommended practices from the Drilling and Completion Committee, Alberta.[35]

Closure on HF

The pathway for contamination of shallow aquifers with such small HF volumes is only along the existing wellbore where the well is being fractured, or if the fracture propagates to an offset well directly, and the fluids propagate upward along the wellbore through a pathway such as a microannular space. These events have never been reported, there is no information to support the existence of such events, and such events are considered highly unlikely with such small volume HF operations for many reasons detailed above and elsewhere (Dusseault and Jackson 2014, footnote 8). The offset distances between wells is large enough and the fracturing volumes small enough that the risk of fracture intersection with the surrounding offset wells and fracture fluids propagating along the outside of the casing are extremely small. Risks would be higher with large treatment volumes, higher pressures, and close legacy wellbores, but the Pavillion Field stimulation activity did not use large enough fracture volumes to intersect adjacent wellbores and provide enough volume to propagate to the shallow groundwater zone.

There is no evidence that a pathway for hydraulic fracturing fluids to migrate from depth to the shallow aquifers has ever existed for any operation on any of the energy wells in the Pavillion Field. Nevertheless, even though the probability that such an even has taken place unnoticed are extremely small, to be scientifically precise, the absence of such evidence cannot be taken as unequivocal proof that no such event has taken place. This inability to establish absolute certainty is characteristic of most environmental issues: a high degree of certainty can be established, but proving that an event has not occurred, no matter how improbable, is not feasible. It is concluded that there is no reason to believe that a fluid pathway through HF propagation to intersect a laterally offset well could have developed in the Pavillion Field well stimulation activities.

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[33] Cases identified where wells are close are:
Pavillion Fee 34-03 and 34-03R/ W.E. Llloyd 1 ~62 and 129 feet (Figure 12E);
Pavillion Fee 14-03 and 14-03W/ Mae H. Rhodes I ~274 and 345 feet (Figure 12H);
Tribal Pavillion 33-10B / Govt Tribal 33X-10 ~360 feet (Figure 12C and 12D);

[34] ERCB Energy Resources Conservation Board 2013. Directive 083: Hydraulic Fracturing – Subsurface Integrity. 14 p, available on the Alberta Energy Regulator website: https://www.aer.ca/rules-and-regulations/directives

[35] Drilling and Completion Committee, Alberta, 2013. IRP 24 FRACTURE STIMULATION: INTERWELLBORE COMMUNICATION. Available from http://www.enform.ca/resources/detail/29/dacc-irp-volume-24-interim-fracture-stimulation-interwellbore-communications (Other IRP documents are available from www.enform.ca)

Seepage of Natural Gas along Wellbores – Wellbore Integrity

Seepage Gas in Pavillion

Gas with a chemical composition that is similar to the deep gas in the Pavillion Field (below 1,500 feet) is found in the Bradenhead annulus in a number of wells. As discussed before, there is reason to believe that natural gas was present in the shallow groundwater-bearing sediments in the Pavillion Field area before energy wells were developed. Nevertheless, it is also possible that natural gas seepage from abandonments and decommissioned wells is taking place or has taken place in the period of time since exploration and energy wells were first drilled. Worldwide experience shows that in all jurisdictions some percentage of energy wellbores will experience gas seepage from depth outside the casing. If such seepage is taking place in the Pavillion Field, it is not known from how many wells or at what rates.

Vertical or lateral gas (or natural formation liquid) seepage from the producing horizons where the fracturing has taken place (Figure 1, Paths 3 or 4) is extremely improbable because these producing horizons become pressure sinks as they are depleted. In other words, at depth, flow is toward the depleted zone because it now is at a lower pressure. Fluids (natural gas) cannot flow away from this zone because the fluids will encounter higher pressures, and this means outward flow is not physically possible.

It appears that the critical pathway for upward migration of fluids is along the energy well, whether it is an active well or a decommissioned legacy well. The seeping gas everywhere in cases of poor well integrity is dominantly methane (CH_4), although other light hydrocarbons (ethane, propane) and traces of other molecules can be present.

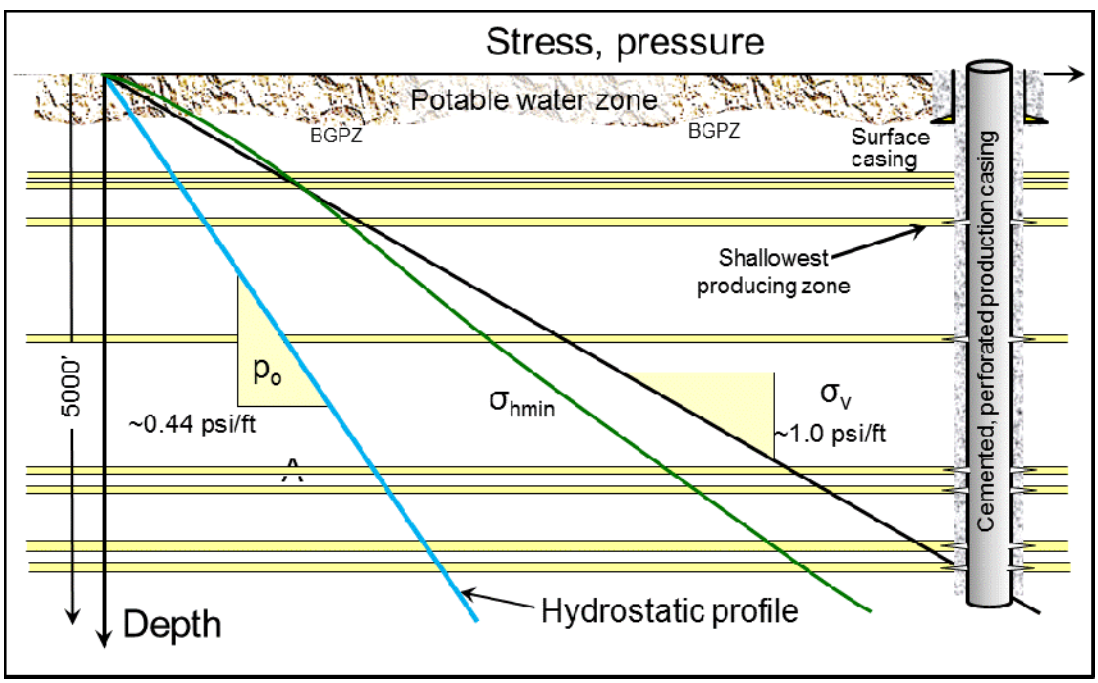

Figure 13: Stresses and Wellbore Disposition in the Pavillion Field

Figure 13 shows the (approximate) initial stresses and pressures in the Pavillion Field, along with the disposition of a typical completed well. The stress transition point is taken to be about 1,100 feet depth, above which the minimum stress is the vertical stress, therefore any induced fractures would have to be approximately horizontal in attitude. An important point is that in the Pavillion area there are shallow thin, non-commercial sands that contain natural gas at a pressure that is approximately hydrostatic. These strata are represented by the thin yellow zones that lie above the shallowest perforated zone (≈1,500 feet deep in Pavillion). Because there is no regional thick seal, such thin gas-bearing zones could even extend into the potable water zone above the BGPZ (base of groundwater protection zone). Exceptionally, there could be gas bearing lenses within the potable groundwater region, but if there are, the quality of the groundwater is probably poor quality because of microbially-mediated degradation processes that consume the natural gas components over time.

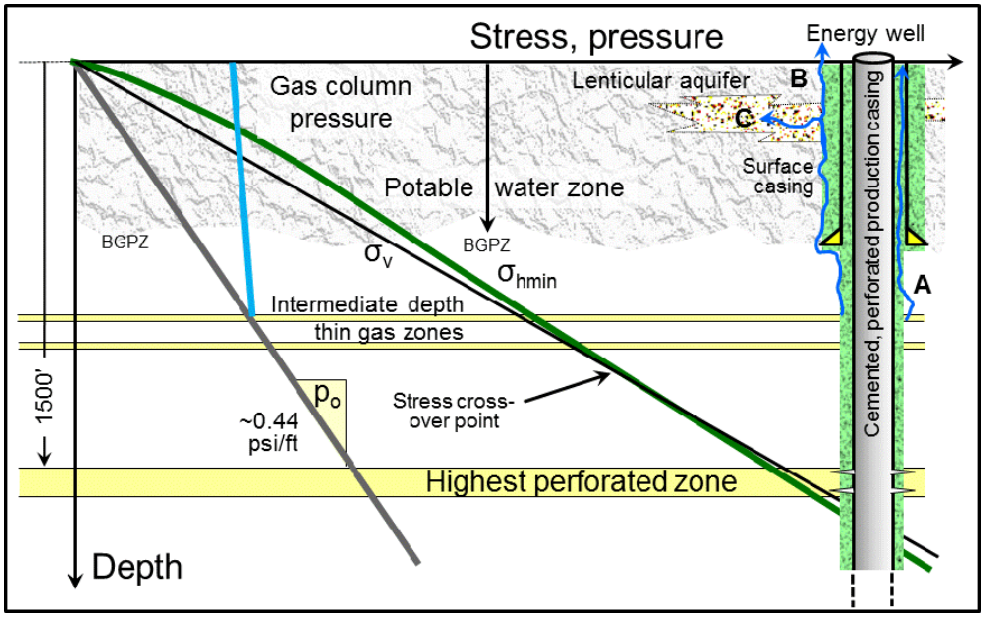

Figure 14: The Top 1,500 Feet of Pavillion Energy Wells, Showing the Pressure Effect of Gas Migration Behind the Cement of the Production Casing

Figure 14 shows perhaps the most important mechanism for gas migration in the Pavillion Field. The figure shows only the section above the highest production zone. The blue line labelled Gas Column Pressure is intended to illustrate the **maximum possible pressure in a shut-in continuous free gas column**, if one could develop. In fact, the actual pressure remains close to hydrostatic because if a significantly larger pressure is generated in the gas column, enough to overcome the capillary entry pressure of a fine-grained sand bed, for example, the gas would tend to enter into that bed and perhaps the vertical migration would be then arrested because of the pressure leak-off. However, if the gas migration continues, there will be a tendency for some gas seepage to higher elevations, into the groundwater protection zone.

The maximum excess pressure (Δp_{max} in excess of hydrostatic) that can develop at the top of a column of free gas is given by the equation $\Delta p_{max} = \Delta\rho \cdot \mathbf{g} \cdot h$. Here, $\Delta\rho$ is the difference in density between the gas

phase and the liquid phase (generally about 0.4 to 0.42 psi/foot), **g** is the gravitational acceleration, and h is the height of the column of free (interconnected) gas, all in consistent units. For example, a column of free gas of 100 feet in height that might develop in the microannular space behind the production casing would lead to a maximum of 40-42 psi of pressure above the hydrostatic pressure at the top of the gas column. The blue line on Figure 14 is approximately representative of such a calculation.

This calculation is also used to estimate the depth from which a gas source might be feeding the Bradenhead pressurization. For example, if the equilibrated surface pressure in the Bradenhead annulus is 175 psi, then, using the same equation, if a continuous gas column is assumed, the gas is sourced at a depth of about 400-420 feet. It is important to note that these estimates must be treated with great care; they are not actual values that apply in the ground, they remain rough estimates based on several assumptions, such as the continuity of the vertical gas column. They are nevertheless valuable because they can give an estimate of the depth, and, when comparative data among wells are available, they may help to give some information of the nature of the source of the Bradenhead pressure.

Remember that the longer the gas column that develops, the greater the pressure difference (Δp_{max}) that could be built up, and therefore the stronger the development of an upward driving force at the top of the gas column. Thus, it may take a very long time (decades) to migrate upward a few meters, but once a substantial column height is generated, the process accelerates. This means, unfortunately, that even if an energy well shows no signs of gas migration at the time of abandonment, it is not an ironclad guarantee that slow gas seepage will not develop some time in the future. This is a real concern of persons attempting to study and quantify these processes: as abandoned energy wells age, seepage may become more common. In Alberta, a well cannot be officially decommissioned until the Bradenhead gas seepage rate is zero; but, this is not a guarantee that gas is not migrating upward outside of the Bradenhead annular space. It is also not a guarantee that slow gas seepage will not occur at some later time (although catastrophic well failure is likely impossible, it is possible that a pathway slowly develops over time).

How many wells slowly leak gas upward along the outside of the production casing? It has proven difficult to arrive at a general estimate for the following reasons:

- Well cementation practices have been improving over time, such that the probability of gas seepage along a modern well because of a poor primary cement job is probably less than along a well completed 20 or more years ago, other factors being equal.
- Wells which have a significant open and uncemented portion of the production casing such that cement did not rise up into the surface casing shoe would seem to be more prone to leakage, but there is variability among wells in the details of the cement level and cement quality.
- Gas seepage is only noted if it is substantial enough to be visually detected, or if there is sufficient vegetal distress. Once a well is decommissioned, seepage of gas is ignored unless obvious gas seepage is noted; yet, for every case of noted seepage at the surface, there must be cases of undetected seepage at depth.
- There appear to be clear geological differences. Wells in the Pavillion Field, where there are many shallow gassy zones, would be expected to have a different frequency of gas migration

along wells than in a region with thick shale seals above the gas reservoirs and no intermediate thin gas zones. Fractured bedrock of low porosity (e.g. Pennsylvania) or unfractured bedrock of higher porosity (e.g. Pavillion) have different seepage mechanisms, and will not behave the same.

It is probably reasonable to estimate that somewhere around 5 to 10 percent of the wells in an area are leaking gas.[36] The frequency of measured surface casing vent flow (Bradenhead annular space flow) in Alberta and British Columbia during the active well life is from 6 to 12 percent, not including thermal heavy oil wells. After abandonment, some wells develop seepage, and the average rate of seepage is generally small because the large emitters are easily identified and rectified.

Pathways for Gas Seepage from Depth

The three blue arrows around the upper part of the energy well show the three pathways of interest. Pathway A is the gradual maintenance of a gas pressure on the Bradenhead annulus by seepage. The pressure that this would generate depends on many factors such as the height of the column of free gas, the leak-off rate into permeable strata below the surface casing shoe, and even whether there is a pathway around the casing shoe. The presence of Bradenhead gas is clearly not proof of the existence or absence of gas elsewhere. Importantly, the absence of Bradenhead gas is not proof that there is no seepage because the cement seal within the Bradenhead annular space may be excellent, and rising gas may be forced outside of the surface casing. Thus, Bradenhead gas condition is valuable information, but insufficient to delineate what is happening at depth and in the shallow surrounding strata.

Pathway B can lead to gas escape to the atmosphere and to the increased presence of soil gas in the region surrounding an energy well (look at the stressed vegetation spots in the Photograph of the canola field in Saskatchewan). The gas is migrating to the surface, displacing some water and leading to geochemical reactions as the gas is biodegraded. Under particular and exceptional circumstances, such gas can accumulate in structures (e.g. well sheds) in quantities that present other risks.[37] The presence of methane in soil gas, however, does not necessarily imply pathway B is occurring as other causes are possible (footnote 37).

Pathway C is more difficult to detect as it is entirely subsurface, with no surface evidence unless WSWs explicitly penetrate the gas containing zone. To demonstrate unequivocally that gas is associated with O&G wells, WSWs would have had to be sampled properly and analyzed in early development phases. Also, although pathway C can lead to changes in groundwater quality, changes in groundwater quality cannot be assumed to be caused by gas migration from O&G wells as there may be other causes. The study in New York (footnote 37) points out that the methane found in over 10 percent of the WSWs sampled in the research was there naturally, not the result of energy development. The report alludes to

[36] King, G.E., King D.E. 2013. Environmental Risk Arising From Well-Construction Failure – Differences Between Barrier and Well Failure, and Estimates of Failure Frequency Across Common Well Types, Locations and Well Ages. Proc. SPE Journal of Production and Operations, November Issue 323-344

[37] Kappel, W.M. and Nystrom E.A. 2012. *Dissolved Methane in New York Groundwater*. United States Geological Survey and US Department of the Interior in cooperation with the New York State Department of Environmental Conservation) 2012. *USGS Open File Report 2012-1162*, 6 pages.

the presence of "black shale" (i.e. high total organic content shale) bedrock under the aquifers known to contain dissolved gas. (These comments are to reinforce the fact that the vast majority of groundwater methane cases are known to be from naturally occurring processes unconnected with energy development).

How could a pathway for such gas migration be generated? The most probably causes are associated with an inadequate primary cementing job. This may have arisen in several ways.

Well Cementation Issues

No Cement to Surface in the Bradenhead Annulus: Modern wells (2015) generally have the production casing cemented to surface, such that the Bradenhead annulus is filled with cement, in part because gas seepage has become a highly public issue. In many of the Pavillion wells, this was not required (this case is shown on Figure 6). In such a configuration, natural gas from zones well below the surface casing shoe can gradually fill the annulus, and there is a tendency for this gas not to be bled off by permeable strata because those strata were plugged by drilling mud during the drilling process. The plugging of the pore space by drilling mud (clays, drilled solids) gives such a high entry pressure that a substantial column of gas can build up in the non-cemented annular space behind the production casing.

Note that if the Bradenhead valve is kept closed, this gas under pressure is forced to migrate outside the casings. In Canada, the Bradenhead valve must be kept open during the active life of the well to avoid forcing the gas elsewhere, and the rate of gas seepage must be regularly measured and reported. Before decommissioning, the well must be remediated to eliminate Bradenhead flow.

Poor Quality Hole Cleaning in Primary Cementation: Inadequate mud cake removal and the presence of breakouts or other issues of hole quality can lead to the development of a continuous space that can become a gas-filled vertical channel. Remnant drill mud and mud cake will shrink in the presence of cement, even after the cementing job is completed. This shrinkage of mud cake can lead to a small channel so that a pathway for gas to migrate slowly upward is created.

Autogenous Cement Shrinkage and Radial Stress Reduction: This is perhaps the least well understood mechanism. Oilfield cements shrink after initial set, a process referred to as "autogenous shrinkage." Even lightweight and foam cements may be susceptible to shrinkage and there is little independent research on this issue (the vast majority of the articles on this subject are thinly veiled sales pitches by service companies that provide the product, or "good news stories" by O&G companies). The deficiency in genuinely independent research, and the general lack of access to the needed data, means that it is hard to be quantitative. Claims that certain additives are effective in stopping gas migration cannot be verified as companies do not permit access to the operations and data by third-party researchers.

When cement shrinks, the radial stress between the solid cement particles and the solid rock particles drops (Figure 15) to the point where it is less than the pore pressure in the fluids behind the casing, then a microannular space can develop and become a channel for formation of a gas column.

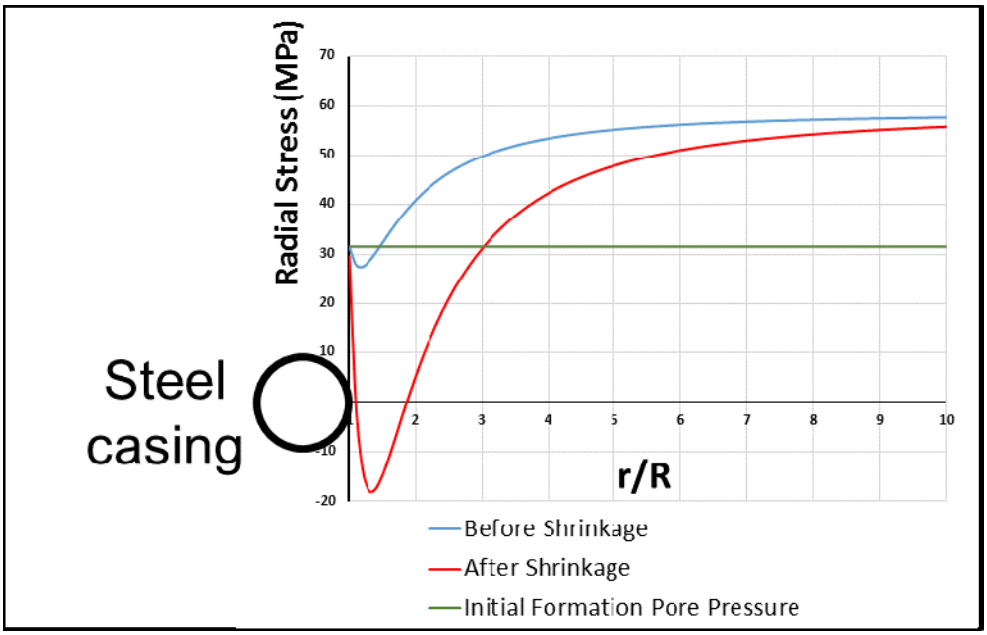

Figure 15: Cement Autogenous Shrinkage Reduces the Sealing Radial Stress

Note that the presence of gas pressure that can be recharged relatively easily at the Bradenhead valve is proof that the annular space between the production tubing and the surface casing is not completely sealed. Because this space is a steel-steel annulus, there should be no mud cake, there are no irregularities in the hole, and if centralizers have been properly used, there should be a continuous cement sheath around the production casing. Remember as well that the pressure of the gas inside the production casing is well below hydrostatic pressure, so gas from inside the production casing cannot be seeping into the Bradenhead annular space. The most likely reason for a pressure communication to exist between the Bradenhead valve and the surface casing shoe is therefore cement shrinkage, if the Bradenhead annulus had been cemented to surface. The following figure (Figure 16) shows the results of a mathematical model of a small amount of shrinkage that leads to the development of a separation space (a “microannulus”). The size of the aperture is, of course, highly exaggerated for illustrative purposes.

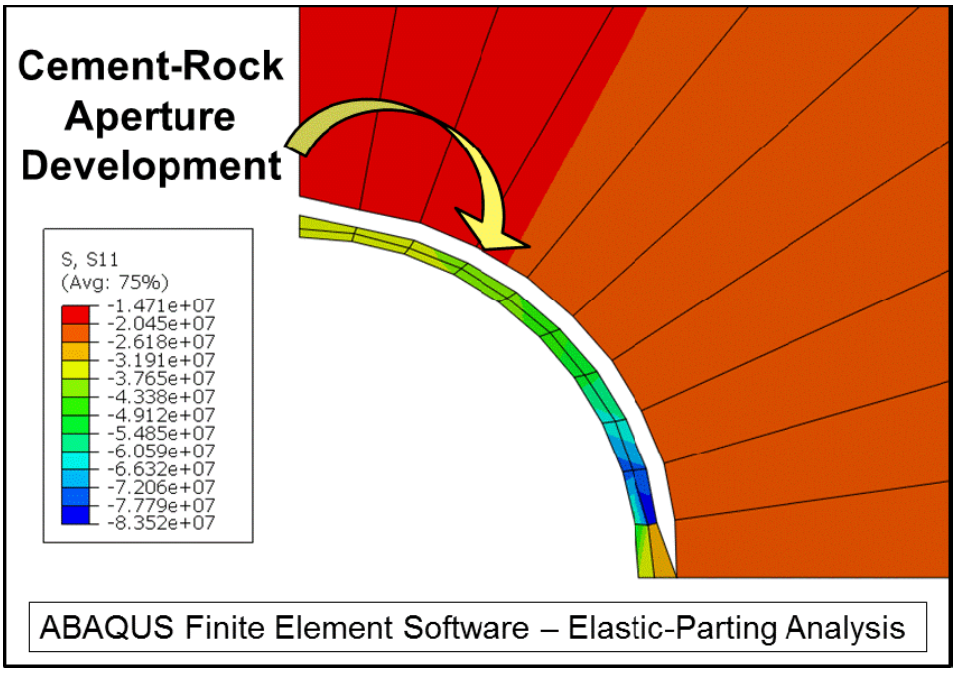

Figure 16: Development of Micro-Annular Aperture from Cement Shrinkage

Vertical Fluids Migration Potential in Pavillion Gas Field

The presence of Bradenhead annular pressurization and the flow of gas and water needed to relieve these pressures in a number of Pavillion Gas Field gas wells are proof that some wells are leaking fluids from the intermediate zone between the surface casing shoe and the production horizons. For example, gas well Unit 44-10 produced both water and gas from the Bradenhead annular space as pressure bleed-off testing was done. This well has approximately 1,400 feet of non-cemented production casing between the surface casing shoe and the top of cement. Gas analyses to highlight possible differences between tubing gas and Bradenhead gas showed that the chemical identification results were not highly discriminatory, so decisions as to the provenance of the Bradenhead gas cannot be firmly made on that basis. The absence of isotopic analyses (C and H isotopes on the hydrocarbons) on the Bradenhead gas and natural vertical gas migration in the Wind River Basin make it difficult to differentiate the gases. No large differences were noted in the C2 and C3 contents of the gas samples from various wells (Bradenhead, production tubing, production casing), suggesting vertical migration, as shallow biogenic gas generation does not lead to C2 and C3 contents as high as noted in the Pavillion well samples.

If water is being produced along with the gas from the Bradenhead annulus, the water can be sampled and analyzed for potential identification of provenance, and this is recommended, although it should be noted that if the water flows through several hundred feet of cement in the Bradenhead annulus, its chemical composition can be altered. Also, because of gas-water capillary effects and the processes that take place in a column of rising fluid, there is no guarantee that the water and the gas are coming from the same horizon. It is possible, for example, in a narrow microannulus between the cement and the rock, that gas is migrating upward slowly, but that some water, more or less at the same pressure, is seeping into the column at a depth somewhat different than the source of the gas. If the gas in the behind-the-casing column is everywhere at a pressure greater than the fluids in adjacent formations (the expected case for gas migration from a slightly overpressured gas zone), this would not happen. However, if the gas pressure is being relieved because of flow into shallower aquifers, this can reduce the pressure at the gas entry point, and the pressurized water in the microannular space can flow from below the gas source to join the gas in upward flux to the shallow groundwater zones.

What is the mechanism for water production along with the gas in the Bradenhead annulus? Most likely, when the Bradenhead valve is opened to relieve the pressure, the gas in the surface casing annulus (as well as the annulus below the surface casing shoe because these are certainly in pressure communication if there is pressurized gas at the Bradenhead valve) expands as pressure declines. Gas that is dissolved in the water comes out of solution as depressurization takes place. If there is water available in the annulus, or a source of water that comes in somewhat when the gas pressure drops, a gas-lift process can take place. Wells that flow brine and gas together are known in some jurisdictions (e.g. Ontario, Canada), despite being in a non-pressurized basin, so the only mechanism that can bring the salt water to surface along with the gas is a reduction of the hydrostatic column because of the gas lift mechanism.

Normally, one would expect a segregation of water and gas to take place in an open annulus, providing the annulus is of sufficient aperture that there are no significant capillary forces that would trap gas bubbles in the annulus. However, when the pressure on the water in an annulus is reduced, dissolved methane can come out of solution and lead to the buoyancy effects. This can happen in an ordinary aquifer where the water is close to saturated with methane if the pressure is dropped. This gas coming

out of solution is known in reservoir engineering as "solution gas drive", which maintains the pressure, but at the expense of well productivity.[38] The gas bubbles also impede the flow to the groundwater well by pore throat blockage, reducing the flow rate to the well despite maintaining the pressure. The author interprets that some of the "new-gas-in-groundwater" issues that have been ascribed to oil and gas development are due to the exsolution of gas because of aquifer depressurization (e.g. the Jessica Ernst case in Alberta[39]). Aquifer depressurization may be taking place in the Pavillion Gas Field area, but given the depth of the completions in the gas wells, this reduction of aquifer head in the upper 700 feet cannot be ascribed to gas production and deep reservoir depletion below 1,500 feet.

This Bradenhead pressurization means that the entire column of fluid behind the production casing is pressurized more than the sources of water in the deep subsurface, unless those sources were originally appreciably overpressured (under appreciable artesian pressure). Artesian conditions have been noted for groundwater in the Wind River Basin and in the Pavillion area in certain locales,[40] but the nature of this overpressure (pressure greater than hydrostatic fresh water pressure) is not quantified, and it is reported as being localized in certain areas and zones.

The criteria for vertical fluids migration along energy well casings are the following:

1. A continuous pathway of sufficient aperture must exist.
    a. This pathway can be inside the casing of the well that is not properly decommissioned.
        i. Gas can migrate toward surface and pressurize the interior of the production casing, whereupon gas could exit the casing through incompletely sealed. threaded couplings or breaches in the casing itself to enter the shallow zones.
        ii. Formation water could also follow this pathway, but with a much smaller probability of significant flow because of less pressure differential and higher viscosity.
    b. This pathway can be outside the outermost well casing as the result of various processes.
        i. A section of the production casing is not cemented below the surface casing shoe (older practices).
        ii. Cement has not been brought far enough into the surface casing to affect a good seal.
        iii. The primary well cementation was improperly done, leaving residual channels through the cement.
        iv. Cement shrinkage has resulted in development of a microannular path that has sufficient height for a gas column to develop and a differential pressure to accumulate in the region below the surface casing.

[38] Tang Q.-T., Sahni A., Gadelle F., Kumar M., Kovscek A.R. 2006. Heavy-Oil Solution Gas Drive in Consolidated and Unconsolidated Rock. *Society of Petroleum Engineers Journal* **11(02)**, 10 p, SPE #87226-PA (downloaded from OnePetro™)

[39] http://ablawg.ca/2015/04/30/leave-to-appeal-granted-in-ernst-v-alberta-energy-regulator/

[40] EPA 2010. Expanded Site Investigation – Field Sampling Plan, PAVILLION AREA GROUNDWATER INVESTIGATION, Pavillion, Fremont County, Wyoming, TDD No. 0901-01. United States Environmental Protection Agency Contract No. EP-W-05-050, 52 p. http://www2.epa.gov/sites/production/files/documents/Pavillion_GWInvestigationFSP.pdf

2. A positive pressure difference must exist between the source and the target location, and this can be generated in the following ways:
    a. The pressure difference arising between columns of fluids of different density such as a column of natural gas and a column of water. This is shown, for an example of a continuous column of methane gas, on Figure 17 as a near-vertical dotted green line intersecting the pressure axis at 180 psi and the freshwater hydrostatic pressure line (black line) at just over 400 feet depth. Because this pressure line lies far to the right of the expected hydrostatic line for water (the black line), it is clear that the development of a free column of gas can lead to pressures large enough to overcome the capillary entry pressure of sands in the upper aquifer zone. (Whether this has actually happened remains conjectural, but likely.)
    b. The presence of greater-than hydrostatic pressures in small gas sands or water sands in the intermediate zone. This is shown on the Figure 17 as a sloped blue line drawn parallel and above the freshwater hydrostatic line (black line) assuming a pressure 5 percent (5 percent) greater than the freshwater hydrostat at a depth of 1,150 feet. This type of mild overpressure can be trapped in strata indefinitely by capillary effects, and is generally ignored by oil and gas companies if it is shallow, as it is still controllable during the drilling of the well with a low density drilling fluid (8.8-9.0 ppg).
    c. The presence of a water pressure near the surface that is substantially less than the hydrostatic pressure because of aquifer drawdown by pumping or because of drainage to a river valley. An example of this is shown on Figure 17 as a drawdown of 50 feet of water, the straight red line below and parallel to the hydrostatic line for freshwater near the top left, giving a pressure drop of about 21-22 psi in the zone affected by drawdown, relative to initial conditions. This creates a pressure difference between fluids at depth that were at the freshwater hydrostat, creating the requisite pressure difference for flow of water or gas, if a continuous column exists behind the production casing.
    d. Co-production of gas and water from the Bradenhead valve means a gas-lift process is taking place when the valve is opened, and the column of fluid below the surface is some combination of gas and water, giving a density less than the freshwater hydrostat, generating the required pressure difference that generates flow and Bradenhead space pressurization. In general, the source of the gas is not known, and because a continuous column of gas and water cannot be a homogeneous mixture, static pressures at the surface detected in the Bradenhead annulus cannot be used to pinpoint the source of the fluids produced from the Bradenhead annulus.

Figure 17 shows a freshwater hydrostat, a saturated NaCl brine hydrostat, and the cases described above. There is a great deal of uncertainty in the pressure plots of different cases because the channel behind the casing, if it is cemented, can be small, such that flow is severely retarded and capillary effects

can be important. Nevertheless, if positive pressure differences exist, flow will take place unless it is restricted by a permeability barrier, or a capillary entry pressure barrier.[41]

The mechanisms for sustained flow from depth to the shallow sediments containing useful water resources are now clarified. The presence of gas and water in the Bradenhead testing indicates gas from some depth below the casing shoe. The excess pressure from a gas column also generated a gas-lift mechanism that most likely helped provide the driving force to bring liquids up the Bradenhead annulus. Flow of gas from the intermediate, non-depleted zones toward the surface can be attributed to several processes that all involve the combination of a pathway and a mechanism (or several acting together) to create a sustained pressure difference between the deep and shallow strata. Individual wells that show leakage can be sealed and improved, but ascribing any purported changes to specific energy well leakage is improbable. As said earlier, one viable option is to do nothing, as identifying the source, if it is indeed anthropogenic, is probably exceedingly difficult.

[41] Chen J., Hopmans J.W., Grismer M.E. 1999. Parameter estimation of two-fluid capillary pressure–saturation and permeability functions. *Advances in Water Resources* **22(5)**, 479–493

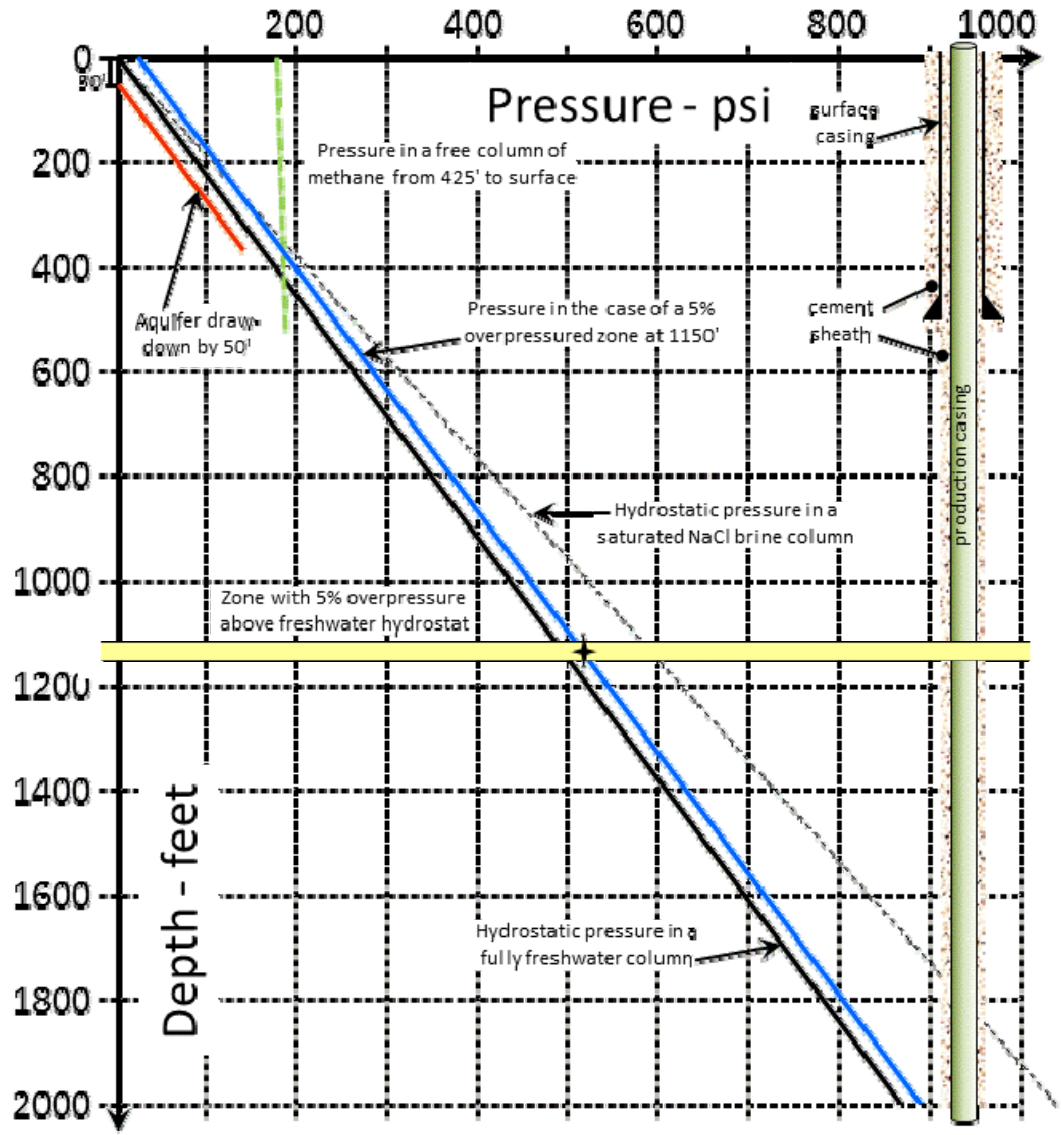

Figure 17: Pressures Behind the Casing in Different Circumstances

There are apparently few options to rectify such wellbore leakage problems in Pavillion Gas Field except to intercept the flow path and seal it in such a way as to create a barrier that either stops the flow entirely, or reduces it to negligible values compared to the natural rate of methane seepage that is happening in the Wind River Basin. Such an approach would likely follow these steps:

- Identify the source of the leakage before well decommissioning, likely using noise logs, perhaps backed up by casing bond logs taken when the production casing is not pressurized.
- For the deepest zone identified with a probable leak, carry out a perf-and-squeeze for a 5-10 m interval above the leaking point (the author prefers the use of resin squeezes to cement squeezes because of better sealing).
- Carry out another noise log above the newly sealed zone to identify the next leaking zone (if any). Repeat the sealing procedure upward through the well.

- Shut in the annulus and record the pressure build-up rate with time, and make decisions accordingly.
- Once leakage is minimal, carry out proper well decommissioning with internal plugs, place properly (bail dumping is the least satisfactory method, but the most common).

This process cannot guarantee no leakage in the future, but, when combined with proper cementation practices in the primary completion (i.e. no open annuluses), the incidence of continued well leakage should be very small. It is a general recommendation of the author that oil and gas regulatory agencies cease the practice of permitting incomplete cementing such that there are sections of open hole against uncemented casing. The two basic reasons for this general recommendation are now clear:

- The presence of an open annulus may allow the accumulation of a gas column, which means that there will be an overpressure, leading to upward seepage of gas from the intermediate zone.
- One of the roles of cement is to create a basic pH environment around the steel casing in order to counteract acidic attack of the steel casing from the outside. The chemical formulation of cement (rich in hydrated oxides) can buffer large amounts of acidity. The two major sources of acidity encountered in oil and gas field development are dissolved CO_2 (weak carbonic acid) and dissolved H_2S (weak sulfurous acid). If steel is sustained in a basic pH, it is resistant to corrosion and seal breaching for long periods of time.

Individual Well Histories

The WOGCC November 2014 Report gives summaries of the wells in the defined regions around the WSWs where quality deterioration has been claimed. These descriptions are on pages 58-96 of the report; Appendix A of the WOGCC Report contains the well report data from the State files, and Appendix B contains gas analyses for the various wells where Bradenhead pressure build-up was observed. One well has been selected from the data provided for further discussion, to provide an idea of the operational practices followed, and the results.

Well Pavillion Fee #13-03W

- Completed in 2005 as a gas well, with several fracturing jobs along the vertical well
- Discussed on pages 60-61 of the WOGCC November 2014 Report
- Data found on pages 11-14 in Appendix A to the WOGCC Report

This well reflects modern practices from the era of 2005. **Nevertheless, it is a well that shows Bradenhead pressure build-up to a value of 168 psi (8 days).** This corresponds to the pressure one would expect if there were a free column of gas to the surface in the range of 360-380 feet (assuming a column of fresh water is balanced). The casing shoe is at a depth of 608 feet, so if gas is sourced from deeper beds (as it must be, either naturally or because of gas migration), there is some permeable aquifer containing gas that is controlling the pressure to this value. Bradenhead gas pressure build-up means that gas is seeping into the annulus between the surface casing and the production casing, but it is not building a complete vertical column of free gas with a hydrostatic pressure at the bottom of the casing shoe, or else the Bradenhead pressure would be in the range of 240 psi. This may be linked to a sub-hydrostatic pressure in the aquifers around the casing shoe that serve as a control for the gas pressure. Examination of the Bradenhead gas analysis shows that it is thermogenic in nature, with a much larger component of C2 and C3 gases (more than 6 percent C2 + C3 in total) than would be expected if the Bradenhead gas is of biogenic origin.

The well was drilled to 608 feet, and surface casing installed with conventional Class G cement. The surface casing shoe was drilled with a 6¼-inch bit to a depth of 4,602 feet. No drilling difficulties were reported, and in such strata, borehole quality would be expected to be reasonable to very good, without serious borehole enlargement or breakouts developing (geophysical logs such as caliper logs would be needed to verify this supposition). In this borehole of reasonable to good quality, 4½-inch steel production casing was placed and cemented to surface with CemCRETE™, a trademark name for a Schlumberger product formulated to achieve a higher solids content than conventional neat Class G slurries. No details of the specific cementing operation procedure used were reported in the available material, such as the number of scratchers or centralizers and where they were placed, preflush, reciprocating time and reciprocation length, and so on. The following image comes from the Schlumberger product website.

CemCRETE Concrete-Based Oilwell Cementing Technology

Optimize slurry performance and mechanical integrity

CemCRETE technology increases the solids content of the slurry using particle-size distribution technology. Smaller particles fill the void between larger particles, requiring less water. This results in a cement slurry with improved flow properties and excellent set properties, such as permeability and strength. A lower water-to-cement ratio during mixing and pumping enables higher long-term performance.

CemCRETE technology offers

- more solids in your cement
- greater compressive strength
- reduced cement permeability
- greater resistance to corrosive fluids.

Copied from http://www.slb.com/services/drilling/cementing/cemcrete_materials.aspx

The WOGCC Report (page 60) and well sketch (p 14 of Appendix A) state that, during the cementing operation, a cement density of 9.5 ppg was used to displace the drilling fluid from the annulus between the production casing and the rock. A low cement density is used to avoid lost-circulation issues that might limit the height to which dense cement slurry can rise behind the primary casing. If CemCRETE™ was actually used, then microspherules (hollow glass beads, plastic beads) had to be added or foamed cement (gas-injected cement) had to be used to achieve such low densities.

The Well Report and well sketch (p 14 of Appendix A) shows that the production casing cement rose in the annulus to the surface. The use of a product such as CemCRETE™, assuming that the operation was executed without anomalous events, would probably tend to reduce the amount of autogenous cement shrinkage that might take place. In an ideal case, little shrinkage would take place as the cement set and cured, greatly reducing the chance for development of a microannular space. In any case, this product, with modern practices, should give a good-quality completion with a low chance of developing gas migration or Bradenhead gas pressure build-up with the Bradenhead valve closed. A cement bond log was run in the well to verify the top of cement and the quality of the cementing job. No anomalies were detected.

The record shows, as do other similar data in Pavillion, that the size of the fracture treatments tends to be small, on the order of 70 to perhaps 200 bbl. Slickwater or water plus CO_2 ("charged water") are used in these treatments. Acid injection was tried extensively in the 1980s, but acid has not been used in recent treatments in the well campaign of (2004-2005), apparently. Acid treatments are usually not (or no longer) injected above fracture pressure because the purpose of the acid is to dissolve clays and precipitated minerals in the near-wellbore environment. Injection of large volumes of acid under fracturing pressures is less desirable than injection at a lower pressure so that the process is dominated by radial interpore flow into the formations.

In summary, a great deal of operational information could be gleaned from the well records and systematically examined. The operating companies could be encouraged to provide additional information that could be useful in further clarifying operations at each well. However, given the

discussion above, leading to the conclusion that the risks of HF communication to the surface are vanishingly small, it is not clear if such additional activity would serve a useful role in the identification of potentially existing issues.

Well Pavillion Fee #13-03W Perforation and Fracturing Depths

Fracture stage	Depth in feet of perforated zone	Perf interval in feet	Fracture fluid volume in bbl	Comments
7	1,496	8	<100 bbl	Slickwater plus sand
6	2,324 2,336	4 4	<100 bbl	Slickwater plus sand
5	2,425	10	<100 bbl	Slickwater plus sand
4	2,691 2,727	5 6	<100 bbl	Slickwater plus sand
3	2,822	8	<100 bbl	Slickwater plus sand
2	3,161	11	108 bbl	Slickwater plus sand
1	4,473 4,493	11 4	134 bbl	Slickwater plus sand

APPENDIX MD-I

Hydraulic Fracturing Mechanisms at Shallow Depth

This Appendix contains a general discussion on hydraulic fracturing, with emphasis on shallow fracturing. This document was not written explicitly for the Pavillion case, but participation in the review did trigger the development of this preliminary discussion.

Hydraulic Fracturing Mechanisms at Shallow Depth

Maurice B Dusseault, University of Waterloo, Waterloo Ontario

Introduction

An article recently published[42] discusses the incidence of shallow hydraulic fracturing in the USA. This compendium should be read by all involved in use of this technology. The article discusses neither fracturing mechanisms nor a geoscience context, which are needed to address in more detail the technical and risk-related issues mentioned in the article and arise in hydraulic fracturing (or "fracking"). Therefore a discussion of these processes is presented below. These processes, for shallow fracturing, are related to the risks of shallow groundwater contamination (consequences and probability).

It is clear that in a number of jurisdictions in North America, the regulations are less stringent than in others. In Canada, regulations are more stringent than in the USA in general, and, it is suspected, better enforced because the resource is generally owned by the province, and thus is an important source of royalty revenue. In contrast, in the USA, almost all shale gas development (and a high proportion of coal-bed methane development) takes place on freehold land. This means that income streams to the states are quite small, and this lack of funding leads to small conservation agencies and perhaps less stringent enforcement. This is not to say that regulatory activities in Canada are invariably better than in the USA, nor are they necessarily good enough to address genuine, fact-based or postulated concerns. Regulatory policy is an evolving issue as we learn more and can measure more parameters easily (e.g., fugitive methane or trace chemicals in groundwater).

Few will take issue with the conclusions that vigilance and knowledge are fundamental. The need for the establishment of better regulations and their enforcement is widely acknowledged and has precipitated action in some states, and regulatory environments are under review in others, particularly because of potential impacts on groundwater (GW) and the potential for affecting people outside of the area of the freehold leases. The need for transparency and reporting of chemicals used in fracturing and other well treatments is clear, not only to address criticisms, but also to make data available to the public so that environmental issues can be addressed. Again, this is accomplished better in Canada than in the USA, but improvements remain to be implemented.

In the discussion, the term "joints" is used to refer to naturally occurring fractures in the rock mass in order to avoid confusing with the terms fracturing, fracture propagation, hydraulic fracturing, and so on.

[42] Jackson, R.B., Lowry, E.R., Pickle, A., Kang, M., DiGiulio, D., Zhao, K.G. 2015. The Depths of Hydraulic Fracturing and Accompanying Water Use Across the United States. Env. Sci. and Technology, accepted for publication July, Preprint widely available on the Web.

Fracture Height Estimates from Monitoring

The rise of Hydraulic Fractures (HF) quoted by Jackson et al. (*Ibid*.) in known cases relies mainly on microseismic data or a pressure response. These are best interpreted as upper-bound estimates of fracture height.

Microseismic Results

The highest microseismic (MS) event (above a specified magnitude threshold) recorded in a monitoring episode is not equivalent to the HF height. Most involved in the process of monitoring using MS and interpretation of the results note that MS events occur more distantly than the actual HF stimulated natural jointed zone because stress is transmitted through the medium much farther than pressures. The local distortion generated by the propping open of joints in a HF treatment causes distortions farther out that can lead to slip of favorably oriented joint surfaces. A HF stimulated region that has been monitored by MS will be enclosed in a "cloud" of MS events that is larger than the region directly affected by the direct contact with HF fluids. In particular, large volume HF, generally only conducted at depths below 1,000-1,500 m, can alter stresses significantly in a large region beyond the volume that experienced HF fluid ingress. However, deformations and stress changes also decay with distance, so MS events in the surrounding cloud are unequivocally linked to the HF process, but attenuate in magnitude and frequency with distance.

Small slips (MS events) that take place beyond the direct HF fluid ingress zone involve sub-millimeter lateral slip along limited area planes that happen to be favorably oriented with respect to the induced stress changes. This can happen without direct fluid communication, but near the HF stimulated zone, the increase of pressure accompanying the HF injection phase acts to reduce the effective stresses that lock joints together, aiding in the slip process. Thus, the presence of MS activity distant from the treatment zone is not proof of either fluid or pressure communication, although it is certainly proof of effective stress changes induced by distortions of the rock mass. These distortions drop off with distance (d'Alembert's Principle) rapidly and can be analyzed using well-understood continuum mechanics methods beyond the zone that has experienced the plastic (irreversible) deformations associated with the wedging open of joints and shear displacement. Deformation measurements would be an aid to these calculations.

It is hoped that in the future more information is published about the MS detection thresholds used, the spatial distribution of the magnitude of the MS events, and the directions of movements, including dilation and slip (permanent opening because of self-propping of joints as they undergo displacement).

Because these MS events occur on oriented planes (joints and bedding planes), a few widely scattered events high above a hydraulic fracture are not going to lead to a significant interconnected flow path for fluids, especially if the events are along bedding plane weaknesses that are usually horizontally oriented.

The conductivity enhancement from the shearing associated with small MS events is ill-understood yet, but it is almost certainly small compared to the region directly affected by HF fluid injection where joints are opened and propped with sand. However, the small aperture increases associated with joint slip and dilation are quite unlikely to serve as substantial pathways once active HF has ceased. This is more so in ductile rocks, and shallow rocks tend to be ductile. Once the shear slip has happened, ductile deformation reduces the remnant aperture. The MS events close to the HF zone are almost certainly evidence of some interconnectivity that enhances gas flow to the well during production, but the rate of

flux in these small aperture pathways is deemed to be small, though their cumulative effects on production rates in the long term are deemed substantial. However, these small aperture features are not as amenable to water flow because of the high capillary entry pressures needed to establish a continuous water phase, therefore it is unlikely that water flux can occur to any significant degree once production ceases.

Pressure Results

A pressure response at a more distant location is usually evidence of some fluid connectivity to the zone undergoing fracture, but it is different than direct fluid communication with the point at which the pressure sensor is located. Pressure responses can be transmitted considerable distances because the aqueous fluid in the surrounding rocks is of low compressibility and in cases of naturally fractured shale gas rock masses, the rock matrix is also of low compressibility. Hence, a pressure response can be associated to a pressure change at a distance, and even to a stress change (a poroelastic effect), but it is not evidence that fluid invasion is anywhere close to the sensor location. Nevertheless, except in the case of a poroelastic response, a pressure increase is proof that there is fluid flux taking place at some distance. If this flux is limited to the HF fluid ingress zone, it is limited in extent, and the volumes of fluid that must move to generate a pressure response are small in stiff systems.

However, there are ancillary issues that should be addressed to better understand the source of the pressure change and the mechanisms involved. These issues are listed as a series of questions for which, unfortunately, detailed analysis is often lacking. Also, these issues are not trivial: a pressure response has a mechanism, and can come from activities far away, yet involve small displacement volumes. Interpretation is necessary, but challenging.

- Is the pressure response through a pathway away from the wellbore or through a pathway behind the casing?
    - The latter is more easily avoided by paying more attention to well completion quality.
    - The former is more problematic and must be analyzed in the hope of explaining it.
- Is it possible that if the pressure response is small it could be connected to the flexing of the production casing during HF stimulation?
- Is the response a short spike, or a prolonged response that has a slow rise time and decay? How consistent and persistent is the pressure response?
    - These pressure response characteristics, and the magnitude of the response as well as its temporal link to the HF activity, and to the later phase of production, are good indicators that can be analyzed.
- Is the response a small poroelastic response that arises because of a stress change as opposed to a pressure communication pathway?
    - Poroelastic responses are well known in many applications because pressure changes always involve volumetric changes, which in turn led to stress changes that can be transmitted large distances from the actual HF fluid ingress zone.
    - The distant stress changes must be carried by the rock mass, and therefore cause small elastic distortions.
    - The induced stresses can be partly carried by the low-compressibility aqueous phase in the more distant rock mass, which is defined as a poroelastic effect. In particular, an increase in compressive stress can lead to a smaller but detectable increase in the pore pressure.
- When the well is placed on production later, there may be no further pressure response whatsoever at the sensor point, even though there is depletion occurring in the reservoir.

- This might be associated with pathway closure such as closure of microannular space between the casing cement and the rock mass, or closure of the joints that were affected by shear and dilation.
- It may be indicative that the response was poroelastic in nature.

Fracturing Processes and Fracturing Fluids

An important factor in assessing risk to shallow GW is the nature of the fracture fluids used because risk must involve an assessment of consequences. Also, the response of the reservoir and the overlying strata are of great interest.

Shallow HF operations in many regions such as Alberta and Wyoming, for development of coalbed methane and shallow gas sands, tend to be water-based HF with few chemical additives. Furthermore, there are regulatory restrictions on fracturing in Alberta and Wyoming to protect GW resources, although these regulations differ in detail. Small HF volumes are used at shallow depths, in the range of perhaps 30-100 m^3, rather than the volumes used at greater depths in deep shale gas development, which may be as high as 3000 m^3 per fracture stage, with as many as 40 stages along a wellbore. Small volumes are used in shallow HF for conventional oil and gas development because the zones at these depths are invariably relatively thin, and because using large volumes means that fluids would be wasted by ingress into the overlying strata, an economic penalty.

Small volume HF in porous rocks with permeabilities greater than a milliDarcy (mD) involves high pressures and the generation of porous flow within the reservoir, so the stimulated zone itself absorbs a significant portion of the injected volume, perhaps all of it once the HF treatment is finished, because of flow or stress conditions. For example, because coal is highly compressible compared to the bounding strata, it is far easier to open larger pathways in the coal, so the stimulation fluids tend to propagate far more easily in the horizontal direction and vertical fracture growth is suppressed. Similarly, thin gas sands usually have permeabilities far larger than 1 mD, in the range of 10-500 mD, and therefore they tend to leak off the injected fluids more readily, particularly if low viscosity HF fluids such as water or gas are used. Bounding strata are invariably of lower permeability, and do not leak off the injected volumes readily, but once fracturing ceases within the stimulated stratum and pressures start to equilibrate, higher pressure HF fluids that entered the overburden tend to slowly flow back toward the stimulated zone, even before production takes place, because the permeable zone allowed the pressure to drop back quickly to the regional values. Flow-back of fluids that may have been injected into the overburden continues as the pressure is depleted.

HF using N_2 or CO_2 has been commonly used in Alberta, and these are small volume HF treatments, using fluids without complex gelling mixtures or acid. There will be exceptions in the past to these points, but the use of large volumes and aggressive chemicals is not done in shallow fracturing in Alberta or British Columbia. HF in shallow shale gas is not done because there is not enough gas at shallow depth to make it worthwhile for economic development. In the case of deep HF stimulation in shale gas strata, the lack of water in the shales means that the CO_2 will be more persistent as a free phase, but because the depths are large, any GW effects are probably non-existent. Even conservative estimates of fracture height growth based on MS data show that the assumed fracture height is many hundreds of meters below the base of GW.
Energized water (liquid CO_2 co-injected with water and some quartz sand) is commonly used for shallow HF stimulation (CO_2 is less effective at depth). These materials are non-toxic, and the CO_2 dissolves gradually in the aqueous phase in the rock mass, or is consumed by reactions of weak carbonic acid (CO_2

dissolved in water) with some minerals. The solubility of CO_2 in water is well known, and as the injected CO_2 moves through the porous medium, it must become absorbed until it disappears as a free gas phase or a liquid CO_2 phase.

Slickwater fracturing may be used for shallow HF treatments, and slickwater is simply water with an added polymer to reduce the resistance to flow through a small aperture crack. It does not reduce the viscosity of the water; the polymer helps form a boundary layer on the fracture wall by adsorption during flow, making it appear smoother to the passing water, and therefore reducing the resistance to flow. Slickwater chemicals are like polyacrylamides, and these molecules are adsorbed on the rock surfaces so that their presence is attenuated as the polymer concentration is depleted with distance and time. Furthermore, these polymers are probably not classified as hazardous materials, and are considered to have low toxicity.

Additives such as oil, biocides, and other chemicals that are ranked as hazardous are in general not currently used in shallow HF operations based on slickwater and quartz sand proppant. Again, particularly in the past, there will have been exceptions to this, as more liberal use of chemicals, even if there was uncertainty as to any beneficial effects, was more common in the past.

Once the high pressure HF injection operation is completed, the excess pressures will dissipate with time even if production does not take place immediately, not only in the direct region fractured, but in the surrounding areas where pressure increase took place during fracturing. This is natural: nature seeks to dissipate excess pressure through flow, therefore the over-pressure (above regional pore pressure conditions) decays. If the strata being stimulated are of moderate permeability (>10-100 mD), this happens quickly, within hours generally. This decay also means that the driving force for pressure communication is dissipated, and flux ceases. Hence, the agents in the aqueous phase no longer are driven to greater distances.

After the well is placed on production, general regional pressure depletion takes place. This means that the flow gradients are now reversed, in comparison to the high-pressure fracturing periods, and flow in the HF stimulated region is toward the production well, not toward the surface or laterally. So, given normal pressure dissipation and the drawdown as production is started, the high pressures in the HF region do not stay high, they are relieved relatively quickly in comparison to the life of the well.

Some of the injected HF fluids (water essentially, with some additives) return to the wellbore, both immediately and over time, in the range of 30-60 percent generally, but the explicit fate of the portion that does not return is ill-understood. Some of the fluids may have become adsorbed or absorbed by the mineral matter in the system, becoming permanently entrapped. Some of the fluids that have been forced into small cracks cannot escape later because of capillary blockage and the reduction in the apertures of the stimulated natural joints as pressures decay or are reduced by production. Some fluid is stored in the increased volume of the joint surfaces associated with the shearing that causes MS emissions; this is largely a permanent volume change. Nevertheless, there may be an unidentified mechanism that traps some of the fluids within the rock mass, but if the fluid is trapped and the driving pressure differences soon disappear, they are not free to migrate farther.

Acid treatments, polymer floods, and other treatments to clean the near-wellbore environment or to displace oil are typically not injected above fracture pressure. The intent of an acid treatment, which is generally quite small and may be limited to 5-10 m^3, is to dissolve clays, precipitates, or carbonate minerals in the region close to and around the wellbore – no more than several meters. The intent is to

reduce the impact of particulate or precipitated matter that is impairing the wellbore productivity. By opening pore throats through the dissolving of clays and minerals, resistance to flow is reduced, and higher production efficiencies can be gained.

Polymer floods, surfactant floods, and related technologies, including solvent injection, are intended to create viscosity contrasts to aid in displacement of oil. These are not used in gas wells.

Stress Conditions at Depth and Fracturing

Stress orientations are the primary control over HF orientation. This is a complex issue, but a general overview can give insight into HF behavior in almost all cases.

In deep strata, below 1,000 to 1,500 m but depending on the geological uplift, erosion and diagenetic history, the smallest stress is horizontal. Because fracturing is a work minimization process (as are all physical processes), an HF will propagate dominantly in an orientation perpendicular to the smallest stress. Deep fracturing is therefore vertical fracturing, with very few known exceptions; deep shale gas HF propagation directions are invariably dominated by vertical propagation.

A well-known barrier to upward HF migration is the zone near the earth's surface in all uplifted basins where the horizontal stresses are greater than the vertical stress. To be clear, this is a barrier to the upward propagation of the wedging open of joints, and it is not necessarily a barrier to porous media flow. However, if there is a barrier to upward HF propagation, it serves as a great reducing influence on the risk of GW interaction for shallow fracturing.

Uplift and erosion has taken place in all terrestrial basins in Canada and most in the United States, with the possible exception of the Lower Mackenzie Basin that includes the Mackenzie Delta and the offshore region, called the Canada Basin, the Gulf Coast region, and a few other basins that were formed by extensional tectonics. As an example, research conducted by the author in the region north of Medicine Hat, Alberta, shows that above about 350 m in this region, induced fractures are horizontal and they tend to stay in the stimulated zones, propagating laterally without further upward propagation. Below about 375 m, the initial fractures departing the well bore are vertical. It is surmised that if induced HF zones propagate upward, they will turn into a horizontal attitude as they pass through and perhaps somewhat above the zone where the vertical stress becomes the minimum stress.

In many environments, such as the Gulf Coast of the USA, which has not been subjected to uplift and erosion, the horizontal stresses in the overlying shales are noted to be somewhat higher than in the underlying reservoirs being stimulated by HF. This acts as a barrier to upward propagation, keeping the vertical HF extension within the reservoir, moving laterally with little vertical component.

Geological Factors

The lithological nature of the strata will affect the response to HF stimulation. Shallow sediments are usually soft, compared with deeper strata. In Alberta, British Columbia and Saskatchewan, and much of the west of the USA (Montana and North Dakota down to the Permian Basin and north Texas regions), the upper thousand meters or more are comprised of more recent sediments (younger than mid-Jurassic) that are of high porosity, rich in clays (often smectite), and more ductile. Shearing events are more ductile than in deep, stiff quartz-illite shales (typical gas shales), so the development of conductive

pathways is suppressed. In extreme cases such as coal, HF success is severely constrained because the proppant penetrates into the coal and the beneficial effects are reduced.

The different strata found in geological conditions play a role in the distribution of stresses and the resistance to fracture rise. In the Barnett Shale (Fort Worth – Dallas Basin), there are two stratigraphic barriers to upward propagation, a competent rock in the upper middle of the target zone, and the caprock itself. MS monitoring shows that upward HF propagation is arrested by these barriers, and the reason is likely to be a combination of a stress barrier and higher fracture toughness (a material property). In fact, a problem with early HF treatments, and a limiting factor on volumes injected, is the tendency for downward HF growth with the risk of intersecting a regional saline water zone. If this happens, the well is an economic failure. Clearly, the lithology and how it interacts over geological time through diagenesis with the stress fields are important factors in understanding vertical HF propagation.

In contrast, the Marcellus Shale in Pennsylvania and surrounding states has no such caprock condition, and upward HF propagation dominates over downward propagation, probably in a ratio of approximately 3:1, based on MS monitoring.

Rising fractures tend to be blunted by intersection with more permeable zones, although this is not a direct consequence of the stress distributions, it is a geological factor. By the time an HF has reached some height, the pressure at the tip is reduced somewhat by friction along the flow path, but it still exceeds the lateral minimum stress (a condition for propagation). Upon contact with a permeable stratum, fluid leak-off is increased, reducing the tendency for further vertical growth, a process referred to as “blunting.” In most geological environments, perhaps most commonly in shallow HF operations, the existence of blunting zones is common.

Summary

Hydraulic fracturing is an industrial process of great importance to the oil and gas industry, and has also seen application in deep solid waste injection and in geothermal energy extraction. Relative to some other energy-related activities, such as the use of coal for electrical power generation, it is relatively safe and has little environmental impact, certainly in the short term, and quite likely so in the long term. In particular, the chemicals and fluids most commonly used currently for shallow fracturing are usually relatively benign (water, CO_2, sand, polymers…). Nevertheless, as with any large industrial activity, there are risks, and the probabilities and consequences that define these risks must be understood and mitigated. Incidents with environmental impact cannot ever be fully eliminated in any industrial activity, but better understanding of the processes, combined with good monitoring and modeling, can lead to methods that reduce the probability of such incidents. The role of regulatory policy and enforcement is paramount.

Pressure data and microseismic monitoring data alone are insufficient in their present use to define hydraulic fracture growth accurately (e.g. at an uncertainty level of ±10 m), but the general behavior and dimensions of stimulated regions in the earth are well understood, and the mechanisms are clear. However, given the processes described, there will always be uncertainty in geomechanical processes at depth, and further development and implementation of methods such as deformation monitoring and better pressure and microseismic monitoring will reduce the level of uncertainty in practice.

Stresses in the earth and the geological disposition of the strata are fundamental controls on hydraulic fracture behavior, and these must be well-understood to guide design and implementation of operations. Good understanding will reduce the probability of incidents, thereby reducing risk.

APPENDIX H

Document Review Index

APPENDIX H

DOCUMENT REVIEW INDEX

Pavillion, Wyoming Area Domestic Water Wells

Final Report and Palatability Study

File #	Document Author	Year	Month	Document Title, Origin	Review Type	File Source	File Notes
1	ATSDR	2010 (not 2000)	August	Water, Pavillion, Wyoming, Fremont County	Detailed review	Internet	
2	Bureau of Reclamation	1951		Annual Project History for Riverton Project	For information	WDEQ provided excerpt	File #33 cites that USBR found gas in drilled water well 500 bgs several years prior to drilling of first producing gas wells in the Pavillion Field
3	Bureau of Reclamation, Robert Autobee	1996		Riverton Unit Pick-Sloan Missouri Basin Program	For information	Internet	Provides a basic history of the Riverton project, including 1950s
4	Encana	2013	October	Data Summary	Detailed review	WDEQ	
5	Encana	2013	October	Well Location Information	For information	WDEQ	
6	Smith-Comeskey Groundwater Science LLC	2013	January	Report on US EPA's Investigatory Approach to Palatability Issues in Domestic Wells Near Pavillion, WY	Detailed review	Internet	
7	Gores and Associates	2011	October	Pavillion Area Water Supply, Level I Study Final Report	For information	Internet	Phase II study also available. It cites File #19 on Wind River Formation and File #21 on water quality. It is cited by File #33
8	Gorody, Anthony	2008	June	Case Study The Louis Meeks Water Well 9-04 to 11-07	Detailed review	WDEQ	A PPT file, reviewed in "USEPA-2009-Hydraulic-Fracturing-Report-of-Preliminary-Analysis-of-Reported-Contamination-.pdf"
9	Johnson, Ronald and Rice, Dudley	1993		Variation in Composition and Origins of Gases from Coal Bed and Conventional Reservoirs, Wind River Basin, Wyoming (USGS Special Symposium)	For information	Internet	
10	Stephens, Daniel B.	2015	January-February	Analysis of the Groundwater Monitoring Controversy at the Pavillion, Wyoming Natural Gas Field, Groundwater Journal	Detailed review	Internet	
11	US EPA	2009	August	Site Inspection - Analytical Results Report: Pavillion Area Groundwater Investigation Site, Pavillion, Fremont County, Wyoming, URS Operating Services, Inc. (Phase I)	Detailed review	Internet	
12	US EPA	2010	August	Expanded Site Investigation - Analytical Results Report: Pavillion Area Groundwater Investigation, Pavillion, Fremont County, Wyoming, URS Operating Services, Inc., (Phase II)	Detailed review	Internet	
13	US EPA	2011	November	Ground-Water Quality Investigation - Pavillion, Wyoming, U.S. Environmental Protection Agency, Methods, Graphics, and Data Tables, (Phases III and IV)	Detailed review	Internet	
14	US EPA	2011	December	DRAFT Investigation of Groundwater Contamination near Pavillion, Wyoming, EPA 600/R-00/000	Detailed review	Internet	
15	US EPA	2012	December	EPA Briefing to the American Petroleum Institute	For information	WDEQ	
16	US EPA	2013	August	Pavillion Oil and Gas Field Pits Evaluation	Detailed review	Internet	
17	US EPA	2013	August	Pavillion Gas Well Integrity Evaluation	Detailed review	Internet	
18	USGS	1959		Ground-Water Resources of Riverton Irrigation Project Area, Wyoming	For information	Internet	
19	USGS	1969		Groundwater Resources of the Wind River Indian Reservation Wyoming	For information	Internet	
20	USGS	1996 (not 1993)		An Assessment of In-Place Gas Resources in Low-Permeability Upper Cretaceous and Lower Tertiary Sandstone Reservoirs, Wind River basin, Wyoming	For information	Internet	

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DOCUMENT REVIEW INDEX

Pavillion, Wyoming Area Domestic Water Wells

Final Report and Palatability Study

File #	Document Author	Year	Month	Document Title, Origin	Review Type	File Source	File Notes
21	USGS	1996		Water Resources of the Wind River Indian Reservation, Wyoming	For information	Internet	
22	USGS	2000	March	Pesticides in Ground Water - Fremont County, Wyoming, 1998-99	Detailed review	Internet	
23	USGS	2012		Sampling and Analysis Plan for the Characterization of Groundwater Quality in Two Monitoring Wells near Pavillion, WY, Open File Report 2012-1197	For information	Internet	
24	USGS	2012		Groundwater-quality and quality-control data for two monitoring wells near Pavillion, Wyoming, April and May 2012, USGS Data Series 718	For information	Internet	
25	WDEQ	2007-2012		Pavillion Case Files (Pavillion Docs_Kevin Files), with additional historical data for several water supply wells provided to AME in July 2015	Detailed review	WDEQ	A compilation of correspondences, reports-memos, and lab reports from the WDEQ CD; additional historical data for the water supply wells of Meeks, Locker, Fenton, Griffin, and Garland.
26	WGS/USGS	2011		Geologic Background Wind River Formation	For information	WDEQ	
27	WOGCC	2014	September	Pavillion Gas Well Integrity Report	Detailed review	Internet	
28	WOGCC	2014	November	Pavillion Oil and Gas Field Pits Report	Detailed review	Internet	Final Report released in June 2015
29	USGS	1995		Water Resources of Fremont County, Wyoming	Additional	Internet	Source of background data for File #01
30	USEPA	2012	December	Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources	Additional	Internet	EPA associated glycols and glycol ethers with hydraulic fracturing fluids
31	Smith et al.	2014		Organic Contaminants in Portland Cements Used in Monitoring Well Construction	Additional	Internet	
32	Encana	2012	April	Initial Comments on USEPA Draft Report on Groundwater Contamination near Pavillion	Additional	Internet	It contains two expert reports (File #33 and File #34) commenting on USEPA's draft report
33	Sterrett, Robert J.	2012	March	Review of the USEPA Draft Report on Groundwater Contamination near Pavillion	Additional	Internet	This report is cited in File #06 on Pavillion Field hydrogeology. It cites File #07 for groundwater quality of the Pavillion Area. Also cited File #19 for artisan wells and File #09 for isotopic composition of gases.
34	Mullen, Mike	2012	April	Review and Evaluation of EPA's Drilling and Cement Jobs for MW01 and MW02	Additional	Internet	
35	S.S. Papadopulos & Associ	2012	April	REVIEW OF U.S. EPA’s December 2011 Draft Report	Additional	Internet	
36	Tom Myers	2012	April	Review of DRAFT Investigation of Ground Water Contamination near Pavillion by USEPA	Additional	Internet	
37	API	2013	June	Review of EPA’s Pavillion December 8, 2011 Draft Report With Focus on Deep Monitoring Wells MW-01 And MW-02	Additional	Internet	
38	USGS	1970		Structural Geology of the Wind River Basin, Wyoming	Additional	WDEQ	Provided by Nicole Twing
39	WDEQ	2014		WDEQ 2014 Request for Information LTRS	Additional	WDEQ	RFI letters from the WDEQ CD
40	USDOE	1981	March	Geologic Overview, Coal, and Coal Bed Methane Resources of the Wind River Basin, Wyoming	Additional	WDEQ	From WDEQ on 4/28/2015
41	Richter	1981	August	Occurrence and Characteristics of Ground Water in the Wind River Basin, Wyoming	Additional	WDEQ	From WDEQ on 4/28/2015

APPENDIX I

Document Review Summaries

Appendix I—Document Review Summaries

Section I Geology and Gas Resources

38. USGS 1970 (by William Keefer) Structural Geology of the Wind River Basin, Wyoming

This technical paper discusses the structural geology of the entire Wind River Basin (see map insert below – **Figure 1** of the document), utilizing information from field observations and boring lithology from numerous gas/oil wells drilled in the basin (**Table 1** of the document). The paper provides thickness or isopach maps of major stratigraphic units of different geologic ages in the basin.

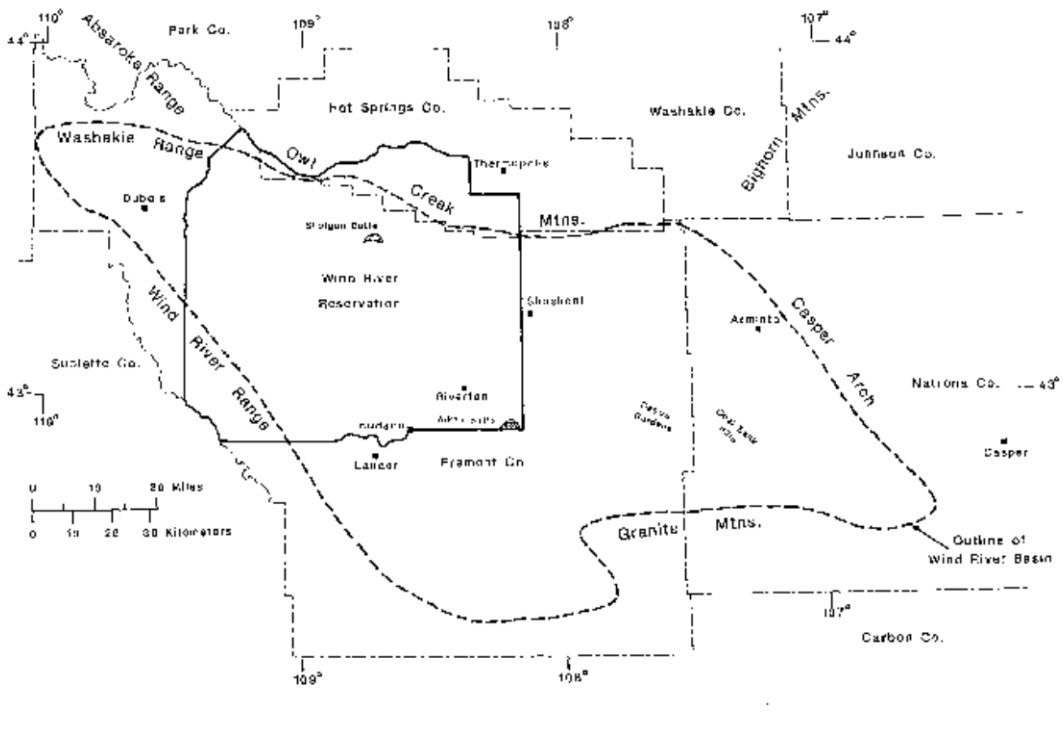

Figure 1: Index map showing location of Wind River Basin and surrounding uplifts. Location of Wind River Reservation is also shown.

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The Wind River Basin is a broad structural depression bounded by the Wind River Range on the west, the Washakie Range and Owl Creek and southern Bighorn Mountains on the north, the Casper arch on the east, and the Granite Mountains on the south (see map insert above). Along the south and west margins of the basin, Paleozoic and Mesozoic strata dip 10°-20° basinward, whereas along the north and east margins the dips are commonly vertical to overturned. The basin floor is thus markedly asymmetric;

the structurally deepest parts are close to the Owl Creek and Bighorn Mountains on the north and to the Casper arch on the east. Southwest asymmetry is a dominant structural characteristic of the region and is exhibited by subsidiary features around the basin margins as well as by all the surrounding mountain uplifts. The northwest structural grain is also conspicuous nearly everywhere.

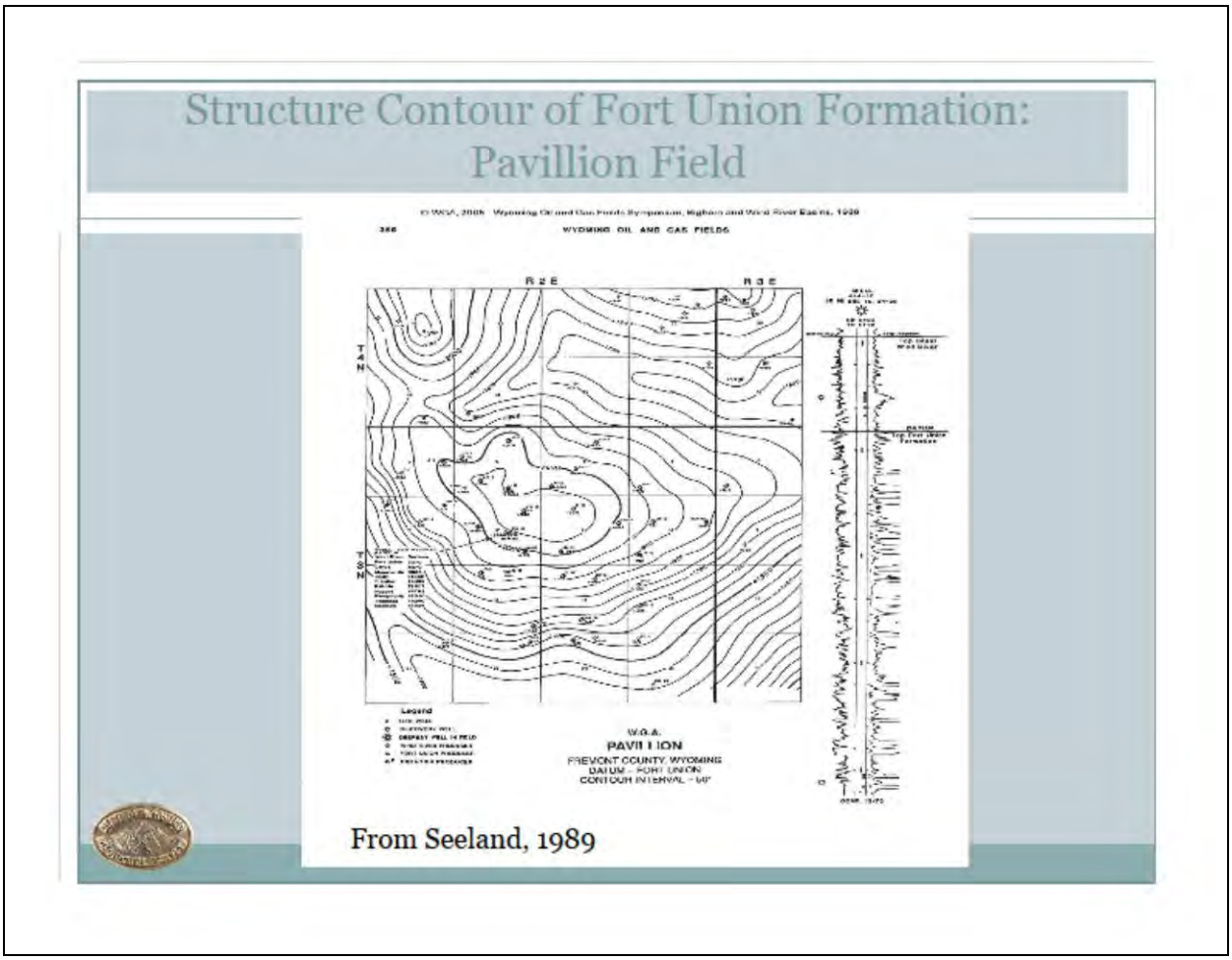
Discussion in this paper is arranged according to major structural provinces or elements within and around the Wind River Basin. Mountain structures discussed include Wind River Range, Washakie Range, Owl Creek Mountains, Southern Bighorn Mountains, Casper Arch, and Granite Mountains. Basin structures discussed include West Margin, North Margin, East Margin, and South Margin. The discussion of structural analysis is arranged into Foreland Deformation, Mechanics of Deformation, Regional Uplift, Volcanism, Crustal Structure and the Implications of Isostasy.

The Wind River Formation, the upper portion of the lower Eocene rocks, is present and forms surface rock over much of basin area. Lithology data indicate that the Wind River Formation is composed primarily of sandstone, conglomerate, siltstone, and claystone. The Wind River Formation, together with the underlying Indian Meadows formation (the lower portion of the lower Eocene rocks), range in thickness from 0 to 9,000 feet (**Figure 6** of the document). Immediately underlying the lower Eocene rocks is the Fort Union Formation of the Paleocene age (**Figure 5** of the document), composed of sandstone, siltstone, and shale. The Cody Shale, part of the upper Cretaceous rocks (**Figure 4** of the document), lies beneath and is composed of shaly sandstone and shale.

26. WGS-USGS 2011 Geologic Background Wind River Formation

This document is a slide package presented at the August 31, 2011 Pavillion working group meeting. The document compiles geologic and hydrogeologic information of the Wind River Formation focusing on the Pavillion Field from a large body of studies mostly by USGS and Wyoming state agencies. The document covers structure contour of Fort Union formation of the Pavillion Field, surface geology, stratigraphy of the Wind River Basin, extent and characteristics of the Wind River Aquifer, potential contaminants and gas migration within the basin, Wind River Formation depositional history, lithology, and source, and cross sections through the Pavillion Field.

In particular the compiled information has indicated the following. First, the structural contours of the Fort Union Formation (i.e., elevation contours of the top of Fort Union Formation or base of the Wind River Formation) in the vicinity of the Pavillion Field show that the Pavillion Field is located on a structural dome in terms of gas operations (see the insert below). Second, water bearing zones in the Wind River Formation are lenticular sandstone beds and conglomerates, varying widely in thickness and geometry. These water bearing zones are considered individual aquifers on a local scale as they are often discontinuous and separated by less-permeable fine grained rocks. Third, wells completed in these aquifers, generally for stock and domestic use, are characterized by relatively low yields and poorer water quality. Fourth, gas resources in the Pavillion Field originate from deeper source rocks as a result of upward gas migration.



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40. USDOE 1981 Geologic Overview, Coal, and Coal Bed Methane Resources of the Wind River Basin, Wyoming

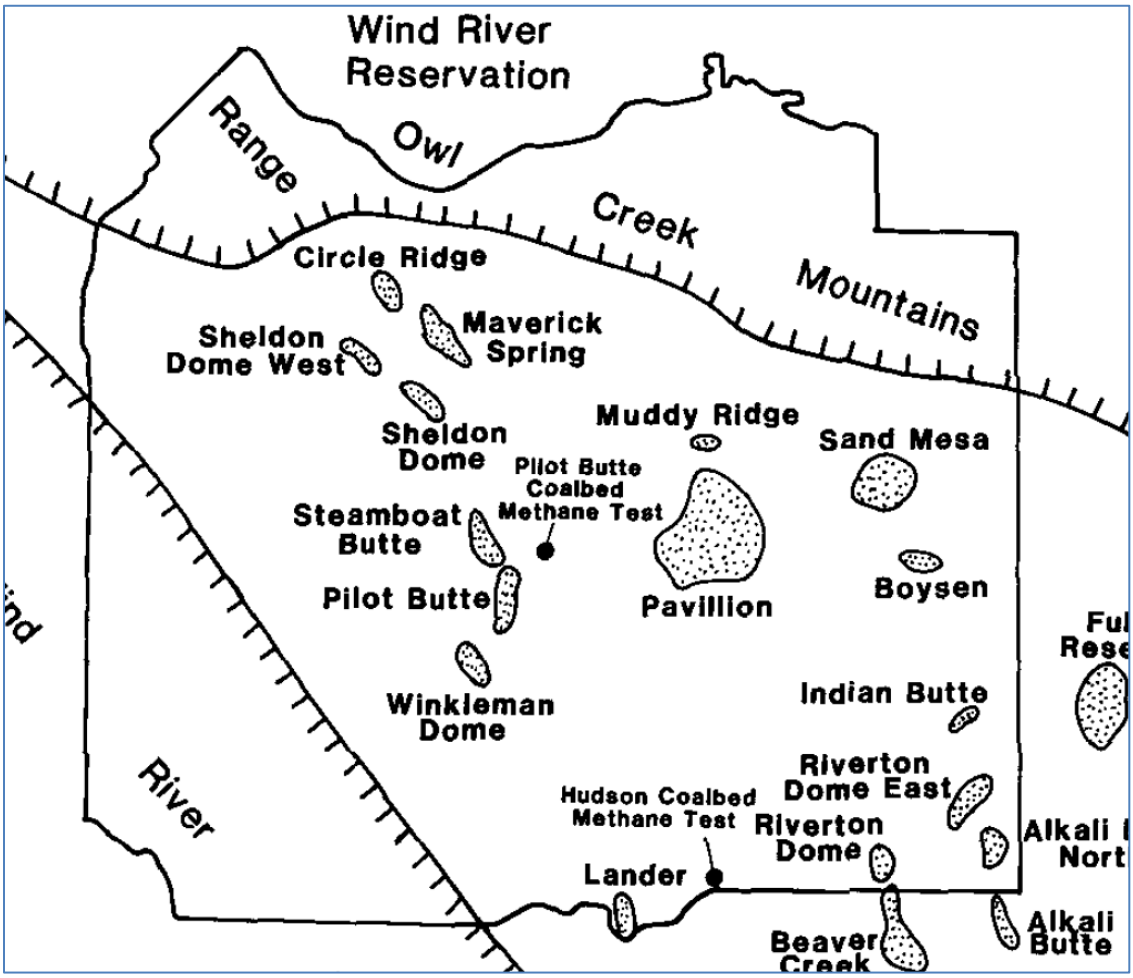
This report was prepared with the intent to be a current, comprehensive handbook of the geology, coal, and coalbed methane resources of the Wind River Basin. Summarized here is information of the Wind River Formation relevant to the Pavillion groundwater investigation. The Eocene Wind River Formation is a minor coal-bearing formation in the Wind River Basin (Glass, 1978). Drilling in the southernmost part of the Beaver Creek coal field, however, documents a few 2- to 3-foot thick coals (Thompson and White, 1952). Most Wind River coals are only a few inches thick, of little economic value, and of no value to the Methane Recovery from Coalbeds Project (MRCP). No data seems to exist for the Pavillion area (see **Figure 4-5** of the document for USGS drilling sites on the Wind River Indian Reservation).

09. Johnson and Rice 1993 Variations in Composition and Origins of Gases from Coal Bed and Conventional Reservoirs, Wind River Basin

This work studied the variations in the chemical and isotopic compositions (methane or $\delta^{13}C_1$) of gases from the Wind River Basin (**Figure 2** of the document; see insert below) to understand the origins of the gases. Gases from all producing intervals in conventional reservoirs at depths ranging from 2,321 to 18,050 feet are predominantly thermal in origin (C_1/ C_{1-5} of 0.82 to 1.0, $\delta^{13}C_1$ of -31. 12 to -47.40‰). Most gases sampled from conventional reservoirs appear to have migrated from deeper, more mature source rocks.

At Pavillion field, west of the pinchout of the Waltman Shale Member, gases from the shallow (3,437 to 3,564 feet), immature reservoirs in the lower Eocene Wind River Formation are isotopically heavy ($\delta^{13}C_1$ of-39.24 to -40.20‰) and were generated by the deeper, mature to post-mature source rocks, probably of the Upper Cretaceous age.

Coalbed gases from two coalbed methane wells found in the structurally shallow areas of the basin within the Wind River Reservation are mixtures of biogenic and thermogenic gases. The thermogenic component of these gases must have migrated into the coals from a deeper, more thermally mature source sometime after the coals were buried in Paleocene time.

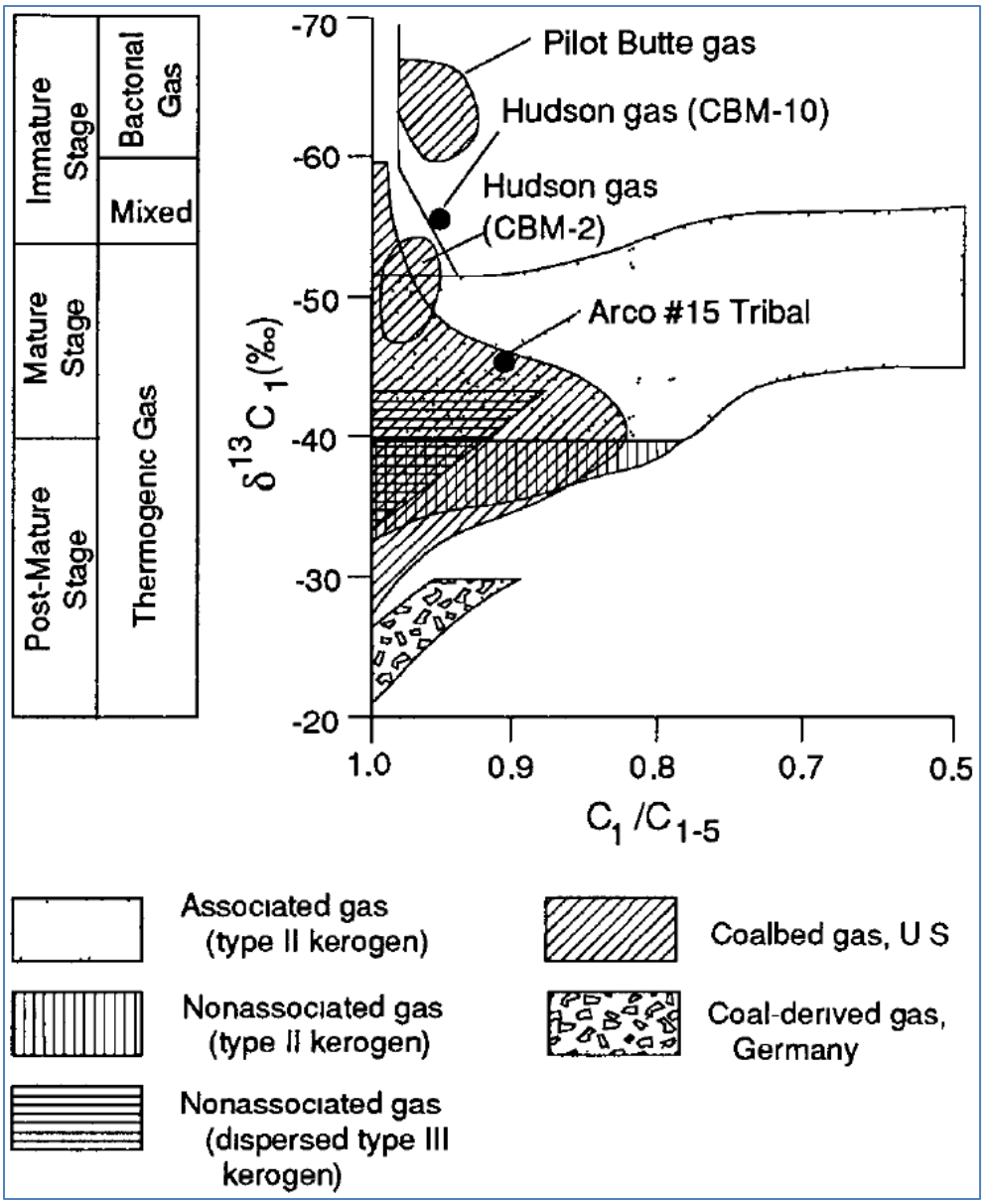


*(Part of **Figure 2** of the document)*

<u>Fundamentals on the Origin of Natural Gas</u>

Natural gas can be of either biogenic or thermogenic origin. Biogenic gas is generated by the breakdown of organic matter by bacteria at temperatures less than 75° C by either CO_2 reduction or, less commonly, by fermentation. Biogenic gas consists mainly of methane (C_1/ C_{1-5} > 0.99) that is usually isotopically light, with $\delta^{13}C_1$ values lighter than -60 ‰.

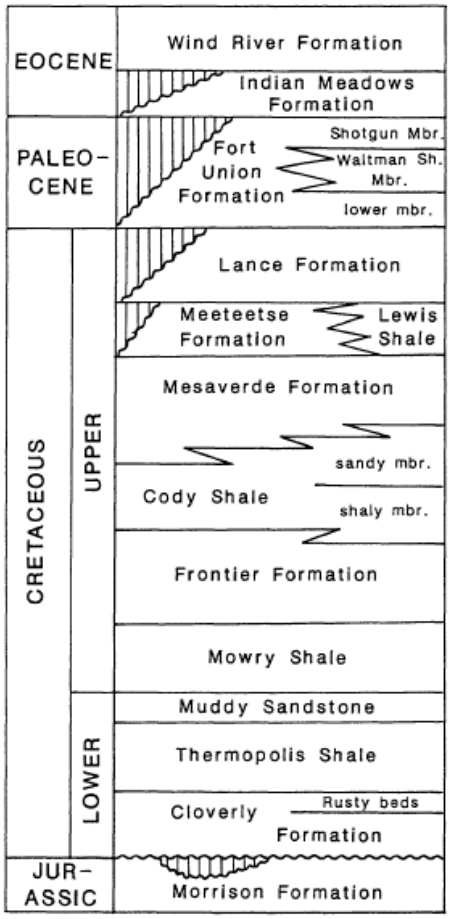
Thermogenic gas is generated at higher temperatures by thermal cracking and degradation processes. During the mature stage of hydrocarbon generation, thermogenic gases are chemically wet (C_1/C_{1-5} values less than 0.95) and generally have $\delta^{13}C_1$ values ranging from about -50 to -40 ‰. With increasing levels of thermal maturity during the late stages of catagenesis, gas is formed by the thermal cracking of previously formed liquid hydrocarbons while type III organic matter continues to generate mainly gas. A $\delta^{13}C_1$ value of -40 ‰ commonly corresponds to the lower preservation limit of liquid hydrocarbons, either oil or condensate, and a vitrinite reflectance (R_m value of 1.30 percent). Gases generated at higher levels of thermal maturity are generally dry (C_1/C_{1-5} >0.95) and were generated during the post mature stage (**Figure 4** of the document; see insert below).



*(**Figure 4** of the document)*

20. USGS 1996 An Assessment of In-Place Gas Resources in Low-Permeability Upper Cretaceous and Lower Tertiary Sandstone Reservoirs, Wind River basin, Wyoming

This is a technical report for gas resource assessment, for the entire Wind River Basin, in the low-permeability sandstone reservoirs in the upper Cretaceous and lower Tertiary rocks (see the insert below). **Figures 6** and **7** of the document provide schematic cross-section illustrations of the stratigraphic units, potential source rocks, and other information within the entire Wind River Basin. Discussions of particular interest to the Pavillion Field are summarized below.



*(Generalized stratigraphic chart, **Figure 2** of the document)*

It is known in the Pavillion Field that the primary gas producing unit is the Fort Union Formation. Basin wide, the Fort Union Formation consists of the Shotgun Member, the Waltman Shale Member, and a lower unnamed member. In general, hydrocarbon production from the Waltman Shale and above is confined to a few small oil and gas fields. Significant gas shows, however, occur throughout the sandstones, shales, and coals of the underlying lower unnamed member of the Fort Union Formation. These results are consistent with the Waltman Shale acting as a regional seal inhibiting the vertical migration of gas throughout the central part of the basin.

The Waltman Shale pinches out in the west part of the basin (**Figure 4** of the document; see insert below). In the Pavillion and Muddy Ridge fields area, west of the pinchout of the Waltman Shale, gas shows occur scattered throughout the Paleocene and Eocene interval, and the Pavillion field has produced large amounts of gas from the Eocene Wind River Formation at depths of as shallow as less than 2,000 feet.

Recent work on the chemical and isotopic compositions of gases in the Wind River Basin by Johnson and Rice (USGS 1993) supports the concept that the Waltman Shale is acting as a regional seal. In the Fuller Reservoir field in the west-central part of the basin where the Waltman Shale is present, non-associated gases from below the Waltman Shale are distinctively heavier isotopically than the small amounts of associated gas produced with heavy waxy oil from deltaic sandstones within the Waltman Shale. In

contrast, gases produced from the lower Eocene Wind River Formation at the Pavillion Field west of the pinchout of the Waltman Shale are isotopically heavy and similar to gases produced from deeper, Paleocene and Upper Cretaceous age formations in the area; these gases probably migrated vertically into Wind River reservoirs from deeper, more mature source rocks.

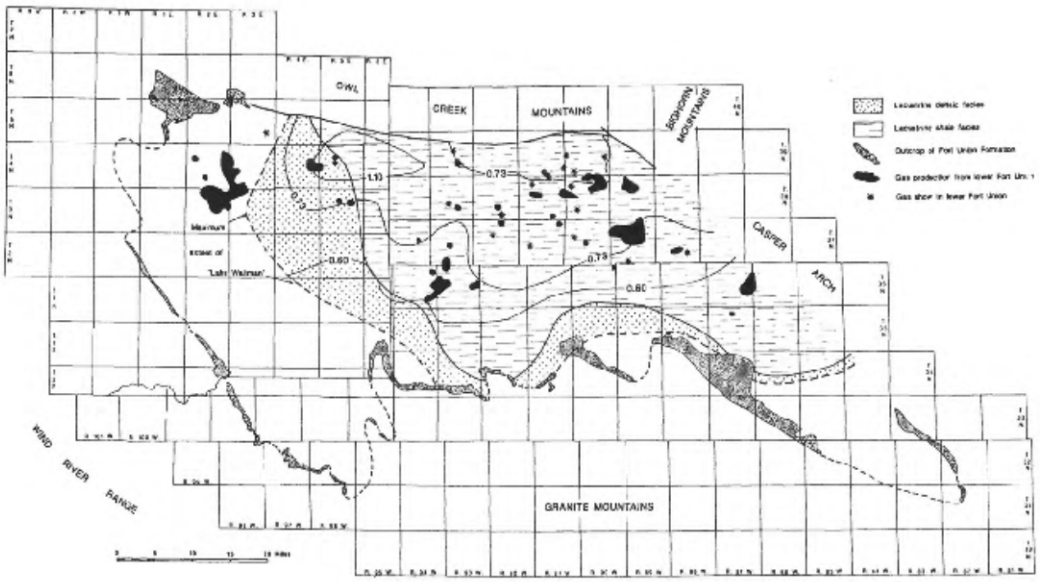


Figure 4: Map showing extent of the Waltman Shale Member of the Paleocene Fort Union Formation and correlative deltaic rocks. Gas production and gas shows in the underlying lower unnamed member of the Fort Union are also shown. Vitrinite reflectance levels at the base of the Waltman are also shown (from Nuccio and Finn, in press).

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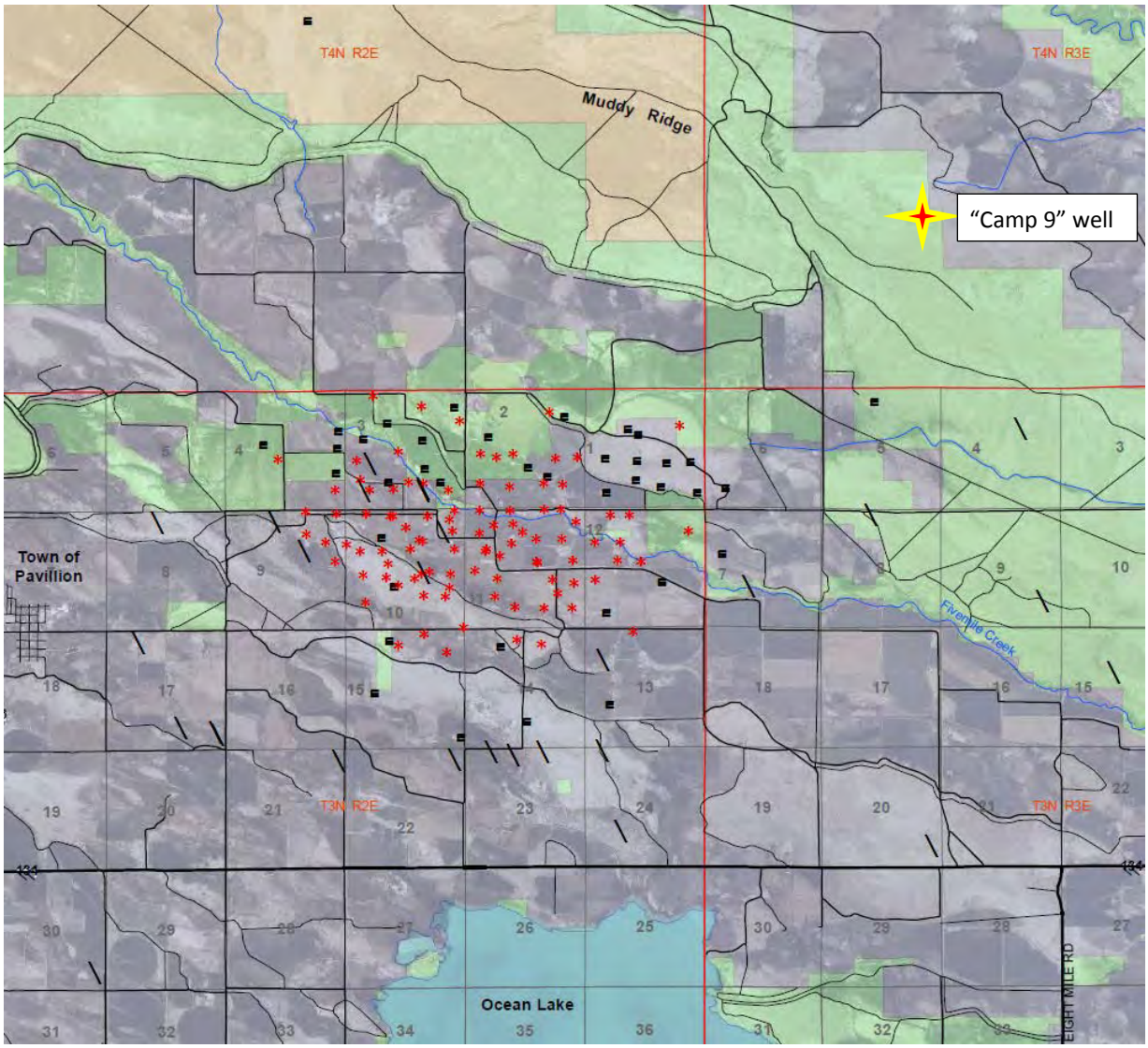
Section II Ground Water Resources

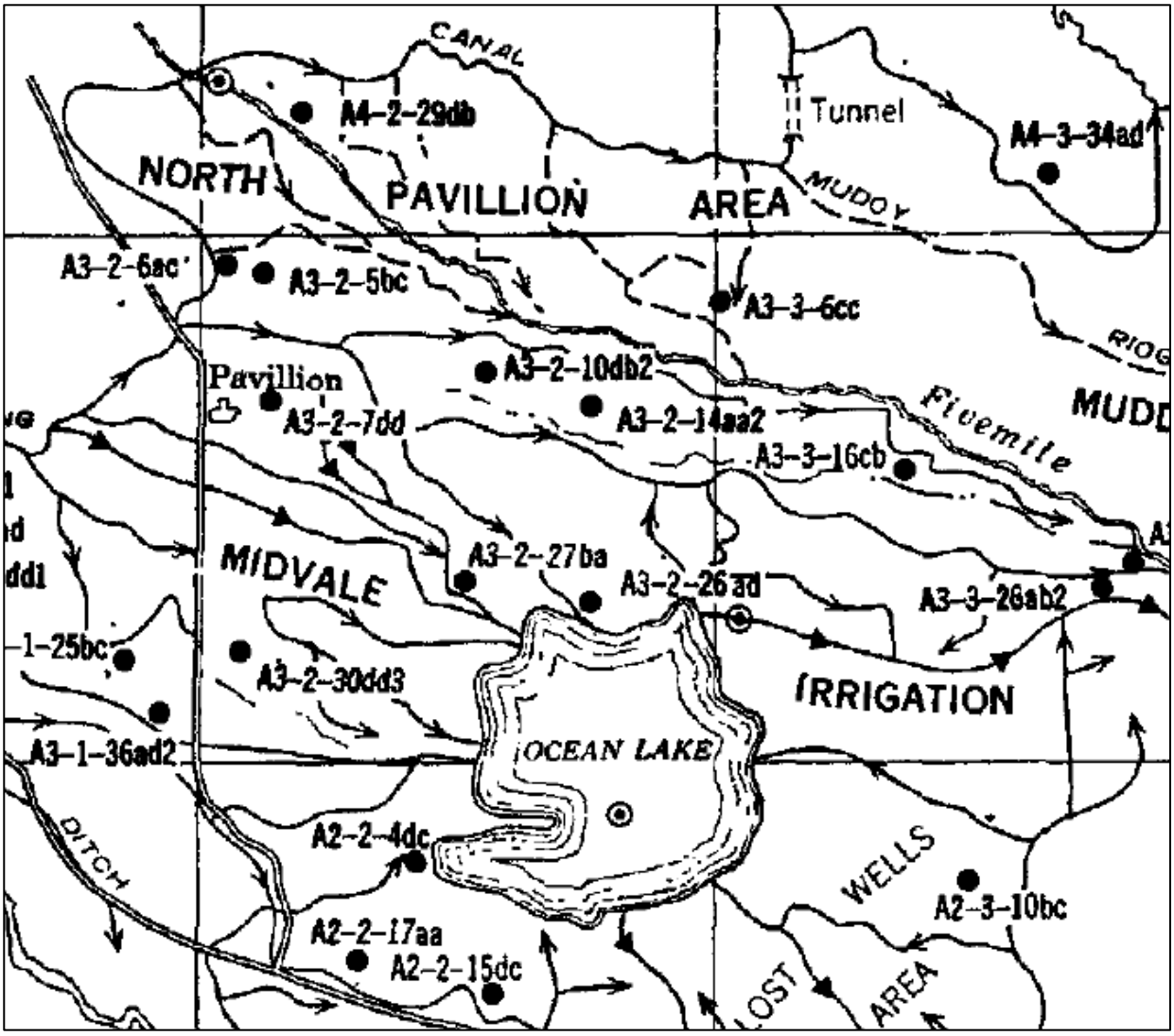
02. Bureau of Reclamation 1951 Annual Project History for Riverton Project – Excerpt

Available for review is only a three-page excerpt from this 1951 USBR report. It documents the "Camp 9" water well drilled in March 1951 that encountered a satisfactory aquifer near the 500 foot depth, but was plugged back due to gas in water. The "Camp 9" well was located in Township 4 North (T4N), Range 3 East (R3E), Section 32. Most of the gas wells in the Pavillion Gas Field are contained in T3N, R2E. This "Camp 9" well is approximately 2 miles northeast of the cluster of active gas wells (see the illustration below modified from WOGCC's Pit Review Report, Map 3). Based on regional geology, this "satisfactory aquifer" near the 500 foot depth is in the Wind River Formation. This gas encountering at a shallow depth predates by several years the drilling of the first producing gas well in the area (by Shell in 1960; review note: the first exploratory gas well in the area was drilled in 1953 and plugged in 1954).



18. USGS 1959 Ground-Water Resources of Riverton Irrigation Project Area, Wyoming

This USGS Water Supply Paper was developed based on field investigation made between June 1948 and November 1951 in the Riverton Irrigation Project Area, which encompasses the Pavilion area. The investigation was aimed to determine the location of available water supplies, the chemical quality of the ground water, the effects of irrigation, and aquifer properties, etc. During the investigation, pumping tests were conducted to determine the hydrologic properties of the Wind River Formation, water wells in the area were examined, water levels in select wells were measured, and samples were collected and analyzed from wells and surface sources at key locations in the area. Some general results and those of particular interest to the Pavillion groundwater investigation are summarized below. The figure below identifies the wells studied in and around the Pavillion area.



*(The above is part of **Figure 23** of the document)*

The depth to water in shallow wells screened in unconfined aquifers ranges from less than 1 foot to about 30 feet below the land surface, depending on the season of the year and on the length of time the

land has been irrigated, as irrigation is considered the principal source of recharge to the shallow aquifers. The water table configuration is similar to but more regular than the general surface topography. In particular, the general shallow groundwater gradient in the Pavillion area is towards southeast (**Plates 2** and **3** of the document). The water level in the wells that tap the deep confined aquifers of the Wind River Formation which receive recharge indirectly from surface sources, fluctuates only slightly because the recharge and discharge are more constant. In most places the depth to water in wells penetrating the deep confined aquifers is much greater than that in shallow wells. But in certain low areas water from the deep aquifers flows at the surface from wells. The only wells under artesian head identified in the document are A2-5-3bb (land surface elevation is 4,879 feet) and A3-6-9bb2 (land surface elevation is 4,686 feet), which are to the east-southeast of the Pavillion area.

In general, wells less than 200 feet deep yield highly mineralized sulfate water, the result of leaching by infiltrating irrigation water. For example, in the North Pavillion area a field permeability test was made by pumping temporary well A3-2-6ac, 41 feet deep. During the test, the total mineralization particularly the hardness (calcium and magnesium) and sulfate increased significantly from the sample collected 36 minutes after pumping began to the sample collected 23 hours and 50 minutes after pumping began (**Table 11** of the document). The data indicate possible induced infiltration of water from an aquifer that contains water having greater concentration of calcium sulfate.

Water from deep aquifers generally is more dilute than that from shallow aquifers. However, groundwater from the deep aquifers, unmixed with irrigation water, generally has a percent sodium greater than 80. An exception is well A3-2-26ad, 321 feet deep and near the north edge of Ocean Lake. This well contains 1,530 ppm of dissolved solids, of which 988 ppm is sulfate, and is more highly mineralized than water from most other wells that are deeper than 300 feet. The water from well A3-3-6cc, 270 feet deep, had a moderately low mineral content (272 ppm) but was reported unsatisfactory for drinking because of the strong hydrogen sulfide odor and the precipitation of sulfur on standing. Although no gas analyses were made, the problem of hydrogen sulfide in water supplies, particularly in deep wells, was observed for new supplies in other tracts. The document recommends a commercial unit of exchange resins as a possible means for the removal of hydrogen sulfide; aeration of the water may also be a satisfactory method if the supply can be protected from freezing.

The United States Public Health Service (1946) recommends the following maximum concentrations of chemical constituents in water to be used for drinking purposes on common carriers:

Constituent	*Maximum concentration (ppm)*	*Constituent*	*Maximum concentration (ppm)*
Iron and manganese together	0.3	Fluoride	[1]1.5
Magnesium	125	Chloride	250
Sulfate	250	Dissolved solids	[2]500

[1] Mandatory upper limit.
[2] Where water of this quality is not available, 1,000 ppm is permitted.

Many supplies in the Riverton Irrigation Project area are of higher mineral content than desirable; sulfate and iron are the principal constituents that exceed the standards. Sulfate and iron exceed the accepted drinking-water standards in more than half of the ground-water samples collected. Nonetheless, water containing minerals in excess of the recommended standards often is used for drinking as well as other purposes. What is interesting per the document is that many consumers in the

Riverton area, having become accustomed to the saline properties of the water, are now finding less mineralized water somewhat less palatable.

Samples obtained from wells in and around the Pavillion Area are provided in **Table 9** of the document. These water quality data and relevant observations (e.g., the sulfide problem described above), predating by almost 10 years the drilling of the first producing gas well in the Pavillion area (by Shell in 1960; review note: the first exploratory gas well was drilled in 1953 and plugged in 1954), may be used as background data for the Pavillion groundwater investigation.

19. USGS 1969 Groundwater Resources of the Wind River Indian Reservation Wyoming

This USGS Water Supply Paper documents the results of study to determine the general hydrologic properties of the rocks and the occurrence and quality of the water in them in the Wind River Indian Reservation. The geologic structure of the reservation consists of the Wind River Basin, which is a large structurally complex basin bounded on the north and southwest by upfolded and faulted mountain ranges. The following summarizes results related to the Wind River Formation that is the main target of the Pavillion groundwater investigation.

Most wells in the study area derive water from the Wind River Formation and the alluvium. The Wind River Formation consists of numerous separate aquifers. Some water-bearing beds of the formation are hydraulically connected, but others, perhaps most, are only remotely connected; some are completely separated. At a single location, aquifers at different depths will have very different water levels. Differences in depth to water of as much as 140 feet were measured in adjacent wells, A3-3-21ada1 and -21ada2, and also in well Al-2-21bbb, which was cased and completed at two different depths.

Most wells in the Wind River Formation tap confined aquifers. Well depths are as much as 900 feet, and depths of more than 400 feet are common. Depths to water generally range from the surface to about 200 feet; but there are many exceptions, and depths to water of more than 500 feet have been measured. A few shallow wells in the Wind River Formation tap unconfined aquifers. The water-table wells are generally less than 70 feet deep, and depths to water are generally less than 30 feet.

Geologically, the Wind River Formation consists primarily of sandstone, conglomerate, siltstone, claystone, and shale. The formation from top down consists of an upper fine-grained sequence (up to 800 feet thick in most of the area), a coarse-grained sequence, and a lower fine-grained sequence (**Figure 13** of the document). Most wells in the Wind River Formation tap sandstone of the upper fine-grained sequence. Yields are as much as 50 gpm, but most wells have lower yields. The most productive aquifers are in the coarse grained sequence. Wells tapping these rocks yield as much as 500 gpm. The range of permeability for water-bearing sandstones of the Wind River Formation is estimated to be about 1-220 gpd per square foot.

The Wind River Formation contains water having dissolved solids that generally range from about 200 to 5,000 ppm. Most of the water in the upper fine-grained sequence contains more than 1,500 ppm of dissolved solids. Water from many wells tapping the coarse-grained sequence has dissolved solids of 200-1,000 ppm; however, some rocks in this sequence have water containing very high concentrations of dissolved solids.

According to the United States Public Health Service (1962), the following chemical substances should not be present in a public water supply in excess of the listed concentrations where other more suitable supplies are or can be made available.

Substance	*Recommended limit (concentration in ppm)*
Chloride (Cl)	250
Fluoride (F)	0.8–1.7
Iron (Fe)	.3
Nitrate (NO_3)	45
Sulfate (SO_4)	250
Total dissolved solids	500

Water quality data from 1948 to 1966 for the Wind River Formation are provided in **Table 6** and on **Plate 1** of the document. These data indicate that total iron and sulfate exceed the recommended drinking water limits more often than not; fluoride concentration exceedances are not uncommon, either. These are “background” proof that wells completed in the aquifers of Wind River Formation have a poor water quality for domestic use.

41. Richter 1981 Occurrence and Characteristics of Ground Water in the Wind River Basin, Wyoming

This report provides baseline information for the implementation of the USEPA’s Underground Injection Control program. Baseline information of hydrogeology, ground water quality, and water use are obtained from existing studies and a field work undertaken during June 1 to June 15, 1981. Information from this document relevant to the Wind River Formation (hydrogeology, flow, and quality) is covered in the various USGS reports in the review list. In particular, the groundwater quality data prior to the 1960 when the Pavillion gas field was first developed can be found in the two USGS reports described above (**File #18** and **File #19**).

29. USGS 1995 Water Resources of Fremont County, Wyoming

This USGS Water-Resources Investigations Report, compiling surface water, ground water, and water quality data, describes and evaluates the water resources of Fremont County, which contains the western majority of the Wind River Basin within its boundary. During this study from 1990 to 1992, additional wells and springs were inventoried with water-quality samples from select sites collected and analyzed for major ions and trace elements.

Groundwater data from selected wells and springs throughout the county are compiled in **Table 16** of the document. The compilation consists of the local number, year drilled, depth of well, primary use of water, altitude of land surface, water level, and discharge. The locations of selected wells and springs are shown on **Plate 2** of the document. Groundwater quality data for common ions, trace elements, radiochemical species, and pesticides are compiled in **Tables 11** through **14** of the document, respectively.

The Wind River Formation of Tertiary age is the most developed geologic unit, as it is the most areally extensive water-bearing unit that occurs at the surface; records of 157 inventoried wells are included in this document. The second most commonly developed geologic unit is the Quaternary alluvium and colluvium (49 inventoried wells). Domestic wells in the Pavillion groundwater investigation area are basically tapping aquifers in the Wind River Formation.

Water in the Wind River Formation occurs under unconfined and confined conditions. Wells completed in the Wind River Formation ranges in depth from 35 to 825 feet except for an extreme of 2,210 feet, and ranges in discharge from 1 to 350 gpm. The general direction of ground-water movement in the Wind River Basin is toward the Wind River according to the study by Whitcomb and Lowry (USGS 1968).

Eighty water samples from 70 sites were collected for chemical analysis from wells completed in and springs issuing from the Wind River Formation – 35 as part of this study and 45 between 1948 and 1990 as part of other studies. The sites are located in the north-central part of the county (**Figure 15** of the document); only two sites are within the Pavillion groundwater investigation area. Dissolved-solids concentrations of water samples from these wells and springs ranged from 248 to 5,110 mg/L. Sulfate concentrations ranged from 0 to 3,300 mg/L. The dissolved solids and sulfate concentrations exceed the recommended drinking water limits, 500 and 250 mg/L respectively, more often than not. The modified Stiff diagram (**Figure 12** of the document) shows that the water was a sodium-calcium sulfate type. One water sample contained a selenium concentration of 58 µg/L, exceeding the EPA MCL of 50 µg/L. Seven water samples were analyzed for radium-226 and uranium. The sample collected in 1991 as part of this study had a radon concentration of 1.2 ± 0.400 pCi/L, and a uranium concentration of 76 ± 11 µg/L. Ten water samples were analyzed for selected pesticides. One sample had a detectable level of two of the selected pesticides: 2,4-D and dicamba.

21. USGS 1996 Water Resources of the Wind River Indian Reservation, Wyoming

This USGS Water-Resources Investigations Report describes the groundwater and surface water resources and the chemical quality of these resources on the reservation. Site characteristics, well yields, water levels, and chemical quality of the ground water for 14 major geologic units are described and evaluated on the basis of hydrologic data obtained from inventoried water-supply wells and springs. An inventory and data summary were compiled for 60 streamflow-gaging stations and 39 miscellaneous surface-water sites on or near the reservation. The compiled data include those from the onsite work conducted for this study from August 1988 through May 1991. The following summarizes results related to the Wind River Formation that is the main target of the Pavillion groundwater investigation.

The Wind River Formation of Tertiary age is exposed in most of the central part of the reservation, and is the major source of drinking water for domestic and public-supply uses in the reservation. Inventory records for 608 wells completed in the Wind River Formation were compiled in this document. Most of these wells are completed in permeable, lenticular, and discontinuous sandstone deposits. The depth of wells ranges from 37 to 994 feet, with a median depth of 190 feet. The discharge of wells ranges from 0.1 to 350 gpm, with a median value of 20 gpm.

Wells completed in the Wind River Formation yield water from both unconfined and confined sandstone layers. Wells less than 90 feet deep usually yield water from unconfined sandstone layers recharged primarily by water from overlying Quaternary deposits and irrigation return flow. Water levels in these

shallow wells, based on data from 93 wells during 1938 to 1991, ranged in depth from land surface to 84 feet below land surface, with a median depth of 15.8 feet. Wells more than 100 feet deep usually yield water from confined sandstone layers, which are usually recharged by surface water or by infiltration of precipitation. Most of the deep wells are completed as open holes or with perforated casing so that water from multiple confined sandstone layers is obtained. Water levels in these deep wells, based on data from 179 wells during 1942-91, ranged from flowing conditions to 533 feet below land surface, with a median depth of 45 feet. Some flowing deep wells were reported but most of them are located near Arapahoe and Riverton.

The chemical quality of water in the Wind River Formation was evaluated on the basis of chemical analyses of 128 to 154 water samples and 205 specific-conductance measurements of water samples collected from selected wells (**Table 12** of the document). Dissolved-solids concentrations ranged from 211 to 5,110 mg/L, with a median value of 490 mg/L. Seventy-three of 154 samples exceeded the EPA SMCL for dissolved-solids concentration and 62 of 154 samples exceeded the EPA SMCL for sulfate. One of 154 samples exceeded the EPA MCL for fluoride (4.0 mg/L). Ten of 154 samples exceeded the SMCL for fluoride (2.0 mg/L). Hardness class was soft for 91 of 154 samples and very hard for 45 of 154 samples. Salinity-hazard class was medium or high for 183 of 205 samples and very high for 21 of 205 samples. Sodium hazard class was variable but the most common class was very high for 57 of 150 samples.

The chemical quality and ionic composition of water samples collected from the Wind River Formation were variable. For most of the water samples, ionic compositions changed with the increase in dissolved-solids concentrations from mixed calcium and sodium with mostly bicarbonate (dissolved-solids less than 325 mg/L), to sodium with mixed bicarbonate and sulfate (dissolved-solids between 325 and 500 mg/L), and to sodium and sulfate (dissolved-solids greater than 325 mg/L).

For samples collected from wells completed in the Wind River Formation, one exceeded EPA MCL for nitrate (10 mg/L) and one exceeded the EPA MCL for selenium (0.01 mg/L). Other trace elements, radio-chemicals, and pesticides were also evaluated for a limited number of samples, and no detections or exceedances over recommended limits were reported.

03. Bureau of Reclamation R. Autobee 1996 Riverton Unit Pick-Sloan Missouri Basin Program

A summary of this document is provided below, although it has little useful information directly related to the Pavillion groundwater investigation.

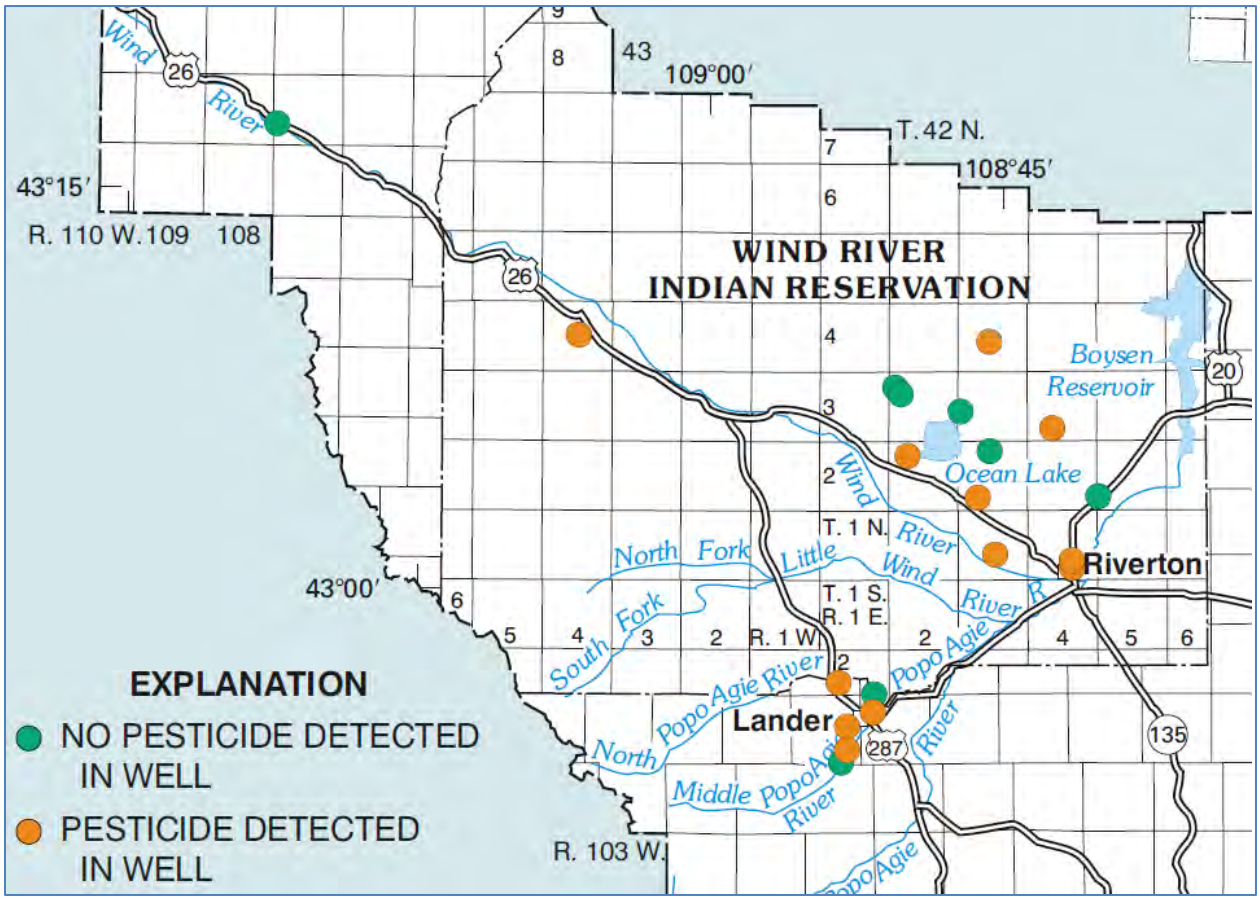
The Federal Government created the Riverton Project to allow access to the Wind River to whites and Indians in the 1920s. Three-quarters of a century later, the demands of both groups threatened the Unit's stability. The debate began in the mid-1970s when a dry cycle forced the Arapahos and Shoshones to exercise their priority over the river. After many years of legal fight, in June 1992, the Wyoming Supreme Court ruled on behalf of the white irrigators, momentarily ending the two tribes plans. As of 1996, threats of further legal action by the Arapaho and Shoshone still fill the Wyoming air. To satisfy all parties, Wyoming has studied building a storage project jointly funded by State, Federal, and tribal governments. Other options include leasing water to non-Indians on a guaranteed annual basis, tapping the groundwater beneath the basin, or another Federal buy out of non-Indian farmers.

Before a drought cycle in the mid-1970s, Wind River's estimated average annual runoff was 897,900 acre-feet. With an average elevation of 4,700 to 5,500 feet, the irrigable lands are mostly sandy. A few inches beneath the top soil, heavy clay underlaid by sandstone and shallow decomposed shale allows no drainage and waterlogs easily. Also working against growers is the high alkali content of the Wind River. The sodium carried by the water prevents the maturation of many crops. Farmers along the Wind River have an average of 140 days to work with between the last killing frosts of May and September's first cold snap. The average annual temperature is 44.5 F. Precipitation in this area totals a little more than nine inches annually. The struggle to water almost 70,000 acres took the better part of a century to reach.

22. USGS 2000 Pesticides in Ground Water - Fremont County, Wyoming, 1998-99

This is a USGS Fact Sheet summarizing the results of a baseline monitoring for pesticides in groundwater in the Fremont County. It is part of the generic State Management Plan for Pesticides in Ground Water for the State of Wyoming (SMP). Eighteen pesticides (focal pesticides) and two degradation products (table 1) were selected, and the monitoring focuses on areas where the ground water is most vulnerable.

The ground water in Fremont County was ranked the fourth most vulnerable to pesticide contamination in Wyoming. Shallow alluvial and terrace deposits were identified as the most vulnerable areas in the county. Twenty sites located in the most vulnerable areas were selected for baseline monitoring in Fremont County (**Figure 3** of the document; see insert below). The wells were inspected and selected with the assistance of the Fremont County Weed and Pest District. All sites were sampled twice, late summer 1998 and spring 1999. These time periods were selected to correspond with the shallowest or deepest water-table conditions.



*(Part of **Figure 3** of the document)*

Six of the 18 focal pesticides and 1 non-focal pesticide were detected in Fremont County (**Table 1** of the document). At least one pesticide was detected in 13 of the 20 wells sampled in Fremont County. All detected concentrations of pesticides were less than the drinking water standards (EPA MCL 1996, WDEQ Drinking Water Equivalent Level 1993, or EPA Lifetime Health Advisory Level 1996). The most commonly detected pesticide in Fremont County was atrazine. The second most commonly detected was prometon.

Judging from **Figure 3** of the document, there are three selected wells within the Pavillion groundwater investigation area, and none of them had detections of pesticides. Since the selected wells were basically completed in shallow alluvial and terrace deposits, they provide no direct information for wells completed in the Wind River Formation.

Section III Pavillion Groundwater Investigations

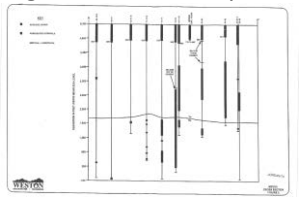
25. WDEQ 2015 Pavillion Case Files

The main package of case files, containing 491 pages, is a compilation of email and letter correspondences, data tables, memos and technical reports, and field and laboratory documents, related to Pavillion groundwater investigations for the period from 2007 to 2013 (not in chronological order). Subjects of the case files include WDEQ, WOGCC, EPA Region 8, Encana, technical consultants or contractors, and domestic water well owners. Key information, findings, and opinions contained in the case files are summarized below. Additional files provided by WDEQ in July 2015 contain information on historical data from as early as 1979 for several water supply wells in the Pavillion area.

Encana letter to WDEQ dated 2/4/2009: Responses to Questions on Meeks Private Well Groundwater Sampling Results and Data Validation Report. The letter includes as attachment an in-depth review of the reported TICs (2,2-Dimethylpropane, tricyclobridged hydrocarbons, etc.) in samples from the Louis Meeks well by Evergreen Analytical Laboratory and a review and explanation of the result by AECOM Environment. The sampling was conducted in October 2008 with a shallow sample and a deep sample collected; the samples were analyzed for VOCs, SVOCs, diesel and gasoline range organics, and bacteria among others. The conclusion of the review is that the TICs, the unidentified peaks seen in GC/MS sample chromatograms, may have come from decaying natural organic matters in the well that contains a moderate to high level of bacteria (iron reducing, slime forming, and sulfate reducing). All related laboratory and data validation reports are provided following this letter.

EPA slides dated 8/11/2009: Pavillion Groundwater Investigation Phase I Sampling Results. The very brief slide package summarizes the sampling objectives (i.e., to determine the presence and characteristics of contamination in domestic wells), reported TICs, dissolved methane detections, summary and interpretation of results, and next steps. The interpretations are 1) no apparent health concerns for most wells sampled; 2) insufficient data on health concern for 11 wells; and 3) potentially a connection between the results and oil and gas production activities, though no specific source can be pinpointed at this time. There are no slides on the details or rationale of these interpretations.

WOGCC memo (by Don Likwartz) dated 9/17/2007: Analysis of Pavillion Well Records. The memo documents an analysis of gas well data (construction information and a cross section map through the Meeks well) pertinent to the Meeks water well blowout. The memo states that “a cursory review suggests that surface casing on oil and gas wells should be set at 800 - 850 feet as a minimum.” But it provides no discussion on how this is determined. The cross section map shows that the surface casing depths of 11 gas wells are all less than 800 feet. Since these wells were drilled following WOGCC regulations, this depth claim of 800 feet as a minimum is confusing.



WOGCC letter (from Don Likwartz) to various state agencies dated 11/5/2007: Review of Pavillion Logs. The letter includes as attachment a review by Gary Strong of the logs (cement bond and porosity) run in the 29 wells drilled in the Louis Meeks water well study area. The key findings of the review are 1) gas producing sands are shallow, thin, lenticular, fluvial, and poorly connected; 2) the Pavillion Field lies on the structural dome with the highest point near the Meeks water well; 3) most of the wells studied had found gas just below surface casing, with many just below 500 feet; 4) no well appears to be completed in such a way to cause gas charging of shallow sands. The review concluded that sands around the Louis Meeks water well are naturally gas charged at very shallow depths, and recommended that no water wells be permitted deeper than 350 feet in the Pavillion Field. Further recommendations include cementing all production casing to above surface casing depth, cement bond logging all wells, and correcting any cement problems. It is worth noting that the new Meeks water well drilled in 2005 that experienced blowout was drilled to a depth of 700 feet, deeper than the 350-foot depth approved by the SEO.

Encana letter to Ms. Randall dated 1/15/2008: Soil and Domestic Water Investigation Data Report. This letter report summarizes the results of subsurface soil and domestic water quality assessment for the Randall property. Subsurface soil investigation was conducted immediately adjacent to the Tribal Pavillion 41-10 natural gas well pad. Results of field monitoring and observation and the levels of concentrations detected were typical of native non-impacted soils. Water samples were collected from the Randall water well (i.e., PGDW30) behind the house, and were analyzed for major ions, gasoline and diesel range organics, metals, and BTEX. Results of the water quality analysis showed no detectable levels of these chemicals except for major ions. Although sulfate (360 mg/L), pH (8.97), and total dissolved solids (637 mg/L) concentrations exceeded the National Secondary Drinking Water Guidelines, these levels were typical of the water quality in the Pavillion area.

Pavillion Chronology/History. It is a documentation of events in the Pavillion Field from 1960 to 2011 focusing on those related to the groundwater investigation. The first event was around 1960 when the first producing gas well was drilled by Shell (review note: the first well was drilled in 1953 and plugged in 1954). The first documented water analysis was in 1979 for the Griffin Ranch wells (likely PGDW14), which showed very high levels of TDS, sulfates, and hardness. The Pavillion Field was first developed by Tom Brown in the 1980s, and was acquired by Encana in 2004 to 2005. Since September 2004, all related events are documented in detail in the chronology.

May 19, 2008 Meeting on Wyoming Oil and Gas Issues. This file contains notes of a stakeholder meeting attended by Pavillion area residents, EPA representatives, and WDEQ staff, among others. It documents the complaints from residents Luis Meeks, Jeff Locker, Bill Garland, and John Fenton. WDEQ staff John Wagner and Carl Anderson made comments on the state's stance and the progress of related investigations. Greg Oberley from EPA stated that the regulations for gas/oil well drilling had not changed in the past 20 years and resources to deal with related groundwater issues had decreased. In the following email correspondence regarding the notes, John Wagner from WDEQ commented that while the notes seemed to accurately record what was said, he did not necessarily agree that everything that was said was factual.

WDEQ memo dated 7/13/2009: Pavillion Gas Well Casing Depths and Water Wells Depths. This memo intends to provide information on the question that the surface casing for the gas wells in the Pavillion Field may not be set deep enough to protect fresh water zones in the Pavillion area. The *Wind River Gas Field Development Project Draft Environmental Impact Statement* (EIS, 2004) was reviewed, but no

specific requirements on surface casing depth were found. The EIS requires that “usable” water zones be protected from any exploration and production activities. Review of approximately 100 water wells (domestic and/or stock) within one mile of Pavillion Field gas wells showed a maximum completion depth of 750 feet, with most of the wells in the range of 150 to 400 feet. Many of the Pavillion gas wells have surface casing set shallower than 650 feet, with the shallowest depth of 387 feet for well Tribal 34-2. The memo infers that if water wells are completed as deep as 750 feet, meaning a "useable" water zone in that depth, surface casing should be required to be placed at least below that depth according to the regulations of the BLM and WOGCC. The memo, however, did not discuss the situation where the “usable” water zones are localized and discontinuous, and what the regulations might be in that case and at the time the gas wells were drilled. Intuitively, these gas wells should have been drilled following, not against, the regulations of their time.

Bureau of Land Management File Review for Pavillion Pit Working Group dated 4/25/2011 and 5/2/2011 with an added column of Pit Group Actions. These spreadsheets provide a brief summary of the cement and pits information from BLM well files reviewed. Based on this information, the Pit Group made their recommendations for the 32 “Public Areas of Concern.” The last or added column identifies the 32 selections with updated information on related investigation and recommendation as of November 2011.

Encana paper dated 12/22/2011: Summary Paper in Response to Environmental Protection Agency Draft Report Relating to Pavillion, Wyoming Ground Water Investigation. The paper provides a preliminary evaluation of the draft EPA report from three aspects: 1) sampling results of the domestic water wells, 2) the relationship between hydraulic fracturing and alleged water contamination, and 3) Encana's cooperation and collaboration with the State of Wyoming. Specifically, there is a lack of “marker” chemicals (e.g., BTEX) from deeper natural gas production in the domestic water samples; the analytical fingerprint of the DRO detections does not match that of diesel fuel; the synthetic components (e.g., glycols and t-butyl alcohol) detected in EPA deep monitoring wells are not associated with natural gas production and likely resulted from sample collection contamination; the high pH in the deep monitoring wells was very likely caused by the soda ash, cement, and grout used to drill and complete the wells; the EPA did not analyze the chemicals used in the drilling of their deep wells; the EPA backfilled the deep monitoring wells with drilling mud and drill cuttings that could have compromised the entire deep well monitoring data and corresponding conclusions; no explanation for the dramatic concentration decrease in multiple compounds between the October 2010 and April2011 sampling events. Therefore, the paper concludes that sampling results from the domestic wells and the deep monitoring wells do not support the EPA's overall conclusions in its draft report.

NewFields Report dated November 2011: Critical Review of ATSDR's Health Consultation: Evaluation of Contaminants in Private Residential Well Water, Pavillion, Wyoming (August 31, 2010). This review report finds a number of problems in ATSDR’s evaluation of the March 2009 and January 2010 EPA groundwater sampling results. ATSDR confuses "petroleum hydrocarbon" that could result from natural organic matters with "petroleum products" from natural gas production. The EPA data do not exhibit a fingerprint (absence or low concentrations of BTEX and PAHs) that is typically associated with oil and gas production-related impacts. The detection of semi-volatile petroleum hydrocarbons above the DRO screening level in well PGDW41 likely resulted from the lack of development (had not been occupied for at least 5 years prior to sampling) and chemicals from the new pump and tubing installed for the sampling purposes. ATSDR places undue emphasis on results from three monitoring wells that are part of ongoing pit remediation projects under the State of Wyoming's Voluntary Remediation Program (VRP),

failing to recognize or consider that water-bearing zones in this area are lenticular and discontinuous. ATSDR uses an outdated and unsubstantiated screening concentration of 200 µg/L for TPH, resulting in an unwarranted overstatement of the health risks of unspecified mixtures. The concentrations of methane detected in seven wells are not suggestive of an explosive hazard, yet ATSDR recommends that Pavillion residents ventilate their bathrooms or even their wells. ATSDR does not acknowledge and factor the naturally poor water quality (high levels of sodium, sulfates, and total TDS) in the study area into their analysis. In addition, only three (two stock wells and one out-of-service domestic well) out of 48 drinking water or stock wells sampled by EPA exceed a regulatory threshold for any constituent other than sulfate. Therefore, the ATSDR's characterization of area groundwater as "highly contaminated" is unsupported and misleading.

Encana Report dated January 2013: Summary of Historic Pit Evaluation and Remediation Activities, Pavillion Field, Wyoming. This report summarizes information on a historic pit review process in Pavillion Field that has been ongoing since 2005. Prior to the 1990s, use of earthen pits to store drilling fluids, production fluids and dispose of drill cuttings was a common practice in the industry and Pavillion Field. Since Tom Brown's acquisition of the Pavillion Field in the late 1980s, a closed-loop process using storage tanks was used for drilling. Since the late 1980s, drill cuttings were only disposed on-site if the well pad is in a dry, non-irrigated location. In 1995, all pits used for production fluids storage, from wells drilled in the 1960's through the early 1980's, were emptied and closed. Beginning in 2005, Encana voluntarily identified and sampled historic production pits to properly manage and document closure in accordance with WOGCC's closure guidelines. A total of 28 historic pit sites were initially identified and investigated by Encana and either met closure guidelines without needing to perform remediation, were remediated by excavating contaminated soils, or were enrolled in the VRP. In 2011, an additional 21 locations were identified by landowners that had not been previously investigated by Encana. Encana conducted additional site investigations and after reviewing the data, the pit sub-group, part of the Pavillion Working Group, reached consensus as to which pits were to be or not to be further evaluated or remediated. The attached table presents the status of the 49 sites as of December 8, 2012. Specifically, four historic pit locations (Tribal Pavillion 24-3, 14-11, and 42X-11, and Blankenship Fee 4-8) with localized groundwater impacts were being addressed under Wyoming's Voluntary Remediation Program (VRP); four additional sites (Tribal Pavillion 14-12, 31X-3, 21-9, and 22-12) were undergoing additional evaluation; no cleanup-related issues were considered necessary for the remaining 41 locations, except for two locations (Pavillion Fee 33-11 and Tribal Pavillion 41-9) where further action and follow-up were necessary. Furthermore, based on multiple years of groundwater monitoring data from the VRP sites, Encana believes that groundwater impacts from the long-closed former pit sites are shallow and very limited in areal extent, none of them impacting domestic water wells.

08. Gorody Anthony 2008 Case Study the Louis Meeks Water Well 9-04 to 11-07

This is a PowerPoint presentation on the study of the source of gas from Meeks water well, from the perspectives of hydrogeology, regional groundwater quality, and analytical results of samples collected from Meeks well between 2004 and 2007.

Geology and hydrogeology indicates that the Meeks well, or wells deeper than 50 feet in the Pavillion area, is tapping bedrock sands that are typically thin and discontinuous. Available water analysis data from various sources, compiled in a piper diagram, show a different geochemistry between water from domestic groundwater wells and produced water from gas wells including the nearest Tribal Pavillion

24-02. Meeks water quality (sodium sulfate dominant) has not changed since the water was first sampled in the baseline program starting 2004.

Gas well lithology data indicate the majority of reservoirs are less than 20 feet thick, and the presence of a major aquitard continuous above Wind River Zone B. Water production from most gas wells is low, not an indication of connection with surface. Stimulated intervals are mostly thin and carbon dioxide (CO_2) volumes are small.

Pavillion gases all have C1-C6 (methane, ethane, propane, butane, pentane, and hexane) components indicating thermogenic origin while C2-C5 components were never detected in Meeks well, except for trace levels of C1. DRO was only detected in the November 2007 sampling event, not previous events.

Observations at Meeks well are consistent with severe biofouling, including declining yield and quality, low dissolved oxygen, and the presence of iron-related bacteria, slime formers (floating filamentous colonies), and sulfate-reducing bacteria.

The presentation also stressed the importance of consistent sampling and analysis protocols.

11. USEPA 2009 Pavillion GW Investigation Analytical Results Report (Phase I)

This report presents data obtained from the USEPA field investigation in the Pavillion area conducted in March 2009 except for one sample collected in May (known as Phase I Investigation). The work is essentially a detection monitoring program with the objectives to determine if contamination is present in domestic wells, contaminant characteristics, and potential impacts to public health and the environment.

The report enumerates the possible sources of groundwater contamination in the study area, but fails to include naturally occurring gas and oil as a potential source. The study appears to target the Pavillion gas operations from the beginning.

Field activities consist of the collection of 37 residential well water and 2 municipal well water samples in Pavillion. Samples were analyzed for all or some of the following parameters: Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Target Analyte List (TAL) total metals, pesticides, polychlorinated biphenyls (PCBs), microbacteriological parameters, anions, and petroleum hydrocarbons including Total Purgable Hydrocarbons (TPH), Gasoline Range Organics (GRO), Total Extractable Hydrocarbons (TEH), and Diesel Range Organics (DRO).

All data from USEPA Control Laboratory Program (CLP) were validated by TechLaw Inc. While the data met all contractual and methodological requirements, the following issues were revealed by the data validation and review. Several SVOC compounds were rejected and flagged with an “R” qualifier. Several VOC, SVOC, and metals results were qualified with a “UJ” flag by validator indicating that the reporting limit is uncertain in those instances. Blank contamination that was less than the Contract Required Detection Limit (CRDL), but above the Method Detection Limit (MDL) resulted in the elimination of several low-level detections for metals. All other changes to data involved the application of J, indicating

the value is estimated, J- indicating the value is estimated and biased low, and J+ indicating that the value is estimated and biased high.

For data quality assurance, all analytical data, including logbooks, Chains of Custody (COC), and long form raw data packages, were reviewed by a URS Operating Services, Inc. (UOS) chemist or by third party data reviewer against the UOS Technical Standard Operating Procedures (TSOPs) or USEPA methods they were generated under. According to the report, the analytical data were found to be acceptable for their intended use. Specifically, all samples were collected within a similar time frame using the same methodology, with the exception of sample PGDW39. PGDW39 should not be used for the evaluation of aquifer chemistry. According to the report, there were no deviations from the Field Sampling Plan, TSOPs, or analytical methods employed to collect the data. All holding time, COC, and preservation requirements for the samples were met. Percent completeness (number of valid samples / total number of measurements planned) was 100% and the data were homogeneous indicating good comparability.

Heterotrophic bacteria, iron related bacteria, and sulfate reducing bacteria were detected in groundwater samples. According to the report, these may be the cause of foul odor and taste in some cases, and may be an indication of groundwater contamination by oil and gas activities or contamination by the water well itself. Also noticed is that sulfate concentrations from most wells exceeded the USEPA Secondary Drinking Water Standard of 250 mg/L.

Many chemical compounds were detected in the groundwater samples, including methane, metals, TPH, pesticides, and some SVOC TICs. In particular, TPH were detected in samples PGDW05 and PGDW30 at 26 ug/L and 25 ug/L, respectively. However, whether the TPH was gas/oil operation-related products or natural organic matters was not evaluated. Sample PGDW05 had a visible sheen on the purge water, which was reported to have a hydrocarbon odor. Two TICs adamantanes and 2-butoxyethanol phosphate were detected in several wells; the former may occur naturally in crude and gas condensate and the latter could form when drilling fluid reacts with naturally occurring phosphates.

In spite of all the detections, there are only several exceedances above the enforceable USEPA MCLs. These exceedances include nitrate of 43.6 mg/L (MCL=10) at well PGDW22, arsenic of 34 ug/L (MCL=10) at well PGDW25, and selenium of 67.3 and 61.8 ug/L (MCL=50) at well PGDW38. The concentrations of bis(2-ethylhexyl)phthalate in samples from wells PGDW20 and PGDW25 exceeded the MCL of 6 ug/L, but were likely non-significant as bis(2-ethylhexyl)phthalate can be found in electronics and piping of groundwater wells.

12. USEPA 2010 Pavillion GW Investigation Analytical Results Report (Phase II)

This report presents data obtained from the USEPA expanded site investigation (ESI; phase II) in the Pavillion area conducted in January 2010. This sampling effort is a follow-up to the Phase I investigation that took place in March 2009, which narrowed the area of concern to an area in and around 11 wells that possessed detections of methane, petroleum hydrocarbons, nitrate, and arsenic, among others. This investigation includes sampling of 19 drinking water wells (17 private and two public), four stock/irrigation wells, three shallow groundwater monitoring wells and soils associated with inactive pits, production fluids from four gas production wells, and surface water and nearby sediment from five

locations on Five Mile Creek. In addition to the laboratory analyses performed in Phase I, geochemistry fingerprinting analyses for isotope, hydrocarbon, and fixed gas were conducted for select samples.

Compared to the Phase I report (**File #11**), this report includes naturally occurring contaminants as a potential source of contamination. However, in the conceptual site model (**Figure 4** of the document), the potential sources fail to include naturally occurring contaminants.

Geochemical data indicate that deep groundwater is dominantly sodium sulfate type and shallow groundwater is more varied, typically with calcium as the dominant cationic component. Total dissolved solid concentrations in groundwater range from about 500 to 5300 mg/L. Sulfate concentrations in many samples exceed the USEPA Secondary Drinking Water Standard of 250 mg/L. pH values in many samples fall out of the desirable range of 6.5 to 8.5.

A number of drinking water and stock wells have low level detections of organic compounds. In particular, 17 of 19 drinking water wells sampled show detections of Total Petroleum Hydrocarbons (TPH). However, whether the TPH was gas/oil operation-related products or natural organic matters was not evaluated. Four private wells show detections of pesticides at very low concentrations. Adamantane compounds were confirmed in four drinking water wells at low concentrations. Only two drinking water wells had constituents exceeding the enforceable USEPA MCLs. They include lead of 38.3 mg/L (MCL=15) and bis(2-ethylhexyl)phthalate of 11 ug/L (MCL=6) at PGDW41, and nitrate of 40.7 mg/L (MCL=10) at PGDW22.

The microbial analyses identified the presence of heterotrophic bacteria, iron related bacteria, and sulfate reducing bacteria in some of the drinking water and stock wells sampled (e.g., PGDW41, PGDW45, and PGDW49). According to the report, these organisms are not harmful to health, but could lead to concerns with odor.

The isotopic analyses indicated that methane in seven of the eight drinking water wells analyzed was of thermogenic origin ($\delta^{13}C$ values heavier than -60 ‰), meaning it originated from the natural gas reservoir (mixture with minor amount of biogenic methane is likely). Methane in one drinking water well (i.e., PGDW04) was of biogenic origin ($\delta^{13}C$ values lighter than -60 ‰), indicating it dominantly resulted from microbial activity in the well. For comparison, methane from the five gas wells analyzed had $\delta^{13}C$ values heavier than -30 ‰.

The report states that EPA has not reached any conclusions about how constituents of concern are occurring in domestic wells. It is unfounded, however, to state that the shallow groundwater is hydrologically connected to the aquifers that are being used for drinking water in the area.

01. ATSDR 2010 Evaluation of Contaminants in Private Residential Well Water, Pavillion, Wyoming, Fremont County

In this report, ATSDR evaluated from public health perspective the groundwater quality data from USEPA's March 2009 (Phase I) and January 2010 (Phase II) investigations at the Pavillion area. In this health consultation, ATSDR examined the exposure pathways of ingestion of drinking well water and

inhalation of contaminants from vapors while showering, and screened the data against values for the most sensitive receptor, a child.

ATSDR considered these potential sources of contamination: 1) natural gas exploration and extraction (petroleum hydrocarbons, brines, and trace metals, and in some cases naturally occurring radioactive material); 2) agricultural practices (salt accumulation, nutrients, trace metals, and pesticides); and 3) septic systems (nitrate and bacteriological contamination). ATSDR did not include naturally occurring organic matters or petroleum hydrocarbons in the list of sources.

ATSDR compared the Phase I and Phase II groundwater quality data to comparison values (CVs) compiled from different regulatory bodies, and background data from Wind River Formation wells sampled between 1987 and 1992 in the Fremont County (USGS 1995; **File #29** described above). The CVs include among others the enforceable Maximum Contaminant Level (MCLs) and the non-enforceable Secondary Maximum Contaminant Levels (SMCLs). For Total Petroleum Hydrocarbon (TPH) in particular, ATSDR used a screening concentration of 200 µg/L based on the Minnesota Total Petroleum Hydrocarbon Value. Results of the comparison indicated that exceedances over the various CVs and background data were widespread for one or more of the groundwater quality parameters. ATSDR concluded that Pavillion area groundwater is "highly contaminated" and groundwater from the residential wells is not suitable for drinking.

ATSDR's evaluation neglected some known facts of the Wind River Formation tapped by the water wells, which are well documented in a number of studies from as early as 1951 by USGS or others. ATSDR did not acknowledge and factor into their analysis the naturally poor water quality, i.e., TDS and sulfate often in excess of SMCLs, and high concentrations of sodium and other ions (e.g., iron and chloride). ATSDR placed excessive emphasis on results from three shallow pit monitoring wells, assuming the surficial water-bearing units are connected to Wind River Formation aquifers, which are lenticular and discontinuous in general. The TPH detected in drinking water wells could be naturally occurring petroleum hydrocarbons and/or other natural organic matters, as the data lacked the characteristics that are typically associated with oil and gas production-related impacts.

In spite of all the detections of organic and inorganic compounds, only several compounds (nitrate, arsenic, lead, and selenium) from three out of 48 drinking water or stock wells were considered exceeding the enforceable regulatory standards (MCLs). This indicates Pavillion groundwater from the drinking water or stock wells in general meets USEPA's public water supply standards.

As such, it may be reasonable for ATSDR, based on the conservatively selected CVs, to claim that groundwater from the residential wells is not suitable for drinking. Characterization of the Pavillion area groundwater as "highly contaminated," however, is unsupported and misleading.

13. USEPA 2011 Pavillion GW Quality Investigation Methods, Graphics, and Data Tables (Phases III and IV)

This report provides a summary of the four phases of the USEPA groundwater investigation in the Pavillion area. It describes the number and type of samples in each phase, installation of the two deep monitoring wells MW01 and MW02, sampling and analysis methods for water and gas, lithology

mapping using geophysical logs, and interpretation of cement bond variable density logs. Graphs, analysis figures, and supporting data tables are provided at the end of the report. Detailed description and interpretations of the four phases of data are provided in the December 2011 USEPA Draft Report (**File #14**).

To differentiate potential deep versus shallow sources of groundwater contamination, USEPA installed two deep monitoring wells MW01 and MW02 in June 2010. Both wells were drilled to a depth of 1,000 feet. MW01 was screened from 765 to 785 feet below ground surface (bgs) and MW02 was screened from 960 to 980 feet bgs. According to the report, testing for drilling fluids was conducted (no mention of the time of testing) and the monitoring wells were purged at least ten screen volumes prior to sampling.

In September 2010 (Phase III), USEPA collected gas samples from well casings of MW01 and MW02. In October 2010, EPA collected groundwater samples from MW01 and MW02 in addition to a previously unsampled domestic well and two previously sampled domestic wells.

In April 2011 (Phase IV), USEPA resampled the deep monitoring wells to compare previous findings and expand the analyte list to include glycols, alcohols, and low molecular weight acids. Eight previously sampled domestic wells and three previously sampled stock/irrigation wells were also sampled at this time.

The report states that lithology in the area of investigation is highly variable and difficult to correlate from borehole to borehole, even for boreholes in close proximity to one another, and this is consistent with other observations in the Wind River Formation. In addition, sandstone and shale layers appeared thin and of limited lateral extent, again consistent with previous observations of lithology in the Wind River Formation. The mapped lithologic cross section (**Figure 3b** of the document), however, appears to have more lenticular, disconnected shale lenses embedded in a more connected sandstone formation, rather than the reverse.

The report also mentions that cement bond variable density logs (CBL/VDL), available for less than half of production wells, were obtained online from the WOGCC to evaluate well integrity.

One thing that was noted during the review is that **SI Table 4c** of the document does not report some of the isotopic data from Phase II investigation, and the values for those reported were inconsistent (see **Table 14** of **File #12**).

07. Gores and Associates 2011 Pavillion Area Water Supply Level I Study Final Report

In response to the August 2010 USEPA advisement that residents of the rural Pavillion area not to drink water from their private domestic wells, the State of Wyoming commissioned a study to provide the residents alternatives for a water supply that they might find more palatable. This report documents the study that involves the evaluation of water demands, water resources inventory, and present water system and supply resources, identification of alternative solutions, cost estimates, and selection of preferred alternatives.

The top three alternatives selected, considering a number of factors, are individual private cisterns, individual private well treatment systems, and water piped from the Town of Pavillion. In terms of the quality of groundwater from the Wind River Formation, the report has the following findings.

This report cites the 1969 USGS study (**File #19**) on the hydrogeology of Wind River Formation and the 1996 USGS study (**File #21**) on the variable water quality in the investigation area. This report clarifies that USEPA only has standards for public drinking water or water supplies – EPA does not regulate private drinking water or water supplies.

After reviewing groundwater quality data including USEPA's Phase I and Phase II sampling results, the report finds that the water produced by the rural private wells meets public drinking water standards (primary standards or USEPA MCLs) with the exception of only three wells. The report further finds that nearly all area wells exceed USEPA secondary drinking water standards for sulfate, a compound very common in Wind River Formation groundwater. Chemicals in USEPA's secondary standards, for aesthetic concerns, are not regulated by the agency. While it is not regulated, nearly all Wind River Formation wells exceed sodium guidelines for persons on a low sodium diet.

In conclusion, the report finds that the Wind River Formation in the rural Pavillion area generally produces water meeting public water supply standards. While the water in many cases is palatably objectionable because of its taste and odor characteristics, it still meets USEPA's public water supply standards.

14. USEPA 2011 DRAFT Investigation of Groundwater Contamination near Pavillion, Wyoming

This USEPA Draft Report provides a detailed description and interpretation of data from four phases of groundwater investigation from 2009 to 2011 in the Pavillion area. The investigation was initiated in response to complaints by domestic well owners regarding objectionable taste and odor problems in well water extracted from the Wind River Formation, but the objective of the USEPA's investigation was to determine the presence of groundwater contamination in the formation and if possible to differentiate shallow source terms (surface pits used in gas exploration, septic systems, agricultural and domestic practices) from deeper source terms (gas production wells).

Through an extensive evaluation of groundwater geochemistry, organic compounds and breakdown products, dissolved gas composition, isotopic data, and gas well construction information, the report finds that pits represent potential shallow source terms for localized ground water plumes of unknown extent, and gas production wells represent potential deep source terms of groundwater contamination in the area of investigation. Accordingly, the shallow stock and domestic wells (e.g., < 100 feet) and their deeper counterparts represent potential receptor pathways associated with the shallow and deep source terms, respectively. In the evaluation, data from the two deep monitoring wells (MW01 and MW02) installed during the investigation were heavily relied upon for the key findings and conclusions reached.

The report concludes that constituents associated with hydraulic fracturing (fracking) have been released into the Wind River Formation drinking water aquifer at depths above the current production zone. The report provides the following lines of reasoning to support its claim.

1. High pH values (11 to 12) in the two deep monitoring wells. The report states that prolonged purging did not show decreasing pH trends and attributes this to potassium hydroxide used in fracking fluids.
2. Elevated potassium and chloride in the two deep monitoring wells (more than 10 times the mean concentrations in domestic wells). Alternative explanations for inorganic geochemical anomalies observed in deep monitoring wells were provided but considered unlikely. The report attributes this to potassium chloride, potassium metaborate, potassium hydroxide, and ammonium chloride used in fracking fluids.
3. Detection of synthetic organic compounds including isopropanol, diethylene glycol, triethylene glycol, and tert-butyl alcohol, most of which were used in fracking fluids.
4. Detection of petroleum hydrocarbons including BTEX, trimethylbenzenes, gasoline range organics (GRO), diesel range organics (DRO), and naphthalene, which were used in fracking fluids. An alternate explanation for detection of petroleum compounds includes use of lubricants on the drillstem and well casing. Another alternate explanation is that detection of petroleum hydrocarbons in ground water is expected above a natural gas field. However, the report believes that gas from Fort Union and Wind River Formations is dry and unlikely to yield liquid condensates at ground water pressure and temperature conditions.
5. Breakdown products of organic compounds such as acetate and benzoic acid from organic contaminants like BTEX and glycols. These breakdown products were more enriched in the shallower of the two monitoring wells, and the report suggests that this resulted from upward/lateral migration with natural degradation and accumulation of daughter products. The report, however, admits that vertical hydraulic gradients were undefined in the area of investigation.
6. Sporadic bonding outside production casing directly above intervals of fracking, creating the potential for fracking fluids to escape upward along the borehole.
7. Fracking into thin discontinuous sandstone units. The report suggests that since there are no laterally continuous shale units serving as lithologic barrier, fracking fluids in the event of excursion from fractures cannot be stopped from migrating upward vertically.

Although some natural migration of gas would be expected above the Pavillion gas field, the report claims that enhanced migration of gas has occurred to ground water at depths used for domestic water supply and to domestic wells. The report provides the following lines of reasoning to support its claim.

1. Hydrocarbon and isotopic compositions of gas similar to those of produced gas. Gas from the deep monitoring wells has undergone little oxidation or biodegradation indicating advective transport. Further, gas present in domestic wells is of thermogenic origin and has undergone a higher level of biodegradation.
2. Levels of dissolved methane in domestic wells generally increase in those wells in proximity to gas production wells.
3. Methane concentrations in groundwater appear highest in the area encompassing MW01, PGDW30, and PGDW05. An alternative explanation is that it is close to the top of the dome comprising the Pavillion gas field which may facilitate natural gas migration toward the surface. However, this geologic feature would also facilitate enhanced gas migration. Also, a mud-gas log at Tribal Pavillion 14-2 located approximately 1000 feet away does not indicate a gas show.

4. Shallow surface casing depths and the lack of cement or sporadic bonding outside production casing. This could be a major potential gas migration pathway to the depth of deep monitoring and domestic wells.
5. Citizens' complaints of taste and odor problems concurrent or after hydraulic fracturing are internally consistent. An alternate explanation is that other residents in the Pavillion area have always had gas in their wells. Unfortunately, no baseline data exists to verify past levels of gas flux to the surface or domestic wells. The report recommends collecting baseline data prior to hydraulic fracturing (in the future) to reduce investigative costs and to verify or refute impacts to groundwater.

Some discussions of the potential issues of the Draft report are summarized below.

Except for a summary of analytical results and referring to previous data reports, this report does not have a complete and accurate documentation of the data collected from the four phases of investigation, nor does the report provide a source where these data can be found. This makes in-depth review of the report very difficult. For example, the analytical results of organic chemicals from Phases III and IV investigations are not provided and could not be found in any of the USEPA publications referenced. Table A3 of the document does not have a complete coverage of the isotopic data, and some of the isotopic data are inconsistent with data previously reported (e.g., Phase II report).

The schematic illustrations of the two deep monitoring wells do not provide information on lithology and construction details along the borehole. This and the lack of other well installation information make it impossible to evaluate if water produced from the deep monitoring wells is representative of the formation they are screened in. Furthermore, it is premature to suggest an upward gradient in the water-bearing zones screened by the two wells, as they are so far apart and likely screened in different sandstone lenses. Though not rigorous, potentiometric levels between the two wells should be compared at the minimum to provide a better indication.

The low recharge rate in deep monitoring well MW02, resulting in a prolonged period of well development, likely indicates well installation problems. The report attributes it in part to gas flow (reduced relative permeability to water) into the well during development. However, the low recharge rate more likely indicates a poorly selected sandstone interval or problems in well completion; it is perhaps better not to use the well.

Although there is no laterally continuous shale unit on a regional scale serving as lithologic barrier, the Wind River Formation is known for having lenticular, discontinuous sandstone layers within a dominant shale backdrop that is more continuous than the sandstone. This over a large vertical distance will makes it very difficult for fracking fluids to migrate upward vertically.

Similarity in the gas compositions does not necessarily indicate enhanced migration, because the deep monitoring wells very likely intercept a gas-containing zone and the area is known for gas of thermogenic origin in shallow depths. Biodegradation is expected to be more significant in the aged and likely less well-maintained domestic wells than the newly installed deep monitoring wells.

There has been documentation of palatability issues of water from the Wind River Formation decades ago. This includes high sulfate-related taste and hydrogen sulfide odor reported in the USGS studies described earlier.

The majority of findings and inferences described in this report are based on the data from the two deep monitoring wells; therefore, the representativeness of data from the two deep monitoring wells have a dominant impact on the credibility of the interpretations and conclusions of the report. Critical reviews by third parties of the USEPA Draft Report, with many focusing on the two deep monitoring wells and additional data obtained from the USEPA, are described in details in the next section of this document review.

23. USGS 2012 Sampling and Analysis Plan for the Characterization of Groundwater Quality in Two Monitoring Wells near Pavillion, WY

This report presents the USGS sampling and analysis plan (SAP), designed in cooperation with the WDEQ, for characterizing groundwater quality in the two deep monitoring wells installed by EPA in June 2010 in the Pavillion groundwater investigation area. The purpose of this study is to provide an independent perspective on the quality of groundwater from the two EPA wells, in response to the December 2011 EPA draft report on Pavillion groundwater contamination investigation, which indicates that groundwater may contain compounds associated with gas production practices.

The approach of this study is to collect representative groundwater and quality-control samples from the two EPA monitoring wells, analyze the samples to replicate the EPA's analysis to the extent possible, review the analytical results, distribute approved results, and publish a study report.

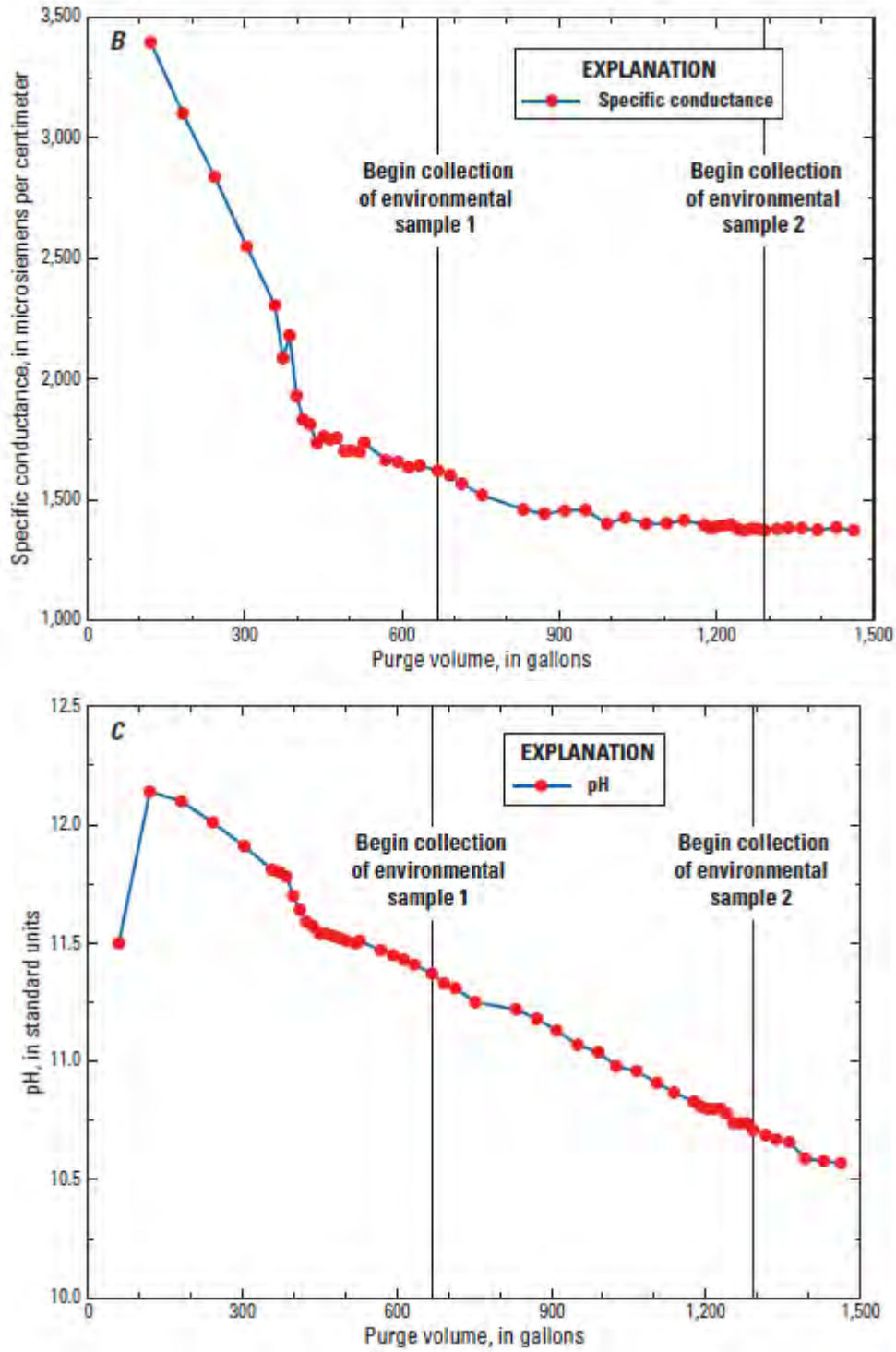
Relying on the standard operating policies and procedures of the USGS, this SAP defines the standard operating procedures that will ensure samples collected in the field and analyzed by the laboratory meet the data needs. The document provides a detailed description of documentation, sampling equipment that will be used, well purging strategy, purge water disposal, sample collection, sample processing, field and laboratory sample analysis, equipment decontamination, and quality-assurance and quality-control (QA/QC) procedures. It also contains information related to data management, review, and publication, as well as health and safety concerns and procedures. This document provides a thorough plan and is expected to result in the collection of representative groundwater samples and analytical results that can stand up to scrutiny.

24. USGS 2012 Groundwater-Quality and Quality-Control Data for Two Monitoring Wells near Pavillion, Wyoming, April and May 2012

This USGS Data Series report summarizes the data collected from the two EPA deep monitoring wells (MW01 and MW02) during April and May 2012 to provide an independent perspective on the quality of groundwater from the two wells. Sample collection generally followed the sampling design (**File #23** above) with a few modifications based on field conditions.

Two groundwater quality samples and quality control (QC) samples were collected from well MW01. Collection of environmental sample 1 and the associated QC samples was intended to begin after one borehole volume of water was purged from the well. Because it took longer for field water quality properties of specific conductivity (SC) and pH to reach stability (**Figure 2** of the document; see insert

below), the collection actually began after about 1.5 borehole volumes had been purged from the well. Collection of environmental sample 2 began after three borehole volumes of water were purged. It is obvious from the data that the pH did not reach stability even after three borehole volumes of water were purged – the pH kept going lower at a fairly constant rate and reached 10.5 at the end of sampling. This is against the field data collected by the EPA during previous investigations of well MW01, which indicated the pH of the groundwater (from the formation) would be greater than 11, casting doubt on the representativeness of the previous EPA groundwater samples from well MW01.



*(Part of **Figure 2** of the document)*

Well MW02 was redeveloped before groundwater sampling was attempted at the well. Because of low yield (about 1 gallon per hour per EPA), resulting in long and thus unacceptable recovery or purge times relative to the standard procedures and recommendations of the USGS, well MW02 was redeveloped by

the USGS in an attempt to increase well yield. Well yield was not increased as a result of the redevelopment effort; consequently, groundwater quality samples were not collected from well MW02. Only two QC samples were collected during well redevelopment. This low yield issue makes it impossible to replicate EPA's previous investigations at well MW02, and raises questions on the validity and interpretation of data from this well.

Analytical results for groundwater quality samples and QC samples are tabulated and discussed in this report. There are similarities as well as differences in the results between this USGS study and EPA previous investigations. The key differences are discussed in third-party reviews in some of the following document reviews.

15. USEPA 2012 EPA Briefing to the American Petroleum Institute

This presentation debriefs Phase V of the groundwater investigation performed by USEPA in coordination with USGS in April 2012. Both USEPA and USGS collected water quality samples from deep monitoring well MW01. USEPA collected replicate samples from MW02 for analysis at two labs; USEPA purged approximately 2,014 liters (1 borehole volume) of water over a period of 6 days prior to the sampling. The USGS, however, did not collect samples from MW02 due to the low yield and thus unacceptable purge times relative to the standard procedures and recommendations of the USGS (**File #24**). USEPA also resampled 5 nearby domestic wells and 1 town of Pavillion municipal well.

The presentation mentions the similarity of results for MW01 between EPA and USGS, and for MW02 between EPA and Test America Lab, in particular the detection of hydrocarbons, GRO/DRO, glycols, benzoic acids, and BTEX. Since no data were provided within this presentation file, no review was conducted on the claimed data similarity.

The message conveyed through this presentation is that EPA's Phase V data supplement the information collected from the previous 4 phases since 2009.

Section IV Review of Pavilion Groundwater Investigations

36. Tom Meyer 2012 Review of DRAFT Investigation of Ground Water Contamination near Pavillion by USEPA

This expert review on the USEPA Draft Report concurs with USEPA that hydraulic fracturing has caused pollution of the Wind River Formation aquifers, and recommends further analyses and investigations to improve and continue the study.

The review believes that geology (no extensive vertical shale barrier, a vertical gradient although inconclusive), poor gas well design (surface casing not extending below the level of water wells, production casing cement not reaching the base of surface casing), and construction issues (sporadic bonding in cement) make the Pavillion-area aquifers especially vulnerable to vertical contaminant transport from the gas production zone or the gas wells.

The difference in inorganic and organic concentration patterns between samples from the USEPA deep monitoring wells and drilling additives makes it unlikely that groundwater chemistry was at all impacted by drilling additives. The substantial difference of geochemistry in USEPA deep monitoring wells (in particular, the elevated levels of potassium, chloride, and pH) from “natural” conditions demonstrates the interaction of fracking fluid with groundwater. Further, all three contaminant transport pathways suggested by the USEPA (compromised gas wells, fluid excursion into more permeable sandstone units, creation of new fractures or enlargement of existing fractures) could be responsible for the contamination moving from the fracking zone to the drinking water wells. Though the situation at Pavillion is not an analogue for other gas plays, the pathways identified at Pavillion could be applicable elsewhere.

The reviewer made these comments largely relying on the information provided in the USEPA Draft Report, and does not appear to have conducted an in-depth assessment of the representativeness and accuracy of the information.

In addition, the reviewer noticed inadequacies in the USEPA investigation and made the following recommendations to USEPA:

- Continue data collection to better verify the sources and map the potential contaminant plumes
- Map the gas production wells according to their construction date and estimate travel times
- Map the depth to water and vertical gradient
- Install deeper monitoring wells near the shallow pits to better map the depth of the plume emanating from those pits
- Data collection should continue so the results can be replicated
- Perform some simple testing to map the extent of fractures

32. Encana 2012 Initial Comments on USEPA Draft Report on Groundwater Contamination near Pavillion

This comment letter encloses two expert reports from Dr. Robert J. Sterrett (**File #33**) and Mr. Michael J. Mullen (**File #34**) in order to address (i) the USEPA Draft Report's mischaracterization of the hydrogeology of the Pavillion Field and (ii) serious concerns about the reliability of deep monitoring wells MW01 and MW02, which were contaminated by EPA's own drilling and completion practices.

The key comments of Sterrett's report include:

- Higher permeability sandstones are discontinuous and relatively small and accounts for approximately 20% of the Wind River Formation.
- The hydraulic gradient in this area is well-documented to be downward.
- The Draft Report does not recognize the hydrogeologic distinction between the shallower Lost Cabin member (or portion) of the Wind River Formation (where domestic water wells are drilled and where MW01 was completed) and the deeper Lysite formation (which contains a rich, natural gas producing horizon and where MW02 was completed).
- Groundwater quality in Pavillion Field is variable, but typically exceeds secondary, palatability-based standards for total dissolved solids and sulfate. These are natural conditions unrelated to oil and gas development.

The key comments of Mullen's report include:

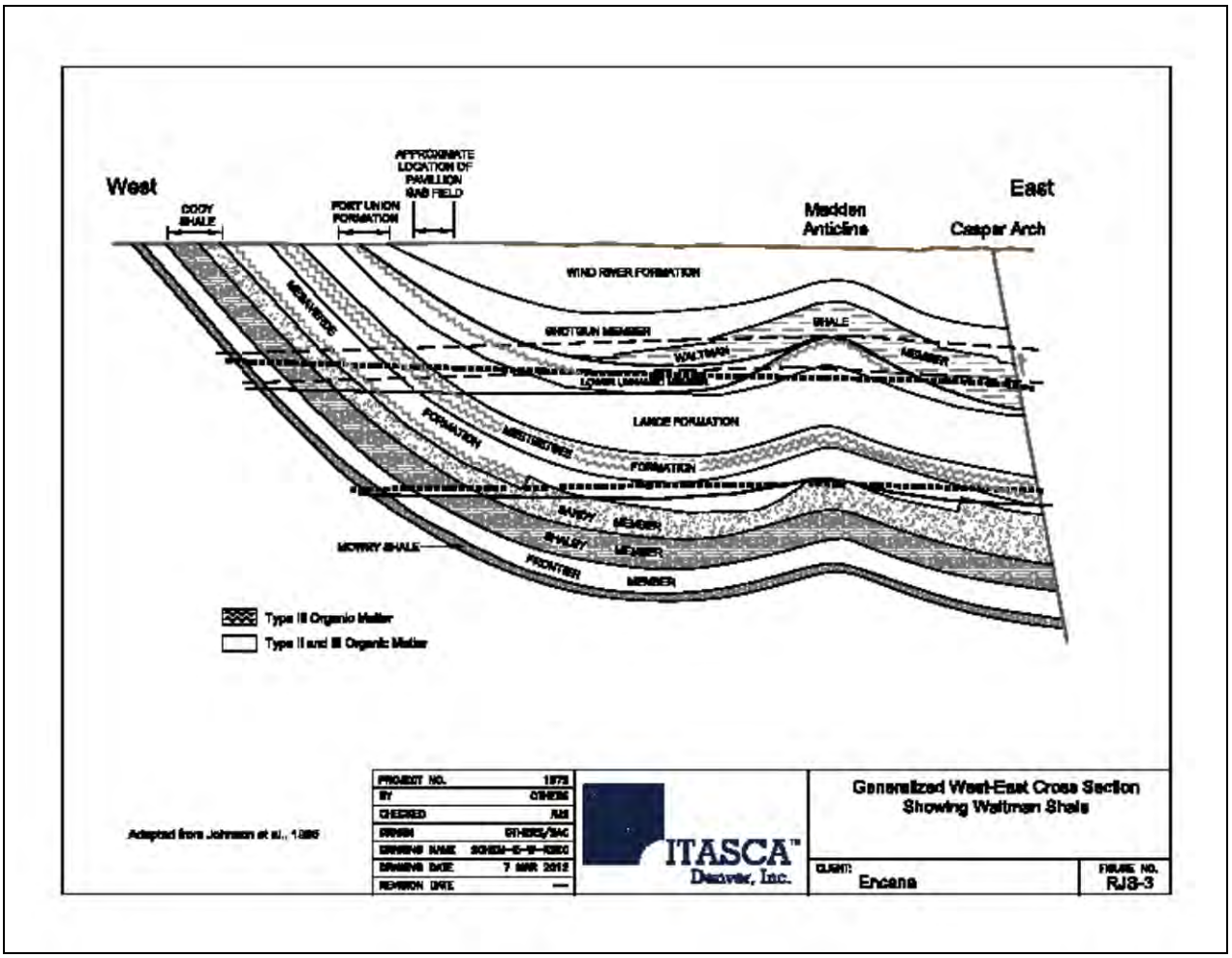
- USEPA, through poor well completion practices, pumped cement slurry (used in well completion) directly into the geologic formation from which water samples were taken at both MW01 and MW02.
- Neither well was properly designed to isolate the screened interval from cement slurry related impacts to the water bearing zone being tested above and, in the case of MW02, below the screen.
- Driller records indicate that, at MW02, EPA pumped cement slurry below, through and around the well screens through which water from the geologic formation is sampled and analyzed by USEPA laboratories.

Comments from the two expert reports are further described below.

33. Sterrett RJ 2012 Review of the USEPA Draft Report on Groundwater Contamination near Pavillion

This expert review on the USEPA Draft Report cited literature of the Wind River Basin and the Pavillion Gas Field, and analyzed data from oil and gas development in the "core area" (Township 3 North, Range 2 East, sections 1 through 4 and 9 through 12; total eight sections each a square mile in area). The key comments on the USEPA Draft Report are summarized above (**File #32**). Further details of the review are provided below.

The Waltman Shale, the wide-spread, thick shale "caprock" separating production zone of the Fort Union Formation from the overlying Wind River Formation, is not present in the Pavillion Field area (**Figure RJS-3** of the document; see insert below). Its absence does not prevent the upward migration of gas through diffusion into shallow depths (less than 800 feet) in the Pavillion Field.



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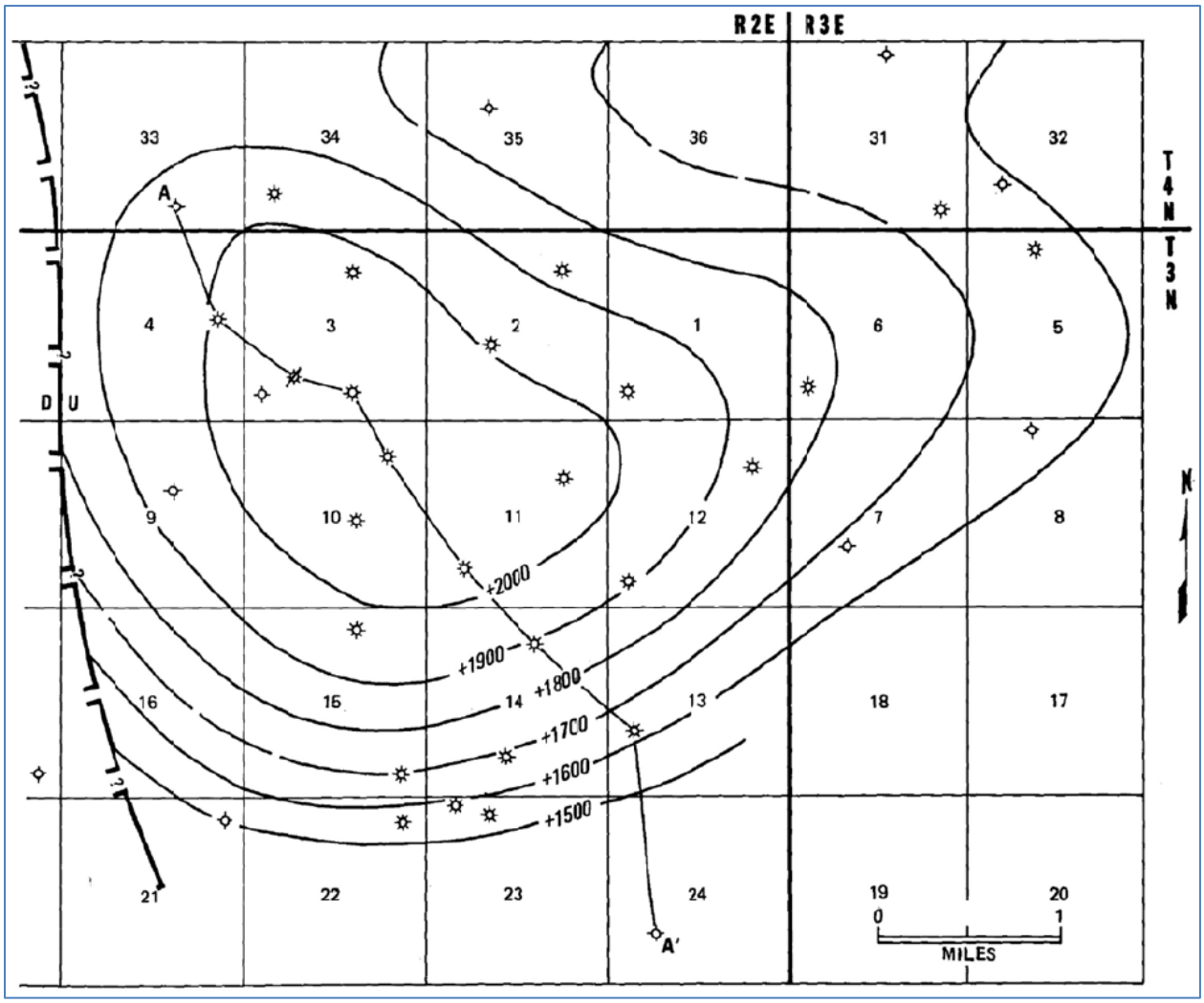
The Pavillion Field gas is produced in multiple sandstone reservoirs within the Wind River Formation and the Upper Fort Union Formation at depths ranging from 1,500 to 5,000 feet below ground surface (bgs) (Bjorklund 1978[1]). Gas accumulation in these reservoirs is localized by stratigraphic variation on the crest and flanks of a broad structural dome (**Figure RJS-5** of the document; see insert below), and the "core area" happens to be on the crest.

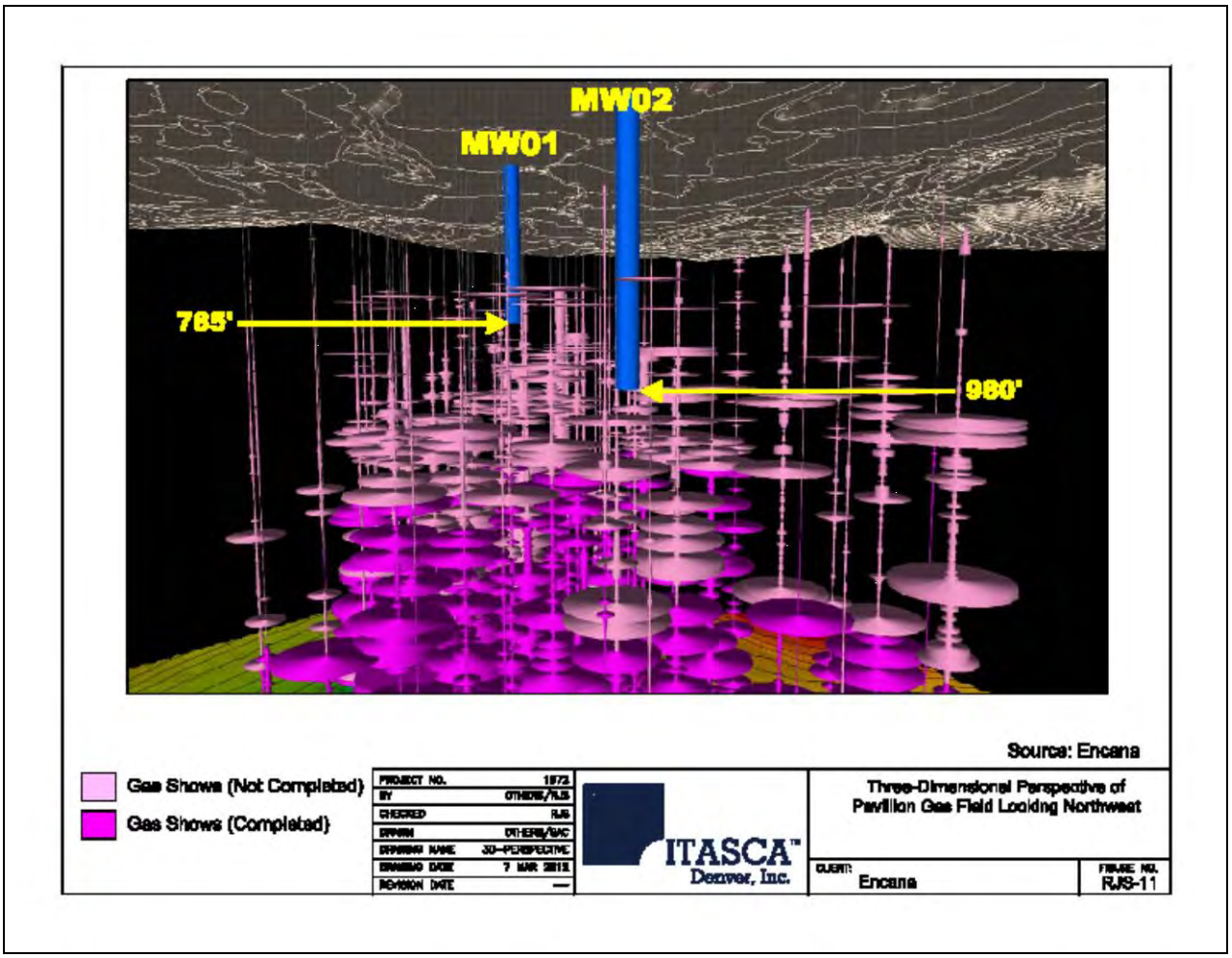
[1] Bjorklund, T.K. 1978. Pavillion Gas Field. In Thirtieth Annual Field Conference, 1978, Wyoming Geological Association Guidebook, p. 255 – 259.



*(Part of **Figure RJS-5** of the document; contours in feet above mean sea level)*

Although the precise geometries of sandstone reservoir bodies are not known, the concept of broad continuous sandstone layers is not correct as the lateral extent of a reservoir is in general ten times its thickness. Production gas well logs within the Pavillion Field (recorded on 20-acre spacings) rarely have sands that can be correlated between several boreholes. An exception is the basal sandstone more than 3,000 feet bgs in the Pavillion Field, which can mapped as a discrete unit over a significant distance (**Figure RJS-6** of the document).

Gas (e.g., methane) in shallow formations, such as the Wind River Formation, originated from deep, older strata and migration has occurred for millions of years (Johnson and Rice 1993, **File #09**). Mud log data acquired in gas wells drilled five years before the USEPA deep monitoring wells (MW01 and MW02) contained gas where the MW01 and MW02 were screened (**Figures RJS-9** to **RJS-11** of the document; see insert below for **Figure RJS-11**).



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Occurrence of gas at shallow depths was documented before the drilling of the first producing gas wells in the Pavillion area in 1960 (review note: the first well was drilled in 1953 and plugged in 1954). US Bureau of Reclamation (USBR), while drilling water supply wells for its workforce, found a satisfactory water-bearing unit at a depth of approximately 500 feet bgs, but the water was not potable due to gas (USBR 1951, **File #02**).

Groundwater quality is variable (USGS 1996, **File #21**) and generally exceeds secondary drinking-water standard for sulfate and total dissolved solids according to the study of Gores & Associates (2011, **File #07**), which concluded that this area has never produced high-quality groundwater.

USEPA has suggested that there is an upward hydraulic gradient in the Pavillion Field area based on one flowing artesian stock well (PGDW44) in the core area. A review of a 1969 USGS study (**File #19**) shows that this is the only flowing well among approximately 44 water wells in the core area. Review of water levels in wells that are in close geographic proximity to the areas of MW01 and MW02 but at different depths, the overall observation is that there is a downward gradient (**Figure RJS-15** of the document). In addition, analysis of shut-in pressures and reservoir pressure change over time (**Figures RJS-16** and **RJS-17** of the document) contradicts the USEPA's assertion that the Pavillion Field is over pressured and that there is an upward gradient.

The review disagrees with the USEPA on the statement that contamination from historical production pits is widespread and threatens the quality of water in domestic wells. Based on information from area pit evaluation and groundwater data from Wyoming's Voluntary Remediation Program (VRP), the pit-related impacts to groundwater quality are generally known, they are localized and limited in area, and domestic wells are not impacted.

Furthermore, the USEPA Draft Report does not provide complete documentation on how MW01 and MW02 were installed, completed, or developed. Review of additional information provided by the USEPA (e.g., daily activity report) resulted in opinions consistent with those from WOGCC that the USEPA did not properly install, complete, and develop MW01 and MW02. As a result, the analyses of water samples collected from both monitoring wells did not accurately represent ambient conditions of the water-bearing zones and could not support decision making.

34. Mullen M 2012 Review and Evaluation of EPA's Drilling and Cement Jobs for MW01 and MW02

This expert report reviews the daily driller's reports during the drilling and cemeting of USEPA deep monitoring wells MW01 and MW02 to identify potential problems during the operations. It concludes that the groundwater and adjacent sandstone lenses were contaminated by the drilling mud and grouting practices in several instances, and rehabilitating these two wells for water quality monitoring purposes would be very difficult. The key comments are summarized earlier in **File #32**. Further details of the review are provided below.

The sources of high pH in MW01 and MW02 would be soda ash that was used in both wells as a mud additive during the drilling for the purpose of raising the pH. The cement slurry would also be a source of high pH in both wells due to the problematic cementing operations.

For MW01, according to volume calculation, the pumped cement volume should be enough to fill the annular space back to surface. However, the actual top of cement was located at 98 feet bgs, indicating that at least 598 gallons of cement was lost into the formation. The pressure gradient of the cement column would be enough to overcome the closure pressure of most of the sands in this wellbore causing cement to break into the sand. The most likely location is the sand around the 20 feet screen. Further, cement was placed in contact with the sand being tested.

For MW02, the cementing was even more problematic. First, there was no mention of running a cement basket on top of the screen to prevent cement from contaminating the sand targeted for testing. Second, the screen and casing were not lowered all the way to the bottom of the borehole.

The first attempt to isolate the cement from the screen failed, leaving 50 gallons of cement somewhere below the top of the screen. Later, 15 feet of cement with calcium was pumped to the bottom because it was unsuccessful to do this with sand and water. No actual depths were mentioned in the driller's record. It is assumed that cement was placed against the formation being tested to plug off the 17 feet of borehole below the screen. However, in the USEPA Draft Report, the wellbore diagram of the MW02 noted mud and cuttings were below the screen, which is contradictory to the driller's log. Also, cement was placed in contact with the sand being tested.

In the second attempt, the Trimie pipe was lowered to the top of screen at 960 feet bgs for the grouting operation. It was likely that the cement being pumped in the annulus between the casing and borehole came into contact with the screen as there was nothing to prevent this from happening. The cement contamination of the screen of MW02 can also be inferred based on the very low flow rates from this well and the details of wellsite activity in the daily report. This further supports the conclusion that the screen in this well has been fouled with cement.

The report also provides a summary chronology of drilling and cementing of MW01 and MW02.

35. S.S. Papadopulos & Associates 2012 Review of USEPA's December 2011 Draft Report

This report, prepared for the Independent Petroleum Association of America, provides a thorough critical review of the USEPA Draft Report in almost all aspects: chemical compounds in domestic wells, geochemical results, issues related to MW-01 and MW-02 (depth, location, construction, development, sampling, number of samples, and interpretation of analytical data), cement bond log interpretation, and USEPA conceptual model for contaminant transport. The review concludes that the USEPA has not provided sufficient data nor analysis to support most of its conclusions. Additional work and an improved study design considering all potential factors are required for USEPA to adequately test their hypothesis that deep groundwater in the Pavillion area is impacted by hydraulic fracturing activities.

The report points out the technical issues in the USEPA Draft Report (**Section 2** of the document) and refutes USEPA's conclusions item-by-item (**Section 3** of the document). The key conclusions from the report are listed below, followed by some details from the report.

- EPA's study design was not sufficient to gather the data, nor draw the conclusions it asserts. Specifically, inadequate conceptual model of area hydrogeology and contaminant fate and transport, insufficient data to distinguish between naturally occurring and anthropogenic occurrences of hydrocarbons or to describe their source(s).
- USEPA deep monitoring wells MW01 and MW02 were beset by well construction, development, and sampling problems that may have impacted or caused the presence of high pH, chloride, potassium, petroleum hydrocarbons, and other organic compounds.
- There are a number of issues with the laboratory methods employed by USEPA, and their reporting. Specifically, the quantification of DRO and GRO results is suspect for nearly all samples, and certain analytical methods remain untested.
- All the "lines of evidence" USEPA cites to support their conclusions can be adequately explained with alternative hypotheses addressing either natural background concentrations or sampling/analytical problems.

The existence of a background methane component in Pavillion groundwater is not surprising given the location of the investigation over a structural high in an area known to have shallow gas deposits. Open-hole geophysical logs reviewed by the USEPA Draft Report indicate the presence of gas-filled porosity at three locations at depths of 650, 682, and 827 feet between the years 1965 and 1973. These results would suggest the presence of natural gas in groundwater at depths used for domestic water supply prior to extensive commercial development. Also, the encountering of gas in water wells drilled was documented as early as 1951 (USBR 1951; **File #02**).

The table insert below provides an itemized discussion of the technical issues related to organic compounds reported in domestic wells (**Table 1** of the document) and geochemical data from deep monitoring wells MW01 and MW02 (**Table 2** of the document). For example in domestic wells, there was only one detection of benzene flagged as J value in Phase II, and the detection was not confirmed. There were also detections of bis(2-ethylhexyl)phthalate in Phases I, II, and IV; most Phase I and II results were qualified; the compound was detected in Phase IV trip blank; these detections were not confirmed. In MW01 and MW02, diesel range organics (DRO) and gasoline range organics (GRO) were detected. However these compounds occur naturally within petroleum reservoirs and gas condensates, and GRO and DRO quantifications are suspect (chromatograms of these samples rarely match standards for the analytical method) and represent a high bias.

S.S. PAPADOPULOS & ASSOCIATES, INC.

Table 1 Organic Compounds Reported in Domestic (PGDW) Wells *

	Analyte	Comment	Issues
1	1,1,2-Trichloro-1,2,2-trifluoroethane	Chlorofluorocarbon, detected in a single well	Unrelated to HF
2	1,3-Dimethyl adamantane	This compound was detected (with qualification) in concentrations up to 1.81 ug/l at 3 locations in phase II. All follow-up samples in Phase IV were similarly qualified. 1,3-dimethyl adamantane was also tentatively identified in at least one blank sample (Sample 1104026-04 (trip blank)) at 1.69 ug/l, a concentration higher than those in the Phase IV domestic wells samples (see page 147 of the Phase IV laboratory document).	Detections are not confirmed
3	2,4,5-Trichlorophenol	Qualified detection in 1 well in Phase II, no confirmation in later Phases	Detections are not confirmed
4	2,6-Dinitrotoluene	Qualified detection in 1 well in Phase II, no confirmation in later Phases	Detections are not confirmed
5	2-Chlorophenol	Qualified detection in 2 wells in Phase II, no confirmation in later Phases	Detections are not confirmed
6	2-Methylnaphthalene	Qualified detections in Phase II, but all Phase IV results were ND	Detections are not confirmed
7	4-Chloro-3-methylphenol	Qualified detections in 3 wells in Phase II, but all Phase IV results were ND	Detections are not confirmed
8	Acenaphthene	Qualified detections in 2 wells in Phase II, but all Phase IV results were ND	Detections are not confirmed
9	Acenaphthylene	Qualified detections in 1 well in Phase II, but all Phase IV results were ND	Detections are not confirmed
10	Acetate	One detection in Phase IV at 0.102 ug/l	Multiple possible sources from degradation of organic matter
11	Adamantane	Qualified detections in Phase II; a single detection in Phase IV, but also apepared in Phase III equipment blank	Detections are not confirmed
12	Aroclor-1016	One detection in Phase II, but no Phase IV follow-up	Detections are not confirmed; Unrelated to HF
13	Benzene	One detection in Phase II, flagged as J value	Detection not confirmed
14	Bis(2-ethylhexyl)phthalate	Detections in Phases I, II and IV; Most phase I and II results qualified; compounds occurs in Phase IV trip blank at concentration higher than most detections	Detections are not confirmed
15	Bis-(2-Ethylhexyl) Adipate	One detection in Phase IV at 1.64 ug/l	Detections are not confirmed
16	Butanes	Several detections in Phase II	Multiple possible sources
17	Butyl benzyl phthalate	Qualified detections in Phase II, but all Phase IV results were ND	Detections are not confirmed; Unrelated to HF
18	Caprolactam	Qualified Detections in Phase I and II, but no Phase IV follow-up	Detections are not confirmed; Unrelated to HF
19	Chloroform	One detection in Phase II, but all Phase IV results were ND	Detections are not confirmed; Unrelated to HF
20	Chloromethane	Qualified detections in Phase II, but all Phase IV results were ND	Detections are not confirmed; Unrelated to HF
21	Dimethylphthalate	Qualified detections in Phase I, but all Phase IV results were ND	Detections are not confirmed; Unrelated to HF
22	Di-n-butyl phthalate	Qualified detections in Phase II, but all Phase IV results were ND	Detections are not confirmed; Unrelated to HF
23	Di-n-octyl phthalate	One Qualified detections in Phase II, but all Phase IV results were ND	Detections are not confirmed; Unrelated to HF
24	Fluorene	Qualified detections in Phase II, but all Phase IV results were ND	Detections are not confirmed
25	Formate	One detection in Phase IV	Multiple possible sources from degradation of organic matter

Page 1 of 2

*(Double-click to open in Adobe PDF; contains **Tables 1** and **2** of the document)*

For deep monitoring wells MW01 and MW02, despite the various issues arising from the construction, development, and sampling practices that were problematic, there are issues in USEPA's interpretation of the data. For example, USEPA provides no justification for asserting that concentration gradients can be discerned from wells MW01 and MW02, which are located nearly 7,400 feet apart. The collection of <=4 samples per well from MW01 and MW02 during only two sampling events is not sufficient for reliable statistical analysis according to USEPA's own guidance document. Further, the lack of

background or baseline data to compare to the current data sets also prevents meaningful conclusions from being drawn.

Although uncemented wellbore intervals below surface casing and poor cement bonding can be conduits for the migration of natural gas or hydraulic fracturing fluids, the isolated sand lenses in the Wind River Formation and WOGCC's 40- and 20-acre spacing orders for the Pavillion field put significant limitations in these sandstone pathways. Though anecdotal reports do exist to suggest that such migration is possible, the USEPA has not, however, documented evidence to support impacts due to local connections between oil and gas activity and the Wind River Formation.

Both USEPA's Pavillion investigation and Draft Report were lacking a coherent model for contaminant fate and transport. The study area for this project encompasses nearly 40 square miles and includes both shallow and deep potential sources. The migration pathways for these contaminants are not identical, nor necessarily consistent across the entire study area. One example is USEPA's repeated assertion that meaningful concentration gradients can be discerned from concentrations in wells MW01 and MW02 that are located nearly 7,400 feet apart, 37 times further apart horizontally than they are vertically. Another example is USEPA's statement that flowing conditions in a number of deep stock wells suggest that upward gradients exist in the area of investigation. Though this may be true locally, a review of the data sources indicates that historic static water levels decreased with well depth, indicative of downward gradients.

Shallow groundwater contamination associated with surface activities at gas drilling and production locations was already known, and is being actively investigated. So far, none of the domestic wells tested in the USEPA investigation show a clear impact from the pits.

Notably, USEPA has not been able to identify whether taste and odor problems in certain domestic wells are tied to any specific contaminants traceable to hydraulic fracturing or other hydrocarbon drilling- and production-related activities.

06. Smith-Comesky Ground Water Science 2013 Report on US EPA's Investigatory Approach to Palatability Issues in Domestic Wells Near Pavillion, WY

This report, prepared at the request of Encana, reviews the USEPA Draft Report and other available information to address the approach to investigating and responding to palatability (i.e., taste and odor) complaints in water well-source supplies. The report concludes that he USEPA investigation was poorly suited to address the causes of the palatability issues and recommends a systematic approach to address the likely proximal causes of taste and odor problems, before and after an attempt at cleaning wells that may have problems due to accumulations of biofouling and associated deposits.

The report provides its own approach to water well taste and odor complaint in two steps. First, establish the nature of the complaint by addressing questions like what does it smell or taste like and what is the intensity. The threshold odor test (TOT) will be used to quantify odors. The TOT provides a threshold odor number (TON), an objective number that can be used to quantify the intensity of an odor. The USEPA refers to the TON in discussion of secondary maximum contaminant levels (SMCL) for drinking water and has established a SMCL for odor of 3 TON. SMCLs are primarily based on aesthetic concerns. For example, the SMCL taste threshold for sulfate is 250 mg/L. It does not appear that the

USEPA used objective testing such as calculating a TON in evaluating taste and odor complaints in its Draft Report. Second, start investigating with the most likely sources of water quality impairment, including bacteriological contamination (e.g., septic tank effluent), likely naturally occurring ground water chemical causes (e.g., iron or sulfide enriched ground water), and human activity (e.g., resource drilling or mining), etc. The technical process will start with issues of 1) water quality of the problem well, 2) well construction of the problem well, 3) hydrogeologic environment, and 4) well aging and maintenance history of the problem well.

There are several deficiencies in the USEPA's procedures for responding to palatability complaints. The USEPA references "taste and odor problems" but does not describe what these are (other than "foul odors"). Without having first firmly establishing the nature of the complaints, and without examining the water quality, well construction, hydrogeologic conditions, and age and condition of the problem wells, the USEPA initiated a CERCLA investigation in response to water well taste-and-odor complaints. The USEPA Draft Report overlooks local, proximal causes that can explain taste and odor problems. Probable causes of a sulfide issue (including sulfate-reducing bacteria or SRB) and potential sources of other unpleasant tastes and odors are found in the wells and ground water tapped by the drinking water wells. In terms of water quality parameters, it is apparent that the USEPA's list of analyzed compounds is not focused on resolving a taste and odor complaint.

Water-quality causes of palatability issues likely lie in the fresh-water zone and the wells themselves. Water quality parameters from some domestic wells (e.g., PGDW05, PGDW20, PGDW21, PGDW30, and PGDW45) can relate to a taste and odor complaint, and specifically to a sulfate or sulfide complaint, as well as producing sheen on a water surface. Hydrogen sulfide (H_2S), which imparts a rotten egg odor, was detected in domestic well field measurements according to U.S. EPA investigation field notes from September and October 2010. Well PGDW49 (unpermitted, no depth data recorded, but reportedly about 50 ft) has very high total concentrations of iron, sulfate, and chloride, and an apparently significant population of iron-reducing bacteria (IRB) and SRB. If the well is indeed shallow, a surficial source for such water quality influence seems more likely.

Domestic well construction issues could also be the causes. Several deficiencies in water well construction can result in a wide range of well water quality problems (cloudiness, silt, color, taste and odor), including breaches in casing or grout, or insufficient well development after drilling. Any of these can permit surface or other undesirable water to reach the intake zone. The symptoms in the above-mentioned case of well PGDW49 support the case that well location and/or construction could be an issue in its poor water quality. The USEPA Draft Report, however, does not mention any attempts to assess the condition of the water wells in question.

The report cites the expert review by Sterrett (2012; **File #33**) for potential hydrogeologic environment influence on water quality. For example, the Draft Report lacks any potentiometric surface map or illustration of head relationships to derive flow gradient. The high sulfate level in the shallow aquifer zones, even if a small fraction is reduced to sulfide, is expected to result in a sulfide odor as well as corrosion.

On-site influences on well water quality are also possible. The presence of herbicides, surfactants, and pesticides in the groundwater, as interpreted by USEPA Region 8 chemists, suggests alternate pollutant sources, including but not limited to, agricultural runoff/infiltration and septic infiltration.

Another potential cause is the aging and lack of maintenance of the domestic wells. One common manifestation of well aging is accumulation of low-redox biochemical deposits that readily impart unpleasant taste. The description of analyses and sampling events for well PGDW05 provides indication that this well has experienced deterioration. Previously unreported, SRB were significant by July 2006, when 1.3 mg/L total sulfide was also reported.

There exist some issues with the microbiological methodology applied by the USEPA. The BART (Biological Activity Reaction Test) methods appeared to have been applied in an unsystematic manner by the USEPA investigators. SRB and IRB occur predominantly in biofilms, yet the sample was typically collected by pumping (along with other water samples) to collect detached viable bacteria. Since energy generated by domestic water well pump suction is only sufficient to detach biofilm bacteria from a small radius, the SRB, IRB, or other cultured microflora detected by BART culturing most likely originated in the water well sampled. However unsatisfactory the microbiological methodology applied by USEPA, SRB positives were consistent with a sulfide complaint. Other likely microbial transformations and biofouling could explain other unpleasant sheens, odors, taste and appearance. The most likely location of these microbial transformations is in the well water columns.

37. API 2013 Review of EPA's Pavillion December 8, 2011 Draft Report with Focus on Deep Monitoring Wells MW-01 and MW-02

This review by American Petroleum Institute (API) on the USEPA Draft Report focuses on issues related to the two deep monitoring wells MW01 and MW02. API believes that these wells were drilled into, or near to, a known, noncommercial, natural gas producing reservoir and are significantly deeper than the typical nearby domestic water wells drilled in the area. This review shows that there are serious issues with drilling, construction, development, sampling, and apparent misinterpretation or inaccurate representations of groundwater quality results from these monitoring wells on the part of USEPA. Specifically,

- The wells were not constructed following USEPA's own guidance documents and work plan (e.g., standard annular seals such as bentonite pellets or slurry were not used, resulting in probable contamination of groundwater with cement containing glycols).
- Construction diagrams contained numerous and significant errors (e.g., representing riser casing as stainless steel when in fact it was black painted/coated carbon steel casing).
- Compounds USEPA attribute to hydraulic fracturing (e.g., glycols, diethylene glycol, phenol, 2-BE, total petroleum hydrocarbons, phenols, isopropanol, and others) were likely present in the drilling/completion materials and/or drilling additives; many of these compounds were not detected in the 2012 USGS study (**File #24**), but were allegedly found in some of the samples in USEPA's studies.
- USEPA only tested 3 of 11 additives or materials for organic compounds used down hole, and then only tested for approximately half of the organic compounds USEPA is attributing to hydraulic fracturing.
- Lack of adequate decontamination on equipment and materials used in well construction as documented in the field notes.
- The materials used in well construction and lack of proper decontamination are the likely cause of contamination of the groundwater in these wells.

- Groundwater from wells may have been contaminated by USEPA's use of non-filtered compressed air (likely contains compressor oils) and surge blocks (rubber materials likely scraped off the swabbing equipment) used to develop both wells.
- Failure to disclose that USEPA had releases of anti-freeze (known to contain glycols), cement, and diesel fuel during field operations at location MW01.
- Use of flawed sampling methods to collect samples from both wells – key indicator parameters (pH, oxidation-reduction potential, and specific conductance) were not stable during sampling; a key and critical component of low-flow sampling (drawdown measurements during well purging) was not done in both wells during the October 2010 Phase III sampling event; during Phase IV, water level measurements were not useable in MW02 and not stable in MW01.
- EPA developed very low analytical detection methods for glycols and ethoxylated alcohols that are not available to standard commercial laboratories and which are not independently verifiable at these very low concentrations; these compounds were not always detected in samples from the same wells; several other compounds were detected in some of the drilling additives, while other compounds were found in trip, field, and/or equipment blanks.
- EPA was unable to find any definitive connection of odor, taste, and color complaints in groundwater from domestic water wells to hydraulic fracturing in the Pavillion area.

API made the following recommendations:

- The USEPA Draft Report and all associated data should be withdrawn.
- Both monitoring wells MW01 and MW02 should be immediately plugged and abandoned.
- Further investigation of the area is not warranted according to USEPA's own finding of the lack of hydraulic fracturing chemicals in the shallow water supply wells of the area.
- USEPA should ensure that qualified contractors and staff are utilized in their ongoing studies to minimize the potential for the types of significant problems documented in this review related to improper field techniques and data evaluation from continuing to occur in other similar studies.

10. Stephens DB 2015 Analysis of the Groundwater Monitoring Controversy at the Pavillion, Wyoming Natural Gas Field

This issue paper, published in *Groundwater Journal*, provides a thorough coverage of the controversy related to the USEPA's groundwater investigation in Pavillion, Wyoming that attempted to link groundwater contamination to hydraulic fracturing. USEPA concluded in their December 2011 Draft Report that constituents associated with hydraulic fracturing in the Pavillion Field had impacted the drinking water in the area. However, under extensive technical criticism from industry and pressure from state and other federal agencies, USEPA has decided to forgo peer review of the draft report, not rely on the draft report's conclusions, and relinquish its lead role in the investigation to the State of Wyoming for further investigation without resolving the source of the taste and odor problem.

The paper reviews the events leading up to the USEPA's conclusion in their Draft Report. USEPA initiated the field investigation, including drilling two deep monitor wells, in response to complaints of taste and odor in private water wells received in 2008. USEPA published the Draft Deport in 2011 after four phases of sampling since 2009. Review of the events suggests that the USEPA work lacked pre-project planning with clear objectives to identify the high national significance and potential implications, and

would benefit from expanded stakeholder involvement and technical input so that some of the difficulties plaguing the investigation could have been eliminated. A more effective way to evaluate potential impacts, however, would have been to collect baseline groundwater quality data prior to initiating hydraulic fracturing.

The paper provides a good summary of background information and findings of studies and responses related to the USEPA investigation. Most of these are covered in the documents reviewed earlier. Some key events or discussions are provided below.

Agency for Toxic Substances and Disease Registry (ATSDR), at USEPA's request after reviewing the Phases I and II test data, found 20 of 41 private wells contained compounds that ATSDR associated with petroleum products including tentatively identified compounds (TICs) and low levels of diesel range organics (DRO) in water which were less than the state cleanup level, as well as methane that was below the explosive limit. Between 5 and 11 wells contained what ATSDR considered to be man-made organic compounds that were either present below health based screening levels or for which there were no screening levels available. ATSDR found that the presence of sulfate and iron and sulfur bacteria may be associated with the odor and foul taste of the water, but the root cause of the problem was not identified (**File #01**).

The oil and gas industry provided extensive, thorough, and consistently critical comments on almost every aspect of USEPA's two deep monitoring wells (e.g., **File #33**, **File #34**, **File #35**, and **File #37**). These responses reach the conclusion that the data collected by USEPA in its two deep monitoring wells are not reliable, and therefore, the findings of USEPA in their Draft Report, that hydraulic fracturing fluids impacted the aquifer, should be dismissed. Without providing rebuttal to these comments, on June 20, 2013, USEPA announced that the agency has no plans to finalize the Draft Report or seek peer review, and later terminated its request for public comment.

Had USEPA's team recognized the national importance of the Pavillion project, prepublication peer review may have been more rigorous, and USEPA contractors likely would have developed a more robust work plan to ensure that more of the questions that should have been anticipated could be answered in a thoroughly documented and transparent manner.

In the absence of input from an advisory panel of stakeholders, there were predictable difficulties with USEPA's relatively fast track field investigation.

Careful external technical review of the Draft Report by industry and consultants suggests that USEPA's prepublication review process was insufficient. During the formal public comment period, inconsistencies were found between the USEPA work plan, the actual field work, and the Draft Report.

USEPA's objectives creeped from initially to determine the cause of the taste and odor complaints to a report focused on detecting hydraulic fracturing chemicals in a drinking water aquifer and domestic wells.

Detailed review also revealed a lack of transparency in the USEPA process (e.g., API 2013 or **File #37**). For example, the Draft Report did not provide specific information and data, nor could they be found in the USEPA website. Additionally, the draft report was silent on the release of glycol-containing

antifreeze during drilling of one deep monitoring well, a potentially relevant fact when developing conclusions about the source of glycol in groundwater samples.

USEPA did not communicate the conclusions in the report and their significance more clearly. For example, in the Draft Report, USEPA found that "the existing data at this time do not establish a definitive link between the deep and shallow contamination of the aquifer." This critical finding, buried on page 27 of the report, would not appear to comport with the more widely read conclusion on page xiii of the Extended Abstract.

From industry's perspective, there were no organic chemicals found in domestic wells exceeding established federal drinking water standards, and USEPA's tests found no indication of oil and gas impacts and no connection to hydraulic fracturing. Many organic constituents such as 2-butoxyethanol phosphate, phenol, and toluene detected in Phases I and II sampling were not detected in Phase IV sampling. Some initial detections of constituents such as adamantanes were not confirmed because of detections in blank samples, whereas other chemicals present, such as toluene, have multiple potential sources (SSPA 2012, **File #35**). This is consistent with the statement of USEPA's administrator that there is no indication that drinking water is at risk.

The Draft Report also failed to communicate that the Pavillion site has unique characteristics. In a pre-report dissemination interview, USEPA's Administrator guarded against extrapolating the findings from Pavillion to other sites, owing to the shallow nature of the Pavillion gas reservoir, but unfortunately, the unique conditions were not discussed in the conclusions of the Draft Report.

However, rather than focusing on detection monitoring for constituents found in hydraulic fracturing fluids, the WDEQ will evaluate the need for additional sampling based on exceedances of established USEPA primary and secondary contaminant levels and WDEQ Rules and Regulations as a trigger. One element of the investigation, a report on production well integrity near the sampled water wells was just released for comment, with recommendations for further study and improved data collection (WOGCC 2014, **File #27**).

It is recommended that field methods, report transparency, clarity of communication, and the peer review process should be improved in future investigation of the impacts of hydraulic fracturing on groundwater, to reach tenable conclusions that are less controversial.

Section V Studies on Gas Well Integrity and Oil and Gas Field Pits

16. USEPA 2013 Pavillion Oil and Gas Field Pits Evaluation

This USEPA evaluation report, by summarizing existing information, describes the universe of pits in the Pavillion gas field, discusses cleanup standards and processes that have been applied to remediate pit concerns, and provides USEPA comments on existing remediation approaches and cleanup standards from a potential health risk perspective.

The current operator of the Pavillion gas field is Encana and the three agencies involved in oversight of pit closure are WOGCC, WDEQ, and Bureau of Land Management (BLM). BLM regulatory closure cleanup requirements are typically determined using the same approach as WOGCC. For all investigated pit sites, Encana used WOGCC's Oil Contaminated Soil Remediation Ranking System (OCSRRS) to score a site based on its environmental sensitivity and correlate the final score to cleanup goals that range from 1,000 to 10,000 mg/kg TPH soil concentration. If a pit was the source of ground water contamination above State ground water quality standards, Encana sought enrollment of the pit site into the WDEQ's Voluntary Remediation Program (VRP); Encana enrolled four pit sites in the VRP. The VRP process typically involves a site characterization, development of a conceptual site model, and establishment of applicable or site-specific risk-based cleanup levels. The VRP provides soil cleanup levels for the pathways of direct human contact and migration to groundwater. The migration to ground water pathway is the pathway of concern in Pavillion as the pits are covered with backfilled material limiting direct human exposure. The VRP soil cleanup levels, however, do not apply to pits already closed using the WOGCC process.

The Pavillion pits workgroup reviewed a total of 51 potential pit sites in an attempt to determine the universe of historic pits in the Pavillion field that were used to store drilling, production, and/or other fluids prior to the use of storage tanks beginning in the mid-1990s. Of these sites, four have been enrolled in the VRP, eight were removed from consideration, 25 were evaluated using the WOGCC process, and eight were identified as "cuttings" pits of low priority, in addition to six others.

Pit information (e.g., TPH concentrations, cleanup goals, and evaluation notes) from previous activities are provided in the report (**Tables 1** through **5** of the document). USEPA data collected as part of its Phase 2 sampling event include three subsurface soil samples and three ground water samples from the three pits that were enrolled in the VRP at the time. These data indicate the presence of elevated levels of contaminants (e.g., benzene as high as 390 µg/L) and identify pits as a potential source of hazardous constituents.

Review of the pit data captured from previous activities indicates two data limitations. First, the GRO, DRO, and TPH analysis are not possible to identify the specific compounds that are present in the sample. Second, some of the analytical detection limits are higher than the USEPA Regional Screening Levels (RSLs) used to assess risk (**Table 6** of the document).

One USEPA comment on cleanup of contaminated soil is that the WOGCC Pit Closure Guidance, alone, presents difficulties in regard to source and risk characterization of contaminated soil. Though TPH can serve as a measure of contamination, using TPH alone as an analytical measurement and cleanup goal might not be protective, as specific contaminant concentrations that may be at levels above risk

screening levels are not known at each site. Currently, analysis for specific analytes occurs at VRP sites. USEPA recommends extending the practice of sampling for site specific contaminants of concern to energy exploration and production sites in general. Another comment is that the guidance procedures are not adequate to determine if use of a pit resulted in contamination to underlying groundwater. The fact that no ground water was encountered during testing and removal of contaminated soil does not confirm that ground water contamination did not occur at the various pit sites, and flood irrigation practices may dramatically influence ground water levels and movement on a seasonal basis. USEPA recommends that a groundwater monitoring well be installed and sampled for contaminants of concern at every pit location where contaminated soils were detected.

Regarding cleanup of contaminated groundwater, USEPA asks for a remedy selection process that discusses the various available remedies with regard to cost, practicability, risks, and the time necessary to reach the cleanup goals. Also, USEPA deems it necessary for further groundwater contaminant characterization to define the source and plume characterizations and the groundwater flow system. Data from this further characterization (e.g., a sufficient number of wells screened at multiple depths and natural attenuation parameters) can help reduce characterization uncertainty, account for seasonal variation in water table, better understand the attenuation processes that will be relied upon, and establish corresponding soil cleanup goals so that selected groundwater remedy will continue to be protective.

In this evaluation, USEPA made a good observation on the limitations of data (lack of analysis for specific compounds and high analytical detection limits), and proposed some reasonable improvement to the existing methodology (e.g., remedial selection process). On the other hand, the USEPA evaluation lacked an in-depth evaluation of pit specifics (e.g., whether the pit is lined, depth to water table, aquifer conditions) such that some of the recommendations (e.g., a monitoring well at every pit) are too general to affect the decisions on pit investigation and remediation.

17. USEPA 2013 Pavillion Gas Well Integrity Evaluation

This USEPA evaluation report (draft) summarizes key industry recommended best practices for isolating Underground Sources of Drinking Water (USDWs) from oil and gas production activities, categorizes the construction condition of Pavillion gas wells, describes the fluid migration potential associated with each well construction condition, and suggests test methods and evaluation procedures to identify wells that may need remedial cementing to ensure isolation of the USDW.

The report reviews industry guidance and recommended practices from the American Petroleum Institute (API), Society of Petroleum Engineers (SPE), Oil Field Review, and Frac Focus, pointing out that well integrity established through sound well design and installation practices are paramount considerations for protecting groundwater resources. For example according to Frac Focus, surface casing is the first line of defense and production casing provides a second layer of protection for groundwater, and that 93% of oil and gas producing states require surface casing to be set below “deepest groundwater.” According to API, surface casing should be set at least 100 feet below the deepest USDW encountered while drilling a well.

A leak in the subsurface may occur if the well annulus is over-pressured by production zone gas and liquid or by entry of shallow non-production zone gas and liquid, and if a pathway is present. To prevent

a potential leak, isolation of production zone gas and liquids and zonal isolation of shallow non-production zone fluids are required. The former prevents production fluids from migrating up the outside of the production casing and into aquifers above the production zones. The latter prevents fluid movement between geologic formations in shallow non-production zone that are in contact with the wellbore. The integrity of casing, tubing, and packer, and an adequate cement seal behind casings are necessary to achieve the isolation.

Multiple testing methods are available to evaluate well integrity and the quality of cement seal. For example, mechanical integrity test (MIT) can be used to test and evaluate the integrity of production casing, tubing, and tubing packer. Bradenhead pressure monitoring and gas and liquid analyses can be used to determine if an over-pressured annulus results from channels or poor bonding conditions in cement above the production zone, or is caused by fluids (including hydraulic fracturing fluids) from the production interval. Cement Bond Logs (CBLs), temperature logs, radioactive tracer surveys, and noise logs can be utilized to evaluate the cement bond conditions. For a gas well having integrity or cementing issues, remedial cementing may be required to ensure isolation of the USDW.

In order to determine the test methods and evaluation procedures appropriate for identifying wells that may need remedial cementing, the report categorizes the construction condition (CC) for vertical wells with two casing strings (surface and production casing) into four types:

1. Surface casing below USDWs and cement of production casing above surface casing shoe. This is a fully cemented well in which USDWs were protected during drilling and have been subsequently isolated with cement and casing.
2. Surface casing below USDWs and cement of production casing below surface casing shoe. This is a partially cemented well in which USDWs have been isolated during drilling and are currently isolated with surface casing and cement.
3. Surface casing above USDWs and cement of production casing below surface casing shoe. This is a partially cemented well in which USDWs were not protected during drilling and are not currently protected with casing and cement.
4. Surface casing above USDWs and cement of production casing above surface casing shoe. This is a fully cemented well in which USDWs were not protected during drilling but have been subsequently isolated with cement and casing.

The report then suggests test and evaluation methods for the potential fluid migration associated with each category of well construction condition. For CC1 and CC4 resulting in fully cemented wells, methods for testing and evaluating primarily include a well design and records evaluation (e.g., casing depths, adequate cement volumes, CBLs, and top of cement). Evaluation of CC1 could also include a formation integrity test or leak-off test after the surface casing has been set and prior to beginning to drill the production hole. For CC4 it would also be important to identify any significant fluid loss zones during the drilling of the production casing borehole and any pressure “kicks” which may identify zones that have pressures that could move fluids into open hole USDW zones below the bottom of the surface casing during drilling. However, even with cement to surface in all annular spaces, fluid migration through micro-channels in a cemented annulus may not be prevented and are very difficult to detect and mitigate.

Testing and evaluation for CC2 (partially cemented) is usually performed by comparing pressure in the bradenhead annulus at the surface to a critical pressure that is calculated based on the fracture pressure adjusted to the depth of the bottom of surface casing. If this critical pressure is exceeded, the pressure

in the bradenhead annulus could promote fractures within the confining unit allowing fluid migration into USDWs above the confining unit (**Figure 4** of the document). A formation integrity test or leak-off test, after the surface casing had been set and prior to beginning to drill the production hole, can provide useful information for later testing and evaluation.

For CC3 that is partially cemented and providing no zonal isolation, testing must focus on evaluating whether fluid can flow from one zone within the open annulus to another zone within the open annulus (**Figure 5** of the document). In this case, differences between annulus pressure and pore pressure in formations adjacent to the open annulus need to be evaluated. Testing and evaluation should be performed to determine gas pressure in the bradenhead annulus, hydrostatic head for water or drilling mud (whichever is appropriate) in the bradenhead annulus, and pore pressure gradient. According to the report, under CC3 an open annulus is exposed to the USDW, and if the bradenhead annulus is overpressured, fluids may migrate from a high pressure zone to a low pressure zone and potentially into USDWs in contact with the open annulus (**Figure 5** of the document). This conceptualization by USEPA, however, is over-simplified and fails to consider the special case that both surface casing shoe and top of production casing cement are set in the same shallow confining unit.

Based on the above description, CC1 and CC4 are of low risk while CC2 and CC3 are of high risk.

The report describes in its last section the results of summary evaluation of Pavillion gas wells, including surface casing depths relative to USDWs, production casing cement conditions, testing performed to date, and mitigation proposed and performed by Encana. In particular, considering entire Wind River Formation as an USDW, no surface casing extends below the USDW; based on this determination, Pavillion gas wells categorized according to construction condition include zero CC1, zero CC2, 55 CC3, 65 CC4, and 25 unknown. Because MITs, bradenhead annulus gas pressure monitoring, and bradenhead hydrostatic pressure monitoring are either ongoing or not conducted, there is little information available to determine future actions. So far the only proposed mitigation known to USEPA is for production casing cement mitigation for Pavillion Fee 12-11W which had fluid flowing at the surface in the bradenhead annulus, but no mitigation information is available for evaluation.

The report provides a reasonable discussion of the potential migration of subsurface fluids to USDWs associated with well construction conditions, and the testing and evaluating methods appropriate for identifying wells that may need remedial cementing. The discussion, however, is more suited for general conditions and neglects some of the unique conditions at the Pavillion gas field. Notably, the report states in the discussion of Pavillion hydrogeology that the lenticular sandstone beds within the fluvial Wind River Formation may have sufficient hydraulic connection to consider the sequence a single aquifer at a regional scale. While this may be true to some extent, the statement is misleading as it makes one think that the shallow aquifers penetrated by the Pavillion gas wells are interconnected, and thus leaks to aquifer(s) at one well location are able to propagate to aquifers of the entire study area. In fact, the recommendation that surface casing be set below the deepest USDW has an implicit assumption – the USDW is laterally continuous and would be the same USDW in which domestic wells are screened. However, it is known from documents reviewed earlier that the lenticular sandstone lenses are thin and discontinuous, and could rarely be correlated between two gas wells. As such, even though the Pavillion gas wells do not have surface casing set below the deepest USDW, the risk of a leak into USDWs should be much lower than analyzed by USEPA in the report.

27. WOGCC 2014 Pavillion Field Well Integrity Review

This report by the WOGCC provides a technical and regulatory analysis of the integrity of gas wells within one-quarter mile of domestic water wells identified by the WDEQ as having quality and palatability issues in the vicinity of the Pavillion Gas Field. This selection criterion results in a total of 50 gas wells, among which eight were permanently plugged and abandoned. The report addresses the adequacy of drilling and completion techniques relating to gas well construction and operation, and the likelihood of fluid migration via these wellbores from deep known natural gas producing sands to shallower sands tapped by domestic wells in the vicinity of the producing wells. A thorough in-depth expert review of this report was conducted by Professor Maurice Dusseault from the University of Waterloo and is described in a separate cover. The following provides a summary of the analysis results and issues identified during the review that need to be addressed.

Surface distance between gas wells and the nearest identified domestic water well ranged from 252 feet to 1,408 feet. Vertical distance from the top of currently producing perforations in the gas wells to the reported bottom of the nearest domestic water well ranged from 882 feet to 5,103 feet. The direct (angular) distance from the top of currently producing perforation in the gas wells to the reported bottom of the nearest domestic water well ranged from 1,122 feet to 5,155 feet. Review of available records determined that all gas wells were properly permitted, drilled, completed, and operated.

The surface casings of the gas wells were set at depths ranging from 221 feet Kelly Bushing (KB) to 911 feet KB. Three water wells were drilled to a depth deeper than the surface casing depths of gas wells.

Eight wells drilled prior to 1982 used a diesel oil-based "invert" mud system below surface casing. Cement bond logs were run on all wells drilled after 1971. Nineteen wells showed primary cement rose to a height insufficient to reach the base of the surface casing. Ten wells were identified as having supplemental cement "squeeze" jobs performed after primary cementing to place additional cement behind the production casing. Most perforated intervals were hydraulic fracture treated using carbon dioxide energized gelled water and sand.

Mechanical integrity tests of the production casing were performed on five wells witnessed by WOGCC, and all passed satisfactorily, with no observed pressure bleed-off.

Bradenhead testing of the annuli between the production casing and surface casing of 41 wells were performed between 2011 and 2013 by Encana. Twenty five wells tested measured zero annulus pressure, and five tested wells had pressure that when bled off did not re-build. Annulus pressures were observed on 11 wells that, when bled off, re-charged over a few days. Bradenhead pressure reoccurred after bleed-off in six wells that showed the top of cement to be above surface casing setting depth. Six wells where the cement top appears to be below the base of the surface casing reported no recurring pressure on the bradenhead. Analysis of gas samples taken during bradenhead testing indicates a different gas composition.

The report concludes:

1. Information is lacking or unverified regarding construction details of the domestic water wells.
2. Several domestic water wells are completed in Wind River Formation sands, which are known to contain both water and natural gas.

3. Wind River and Fort Union sands appear to be normally or under-pressured, at the time of drilling based on drilling records and reported mud weights.
4. Hydrostatic pressure from fluids behind the casing can create a hydraulic seal that prevents migration of fluids between formations until or unless the pressure in one of the formations is great enough to displace the liquids in the wellbore annulus. No evidence was found indicating this formation pressure differential condition is present in the Pavillion Gas Field.
5. Plugged and abandoned gas wells were plugged in accordance with state and/or federal guidelines and adequately isolate potential gas zones from domestic water sources.
6. Bradenhead testing indicated no casing or wellhead leaks. Of the wells with recurring bradenhead pressure where samples were analyzed, there was enough variance in chemical composition. The bradenhead gas likely result from shallow gas bearing Wind River Sands penetrated after surface casing was set.

The report recommends:

1. Obtain accurate information regarding water well depths and construction for a full analysis of aquifer impacts due to oil and gas development.
2. A comprehensive geologic and hydrologic study should be undertaken to better understand the structural and stratigraphic relationship between individual reservoirs, and to more accurately predict natural fluid flow pathways.
3. Monitor and bleed off on a quarterly basis the bradenhead pressure of all gas wells with reported positive bradenhead pressure.
4. Obtain and submit to the WOGCC cement bond logs for gas wells Tribal 14-2, Tribal Pavillion 43-10, and Unit 22-12.
5. Perform mechanical integrity tests on all gas wells with recurring bradenhead pressure not previously tested.
6. Producing well operators should provide all available stimulation treatment records for all Pavillion wells.
7. Consideration should be given to installing groundwater monitor wells around selected domestic water wells to better understand fluid characteristics and groundwater flow patterns, specially, PGDW41, PGDW30, PGDW44, and LD02.

During the review of this report, it was found that potential errors, in the order of several hundred feet, exist in the coordinates of many of the gas wells when comparing coordinates from Encana and WOGCC and aerial photography. A field verification was conducted for a select set of gas wells and the results confirmed the suspicion; details of the field verification are available in the investigation report. In addition, some of the conclusions from this report are debatable. For example, while the Bradenhead testing and gas analysis may not indicate casing or wellhead leaks or migration of fluids between formations, the data cannot rule out the possibility of fluid migration within the same formation or through micro-channels in cemented annuli. Detailed discussion can be found in the expert review by Professor Maurice Dusseault.

28. WOGCC 2014 Pavillion Field Pit Review

This report by the WOGCC provides a technical and regulatory analysis of pits associated with gas wells located within the Pavillion Field. The use, status, closure, and reclamation information of the pits are provided, and those within one-quarter mile of the 14 water supply[2] wells (the area of review or AOR) identified by WDEQ as having quality and palatability issues are noted and evaluated for potential to contribute to water quality issues at the water supply wells. One objective of the report was to address the adequacy of Pavillion Field site investigations and pit reclamation in protecting water quality in all water wells within approximately one-quarter mile radius of each pit location. Below is a summary of determinations and recommendations of the WOGCC review, followed by comments at the end.

The report provides a brief description of the Pavillion Field and a summary of current regulations concerning the permitting, usage, and closure of the pits. Specifically, development of the natural gas resources in this area began in 1960 and continued through 2006. Of the 169 gas wells in the Pavillion Field, 98 are currently in active production, 40 are shut-in, and 31 have been plugged. The WOGCC has primary regulatory authority over oil and gas well field pits and waste materials contained by the pits. If oil contaminated soils are present in a pit or immediate area, the WOGCC's risk based closure method – the Oil Contaminated Soil Remediation Ranking System (OCSRRS), though other rigorous detailed site and health/environmental assessment is also suggested, is typically applied to score the pit based on sensitivity of the site to contaminant migration and assign a corresponding TPH cleanup level in soils that must be met. Notably, the OCSRRS process is for oil contaminated soils only and does not address inorganic constituents.

If water contamination occurs, WDEQ regulations are primary, and its Voluntary Remediation Program (VRP) provides very specific individual constituent concentration limits that must be met. Notably, pit construction and closure requirements prior to April 26, 1984 were not as rigorous as current regulations for protection of human health and the environment. Thus historical or legacy pits exist which are commonly unlined and which may have contained oil-based fluids (oil-based mud or OBM) or other petroleum product from drilling or exploration.

Of the 169 Pavillion Field wells, 92 are associated with pits. Fifty of the 169 Pavillion Field wells are located within the WDEQ AOR. Of the 50 gas wells, 12 were drilled between 1953 and 1981. Reserve pits are associated with all 12 of these wells, and 11 of the 12 pits were used to contain OBM. Lined cuttings pits are associated with 14 of the remaining 38 wells drilled between 1993 and 2005.

Regarding the water supply wells within the WDEQ AOR, this report illustrates that information regarding construction details and local hydrogeology is lacking or unverified (**Tables 4** and **5** of the document and discussions in **File #27**) and should be obtained through direct measurement or from written well records when possible.

The report provides a detailed review of the nine OCSRRS ranking characteristics (hydrogeology, aquifer water quality, soil medium, distance to water well, and so on) specific to the Pavillion Field. In particular, the report concludes based on a review of Pavillion area hydrogeology and groundwater resources that it is quite likely that relatively deep sandstone lenses in the Wind River Formation are not in hydraulic

[2] WOGCC used "domestic" instead of "water supply" in the report. "Water supply" is more accurate as not all 14 wells are domestic wells.

connection with the shallow alluvial/colluvial deposits and shallow Wind River deposits in which the pits are located. For example, as stated in several USGS studies (**File #18** and **File #19**), the lenticular water-bearing sandstone beds in the Wind River Formation are discontinuous and hydraulically isolated to varying degrees by interbedded fine-grained confining units, and the Wind River Formation effectively consists of numerous separate aquifers. However, available data are insufficient to determine groundwater flow patterns and gradients and possible hydraulic connection between the surficial aquifers in which the pits are located and the Wind River aquifer in the vicinity of the water wells. As such, the report suggests that a comprehensive geologic and hydrologic study of the Pavillion Field area be undertaken using all available well logs / cores and a synoptic set of recent water level data, as well as other pertinent information.

To demonstrate and evaluate its practical application, the OCSRRS was applied to generate the scores and corresponding TPH cleanup levels for the 11 reserve/production pits that contained OBM and are located within the WDEQ AOR (**Table 10** of the document). The scoring indicates that the most conservative TPH cleanup limit of 1,000 mg/kg would apply for 8 of the 11 pits. In all but one instance the TPH limits agree with the operator-reported cleanup limits, where applicable, for previous investigation and remediation work.

Recognizing the difficulty to assess the adequacy of investigations and remediation work associated with Pavillion Field pits with respect to protection of water wells, given the lack of knowledge pertaining to the water wells, the report makes the following determination and recommendations (**Table 12** of the document).

Of the 92 pits in the Pavillion Field, 31 are associated with gas wells drilled using water-based mud systems and, and three are of unknown type (one was converted to water well, and two are not within 1,475 feet of known water well). No investigations are recommended for these locations.

Nine Pavillion Field pits were cuttings pits associated with wells drilled using KCL polymer systems. It is recommended that soil/cuttings and groundwater samples be obtained at one of these pit locations and the results be used to determine the need for additional work at KCL pit locations.

The remaining 49 Pavillion Field pits (legacy pits) were reserve pits or reserve and production pits used to contain OBM. These pits are associated with wells drilled by various operators between 1960 and 1983. No investigations or remedial work was conducted at 18 of these pit locations. Eleven of the uninvestigated pit locations are not within the WDEQ AOR and are not located within 1,475 feet of any SEO groundwater permit location, and thus no investigation is recommended. The remaining seven uninvestigated pits are within 1,475 feet of SEO groundwater permit locations and one is in the WDEQ AOR, and investigations are recommended.

Investigations have been conducted at 31 of the legacy OBM pits. Twenty six (26) had been accepted in the WDEQ VRP program in September 2005. Encana subsequently requested, and was granted, approval to withdraw VRP applications for 23 pits either due to site access problems or because investigations were to be conducted under WOGCC direction. Five sites were reinstated into the VRP program and eight sites were enrolled in the program as of November 2014. The investigations, monitoring, and remediation at these sites have been, and are being, conducted based on the guidelines of the VRP. No assessment of remediation status or recommendations for further investigation are provided for these eight pits.

For the remaining 23 previously investigated reserve/OBM pits, the existing site assessment and remediation is adequate for six pits and no further work is recommended; further site investigation and remediation is recommended for 12 pits to define the location and extent of the pit contents, collect samples of the pit contents and groundwater, and conduct soil remediation if necessary; recommendations for five pits are pending review of further information or verification of the existence of water wells within 1,475 feet of the pit.

To assess whether the 1,000 mg/kg TPH standard for soils in high risk sites provides adequate protection from soil and groundwater contamination, the report describes two evaluations using data from sites that have undergone investigation.

The first evaluation involves comparing the highest TPH, BTEX, and naphthalene concentrations for two populations of soil samples: 1) 148 samples in which the total TPH (sum of TPH-GRO and TPH-DRO) concentration was determined to be less than 1,000 mg/kg, and 2) 37 samples in which the total TPH concentration was greater than 1,000 mg/kg (**Table 16** of the document). For the first population, there were no benzene detections, the maximum toluene, total xylenes, and naphthalene concentrations were below the WDEQ migration to groundwater cleanup level, and the maximum ethylbenzene detection was slightly above the WDEQ migration to groundwater cleanup level. For the second population, the maximum concentration of all constituents except toluene exceeded the WDEQ residential soil cleanup level at one or more pit location. This evaluation indicates the utility of using 1,000 mg/kg total TPH in soils as an indicator of concentrations of other constituents of concern in soils.

The second evaluation involves comparing analytical data for soil and groundwater samples that were collected from the same borehole (**Table 17** of the document). Scatter plots were created using these data to visually assess the relation between concentrations of constituents of concern in soil and groundwater (**Figure 2** of the document). The results are inconclusive: relatively high concentrations of TPH in groundwater can occur in association with relatively low soil TPH concentrations, while low TPH concentrations in groundwater can be associated with relatively high soil TPH concentrations, and it is not known with certainty whether the groundwater that was sampled had been in contact with the sampled soil. Future work may provide additional data that could be used to further assess the relation, and it is suggested that future pit investigation work in the Pavillion Field area include analysis for specific soil constituents of concern.

Many determinations and recommendations presented in this report are reasonable, including the lack of and the need to collect more information on water wells, the recommendation to further assesses the relation between concentrations of constituents of concern in soil and groundwater, the suggestion that future pit investigation work include analysis for specific soil constituents of concern, and the recommendation to undertake a comprehensive geologic and hydrologic study of the Pavillion Field area.

However, the report is inadequate in addressing its key objective, explaining some of the key concepts, and justifying some of the determinations and recommendations. According to the WDEQ framework document, the objective of the WOGCC pit report is to determine if the site investigations and/or reclamation was sufficient to protect those water supply wells within one-quarter mile radius of the pit locations. Steps that could have furthered the analysis to address this objective include:

1. Provide a comprehensive conceptual site model (CSM) for contaminant migration from pits, including differences in length of pit operation and pit use (i.e. production pits versus cuttings only), in addition to original use and drilling fluids type.
2. Utilize available general guidance or survey studies of characteristic water quality impacts of various types of pits (e.g. typical indicators that may appear in water wells), and any available data that bracket possible scale of impacts (e.g., statistical analysis of plume lengths etc.).
3. Evaluate data for pits in the VRP, rather than exclude them, as these are the ones with known groundwater impact and the most data.
4. Generalized statements on degree of direct hydraulic connection insufficient to imply possible protection from impacts from surface pits, given that a) some supply wells are relatively shallow, b) depth of surface seals not always known, and c) connection of producing zone for well and shallower groundwater at a particular site cannot be generalized (see Step 1 on CSM).
5. Depending on conditions (see Step 1 on CSM), addressing questions sufficiently may require not only soil data, but also groundwater data.
6. The report does not consider water quality impacts other than WDEQ cleanup levels for GRO, DRO, BTEX, naphthalene. Other water quality impacts from petroleum releases directly or through subsequent biodegradation of hydrocarbons include increased TDS, dissolved salts, and metals, plus palatability issues.
7. The utility of the OCSRRS and associated soil cleanup levels alone to eliminate pits from further consideration is not demonstrated. Note the lack of correlation between soil samples and pit impacts to groundwater. The main issue is the use of prospective ranking system for selecting soil cleanup levels (“at the bottom of contamination”) to extrapolate impacts of historical pits with different operating histories and different previous closure steps that are not documented.

Regarding the WOGCC’s OCSRRS, the report does not explain how the TPH cleanup limit was derived in the first place. The OCSRRS scoring does not seem to address the history of pit (e.g. pre-1985 pits or those which may have been production pits). Also, it would be helpful to point out that WOGCC's TPH cleanup limits are different from the WDEQ soil cleanup levels, and include a discussion on the differences in approaches and thus the difference in cleanup levels.

The report also has some inconsistencies in the pit locations. It appears that where soil or groundwater investigations were performed, pit locations were adjusted on the maps and the GIS shape files, but the lat/long data in the GIS attribute tables and report tables were not updated and are the same as those of the associated gas wells. The pit locations are better to be verified depending on the quality of original survey data, by using techniques such as geophysical surveys if difficult to identify from surface. Using GPR for pits identification may not be effective (Section 8.1), as GPR generally has a poor response to hydrocarbons and LNAPL must be shallow for it to work. Using electro-magnetic (EM) methods for contrasting soil conductivity may be a better option.

Regarding well assessment, although well construction data are helpful, direct assessment using logging tools with active sources is not necessarily the best method. Hydrophysical logging and depth profile sampling would be more instructive. This would require pulling the pumps and logging under both static and pumping conditions. However, this may not be the best use of limited resources.

Section VI Other Documents

30. USEPA 2012 Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources

In 2011, the USEPA began research under its *Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources*. The purpose of the study is to assess the potential impacts of hydraulic fracturing on drinking water resources, if any, and to identify the driving factors that may affect the severity and frequency of such impacts.

This report describes 18 research projects underway to answer these research questions and presents the progress made as of September 2012 for each of the projects. Information presented as part of this report cannot be used to draw conclusions about potential impacts to drinking water resources from hydraulic fracturing.

"The EPA recently associated glycols and glycol ethers with hydraulic fracturing fluids" is the motivation for the study presented in **File #31** published in *Ground Water Monitoring & Remediation*, 34 (4), 2014.

31. Smith et al. 2014 Organic Contaminants in Portland Cements Used in Monitoring Well Construction

This paper reports the results of two independent laboratory investigations to evaluate total and leachable concentrations of glycols, glycol ethers, phenol, and other compounds in representative Type I and Type I/II Portland cement products often used as annular sealants in monitoring well completions. USEPA has included some of these compounds for analysis in their *National Hydraulic Fracturing Study* to evaluate the effects of hydraulic fracturing on ground- and surface water resources. Three of five bulk cement products tested contained part per million (ppm) (mg/kg) concentrations of diethylene glycol, ethylene glycol, tetraethylene glycol, and triethylene glycol; chemicals added as grinding aids during manufacture. Some cements also contained ppb (µg/kg) concentrations of benzoic acid, phenols, propylene glycol, and 2-butoxyethanol. Leaching of cured cement samples in water produced ppm (mg/L) concentrations of glycols in the supernatant. These results show that cured cements in monitoring or water wells can contaminate groundwater samples with glycols and phenol. These findings should help prevent future sample bias and false positives when testing for glycol compounds and phenol in groundwater samples from monitoring or water wells and highlight the need to test materials or products used in monitoring or water well drilling, completions, development, and sampling to avoid false positives when sampling and analyzing for less common analytical constituents.

04. Encana 2013 Data Summary

This is an Excel file containing several data tabs that provides a concise summary of the analytical results from the five rounds of USEPA sampling:

- Topics – key points and references for geology, hydrogeology, well construction, and geochemistry. For example, it lists the lack of Waltman Shale Cap to prevent vertical migration

of gas (USGS 1996 [**File #20**]), and the occurrence of shallow gas historically (BOR 1951 [**File #02**], USGS 1969 [**File #19**]).

- Exec Summary – analytes that exceed EPA MCL/SMCL for the five rounds of domestic well water sampling by USEPA and USGS. Round #5 was conducted in April 2012 as described in **File #15**.
- Methane – methane analysis results for the five rounds of sampling.
- DRO-GRO – Summary of GRO-DRO detections and associated speciated analyses. None of DRO-GRO concentrations exceed Wyoming standard (VPR Fact Sheet 13).
- ATSDR – Summary of ATSDR Health Risk Evaluation.
- Hydrocarbon – Summary of hydrocarbons detections reported. Drinking water standards are provided for comparison.
- DRO Chromatograms – DRO chromatograms of samples collected during Phase II. All deviate from diesel standard.

05. Encana 2013 Well location Information

This Excel file contains coordinates (Latitude/Longitude) and total depth information for domestic water wells and the gas wells owned by Encana. Potential errors, in the order of several hundred feet, exist in the coordinates of many of the gas wells when comparing against the WOGCC data. A field verification plan was submitted to WDEQ and a tentative date for the field work was scheduled.

39. WDEQ 2014 Request for Information LTRS

This file contains WDEQ request for information letters to the Eastern Shoshone Tribe, Northern Arapahoe Tribe, USGS, Wyoming State Engineer's Office (WSEO), Wyoming Oil and Gas Conservation Commission (WOGCC), Bureau of Land Management, Encana, and USEPA Region 8. These request for information letters were part of WDEQ's effort to evaluate the current condition of water quality in Pavillion Field area domestic wells.

This file also contains a letter to WOGCC confirming that WDEQ has reviewed WOGCC's request for information letter relating to the development of Well Integrity and Pit Use reports, and provided all pertinent reports and information to WOGCC.

APPENDIX J

List of Permitted Water-Supply Wells within the Cistern Area

APPENDIX J

LIST OF PERMITTED WATER-SUPPLY WELLS WITHIN THE CISTERN AREA

Pavillion, Wyoming Area Domestic Water Wells

Final Report and Palatability Study

PERMIT	PRIORITY	STATUS	USES	TOWNSHIP	TNS_SUF	RANGE	RNG_SUF	SECTION	QTR	QTRQTR	LATITUDE	LONGITUDE	APPLICANT	FACNAME	YLDACT	S_DEPTH	W_DEPTH	MWBZ_TOP	MWBZ_BOT	WELL_LOG	CHEMICAL
P190920.0W	7/7/2009	INC	DOM_GW	3	N	2	E	2	SW	SWSW	43.260320	-108.613700	MEEKS LOUIS	MEEKS #1	25	0	0	0	0	NULL	NULL
P197335.0W	1/27/2012	INC	DOM_GW; STK	3	N	2	E	3	NW	NENW	43.271060	-108.630900	DOLBOW VINCENT	HILL FARM NEW PENS 1	25	0	0	0	0	NULL	NULL
P197336.0W	1/27/2012	INC	DOM_GW; STK	3	N	2	E	3	NW	NENW	43.270780	-108.630800	DOLBOW VINCENT	HILL FARM NEW PENS 2	25	0	0	0	0	NULL	NULL
P66345.0W	1/31/1984	FADJ	DOM_GW; STK	3	N	2	E	3	SW	NWSW	43.263650	-108.635800	GARLAND B. W. & LYDA	GARLAND #1	7	7	70	15	25	NULL	No
P14916.0P	6/30/1906	FADJ	DOM_GW	3	N	2	E	8	NE	SENE	43.252590	-108.660600	WEMPEN, JR. JOHN & BONNIE L.	WEMPEN #3	25	30	130	-1	-1	NULL	No
P196111.0W	7/5/2011	INC	DOM_GW; STK	3	N	2	E	8	SW	NWSW	43.248370	-108.675400	CHRISTIAN L. SHANE	CHRISTIAN # 2	25	0	0	0	0	NULL	NULL
P46173.0W	11/29/1978	FADJ	DOM_GW; STK	3	N	2	E	8	NW	NWNW	43.256130	-108.675500	DANOVSKY PERRY J.	DANOVSKY #3	15	40	260	220	258	NULL	No
P92056.0W	6/11/1993	COM	DOM_GW	3	N	2	E	8	SW	SWSW	43.245260	-108.675500	KEEN CARLOS L.	KEEN #1	15	50	70	50	70	NULL	No
P41517.0W	11/29/1977	FADJ	DOM_GW; STK	3	N	2	E	9	NW	NENW	43.256280	-108.650700	NEWKIRK ROBERT D. OR GWENDOLYN R.	NEWKIRK #2	25	50	200	180	200	NULL	No
P124049.0W	3/6/2000	COM	DOM_GW; STK	3	N	2	E	10	SW	SESW	43.245520	-108.630900	Lozier Robert E	Lozier Well #1	25	246	484	410	484	NULL	No
P200885.0W	8/16/2013	INC	DOM_GW;STK	3	N	2	E	10		SE1/4SE1/4	43.246419	-108.619150	CARL RAY PACE	ROOSTER KEY #1	25	0	0	0	0		
P24506.0P	12/31/1932	FADJ	DOM_GW; STK	3	N	2	E	10	SE	NWSE	43.249180	-108.625900	GRIFFIN MARVIN & EVELYN	MILLER #1	5	90	750	-1	-1	NULL	No
P24507.0P	12/31/1942	FADJ	DOM_GW; STK	3	N	2	E	10	SE	NWSE	43.249180	-108.625900	GRIFFIN MARVIN & EVELYN	MILLER #2	7	80	750	-1	-1	NULL	No
P24508.0P	12/31/1964	FADJ	STK	3	N	2	E	10	SE	NESE	43.249200	-108.621000	GRIFFIN MARVIN & EVELYN	MILLER #3	25	80	175	-1	-1	NULL	No
P166481.0W	4/7/2005	COM	STK	3	N	2	E	11	SE	SWSE	43.245200	-108.608400	ROBINSON JACK	ROBINSON #1	10	50	200	190	200	No	No
P31805.0W	1/20/1976	FADJ	DOM_GW; STK	3	N	2	E	11	SW	SESW	43.245620	-108.611100	FIKE WILLIAM J.	FIKE #3	5	50	100	70	90	NULL	No
P69549.0W	2/25/1985	COM	DOM_GW; STK	3	N	2	E	11	SW	SESW	43.245620	-108.611100	SCHUERMAN JAMES D. & BEVERLY D.	SCHUERMAN #1	15	45	100	45	100	NULL	No
P22660.0P	9/30/1938	FADJ	STK	3	N	2	E	13	NW	NWNW	43.242080	-108.596100	DENNIS JOSEPH B.	HUNT #1	25	12	175	-1	-1	NULL	No
P22661.0P	8/31/1947	FADJ	DOM_GW	3	N	2	E	13	NW	NENW	43.242120	-108.591100	DAVIS JOSEPH B.	HUNT #2	25	10	48	10	34	NULL	No
P22662.0P	12/31/1934	FADJ	DOM_GW	3	N	2	E	13	NW	SWNW	43.238440	-108.596100	DENNIS JOSEPH	HIPPE #1	25	10	30	-1	-1	NULL	No
P42890.0W	4/14/1978	FADJ	DOM_GW	3	N	2	E	13	NE	SENE	43.238540	-108.581100	BLAIR DOUGLAS E. & LINDA KARIN	BLAIR #1	15	14	57	-1	-1	NULL	Yes
P50375.0W	10/15/1979	FADJ	DOM_GW	3	N	2	E	13	NE	NWNE	43.242160	-108.586100	KLINKER MICHAEL D. & OR PATTY A.	KLINKER #1	22	12	100	64	83	NULL	No
P60032.0W	3/23/1982	FADJ	DOM_GW; STK	3	N	2	E	13	SW	NWSW	43.234800	-108.596100	NOLTING DEAN L.	NOLTING #1	15	18	86	75	85	NULL	No
P64110.0W	5/24/1983	FADJ	DOM_GW; STK	3	N	2	E	13	NW	NWNW	43.242080	-108.596100	DENNIS JOE B.	DENNIS #1	20	235	675	661	669	NULL	Yes
P9434.0P	12/31/1930	FADJ	STK	3	N	2	E	13	NE	SENE	43.238540	-108.581100	MOTHERSBAUGH GERALD D.	AGGIE #1	7.5	30	80	-1	-1	NULL	No
P24502.0P	12/31/1942	FADJ	DOM_GW; STK	3	N	2	E	14	SE	SWSE	43.232480	-108.604200	GRIFFIN MARVIN	SAM BLACK #185	-1	35	180	-1	-1	NULL	No
P29496.0P	3/31/1975	FADJ	DOM_GW; STK	3	N	2	E	14	NW	NENW	43.241980	-108.611100	HENRY JAMES E. & BARBARA J.	HENRY #1	20	20	130	-1	-1	NULL	No
P41320.0W	12/19/1977	FADJ	DOM_GW	3	N	2	E	14	NE	NWNE	43.242010	-108.606100	HUGHES GLEN L.	#1	12	40	100	80	90	NULL	No
P44255.0W	7/18/1978	FADJ	DOM_GW	3	N	2	E	14	NE	NWNE	43.242010	-108.606100	HUGHES GLEN L.	ENL #1	12	60	225	195	225	NULL	No

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Final Report and Palatability Study

PERMIT	PRIORITY	STATUS	USES	TOWNSHIP	TNS_SUF	RANGE	RNG_SUF	SECTION	QTR	QTRQTR	LATITUDE	LONGITUDE	APPLICANT	FACNAME	YLDACT	S_DEPTH	W_DEPTH	MWBZ_TOP	MWBZ_BOT	WELL_LOG	CHEMICAL
P59499.0W	2/3/1982	FADJ	DOM_GW; STK	3	N	2	E	14	SW	NESW	43.234710	-108.611000	ZUBER JOE & DELORES M.	ZUBER #3	15	60	110	80	104	NULL	No
P61489.0W	7/15/1982	FADJ	DOM_GW; STK	3	N	2	E	14	SE	NWSE	43.236110	-108.604200	NOLTING DEAN &OR KAY	NOLTING #2	15	25	85	55	85	NULL	No
P91293.0W	4/5/1993	COM	STK	3	N	2	E	14	NW	NWNW	43.241950	-108.616100	BISBEE DAN	PONDEROSA #1	1.5	-4	10	8	10	NULL	No
P99671.0W	6/28/1995	COM	DOM_GW; STK	3	N	2	E	14	NE	NWNE	43.242010	-108.606100	MYERS JERRY J. & SANDRA J.	DUSTIN #1	5	28	55	-1	-1	NULL	No
P102252.0W	5/3/1996	COM	DOM_GW; STK	3	N	2	E	15	SW	SWSW	43.230990	-108.635800	KILLEBREW HOWARD E	YODER #1	10	150	375	325	370	NULL	No
P108128.0W	11/5/1997	COM	DOM_GW; STK	3	N	2	E	15	SE	SESE	43.231040	-108.620900	FOXWORTHY RAY	CROWN HEART #1	2	60	379	310	379	NULL	No
P146856.0W	9/5/2002	COM	STK	3	N	2	E	15	SE	SESE	43.231040	-108.620900	FOXWORTHY RAY	CROWN HEART # 2	5	89	380	355	370	NULL	No
P19279.0P	5/1/1940	FADJ	DOM_GW; STK	3	N	2	E	15	SW	SWSW	43.230990	-108.635800	LOCKER RUSSELL	VERMILION #1	10	80	120	-1	-1	NULL	No
P150480.0W	4/21/2003	COM	DOM_GW; STK	3	N	2	E	16	SW	NWSW	43.234290	-108.655800	CHAPMAN CARL T. AND KATHY	BEARD # 1	12	40	467	0	0	Yes	No
P183732.0W	10/11/2007	COM	DOM_GW; STK	3	N	2	E	16	SW	NWSW	43.235720	-108.656500	CHAPMAN CARL AND KATHY	CHAPMAN #1	15	220	740	710	735	No	No
P9217.0P	12/31/1932	FADJ	DOM_GW	3	N	2	E	16	SE	NWSE	43.234570	-108.645700	FEDERAL HOUSING AUTHORITY / DENKE DELORES / DENKE DONALD	ROCK HOUSE WELL #1	7.5	40	100	-1	-1	NULL	No
P9218.0P	12/31/1930	FADJ	DOM_GW; STK	3	N	2	E	16	NE	SWNE	43.238200	-108.645700	FEDERAL HOUSING AUTHORITY / DENKE DELORES / DENKE DONALD	THE WELL #1	7.5	40	95	-1	-1	NULL	No
P101483.0W	2/12/1996	COM	DOM_GW	3	N	2	E	17	NE	NWNE	43.241700	-108.665500	HOLMES BRUCE C/JOHANNA	HOLMES #1	10	8	80	50	70	NULL	No
P108882.0W	2/2/1998	COM	STK	3	N	2	E	17	SW	SWSW	43.230750	-108.675500	CHILDERS WESLEY/THELMA	CHILDERS #1	5	45	78	60	70	NULL	No
P151201.0W	5/14/2003	COM	DOM_GW; STK	3	N	2	E	17	SW	NWSW	43.234380	-108.675500	PIERNICK LISA	PIERNICK # 1	10	234	480	424	475	NULL	No
P182983.0W	8/9/2007	COM	DOM_GW	3	N	2	E	17	NE	SENE	43.237980	-108.658300	MCFALL ROB AND ANN	MCFALL 1	14	350	760	720	755	No	No
P187102.0W	6/9/2008	INC	DOM_GW	3	N	2	E	17	SE	NESE	43.234172	-108.660544	HALL JOSEPH	HALL'S #1	10	0	0	0	0		
P46362.0W	1/18/1979	FADJ	DOM_GW	3	N	2	E	17	NW	SWNW	43.238010	-108.675500	DAVENPORT THOMAS / CLOMAN CLIFFORD & DONNA	CLOMAN #3	25	170	220	170	180	NULL	No
P65111.0W	8/3/1983	FADJ	DOM_GW	3	N	2	E	17	SW	SESW	43.230780	-108.670500	JELLISON BERT OR DEBBIE	JELLISION #1	13	45	90	30	39	NULL	No
P85382.0W	6/19/1991	COM	DOM_GW; STK	3	N	2	E	17	NE	NWNE	43.241700	-108.665500	RAYMOND ARNOLD G. AND RUTH DIANE	RAYMOND #1	10	8	100	55	95	NULL	No
P95171.0W	5/9/1994	COM	STK	3	N	2	E	17	SW	SESW	43.230780	-108.670500	CHILDERS WESLEY/THELMA	CHILDERS #2	3	12	85	-1	-1	NULL	No
P120203.0W	11/8/1999	COM	DOM_GW; STK	3	N	2	E	20	NE	NENE	43.227250	-108.660500	FINLAYSON D. G.	Finlayson #3	25	100	450	410	450	NULL	No
P145563.0W	7/1/2002	COM	DOM_GW; STK	3	N	2	E	20	SW	NESW	43.219940	-108.670500	TAFT ROB	TAFT #1	15	143	410	340	410	NULL	No
P23056.0P	1/4/1960	FADJ	DOM_GW; STK	3	N	2	E	20	NE	NENE	43.227250	-108.660500	FINLAYSON D. G.	FINLAYSON #2	25	5	65	-1	-1	NULL	Yes
P25636.0W	1/7/1974	FADJ	DOM_GW; STK	3	N	2	E	20	SW	SESW	43.216320	-108.670500	BASHORE LLOYD & MILDRED	BASHORE #3	25	21	41	-1	-1	NULL	No
P52132.0W	5/14/1980	FADJ	DOM_GW	3	N	2	E	21	SW	SWSW	43.216410	-108.655500	PARK JACK L. & JEAN A.	JACK #1	6	60	120	60	120	NULL	No

APPENDIX J

LIST OF PERMITTED WATER-SUPPLY WELLS WITHIN THE CISTERN AREA

Pavillion, Wyoming Area Domestic Water Wells

Final Report and Palatability Study

PERMIT	PRIORITY	STATUS	USES	TOWNSHIP	TNS_SUF	RANGE	RNG_SUF	SECTION	QTR	QTRQTR	LATITUDE	LONGITUDE	APPLICANT	FACNAME	YLDACT	S_DEPTH	W_DEPTH	MWBZ_TOP	MWBZ_BOT	WELL_LOG	CHEMICAL
P52267.0W	5/14/1980	FADJ	DOM_GW	3	N	2	E	21	SW	SWSW	43.216410	-108.655500	FOXWORTHY RAY	RAY #1	11.5	50	200	60	120	NULL	No
P94228.0W	1/3/1994	COM	DOM_GW	3	N	2	E	21	SE	SWSE	43.216500	-108.645800	ALBRIGHT SAM & TRACY	POOR BOY 1	24	20	57	50	57	NULL	No
P110443.0W	6/12/1998	COM	DOM_GW; STK	3	N	2	E	22	SW	SESW	43.216560	-108.631000	DENKE DONALD/DELORES	NEW RODEN PLACE WELL	10	214	420	364	417	NULL	No
P148807.0W	1/15/2003	COM	DOM_GW	3	N	2	E	22	SE	SWSE	43.216560	-108.626000	GRIFFITH STEVE	GRIFFITH #2	20	31	135	105	135	NULL	No
P19278.0P	6/2/1941	FADJ	DOM_GW; STK	3	N	2	E	22	NW	NENW	43.227390	-108.630800	LOCKER RUSSELL	DAIGLE #1	20	50	120	-1	-1	NULL	No
P194701.0W	12/6/2010	INC	DOM_GW; STK	3	N	2	E	22	NE	SWNE	43.224660	-108.625900	FOXWORTHY RAYMOND	SWIFT	25	0	0	0	0	NULL	NULL
P201293.0W	11/12/2013	INC	DOM_GW; STK	3	N	2	E	22		SW1/4SE1/	43.216590	-108.625950	STEVE AND PATTI GRIFFITH	GRIFFITH #1	25	0	0	0	0		
P102933.0W	7/5/1996	COM	DOM_GW	3	N	2	E	23	SW	SWSW	43.216580	-108.615900	COULSON TIM/HEIDI	COULSON #1	15	140	200	170	198	NULL	No
P106821.0W	7/21/1997	COM	DOM_GW; STK	3	N	2	E	23	SE	NWSE	43.220240	-108.606000	NULL	ABNEY #1	25	80	120	-1	-1	NULL	No
P141375.0W	12/13/2001	COM	STK	3	N	2	E	23	SW	SWSW	43.216580	-108.615900	HENRY CHARLES & KYLA	HENRY #1	2	40	80	72	77	NULL	No
P21711.0P	12/31/1936	FADJ	DOM_GW; STK	3	N	2	E	23	NW	SWNW	43.223820	-108.615900	TAYLOR DARYL W.	BROWNE #1	22.5	-1	150	-1	-1	NULL	No
P42224.0W	3/2/1978	FADJ	DOM_GW; STK	3	N	2	E	23	NW	SWNW	43.223820	-108.615900	TAYLOR DARYL W. & LUADA	TAYLOR #6	8	19	90	52	76	NULL	No
P58302.0W	9/23/1981	FADJ	DOM_GW	3	N	2	E	23	SW	SWSW	43.216580	-108.615900	ASAY KEN & SHIRLEY	ASAY #1	25	13	65	30	65	NULL	No
P76476.0W	3/21/1988	COM	DOM_GW	3	N	2	E	23	SE	SWSE	43.216610	-108.606000	ABNEY WM. SCOTT & MARY M.	ABNEY #1	11	60	120	105	120	NULL	No
P26200.0W	3/15/1974	FADJ	DOM_GW	3	N	2	E	24	SE	SESE	43.216710	-108.581300	LINDSTADT GILBER H.	LINDSTADT #1	12	30	740	275	290	NULL	Yes
P28496.0W	11/25/1974	FADJ	DOM_GW	3	N	2	E	24	SE	NESE	43.220330	-108.581400	LINDSTADT G. H.	LINDSTADT #2	6	18	65	20	36	NULL	Yes
P13206.0P	9/30/1937	FADJ	DOM_GW; STK	3	N	3	E	18	NW	NENW	43.242120	-108.571700	PATTISON CLIFFORD F.	PATTISON #1	6	110	270	-1	-1	NULL	No
P13208.0P	7/31/1942	FADJ	DOM_GW; STK	3	N	3	E	18	NE	SENE	43.238350	-108.561900	PATTISON VERA	PATTISON #3	6	330	590	-1	-1	NULL	No
P187230.0W	7/7/2008	COM	DOM_GW	3	N	3	E	18	SW	SWSW	43.231120	-108.575800	LINDSTADT MICHAEL AND THERESA	OCEAN LAKE VIEW 1	10	30	160	130	160	No	No
P27667.0W	8/13/1974	FADJ	DOM_GW; STK	3	N	3	E	18	SW	SESW	43.231170	-108.571800	LANGMAN PAUL M. & MARJORIE H.	LANGMAN #2	4.5	40	140	125	135	NULL	No
P9694.0P	12/31/1940	FADJ	DOM_GW; STK	3	N	3	E	18	SE	SESE	43.231080	-108.561900	MIRANDA CHARLES F.	MIRANDA #1	15	12	80	-1	-1	NULL	No
P103447.0W	8/13/1996	COM	DOM_GW	3	N	3	E	19	SW	NWSW	43.220310	-108.576600	KRISCHE RALPH J/TINA M	COLLEEN ONE	25	45	97	80	90	NULL	No
P103691.0W	9/6/1996	COM	DOM_GW	3	N	3	E	19	SW	NWSW	43.220310	-108.576600	KRISCHE RALPH J/TINA M	COLLEEN TWO	4	50	125	-1	-1	NULL	No
P106029.0W	5/15/1997	COM	DOM_GW	3	N	3	E	19	NE	SENE	43.223820	-108.561900	LENIGER NINA	LENIGER #2	15	247	497	399	-1	NULL	No
P124584.0W	4/10/2000	COM	DOM_GW	3	N	3	E	19	SE	SESE	43.216540	-108.561900	ACKLEY GEORGE LAWRENCE	ACKLEY #1	25	98	496	455	496	NULL	No
P177246.0W	9/12/2006	COM	DOM_GW	3	N	3	E	19	SE	SWSE	43.216580	-108.565800	SUMMERLIN DANIEL I. AND SHEILA R.	SUMMERLIN 1	25	162	1000	980	1000	No	No
P190223.0W	4/27/2009	COM	DOM_GW	3	N	3	E	19	SW	NESW	43.219120	-108.571300	STOYSICH JOHN	STOYSICH	20	250	1055	100	1050	No	No
P191209.0W	7/17/2009	COM	DOM_GW; STK	3	N	3	E	19	SW	SWSW	43.216590	-108.576400	EVANS ALBERT LEON	EVANS WELL	25	0	0	0	0	NULL	NULL
P23972.0W	8/14/1973	FADJ	DOM_GW; STK	3	N	3	E	19	SE	SWSE	43.216590	-108.566900	CARROLL C. MELVIN & CLARA A.	CARROLL #1	25	-1	72	-1	-1	NULL	Yes
P27567.0W	7/29/1974	FADJ	DOM_GW	3	N	3	E	19	SW	NWSW	43.220310	-108.576600	RORABAUGH E. L.	RORABAUGH #1	20	12	60	30	40	NULL	No
P27666.0W	8/13/1974	FADJ	DOM_GW	3	N	3	E	19	NW	NENW	43.228910	-108.573600	LANGMAN PAUL M. & MARJORIE H.	LANGMAN #1	10	25	300	280	300	NULL	No

APPENDIX J

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Pavillion, Wyoming Area Domestic Water Wells

Final Report and Palatability Study

PERMIT	PRIORITY	STATUS	USES	TOWNSHIP	TNS_SUF	RANGE	RNG_SUF	SECTION	QTR	QTRQTR	LATITUDE	LONGITUDE	APPLICANT	FACNAME	YLDACT	S_DEPTH	W_DEPTH	MWBZ_TOP	MWBZ_BOT	WELL_LOG	CHEMICAL
P27668.0W	8/13/1974	FADJ	STK	3	N	3	E	19	NW	NENW	43.228910	-108.573600	LANGMAN PAUL M. & MARJORIE H.	LANGMAN #3	7	25	80	50	60	NULL	No
P28859.0W	1/17/1975	FADJ	DOM_GW	3	N	3	E	19	NE	SENE	43.223820	-108.561900	WILSON ZANE G.	WILSON #1	15	55	120	-1	-1	NULL	No
P31016.0W	8/21/1975	FADJ	DOM_GW	3	N	3	E	19	SW	SESW	43.216640	-108.571900	FRANK BILL & ELIZABETH	FRANK #1	10	40	140	105	130	NULL	No
P34376.0W	8/5/1976	FADJ	DOM_GW	3	N	3	E	19	SE	SWSE	43.216590	-108.566900	WITTHAR JULIAN DAVID & JOYCE ANN	WITTHAR #1	24	45	150	130	140	NULL	No
P35829.0W	1/10/1977	FADJ	DOM_GW; STK	3	N	3	E	19	SE	SWSE	43.216590	-108.566900	GILLILAND ROBERT J. & FAY	FAY #2	25	30	44	30	40	NULL	Yes
P41024.0W	9/22/1977	FADJ	DOM_GW; STK	3	N	3	E	19	SE	NESE	43.221560	-108.563800	LONG GRACIA M. / LONG JAMES M.	LAKEN #1	15	80	350	330	340	NULL	Yes
P45059.0W	9/19/1978	FADJ	DOM_GW	3	N	3	E	19	NE	SWNE	43.223860	-108.566900	WYANT GENE E.	WYANT #1	10	50	307	285	300	NULL	No
P45065.0W	9/21/1978	FADJ	DOM_GW; STK	3	N	3	E	19	NW	NENW	43.228910	-108.573600	UDEN GERALD LEE	UDEN #1	20	40	160	137	148	NULL	No
P47997.0W	5/16/1979	FADJ	DOM_GW	3	N	3	E	19	NE	NWNE	43.227490	-108.566900	STORKEL GAYLEN & ROBERTA L.	STOCKEL #1	25	15	60	38	60	NULL	No
P69458.0W	2/26/1985	COM	DOM_GW	3	N	3	E	19	NW	SENW	43.225280	-108.573700	SEATON JACK & EILEEN	SEATON #1	8	55	330	309	329	NULL	No
P86439.0W	10/17/1991	COM	DOM_GW	3	N	3	E	19	SE	SWSE	43.216590	-108.566900	BAKER WILLIAM & IRENE	BILL #1	25	12	45	25	40	NULL	No

APPENDIX K

Location Verification of Oil and Gas Wells and Associated Pits

Appendix K Table 1

COMPARISON OF LATITUDE AND LONGITUDE DATA BETWEEN WOGCC AND ENCANA AND SELECTION OF LOCATIONS FOR VERIFICATION BY % ERROR
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC LOCATION	Error as % WOGCC Distance to Water Well	Error as % ENCANA Distance to Water Well	Verify	Notes/ Selected Detailed Notes for Some Wells	DISTANCE WOGCC TO ENCANA (FEET)	NEAREST Water Well TO WOGCC	DISTANCE WOGCC TO Water Well	ENCANA LOCATION	NEAREST Water Well TO ENCANA	DISTANCE ENCANA TO Water Well	WOGCC API	ENCANA API (7-DIGIT)	ENCANA API (FULL)	WOGCC LATITUDE	WOGCC LONGITUDE	ENCANA LATITUDE	ENCANA LONGITUDE	WOGCC DEPTH	ENCANA DEPTH	WOGCC SPUD_DATE	ENCANA SPUD_DATE
Pavillion Fee 11-11	197%	93%	Y	WOGCC well integrity report lat/long appear correct; near apparent wellhead on aerial. Encana erroneous lat/long, maps at another well, 13-11. Survey document on WOGCC website erroneous, places well near other equipment to north of actual well head.	2357.90	PGDW49	1197.68	Pavillion Fee 11-11	PGDW23	2525.03	1322059	1322059	4901322059	43.255109	-108.613611	43.248650	-108.613110	5,846	5846	12/7/2000	12/7/2000
Leonhardt 41-26	194%	66%	N	Use lat/long from WOGCC well integrity report: is in correct T,R,S, 1/4-1/4; also matches survey document on WOGCC website. However, lat long on WOGCC website summary record is incorrect; this same incorrect value is in Encana data set (well not operated by Encana). On aerial imagery apparent ouline of former pad/pit visible.	61444.35	PGDW32	31725.81	Leonhardt 41-26	PGDW32	92592.23	1323068	1323068	4901323068	43.213611	-108.481028	43.124900	-108.285170	5,100	7500	5/20/2007	5/20/2007
Tribal Pavillion 32-10	128%	112%	Y		946.19	PGDW14	739.69	Tribal Pavillion 32-10	PGDW14	846.64	1321968	1321968	4901321968	43.253300	-108.626000	43.253220	-108.629550	5,593	5600	2/27/2000	2/27/2000
Pavillion Fee 34-03	103%	53%	Y	Plugged 2003.	1275.66	PGDW30	1234.71	Pavillion Fee 34-03	PGDW30	2385.58	1322005	1322005	4901322005	43.260280	-108.625280	43.263780	-108.625260	192	3600	12/9/2000	12/28/2000
Pavillion Fee 13X-3	73%	157%	Y	Plugged 1999.	786.30	PGDW41B	1070.96	Pavillion Fee 13X-03	PGDW41B	502.03	1321904	1321904	4901321904	43.263330	-108.634170	43.263410	-108.637120	6,044	6044	1/8/1999	1/8/1999
Tribal Pavillion 32-10C	70%	58%	Y		176.77	PGDW14	252.98	Tribal Pavillion 32-10C	PGDW14	302.94	1322419	1322419	4901322419	43.252220	-108.627500	43.252270	-108.626840	4,020	4020	1/27/2005	1/27/2005
Pavillion Fee 13-03W	38%	28%	Y		178.26	PGDW41B	475.24	Pavillion Fee 13-03W	PGDW41B	633.35	1322246	1322246	4901322246	43.262920	-108.636417	43.262960	-108.635750	4,602	4602	4/3/2005	4/3/2005
Tribal Pavillion 33-10B	32%	41%	Y		178.90	PGDW23	550.85	Tribal Pavillion 33-10B	PGDW23	432.07	1322274	1322274	4901322274	43.249530	-108.624278	43.249580	-108.623610	5,610	5610	11/7/2004	11/7/2004
Tribal Pavillion 43-10B	31%	25%	Y		177.85	PGDW23	581.50	Tribal Pavillion 43-10B	PGDW23	714.66	1322420	1322420	4901322420	43.247610	-108.620944	43.247660	-108.620280	5,760	5760	10/28/2004	10/28/2004
Tribal Pavillion 33-10	28%	26%	Y		132.29	PGDW44	466.81	Tribal Pavillion 33-10	PGDW44	513.63	1321862	1321862	4901321862	43.249170	-108.625560	43.248920	-108.625920	5,970	6000	2/13/1999	2/13/1999
Pavillion Fee 12-11B	27%	22%	Y		177.30	PGDW49	649.39	Pavillion Fee 12-11B	PGDW49	801.43	1322272	1322272	4901322272	43.254220	-108.615972	43.254270	-108.615310	3,860	3860	12/16/2004	12/16/2004
Pavillion Fee 43-04	27%	36%	Y		177.27	PGDW41A	653.33	Pavillion Fee 43-04	PGDW41A	492.77	1322633	1322633	4901322633	43.262610	-108.640222	43.262660	-108.639560	4,744	4744	3/1/2005	3/1/2005
Pavillion Fee 41-10B	27%	23%	Y		179.22	PGDW30	672.15	Pavillion Fee 41-10B	PGDW49	787.24	1322624	1322624	4901322624	43.256940	-108.620167	43.256986	-108.619497	3,841	3841	4/12/2005	4/12/2005
Tribal Pavillion 33-10W	25%	27%	Y		148.36	PGDW44	586.32	Tribal Pavillion 33-10W	PGDW44	551.24	1322195	1322195	4901322195	43.248690	-108.626806	43.248770	-108.626260	5,070	5070	10/9/2001	10/9/2001
Tribal Pavillion 23-11	22%	26%	N	Both locations > 1/4 mile. Use Encana has correct 1/4-1/4 section.	732.87	PGDW05	3382.81	Tribal Pavillion 23-11	PGDW49	2830.00	1321806	1321806	4901321806	43.250710	-108.606530	43.250760	-108.609280	5,540	5540	10/19/1997	10/19/1997
Tribal Pavillion 21-11B	21%	19%	Y		178.61	PGDW05	832.47	Tribal Pavillion 21-11B	PGDW05	928.25	1322586	1322586	4901322586	43.256940	-108.610917	43.256990	-108.610250	3,875	3875	3/28/2005	3/28/2005
Tribal 42-10	21%	20%	Y		138.73	PGDW49	652.03	Tribal Pavillion 42-10	PGDW49	699.29	1321696	1321696	4901321696	43.254540	-108.620440	43.254160	-108.620410	5,995	5995	5/2/1994	5/2/1994
Pavillion Fee 14-03W	18%	16%			137.60	PGDW41A	760.72	Pavillion Fee 14-03W	PGDW41B	878.69	1322219	1322219	4901322219	43.260720	-108.635750	43.260660	-108.635240	5,700	5700	3/19/2002	3/19/2002
Tribal Pavillion 32-10B	18%	16%			144.70	PGDW14	826.28	Tribal Pavillion 32-10B	PGDW14	900.17	1322224	1322224	4901322224	43.253280	-108.625389	43.253190	-108.624860	5,850	5850	2/23/2002	2/23/2002
Pavillion Fee 12-11W	17%	15%			238.47	PGDW49	1412.43	Pavillion Fee 12-11W	PGDW49	1581.99	1322102	1322102	4901322102	43.251940	-108.615000	43.251870	-108.614110	3,250	3250	4/15/2001	4/15/2001
Tribal Pavillion 23-10B	16%	19%			177.31	PGDW14	1098.04	Tribal Pavillion 23-10B	PGDW14	927.68	1322417	1322417	4901322417	43.250470	-108.631222	43.250520	-108.630560	5,646	5646	9/28/2004	9/28/2004
Tribal Pavillion 32-02	16%	19%			684.52	PGDW05	4261.73	Tribal Pavillion 32-02	PGDW05	3584.22	1322245	1322245	4901322245	43.268861	-108.604361	43.267140	-108.605390	5,280	5280	2/24/2006	2/24/2006
Pavillion Fee 11-11B	16%	15%			143.39	PGDW49	897.94	Pavillion Fee 11-11B	PGDW49	970.83	1322220	1322220	4901322220	43.256970	-108.615944	43.256880	-108.615420	4,780	4780	1/22/2002	1/22/2002
Pavillion Fee 44-04	16%	17%			177.81	PGDW41A	1125.52	Pavillion Fee 44-04	PGDW41A	1032.65	1322634	1322634	4901322634	43.259440	-108.639944	43.259490	-108.639280	5,700	5700	2/6/2005	2/6/2005
Tribal Pavillion 23-10C	15%	17%			177.31	PGDW44	1186.66	Tribal Pavillion 23-10C	PGDW44	1059.80	1322418	1322418	4901322418	43.247890	-108.629472	43.247940	-108.628810	5,730	5730	9/19/2004	9/19/2004
Tribal Pavillion 42-10B	15%	16%			177.83	PGDW49	1191.18	Tribal Pavillion 42-10B	PGDW49	1102.46	1322324	1322324	4901322324	43.252190	-108.620194	43.252240	-108.619530	5,605	5605	1/7/2005	1/7/2005
Pavillion Fee 32-09W	15%	13%			136.59	PGDW42	919.44	Pavillion Fee 32-09W	PGDW42	1030.20	1322227	1322227	4901322227	43.254080	-108.644722	43.254060	-108.644210	3,460	3460	3/4/2002	3/4/2002
Pavillion Fee 31-10B	14%	14%			177.29	PGDW14	1262.58	Pavillion Fee 31-10B	PGDW14	1261.08	1322268	1322268	4901322268	43.254940	-108.628222	43.254990	-108.627560	5,555	5555	12/10/2004	12/10/2004
Govt Tribal 33X-10	13%	14%		AME has GPS data.	40.63	PGDW44	311.25	Tribal Pavillion 33X-10	PGDW44	285.67	1306363	1306363	4901306363	43.250190	-108.625280	43.250280	-108.625370	19,235	19235	5/21/1963	5/21/1963
Pavillion Fee 14-03B	13%	12%			176.75	PGDW41A	1372.39	Pavillion Fee 14-03B	PGDW41B	1488.90	1322623	1322623	4901322623	43.259440	-108.634250	43.259490	-108.633590	3,934	3934	3/20/2005	3/20/2005
Tribal Pavillion 44-03C	13%	13%			178.87	PGDW30	1393.23	Tribal Pavillion 44-03C	PGDW30	1415.07	1322721	1322721	4901322721	43.261360	-108.622778	43.261410	-108.622110	3,903	3903	5/15/2005	5/15/2005
Pavillion Unit 12-11	12%	12%			167.02	PGDW49	1345.78	Pavillion Fee 12-11	PGDW49	1419.47	1321669	1321669	4901321669	43.252270	-108.614830	43.251860	-108.615110	6,482	6482	6/17/1993	6/17/1993

Appendix K Table 1

COMPARISON OF LATITUDE AND LONGITUDE DATA BETWEEN WOGCC AND ENCANA AND SELECTION OF LOCATIONS FOR VERIFICATION BY % ERROR
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC LOCATION	Error as % WOGCC Distance to Water Well	Error as % ENCANA Distance to Water Well	Verify	Notes/ Selected Detailed Notes for Some Wells	DISTANCE WOGCC TO ENCANA (FEET)	NEAREST Water Well TO WOGCC	DISTANCE WOGCC TO Water Well	ENCANA LOCATION	NEAREST Water Well TO ENCANA	DISTANCE ENCANA TO Water Well	WOGCC API	ENCANA API (7-DIGIT)	ENCANA API (FULL)	WOGCC LATITUDE	WOGCC LONGITUDE	ENCANA LATITUDE	ENCANA LONGITUDE	WOGCC DEPTH	ENCANA DEPTH	WOGCC SPUD_DATE	ENCANA SPUD_DATE
Tribal Pavillion 32-1	11%	12%			700.52	PGDW20	6102.85	Tribal Pavillion 32-01	PGDW20	5872.50	1322026	1322026	4901322026	43.267220	-108.582780	43.267200	-108.585410	3,380	3380	1/28/2001	1/26/2001
Pavillion Fee 34-03R	11%	12%			136.56	PGDW30	1234.39	Pavillion Fee 34-03R	PGDW30	1137.85	1322087	1322087	4901322087	43.260280	-108.625278	43.260207	-108.624775	3,400	3600	12/28/2000	12/28/2000
Tribal Pavillion 13-02B	11%	11%			178.59	PGDW45	1622.01	Tribal Pavillion 13-02B	PGDW45	1645.15	1322627	1322627	4901322627	43.263330	-108.613167	43.263380	-108.612500	3,970	3970	3/5/2005	3/5/2005
Tribal Pavillion 12-1	10%	11%			601.26	PGDW20	5874.14	Tribal Pavillion 12-01	PGDW20	5552.09	1322181	1322181	4901322181	43.267780	-108.591694	43.266810	-108.593520	3,505	3700	9/16/2001	9/16/2001
Tribal Pavillion 23-10W	10%	11%			147.63	PGDW44	1449.98	Tribal Pavillion 23-10W	PGDW44	1306.14	1322217	1322217	4901322217	43.248860	-108.631528	43.248920	-108.630980	4,590	4590	3/13/2002	3/13/2002
Pavillion Fee 21-10B	10%	10%			176.96	PGDW14	1860.90	Pavillion Fee 21-10B	PGDW14	1739.47	1322269	1322269	4901322269	43.254810	-108.632722	43.254850	-108.632060	5,625	5625	12/24/2004	12/24/2004
Pavillion Fee 13-11B	9%	9%			149.26	PGDW23	1600.59	Pavillion Fee 13-11B	PGDW23	1749.71	1322240	1322240	4901322240	43.249610	-108.616722	43.249680	-108.616170	5,660	5660	2/13/2002	2/13/2002
Pavillion Fee 31-9	9%	10%			71.36	PGDW42	769.78	Pavillion Fee 31-09	PGDW42	701.88	1322172	1322172	4901322172	43.256860	-108.644861	43.256810	-108.645120	3,445	3445	9/25/2001	9/25/2001
Pavillion Fee 22-11C	9%	9%			176.69	PGDW05	1935.60	Pavillion Fee 22-11C	PGDW05	2020.65	1322314	1322314	4901322314	43.254310	-108.608861	43.254350	-108.608200	3,850	3850	2/1/2005	2/1/2005
Tribal Pavillion 12-13	9%	8%			40.44	PGDW33	443.68	Tribal Pavillion 12-13	PGDW33	476.16	1320855	1320855	4901320855	43.239590	-108.595560	43.239700	-108.595580	5,400	5331	12/27/1978	12/27/1978
Tribal Pavillion 33-02C	9%	9%			176.48	PGDW05	1943.56	Tribal Pavillion 33-02C	PGDW05	2064.65	1322617	1322617	4901322617	43.263190	-108.608389	43.263240	-108.607730	3,710	3710	2/10/2005	2/10/2005
Pavillion Fee 22-11B	9%	8%			176.51	PGDW49	1962.95	Pavillion Fee 22-11B	PGDW49	2085.14	1322271	1322271	4901322271	43.251470	-108.612639	43.251520	-108.611980	4,500	4500	1/21/2005	1/21/2005
Pavillion Fee 13-12W	9%	9%			161.82	LD-02	1860.60	Pavillion Fee 13-12W	LD-02	1726.65	1322214	1322214	4901322214	43.248500	-108.596806	43.248530	-108.596200	4,025	4025	12/8/2001	12/8/2001
Tribal 14-2	9%	9%			76.72	PGDW45	895.03	Tribal Pavillion 14-02	PGDW45	860.73	1321128	1321128	4901321128	43.260210	-108.615830	43.260000	-108.615850	5,175	5250	11/3/1980	11/17/1980
Pavillion Fee 42-04B	9%	9%			177.79	PGDW41B	2081.52	Pavillion Fee 42-04B	PGDW41B	2059.05	1322635	1322635	4901322635	43.267640	-108.639944	43.267690	-108.639280	3,968	3968	3/13/2005	3/13/2005
Tribal Pavillion 44-03	8%	7%			62.80	PGDW30	791.65	Tribal Pavillion 44-03	PGDW30	843.21	1321906	1321906	4901321906	43.259440	-108.621110	43.259611	-108.621139	6,009	6009	1/25/1999	1/25/1999
Pavillion Fee 42-09W	8%	7%			141.04	PGDW42	1809.72	Pavillion Fee 42-09W	PGDW42	1939.84	1322228	1322228	4901322228	43.253080	-108.641583	43.253020	-108.641060	3,420	3420	3/9/2002	3/9/2002
Pavillion Fee 13-10	8%	8%			176.52	PGDW14	2312.83	Pavillion Fee 13-10	PGDW14	2144.19	1322243	1322243	4901322243	43.249110	-108.635389	43.249160	-108.634730	5,705	5705	11/18/2004	11/18/2004
Pavillion Fee 21-10W	7%	7%			136.09	PGDW14	1898.58	Pavillion Fee 21-10W	PGDW14	1818.99	1322188	1322188	4901322188	43.256250	-108.630389	43.256170	-108.629890	4,400	4400	8/31/2001	8/31/2001
Pavillion Fee 21-10	7%	7%			138.43	PGDW14	1944.81	Pavillion Fee 21-10	PGDW14	1858.80	1322125	1322125	4901322125	43.256250	-108.630778	43.256170	-108.630270	5,930	5930	7/10/2001	7/11/2001
Pavillion 11-10	7%	7%			155.38	PGDW41A	2213.53	Tribal Pavillion 11-10	PGDW41A	2347.44	1321676	1321676	4901321676	43.256480	-108.634800	43.256060	-108.634900	8,082	8082	8/23/1993	8/23/1993
Mae H. Rhodes 1	7%	6%			69.71	PGDW41A	1028.00	Rhodes Mae	PGDW41A	1073.81	1306388	1306388	4901306388	43.260090	-108.635190	43.259900	-108.635220	11,000	10943	8/10/1953	8/10/1953
Pavillion Fee 32-11	7%	6%			169.71	PGDW05	2502.97	Pavillion Fee 32-11	PGDW05	2640.95	1322223	1322223	4901322223	43.253560	-108.606639	43.253450	-108.606020	4,000	4000	2/3/2002	2/3/2002
Pavillion Fee 43-11	7%	7%			164.59	PGDW20	2461.83	Pavillion Fee 43-11	PGDW20	2297.24	1322200	1322200	4901322200	43.250890	-108.600444	43.250940	-108.599830	4,000	4000	12/1/2001	12/1/2001
Pavillion Fee 43-9	7%	6%			176.97	PGDW42	2657.40	Pavillion Fee 43-09	PGDW42	2780.40	1322171	1322171	4901322171	43.250810	-108.639972	43.250850	-108.639310	5,668	5668	4/24/2005	4/24/2005
W.E. Lloyd 1	7%	7%			78.78	PGDW30	1185.17	WE Lloyd 1	PGDW30	1137.80	1320298	1320298	4901320298	43.260110	-108.625280	43.259900	-108.625350	15,575	15575	11/9/1970	11/9/1970
Pavillion Fee 43-11B	6%	7%			177.24	LD-02	2744.82	Pavillion Fee 43-11B	LD-02	2582.38	1322600	1322600	4901322600	43.248060	-108.600333	43.248100	-108.599670	3,948	3948	1/14/2005	1/14/2005
Tribal Pavillion 22-03	6%	6%			177.79	PGDW41B	2821.18	Tribal Pavillion 22-03	PGDW41B	2941.75	1322258	1322258	4901322258	43.268440	-108.631694	43.268490	-108.631030	5,500	5500	5/23/2005	5/23/2005
Tribal Pavillion 44-2	6%	6%			173.61	PGDW05	2824.55	Tribal Pavillion 44-02	PGDW05	2982.57	1322147	1322147	4901322147	43.260110	-108.602167	43.259980	-108.601540	4,100	4100	6/30/2001	6/30/2001
Tribal Pavillion 33-02B	6%	6%			178.78	PGDW05	2944.22	Tribal Pavillion 33-02B	PGDW05	3103.77	1322625	1322625	4901322625	43.263220	-108.603333	43.263264	-108.602665	3,705	3705	2/26/2005	2/26/2005
Tribal 21-9	6%	6%			45.72	PGDW42	780.80	Tribal Pavillion 21-09	PGDW42	755.87	1321130	1321130	4901321130	43.256390	-108.650110	43.256270	-108.650060	5,304	5304	11/21/1980	11/21/1980
Tribal Pavillion 42-15	6%	6%			180.19	PGDW23	3239.88	Tribal Pavillion 42-15	PGDW23	3247.25	1322100	1322100	4901322100	43.239810	-108.621444	43.239850	-108.620770	5,497	5497	11/26/2006	11/26/2006
Pavillion Fee 44-11B	6%	6%			178.91	PGDW32	3252.06	Pavillion Fee 44-11B	PGDW32	3137.72	1322599	1322599	4901322599	43.246860	-108.603028	43.246910	-108.602360	3,948	3948	1/5/2005	1/5/2005
Tribal Pavillion 13-2	5%	6%			104.58	PGDW45	1911.00	Tribal Pavillion 13-02	PGDW45	1832.27	1322070	1322070	4901322070	43.263710	-108.615800	43.263580	-108.615450	3,400	3400	2/4/2001	2/4/2001
Tribal Pavillion 11-12	5%	6%			103.55	PGDW20	1893.40	Tribal Pavillion 11-12	PGDW20	1852.30	1322105	1322105	4901322105	43.256390	-108.594222	43.256389	-108.593833	3,184	3184	6/14/2001	6/14/2001
Tribal Pavillion 32-03	5%	5%			177.00	PGDW30	3410.31	Tribal Pavillion 32-03	PGDW30	3386.93	1322259	1322259	4901322259	43.266580	-108.625861	43.266630	-108.625200	5,458	5458	5/4/2005	5/4/2005
Pavillion Fee 33-11B	5%	5%			177.04	PGDW05	3436.47	Pavillion Fee 33-11B	PGDW05	3509.89	1322313	1322313	4901322313	43.250610	-108.606361	43.250660	-108.605700	3,975	3975	12/25/2004	12/25/2004
Tribal Pavillion 24-11	5%	5%			178.31	PGDW23	3545.24	Tribal Pavillion 24-11	PGDW23	3706.70	1322222	1322222	4901322222	43.245170	-108.610167	43.245210	-108.609500	3,926	3926	11/28/2004	11/28/2004
Pavillion 24X-3	5%	5%			82.32	PGDW41B	1676.64	Tribal Pavillion 24X-03	PGDW41B	1671.15	1306387	1306387	4901306387	43.261510	-108.631610	43.261290	-108.631680	4,896	4896	10/27/1965	10/27/1965
Tribal Pavillion 21-14	5%	5%			178.06	PGDW33	3704.57	Tribal Pavillion 21-14	PGDW33	3537.93	1322216	1322216	4901322216	43.241250	-108.609806	43.241290	-108.609140	5,600	5600	11/30/2004	11/30/2004
Pavillion Fee 11-03	5%	4%			151.34	PGDW41B	3355.16	Pavillion Fee 11-03	PGDW41B	3365.02	1322212	1322212	4901322212	43.270830	-108.633694	43.270710	-108.633150	3,991	3991	11/14/2001	11/15/2001
Pavillion Fee 22-4	4%	5%			178.78	PGDW42	3995.14	Pavillion Fee 22-04	PGDW42	3952.34	1322825	1322825	4901322825	43.266060	-108.652389	43.266100	-108.651720	5,491	5491	11/13/2006	11/13/2006
Tribal Pavillion 33-3	4%	4%			95.76	PGDW30	2165.19	Tribal Pavillion 33-03	PGDW30	2221.40	1321907	1321907	4901321907	43.263060	-108.625560	43.263120	-108.625910	3,903	3903	2/27/1999	2/27/1999
Pavillion Fee 22-11	4%	4%			93.76	PGDW49	2127.12	Pavillion Fee 22-11	PGDW49	2141.31	1322215	1322215	4901322215	43.252980	-108.610657	43.252730	-108.610740	3,190	3190	11/23/2001	11/23/2001
Tribal Pavillion 12-10	4%	4%			98.53	PGDW14	2263.08	Tribal Pavillion 12-10	PGDW14	2276.76	1322141	1322141	4901322141	43.251916	-108.635844	43.251650	-108.635910	4,908	5397	7/24/2001	7/24/2001
Tribal Pavillion 34-2	4%	4%			84.50	PGDW05	2008.40	Tribal Pavillion 34-02	PGDW05	1978.66	1322072	1322072	4901322072	43.260230	-108.605330	43.260000	-108.605370	3,400	3500	2/8/2001	2/8/2001
Tribal Pavillion 43-1	4%	4%			215.43	PGDW20	5139.47	Tribal Pavillion 43-01	PGDW20	5210.37	1322145	1322145	4901322145	43.263780	-108.581389	43.263650	-108.580600	3,400	3700	6/26/2001	6/26/2001
Tribal Pavillion 34-1	4%	4%			146.14	PGDW20	3583.60	Tribal Pavillion 34-01	PGDW20	3592.52	1322146	1322146	4901322146	43.260830	-108.586389	43.260700	-108.585870	3,345	3345	9/11/2001	9/11/2001
Unit 21-11	4%	4%			58.56	PGDW05	1454.83	Tribal Pavillion 21-11	PGDW05	1506.11	1320854	1320854	4901320854	43.255210	-108.610390	43.255050	-108.610410	5,103	5103	11/26/1978	11/26/1978
USA Tribal 22-10	4%	4%			52.13	PGDW14	1301.78	Tribal Pavillion 22-10	PGDW14	1307.59	1320876	1320876	4901320876	43.251940	-108.632220	43.251800	-108.632260	5,152	5152	6/26/1979	6/26/1979
USA Tribal 41-9	4%	4%			80.36	PGDW42	2018.64	Tribal Pavillion 41-09	PGDW42	2014.44	1320875	1320875	4901320875	43.256510	-108.639810	43.256290	-108.639790	5,281	5200	5/15/1979	5/15/1979
Tribal Pavillion 12-2	4%	4%			118.11	PGDW45	2987.58	Tribal Pavillion 12-02	PGDW45	2936.48	1322182	1322182	4901322182	43.266940	-108.615056	43.266850	-108.614630	4,070	3700	10/30/2001	10/30/2001
Pavillion Fee 41-11	4%	4%			100.24	PGDW20	2725.75	Pavillion Fee 41-11	PGDW20	2801.21	1321866	1321866	4901321866	43.255560	-108.600000	43.255510	-108.600370	5,100	5100	12/14/1998	12/13/1998

Appendix K Table 1

COMPARISON OF LATITUDE AND LONGITUDE DATA BETWEEN WOGCC AND ENCANA AND SELECTION OF LOCATIONS FOR VERIFICATION BY % ERROR
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC LOCATION	Error as % WOGCC Distance to Water Well	Error as % ENCANA Distance to Water Well	Verify	Notes/ Selected Detailed Notes for Some Wells	DISTANCE WOGCC TO ENCANA (FEET)	NEAREST Water Well TO WOGCC	DISTANCE WOGCC TO Water Well	ENCANA LOCATION	NEAREST Water Well TO ENCANA	DISTANCE ENCANA TO Water Well	WOGCC API	ENCANA API (7-DIGIT)	ENCANA API (FULL)	WOGCC LATITUDE	WOGCC LONGITUDE	ENCANA LATITUDE	ENCANA LONGITUDE	WOGCC DEPTH	ENCANA DEPTH	WOGCC SPUD_DATE	ENCANA SPUD_DATE
Tribal Pavillion 34-10	3%	3%			36.12	PGDW23	1040.03	Tribal Pavillion 34-10	PGDW23	1033.98	1322149	1322149	4901322149	43.246580	-108.625260	43.246660	-108.625340	5,732	5732	7/31/2001	7/31/2001
Tribal Unit 1	3%	3%			203.87	PGDW33	5969.08	Tribal Unit 1	PGDW33	6152.16	1320654	1320654	4901320654	43.228490	-108.614090	43.228380	-108.614840	3,670	3670	10/15/1976	10/15/1976
Pavillion Fee 33-11	3%	3%			120.30	PGDW20	3563.37	Pavillion Fee 33-11	PGDW20	3457.10	1321670	1321670	4901321670	43.248460	-108.603900	43.248700	-108.603590	5,050	5050	5/27/1993	5/27/1993
Tribal Pavillion 42-3	3%	3%			122.85	PGDW45	3641.71	Tribal Pavillion 42-03	PGDW45	3686.01	1322191	1322191	4901322191	43.267780	-108.619222	43.267740	-108.619680	4,025	4025	10/17/2001	10/29/2001
Maxson 32-9	3%	3%			40.18	PGDW42	1229.94	Maxson 32-09	PGDW42	1266.55	1320084	1320084	4901320084	43.252780	-108.645110	43.252670	-108.645100	3,511	3511	5/16/1968	5/16/1968
Pavillion Fee 24-3B	3%	3%			64.07	PGDW30	2193.44	Pavillion Fee 24-03B	PGDW30	2194.97	1322229	1322229	4901322229	43.259565	-108.630307	43.259400	-108.630390	5,680	5680	1/12/2002	1/12/2002
Unit 42X-12	3%	3%			80.21	PGDW20	2818.22	Tribal Pavillion 42X-12	LD-02	2768.06	1320443	1320443	4901320443	43.254440	-108.581390	43.254230	-108.581480	4,950	4950	8/26/1973	8/26/1973
Pavillion Fee 21-13	3%	3%			31.04	PGDW32	1099.75	Pavillion Fee 21-13	PGDW32	1069.89	1322057	1322057	4901322057	43.242179	-108.590496	43.242120	-108.590580	3,500	3500	1/10/2001	1/10/2001
Tribal Pavillion 23-02	3%	3%			52.74	PGDW05	1868.90	Tribal Pavillion 23-02	PGDW05	1816.30	1306395	1306395	4901306395	43.263710	-108.610390	43.263570	-108.610440	5,200	5200	6/15/1962	6/15/1962
Pavillion Fee 42X-9	3%	3%			74.63	PGDW42	2691.95	Pavillion Fee 42X-09	PGDW42	2648.73	1321905	1321905	4901321905	43.252780	-108.638060	43.252980	-108.638120	5,969	5969	11/29/1998	11/29/1998
Tribal Pavillion 22-1	3%	3%			154.70	PGDW20	5688.17	Tribal Pavillion 22-01	PGDW20	5658.23	1322180	1322180	4901322180	43.267250	-108.590111	43.267140	-108.589550	3,510	3700	9/30/2001	9/30/2001
Tribal Pavillion 24-1	3%	3%			97.21	PGDW20	3649.90	Tribal Pavillion 24-01	PGDW20	3582.25	1322101	1322101	4901322101	43.261667	-108.590556	43.261470	-108.590310	3,400	3400	2/15/2001	2/15/2001
Pavillion Fee 23-3	3%	3%			61.73	PGDW41B	2350.33	Pavillion Fee 23-03	PGDW41B	2313.75	1322207	1322207	4901322207	43.264110	-108.629444	43.263950	-108.629520	5,575	6000	11/7/2001	11/8/2001
Tribal Pavillion 14-1	3%	3%			84.88	PGDW20	3303.99	Tribal Pavillion 14-01	PGDW20	3229.69	1306389	1306389	4901306389	43.260210	-108.595410	43.259980	-108.595460	4,115	4115	1/30/1963	1/30/1963
Tribal-Pav 14-6	2%	2%			109.60	PGDW20	5292.44	Tribal Pavillion 14-06	PGDW20	5198.66	1306392	1306392	4901306392	43.260560	-108.575560	43.260280	-108.575710	4,000	4000	6/9/1963	6/9/1963
John K. Coolidge 1-4	2%	2%			56.38	PGDW42	2725.59	Coolidge John K 01-04	PGDW42	2670.73	1321087	1321087	4901321087	43.263060	-108.649440	43.262920	-108.649350	3,750	3750	2/22/1982	2/22/1982
Pavillion Fee 13-11	2%	2%			51.66	PGDW23	2539.48	Pavillion Fee 13-11	PGDW23	2588.97	1322058	1322058	4901322058	43.248610	-108.613056	43.248650	-108.612870	5,800	5800	12/27/2000	12/27/2000
Tribal Pavillion 14-10	2%	2%			55.29	PGDW44	2796.67	Tribal Pavillion 14-10	PGDW44	2815.72	1322099	1322099	4901322099	43.245833	-108.635000	43.245920	-108.635170	3,500	3500	1/20/2001	1/20/2001
Tribal-Pav 15-21X	2%	2%			63.95	PGDW23	3485.50	Tribal Pavillion 15-21X	PGDW23	3452.04	1321840	1321840	4901321840	43.240550	-108.629520	43.240550	-108.629280	16,140	16140	4/21/1998	4/21/1998
W.H. Paul Patent 42X-1	2%	2%			55.25	PGDW20	3016.74	Tribal Pavillion 42X-11	PGDW20	3012.99	1320442	1320442	4901320442	43.253490	-108.602310	43.253340	-108.602340	5,028	5028	8/6/1973	8/6/1973
Unit 44-10	2%	2%			15.19	PGDW23	832.63	Tribal Pavillion 44-10	PGDW23	821.61	1320879	1320879	4901320879	43.246490	-108.621610	43.246510	-108.621660	5,200	5200	6/3/1979	6/3/1979
14-11	2%	2%			45.02	PGDW23	2569.86	Tribal Pavillion 14X-11	PGDW23	2546.54	1306355	1306355	4901306355	43.246490	-108.613410	43.246610	-108.613450	4,930	4930	11/9/1965	11/9/1965
Tribal Pavillion 12-7	2%	2%			69.25	LD-02	4034.51	Tribal Pavillion 12-07	LD-02	4028.18	1322126	1322126	4901322126	43.252650	-108.576130	43.252460	-108.576130	3,350	3350	6/8/2001	6/8/2001
Tribal Pavillion 41-3	2%	2%			78.33	PGDW45	4707.88	Tribal Pavillion 41-03	PGDW45	4696.75	1322153	1322153	4901322153	43.270560	-108.620556	43.270440	-108.620800	4,030	4030	10/22/2001	10/22/2001
Pavillion Fee 44-11	2%	2%			36.54	PGDW32	2346.96	Pavillion Fee 44-11	PGDW32	2373.82	1322199	1322199	4901322199	43.245130	-108.600590	43.245230	-108.600600	4,070	4070	2/8/2002	2/8/2002
Tribal Pavillion 13-1	2%	2%			73.21	PGDW20	4753.27	Tribal Pavillion 13-01	PGDW20	4697.57	1322128	1322128	4901322128	43.264330	-108.595528	43.264150	-108.595650	3,514	3514	6/3/2001	6/30/2001
Tribal Pavillion 21-12	1%	2%			25.51	PGDW20	1722.02	Tribal Pavillion 21-12	PGDW20	1696.52	1322150	1322150	4901322150	43.256390	-108.591139	43.256320	-108.591139	3,227	3700	9/29/2001	9/29/2001
USA Tribal 258 21-15	1%	1%			48.05	PGDW44	3261.99	Tribal Pavillion 21-15	PGDW44	3221.99	1320889	1320889	4901320889	43.242090	-108.631390	43.242220	-108.631420	5,200	5200	7/13/1979	7/13/1979
Unit 31X-14	1%	1%			37.73	PGDW33	2597.05	Tribal Pavillion 31X-14	PGDW33	2624.93	1320456	1320456	4901320456	43.240710	-108.605690	43.240800	-108.605760	5,000	5148	9/8/1973	9/8/1973
Tribal-Pav 31-15	1%	1%			36.80	PGDW23	2545.47	Tribal Pavillion 31-15	PGDW23	2536.90	1320062	1320062	4901320062	43.241940	-108.625190	43.241990	-108.625310	3,445	3445	1/26/1968	1/26/1968
Blankenship 4-8	1%	1%			19.36	PGDW41B	1382.88	Blankenship 04-08	PGDW41B	1380.06	1320668	1320668	4901320668	43.265560	-108.640090	43.265530	-108.640150	5,204	5204	1/31/1977	1/31/1977
Unit 12-3	1%	1%			23.95	PGDW41B	1720.95	Tribal Pavillion 12-03	PGDW41B	1703.62	1321129	1321129	4901321129	43.266590	-108.635690	43.266560	-108.635770	5,216	5216	10/13/1980	10/13/1980
Tribal Pavillion 33-1	1%	1%			62.02	PGDW20	4697.25	Tribal Pavillion 33-01	PGDW20	4638.01	1322144	1322144	4901322144	43.263810	-108.585360	43.263640	-108.585370	3,475	3475	6/18/2001	6/18/2001
Tribal Unit 238 11-14	1%	1%			48.05	PGDW23	3651.00	Tribal Pavillion 11-14	PGDW23	3611.69	1320857	1320857	4901320857	43.241510	-108.612990	43.241640	-108.613020	5,250	5250	7/28/1979	7/28/1979
Tribal Pavillion 41X-2	1%	1%			52.74	PGDW05	4722.90	Tribal Pavillion 41X-02	PGDW05	4673.56	1320454	1320454	4901320454	43.269440	-108.602410	43.269300	-108.602460	5,006	5006	9/7/1973	9/7/1973
Tribal Pavillion 44-1	1%	1%			45.14	PGDW20	4290.91	Tribal Pavillion 44-01	PGDW20	4299.59	1322027	1322027	4901322027	43.260270	-108.580270	43.260370	-108.580370	3,500	3500	1/15/2001	1/15/2001
Unit 13-13	1%	1%			13.81	PGDW33	1523.43	Tribal Pavillion 13-13	PGDW33	1516.67	1306341	1306341	4901306341	43.234490	-108.595000	43.234500	-108.595050	4,639	4639	6/21/1963	6/21/1963
Tribal Pavillion 43-2	1%	1%			29.53	PGDW05	3806.63	Tribal Pavillion 43-02	PGDW05	3778.60	1322068	1322068	4901322068	43.263330	-108.599720	43.263320	-108.599830	3,400	3400	1/28/2001	1/28/2001
Pavillion Fee 34-11	1%	1%			26.08	PGDW33	3377.52	Pavillion Fee 34-11	PGDW33	3390.00	1322103	1322103	4901322103	43.245140	-108.605306	43.245120	-108.605400	3,360	3360	5/23/2001	5/24/2001
Tribal 24-4	1%	1%			26.36	PGDW33	3668.43	Tribal 24-4	PGDW33	3656.33	1320775	1320775	4901320775	43.228490	-108.595690	43.228520	-108.595780	3,990	3990	5/12/1978	5/12/1978
Unit 31X-3	1%	1%			29.64	PGDW41B	4229.22	Tribal Pavillion 31X-03	PGDW41B	4206.67	1320457	1320457	4901320457	43.269490	-108.625560	43.269410	-108.625580	5,148	5148	9/30/1973	9/30/1973
Tribal Pavillion 43-10	1%	1%			3.64	PGDW23	532.26	Tribal Pavillion 43-10	PGDW23	530.80	1321704	1321704	4901321704	43.249250	-108.620760	43.249240	-108.620760	5,956	5956	8/16/1994	8/16/1994
Tribal Pavillion 23-10	1%	1%			7.76	PGDW44	1236.96	Tribal Pavillion 23-10	PGDW44	1231.56	1321692	1321692	4901321692	43.248890	-108.630680	43.248910	-108.630670	6,000	6000	5/28/1994	5/28/1994
Tribal-Unit 2	1%	1%			26.90	PGDW33	4425.66	Tribal Unit 2	PGDW33	4437.37	1308274	1308274	4901308274	43.228410	-108.605560	43.228420	-108.605660	4,296	4300	6/13/1979	6/13/1979
Ora Wells 14-12	1%	1%			10.93	PGDW32	1843.25	Tribal Pavillion 14-12	PGDW32	1853.98	1306357	1306357	4901306357	43.245710	-108.595490	43.245740	-108.595490	6,505	6505	6/25/1960	6/25/1960
Govt 21-8	1%	1%			61.67	LD-02	10870.54	IND 14-20-258-1315 21-	LD-02	10827.09	1306376	1306376	4901306376	43.257110	-108.551110	43.256970	-108.551240	4,500	4500	3/19/1963	3/19/1963
Taylor Patented 1	0%	0%			26.06	PGDW33	5340.54	Taylor Patented	PGDW33	5355.11	1320598	1320598	4901320598	43.228060	-108.610410	43.227990	-108.610390	4,010	4010	4/22/1976	4/22/1976
Unit TR1-22	0%	0%			27.65	PGDW33	7525.54	IND 14-20-0258-2963 T	PGDW33	7530.37	1320581	1320581	4901320581	43.227410	-108.620190	43.227340	-108.620150	4,200	4200	12/15/1975	12/15/1975
Tribal-Pav 41-15	0%	0%			7.76	PGDW23	2389.32	Tribal Pavillion 41-15	PGDW23	2397.04	1321695	1321695	4901321695	43.242770	-108.618650	43.242750	-108.618640	6,526	6526	7/28/1994	7/28/1994
Gov't 23-7	0%	0%			15.19	LD-02	5399.31	Govt 23-07	LD-02	5384.75	1306359	1306359	4901306359	43.248410	-108.571390	43.248430	-108.571440	8,038	8038	3/3/1961	3/3/1961
21-05	0%	0%			31.04	PGDW20	12857.29	Tribal Pavillion 21-05	PGDW20	12832.35	1306413	1306413	4901306413	43.271110	-108.550990	43.271030	-108.551030	5,000	5000	2/24/1963	2/23/1963
Pavillion Fee 13-12	0%	0%			1.21	LD-02	558.96	Pavillion Fee 13-12	LD-02	558.28	1322060	1322060	4901322060	43.250830	-108.593056	43.250833	-108.593056	3,275	3275	11/23/2000	11/23/2000
Tribal Pavillion 33-2	0%	0%			4.51	PGDW05	2298.04	Tribal Pavillion 33-02	PGDW05	2293.89	1321693	1321693	4901321693	43.262080	-108.605220	43.262070	-108.605230	5,498	5498	6/17/1994	6/17/1994

Appendix K Table 1

COMPARISON OF LATITUDE AND LONGITUDE DATA BETWEEN WOGCC AND ENCANA AND SELECTION OF LOCATIONS FOR VERIFICATION BY % ERROR
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC LOCATION	Error as % WOGCC Distance to Water Well	Error as % ENCANA Distance to Water Well	Verify	Notes/ Selected Detailed Notes for Some Wells	DISTANCE WOGCC TO ENCANA (FEET)	NEAREST Water Well TO WOGCC	DISTANCE WOGCC TO Water Well	ENCANA LOCATION	NEAREST Water Well TO ENCANA	DISTANCE ENCANA TO Water Well	WOGCC API	ENCANA API (7-DIGIT)	ENCANA API (FULL)	WOGCC LATITUDE	WOGCC LONGITUDE	ENCANA LATITUDE	ENCANA LONGITUDE	WOGCC DEPTH	ENCANA DEPTH	WOGCC SPUD_DATE	ENCANA SPUD_DATE
Runner Herefords 44-17	0%	0%			16.63	PGDW42	9644.40	Runner Herfords 44-17	PGDW42	9660.84	1308017	1308017	4901308017	43.230910	-108.659810	43.230870	-108.659840	4,240	4240	5/18/1964	5/18/1964
Runner Herefords 1	0%	0%			15.27	PGDW42	9735.48	Runner Herford	PGDW42	9721.63	1321157	1321157	4901321157	43.230560	-108.659490	43.230590	-108.659450	4,006	4006	9/17/1981	9/17/1981
Doles Unit 44-15	0%	0%			9.03	PGDW23	6645.04	Tribal Pavillion 44-15	PGDW23	6637.16	1320764	1320764	4901320764	43.230560	-108.619590	43.230580	-108.619610	5,375	5375	2/26/1978	2/26/1978
Pavillion Fee 23-12	0%	0%			0.81	LD-02	618.55	Pavillion Fee 23-12	LD-02	618.24	1322186	1322186	4901322186	43.250720	-108.589167	43.250722	-108.589167	3,260	3260	7/20/2001	7/20/2001
Unit 24-14	0%	0%			4.52	PGDW33	3966.72	Tribal Pavillion 24X-14	PGDW33	3962.45	1306336	1306336	4901306336	43.232310	-108.608610	43.232320	-108.608600	3,803	3803	11/5/1963	11/5/1963
Tribal Pavillion 23-1	0%	0%			4.51	PGDW20	4489.88	Tribal Pavillion 23-01	PGDW20	4486.42	1321697	1321697	4901321697	43.263960	-108.590190	43.263950	-108.590180	5,306	5306	7/10/1994	7/10/1994
Tribal Pavillion 24-02	0%	0%			0.44	PGDW05	581.80	Tribal Pavillion 24-02	PGDW05	581.47	1322236	1322236	4901322236	43.259890	-108.610972	43.259889	-108.610972	3,942	3942	10/9/2004	10/9/2004
Pavillion Fee 34-03B	0%	0%			1.21	PGDW30	1735.49	Pavillion Fee 34-03B	PGDW30	1736.26	1322270	1322270	4901322270	43.260330	-108.627833	43.260333	-108.627833	5,580	6000	10/18/2004	10/17/2004
Pavillion Fee 41-10	0%	0%			0.41	PGDW30	751.77	Pavillion Fee 41-10	PGDW30	751.49	1322198	1322198	4901322198	43.255860	-108.620917	43.255861	-108.620917	3,180	3180	1/7/2002	1/7/2002
Pavillion Fee 33-12	0%	0%			0.80	LD-02	1580.02	Pavillion Fee 33-12	LD-02	1580.47	1322824	1322824	4901322824	43.249280	-108.586139	43.249278	-108.586139	5,520	5520	2/3/2006	2/3/2006
Pavillion Fee 31-11	0%	0%			0.81	PGDW05	2067.71	Pavillion Fee 31-11	PGDW05	2068.04	1322106	1322106	4901322106	43.257030	-108.605278	43.257028	-108.605278	3,960	3960	1/29/2002	1/29/2002
Tribal 1-21	0%	0%			2.67	PGDW23	8952.69	Tribal 1-21	PGDW23	8954.02	1320586	1320586	4901320586	43.227410	-108.639440	43.227410	-108.639450	3,966	3965	3/5/1976	3/5/1976
Pavillion Fee 41-11B	0%	0%			0.80	PGDW05	2778.75	Pavillion Fee 41-11B	PGDW05	2778.94	1322601	1322601	4901322601	43.257030	-108.602500	43.257028	-108.602500	3,900	3900	3/22/2005	3/22/2005
Tribal Pavillion 12-12	0%	0%			0.08	PGDW20	1561.10	Tribal Pavillion 12-12	PGDW20	1561.18	1322255	1322255	4901322255	43.253000	-108.596833	43.253000	-108.596833	3,955	3955	2/18/2005	2/18/2005
Clair C Day 1	0%	0%			0.00	PGDW42	21538.14	Clair C Day	PGDW42	21538.14	1320491	1320491	4901320491	43.201670	-108.679910	43.201670	-108.679910	8,021	8021	4/20/1974	4/20/1974
Finlayson 1-17	0%	0%			0.00	PGDW42	10120.59	Finlayson 01-17	PGDW42	10120.59	1321086	1321086	4901321086	43.231390	-108.665560	43.231390	-108.665560	5,610	5610	8/19/1980	8/19/1980
Garrett 1	0%	0%			0.00	PGDW42	8469.48	Garrett 1	PGDW42	8469.48	1320965	1320965	4901320965	43.241670	-108.672610	43.241670	-108.672610	5,494	5494	10/13/1979	10/13/1979
Govt 32-4	0%	0%			0.00	LD-02	18229.33	Govt 32-04	LD-02	18229.33	1306402	1306402	4901306402	43.267390	-108.526290	43.267390	-108.526290	5,000' (?)	5000	7/10/1963	7/10/1963
Govt 44-20	0%	0%			0.00	PGDW32	16564.91	Govt 44-20	PGDW32	16564.91	1306273	1306273	4901306273	43.216940	-108.541190	43.216940	-108.541190	5,000	5000	3/9/1963	3/9/1963
Govt-Ocean Lake 1	0%	0%			0.00	LD-02	18339.50	Govt-Ocean Lake	LD-02	18339.50	1306358	1306358	4901306358	43.246490	-108.522710	43.246490	-108.522710	6,000	6000	5/11/1963	5/11/1963
Haymaker 14-21	0%	0%			0.00	LD-02	25985.98	Haymaker 14-21	LD-02	25985.98	1322819	1322819	4901322819	43.242080	-108.494528	43.242080	-108.494528	11,164	11800	11/23/2005	11/23/2005
Ocean Lake Tribal 1-15	0%	0%			0.00	LD-02	21963.21	Ocean Lake Tribal 01-15	LD-02	21963.21	1321312	1321312	4901321312	43.237890	-108.510910	43.237890	-108.510910	15,770	15770	11/1/1982	11/1/1982
Unit 41X-10	0%	0%			0.00	PGDW30	897.72	Pavillion 41X-10	PGDW30	897.72	1320414	1320414	4901320414	43.255110	-108.622010	43.255110	-108.622010	5,047	5047	10/27/1972	10/27/1972
Pavillion Fee 13-15	0%	0%			0.00	PGDW23	5561.84	Pavillion Fee 13-15	PGDW23	5561.84	1322104	1322104	4901322104	43.235830	-108.633889	43.235830	-108.633889	3,650	3650	4/10/2001	4/10/2001
Shoshone-Arapahoe 24-1	0%	0%			0.00	LD-02	26574.45	Shoshone-Arapahoe 24-1	LD-02	26574.45	1320748	1320748	4901320748	43.245560	-108.491790	43.245560	-108.491790	14,975	14975	12/11/1977	12/11/1977
Tribal 14-24	0%	0%			0.00	PGDW32	33618.18	Tribal 14-24	PGDW32	33618.18	1321302	1321302	4901321302	43.216310	-108.472500	43.216310	-108.472500	8,850	8852	7/22/1982	7/22/1982
Unit 22-12	0%	0%			0.00	PGDW20	634.26	Tribal Pavillion 22-12	PGDW20	634.26	1320878	1320878	4901320878	43.253060	-108.592690	43.253060	-108.592690	5,200	5200	8/15/1979	8/15/1979
Pavillion Fee 31-10	0%	0%			0.00	PGDW30	701.64	Tribal Pavillion 31-10	PGDW30	701.64	1321691	1321691	4901321691	43.256330	-108.624600	43.256330	-108.624600	5,972	5972	3/16/1994	3/16/1994
West Pavillion 1-8-1B	0%	0%			0.00	PGDW42	5896.16	West Pavillion 1-8-1B	PGDW42	5896.16	1321088	1321088	4901321088	43.256190	-108.669440	43.256190	-108.669440	5,207	5207	5/30/1981	5/30/1981
Woodring 23X-24	0%	0%			0.00	PGDW33	7265.89	Woodring 23X-24	PGDW33	7265.89	1306281	1306281	4901306281	43.218790	-108.592710	43.218790	-108.592710	5,252	4100	4/17/1964	4/17/1964
NO MATCH					NO MATCH	NA	NA	Fike Tribal A-01	PGDW41B	11238.81	NA	1321346	4901321346	NA	NA	43.292590	-108.644490	NA	5364	NA	12/28/1982
NO MATCH					NO MATCH	NA	NA	Govt 34-33	PGDW41B	4771.87	NA	1306424	4901306424	NA	NA	43.274280	-108.644550	NA	5113	NA	4/29/1964
NO MATCH					NO MATCH	NA	NA	IND 14-20-058-1555	PGDW20	13203.62	NA	1306917	4901306917	NA	NA	43.275820	-108.554320	NA	3860	NA	8/25/1965
Shoshone-Arapahoe 16-34					NO MATCH	PGDW41B	20194.73	NO MATCH	NA	NA	1321682	NA	NA	43.317310	-108.644850	NA	NA	7007	NA	10/14/1995	NA
NO MATCH					NO MATCH	NA	NA	NW Pavillion 17-01	PGDW41B	24401.52	NA	1320120	4901320120	NA	NA	43.324910	-108.669720	NA	6000	NA	10/26/1968
NO MATCH					NO MATCH	NA	NA	NW Pavillion Fee 34-28	PGDW41B	10205.96	NA	1322642	4901322642	NA	NA	43.289690	-108.644694	NA	5645	NA	3/10/2005
NO MATCH					NO MATCH	NA	NA	Pavillion 43-03	PGDW30	1963.83	NA	1322077	4901322077	NA	NA	43.262780	-108.620830	NA	NA	NA	NA
NO MATCH					NO MATCH	NA	NA	Pavillion Fee 33-04	PGDW41A	2401.88	NA	1322733	4901322733	NA	NA	43.262780	-108.646833	NA	NA	NA	NA
NO MATCH					NO MATCH	NA	NA	Roland Patented 34-13	PGDW41B	4857.27	NA	1320700	4901320700	NA	NA	43.275150	-108.633900	NA	6500	NA	6/3/1977
NO MATCH					NO MATCH	NA	NA	Shell-Govt 22-35	PGDW45	8383.16	NA	1306451	4901306451	NA	NA	43.281790	-108.610190	NA	5499	NA	2/11/1963
NO MATCH					NO MATCH	NA	NA	Tribal 1-31	PGDW20	11478.32	NA	1320602	4901320602	NA	NA	43.274020	-108.560910	NA	3852	NA	5/8/1976
NO MATCH					NO MATCH	NA	NA	Tribal Hunt 01-17	PGDW41B	23978.27	NA	1320805	4901320805	NA	NA	43.324910	-108.664810	NA	10212	NA	7/21/1978
NO MATCH					NO MATCH	NA	NA	Tribal NP 31-11X	PGDW20	12909.88	NA	1321834	4901321834	NA	NA	43.284800	-108.574130	NA	14500	NA	10/31/1997
NO MATCH					NO MATCH	NA	NA	Tribal Pavillion 12-05	PGDW20	11033.81	NA	1322061	4901322061	NA	NA	43.267380	-108.555860	NA	3470	NA	12/17/2000
NO MATCH					NO MATCH	NA	NA	Tribal Pavillion 12-06	PGDW20	7250.99	NA	1322069	4901322069	NA	NA	43.267890	-108.575510	NA	3600	NA	2/25/2001
NO MATCH					NO MATCH	NA	NA	Tribal Pavillion 14-11	NA	NA	NA	1322732	4901322732	NA	NA	NA	NA	NA	NA	NA	NA
NO MATCH					NO MATCH	NA	NA	Tribal Pavillion 16-28	PGDW20	22762.62	NA	1321026	4901321026	NA	NA	43.290280	-108.524090	NA	4548	NA	4/3/1980
NO MATCH					NO MATCH	NA	NA	Tribal Pavillion 43-06	PGDW20	9638.89	NA	1321720	4901321720	NA	NA	43.264700	-108.559780	NA	4000	NA	4/24/1995

Appendix K Table 2

COMPARISON OF LATITUDE AND LONGITUDE DATA BETWEEN WOGCC AND ENCANA AND SELECTION OF LOCATIONS FOR VERIFICATION BY DISTANCE TO WATER WELL
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC LOCATION	Error as % Distance to Water Well	DISTANCE WOGCC TO ENCANA (FEET)	NEAREST Warter Well TO WOGCC	DISTANCE WOGCC TO Water Well	Verify	Notes	ENCANA LOCATION	WOGCC API	ENCANA API (7-DIGIT)	ENCANA API (FULL)	WOGCC LATITUDE	WOGCC LONGITUDE	ENCANA LATITUDE	ENCANA LONGITUDE	WOGCC DEPTH	ENCANA DEPTH	WOGCC SPUD_DATE	ENCANA SPUD_DATE
Tribal Pavillion 32-10C	70%	176.77	PGDW14	252.98	Y	Listed in Table 1	Tribal Pavillion 32-10C	1322419	1322419	4901322419	43.252220	-108.627500	43.252270	-108.626840	4,020	4020	1/27/2005	1/27/2005
Govt Tribal 33X-10	13%	40.63	PGDW44	311.25	N	AME has GPS data	Tribal Pavillion 33X-10	1306363	1306363	4901306363	43.250190	-108.625280	43.250280	-108.625370	19,235	19235	5/21/1963	5/21/1963
Tribal Pavillion 12-13	9%	40.44	PGDW33	443.68	Y	Plugged 2001	Tribal Pavillion 12-13	1320855	1320855	4901320855	43.239590	-108.595560	43.239700	-108.595580	5,400	5331	12/27/1978	12/27/1978
Tribal Pavillion 33-10	28%	132.29	PGDW44	466.81	Y	Listed in Table 1	Tribal Pavillion 33-10	1321862	1321862	4901321862	43.249170	-108.625560	43.248920	-108.625920	5,970	6000	2/13/1999	2/13/1999
Pavillion Fee 13-03W	38%	178.26	PGDW41B	475.24	Y	Listed in Table 1	Pavillion Fee 13-03W	1322246	1322246	4901322246	43.262920	-108.636417	43.262960	-108.635750	4,602	4602	4/3/2005	4/3/2005
Tribal Pavillion 43-10	1%	3.64	PGDW23	532.26	Y		Tribal Pavillion 43-10	1321704	1321704	4901321704	43.249250	-108.620760	43.249240	-108.620760	5,956	5956	8/16/1994	8/16/1994
Tribal Pavillion 33-10B	32%	178.90	PGDW23	550.85	Y	Listed in Table 1	Tribal Pavillion 33-10B	1322274	1322274	4901322274	43.249530	-108.624278	43.249580	-108.623610	5,610	5610	11/7/2004	11/7/2004
Pavillion Fee 13-12	0%	1.21	LD-02	558.96	Y		Pavillion Fee 13-12	1322060	1322060	4901322060	43.250830	-108.593056	43.250833	-108.593056	3,275	3275	11/23/2000	11/23/2000
Tribal Pavillion 43-10B	31%	177.85	PGDW23	581.50	Y	Listed in Table 1	Tribal Pavillion 43-10B	1322420	1322420	4901322420	43.247610	-108.620944	43.247660	-108.620280	5,760	5760	10/28/2004	10/28/2004
Tribal Pavillion 24-02	0%	0.44	PGDW05	581.80	Y		Tribal Pavillion 24-02	1322236	1322236	4901322236	43.259890	-108.610972	43.259889	-108.610972	3,942	3942	10/9/2004	10/9/2004
Tribal Pavillion 33-10W	25%	148.36	PGDW44	586.32	Y	Listed in Table 1	Tribal Pavillion 33-10W	1322195	1322195	4901322195	43.248690	-108.626806	43.248770	-108.626260	5,070	5070	10/9/2001	10/9/2001
Pavillion Fee 23-12	0%	0.81	LD-02	618.55	Y		Pavillion Fee 23-12	1322186	1322186	4901322186	43.250720	-108.589167	43.250722	-108.589167	3,260	3260	7/20/2001	7/20/2001
Unit 22-12	0%	0.00	PGDW20	634.26	Y		Tribal Pavillion 22-12	1320878	1320878	4901320878	43.253060	-108.592690	43.253060	-108.592690	5,200	5200	8/15/1979	8/15/1979
Pavillion Fee 12-11B	27%	177.30	PGDW49	649.39	Y	Listed in Table 1	Pavillion Fee 12-11B	1322272	1322272	4901322272	43.254220	-108.615972	43.254270	-108.615310	3,860	3860	12/16/2004	12/16/2004
Tribal 42-10	21%	138.73	PGDW49	652.03	Y	Listed in Table 1	Tribal Pavillion 42-10	1321696	1321696	4901321696	43.254540	-108.620440	43.254160	-108.620410	5,995	5995	5/2/1994	5/2/1994
Pavillion Fee 43-04	27%	177.27	PGDW41A	653.33	Y	Listed in Table 1	Pavillion Fee 43-04	1322633	1322633	4901322633	43.262610	-108.640222	43.262660	-108.639560	4,744	4744	3/1/2005	3/1/2005
Pavillion Fee 41-10B	27%	179.22	PGDW30	672.15	Y	Listed in Table 1	Pavillion Fee 41-10B	1322624	1322624	4901322624	43.256940	-108.620167	43.256986	-108.619497	3,841	3841	4/12/2005	4/12/2005
Pavillion Fee 31-10	0%	0.00	PGDW30	701.64	Y		Tribal Pavillion 31-10	1321691	1321691	4901321691	43.256330	-108.624600	43.256330	-108.624600	5,972	5972	3/16/1994	3/16/1994
Tribal Pavillion 32-10	128%	946.19	PGDW14	739.69	Y	Listed in Table 1	Tribal Pavillion 32-10	1321968	1321968	4901321968	43.253300	-108.626000	43.253220	-108.629550	5,593	5600	2/27/2000	2/27/2000
Pavillion Fee 41-10	0%	0.41	PGDW30	751.77	Y		Pavillion Fee 41-10	1322198	1322198	4901322198	43.255860	-108.620917	43.255861	-108.620917	3,180	3180	1/7/2002	1/7/2002
Pavillion Fee 14-03W	18%	137.60	PGDW41A	760.72			Pavillion Fee 14-03W	1322219	1322219	4901322219	43.260720	-108.635750	43.260660	-108.635240	5,700	5700	3/19/2002	3/19/2002
Pavillion Fee 31-9	9%	71.36	PGDW42	769.78			Pavillion Fee 31-09	1322172	1322172	4901322172	43.256860	-108.644861	43.256810	-108.645120	3,445	3445	9/25/2001	9/25/2001
Tribal 21-9	6%	45.72	PGDW42	780.80	N	Plugged 1992. Encana to DW 755.87	Tribal Pavillion 21-09	1321130	1321130	4901321130	43.256390	-108.650110	43.256270	-108.650060	5,304	5304	11/21/1980	11/21/1980
Tribal Pavillion 44-03	8%	62.80	PGDW30	791.65			Tribal Pavillion 44-03	1321906	1321906	4901321906	43.259440	-108.621110	43.259611	-108.621139	6,009	6009	1/25/1999	1/25/1999
Tribal Pavillion 32-10B	18%	144.70	PGDW14	826.28			Tribal Pavillion 32-10B	1322224	1322224	4901322224	43.253280	-108.625389	43.253190	-108.624860	5,850	5850	2/23/2002	2/23/2002
Tribal Pavillion 21-11B	21%	178.61	PGDW05	832.47			Tribal Pavillion 21-11B	1322586	1322586	4901322586	43.256940	-108.610917	43.256990	-108.610250	3,875	3875	3/28/2005	3/28/2005
Unit 44-10	2%	15.19	PGDW23	832.63			Tribal Pavillion 44-10	1320879	1320879	4901320879	43.246490	-108.621610	43.246510	-108.621660	5,200	5200	6/3/1979	6/3/1979
Tribal 14-2	9%	76.72	PGDW45	895.03			Tribal Pavillion 14-02	1321128	1321128	4901321128	43.260210	-108.615830	43.260000	-108.615850	5,175	5250	11/3/1980	11/17/1980
Unit 41X-10	0%	0.00	PGDW30	897.72			Pavillion 41X-10	1320414	1320414	4901320414	43.255110	-108.622010	43.255110	-108.622010	5,047	5047	10/27/1972	10/27/1972
Pavillion Fee 11-11B	16%	143.39	PGDW49	897.94			Pavillion Fee 11-11B	1322220	1322220	4901322220	43.256970	-108.615944	43.256880	-108.615420	4,780	4780	1/22/2002	1/22/2002
Pavillion Fee 32-09W	15%	136.59	PGDW42	919.44			Pavillion Fee 32-09W	1322227	1322227	4901322227	43.254080	-108.644722	43.254060	-108.644210	3,460	3460	3/4/2002	3/4/2002
Mae H. Rhodes 1	7%	69.71	PGDW41A	1028.00			Rhodes Mae	1306388	1306388	4901306388	43.260090	-108.635190	43.259900	-108.635220	11,000	10943	8/10/1953	8/10/1953
Tribal Pavillion 34-10	3%	36.12	PGDW23	1040.03			Tribal Pavillion 34-10	1322149	1322149	4901322149	43.246580	-108.625260	43.246660	-108.625340	5,732	5732	7/31/2001	7/31/2001
Pavillion Fee 13X-3	73%	786.30	PGDW41B	1070.96			Pavillion Fee 13X-03	1321904	1321904	4901321904	43.263330	-108.634170	43.263410	-108.637120	6,044	6044	1/8/1999	1/8/1999
Tribal Pavillion 23-10B	16%	177.31	PGDW14	1098.04			Tribal Pavillion 23-10B	1322417	1322417	4901322417	43.250470	-108.631222	43.250520	-108.630560	5,646	5646	9/28/2004	9/28/2004
Pavillion Fee 21-13	3%	31.04	PGDW32	1099.75			Pavillion Fee 21-13	1322057	1322057	4901322057	43.242179	-108.590496	43.242120	-108.590580	3,500	3500	1/10/2001	1/10/2001
Pavillion Fee 44-04	16%	177.81	PGDW41A	1125.52			Pavillion Fee 44-04	1322634	1322634	4901322634	43.259440	-108.639944	43.259490	-108.639280	5,700	5700	2/6/2005	2/6/2005
W.E. Lloyd 1	7%	78.78	PGDW30	1185.17			WE Lloyd 1	1320298	1320298	4901320298	43.260110	-108.625280	43.259900	-108.625350	15,575	15575	11/9/1970	11/9/1970
Tribal Pavillion 23-10C	15%	177.31	PGDW44	1186.66			Tribal Pavillion 23-10C	1322418	1322418	4901322418	43.247890	-108.629472	43.247940	-108.628810	5,730	5730	9/19/2004	9/19/2004
Tribal Pavillion 42-10B	15%	177.83	PGDW49	1191.18			Tribal Pavillion 42-10B	1322324	1322324	4901322324	43.252190	-108.620194	43.252240	-108.619530	5,605	5605	1/7/2005	1/7/2005
Pavillion Fee 11-11	197%	2357.90	PGDW49	1197.68			Pavillion Fee 11-11	1322059	1322059	4901322059	43.255109	-108.613611	43.248650	-108.613110	5,846	5846	12/7/2000	12/7/2000
Maxson 32-9	3%	40.18	PGDW42	1229.94			Maxson 32-09	1320084	1320084	4901320084	43.252780	-108.645110	43.252670	-108.645100	3,511	3511	5/16/1968	5/16/1968
Pavillion Fee 34-03R	11%	136.56	PGDW30	1234.39			Pavillion Fee 34-03R	1322087	1322087	4901322087	43.260280	-108.625278	43.260207	-108.624775	3,400	3600	12/28/2000	12/28/2000
Pavillion Fee 34-03	103%	1275.66	PGDW30	1234.71			Pavillion Fee 34-03	1322005	1322005	4901322005	43.260280	-108.625280	43.263780	-108.625260	192	3600	12/9/2000	12/28/2000

Appendix K Table 2

COMPARISON OF LATITUDE AND LONGITUDE DATA BETWEEN WOGCC AND ENCANA AND SELECTION OF LOCATIONS FOR VERIFICATION BY DISTANCE TO WATER WELL
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC LOCATION	Error as % Distance to Water Well	DISTANCE WOGCC TO ENCANA (FEET)	NEAREST Warter Well TO WOGCC	DISTANCE WOGCC TO Water Well	Verify	Notes	ENCANA LOCATION	WOGCC API	ENCANA API (7-DIGIT)	ENCANA API (FULL)	WOGCC LATITUDE	WOGCC LONGITUDE	ENCANA LATITUDE	ENCANA LONGITUDE	WOGCC DEPTH	ENCANA DEPTH	WOGCC SPUD_DATE	ENCANA SPUD_DATE
Tribal Pavillion 23-10	1%	7.76	PGDW44	1236.96			Tribal Pavillion 23-10	1321692	1321692	4901321692	43.248890	-108.630680	43.248910	-108.630670	6,000	6000	5/28/1994	5/28/1994
Pavillion Fee 31-10B	14%	177.29	PGDW14	1262.58			Pavillion Fee 31-10B	1322268	1322268	4901322268	43.254940	-108.628222	43.254990	-108.627560	5,555	5555	12/10/2004	12/10/2004
USA Tribal 22-10	4%	52.13	PGDW14	1301.78			Tribal Pavillion 22-10	1320876	1320876	4901320876	43.251940	-108.632220	43.251800	-108.632260	5,152	5152	6/26/1979	6/26/1979
Pavillion Unit 12-11	12%	167.02	PGDW49	1345.78			Pavillion Fee 12-11	1321669	1321669	4901321669	43.252270	-108.614830	43.251860	-108.615110	6,482	6482	6/17/1993	6/17/1993
Pavillion Fee 14-03B	13%	176.75	PGDW41A	1372.39			Pavillion Fee 14-03B	1322623	1322623	4901322623	43.259440	-108.634250	43.259490	-108.633590	3,934	3934	3/20/2005	3/20/2005
Blankenship 4-8	1%	19.36	PGDW41B	1382.88			Blankenship 04-08	1320668	1320668	4901320668	43.265560	-108.640090	43.265530	-108.640150	5,204	5204	1/31/1977	1/31/1977
Tribal Pavillion 44-03C	13%	178.87	PGDW30	1393.23			Tribal Pavillion 44-03C	1322721	1322721	4901322721	43.261360	-108.622778	43.261410	-108.622110	3,903	3903	5/15/2005	5/15/2005
Pavillion Fee 12-11W	17%	238.47	PGDW49	1412.43			Pavillion Fee 12-11W	1322102	1322102	4901322102	43.251940	-108.615000	43.251870	-108.614110	3,250	3250	4/15/2001	4/15/2001
Tribal Pavillion 23-10W	10%	147.63	PGDW44	1449.98			Tribal Pavillion 23-10W	1322217	1322217	4901322217	43.248860	-108.631528	43.248920	-108.630980	4,590	4590	3/13/2002	3/13/2002
Unit 21-11	4%	58.56	PGDW05	1454.83			Tribal Pavillion 21-11	1320854	1320854	4901320854	43.255210	-108.610390	43.255050	-108.610410	5,103	5103	11/26/1978	11/26/1978
Unit 13-13	1%	13.81	PGDW33	1523.43			Tribal Pavillion 13-13	1306341	1306341	4901306341	43.234490	-108.595000	43.234500	-108.595050	4,639	4639	6/21/1963	6/21/1963
Tribal Pavillion 12-12	0%	0.08	PGDW20	1561.10			Tribal Pavillion 12-12	1322255	1322255	4901322255	43.253000	-108.596833	43.253000	-108.596833	3,955	3955	2/18/2005	2/18/2005
Pavillion Fee 33-12	0%	0.80	LD-02	1580.02			Pavillion Fee 33-12	1322824	1322824	4901322824	43.249280	-108.586139	43.249278	-108.586139	5,520	5520	2/3/2006	2/3/2006
Pavillion Fee 13-11B	9%	149.26	PGDW23	1600.59			Pavillion Fee 13-11B	1322240	1322240	4901322240	43.249610	-108.616722	43.249680	-108.616170	5,660	5660	2/13/2002	2/13/2002
Tribal Pavillion 13-02B	11%	178.59	PGDW45	1622.01			Tribal Pavillion 13-02B	1322627	1322627	4901322627	43.263330	-108.613167	43.263380	-108.612500	3,970	3970	3/5/2005	3/5/2005
Pavillion 24X-3	5%	82.32	PGDW41B	1676.64			Tribal Pavillion 24X-03	1306387	1306387	4901306387	43.261510	-108.631610	43.261290	-108.631680	4,896	4896	10/27/1965	10/27/1965
Unit 12-3	1%	23.95	PGDW41B	1720.95			Tribal Pavillion 12-03	1321129	1321129	4901321129	43.266590	-108.635690	43.266560	-108.635770	5,216	5216	10/13/1980	10/13/1980
Tribal Pavillion 21-12	1%	25.51	PGDW20	1722.02			Tribal Pavillion 21-12	1322150	1322150	4901322150	43.256390	-108.591139	43.256320	-108.591139	3,227	3700	9/29/2001	9/29/2001
Pavillion Fee 34-03B	0%	1.21	PGDW30	1735.49			Pavillion Fee 34-03B	1322270	1322270	4901322270	43.260330	-108.627833	43.260333	-108.627833	5,580	6000	10/18/2004	10/17/2004
Pavillion Fee 42-09W	8%	141.04	PGDW42	1809.72			Pavillion Fee 42-09W	1322228	1322228	4901322228	43.253080	-108.641583	43.253020	-108.641060	3,420	3420	3/9/2002	3/9/2002
Ora Wells 14-12	1%	10.93	PGDW32	1843.25			Tribal Pavillion 14-12	1306357	1306357	4901306357	43.245710	-108.595490	43.245740	-108.595490	6,505	6505	6/25/1960	6/25/1960
Pavillion Fee 13-12W	9%	161.82	LD-02	1860.60			Pavillion Fee 13-12W	1322214	1322214	4901322214	43.248500	-108.596806	43.248530	-108.596200	4,025	4025	12/8/2001	12/8/2001
Pavillion Fee 21-10B	10%	176.96	PGDW14	1860.90			Pavillion Fee 21-10B	1322269	1322269	4901322269	43.254810	-108.632722	43.254850	-108.632060	5,625	5625	12/24/2004	12/24/2004
Tribal Pavillion 23-02	3%	52.74	PGDW05	1868.90			Tribal Pavillion 23-02	1306395	1306395	4901306395	43.263710	-108.610390	43.263570	-108.610440	5,200	5200	6/15/1962	6/15/1962
Tribal Pavillion 11-12	5%	103.55	PGDW20	1893.40			Tribal Pavillion 11-12	1322105	1322105	4901322105	43.256390	-108.594222	43.256389	-108.593833	3,184	3184	6/14/2001	6/14/2001
Pavillion Fee 21-10W	7%	136.09	PGDW14	1898.58			Pavillion Fee 21-10W	1322188	1322188	4901322188	43.256250	-108.630389	43.256170	-108.629890	4,400	4400	8/31/2001	8/31/2001
Tribal Pavillion 13-2	5%	104.58	PGDW45	1911.00			Tribal Pavillion 13-02	1322070	1322070	4901322070	43.263710	-108.615800	43.263580	-108.615450	3,400	3400	2/4/2001	2/4/2001
Pavillion Fee 22-11C	9%	176.69	PGDW05	1935.60			Pavillion Fee 22-11C	1322314	1322314	4901322314	43.254310	-108.608861	43.254350	-108.608200	3,850	3850	2/1/2005	2/1/2005
Tribal Pavillion 33-02C	9%	176.48	PGDW05	1943.56			Tribal Pavillion 33-02C	1322617	1322617	4901322617	43.263190	-108.608389	43.263240	-108.607730	3,710	3710	2/10/2005	2/10/2005
Pavillion Fee 21-10	7%	138.43	PGDW14	1944.81			Pavillion Fee 21-10	1322125	1322125	4901322125	43.256250	-108.630778	43.256170	-108.630270	5,930	5930	7/10/2001	7/11/2001
Pavillion Fee 22-11B	9%	176.51	PGDW49	1962.95			Pavillion Fee 22-11B	1322271	1322271	4901322271	43.251470	-108.612639	43.251520	-108.611980	4,500	4500	1/21/2005	1/21/2005
Tribal Pavillion 34-2	4%	84.50	PGDW05	2008.40			Tribal Pavillion 34-02	1322072	1322072	4901322072	43.260230	-108.605330	43.260000	-108.605370	3,400	3500	2/8/2001	2/8/2001
USA Tribal 41-9	4%	80.36	PGDW42	2018.64			Tribal Pavillion 41-09	1320875	1320875	4901320875	43.256510	-108.639810	43.256290	-108.639790	5,281	5200	5/15/1979	5/15/1979
Pavillion Fee 31-11	0%	0.81	PGDW05	2067.71			Pavillion Fee 31-11	1322106	1322106	4901322106	43.257030	-108.605278	43.257028	-108.605278	3,960	3960	1/29/2002	1/29/2002
Pavillion Fee 42-04B	9%	177.79	PGDW41B	2081.52			Pavillion Fee 42-04B	1322635	1322635	4901322635	43.267640	-108.639944	43.267690	-108.639280	3,968	3968	3/13/2005	3/13/2005
Pavillion Fee 22-11	4%	93.76	PGDW49	2127.12			Pavillion Fee 22-11	1322215	1322215	4901322215	43.252980	-108.610657	43.252730	-108.610740	3,190	3190	11/23/2001	11/23/2001
Tribal Pavillion 33-3	4%	95.76	PGDW30	2165.19			Tribal Pavillion 33-03	1321907	1321907	4901321907	43.263060	-108.625560	43.263120	-108.625910	3,903	3903	2/27/1999	2/27/1999
Pavillion Fee 24-3B	3%	64.07	PGDW30	2193.44			Pavillion Fee 24-03B	1322229	1322229	4901322229	43.259565	-108.630307	43.259400	-108.630390	5,680	5680	1/12/2002	1/12/2002
Pavillion 11-10	7%	155.38	PGDW41A	2213.53			Tribal Pavillion 11-10	1321676	1321676	4901321676	43.256480	-108.634800	43.256060	-108.634900	8,082	8082	8/23/1993	8/23/1993
Tribal Pavillion 12-10	4%	98.53	PGDW14	2263.08			Tribal Pavillion 12-10	1322141	1322141	4901322141	43.251916	-108.635844	43.251650	-108.635910	4,908	5397	7/24/2001	7/24/2001
Tribal Pavillion 33-2	0%	4.51	PGDW05	2298.04			Tribal Pavillion 33-02	1321693	1321693	4901321693	43.262080	-108.605220	43.262070	-108.605230	5,498	5498	6/17/1994	6/17/1994
Pavillion Fee 13-10	8%	176.52	PGDW14	2312.83			Pavillion Fee 13-10	1322243	1322243	4901322243	43.249110	-108.635389	43.249160	-108.634730	5,705	5705	11/18/2004	11/18/2004
Pavillion Fee 44-11	2%	36.54	PGDW32	2346.96			Pavillion Fee 44-11	1322199	1322199	4901322199	43.245130	-108.600590	43.245230	-108.600600	4,070	4070	2/8/2002	2/8/2002
Pavillion Fee 23-3	3%	61.73	PGDW41B	2350.33			Pavillion Fee 23-03	1322207	1322207	4901322207	43.264110	-108.629444	43.263950	-108.629520	5,575	6000	11/7/2001	11/8/2001
Tribal-Pav 41-15	0%	7.76	PGDW23	2389.32			Tribal Pavillion 41-15	1321695	1321695	4901321695	43.242770	-108.618650	43.242750	-108.618640	6,526	6526	7/28/1994	7/28/1994
Pavillion Fee 43-11	7%	164.59	PGDW20	2461.83			Pavillion Fee 43-11	1322200	1322200	4901322200	43.250890	-108.600444	43.250940	-108.599830	4,000	4000	12/1/2001	12/1/2001
Pavillion Fee 32-11	7%	169.71	PGDW05	2502.97			Pavillion Fee 32-11	1322223	1322223	4901322223	43.253560	-108.606639	43.253450	-108.606020	4,000	4000	2/3/2002	2/3/2002

Appendix K Table 2

COMPARISON OF LATITUDE AND LONGITUDE DATA BETWEEN WOGCC AND ENCANA AND SELECTION OF LOCATIONS FOR VERIFICATION BY DISTANCE TO WATER WELL
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC LOCATION	Error as % Distance to Water Well	DISTANCE WOGCC TO ENCANA (FEET)	NEAREST Warter Well TO WOGCC	DISTANCE WOGCC TO Water Well	Verify	Notes	ENCANA LOCATION	WOGCC API	ENCANA API (7-DIGIT)	ENCANA API (FULL)	WOGCC LATITUDE	WOGCC LONGITUDE	ENCANA LATITUDE	ENCANA LONGITUDE	WOGCC DEPTH	ENCANA DEPTH	WOGCC SPUD_DATE	ENCANA SPUD_DATE
Pavillion Fee 13-11	2%	51.66	PGDW23	2539.48			Pavillion Fee 13-11	1322058	1322058	4901322058	43.248610	-108.613056	43.248650	-108.612870	5,800	5800	12/27/2000	12/27/2000
Tribal-Pav 31-15	1%	36.80	PGDW23	2545.47			Tribal Pavillion 31-15	1320062	1320062	4901320062	43.241940	-108.625190	43.241990	-108.625310	3,445	3445	1/26/1968	1/26/1968
14-11	2%	45.02	PGDW23	2569.86			Tribal Pavillion 14X-11	1306355	1306355	4901306355	43.246490	-108.613410	43.246610	-108.613450	4,930	4930	11/9/1965	11/9/1965
Unit 31X-14	1%	37.73	PGDW33	2597.05			Tribal Pavillion 31X-14	1320456	1320456	4901320456	43.240710	-108.605690	43.240800	-108.605760	5,000	5148	9/8/1973	9/8/1973
Pavillion Fee 43-9	7%	176.97	PGDW42	2657.40			Pavillion Fee 43-09	1322171	1322171	4901322171	43.250810	-108.639972	43.250850	-108.639310	5,668	5668	4/24/2005	4/24/2005
Pavillion Fee 42X-9	3%	74.63	PGDW42	2691.95			Pavillion Fee 42X-09	1321905	1321905	4901321905	43.252780	-108.638060	43.252980	-108.638120	5,969	5969	11/29/1998	11/29/1998
John K. Coolidge 1-4	2%	56.38	PGDW42	2725.59			Coolidge John K 01-04	1321087	1321087	4901321087	43.263060	-108.649440	43.262920	-108.649350	3,750	3750	2/22/1982	2/22/1982
Pavillion Fee 41-11	4%	100.24	PGDW20	2725.75			Pavillion Fee 41-11	1321866	1321866	4901321866	43.255560	-108.600000	43.255510	-108.600370	5,100	5100	12/14/1998	12/13/1998
Pavillion Fee 43-11B	6%	177.24	LD-02	2744.82			Pavillion Fee 43-11B	1322600	1322600	4901322600	43.248060	-108.600333	43.248100	-108.599670	3,948	3948	1/14/2005	1/14/2005
Pavillion Fee 41-11B	0%	0.80	PGDW05	2778.75			Pavillion Fee 41-11B	1322601	1322601	4901322601	43.257030	-108.602500	43.257028	-108.602500	3,900	3900	3/22/2005	3/22/2005
Tribal Pavillion 14-10	2%	55.29	PGDW44	2796.67			Tribal Pavillion 14-10	1322099	1322099	4901322099	43.245833	-108.635000	43.245920	-108.635170	3,500	3500	1/20/2001	1/20/2001
Unit 42X-12	3%	80.21	PGDW20	2818.22			Tribal Pavillion 42X-12	1320443	1320443	4901320443	43.254440	-108.581390	43.254230	-108.581480	4,950	4950	8/26/1973	8/26/1973
Tribal Pavillion 22-03	6%	177.79	PGDW41B	2821.18			Tribal Pavillion 22-03	1322258	1322258	4901322258	43.268440	-108.631694	43.268490	-108.631030	5,500	5500	5/23/2005	5/23/2005
Tribal Pavillion 44-2	6%	173.61	PGDW05	2824.55			Tribal Pavillion 44-02	1322147	1322147	4901322147	43.260110	-108.602167	43.259980	-108.601540	4,100	4100	6/30/2001	6/30/2001
Tribal Pavillion 33-02B	6%	178.78	PGDW05	2944.22			Tribal Pavillion 33-02B	1322625	1322625	4901322625	43.263220	-108.603333	43.263264	-108.602665	3,705	3705	2/26/2005	2/26/2005
Tribal Pavillion 12-2	4%	118.11	PGDW45	2987.58			Tribal Pavillion 12-02	1322182	1322182	4901322182	43.266940	-108.615056	43.266850	-108.614630	4,070	3700	10/30/2001	10/30/2001
W.H. Paul Patent 42X-11	2%	55.25	PGDW20	3016.74			Tribal Pavillion 42X-11	1320442	1320442	4901320442	43.253490	-108.602310	43.253340	-108.602340	5,028	5028	8/6/1973	8/6/1973
Tribal Pavillion 42-15	6%	180.19	PGDW23	3239.88			Tribal Pavillion 42-15	1322100	1322100	4901322100	43.239810	-108.621444	43.239850	-108.620770	5,497	5497	11/26/2006	11/26/2006
Pavillion Fee 44-11B	6%	178.91	PGDW32	3252.06			Pavillion Fee 44-11B	1322599	1322599	4901322599	43.246860	-108.603028	43.246910	-108.602360	3,948	3948	1/5/2005	1/5/2005
USA Tribal 258 21-15	1%	48.05	PGDW44	3261.99			Tribal Pavillion 21-15	1320889	1320889	4901320889	43.242090	-108.631390	43.242220	-108.631420	5,200	5200	7/13/1979	7/13/1979
Tribal Pavillion 14-1	3%	84.88	PGDW20	3303.99			Tribal Pavillion 14-01	1306389	1306389	4901306389	43.260210	-108.595410	43.259980	-108.595460	4,115	4115	1/30/1963	1/30/1963
Pavillion Fee 11-03	5%	151.34	PGDW41B	3355.16			Pavillion Fee 11-03	1322212	1322212	4901322212	43.270830	-108.633694	43.270710	-108.633150	3,991	3991	11/14/2001	11/15/2001
Pavillion Fee 34-11	1%	26.08	PGDW33	3377.52			Pavillion Fee 34-11	1322103	1322103	4901322103	43.245140	-108.605306	43.245120	-108.605400	3,360	3360	5/23/2001	5/24/2001
Tribal Pavillion 23-11	22%	732.87	PGDW05	3382.81			Tribal Pavillion 23-11	1321806	1321806	4901321806	43.250710	-108.606530	43.250760	-108.609280	5,540	5540	10/19/1997	10/19/1997
Tribal Pavillion 32-03	5%	177.00	PGDW30	3410.31			Tribal Pavillion 32-03	1322259	1322259	4901322259	43.266580	-108.625861	43.266630	-108.625200	5,458	5458	5/4/2005	5/4/2005
Pavillion Fee 33-11B	5%	177.04	PGDW05	3436.47			Pavillion Fee 33-11B	1322313	1322313	4901322313	43.250610	-108.606361	43.250660	-108.605700	3,975	3975	12/25/2004	12/25/2004
Tribal-Pav 15-21X	2%	63.95	PGDW23	3485.50			Tribal Pavillion 15-21X	1321840	1321840	4901321840	43.240550	-108.629520	43.240550	-108.629280	16,140	16140	4/21/1998	4/21/1998
Tribal Pavillion 24-11	5%	178.31	PGDW23	3545.24			Tribal Pavillion 24-11	1322222	1322222	4901322222	43.245170	-108.610167	43.245210	-108.609500	3,926	3926	11/28/2004	11/28/2004
Pavillion Fee 33-11	3%	120.30	PGDW20	3563.37			Pavillion Fee 33-11	1321670	1321670	4901321670	43.248460	-108.603900	43.248700	-108.603590	5,050	5050	5/27/1993	5/27/1993
Tribal Pavillion 34-1	4%	146.14	PGDW20	3583.60			Tribal Pavillion 34-01	1322146	1322146	4901322146	43.260830	-108.586389	43.260700	-108.585870	3,345	3345	9/11/2001	9/11/2001
Tribal Pavillion 42-3	3%	122.85	PGDW45	3641.71			Tribal Pavillion 42-03	1322191	1322191	4901322191	43.267780	-108.619222	43.267740	-108.619680	4,025	4025	10/17/2001	10/29/2001
Tribal Pavillion 24-1	3%	97.21	PGDW20	3649.90			Tribal Pavillion 24-01	1322101	1322101	4901322101	43.261667	-108.590556	43.261470	-108.590310	3,400	3400	2/15/2001	2/15/2001
Tribal Unit 238 11-14	1%	48.05	PGDW23	3651.00			Tribal Pavillion 11-14	1320857	1320857	4901320857	43.241510	-108.612990	43.241640	-108.613020	5,250	5250	7/28/1979	7/28/1979
Tribal 24-4	1%	26.36	PGDW33	3668.43			Tribal 24-4	1320775	1320775	4901320775	43.228490	-108.595690	43.228520	-108.595780	3,990	3990	5/12/1978	5/12/1978
Tribal Pavillion 21-14	5%	178.06	PGDW33	3704.57			Tribal Pavillion 21-14	1322216	1322216	4901322216	43.241250	-108.609806	43.241290	-108.609140	5,600	5600	11/30/2004	11/30/2004
Tribal Pavillion 43-2	1%	29.53	PGDW05	3806.63			Tribal Pavillion 43-02	1322068	1322068	4901322068	43.263330	-108.599720	43.263320	-108.599830	3,400	3400	1/28/2001	1/28/2001
Unit 24-14	0%	4.52	PGDW33	3966.72			Tribal Pavillion 24X-14	1306336	1306336	4901306336	43.232310	-108.608610	43.232320	-108.608600	3,803	3803	11/5/1963	11/5/1963
Pavillion Fee 22-4	4%	178.78	PGDW42	3995.14			Pavillion Fee 22-04	1322825	1322825	4901322825	43.266060	-108.652389	43.266100	-108.651720	5,491	5491	11/13/2006	11/13/2006
Tribal Pavillion 12-7	2%	69.25	LD-02	4034.51			Tribal Pavillion 12-07	1322126	1322126	4901322126	43.252650	-108.576130	43.252460	-108.576130	3,350	3350	6/8/2001	6/8/2001
Unit 31X-3	1%	29.64	PGDW41B	4229.22			Tribal Pavillion 31X-03	1320457	1320457	4901320457	43.269490	-108.625560	43.269410	-108.625580	5,148	5148	9/30/1973	9/30/1973
Tribal Pavillion 32-02	16%	684.52	PGDW05	4261.73			Tribal Pavillion 32-02	1322245	1322245	4901322245	43.268861	-108.604361	43.267140	-108.605390	5,280	5280	2/24/2006	2/24/2006
Tribal Pavillion 44-1	1%	45.14	PGDW20	4290.91			Tribal Pavillion 44-01	1322027	1322027	4901322027	43.260270	-108.580270	43.260370	-108.580370	3,500	3500	1/15/2001	1/15/2001
Tribal-Unit 2	1%	26.90	PGDW33	4425.66			Tribal Unit 2	1308274	1308274	4901308274	43.228410	-108.605560	43.228420	-108.605660	4,296	4300	6/13/1979	6/13/1979
Tribal Pavillion 23-1	0%	4.51	PGDW20	4489.88			Tribal Pavillion 23-01	1321697	1321697	4901321697	43.263960	-108.590190	43.263950	-108.590180	5,306	5306	7/10/1994	7/10/1994
Tribal Pavillion 33-1	1%	62.02	PGDW20	4697.25			Tribal Pavillion 33-01	1322144	1322144	4901322144	43.263810	-108.585360	43.263640	-108.585370	3,475	3475	6/18/2001	6/18/2001
Tribal Pavillion 41-3	2%	78.33	PGDW45	4707.88			Tribal Pavillion 41-03	1322153	1322153	4901322153	43.270560	-108.620556	43.270440	-108.620800	4,030	4030	10/22/2001	10/22/2001
Tribal Pavillion 41X-2	1%	52.74	PGDW05	4722.90			Tribal Pavillion 41X-02	1320454	1320454	4901320454	43.269440	-108.602410	43.269300	-108.602460	5,006	5006	9/7/1973	9/7/1973

Appendix K Table 2

COMPARISON OF LATITUDE AND LONGITUDE DATA BETWEEN WOGCC AND ENCANA AND SELECTION OF LOCATIONS FOR VERIFICATION BY DISTANCE TO WATER WELL
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC LOCATION	Error as % Distance to Water Well	DISTANCE WOGCC TO ENCANA (FEET)	NEAREST Warter Well TO WOGCC	DISTANCE WOGCC TO Water Well	Verify	Notes	ENCANA LOCATION	WOGCC API	ENCANA API (7-DIGIT)	ENCANA API (FULL)	WOGCC LATITUDE	WOGCC LONGITUDE	ENCANA LATITUDE	ENCANA LONGITUDE	WOGCC DEPTH	ENCANA DEPTH	WOGCC SPUD_DATE	ENCANA SPUD_DATE
Tribal Pavillion 13-1	2%	73.21	PGDW20	4753.27			Tribal Pavillion 13-01	1322128	1322128	4901322128	43.264330	-108.595528	43.264150	-108.595650	3,514	3514	6/3/2001	6/30/2001
Tribal Pavillion 43-1	4%	215.43	PGDW20	5139.47			Tribal Pavillion 43-01	1322145	1322145	4901322145	43.263780	-108.581389	43.263650	-108.580600	3,400	3700	6/26/2001	6/26/2001
Tribal-Pav 14-6	2%	109.60	PGDW20	5292.44			Tribal Pavillion 14-06	1306392	1306392	4901306392	43.260560	-108.575560	43.260280	-108.575710	4,000	4000	6/9/1963	6/9/1963
Taylor Patented 1	0%	26.06	PGDW33	5340.54			Taylor Patented	1320598	1320598	4901320598	43.228060	-108.610410	43.227990	-108.610390	4,010	4010	4/22/1976	4/22/1976
Gov't 23-7	0%	15.19	LD-02	5399.31			Govt 23-07	1306359	1306359	4901306359	43.248410	-108.571390	43.248430	-108.571440	8,038	8038	3/3/1961	3/3/1961
Pavillion Fee 13-15	0%	0.00	PGDW23	5561.84			Pavillion Fee 13-15	1322104	1322104	4901322104	43.235830	-108.633889	43.235830	-108.633889	3,650	3650	4/10/2001	4/10/2001
Tribal Pavillion 22-1	3%	154.70	PGDW20	5688.17			Tribal Pavillion 22-01	1322180	1322180	4901322180	43.267250	-108.590111	43.267140	-108.589550	3,510	3700	9/30/2001	9/30/2001
Tribal Pavillion 12-1	10%	601.26	PGDW20	5874.14			Tribal Pavillion 12-01	1322181	1322181	4901322181	43.267780	-108.591694	43.266810	-108.593520	3,505	3700	9/16/2001	9/16/2001
West Pavillion 1-8-1B	0%	0.00	PGDW42	5896.16			West Pavillion 1-8-1B	1321088	1321088	4901321088	43.256190	-108.669440	43.256190	-108.669440	5,207	5207	5/30/1981	5/30/1981
Tribal Unit 1	3%	203.87	PGDW33	5969.08			Tribal Unit 1	1320654	1320654	4901320654	43.228490	-108.614090	43.228380	-108.614840	3,670	3670	10/15/1976	10/15/1976
Tribal Pavillion 32-1	11%	700.52	PGDW20	6102.85			Tribal Pavillion 32-01	1322026	1322026	4901322026	43.267220	-108.582780	43.267200	-108.585410	3,380	3380	1/28/2001	1/26/2001
Doles Unit 44-15	0%	9.03	PGDW23	6645.04			Tribal Pavillion 44-15	1320764	1320764	4901320764	43.230560	-108.619590	43.230580	-108.619610	5,375	5375	2/26/1978	2/26/1978
Woodring 23X-24	0%	0.00	PGDW33	7265.89			Woodring 23X-24	1306281	1306281	4901306281	43.218790	-108.592710	43.218790	-108.592710	5,252	4100	4/17/1964	4/17/1964
Unit TR1-22	0%	27.65	PGDW33	7525.54			IND 14-20-0258-2963 TR	1320581	1320581	4901320581	43.227410	-108.620190	43.227340	-108.620150	4,200	4200	12/15/1975	12/15/1975
Garrett 1	0%	0.00	PGDW42	8469.48			Garrett 1	1320965	1320965	4901320965	43.241670	-108.672610	43.241670	-108.672610	5,494	5494	10/13/1979	10/13/1979
Tribal 1-21	0%	2.67	PGDW23	8952.69			Tribal 1-21	1320586	1320586	4901320586	43.227410	-108.639440	43.227410	-108.639450	3,966	3965	3/5/1976	3/5/1976
Runner Herefords 44-17	0%	16.63	PGDW42	9644.40			Runner Herfords 44-17	1308017	1308017	4901308017	43.230910	-108.659810	43.230870	-108.659840	4,240	4240	5/18/1964	5/18/1964
Runner Herefords 1	0%	15.27	PGDW42	9735.48			Runner Herford	1321157	1321157	4901321157	43.230560	-108.659490	43.230590	-108.659450	4,006	4006	9/17/1981	9/17/1981
Finlayson 1-17	0%	0.00	PGDW42	10120.59			Finlayson 01-17	1321086	1321086	4901321086	43.231390	-108.665560	43.231390	-108.665560	5,610	5610	8/19/1980	8/19/1980
Govt 21-8	1%	61.67	LD-02	10870.54			IND 14-20-258-1315 21-8	1306376	1306376	4901306376	43.257110	-108.551110	43.256970	-108.551240	4,500	4500	3/19/1963	3/19/1963
21-05	0%	31.04	PGDW20	12857.29			Tribal Pavillion 21-05	1306413	1306413	4901306413	43.271110	-108.550990	43.271030	-108.551030	5,000	5000	2/24/1963	2/23/1963
Govt 44-20	0%	0.00	PGDW32	16564.91			Govt 44-20	1306273	1306273	4901306273	43.216940	-108.541190	43.216940	-108.541190	5,000	5000	3/9/1963	3/9/1963
Govt 32-4	0%	0.00	LD-02	18229.33			Govt 32-04	1306402	1306402	4901306402	43.267390	-108.526290	43.267390	-108.526290	5,000' (?)	5000	7/10/1963	7/10/1963
Govt-Ocean Lake 1	0%	0.00	LD-02	18339.50			Govt-Ocean Lake	1306358	1306358	4901306358	43.246490	-108.522710	43.246490	-108.522710	6,000	6000	5/11/1963	5/11/1963
Shoshone-Arapahoe 16-34		NO MATCH	PGDW41B	20194.73			NO MATCH	1321682	NA	NA	43.317310	-108.644850	NA	NA	7007	NA	10/14/1995	NA
Clair C Day 1	0%	0.00	PGDW42	21538.14			Clair C Day	1320491	1320491	4901320491	43.201670	-108.679910	43.201670	-108.679910	8,021	8021	4/20/1974	4/20/1974
Ocean Lake Tribal 1-15	0%	0.00	LD-02	21963.21			Ocean Lake Tribal 01-15	1321312	1321312	4901321312	43.237890	-108.510910	43.237890	-108.510910	15,770	15770	11/1/1982	11/1/1982
Haymaker 14-21	0%	0.00	LD-02	25985.98			Haymaker 14-21	1322819	1322819	4901322819	43.242080	-108.494528	43.242080	-108.494528	11,164	11800	11/23/2005	11/23/2005
Shoshone-Arapahoe 24-1	0%	0.00	LD-02	26574.45			Shoshone-Arapahoe 24-11	1320748	1320748	4901320748	43.245560	-108.491790	43.245560	-108.491790	14,975	14975	12/11/1977	12/11/1977
Leonhardt 41-26	194%	61444.35	PGDW32	31725.81			Leonhardt 41-26	1323068	1323068	4901323068	43.213611	-108.481028	43.124900	-108.285170	5,100	7500	5/20/2007	5/20/2007
Tribal 14-24	0%	0.00	PGDW32	33618.18			Tribal 14-24	1321302	1321302	4901321302	43.216310	-108.472500	43.216310	-108.472500	8,850	8852	7/22/1982	7/22/1982
NO MATCH		NO MATCH	NA	NA			Fike Tribal A-01	NA	1321346	4901321346	NA	NA	43.292590	-108.644490	NA	5364	NA	12/28/1982
NO MATCH		NO MATCH	NA	NA			Govt 34-33	NA	1306424	4901306424	NA	NA	43.274280	-108.644550	NA	5113	NA	4/29/1964
NO MATCH		NO MATCH	NA	NA			IND 14-20-058-1555	NA	1306917	4901306917	NA	NA	43.275820	-108.554320	NA	3860	NA	8/25/1965
NO MATCH		NO MATCH	NA	NA			NW Pavillion 17-01	NA	1320120	4901320120	NA	NA	43.324910	-108.669720	NA	6000	NA	10/26/1968
NO MATCH		NO MATCH	NA	NA			NW Pavillion Fee 34-28	NA	1322642	4901322642	NA	NA	43.289690	-108.644694	NA	5645	NA	3/10/2005
NO MATCH		NO MATCH	NA	NA			Pavillion 43-03	NA	1322077	4901322077	NA	NA	43.262780	-108.620830	NA	NA	NA	NA
NO MATCH		NO MATCH	NA	NA			Pavillion Fee 33-04	NA	1322733	4901322733	NA	NA	43.262780	-108.646833	NA	NA	NA	NA
NO MATCH		NO MATCH	NA	NA			Roland Patented 34-13	NA	1320700	4901320700	NA	NA	43.275150	-108.633900	NA	6500	NA	6/3/1977
NO MATCH		NO MATCH	NA	NA			Shell-Govt 22-35	NA	1306451	4901306451	NA	NA	43.281790	-108.610190	NA	5499	NA	2/11/1963
NO MATCH		NO MATCH	NA	NA			Tribal 1-31	NA	1320602	4901320602	NA	NA	43.274020	-108.560910	NA	3852	NA	5/8/1976
NO MATCH		NO MATCH	NA	NA			Tribal Hunt 01-17	NA	1320805	4901320805	NA	NA	43.324910	-108.664810	NA	10212	NA	7/21/1978
NO MATCH		NO MATCH	NA	NA			Tribal NP 31-11X	NA	1321834	4901321834	NA	NA	43.284800	-108.574130	NA	14500	NA	10/31/1997
NO MATCH		NO MATCH	NA	NA			Tribal Pavillion 12-05	NA	1322061	4901322061	NA	NA	43.267380	-108.555860	NA	3470	NA	12/17/2000
NO MATCH		NO MATCH	NA	NA			Tribal Pavillion 12-06	NA	1322069	4901322069	NA	NA	43.267890	-108.575510	NA	3600	NA	2/25/2001
NO MATCH		NO MATCH	NA	NA			Tribal Pavillion 14-11	NA	1322732	4901322732	NA	NA	NA	NA	NA	NA	NA	NA
NO MATCH		NO MATCH	NA	NA			Tribal Pavillion 16-28	NA	1321026	4901321026	NA	NA	43.290280	-108.524090	NA	4548	NA	4/3/1980

Appendix K Table 2

COMPARISON OF LATITUDE AND LONGITUDE DATA BETWEEN WOGCC AND ENCANA AND SELECTION OF LOCATIONS FOR VERIFICATION BY DISTANCE TO WATER WELL
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC LOCATION	Error as % Distance to Water Well	DISTANCE WOGCC TO ENCANA (FEET)	NEAREST Warter Well TO WOGCC	DISTANCE WOGCC TO Water Well	Verify	Notes	ENCANA LOCATION	WOGCC API	ENCANA API (7-DIGIT)	ENCANA API (FULL)	WOGCC LATITUDE	WOGCC LONGITUDE	ENCANA LATITUDE	ENCANA LONGITUDE	WOGCC DEPTH	ENCANA DEPTH	WOGCC SPUD_DATE	ENCANA SPUD_DATE
NO MATCH		NO MATCH	NA	NA			Tribal Pavillion 43-06	NA	1321720	4901321720	NA	NA	43.264700	-108.559780	NA	4000	NA	4/24/1995

Appendix K Table 3

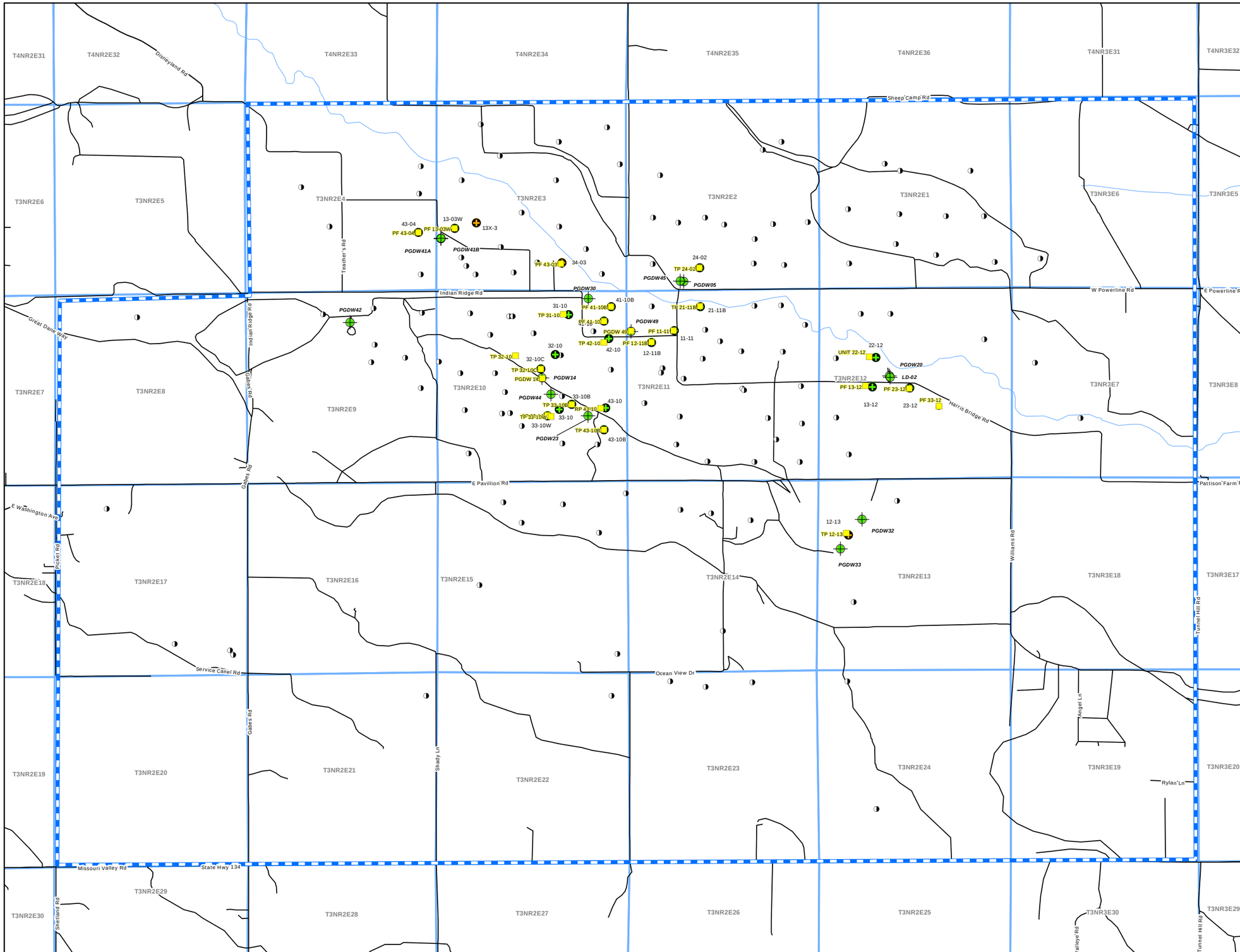
RESULTS OF FIELD VERIFICATION AND COMPARISON OF ERRORS
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC API	LOCATION	WOGCC Latitude	WOGCC Longitude	ENCANA Latitude	ENCANA Longitude	Field GPS Latitude	Field GPS Longitude	Distance WOGCC to Field GPS (feet)	Distance ENCANA to Field GPS (feet)
1320855	Tribal Pavillion 12-13	43.239590	-108.595560	43.239700	-108.595580	43.239720	-108.595768	72.8	50.6
1320878	Unit 22-12	43.253060	-108.592690	43.253060	-108.592690	43.253096	-108.593332	171.3	171.6
1321691	Pavillion Fee 31-10	43.256330	-108.624600	43.256330	-108.624600	43.256365	-108.625138	143.9	143.9
1321696	Tribal 42-10	43.254540	-108.620440	43.254160	-108.620410	43.254231	-108.620931	172.6	141.3
1321704	Tribal Pavillion 43-10	43.249250	-108.620760	43.249240	-108.620760	43.249234	-108.621267	135.2	135.1
1321862	Tribal Pavillion 33-10	43.249170	-108.625560	43.248920	-108.625920	43.248612	-108.626454	313.2	181.2
1321904	Pavillion Fee 13X-3	43.263330	-108.634170	43.263410	-108.637120	Not Located	Not Located	--	--
1321968	Tribal Pavillion 32-10	43.253300	-108.626000	43.253220	-108.629550	43.253238	-108.630100	1092.6	146.7
1322005	Pavillion Fee 34-03	43.260280	-108.625280	43.263780	-108.625260	43.260218	-108.625389	36.8	1298.7
1322059	Pavillion Fee 11-11	43.255109	-108.613611	43.248650	-108.613110	43.255122	-108.613706	25.6	2364.2
1322060	Pavillion Fee 13-12	43.250830	-108.593056	43.250833	-108.593056	43.250891	-108.593728	180.2	180.4
1322186	Pavillion Fee 23-12	43.250720	-108.589167	43.250722	-108.589167	43.250699	-108.589188	9.3	10.1
1322195	Tribal Pavillion 33-10W	43.248690	-108.626806	43.248770	-108.626260	43.248702	-108.626805	4.5	147.9
1322198	Pavillion Fee 41-10	43.255860	-108.620917	43.255861	-108.620917	43.255851	-108.620913	3.3	3.6
1322236	Tribal Pavillion 24-02	43.259890	-108.610972	43.259889	-108.610972	43.259882	-108.610983	4.2	3.9
1322246	Pavillion Fee 13-03W	43.262920	-108.636417	43.262960	-108.635750	43.262919	-108.636420	1.2	179.2
1322272	Pavillion Fee 12-11B	43.254220	-108.615972	43.254270	-108.615310	43.254237	-108.615986	7.3	180.6
1322274	Tribal Pavillion 33-10B	43.249530	-108.624278	43.249580	-108.623610	43.249535	-108.624267	3.4	175.8
1322419	Tribal Pavillion 32-10C	43.252220	-108.627500	43.252270	-108.626840	43.252211	-108.627491	4.1	174.7
1322420	Tribal Pavillion 43-10B	43.247610	-108.620944	43.247660	-108.620280	43.247613	-108.620928	4.3	173.6
1322586	Tribal Pavillion 21-11B	43.256940	-108.610917	43.256990	-108.610250	43.256953	-108.610928	5.4	181.1
1322624	Pavillion Fee 41-10B	43.256940	-108.620167	43.256986	-108.619497	43.256943	-108.620175	2.4	181.4
1322633	Pavillion Fee 43-04	43.262610	-108.640222	43.262660	-108.639560	43.262618	-108.640212	3.8	174.3

Appendix K Table 4

RECONCILIATION OF LOCATION INCONSISTENCIES FOR PITS WITHIN 1,420 FEET OF WATER WELLS
2014 Groundwater Investigation
Fremont County, Pavillion, Wyoming

WOGCC API	PIT LOCATION	INVESTTYPE	WOGCC Table Latitude	WOGCC Table Longitude	WOGCC Shape File Latitude	WOGCC Shape File Longitude	Adopted Latitude	Adopted Longitude	Adopted Latitude/ Longitude Note	Distance WOGCC Table to Adopted (Feet)	Distance WOGCC Shape File to Adopted (Feet)
1320668	Blankenship 4-8	Soil and Groundwater (VRP)	43.26556	-108.64009	43.265799	-108.640282	43.265799	-108.640282	WOGCC Shape File	101.1	0.0
1306363	Govt Tribal 33X-10	Soil (Excavation)	43.25019	-108.62528	43.251156	-108.624980	43.251156	-108.624980	WOGCC Shape File	361.1	0.0
1306388	Mae H. Rhodes 1	No Investigation	43.26009	-108.63519	43.260090	-108.635190	43.260090	-108.635190	WOGCC Shape File	0.1	0.0
1320084	Maxson 32-9	No Investigation	43.25278	-108.64511	43.252780	-108.645109	43.252780	-108.645109	WOGCC Shape File	0.2	0.0
1321904	Pavillion Fee 13X-3	No Investigation	43.26333	-108.63417	43.263330	-108.634170	43.263330	-108.634170	WOGCC Shape File	0.1	0.0
1322172	Pavillion Fee 31-9	Soil	43.25686	-108.644861	43.256666	-108.646053	43.256666	-108.646053	WOGCC Shape File	325.4	0.0
1321669	Pavillion Unit 12-11	No Investigation	43.25227	-108.61483	43.252270	-108.614830	43.252270	-108.614830	WOGCC Shape File	0.1	0.0
1321128	Tribal 14-2	Soil (Excavation) and Groundwater (VRP)	43.26021	-108.61583	43.260189	-108.616637	43.260189	-108.616637	WOGCC Shape File	215.1	0.0
1321130	Tribal 21-9	Soil (Excavation) and Groundwater	43.25639	-108.65011	43.256414	-108.650675	43.256414	-108.650675	WOGCC Shape File	150.8	0.0
1321696	Tribal 42-10	No Investigation	43.25454	-108.62044	43.254540	-108.620440	43.254231	-108.620931	Field GPS	0.0	172.6
1320855	Tribal Pavillion 12-13	Soil	43.23959	-108.59556	43.240041	-108.595714	43.240041	-108.595714	WOGCC Shape File	169.4	0.0
1321692	Tribal Pavillion 23-10	No Investigation	43.24889	-108.63068	43.248890	-108.630680	43.248890	-108.630680	WOGCC Shape File	0.1	0.0
1322417	Tribal Pavillion 23-10B	No Investigation	43.25047	-108.631222	43.250470	-108.631222	43.250470	-108.631222	WOGCC Shape File	0.1	0.0
1322418	Tribal Pavillion 23-10C	No Investigation	43.24789	-108.629472	43.247890	-108.629472	43.247890	-108.629472	WOGCC Shape File	0.1	0.0
1321968	Tribal Pavillion 32-10	No Investigation	43.2533	-108.626	43.253300	-108.626000	43.253238	-108.630100	Field GPS	0.0	1092.6
1321862	Tribal Pavillion 33-10	No Investigation	43.24917	-108.62556	43.249170	-108.625560	43.248612	-108.626454	Field GPS	0.1	313.2
1322274	Tribal Pavillion 33-10B	No Investigation	43.24953	-108.624278	43.249530	-108.624278	43.249535	-108.624267	Field GPS	0.0	3.4
1321704	Tribal Pavillion 43-10	No Investigation	43.24925	-108.62076	43.249250	-108.620760	43.249234	-108.621267	Field GPS	0.0	135.2
1322420	Tribal Pavillion 43-10B	No Investigation	43.24761	-108.620944	43.247610	-108.620944	43.247613	-108.620928	Field GPS	0.0	4.3
1321906	Tribal Pavillion 44-03	No Investigation	43.25944	-108.62111	43.259440	-108.621110	43.259440	-108.621110	WOGCC Shape File	0.0	0.0
1320878	Unit 22-12	Soil (Excavation) and Groundwater (VRP)	43.25306	-108.59269	43.253318	-108.593446	43.253318	-108.593446	WOGCC Shape File	222.3	0.0
1320414	Unit 41X-10	Soil and Groundwater	43.25511	-108.62201	43.254792	-108.622366	43.254792	-108.622366	WOGCC Shape File	149.8	0.0
1320879	Unit 44-10	Soil (Excavation)	43.24649	-108.62161	43.246680	-108.622413	43.246680	-108.622413	WOGCC Shape File	224.8	0.0
1320876	USA Tribal 22-10	Soil	43.25194	-108.63222	43.252033	-108.632856	43.252033	-108.632856	WOGCC Shape File	172.8	0.0
1320298	W.E. Lloyd 1	Soil and Groundwater	43.26011	-108.62528	43.260478	-108.625590	43.260478	-108.625590	WOGCC Shape File	157.5	0.0



Legend

Gas Well Locations for Field Verification

- Active
- Shut In
- Plugged
- Domestic Water Wells (Sub-meter GPS)
- Other Gas Well Locations
- Encana Gas Wells from Coordinates
- DEQ Gas and Domestic Wells (Sub-meter GPS)
- Streams
- Township-Range-Section (T3NR2E16)
- Cistern Area

N

0 0.25 0.5

1 inch equals 0.5 miles

FIGURE **DRAFT**

SELECTED GAS WELLS FOR LOCATION VERIFICATION

Pavillion 2015 Groundwater Investigation
Freemont County, Wyoming

AME
Engineers and Earth Scientists

1107 Investment Blvd., #290, El Dorado Hills, California 95762 (916) 939-7550

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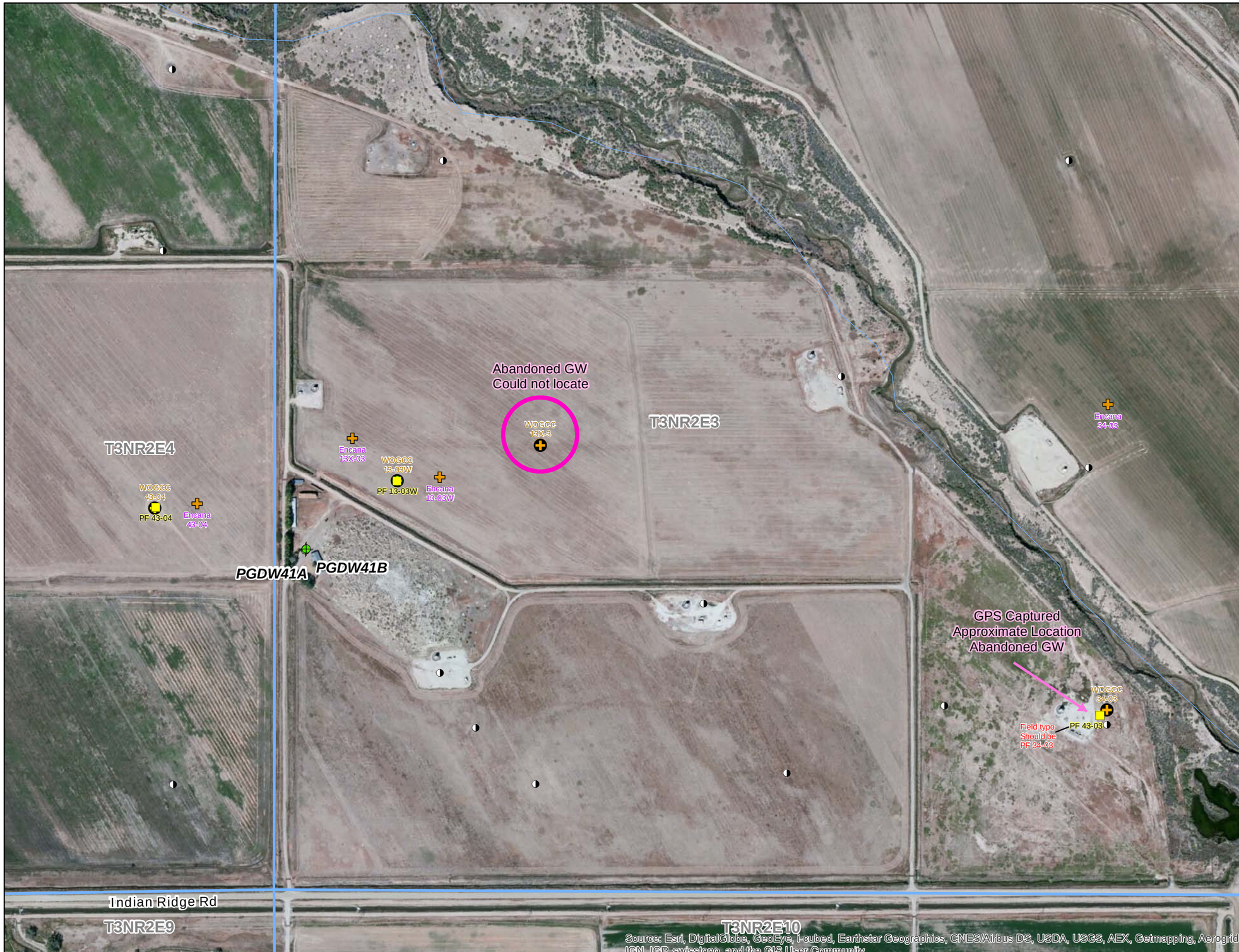


Legend

Gas Well Locations for Field Verification

- Active
- Shut In
- Plugged

Domestic Water Wells (Sub-meter GPS)

Other Gas Well Locations

Encana Gas Wells from Coordinates

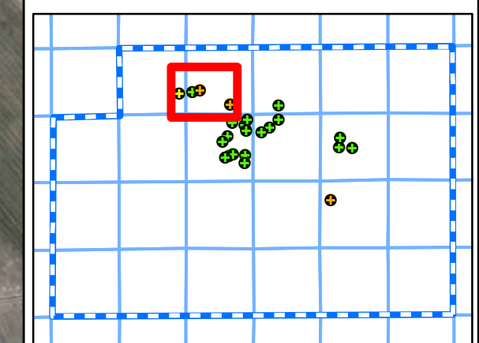
DEQ Gas and Domestic Wells (Sub-meter GPS)

Streams

Township-Range-Section

T3NR2E16

Cistern Area



N

0 200 400

1 inch equals 400 feet

FIGURE **DRAFT**

SELECTED GAS WELLS FOR LOCATION VERIFICATION

Pavillion 2015 Groundwater Investigation
Freemont County, Wyoming

AME
Engineers and Earth Scientists

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2015-05-28 T:\90081_Pavillion\GPS\MXD\fig1_T3NR2Esection3_4.mxd JW

Legend

Gas Well Locations for Field Verification

- Active
- Shut In
- Plugged

Domestic Water Wells (Sub-meter GPS)

Other Gas Well Locations

Encana Gas Wells from Coordinates

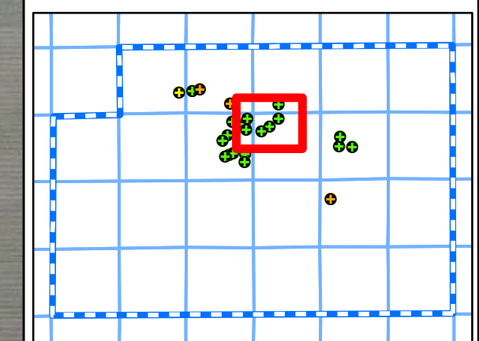
DEQ Gas and Domestic Wells (Sub-meter GPS)

Streams

Township-Range-Section

T3NR2E16

Cistern Area



N

0 200 400

1 inch equals 400 feet

FIGURE **DRAFT**

SELECTED GAS WELLS FOR LOCATION VERIFICATION

Pavillion 2015 Groundwater Investigation
Freemont County, Wyoming

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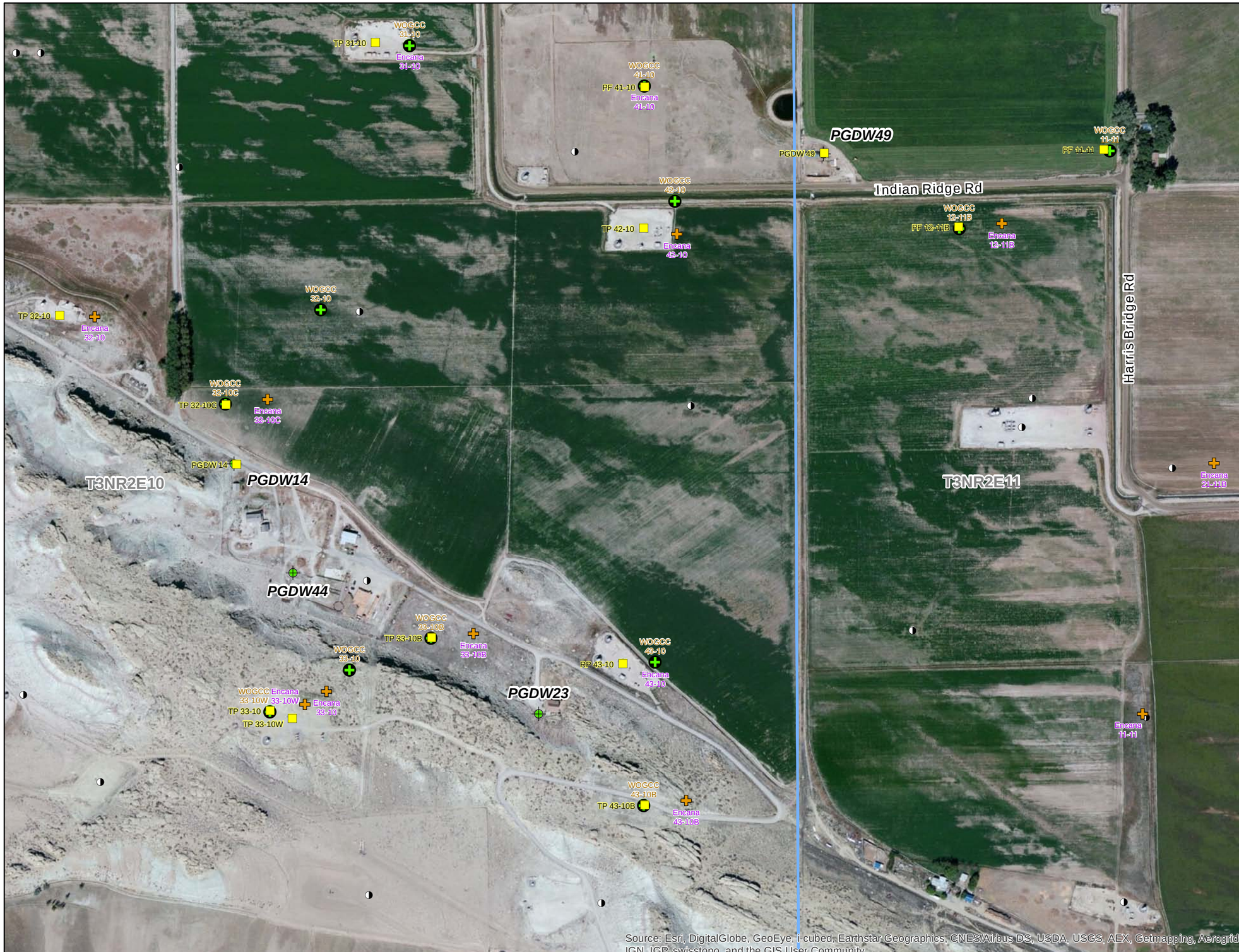

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Legend

Gas Well Locations for Field Verification

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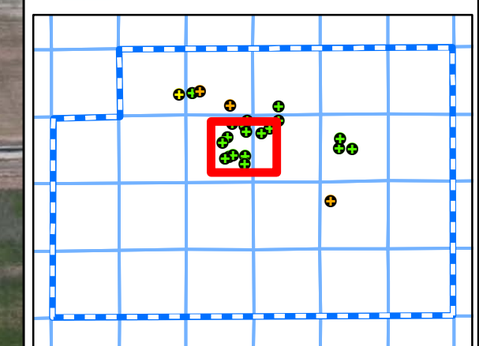
- Township-Range-Section (T3NR2E16)
- Cistern Area



N

0 200 400

1 inch equals 400 feet

FIGURE **DRAFT**

SELECTED GAS WELLS FOR LOCATION VERIFICATION

Pavillion 2015 Groundwater Investigation
Freemont County, Wyoming

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Engineers and Earth Scientists

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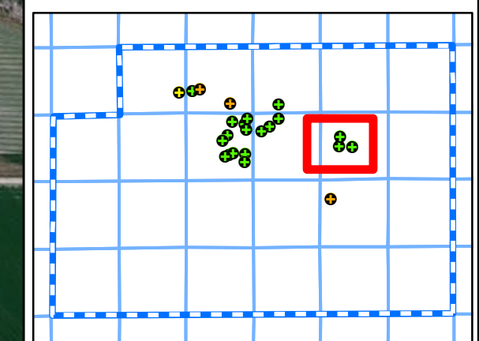
Legend

Gas Well Locations for Field Verification

- Active
- Shut In
- Plugged
- Domestic Water Wells (Sub-meter GPS)
- Other Gas Well Locations
- Encana Gas Wells from Coordinates
- DEQ Gas and Domestic Wells (Sub-meter GPS)
- Streams
- Township-Range-Section (T3NR2E16)
- Cistern Area



N

0 200 400

1 inch equals 400 feet

FIGURE **DRAFT**

SELECTED GAS WELLS FOR LOCATION VERIFICATION

Pavillion 2015 Groundwater Investigation
Freemont County, Wyoming

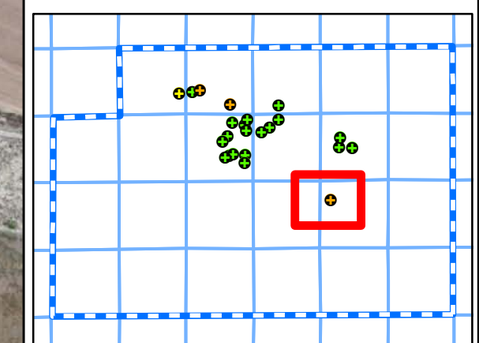
AME
Engineers and Earth Scientists
1107 Investment Blvd., #290, El Dorado Hills, California 95762 (916) 939-7550

2015-05-28 T:\90081_Pavillion\GPS\MXD\fig4_T3NR2Esection11_12.mxd JW

Legend

Gas Well Locations for Field Verification

- Active
- Shut In
- Plugged
- Domestic Water Wells (Sub-meter GPS)
- Other Gas Well Locations
- Encana Gas Wells from Coordinates
- DEQ Gas and Domestic Wells (Sub-meter GPS)
- Streams
- Township-Range-Section (T3NR2E16)
- Cistern Area



N

0 200 400

1 inch equals 400 feet

FIGURE **DRAFT**

SELECTED GAS WELLS FOR LOCATION VERIFICATION

Pavillion 2015 Groundwater Investigation
Freemont County, Wyoming

AME
Engineers and Earth Scientists

1107 Investment Blvd., #290, El Dorado Hills, California 95762 (916) 939-7550

2015-05-28 T:\90081_Pavillion\GPS\MXD\fig5_T3NR2Esection13_14.mxd JW

APPENDIX L

Construction Dates of Residences and Structures from Fremont County Assessor's Records

APPENDIX L

FIELD VERIFICATION OF OIL AND GAS WELLS AND ASSOCIATED PITS

Pavillion, Wyoming Area Domestic Water Wells

Final Report and Palatability Study

Well	Residence Year Built	Other Structure Earliest Year Built	SEO Well Permit Year	Note	pidn	Account Number	Tax id	Subno	Lot	Name	Address	Addresscsz	St_num	Street alp	St_dir	Street Name	St_type
PGDW05, PGDW45, PGDW49	1972	1934	1973/ -/-	PGDW49 stock well remote from residence.	91320230012300	R0024116	0000000000023541			MEEKS LOUIS AUSTIN FAMILY TRUST DTD FEB 7 1995	HCR-65 212 POWERLINE ROAD	PAVILLION, WY 82523	212			POWERLINE	RD
PGDW41A, PGDW41B	1987	1986	-/1984		91320330003800	R0024121	0000000000023546			TOYNE LEON & AMIE	179 INDIAN RIDGE RD	PAVILLION, WY 82523	179			INDIAN RIDGE	RD
PGDW42	-	1936	1981	Former residence may be classified as farm structure.	91320910007300	R0024251	0000000000023676			MUNGER JOHN E & LOSA L	PO BOX 674	CASPER, WY 82602	118			INDIAN RIDGE	RD
PGDW44	-	2001	1964	Stock well only on ranch parcel w/ farm structure vicinity of PGDW14.	91321010008400	R0024257	0000000000023682			INDIAN RIDGE AG ENT LLC	BOX 21	PAVILLION, WY 82523					
PGDW30	1985	1990	-		91321010021200	R0024259	0000000000023684			RANDALL BRIAN S & ZOEANNE M	219 INDIAN RIDGE RD	PAVILLION, WY 82523	219			INDIAN RIDGE	RD
PGDW14	1976	1935	-		91321010033300	R0024261	0000000000036041			GRIFFIN MARVIN & EVELYN	P O BOX 21 TRUSTEES	PAVILLION, WY 82523	330		E	PAVILLION	RD
PGDW23	2002	-	-	Consistent with year built reported by owner.	91321040033200	R0024266	0000000000036042			FENTON JOHN V & CATHERINE A	202 INDIAN RIDGE RD	PAVILLION, WY 82523	202			INDIAN RIDGE	RD
PGDW20, LD02	1941	1932	-/-		91321110011400	R0024267	0000000000023690			LOCKER JEFFREY D & RHONDA F	124 HARRIS BRIDGE ROAD	PAVILLION, WY 82523	124			HARRIS BRIDGE	RD
PGDW33	-	1942	1934	Ranch parcel; abandoned log house near PGDW33. Supplies hydrant near PGDW32.	91321310005800	R0024281	0000000000023703			DENNIS RANCH LTD A LIMITED LIABILITY COMPANY	375 EAST PAVILLION ROAD	PAVILLION, WY 82523	1960		E	MISSOURI VALLEY	RD
PGDW32	1971	1930	1983		91321310015800	R0036362				DENNIS JOE B	375 E PAVILLION RD	PAVILLION, WY 82523	375		E	PAVILLION	RD

APPENDIX L

FIELD VERIFICATION OF OIL AND GAS WELLS AND ASSOCIATED PITS

Pavillion, Wyoming Area Domestic Water Wells

Final Report and Palatability Study

Well	St_address	Bookpage	Description	Area_tax	area_calc	acct_type	lea	grossacres	netacres	grosssf	netsf	land_val	acct_val	areaid	deed_date
PGDW05, PGDW45, PGDW49	212 POWERLINE RD		TWP 03N RNG 002E SEC 02: PARCEL IN TR 4 AND TR 6 & SEC 11 FR NWNW WD 1293698	46.909999999999900		Agricultural	8800I	46.9100	46.9100	2043399.6000	2043399.6000	20457.00	126591.00	0600	7/10/2007
PGDW41A, PGDW41B	179 INDIAN RIDGE RD		TWP 03N RNG 002E SEC 3: SW/4 (EXCEPT A 5 ACRE PLOT) WD2012-1356277	155.000000000000000		Agricultural	8800I	155.0000	155.0000	6751800.0000	6751800.0000	0.00	182625.00	0600	9/7/2012
PGDW42	118 INDIAN RIDGE RD		TWP 03N RNG 002E SEC 9: NE/4, NESE AND SEC 10: NWNW, N/2SENW, NESWNW WD 2009-1321959 CON 2010-1337167 WD 2014-1372458	270.000000000000000		Residential	8800D	270.0000	270.0000	11761200.0000	11761200.0000	127095.00	129373.00	0600	6/26/2014
PGDW44		9999 CONV 9999	TWP 03N RNG 002E SEC 10 S/2NE, N/2SE QCD 1235832	155.639999999999000		Agricultural	8800I	155.6400	155.6400	6779678.0000	6779678.4000	0.00	25182.00	0600	11/15/2002
PGDW30	219 INDIAN RIDGE RD		TWP 03N RNG 002E SEC 10 2 Comment: FR NENE- WD 789-421	2.000000000000000		Residential	8800D	2.0000	2.0000	87120.0000	87120.0000	16947.00	178017.00	0600	00000000
PGDW14	330 E PAVILLION RD	9999 CONV 9999	TWP 03N RNG 002E SEC 10 A TRACT OF LAND IN S/2NE N/2SE DOC 2001-1235831	2.210000000000000		Residential	8800D	2.2100	2.2100	96267.6000	96267.6000	8779.00	130671.00	0600	11/15/2002
PGDW23	202 INDIAN RIDGE RD	9999 CONV 9999	TWP 03N RNG 002E SEC 10 A PARCEL OF LAND IN N/2SE	2.150000000000000		Residential	8800D	2.1500	2.1500	93654.0000	93654.0000	8694.00	136074.00	0600	11/15/2002
PGDW20, LD02	124 HARRIS BRIDGE RD		TWP 03N RNG 002E SEC 11 FR NE/4 SEC 12 SWSENE, FR S/2SWNE, NWSENW, S/2SENW, FR SWNW TWP 03N RNG 003E SEC 20 S/2NE, E/2SE, SWSW, SE SEC 21 W/2SW, SESW, S/2NWSE, SWSE SEC 28 FR NWNE, N/2NW, S	966.159999999999000		Agricultural	8800I	966.1600	966.1600	42085929.6000	42085929.6000	175013.00	226724.00	0600	5/6/2008
PGDW33	1960 E MISSOURI VALLEY RD		TWP 03N RNG 002E SEC 13 ALL EXCEPT THE NWNW AND A TRACT IN THE NENW (571.2 AC) SEC 14 S/2 SE (80 AC), TR NE/4 (123.01 AC) SEC 23 N/2 EXC W/2SWSWNW (315 AC), SE N OF PAVILLION E B LATERAL (104.2 AC) SEC 24 N/2, SW EX HWY ROW (479.1 AC) QCD	1672.509999999990000		Agricultural	8800I	1672.5100	1672.5100	72854535.6000	72854535.6000	823851.00	909854.00	0600	9/4/2008
PGDW32	375 E PAVILLION RD		T03N R02E SEC 13: NWNW, TRACT IN THE NENW QCD 2012-1359153	68.799999999999900		Agricultural	8800I	68.8000	68.8000	2996928.0000	2996928.0000	64465.00	441563.00	0600	12/31/2012

APPENDIX N

Sampling/Development Information Forms

START

CALIBRATION WORK SHEET

Date of Calibration: 6-9-14 2200 TIME Sonde ID: 00F0052 AE
Technician: K. EMERY

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	~~5.4~~	Range	5.0 ± .45
Integrated conductivity cell constant	5.4	Range	5.0 ± .70
pH mv Buffer 7	-11	Range	0 ± 50 mv
pH mv Buffer 4	155	Range	+180 ± 50 mv*
pH mv Buffer 10	-181.8	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	NA	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0

Manufacturer and part number 2-AC00-2

Barometric Pressure: ~~759.9-15~~ 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

Standard	Pre Cal	Post Cal
Temperature	20.5	20.2 Sonde
Conductivity	4.49	4.45 / 4.49
pH 7	7.00	6.99 / 7.00
pH 4	4.00	4.04 / 4.00
pH 10	10.0	10.07 / 10.01
ORP	237.5 @ 20.2	234.0 / 237.5
Turbidity	0	1.6 / 0.1
Turbidity	—	— / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82% SET AIR	— / 82.1
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes:

NEW D.O. WIPERS

Solution ORDERING	LOT #	EXP.	Solution	LOT #	EXP
pH 4	9256	10/17/2015	NTU	9256	10/2015
pH 7	10931	4/2015	Conductivity	9256	10/2015
pH 10	10947	4/2015	ORP	060114	8/2015

Solution was purchased from EQUIPCO

START

CALIBRATION WORK SHEET

Date of Calibration: 6-9-14 2200 Time Sonde ID: 99 J 0941 AC
Technician: K. EMERY

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.3 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.1	Range	5.0 ± .70
pH mv Buffer 7	+10.8	Range	0 ± 50 mv
pH mv Buffer 4	142.4	Range	+180 ± 50 mv*
pH mv Buffer 10	-197.9	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	NA	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0

Manufacturer and part number 2-AC00-2

623.0 @ 5400'

Barometric Pressure: ~~759.9~~ 759.4 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

Standard	Pre Cal	Post Cal
Temperature	20.5	20.3 Sonde
Conductivity	4.49	4.48 / 4.49
pH 7	7.00	6.89 / 7.0
pH 4	4.00	4.02 / 4.0
pH 10	10.0	10.77 / 10.02
ORP	237.5 @ 20°C	234.3 / 237.4
Turbidity	0	1.5 / 0.0
Turbidity	—	— / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82% SAT% AIR	— / 81.9
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes:

ORDERING NEW D.O. wipers

Solution	LOT #	EXP.	Solution	LOT #	EXP
pH 4	9256	10/2015	NTU 0.0	9256	10/2015
pH 7	10931	4/2015	Conduct 4.49	9256	10/2015
pH 10	10947	4/2015	ORP	060114	8/2015

Solution From EQUIPCO

PRE-START

CALIBRATION WORK SHEET

Date of Calibration: 6-11-14 0500 TIME Sonde ID: 9950941 AC
Technician: R. EMERY

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? (Y) N BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.9 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant — Range 5.0 ± .45
Integrated conductivity cell constant 5.6 in Range 5.0 ± .70
pH mv Buffer 7 -22.4 Range 0 ± 50 mv
pH mv Buffer 4 150.4 Range +180 ± 50 mv*
pH mv Buffer 10 -180.9 Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) — Range 25 to 75
DO gain — Range 0.7 to 1.4
ODO gain — Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7
Manufacturer and part number distilled H_2O / YSI 6072 LOT# 14E461487 EXP 5/2015

Barometric Pressure: 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	—	Sonde
Conductivity	4.49	4.42 / 4.49
pH 7	7.0	6.89 / 7.0
pH 4	4.0	4.08 / 4.0
pH 10	10.0	10.03 / —
ORP	237.5	237.6 / —
Turbidity	0.0	0.4 / 0.0
Turbidity	12.7	14.8 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	81.8 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

distilled H_2O 2.03

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes:

Solution	LOT#	EXP	Solution	LOT#	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conduct.	9256	10/2015
pH 10.0	10947	4/2015			

PRE-START

CALIBRATION WORK SHEET

Date of Calibration: 6-11-14 0500 TIME Sonde ID: 00F0052 AE
Technician: K. Emery

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? (Y) N — IVM
ROX DO wiper changed? (Y) N
BGA-PC wiper changed? Y (N)
Chlorophyll wiper changed? Y (N)
BGA-PE wiper changed? Y (N)
Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.50	Range	5.0 ± .70
pH mv Buffer 7	-8.6	Range	0 ± 50 mv
pH mv Buffer 4	154.1	Range	+180 ± 50 mv*
pH mv Buffer 10	-177.9	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7
Manufacturer and part number Distilled H2O / YSI 6072 LOT # 14E467487 EXP. 5/2015

Barometric Pressure: 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	—	Sonde
Conductivity	4.49	4.46 / 4.49
pH 7	7.0	7.03 / —
pH 4	4.0	4.02 / —
pH 10	10.0	9.95 / —
ORP	237.5	237.3 / —
Turbidity	0.0	0.8 / 0.0
Turbidity	12.7	11.9 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82.0%	82.4 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —
distilled H2O	1.03	

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes:

Solution	LOT #	EXP	Solution	LOT #	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conduct	9256	10/2015
pH 10.0	10947	4/2015			

PRE-START

CALIBRATION WORK SHEET

Date of Calibration: 6/12/14 0520 Time Sonde ID: 00F0052AE
Technician: K. Emery

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant — Range 5.0 ± .45
Integrated conductivity cell constant 5.36 Range 5.0 ± .70
pH mv Buffer 7 -7.8 Range 0 ± 50 mv
pH mv Buffer 4 155.7 Range +180 ± 50 mv*
pH mv Buffer 10 -182.4 Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) — Range 25 to 75
DO gain — Range 0.7 to 1.4
ODO gain — Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7
Manufacturer and part number Distilled H2O @ 5,400' / YSI 6072 LOT # 14E467487 EX 5/2015

Barometric Pressure: 623 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	20.9	Sonde
Conductivity	4.49	4.52 / 4.49
pH 7	7.0	7.02 / 7.0
pH 4	4.0	4.07 / 4.00
pH 10	10.0	10.11 / 10.00
ORP	237.5	238.6 —
Turbidity	0.0	-1.9 / 0.6
Turbidity	12.7	13.6 / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82.2% Sat.	82.3 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Solution From EQUIPCO

Solution	Lot #	Ex	Solution	Lot #	Exp
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conduct	9256	10/2015
pH 10.0	10947	4/2015			

PRE - START

CALIBRATION WORK SHEET

Date of Calibration: 6/12/14 0520 TIME Sonde ID: 99J0941 AC

Technician: K.EMERY

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.48	Range	5.0 ± .70
pH mv Buffer 7	-8.8	Range	0 ± 50 mv
pH mv Buffer 4	143.8	Range	+180 ± 50 mv*
pH mv Buffer 10	-165.4	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number distilled H2O / YSI 6072 Lot # 14E467487 EXP. 5/2015

Barometric Pressure: 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values	Standard	Pre Cal / Post Cal
Temperature	21.1	___ Sonde
Conductivity	4.49	4.71 / 4.49
pH 7	7.0	/
pH 4	4.0	4.02 / 4.00
pH 10	10.00	9.96 / —
ORP	237.5	238.6 / 237.5
Turbidity	12.7	13.0 / —
Turbidity	0.0	-0.1 / 0.0
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82% SAT	78.3 / 82%
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Cal Solution From EQUIPCO

Notes:

solution	LOT #	EXP	Solution	LOT #	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conduct.	9256	10/2015
pH 10.0	10947	4/2015			

PRE-START

CALIBRATION WORK SHEET

Date of Calibration: 6-13-14 ~~[illegible]~~ 0510 Sonde ID: 00F0052 AE

Technician: K. Ewen

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.40	Range	5.0 ± .70
pH mv Buffer 7	-7.9	Range	0 ± 50 mv
pH mv Buffer 4	155.7	Range	+180 ± 50 mv*
pH mv Buffer 10	-178.6	Range	-180 ± 50 mv *
DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	22.18	— Sonde
Conductivity	4.49	4.51 / —
pH 7	7.0	7.03 / —
pH 4	4.0	4.02 / —
pH 10	10.0	9.93 / 10.0
ORP	237.5	232 / 237.5
Turbidity	0.0	-1.0 / 0.0
Turbidity	12.7	13.0 / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	81.2 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H_2O / YSI 6072 Lot # 14E467487 Exp 5/2015

Barometric Pressure: 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Cal Solution From. EQUIPCO

Notes:

Solution	Lot #	Exp	Solution	Lot #	Exp
pH 4.0	9256	10/2015	ORP	060114	9/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10947	4/2015			

PRE-START

CALIBRATION WORK SHEET

Date of Calibration: 06-13-14 0510 Sonde ID: 99 J0941 AC

Technician: K. Emery

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.9 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.2	Range	5.0 ± .70
pH mv Buffer 7	-11.8	Range	0 ± 50 mv
pH mv Buffer 4	156.3	Range	+180 ± 50 mv*
pH mv Buffer 10	-186.4	Range	-180 ± 50 mv *

*Note: Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number distilled H2O / YSI 6072 LOT# 14E 467487 EXP 5/2015

Barometric Pressure: 623 @ 5,400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	22.14	— Sonde
Conductivity	4.49	4.39 / 4.49
pH 7	7.0	6.89 / 7.0
pH 4	4.0	4.06 / 4.00
pH 10	10.00	10.00 / —
ORP	237.5	235.1 / 237.5
Turbidity	0.0	0.6 / —
Turbidity	12.7	12.8 / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	81.8 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

EQUIPCO Solution

Notes:

Solution	LOT #	EXP	Solution	LOT #	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10947	4/2015			

PRE-START

CALIBRATION WORK SHEET

Date of Calibration: 6-16-14 0500 Sonde ID: 00F00 52AE

Technician: K. E McEry

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant — Range 5.0 ± .45

Integrated conductivity cell constant 5.31 Range 5.0 ± .70

pH mv Buffer 7 -7.0 Range 0 ± 50 mv

pH mv Buffer 4 154.9 Range +180 ± 50 mv*

pH mv Buffer 10 -184.6 Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) — Range 25 to 75

DO gain — Range 0.7 to 1.4

ODO gain — Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H_2O / YSI 6072 Lot #14E 467487 EX 5/2015

Barometric Pressure: 623 @0500 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

Standard		Pre Cal / Post Cal
Temperature	23.08	___ Sonde
Conductivity	4.49	4.52 / 4.49
pH 7	7.0	6.94 / 7.00
pH 4	4.0	4.09 / 4.00
pH 10	10.0	10.11 / 10.00
ORP	237.5	235.2 / 237.5
Turbidity	0.0	-2.1 / 0.0
Turbidity	12.7	11.8 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	80.9 / 82.00
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes: EQuipco Solution

Solution	Lot #	Exp	Solution	Lot #	Exp
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10947	4/2015			

prestart

CALIBRATION WORK SHEET

Date of Calibration: 6-16-14 0500 Sonde ID: 99J0941 AC

Technician: Ki Emery

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.4 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.40	Range	5.0 ± .70
pH mv Buffer 7	-1.4	Range	0 ± 50 mv
pH mv Buffer 4	153.4	Range	+180 ± 50 mv*
pH mv Buffer 10	-149.4	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)		Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H_2O / YSI 6072 LOT# 14E467487 Exp 5/15

Barometric Pressure: 623 @ 5,400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

Standard		Pre Cal / Post Cal
Temperature	22.88	___ Sonde
Conductivity	4.49	4.50 / —
pH 10	10.00	10.30 / 10.00
pH 4	4.00	4.02 / —
pH ~~10~~ 7	7.0	6.89 / 7.0
ORP	237.5	/
Turbidity	0.0	.8 / —
Turbidity	12.7	130 / —
Turbidity 0.5	—	+
Chlorophyll	—	T
Chlorophyll	—	T
DO RP	—	+
DO ROX	82%	82.2 / 82.0
BGA PE/PC	—	+
BGA PE/PC	—	T
Rhodamine	—	+
Distilled H_2O	0.03	0.005

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes: EQUIPCO Solution

Solution	LOT#	EXP	Solution	LOT#	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10947	4/2015			

PRE - START.

CALIBRATION WORK SHEET

Date of Calibration: 6-17-14 0510 Sonde ID: 00F0052 AE

Technician: KEMERY

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.40	Range	5.0 ± .70
pH mv Buffer 7	-7.6	Range	0 ± 50 mv
pH mv Buffer 4	154.6	Range	+180 ± 50 mv*
pH mv Buffer 10	-191.4	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H_2O / YSI 6072 LOT # 14E467487

Barometric Pressure: 623 @ 5400 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	27.41	___ Sonde
Conductivity	4.49	4.51 / 4.49
pH 7	7.0	6.90 / 7.0
pH 4	4.0	4.06 / —
pH 10	10.0	10.05 / 10.00
ORP	237.5	237.6 / —
Turbidity	0.0	-.43 / 0.0
Turbidity	12.7	12.9 / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82.8	87.4 / 82.0
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes: EO-pro Solution

Solution	Lot #	Exp	Solution	Lot #	Exp
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10947	4/2015			

PRESTART

CALIBRATION WORK SHEET

Date of Calibration: 6-17-14 0510 Sonde ID: 9950941 AC

Technician: K. EME

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.7 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.27	Range	5.0 ± .70
pH mv Buffer 7	-21.8	Range	0 ± 50 mv
pH mv Buffer 4	155.1	Range	+180 ± 50 mv*
pH mv Buffer 10	-182.1	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / ~~1.5~~ 12.7

Manufacturer and part number Dibl/DI H2O / YSI 6072 Lot# 14E447487 5/2015

Barometric Pressure: 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	21.56	___ Sonde
Conductivity	4.49	4.50 / —
pH 7	7.0	6.94 / 7.0
pH 4	4.0	3.94 / 4.0
pH 10	10.0	9.94 / 10.0
ORP	237.5	236.4 / —
Turbidity	0.0	0.2 / —
Turbidity	12.7	13.4 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	84.1 / 82.0
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

EQUIPCO Solution

Notes:

Solution	Lot #	Exp	Solution	Lot #	Exp
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10947	4/2015			

PRE START

CALIBRATION WORK SHEET

Date of Calibration: 6-18-14 0500 Sonde ID: 995 0941 AC

Technician: K. EMERY

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.7 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.26	Range	5.0 ± .70
pH mv Buffer 7	-19.1	Range	0 ± 50 mv
pH mv Buffer 4	158.2	Range	+180 ± 50 mv*
pH mv Buffer 10	-186.7	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number D3H/lot 1620 / YSI 6072 LOT # 14E967487 EXP 5/2015

Barometric Pressure: 623 @ 5400 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	21.57	___ Sonde
Conductivity	4.49	4.51 / —
pH 7	7.0	6.98 / —
pH 4	4.0	3.91 / 4.0
pH 10	10.0	9.89 / 10.0
ORP	237.5	235.4 / 237.5
Turbidity	0.0	0.8 / 0.0
Turbidity	12.7	13.0 / 12.7
Turbidity 0.5	—	—
Chlorophyll	—	—
Chlorophyll	—	—
DO RP	—	—
DO ROX	82%	~~83.7~~ 82.0
BGA PE/PC	—	—
BGA PE/PC	—	—
Rhodamine	—	—

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

EQUIPCO Solution

Notes:

Solution	LOT #	EXP	Solution	LOT #	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10947	4/2015			

Pre-START

CALIBRATION WORK SHEET

Date of Calibration: 6-18-14 0500 Sonde ID: 00F0052 AE

Technician: K. Emery

RP DO membrane changed? Y (N) *Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)*

RP DO membrane o-ring changed? Y (N)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.8 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant — Range 5.0 ± .45

Integrated conductivity cell constant 5.41 Range 5.0 ± .70

pH mv Buffer 7 −11.9 Range 0 ± 50 mv

pH mv Buffer 4 149.6 Range +180 ± 50 mv*

pH mv Buffer 10 −184.2 Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) — Range 25 to 75

DO gain — Range 0.7 to 1.4

ODO gain — Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Dish H2O / YSI 6072 LOT # E467484 Exp 5/2015

Barometric Pressure: 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	21.64	Sonde
Conductivity	4.49	4.49 / —
pH 7	7.0	7.04 / 7.0
pH 4	4.0	4.06 / 4.0
pH 10	10.0	10.00 / —
ORP	237.5	237.6 / —
Turbidity	0.0	-1.2 / 0.0
Turbidity	12.7	12.6 / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82.2	82.6 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes:

Solution	LOT #	EXP.	Solution	LOT #	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Condu.	9256	10/2015
pH 10.0	10947	4/2015			

PRE-START

CALIBRATION WORK SHEET

Date of Calibration: 6-19-14 0500 Sonde ID: 99J0941 AC

Technician: K. Emery

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.8 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.26	Range	5.0 ± .70
pH mv Buffer 7	-19.9	Range 0	± 50 mv
pH mv Buffer 4	150.4	Range +180	± 50 mv*
pH mv Buffer 10	-195.8	Range -180	± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number / YSI 6072 Lot # 14E461487 EXP 5/2015

Barometric Pressure: 623 @5,400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	19.52	___ Sonde
Conductivity	4.49	4.49 / —
pH 7	7.0	6.94 / 7.0
pH 4	4.0	3.95 / —
pH 10	10.0	10.08 / 10.0
ORP	237.5	240 / 237.5
Turbidity	0.0	0.7 / 0.0
Turbidity	12.7	12.4 / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82	82.1 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes: Solutions from Equipco

Solution	Lot #	Exp.	Solution	Lot #	Exp.
pH 4.0	9256	10/2015	ORP	0L0114	8/2015
pH 7.0	10931	4/2015	Cond	9256	10/2015
pH 10.0	10946	4/2015			

PRE-START

CALIBRATION WORK SHEET

Date of Calibration: 6-19-14 0500 Sonde ID: 00F0052 AG

Technician: K. Emery

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.60	Range	5.0 ± .70
pH mv Buffer 7	-11.2	Range	0 ± 50 mv
pH mv Buffer 4	152.2	Range	+180 ± 50 mv*
pH mv Buffer 10	-182.2	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Dist H2O / YSI 6072 LOT# 14E467487 @ 5400 Ex

Barometric Pressure: 623 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	19.38	___ Sonde
Conductivity	4.49	4.24 / 4.49
pH 7	7.0	6.91 / 7.0
pH 4	4.0	4.12 / 4.0
pH 10	10.0	10.10 / 10.0
ORP	237.5	241.4 / 237.5
Turbidity	0.0	-1.4 / 0.0
Turbidity	12.7	15.0 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	83 / 82%
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes: Solution From Equipco

Solution	LOT#	Exp	Solution	LOT#	Exp
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Cond.	9252	10/2015
pH 10.0	10946	4/2015			

PRE-START

CALIBRATION WORK SHEET

Date of Calibration: 6-20-14 0445 Sonde ID: 00F0052 AE

Technician: K. EMEN

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.40	Range	5.0 ± .70
pH mv Buffer 7	-8.9	Range 0	± 50 mv
pH mv Buffer 4	160.9	Range +180	± 50 mv*
pH mv Buffer 10	184.3	Range -180	± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled / YSI 6072 #20 LOT # 14E467487

Barometric Pressure: 623 @540 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	20.6	Sonde
Conductivity	4.49	4.56 / —
pH 7	7	7.08 / 7.0
pH 4	4	3.96 / 4.0
pH 10	10	9.93 / 10
ORP	237.5	232 / 237
Turbidity	0.0	2.4 / 0.0
Turbidity	12.7	14.0 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	81.8 / 82.0
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Solution From EQUIPCO

Notes:

Solution	Lot #	Exp	Solution	Lot #	Exp.
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10946	4/2015			

Pre-start

CALIBRATION WORK SHEET

Date of Calibration: 6-20-14 0435 Sonde ID: 99J0941 AC
Technician: K. Emery

RP DO membrane changed? Y (N) *Note: Wait 3 to 6 hours before calibrating for unattended*
RP DO membrane o-ring changed? Y (N) *deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)*

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.7 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant		Range	5.0 ± .70
pH mv Buffer 7	+10.4	Range	0 ± 50 mv
pH mv Buffer 4	146.8	Range	+180 ± 50 mv*
pH mv Buffer 10	-192.1	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7
Manufacturer and part number Distilled / YSI 6072

Barometric Pressure: 623 @ 5400 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	20.5	Sonde
Conductivity	4.49	4.56 / 4.49
pH 7	7	6.88 / 7.0
pH 4	4	4.06 / 10
pH 10	10	10.10 / 10.0
ORP	237.5	237.6 / —
Turbidity	0.0	0.8 / —
Turbidity	12.7	12.6 / —
Turbidity 0.5	—	—
Chlorophyll	—	—
Chlorophyll	—	—
DO RP	—	—
DO ROX	82%	84.1 / 82.0
BGA PE/PC	—	—
BGA PE/PC	—	—
Rhodamine	—	—
Distilled	0.03	

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Solution From Equipco

Notes:

pH	4.0	9256	10/2015	ORP	060114	8/2015
pH	7.0	10931	4/2015			
pH	10.0	10946	4/2015	Cond.	9256	10/2015

Post

CALIBRATION WORK SHEET

Date of Calibration: 6-10-14 1630 TIME Sonde ID: 00F0052 AE

Technician: K. EMERY

Used THIS YSI FOR PGDW 33

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.9 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.10	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-6.2	Range	0 ± 50 mv
pH mv Buffer 4	159.4	Range	+180 ± 50 mv*
pH mv Buffer 10	-181.6	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range 25 to 75
DO gain	—	Range 0.7 to 1.4
ODO gain	—	Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H_2O / YSI 6072 LOT# 14E467487 EXP. 5/2015

Barometric Pressure: 623 @ 5400 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	—	23.20 Sonde
Conductivity	4.49	4.45 / 4.49
pH 7	7.0	6.89 / 7.0
pH 4	4.0	4.00 / —
pH 10	10.09	10.09 / 10.0
ORP	237.5	235.6 / —
Turbidity	0.0	0.0 / —
Turbidity	12.7	12.9 / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82% AIR SAT	/ 81.9
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —
distilled H_2O	<0.03	0.024 / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Solution From EQUIPCO

Notes:

Solution	LOT#	EXP	Solution	LOT#	EXP.
pH 4.0	9251	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conductivity 4	9256	10/2015
pH 10.0	10947	4/2015			

POST

CALIBRATION WORK SHEET

Date of Calibration: 6-10-14 1630 TIME Sonde ID: 99J0941AC
Technician: K. EMERY

RP DO membrane changed? Y (N) *Note: Wait 3 to 6 hours before calibrating for unattended*
RP DO membrane o-ring changed? Y (N) *deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)*

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant 5.40 Range 5.0 ± .45
Integrated conductivity cell constant — Range 5.0 ± .70
pH mv Buffer 7 -19.8 Range 0 ± 50 mv
pH mv Buffer 4 139.8 Range +180 ± 50 mv*
pH mv Buffer 10 194.9 Range -180 ± 50 mv *
***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv
Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv
DO charge (RP only) — Range 25 to 75
DO gain — Range 0.7 to 1.4
ODO gain — Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7
Manufacturer and part number Distilled H2O / YSI 6072 LOT# 14E467467 Exp 5/2015
5,400
Barometric Pressure: 623.0 mmHg
DO % Calculated – (BARO mmHg divided by 7.6) = % saturation
Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values	Standard	Pre Cal / Post Cal
Temperature	—	23.2 Sonde
Conductivity	4.49	4.59 / 4.49
pH 7	7.0	6.82 / 7.01
pH 4	4.0	4.26 / 4.00
pH 10	10.0	10.17 / 10.00
ORP	237.5	234.3 / 237.5
Turbidity	0.0	1.8 / 0.5
Turbidity	~~12.7~~	~~12.8~~ / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82.0 AIR SA	— / 82.3
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —
distilled H2O	0.003	0.03 —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg
Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg
Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Solution From EQuipco

Notes:

Solution	LOT#	EXP	Solution	LOT#	EXP.
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conductivity	9256	10/2015
pH 10.0	10947	4/2015			

Post

CALIBRATION WORK SHEET

Date of Calibration: 6-11-14
Technician: K. EMERY

Sonde ID: 00F0052 AE
USED METER FOR Sampling PGDW 32 + Dupe-1

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N)
ROX DO wiper changed? Y (N)
BGA-PC wiper changed? Y (N)
Chlorophyll wiper changed? Y (N)
BGA-PE wiper changed? Y (N)
Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant — Range 5.0 ± .45
Integrated conductivity cell constant 5.09 Range 5.0 ± .70
pH mv Buffer 7 -7.6 Range 0 ± 50 mv
pH mv Buffer 4 157.2 Range +180 ± 50 mv*
pH mv Buffer 10 -181.9 Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) — Range 25 to 75
DO gain — Range 0.7 to 1.4
ODO gain — Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7
Manufacturer and part number Distilled H_2O / YSI 6072 Lot # 14E467487 Exp. 5/2015

Barometric Pressure: 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	~~23.40~~	___ Sonde
Conductivity	4.49	4.56 / —
pH 7	7.0	6.98 / —
pH 4	4.0	4.04 / —
pH 10	10.0	9.98 / —
ORP	237.5	235.6 —
Turbidity	0.0	-0.3 / —
Turbidity	12.7	13.4 / —
Turbidity 0.5	~~0.0~~	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX		— / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Solution From EQUIPCO

Notes:

Solution	Lot#	Exp	Solution	Lot#	Exp
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conductivity	9256	10/2015
pH 10.0	10947	4/2015			

Post CALIBRATION WORK SHEET

Date of Calibration: 6-12-14 1740 Sonde ID: 00F0052 AE

Technician: K. Emery

Used METER to Sample PGDW 44+14

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.4 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.40	Range	5.0 ± .70
pH mv Buffer 7	-6.5	Range	0 ± 50 mv
pH mv Buffer 4	156.4	Range	+180 ± 50 mv*
pH mv Buffer 10	-183.4	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H_2O / YSI

LOT# NE 469487 EXP 5/2015

@ 5400'

Barometric Pressure: 623 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	21.00	— / ~~Sonde~~
Conductivity	4.49	4.31 / 4.49
pH 7	7.0	6.94 / 7.0
pH 4	4.0	4.02 / —
pH 10	10.0	10.04 / 10.0
ORP	237.5	237.9 / —
Turbidity	0.0	-0.3 / —
Turbidity	12.7	13.0 / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	82.3 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

distilled H_2O <0.03

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Cal Solution From EQuipCO

Notes:

Solution	LOT #	EXP	Solution	LOT #	EXP
pH 4.0	9256	10/2015	ORP	060114	5/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10947	4/2015			

POST

CALIBRATION WORK SHEET

Date of Calibration: 6-13-14 1600 TIME Sonde ID: 99J0941 AC

Technician: K. EMERY

USED as Duplicate meter at PGDW23

RP DO membrane changed? Y (N) *Note: Wait 3 to 6 hours before calibrating for unattended*

RP DO membrane o-ring changed? Y (N) *deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)*

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant — Range 5.0 ± .45

Integrated conductivity cell constant 5.40 Range 5.0 ± .70

pH mv Buffer 7 -3.9 Range 0 ± 50 mv

pH mv Buffer 4 158.9 Range +180 ± 50 mv*

pH mv Buffer 10 -179.3 Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) — Range 25 to 75

DO gain — Range 0.7 to 1.4

ODO gain — Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H_2O / YSI 6072 LOT# 14E467487 EXP 5/2015

Barometric Pressure: 625 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	22.8	Sonde
Conductivity	4.49	4.52 / —
pH 7	7.0	6.95 / 7.0
pH 4	4.0	4.04 / 4.00
pH 10	10.0	9.97 / 10.00
ORP	237.5	237.8 / —
Turbidity	0.0	2.0 / —
Turbidity	12.7	14.61 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	81.2 / 82.00
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes: EQUIPCO Solution

Solution	LOT #	EXP	Solution	LOT #	EXP.
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015			
pH 10.0	10947	4/2015	Cond.	9256	10/2015

POST

CALIBRATION WORK SHEET

Date of Calibration: 6-13-14 1600 TIME Sonde ID: 00F0052 AE

Technician: K. EMERY

USED @ PGDW23 as main meter at

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.30	Range	5.0 ± .70
pH mv Buffer 7	-10.7	Range	0 ± 50 mv
pH mv Buffer 4	148.7	Range	+180 ± 50 mv*
pH mv Buffer 10	-197.0	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Dist/Ind 1420 / YSI 6072 LOT 14E467487 EXP 5/2015

Barometric Pressure: 623 @ 5400 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values	Standard	Pre Cal / Post Cal
Temperature	22.67	Sonde
Conductivity	4.49	4.49 / —
pH 7	7.0	6.94 / 7.00
pH 4	4.0	4.07 / —
pH 10	10.0	10.04 / 10.00
ORP	237.5	237.4 / —
Turbidity	0.0	0.7 / —
Turbidity	12.7	12.9 / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	80.9 / 82%
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes: EQUIPCO solution

Solution	LOT #	EXP	Solution	LOT #	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015			
pH 10.0	10947	4/2015	Cond	09256	10/2015

POST

CALIBRATION WORK SHEET

Date of Calibration: 6-16-14 1750

Technician: K. EMERY

Sonde ID: 00F0052 AE

used to sample PGDW 45 + PGDW 05

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.36	Range	5.0 ± .70
pH mv Buffer 7	-8.9	Range	0 ± 50 mv
pH mv Buffer 4	+151.2	Range	+180 ± 50 mv*
pH mv Buffer 10	-184.6	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H2O / YSI 6072 EXP 5/2015 LOT# 14E 467487

Barometric Pressure: 623 @ 540 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	22.0	— Sonde
Conductivity	4.49	4.51 / —
pH 7	7.0	7.06 / 7.0
pH 4	4.0	4.10 / 4.0
pH 10	10.0	9.96 / —
ORP	237.5	237.4 / —
Turbidity	0.0	-0.8 / 0.0
Turbidity	12.7	13.1 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82.6	81.6 / 82.0
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes: EQUIPCO Solution

Solution	LOT#	EXP	Solution	LOT#	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015			
pH 10.0	10947	4/2015	Cond.	9252	10/2015

Post

CALIBRATION WORK SHEET

Date of Calibration: 6-17-14 1830

Technician: K. Emery

Sonde ID: 00F0052 AE

used to sample PGDW 49

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.40	Range	5.0 ± .70
pH mv Buffer 7	-11.6	Range	0 ± 50 mv
pH mv Buffer 4	156.3	Range	+180 ± 50 mv*
pH mv Buffer 10	-183.9	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H_2O @5400 / YSI 6072 LOT# 14E467487 Exp. 5/2015

Barometric Pressure: 623 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	21.96	___ Sonde
Conductivity	4.49	4.55 / 4.49
pH 7	7.0	6.90 / 7.0
pH 4	4.0	4.01 / —
pH 10	10.0	10.04 / —
ORP	237.5	236.9 / —
Turbidity	0.0	-0.4 / 0.0
Turbidity	12.7	13.4 / 12.7
Turbidity 0.5	—	—
Chlorophyll	—	—
Chlorophyll	—	—
DO RP	—	—
DO ROX	82 %	83.1 / 82.0
BGA PE/PC	—	—
BGA PE/PC	—	—
Rhodamine	—	—

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Equipco Solution

Notes:

Solution	Lot #	Exp	Solution	Lot #	Exp
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conductivity	9256	10/2015
pH 10.0	10947	4/2015			

Post.

CALIBRATION WORK SHEET

Date of Calibration: 6-18-14 1540

Technician: K. Emery

Sonde ID: 00F0052 AE

used to sample PGDW 30

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.6 (if applicable)
NEW BATTERIES

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.40	Range	5.0 ± .70
pH mv Buffer 7	-8.6	Range	0 ± 50 mv
pH mv Buffer 4	150.4	Range	+180 ± 50 mv*
pH mv Buffer 10	-188.6	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled H_2O / YSI 6072 LOT # 14E467484 EXP

Barometric Pressure: 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values	Standard	Pre Cal / Post Cal
Temperature	21.49	___ Sonde
Conductivity	4.49	4.45 / —
pH 7	7.0	6.92 / 7.0
pH 4	4.0	4.03 / —
pH 10	10.0	9.96 / —
ORP	237.5	237.4 / —
Turbidity	0.0	0.9 / 0.0
Turbidity	12.7	14.0 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82	82.6 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes: Expired Solution

Solution	Lot #	EXP	Solution	Lot #	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Cond.	9256	10/2015
pH 10.0	10941	4/2015			

Post.

CALIBRATION WORK SHEET

Date of Calibration: 6-19-14 1730 Sonde ID: 99J 0941 AC

Technician: K. Emery

used to sample PGDW41A + 41B

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.8 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant — Range 5.0 ± .45

Integrated conductivity cell constant 5.26 Range 5.0 ± .70

pH mv Buffer 7 -9.6 Range 0 ± 50 mv

pH mv Buffer 4 150.9 Range +180 ± 50 mv*

pH mv Buffer 10 -188.4 Range -180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only) — Range 25 to 75

DO gain — Range 0.7 to 1.4

ODO gain — Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Dist H2O / YSI 607Z LOT # 14E4674487 EXP 6/2015

Barometric Pressure: 623 @ 5400' mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values	Standard	Pre Cal / Post Cal
Temperature	21.	Sonde
Conductivity	4.49	4.51 / —
pH 7	7.0	6.90 / 7.0
pH 4	4.0	4.03 / —
pH 10	10.0	9.96 / —
ORP	237.5	236.4 / —
Turbidity	0.0	0.2 / —
Turbidity	12.7	13.9 / 12.7
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	81.4 / 82.
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes:

Equipod Solution	LOT #	EXP	Solution	LOT #	EXP
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Condut.	9256	10/2015
pH 10.0	10947	4/2015			

Post

CALIBRATION WORK SHEET

Date of Calibration: 6-20-14 ~~20~~ 2300

Technician: K. Finnerty

Sonde ID: 99J0941AC

Sampled @ PGDW20 + LD02 end of June sampling event

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.7 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	—	Range	5.0 ± .45
Integrated conductivity cell constant	5.26	Range	5.0 ± .70
pH mv Buffer 7	-19.2	Range	0 ± 50 mv
pH mv Buffer 4	158.6	Range	+180 ± 50 mv*
pH mv Buffer 10	-199.8	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	—	Range	25 to 75
DO gain	—	Range	0.7 to 1.4
ODO gain	—	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0

Manufacturer and part number Distilled H_2O

Barometric Pressure: 623 @ 5400 mmHg

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	21.0	___ Sonde
Conductivity	4.49	4.54 / —
pH 7	7.0	6.97 / —
pH 4	4.0	3.94 / —
pH 10	10.0	10.04 / —
ORP	237.5	238.4 / —
Turbidity	0.0	-0.2 / —
Turbidity	—	— / —
Turbidity 0.5	—	— / —
Chlorophyll	—	— / —
Chlorophyll	—	— / —
DO RP	—	— / —
DO ROX	82%	82.5 / —
BGA PE/PC	—	— / —
BGA PE/PC	—	— / —
Rhodamine	—	— / —
Distilled Conduct.	<0.03	0.02

Depth Calibration - If zero was entered, record barometric pressure at time of calibration NA mmHg

Depth Calibration - If offset depth was entered, record value — meters/feet and pressure NA mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 NA

Notes:

Equipco Solution	LOT#	EXP	Solution	LOT #	EXP.
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conduct.	9256	10/2015
pH 10.0	10941	4/2015			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: LD02 ST
Sample ID: LD02 ST-06_____2014
QA/QC Sample IDs: –
MS/MSD for this Sample? –
Location Description: Well near driveway
Well Condition: Unused. Cap on casing.

Date: June 20, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Thin overcast, 60s, 5mph
FID/PID at Well Headspace (ppm): –

PURGING PARAMETERS

Casing Diameter (D, inches): 6
Approx. Screen Depth (feet bmp): – to 610
Depth to Water (H, feet bmp): 166.1 = 166.1
Casing Volume (gallons): 650
Calculated Purge Volume (gallons): 2000
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☒	☐	
Bailer	☐	☐	
Tap/ Other	☐	☒	Hydrasleeve
Dedicated Equipment?	☐	☒	

Intake Depth (feet bmp): 200

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water Removed (gal) (l)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
1250	0	0	166.9							Start purge.
1310										Grab sample
1435										Grab sample done.
1503	–	–	–	24.2	3.61	1.70	8.29	+24.5	4.5	1.90
										End purge.

1503 Other measurements (units): Ferrous Iron 0.04

Time Samples Collected: ~~1305~~ 1310
Sample Appearance: Note 1
Laboratory:

Note Any Sampling Problem:
Equipment Decontamination:
Purge Water Disposition:

Water Meter Model/No: YSI 6921 9930941 AC
Hach DR890 9711000807

Comments: Will collect grab sample with hydrasleeve, 1310 to approximately 1435.
Maintain sampling order by collecting hydrasleeve for filtered samples and retaining until end to filter using a peristaltic pump. Note 1: Greenish yellow globs 1/cm appearance similar to algae.

Signature: [signature]
Date: 6/20/2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	LD02 ST	Date:	June 20, 2014
Sample ID:	LD02 ST-06_____2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW05
Sample ID: PGDW05-06 16 2014
QA/QC Sample IDs: —
MS/MSD for this Sample? —
Location Description: Tap on side of house
Well Condition: Lives in home.

Date: June 16 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Overcast, breezy, 60s.
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 7
Approx. Screen Depth (feet bmp): — to 210
Depth to Water (H, feet bmp): Assume ~110
Casing Volume (gallons): 200
Calculated Purge Volume (gallons): 600*
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water ~~Removed~~ (gal) (l)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm) **	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
1305	0	4838 Meter	—							Start purge.
1310	2.4	4850	—	11.60	0.955	0.63	9.27	~~-137~~	-4.2	0.47
1317	2.7	4869	—	10.78	0.887	0.35	9.28	~~-129~~	-3.6	0.47
1322	2.6	4882	—	10.78	0.893	0.22	9.29	~~-138~~	-3.2	0.44
1332	1.6	4908	—	10.83	0.896	0.18	9.29	~~-139~~	-2.9	0.44
1339	2.4	4925	—	10.78	0.893	0.16	9.30	-174	-3.3	0.44
1343	2.3	4934	—	10.91	0.890	0.15	9.30	-174	-2.7	0.44
1347	2.5	4944	—	10.84	0.890	0.14	9.30	-175	-2.6	0.44
1356	2.2	4964	—	10.85	0.887	0.13	9.29	-167	-2.8	0.46
1404	2.3	4982	—	10.84	0.884	0.13	9.29	-151	-2.7	0.44
1411	2.7	4999	—	10.91	0.883	0.13	9.29	-134	-3.0	0.45
1415	2.3	5008	—	10.88	0.898	0.13	9.29	-132	-2.9	0.44
1415		170 = Total								End purge.

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected: 1416 (to 1502)
Sample Appearance: Note ***
Laboratory: CTEtal.
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Landscape.
Water Meter Model/No: YSI 6920 00F0052AE

Comment: *Owner reports well runs dry. Will monitor for stabilization at flow rate ~3 gpm to avoid dewatering well
** Gas bubbles affecting conductance readings slightly.
*** Note water has small (<0.5 cm) filamentatious clumps of semitransparent matter floating on surface. Also few ~~<0.5~~ <1 cm strands of apparent sheen. Observed in bucket. Photo. More light sheen ~30% later

Signature: [signature]
Date: June 16, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW05	Date:	June 16, 2014
Sample ID:	PGDW05-06 16 2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW14
Sample ID: PGDW14-06 12 2014
QA/QC Sample IDs: –
MS/MSD for this Sample? –
Location Description: Blue hydrant by vault
Well Condition: –

Date: June 12, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Clear, breeze, 60s
FID/PID at Well Headspace (ppm): –

PURGING PARAMETERS

Casing Diameter (D, inches) 6
Approx. Screen Depth (feet bmp): – to 190
Depth to Water (H, feet bmp): Assume 100 ft.
Casing Volume (gallons): 130
Calculated Purge Volume (gallons): 400
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒

Intake Depth (feet bmp):

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water ~~Removed~~ (gal) ~~(l)~~	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity* (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0816	2110 0	~~2210~~ 0								Start purge.
0831		2158								3.2 gpm
0847	3.4	2213								Open hydrant.
0901	6.0	2297	–	10.9	3.34	0.40	7.11	+149	14 *	
0917	6.5	2401	–	10.4	3.69	0.35	7.48	+134	2	2.23
0924	6.3	2445	–	10.4	3.95	0.24	7.54	+129	6	2.24
0934	7.0	2505	–	10.5	3.73	0.19	7.59	+126	20	2.20
0942	6.8	2559	–	10.4	3.60	0.20	7.62	+120	2	1.90
0949	6.4	2604	–	10.4	3.70	0.16	7.63	+118	6	~~2~~ 1.96
0952	6	2622	–	10.5	3.90	0.16	7.64	+117	6	2.08
0957	6	2651	–	10.4	3.78	0.16	7.64	+115	8	2.20
1001	6	2677	–	10.5	3.86	0.16	7.65	+114	16	2.05
1004		2698	–	10.5	3.92	0.15	7.65	+113	12	2.08
										End purge.

Other measurements (units): ~~Sulfide 0.0 mg/L~~ Ferrous Iron 0.0 mg/L

Time Samples Collected: 1006 (to 1057)
Sample Appearance: Clear, bubbles
Laboratory: CTS et al.
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Lawn
Water Meter Model/No: YSI 6920 00F0052AE

Comments: * Small bubbles in water. Turbidity readings unstable. Need to run "clean optics" to read. Estimated depth to water for purge volume.

Signature: [signature]
Date: June 12/2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW14	Date:	June 12, 2014
Sample ID:	PGDW14-06 12 2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
dI3C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW20
Sample ID: PGDW20-06-20-2014
QA/QC Sample IDs: —
MS/MSD for this Sample? —
Location Description: Hydrant by corral
Well Condition: Not in use.

Date: June 20, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Mostly clear, 50's, breeze
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 5
Approx. Screen Depth (feet bmp): — to 380
Depth to Water (H, feet bmp): ~166
Casing Volume (gallons): 220
Calculated Purge Volume (gallons): 660
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water ~~Removed~~ (gal) ~~(l)~~	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0740	0	8950 0	—							Start purge.
0753	4.0	9002								
0810	3.4	9060	—	11.7	2.43	0.22	8.88	-159	0.4	1.27
0830	3.4	9127	—	11.6	2.90	0.06	8.75	-150	1.6	1.52
0850	3.3	9192	—	11.6	2.91	0.03	8.82	-148	2.3	1.52
0927	3.2	9311	—	11.6	2.90	0.00	8.82	-139	1.4	1.52
0944	3.2	9366	—	11.6	2.89	-0.01	8.84	-137	1.4	1.51
0957	3.2	9408	—	11.5	2.89	-0.01	8.87	-139	0.8	1.51 (0957)
1018	3.2	9475	—	11.5	2.89	-0.01	8.88	-154	0.9	1.51
1053	3.1	9555	—	11.6	2.86	-0.02	8.86	-146	0.4	1.51
1108		9629	—	11.6	2.88	-0.02	8.84	-143	0.6	1.50
										End purge.

Meter

Other measurements (units): Ferrous iron 0.0 mg/L

Time Samples Collected: 1111 (to 1200) Note Any Sampling Problem: —
Sample Appearance: Clear, few bubbles Equipment Decontamination: None
Laboratory: CT&T et al. Purge Water Disposition: Irrigation canal

Water Meter Model/No:
YSI 6920 99J0941 AC
Hach HR890 9711000807

Comments:
Flow rate is 3.1-3.4 gpm because set screw on hydrant appears to have slipped since was sampled by EPA in past.

Signature: [signature] Date: 6/20/2014

~2:40

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW20	Date:	June 29, 2014
Sample ID:	PGDW20-06_____2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW23
Sample ID: PGDW23-06 13 2014
QA/QC Sample IDs: —
MS/MSD for this Sample? —
Location Description: Tank shed near house
Well Condition: Total depth 475 5-inch casing per driller log

Date: June 13, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Clear, calm, 60s
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): ~~6~~ 5
Approx. Screen Depth (feet bmp): 445 to 465 ~~500 (175?)~~
Depth to Water (H, feet bmp): 120 (drillers log)
Casing Volume (gallons): 360
Calculated Purge Volume (gallons): 1,100
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water Removed (gal) (l) *	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU) **	Notes (e.g. pump adjustments) Salinity (ppt)
0600	0	0								Start purge.
0815	8	1080	—							Rate by bucket
0850	8	2922								Start meter
0901		3010	—	12.4	1.10	0.55	8.74	-106	-0.8	0.56
0904	6	3029		12.4	1.09	0.40	8.96	-120	-0.8	0.54
0908	9	3055		12.3	1.10	0.33	9.08	-125	-0.8	0.55
0911	6	3074		12.5	1.09	0.34	9.13	-127	-0.5	0.55
0915	7	3100		12.7	1.09	0.29	9.15	-128	-0.2	0.54
0919	6	3125		12.5	1.09	0.28	9.20	-131	-0.2	0.54
0923	7	3151		12.6	1.08	0.28	9.22	-132	-0.2	0.54
0927	7	3177		12.5	1.07	0.22	9.24	-133	-0.2	0.54
0930	6	3196		12.7	1.08	0.22	9.25	-133	-0.2	0.54
0933	6	3215		12.6	1.08	0.23	9.27	-135	1.1	0.54
0935	6	3228		12.6	1.08	0.23	9.28	-135	-0.3	0.54
0938	6	3246		12.7	1.09	0.20	9.27	-135	-0.1	0.55
0941	6	3265		12.6	1.08	0.20	9.28	-136	0.0	End purge. 0.54

Other measurements (units): Ferrous iron 0.0 mg/L

Time Samples Collected: 0950 (1032)
Note Any Sampling Problem: None
Sample Appearance: Clear
Equipment Decontamination: None
Laboratory: CTEtal.
Purge Water Disposition: Landscape
Water Meter Model/No: 4516920 00F0052AE

Comments: Owner started well running full on at 0600. Rate from bucket test 8 gpm. ** Small gas bubbles affect turbidity data.
* Comulative meter reading starting at 0850
Duplicate meter read; meter in series: 12.9/1.09/0.23/9.31/-144/0.4/0.55 at 0927. 0941: 13.0/1.09/0.11/9.39/-149/0.6/0.56

Signature: [signature]
Date: June 13, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW23
Sample ID: PGDW23-06 13 2014

Date: June 13, 2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW30
Sample ID: PGDW30-06 18 2014
QA/QC Sample IDs: FB-1-06 18 2014
MS/MSD for this Sample? —
Location Description: Tap outside well house
Well Condition: — Irrigation use?

Date: June 18, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: SCT, 40s, wind WNW 10
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 6
Approx. Screen Depth (feet bmp): — to 260
Depth to Water (H, feet bmp): Assume 100 feet / 30 feet
Casing Volume (gallons): 235
Calculated Purge Volume (gallons): 700
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Meter *

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water ~~Removed~~ (gal) ~~(l)~~	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	** Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0822	5 0	1100 0								Start purge.
0822		7195								Start meter
0840	5.0	7285		10.62	1.090	1.40	9.15	-14.9	-5.7	0.53
0847	5.0	7320		10.5	1.05	1.45	9.18	-70.7	-5.7	0.52
0852	5	7345		10.5	1.05	1.23	9.18	~~-72.9~~	-5.7	0.52 ORP -74.6
0857	5	7370		10.6	1.05	1.53	9.19	-66.8	-5.6	0.52
0901	5	7390		10.7	1.07	1.48	9.18	-65.3	-5.6	0.52
0904	5	7406		10.7	1.05	1.46	9.17	-68.8	-5.5	0.52
0910	5.0	7436		10.7	1.09	1.47	9.18	-92.0	-5.4	0.54
0914	5	7454		10.8	1.05	1.44	9.18	-88.3	-4.9	0.52
0921	5	7489		10.7	1.05	1.43	9.19	-94.1	-5.5	0.52
0925	5	7508		10.9	1.05	1.45	9.18	-77.6	-5.3	0.52
0928	5	7523		10.9	1.05	1.33	9.18	-73.9		0.52 Note 1
0931	5.	7538		10.9	1.04	1.09	9.18	-81.1	-5.3	0.52
0936		7562		10.9	1.04	1.08	9.19	-99.6	-5.4	0.52
0939	5	7577		10.9	1.04	1.23	9.19	-101.7	-5.3	End purge. 0.52

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected: 0950
Sample Appearance: Clear small bubbles
Laboratory: CT et al.
Note Any Sampling Problem:
Equipment Decontamination: None
Purge Water Disposition: Ditch at field
Water Meter Model/No: YSI 6920 OUFO52AE

Comments: * 0822 cumulative water removed, then flow meter reading
** Small gas bubbles affect DO reading. DO seems unstable, and occasionally jumps down 0.3 ~~mg~~ to 0.2 mg/L relative to reading. Not clear why.
Note 1: 0928 adjust sample manifold slight air leak

Signature: [signature]
Date: June 18, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW30
Sample ID: PGDW30-06 18 2014

Date: June 18, 2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW32
Sample ID: PGDW32-06 10 2014
QA/QC Sample IDs: Dupe-1-06 10 2014
MS/MSD for this Sample? —
Location Description: Red hydrant.
Well Condition: —

Date: June 10, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: SCT, breeze, 70s
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 6
Approx. Screen Depth (feet bmp): — to 900
Depth to Water (H, feet bmp): 254.6 1015
Casing Volume (gallons): 950
Calculated Purge Volume (gallons): 2,800
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)2]*[7.48 gallons/ft3
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch wel

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp):

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment ~~(gal)~~ ~~(l)~~	Cumulative Water Removed (gal) ~~(l)~~	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0925	4 0	0								Start purge.
1025	10	240								Increase 10 gpm
1100	10	350								DTW 271.2
1115	0	—							Off	~~DTW 234.6~~
1145	0	—								DTW 234.6
										End purge.

Time Samples Collected:
Sample Appearance:
Laboratory:
Note Any Sampling Problem:
Equipment Decontamination:
Purge Water Disposition:
Water Meter Model/No:

Comments: Owner ran well ~~at~~ for an hour. Assume 4 gpm × 60 = 24 gpm purged before our arrival.
~~S~~ Water levels only. Will sample tomorrow ~~S~~

Signature: [signature]
Date: June 10, 2014

1.47 (2)

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW32
Sample ID: PGDW32-06 11 2014 11:15
QA/QC Sample IDs: Dupe-1-06 11 2014 12:00
MS/MSD for this Sample? —
Location Description: Red hydrant.
Well Condition: —

Date: June 11, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Clear, breezes, 60°s
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches) 6
Approx. Screen Depth (feet bmp): — to 900
Depth to Water (H, feet bmp): 250.3 at 0805
Casing Volume (gallons): 950
Calculated Purge Volume (gallons): 2,900 ~~gal~~
Note if LPH (feet thickness): N/A
0.0408 CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
$V^2 \times H$ 0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	
Intake Depth (feet bmp):	—	—	

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water* ~~Removed~~ (gal) ~~(l)~~	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	** Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0825	— 0	207 0								Start purge.
0832	4	232								Adjust up.
0846	7	332								
0908	7.3	493	264.8							DTW 264.8
0949	7.5	800	263							DTW 263
1000	7.5	882		12.8	1.15	0.52	9.87	-144	-2.3	
1017	7.4	1008		12.9	1.14	0.27	9.93	-138	4	
1028	7.5	1091	275.5	12.9	1.08	0.25	9.94	-193	-3	0.56
1038		1166		12.8	1.08	0.16	9.94	-191	-1	0.54
1044		1211		12.8	1.08	0.19	9.95	-183	-2	0.55
1051		1260		12.9	1.10	0.18	9.95	-176	-3	0.55
1058		1313		12.8	1.12	0.16	9.94	-171	0.3	0.56
1103		1350		12.9	1.10	0.16	9.95	-169	-0.4	0.56
1108		1388	278.1	12.9	1.10	0.16	9.96	-174	-2	0.55
1111		1410		12.9	1.11	0.14	9.97	-175	-3	0.56
										End purge.

Meter

Other measurements (units): Ferrous Iron 0.01 mg/L

Time Samples Collected: 11:15 and 1245
Sample Appearance: Clear, bubbles
Laboratory: CT et al.
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Lawn.
Water Meter Model/No: YSI 6920 00F0052 AE

Comments: DTW 250.3 0805. Well is running sprinkler at 8 gpm (bucket test) for 2 hours, 960 gallons purged. *Note meter started at 207. ** Small bubbles in water, turbidity will be unstable. Note sampled beginning at 11AM due to estimated time to collect + prep. Redact time written on sample labels for duplicate sample with marker.

Signature: [signature]
Date: June 11, 2014

TB-1-06112014 0830

Well purged to 8 gpm.

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s 11 14
Well/ Sample Location:	PGDW32	Date:	June 29, 2014
Sample ID:	PGDW32-06 11 2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	8	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	6	No	HCl	C&T
Glycols	8015B	VOA	40	6	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	2	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	6	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	6	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	2	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	2	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	4	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	2	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	2	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	4	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	4	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	2	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	2	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	2	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	2	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	2	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	2	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	2	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	2	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	2	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	2	No	HCl	C&T
Radon	NS	VOA	40	4	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	2	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	2	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	2	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	2	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	2	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	2	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	2	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW33
Sample ID: PGDW33-06-10-2014
QA/QC Sample IDs: TB01-06102014
MS/MSD for this Sample? —
Location Description: Blue hydrant ~~at Drain~~
Well Condition: ~~OK~~ —

Date: June 10, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: SCT, breeze, ~~60s~~-70s
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 6
Approx. Screen Depth (feet bmp): — to 30
Depth to Water (H, feet bmp): Assume 20
Casing Volume (gallons): Approximately 15 gal
Calculated Purge Volume (gallons): 45
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)2]*[7.48 gallons/ft3
0.0408 0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch wel

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water Removed (gal) ~~(l)~~	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0848	0	74 0								Start purge.
0853	1.2	80	—	12.8	1.86	1.77	6.96	161	-3.5	0.95
0901	1.0	88	—	13.9	1.87	1.25	7.03	122	-4.0	0.96
0909	0.9	95	—	14.0	1.88	1.13	7.05	97.3	-4.0	0.96
0915	0.8	100	—	14.0	1.86	1.03	7.05	86.6	-4.1	0.96
0924	0.9	110	—	14.0	1.87	0.99	7.06	76.1	-4.2	0.95
0930	0.8	115	—	14.0	1.86	0.98	7.06	77.7	-4.2	0.95
0936	0.8	120	—	14.0	1.86	0.99	7.05	73.8	-3.5	0.95
0940										End Purge
1200	1									
1210		10						Ferrous Iron		→ 0.0
0940										End purge.

Time Samples Collected: 0940 (1110)
Sample Appearance: Clear
Laboratory: See attached

Note Any Sampling Problem: None.
Equipment Decontamination: None.
Purge Water Disposition: Lawn.

Water Meter Model/No: YSI 6920 00F0052AE

Comments: Well is 1100 feet away. Volume of 1-inch pipe 1100 ft ~ 45 gal
Owner ran well at low rate 1gpm +/- for 1 hour prior to sampling. Also used for stock. Estimate 60 gallons.
Monitor parameters now so well will not run dry.

Signature: [signature]
Date: ~~June~~ June 10, 2014

(1)

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW33	Date:	June 10, 2014
Sample ID:	PGDW33-06-10-2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

(1)

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW41A
Sample ID: PGDW41A-06 19 2014
QA/QC Sample IDs: –
MS/MSD for this Sample? –
Location Description: 8 feet SW of vault
Well Condition: –

Date: June 19, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather:
FID/PID at Well Headspace (ppm): –

PURGING PARAMETERS

Casing Diameter (D, inches) 6
Approx. Screen Depth (feet bmp): – to 370
Depth to Water (H, feet bmp): Assume 50
Casing Volume (gallons): 480
Calculated Purge Volume (gallons): 1500
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): –

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water ~~Removed~~ (gal) (l)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
1026	0	8444 0	–							Start purge.
1046	6.0	8564	–							
1113	5.8	8720	–							
1128	2.2	8778	3.7 gpm	8778						Pump off.
1156		8778	–							Pump on low
1200	3.5	8792	–							" " "
1203	3	8800	–	9.50	7.70	6.94	7.43	+93.2	0.7	4.27
1206	3	8808	–	9.71	7.67	6.89	7.33	+94.5	1.0	4.25
1209	3	8815	–	9.74	7.66	6.88	7.31	+95.0	0.1	4.26
1212	3	8824	–	9.54	7.69	7.30	7.37	+94.6	0.6	4.26
1215		8831	–	9.66	7.68	7.35	7.22	+95.5	0.3	4.26
										End purge.

Other measurements (units): Ferrous iron 0.0 mg/L

Time Samples Collected: 1220 to 1307
Sample Appearance: Clear
Laboratory: CTetal
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Ditch near Rd
Water Meter Model/No.: YSI 6920 99J0941AC

Comments:
1126: Pump begins to surge. Average flow down to 3.7 gpm. Turn off pump to allow recovery.
1156: Pump on low to monitor parameters and collect sample will collect 5 readings then sample so pump does not run dry.

Signature:
Date: June 19, 2014

(2)

~4 hr

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW41A	Date:	June 19, 2014
Sample ID:	PGDW41A-06 19 2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

(2)

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW41B
Sample ID: PGDW41B-06 19 2014
QA/QC Sample IDs: —
MS/MSD for this Sample?
Location Description: 4 feet SW of vault.
Well Condition: ~~Stick/fringe~~ fair

Date: June 19, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Clear, 50° in AM, NNW 5
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 8
Approx. Screen Depth (feet bmp): — to 70
Depth to Water (H, feet bmp): Assume 30
Casing Volume (gallons): 100
Calculated Purge Volume (gallons): 300
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water ~~Removed~~ (gal) ~~(l)~~	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0830	0	7806 0								Start purge.
0842	4.3	7858								Bucket 5.5 gpm
0854	6.0	7930								
0900 ~~0854~~	5.2	7961	—	10.4	5.24	0.34	6.92	-35.6	6.0	(0900) 2.84
0904	6	7986	—	10.5	5.24	0.33	7.16	-53.8	9.6	2.83
0912 ~~0908~~	6.0	8034	—	10.1	5.24	0.07	7.39	-82.6	36	2.84 Note 1
0916	6	8059	—	10.2	5.24	0.04	7.43	-86.5	28	2.84
0919	6	8076	—	10.1	5.25	0.04	7.48	-89.7	47	2.84
0922	6	8095	—	10.2	5.24	0.03	7.54	-92.8	32	2.84
0925	6	8112	—	10.1	5.25	0.03	7.54	-93.5	30	2.84
0928	6	8131	—	10.2	5.24	0.02	7.61	-91.2	29	2.84
										End purge.

Other measurements (units): Ferrous Iron 0.73 mg/L

Time Samples Collected: 0940 (to 1019)
Sample Appearance: Cloudy milky / clear
Laboratory: CT et al
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Ditch by field
Water Meter Model/No: YSI 6920-99J0941AC

Comments: Pump #2 on breaker panel.
Note 1: Occasional small droplets of sheen < 4 mm.
Turbidity > 20 NTU so will NOT collect unfiltered samples for metals.

Signature:
Date: June 19, 2014

1

~0.4 hr?

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW41B	Date:	June 19, 2014
Sample ID:	PGDW41B-06 19 2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW44	Date:	June 12, 2014
Sample ID:	PGDW44-06 12 2014	Field Crew:	KGE, DMJ, JRH
QA/QC Sample IDs:	—	Purging Subcontractor:	N/A
MS/MSD for this Sample?	—	Weather:	Clear, breeze, 60s
Location Description:	Hydrant near converted tank ~~Steed~~	FID/PID at Well Headspace (ppm):	—
Well Condition:			

PURGING PARAMETERS

Casing Diameter (D, inches)	9
Approx. Screen Depth (feet bmp):	— to 750 (?)
Depth to Water (H, feet bmp):	278 @ 0810
Casing Volume (gallons):	1500
Calculated Purge Volume (gallons):	4500
Note if LPH (feet thickness):	N/A

CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]

0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒
Intake Depth (feet bmp):		

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water Removed (gal) (l)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance ~~**~~ (mS/cm)	Dissolved Oxygen ~~**~~ (mg/L)	pH (units)	ORP (mV)	Turbidity ** (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0810	9 0	0	278							Start purge.
0948	8		367							
1010	0	960	—							Running Dry.
1020	0		—							Stop Purge
1144	0	—	268							
1311	0	3066 * 2566								Pump on low
1320	2.7	3090		11.5	5.78	0.74	7.75	-114	2	3.15
1325	2	3098	298	11.6	5.72	0.48	7.86	-159	0.8	3.12
1336	1.3	3106		11.5	5.48	0.35	7.94	-175	6	3.22 (1331)
1337	1.3	3115		11.7	5.43	0.27	7.98	-181	0.3	2.95
1346	~~0.8~~	3120		11.5	5.59	0.24	8.01	-184	-0.3	2.98
1347	1.3	1328		11.5	5.59	0.20	8.06	-209	-0.8	3.04
1351	1	1332		11.5	5.72	0.18	8.09	-218	-0.8	3.12
1354	1.3	1336	337	11.5	5.69	0.18	8.09	-218	-1.2	3.09
1359		1342		11.4	5.68	0.17	8.11	-225	2.6	3.09
										End purge.

Other measurements (units): Ferrous iron 2.26 mg/L

Time Samples Collected:	1400 (1438)	Note Any Sampling Problem:	Water Meter Model/No:
Sample Appearance:		Equipment Decontamination:	
Laboratory:		Purge Water Disposition:	

Comments: * Cumulative meter reading at this time 1311 onward.
Note well ran dry at 1010; pump off 1020. Allow to recover.
Return to sample well, restart purge at 1311 at low rate.
** Fine bubbles in water. Turbidity unstable; also conductivity
** Gas bubbles also affecting DO readings. Need to run "clean optics" to read

Signature: [signature] Date: June 12, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW44	Date:	June 12, 2014
Sample ID:	PGDW44-06-12-2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW45
Sample ID: PGDW45-06 16 2014
QA/QC Sample IDs: Dupe-2-06 16 2014
MS/MSD for this Sample? –
Location Description: Well head in yard.
Well Condition: Used for stock.

Date: June 16 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Clear, calm, 50s.
FID/PID at Well Headspace (ppm):

PURGING PARAMETERS

Casing Diameter (D, inches) 6
Approx. Screen Depth (feet bmp): – to 45 to 48
Depth to Water (H, feet bmp): 25.8 @ 0835
Casing Volume (gallons): 32
Calculated Purge Volume (gallons): 96
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒

Intake Depth (feet bmp): ~

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment ~~(gal) (l)~~	Cumulative Water Removed (gal) (l)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
~~0830~~ 1032	0	3625 0	~~25.8~~	17.8 µmhos						Start purge.
1037	7.4	3662		8.93	1.26	2.70	6.95	+181	-6.1	0.63
1040	13	3700		8.77	1.29	1.61	7.07	+173	-6.0	0.65
1046	9.8	3759		8.64	1.30	1.35	7.14	+168	-6.0	0.65
1049	9.8	3788		8.63	1.31	1.30	7.15	+165	-6.0	0.66
1053	10	3827		8.65	1.31	1.23	7.16	+164	-6.0	0.66
1056	10	3856		8.64	1.31	1.22	7.16	+162	-6.0	0.66
1059	10	3885		8.67	1.31	1.19	7.16	+161	-6.1	0.66
1102	10	3914		8.67	1.31	1.18	7.16	+160	-6.1	0.66
1105	10	3944		8.66	1.31	1.17	7.17	+159	-6.1	0.66
1108	10	3974		8.64	1.31	1.17	7.17	+159	-6.1	0.66
1111	10	4002	22.0	8.65	1.31	1.16	7.17	+158	-6.1	0.66
1111		377 = Total								End purge.

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected: 1015 (to 1200)
Sample Appearance: Clear
Laboratory: C+T et al.
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Landscape
Water Meter Model/No: YSI 6920 00F0052 AE

Comments: Samples collected from "Y" fitting on line from well. 12:00 Collect duplicate sample. 1245 duplicate sample collected.

Signature: [signature]
Date: June 16, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW45	Date:	June 16, 2014
Sample ID:	PGDW45-06 16 2014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	8	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	6	No	HCl	C&T
Glycols	8015B	VOA	40	6	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	2	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	6	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	6	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	2	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	2	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	4	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	2	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	2	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	4	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	4	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	2	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	2	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	2	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	2	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	2	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	2	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	2	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	2	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	2	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	2	No	HCl	C&T
Radon	NS	VOA	40	4	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	2	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	2	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	2	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	2	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	2	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	2	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	2	No	Cold	Precision; 30-hr hold time call Sat

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW49
Sample ID: PGDW49-0617 2014
QA/QC Sample IDs: —
MS/MSD for this Sample? Yes
Location Description: Well near cattle shed.
Well Condition: Not in use.

Date: June 17, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Broken overcast, 10mph wind to 15
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 6
Approx. Screen Depth (feet bmp): to 50
Depth to Water (H, feet bmp): 10.1 ft bmp 0855
Casing Volume (gallons): 59
Calculated Purge Volume (gallons): 180
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)^2]*[7.48 gallons/ft3]
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch well

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water ~~Removed~~ (gal) ~~(l)~~	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L) Note 2	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0858	0	5108 0						NR		Start purge.
0911	8.9	5224	-	9.72	6.60	0.70	7.19	-54.7	42	Started just slowed
0916	8.8	5268	15.6	9.75	6.56	0.40	7.26	-66.8	20	3.42 Clearing.
0921	8.2	5309		9.80	6.49	0.33	7.28	-71.9	19.6	3.55
0928	9.6	5376	15.8	9.94	6.34	0.48	7.31	-58.1	27.8	3.32 Bubbles.
0953		5581		9.86	6.26	0.75	7.32	-14.3	18.0	
1000	8.6	5641	15.9	10.01	5.97	0.70	7.31	-35.9	13.7	3.26
1008	8.5	5709		10.01	5.97	0.73	7.33	-26.4	10.7	3.26 DO 0.73
1013	8.6	5752		10.06	5.93	0.72	7.32	-26.2	7.0	3.23
1017	8.9	5787		10.16	5.90	0.71	7.32	-26.1	6.2	3.22
1022		5830		10.37	5.87	0.68	7.33	-26.7	6.0	3.22
1025	8	5855		10.21	5.99	0.69	7.32	-26.3	6.2	3.27
1028		5881	16.0	9.84	5.94	0.74	7.32	-25.8	4.0	Note 1.
1031		5906		9.81	5.94	0.72	7.32	-25.7	6.1	3.24
1034	8	5932		9.80	5.93	0.74	7.31	-25.7	3.6	3.23
1037		5957		9.79	5.89	0.79	7.32	-25.9	3.7	End purge 3.21

Other measurements (units): Ferrous Iron 0.10 mg/L

Time Samples Collected: 1115 (to 1255)
Sample Appearance: Clear. ~~Mins odd~~
Laboratory: CT Et al.
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Field
Water Meter Model/No: YSI 6920 00P0052AE

Comments: Water has gas bubbles visible in sonde flow through cell.
Note 1: Adjust rate of flow through cell, up slightly. Note change in temperature due to minor line heating (water is very cold.)
Note 2: DO measurements are unstable. Possibly affected by gas bubbles, or water chemistry.

Signature: [signature]
Date: June ~~14~~ 17, 2004

SAMPLING/DEVELOPMENT INFORMATION

Page 2 of 2

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW49
Sample ID: PGDW49-0617 2014
QA/QC Sample IDs: –
MS/MSD for this Sample? Yes
Location Description: well near cattle shed
Well Condition: Not in use.

Date: June 17, 2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: OVC, wind WNW 10 mph to 15 mph
FID/PID at Well Headspace (ppm): –

PURGING PARAMETERS

Casing Diameter (D, inches)
Approx. Screen Depth (feet bmp): to
Depth to Water (H, feet bmp):
Casing Volume (gallons):
Calculated Purge Volume (gallons):
Note if LPH (feet thickness): N/A
CASING VOLUME: ([TD-H]*[3.14*(D/24)2]*[7.48 gallons/ft3
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch wel

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): –

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) ~~(lpm)~~ or Increment (gal) ~~(l)~~	Cumulative Water ~~Removed~~ (gal) ~~(l)~~ (Meter)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L) (Note 2)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
	0	0								Start purge.
1041	9	5991	–	9.80	5.86	0.60	7.31	+14.6	6.0	3.26
1044	8	6016	–	9.82	5.83	0.69	7.31	+15.1	1.4	3.17
1047		6042	–	9.81	5.79	0.68	7.32	+16.8	1.7	3.17 Mt
1050	8	6067		9.80	5.82	~~0.70~~	7.31	+18.0	2.1	3.17 DO 0.69
1053		6093		9.82	5.89	0.66	7.31	+17.6	1.8	3.21
1056		6118	–	9.85	5.87	0.72	7.32	+18.8		3.19 DO 0.71
1059		6146		9.82	5.89	0.68	7.31	+19.1	1.8	3.21
1102		6170	16.0	9.86	5.84	0.56	7.31	+18.6		3.18 Note 2
										End purge.

Time Samples Collected: 1115 (to 1255)
Sample Appearance:
Laboratory:
Note Any Sampling Problem:
Equipment Decontamination:
Purge Water Disposition:
Water Meter Model/No: YSI 6920

Comments: Note 2: See page 1.

Signature: [signature]
Date: June 17, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW49
Sample ID: PGDW49-06 17 2014

Date: June 17, 2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	9	No	HCl	C&T
Glycols	8015B	VOA	40	9	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	3	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	9	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	9	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	3	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	6	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	3	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	3	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	6	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	6	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	3	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	3	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	3	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	3	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	60	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	3	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	3	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	3	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	3	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Stontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat

EQUIPCO RENTALS

YSI 6920V2 RENTAL
CALIBRATION CERTIFICATE

SERVICE TECHNICIAN: MM DATE: 8/7/14

INSTRUMENT INFORMATION

RENTAL I.D. NUMBER: YSI-6920V2.02

SERIAL NUMBER:

CALIBRATION INFORMATION

PARAMETER:	STANDARD:	PASS ( )	LOT #
1. CONDUCTIVITY	1,000 µMhos	X	10932
2. pH ZERO	pH 7	X	37894
pH SLOPE	pH 4	X	37506
pH SLOPE	pH 10	X	37982
3. DISSOLVED OXYGEN	Air Calibration Barometric pressure = 760mmHg	X	N/A
DISSOLVED OXYGEN ZERO TEST	(Sodium Sulfite)	X	8714
4. TURBIDITY ZERO	0.0 NTU's	X	8714
TURBIDITY SPAN	20 NTU's	X	8714
5. REDOX (ORP)	231mV (YSI Zobell solution)	X	063014

EQUIPCO RENTALS

YSI 6920V2 RENTAL
CALIBRATION CERTIFICATE

SERVICE TECHNICIAN: MM DATE: 8/7/14

INSTRUMENT INFORMATION

RENTAL I.D. NUMBER: YSI-6920V2.04

SERIAL NUMBER:

CALIBRATION INFORMATION

PARAMETER:	STANDARD:	PASS ( )	LOT #
1. CONDUCTIVITY	1,000 µMhos	X	10932
2. pH ZERO	pH 7	X	32894
pH SLOPE	pH 4	X	37500
pH SLOPE	pH 10	X	37982
3. DISSOLVED OXYGEN	Air Calibration Barometric pressure = 760mmHg	X	N/A
DISSOLVED OXYGEN ZERO TEST	(Sodium Sulfite)	X	8-7-14
4. TURBIDITY ZERO	0.0 NTU's	X	8-7-14
TURBIDITY SPAN	20 NTU's	X	8-7-14
5. REDOX (ORP)	231mV (YSI Zobell solution)	X	063014

2100 Meridian Park Blvd, Concord, CA. 94520 Phone (888) 234-5678 Fax (925) 305-1301

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-8-2014 Sonde ID: YSI 6920 V2.02

Technician: K. Emery Used on Pre Job

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.2 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	4.73	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-10.2	Range	0 ± 50 mv
pH mv Buffer 4	153.6	Range	+180 ± 50 mv*
pH mv Buffer 10	-184.1	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Barometric Pressure: 737 mmHg @841' EDH

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal	
Temperature	29.5		Sonde
Conductivity	4.49	4.26 /	4.49
pH 7	7.0	7.03 /	7.00
pH 4	4.0	3.96 /	—
pH 10	10.0	10.1 /	
ORP	224.5	223.7	224.5
Turbidity	0.0	-0.1 /	0.0
Turbidity	12.7	12.8 /	—
Turbidity 0.5	--	/	
Chlorophyll	--	/	
Chlorophyll	--	/	
DO RP	--	/	
DO ROX	737 @ 841'	740 /	737. 98%
BGA PE/PC	--	/	
BGA PE/PC	--	/	
Rhodamine	--	/	

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQuipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	050113	9/2014
pH 7.0	10756	12/2014	Conuctivity	9256	10/2015
pH 10.0	10793	1/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-8-2014 Sonde ID: YSI 6920 V2.04

Technician: K. Emery Used on Pre-Job

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.1 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.14	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-13.1	Range	0 ± 50 mv
pH mv Buffer 4	143.3	Range	+180 ± 50 mv*
pH mv Buffer 10	-182.8	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Barometric Pressure: 737 mmHg @ 841' EDH

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	29.7	___ Sonde
Conductivity	4.49	4.73 / 4.49
pH 7	7.0	7.11 / 7.0
pH 4	4.0	3.57 / 4.0
pH 10	10.0	9.93 / 10.0
ORP	224.5	217 / 224.5
Turbidity	0.0	-0.8 / 0.0
Turbidity	12.7	13.0 / —
Turbidity 0.5	--	___ / ___
Chlorophyll	--	___ / ___
Chlorophyll	--	___ / ___
DO RP	--	___ / ___
DO ROX	737 @841'	700 / 737 98%
BGA PE/PC	--	___ / ___
BGA PE/PC	--	___ / ___
Rhodamine	--	___ / ___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	050113	9/2014
pH 7.0	10756	12/2014	Conuctivity	9256	10/2015
pH 10.0	10793	1/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-12-14 0530 Sonde ID: YSI-6920V2.04

Technician: K. Emery Used on Pre-Sample

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N Chlorophyll wiper changed? Y N

ROX DO wiper changed? Y N BGA-PE wiper changed? Y N

BGA-PC wiper changed? Y N Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.2 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.40	Range	5.0 ± .45
Integrated conductivity cell constant		Range	5.0 ± .70
pH mv Buffer 7	-6.3	Range	0 ± 50 mv
pH mv Buffer 4	141.4	Range	+180 ± 50 mv*
pH mv Buffer 10	-167.4	Range	-180 ± 50 mv *
DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot # 14E46748A 5/2015

Barometric Pressure: 623 mmHg @ 5,400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values	Standard	Pre Cal / Post Cal
Temperature	19.78	Sonde
Conductivity	4.49	4.39 / 4.49
pH 7	7.0	6.96 / 7.0
pH 4	4.0	4.15 / 4.0
pH 10	10.0	10.04 / 10.0
ORP	237.5	236.9 / —
Turbidity	0.0	0.0 / —
Turbidity	12.7	12.6 / —
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82.0	86.2 / 82.0
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	109117	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-12-14 0530 Sonde ID: YSI-6920V2.02

Technician: K. Emery Used on PRE-SAMPLE

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.0 (if applicable)

Record the following diagnostic numbers after calibration.

				Record Calibration Values	Standard	Pre Cal / Post Cal
6560 Conductivity cell constant	5.14	Range	5.0 ± .45	Temperature	20.02	Sonde
Integrated conductivity cell constant		Range	5.0 ± .70	Conductivity	4.49	4.42 / 4.49
pH mv Buffer 7	+27.6	Range	0 ± 50 mv	pH 7	7.0	7.06 / 7.0
pH mv Buffer 4	139.9	Range	+180 ± 50 mv*	pH 4	4.0	3.94 / 4.0
pH mv Buffer 10	-194.6	Range	-180 ± 50 mv *	pH 10	10.0	10.02 / —
*Note: Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv				ORP	237.5	237.5 / —
Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv				Turbidity	0.0	0.01 / —
DO charge (RP only)	--	Range	25 to 75	Turbidity	12.7	13.0 / —
DO gain	--	Range	0.7 to 1.4	Turbidity 0.5	--	/
ODO gain	--	Range	0.85 to 1.15	Chlorophyll	--	/
				Chlorophyll	--	/
Turbidity standard used in calibration	0.0 / 12.7			DO RP	--	/
Manufacturer and part number	Distilled Water / YSI 6072 LOT # 14E487487 5/2015			DO ROX	82.0	81.2 / 81.9
				BGA PE/PC	--	/
Barometric Pressure:	623 mmHg @ 5,400'			BGA PE/PC	--	/
DO % Calculated – (BARO mmHg divided by 7.6) = % saturation				Rhodamine	--	/

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-12-14 1500 Sonde ID: YSI 6920V2.04

Technician: K. Ewing Used on PGDW 30

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 13.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.10	Range	5.0 ± .45
Integrated conductivity cell constant		Range	5.0 ± .70
pH mv Buffer 7	-9.4	Range	0 ± 50 mv
pH mv Buffer 4	148.6	Range	+180 ± 50 mv*
pH mv Buffer 10	-168.2	Range	-180 ± 50 mv *
DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

5/2015 Lot# 14E467487

Barometric Pressure: 623 mmHg @5400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	20.4	___ Sonde
Conductivity	4.49	4.51 / —
pH 7	7.0	6.95 / 7.0
pH 4	4.0	4.07 / 4.0
pH 10	10.0	10.0 / —
ORP	237.5	235.4 / 237.5
Turbidity	0.0	-0.02 / 0.0
Turbidity	12.7	13.0 / 12.7
Turbidity 0.5	--	___ / ___
Chlorophyll	--	___ / ___
Chlorophyll	--	___ / ___
DO RP	--	___ / ___
DO ROX	82.0	81.5 / 82.0
BGA PE/PC	--	___ / ___
BGA PE/PC	--	___ / ___
Rhodamine	--	___ / ___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipu

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8/13/14 0515 Sonde ID: YSI 6920 V2.04

Technician: K. Emery Used on _____

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N Chlorophyll wiper changed? Y N

ROX DO wiper changed? Y N BGA-PE wiper changed? Y N

BGA-PC wiper changed? Y N Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.9 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.14	Range 5.0 ± .45	
Integrated conductivity cell constant	—	Range 5.0 ± .70	
pH mv Buffer 7	-25.9	Range 0 ± 50 mv	
pH mv Buffer 4	135.2	Range +180 ± 50 mv*	
pH mv Buffer 10	-188.7	Range -180 ± 50 mv *	
DO charge (RP only)	--	Range 25 to 75	
DO gain	--	Range 0.7 to 1.4	
ODO gain	--	Range 0.85 to 1.15	

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot# 14E467487 5/2015

Barometric Pressure: 623 mmHg @ 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	23.43	___ Sonde
Conductivity	4.49	4.39 / 4.49
pH 7	7.0	6.88 / 7.0
pH 4	4.0	4.15 / 4.0
pH 10	10.0	10.09 / 10.0
ORP	~~251.5~~ 231	235.4 / 231
Turbidity	0.0	-0.01 / 0.0
Turbidity	12.7	12.7 / —
Turbidity 0.5	--	___ / ___
Chlorophyll	--	___ / ___
Chlorophyll	--	___ / ___
DO RP	--	___ / ___
DO ROX	82.7%	83.6 / 82.0%
BGA PE/PC	--	___ / ___
BGA PE/PC	--	___ / ___
Rhodamine	--	___ / ___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQuipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8/13/14 0515 Sonde ID: YSI 6920V2.02

Technician: EMERY Used on N/A

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N Chlorophyll wiper changed? Y N

ROX DO wiper changed? Y N BGA-PE wiper changed? Y N

BGA-PC wiper changed? Y N Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	4.80	Range 5.0 ± .45	
Integrated conductivity cell constant	—	Range 5.0 ± .70	
pH mv Buffer 7	-9.1	Range 0 ± 50 mv	
pH mv Buffer 4	137.9	Range +180 ± 50 mv*	
pH mv Buffer 10	-169.9	Range -180 ± 50 mv *	
DO charge (RP only)	--	Range 25 to 75	
DO gain	--	Range 0.7 to 1.4	
ODO gain	--	Range 0.85 to 1.15	

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot # 14E487487 5/2015

Barometric Pressure: 623 mmHg 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	23.51	— Sonde
Conductivity	4.49	4.47 / 4.49
pH 7	7.0	6.89 / 7.0
pH 4	4.0	4.14 / 4.0
pH 10	10.0	10.14 / 10.0
ORP	231	236 / 231
Turbidity	0.0	0.0 / —
Turbidity	12.7	12.9 / —
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82%	82.8 / 82%
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8/13 /14 / 700 Sonde ID: YSI 6920V2.0

Technician: K. Emery Used on PGDW 33-32

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.9 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.14	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-10.4	Range	0 ± 50 mv
pH mv Buffer 4	146.1	Range	+180 ± 50 mv*
pH mv Buffer 10	-171.8	Range	-180 ± 50 mv *

*Note: Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot# 14E467487 5/2015

Barometric Pressure: 623 mmHg @ 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	23.1	— Sonde
Conductivity	4.49	4.56 / 4.49
pH 7	7.0	6.89 / 7.0
pH 4	4.0	4.10 / 4.0
pH 10	10.0	10.09 / 10.0
ORP	231.0	235 / 231
Turbidity	0.0	0.0 / —
Turbidity	12.7	13.0 / —
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82%	84.7 / 82%
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8/14/14 0600 Sonde ID: YSI 692DV2.02

Technician: KIEHNEY Used on pre-sampling

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accèlerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	4.87	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	+14.1	Range	0 ± 50 mv
pH mv Buffer 4	140.8	Range	+180 ± 50 mv*
pH mv Buffer 10	−191.3	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

LOT # 14E467487 5/2015

Barometric Pressure: 623 mmHg @ 5400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	22.8	— / Sonde
Conductivity	4.49	4.48 / —
pH 7	7.0	6.95 / 7.00
pH 4	4.0	4.07 / 4.00
pH 10	10.0	10.09 / 10.00
ORP	237.5	234.8 / 237.5
Turbidity	0.0	-0.04 / 0.0
Turbidity	12.7	13.3 / —
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82%	86.1 / 82%
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	5/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 08/14/14 0600 Sonde ID: YSI 6920.02.04

Technician: K. Emery Used on pre-sampling

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N Chlorophyll wiper changed? Y N

ROX DO wiper changed? Y N BGA-PE wiper changed? Y N

BGA-PC wiper changed? Y N Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.9 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.21	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-9.8	Range	0 ± 50 mv
pH mv Buffer 4	164.1	Range	+180 ± 50 mv*
pH mv Buffer 10	189.1	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

LOT # 14E467487 Exp. 5/2015

Barometric Pressure: 623 mmHg @ 5400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	22.6	___ Sonde
Conductivity	4.49	4.56 / 4.49
pH 7	7.0	6.96 / —
pH 4	4.0	4.01 / —
pH 10	10.0	9.94 / 10.0
ORP	237.5	239.1 / 237.5
Turbidity	0.0	0.01 / 0.00
Turbidity	12.7	13.1 / 12.7
Turbidity 0.5	--	___ / ___
Chlorophyll	--	___ / ___
Chlorophyll	--	___ / ___
DO RP	--	___ / ___
DO ROX	82%	84.9 / 82%
BGA PE/PC	--	___ / ___
BGA PE/PC	--	___ / ___
Rhodamine	--	___ / ___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8/14/14 1730 Sonde ID: YSI 6920V2 04

Technician: K. Energ Used on PGDW 14 + 44

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.0 (if applicable)

Record the following diagnostic numbers after calibration.

				Record Calibration Values	Standard	Pre Cal / Post Cal
6560 Conductivity cell constant	5.32	Range	5.0 ± .45	Temperature	24.27	___ Sonde
Integrated conductivity cell constant	—	Range	5.0 ± .70	Conductivity	4.49	4.53 / —
pH mv Buffer 7	20.1	Range	0 ± 50 mv	pH 7	7.0	7.10 / 7.0
pH mv Buffer 4	136.1	Range	+180 ± 50 mv*	pH 4	4.0	4.11 / 4.0
pH mv Buffer 10	-141.4	Range	-180 ± 50 mv *	pH 10	10.0	9.98 / —
				ORP	231	234 / 231
				Turbidity	0.0	0.04 / 0.0
DO charge (RP only)	--	Range	25 to 75	Turbidity	12.7	13.3 / 12.7
DO gain	--	Range	0.7 to 1.4	Turbidity 0.5	--	___ / ___
ODO gain	--	Range	0.85 to 1.15	Chlorophyll	--	___ / ___
				Chlorophyll	--	___ / ___
				DO RP	--	___ / ___
				DO ROX	82.6	84.2 / 82.0
				BGA PE/PC	--	___ / ___
				BGA PE/PC	--	___ / ___
				Rhodamine	--	___ / ___

*Note: Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot 14E487487 Ex. 5/2015

Barometric Pressure: 623 mmHg @ 5400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	04/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 08/15/14 0800 Sonde ID: YSI 6920V2.04

Technician: K. [illegible] Used on pre-sample

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.18	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	−11.1	Range	0 ± 50 mv
pH mv Buffer 4	164.3	Range	+180 ± 50 mv*
pH mv Buffer 10	−171.8	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot, 14E467487 5/2015

Barometric Pressure: 623 mmHg (8) 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	24.4	___ Sonde
Conductivity	4.49	4.61 / 4.49
pH 7	7.0	7.14 / 7.0
pH 4	4.0	4.07 / 4.0
pH 10	10.0	10.01 / —
ORP	237.5	238.1 / 237.5
Turbidity	0.0	-0.1 / —
Turbidity	12.7	12.9 / —
Turbidity 0.5	--	___/___
Chlorophyll	--	___/___
Chlorophyll	--	___/___
DO RP	--	___/___
DO ROX	82%	83.7 / 82.0
BGA PE/PC	--	___/___
BGA PE/PC	--	___/___
Rhodamine	--	___/___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	9/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 08/15/14 0600 Sonde ID: YSI 6920 V2.02

Technician: K. Emery Used on pre-sampling.

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.9 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	4.86	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-1.4	Range	0 ± 50 mv
pH mv Buffer 4	141.6	Range	+180 ± 50 mv*
pH mv Buffer 10	-138.3	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot # 14E462487 5/2015

Barometric Pressure: 623 mmHg (@ 5400)

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	24.6	___ Sonde
Conductivity	4.49	4.58 / 4.49
pH 7	7.0	7.11 / 7.0
pH 4	4.0	4.01 / —
pH 10	10.0	10.09 / 10.0
ORP	237.5	241.9 / 237.5
Turbidity	0.0	0.5 / 0.0
Turbidity	12.7	13.6 / 12.7
Turbidity 0.5	--	___ / ___
Chlorophyll	--	___ / ___
Chlorophyll	--	___ / ___
DO RP	--	___ / ___
DO ROX	82%	86.1 / 82%
BGA PE/PC	--	___ / ___
BGA PE/PC	--	___ / ___
Rhodamine	--	___ / ___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8/15/14 1630 Sonde ID: YSI 6920 V2.04

Technician: K. Emery Used on PRDW23 (Fenty)

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N Chlorophyll wiper changed? Y N

ROX DO wiper changed? Y N BGA-PE wiper changed? Y N

BGA-PC wiper changed? Y N Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.8 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.27	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-10.1	Range	0 ± 50 mv
pH mv Buffer 4	146.9	Range	+180 ± 50 mv*
pH mv Buffer 10	-180.1	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072 (LOT # 14E467487 5/2015)

Barometric Pressure: 623 mmHg @ 5400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	24.6	— Sonde
Conductivity	4.49	4.59 / 4.49
pH 7	7.0	7.03 / —
pH 4	4.0	3.98 / —
pH 10	10.0	10.15 / 10.0
ORP	231	236.4 / 231
Turbidity	0.0	-0.5 / 0.0
Turbidity	12.7	13.8 / 12.7
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82%	84% / 82%
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10731	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-18-14 0600 Sonde ID: YSI 692002.04

Technician: K. Enez Used on Pre-Sampling

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.2 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.37	Range	5.0 ± .45
Integrated conductivity cell constant	✓	Range	5.0 ± .70
pH mv Buffer 7	11.8	Range	0 ± 50 mv
pH mv Buffer 4	138.6	Range	+180 ± 50 mv*
pH mv Buffer 10	-189.5	Range	-180 ± 50 mv *
DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

LOT # 14E467487 5/2015

Barometric Pressure: 623 mmHg @ 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Record Calibration Values	Standard	Pre Cal / Post Cal
Temperature	23.80	— / Sonde
Conductivity	4.49	4.41 / 4.49
pH 7	7.0	6.95 / —
pH 4	4.0	4.06 / —
pH 10	10.0	10.14 / 10.0
ORP	231	248.8 / 231
Turbidity	0.0	0.3 / —
Turbidity	12.7	13.4 / 12.7
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82.0	82.1 / —
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Notes: Calibration Solution Manufacturer: EQuipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	7/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015 i
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-18-14 0600 Sonde ID: YSI6920V2.02

Technician: Kenny Used on presampling

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.19	Range	5.0 ± .45
Integrated conductivity cell constant		Range	5.0 ± .70
pH mv Buffer 7	~~-30.9~~ -23.7	Range	0 ± 50 mv
pH mv Buffer 4	144.7	Range	+180 ± 50 mv*
pH mv Buffer 10	-184.1	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot# 14E467487

Barometric Pressure: 623 mmHg @ 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	23.17	/ Sonde
Conductivity	4.49	4.47 / —
pH 7	7.0	7.11 / 7.0
pH 4	4.0	4.14 / 4.0
pH 10	10.0	9.98 / —
ORP	231.0	235.4 / 231.0
Turbidity	0.0	-0.1 / —
Turbidity	12.7	13.1 / 12.7
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82.0	82.4 / —
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10831	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-18-14 1530 Sonde ID: YSI 692002.04

Technician: K. Emery Used on PGDW-05 + PGDW45

RP DO membrane changed? Y (N) *Note: Wait 3 to 6 hours before calibrating for unattended*

RP DO membrane o-ring changed? Y (N) *deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)*

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.2 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.29	Range	5.0 ± .45
Integrated conductivity cell constant	/	Range	5.0 ± .70
pH mv Buffer 7	-327	Range	0 ± 50 mv
pH mv Buffer 4	141.7	Range	+180 ± 50 mv*
pH mv Buffer 10	-174.6	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

LOT# 14E467487 5/2015

Barometric Pressure: 623 mmHg @ 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	24.6	– Sonde
Conductivity	4.49	4.58 / 4.49
pH 7	7.0	7.07 / 7.0
pH 4	4.0	4.11 / 4.0
pH 10	10.0	9.94 / 10.0
ORP	231	235.4 / 231
Turbidity	0.0	0.1 / –
Turbidity	12.7	13.8 / 12.7
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82	82.3 / –
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9252	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 08-19-14 0600 Sonde ID: 4E6920U2.02

Technician: K. Emery Used on pre-sampling

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.31	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	11.8	Range	0 ± 50 mv
pH mv Buffer 4	146.4	Range	+180 ± 50 mv*
pH mv Buffer 10	-189.8	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

LOT# 14E467487

Barometric Pressure: 623 mmHg @ 5400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	23.61	— Sonde
Conductivity	4.49	4.56 / 4.49
pH 7	7.0	6.94 / 7.0
pH 4	4.0	4.15 / 4.0
pH 10	10.0	10.08 / 10.0
ORP	237.5	239.1 / 237.5
Turbidity	0.0	0.3 / 0.0
Turbidity	12.7	12.9 / —
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82%	83.4 / 82
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 08-19-14 0600 Sonde ID: YSI 6920 V2.04

Technician: K. Emery Used on pre-sampling

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y N

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	4.84	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-11.8	Range	0 ± 50 mv
pH mv Buffer 4	135.4	Range	+180 ± 50 mv*
pH mv Buffer 10	-194.6	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

LOT# 1YE467487 5/2015

Barometric Pressure: 623 mmHg @ 5,400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	23.47	— / Sonde
Conductivity	4.49	4.47 / 4.49
pH 7	7.0	7.04 / —
pH 4	4.0	4.08 / 4.0
pH 10	10.0	10.21 / 10.0
ORP	237.5	240.1 / 237.5
Turbidity	0.0	-0.1 / 0.0
Turbidity	12.7	13.0 / 12.7
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82.0	84.1 / 82.1
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	8/10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-19-14 1700 Sonde ID: YSI 6920V2.04

Technician: K. Emery Used on PGDW 49 (MEEKS)

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N Chlorophyll wiper changed? Y N

ROX DO wiper changed? Y N BGA-PE wiper changed? Y N

BGA-PC wiper changed? Y N Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.1 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.04	Range	5.0 ± .45	Temperature	24.6	—	Sonde
Integrated conductivity cell constant	—	Range	5.0 ± .70	Conductivity	4.49	4.48	—
pH mv Buffer 7	-6.9	Range	0 ± 50 mv	pH 7	7.0	6.94	7.0
pH mv Buffer 4	142.7	Range	+180 ± 50 mv*	pH 4	4.0	4.11	4.0
pH mv Buffer 10	188.5	Range	-180 ± 50 mv *	pH 10	10.0	10.04	10.0
				ORP	231	235	231
				Turbidity	0.0	0.0	—
DO charge (RP only)	--	Range	25 to 75	Turbidity	12.7	13.0	12.7
DO gain	--	Range	0.7 to 1.4	Turbidity 0.5	--		
ODO gain	--	Range	0.85 to 1.15	Chlorophyll	--		
				Chlorophyll	--		
				DO RP	--		
				DO ROX	82.0	81.1	82.0
				BGA PE/PC	--		
				BGA PE/PC	--		
				Rhodamine	--		

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot 14E467487 5/2015

Barometric Pressure: 623 mmHg @ 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9251	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-20-14 0600 Sonde ID: YSI 6920V2.04

Technician: K. Emery Used on Presamp

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.1 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.33	Range 5.0 ± .45	
Integrated conductivity cell constant	—	Range 5.0 ± .70	
pH mv Buffer 7	-17.9	Range 0 ± 50 mv	
pH mv Buffer 4	141.6	Range +180 ± 50 mv*	
pH mv Buffer 10	-169.1	Range -180 ± 50 mv *	

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range 25 to 75
DO gain	--	Range 0.7 to 1.4
ODO gain	--	Range 0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

LOT# 14E462487 5/2015

Barometric Pressure: 623 mmHg @ 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	24.1	— / Sonde
Conductivity	4.49	4.52 / 4.49
pH 7	7.0	6.89 / 7.0
pH 4	4.0	3.88 / 4.0
pH 10	10.0	9.98 / —
ORP	231.0	234 / 231
Turbidity	0.0	0.5 / 0.0
Turbidity	12.7	13.1 / 12.7
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82.0	81.8 / 82
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9251	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9251	10/2015
pH 10.0	10917	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-20-14 0600 Sonde ID: YSI 6920V2.02

Technician: K. Ewen Used on PRESampling

RP DO membrane changed? Y (N)
RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)
ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)
BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	12.0	Range 5.0 ± .45	
Integrated conductivity cell constant		Range 5.0 ± .70	
pH mv Buffer 7	-11.8	Range 0 ± 50 mv	
pH mv Buffer 4	141.9	Range +180 ± 50 mv*	
pH mv Buffer 10	-195	Range -180 ± 50 mv *	
DO charge (RP only)	--	Range 25 to 75	
DO gain	--	Range 0.7 to 1.4	
ODO gain	--	Range 0.85 to 1.15	

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot # 14E467487 5/2015

Barometric Pressure: 623 mmHg @ 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	23.8	— Sonde
Conductivity	4.49	4.56 / 4.49
pH 7	7.0	6.94 / 7.0
pH 4	4.0	4.04 4.0
pH 10	10.0	9.96 / —
ORP	231	232 —
Turbidity	0.0	0.5 / 0.0
Turbidity	12.7	13.4 / 12.7
Turbidity 0.5	--	/
Chlorophyll	--	/
Chlorophyll	--	/
DO RP	--	/
DO ROX	82.0	83.4 / 82
BGA PE/PC	--	/
BGA PE/PC	--	/
Rhodamine	--	/

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10949	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-20-14 1740 Sonde ID: VSI 6920V2.04

Technician: K. Emery Used on PGDW 41A + 41B

RP DO membrane changed? Y N *Note: Wait 3 to 6 hours before calibrating for unattended*

RP DO membrane o-ring changed? Y N *deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)*

Turbidity wiper changed? Y N Chlorophyll wiper changed? Y N

ROX DO wiper changed? Y N BGA-PE wiper changed? Y N

BGA-PC wiper changed? Y N Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

NEW Batteries

Record sonde battery voltage: 13.0 (if applicable)

Record the following diagnostic numbers after calibration.

				Record Calibration Values	Standard	Pre Cal / Post Cal
6560 Conductivity cell constant	5.31	Range	5.0 ± .45	Temperature	24.1	— / Sonde
Integrated conductivity cell constant	—	Range	5.0 ± .70	Conductivity	4.49	4.52 / —
pH mv Buffer 7	-11.9	Range	0 ± 50 mv	pH 7	7.0	7.07 / 7.0
pH mv Buffer 4	151.6	Range	+180 ± 50 mv*	pH 4	4.0	4.09 / 4.0
pH mv Buffer 10	-171.3	Range	-180 ± 50 mv *	pH 10	10.0	9.96 / 10.0
				ORP	231	237.4 / 231
				Turbidity	0.0	0.1 / —
DO charge (RP only)	--	Range	25 to 75	Turbidity	12.7	12.8 / —
DO gain	--	Range	0.7 to 1.4	Turbidity 0.5	--	/
ODO gain	--	Range	0.85 to 1.15	Chlorophyll	--	/
				Chlorophyll	--	/
				DO RP	--	/
				DO ROX	82%	84.1 / 82%
				BGA PE/PC	--	/
				BGA PE/PC	--	/
				Rhodamine	--	/

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot 14E467487 5/2015

Barometric Pressure: 623 mmHg @ 5400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10949	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-21-14 0600 Sonde ID: YSI 6920V2.04

Technician: K. Emery Used on Presampling

RP DO membrane changed? Y (N)

RP DO membrane o-ring changed? Y (N)

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y (N) Chlorophyll wiper changed? Y (N)

ROX DO wiper changed? Y (N) BGA-PE wiper changed? Y (N)

BGA-PC wiper changed? Y (N) Rhodamine wiper changed? Y (N)

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 11.9 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.32	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-11.9	Range	0 ± 50 mv
pH mv Buffer 4	137.2	Range	+180 ± 50 mv*
pH mv Buffer 10	-174.4	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot# 14E467487 5/2015

Barometric Pressure: 623 mmHg (8) 5400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	22.85	___ Sonde
Conductivity	4.49	4.44 / 4.49
pH 7	7.0	7.08 / 7.0
pH 4	4.0	4.12 / 4.0
pH 10	10.0	10.07 / 10.0
ORP	237.5	239.6 / 237.
Turbidity	0.0	0.6 / 0.0
Turbidity	12.7	13.0 / 12.7
Turbidity 0.5	--	___ / ___
Chlorophyll	--	___ / ___
Chlorophyll	--	___ / ___
DO RP	--	___ / ___
DO ROX	82.0	83.2 / 82.0
BGA PE/PC	--	___ / ___
BGA PE/PC	--	___ / ___
Rhodamine	--	___ / ___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: EQUIPCO

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-21-14 0600 Sonde ID: YSI6920V2.02

Technician: K. Enay Used on Presampling

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N Chlorophyll wiper changed? Y N

ROX DO wiper changed? Y N BGA-PE wiper changed? Y N

BGA-PC wiper changed? Y N Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 12.0 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.14	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-21.6	Range	0 ± 50 mv
pH mv Buffer 4	136.0	Range	+180 ± 50 mv*
pH mv Buffer 10	-141.0	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

Lot # 14E 467487 5/2015

Barometric Pressure: 623 mmHg @ 5400'

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	23.00	___ Sonde
Conductivity	4.49	4.49 / —
pH 7	7.0	6.99 / —
pH 4	4.0	4.15 / 4.00
pH 10	10.0	10.11 / 10.0
ORP	231	233 / 231
Turbidity	0.0	0.5 / 0.0
Turbidity	12.7	13.0 / ~~12.0~~ 12.7
Turbidity 0.5	--	___ / ___
Chlorophyll	--	___ / ___
Chlorophyll	--	___ / ___
DO RP	--	___ / ___
DO ROX	82.0	81.3 / 82.0
BGA PE/PC	--	___ / ___
BGA PE/PC	--	___ / ___
Rhodamine	--	___ / ___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: Equipco

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9251	10/2015
pH 10.0	10947	4/2015			

CALIBRATION WORK SHEET

Prior to Sampling / Post Sampling

Date of Calibration: 8-21-14 1425 Sonde ID: YSI 6920V2.04

Technician: K. Emery Used on PGDW 20 + CD02

RP DO membrane changed? Y N

RP DO membrane o-ring changed? Y N

Note: Wait 3 to 6 hours before calibrating for unattended deployments; run in Discrete mode for 10 minutes to accelerate burn in. (Rapid Pulse DO Only)

Turbidity wiper changed? Y N

ROX DO wiper changed? Y N

BGA-PC wiper changed? Y N

Chlorophyll wiper changed? Y N

BGA-PE wiper changed? Y N

Rhodamine wiper changed? Y N

Note: If parking problems occur with optical probes having a serial number 07L (Dec 07) or older, be sure the firmware is 3.06 or later. Parking issues with optical probes having a serial number prior to 07L may be related to a dirty wiper body or pad.

Record sonde battery voltage: 11.8 (if applicable)

Record the following diagnostic numbers after calibration.

6560 Conductivity cell constant	5.18	Range	5.0 ± .45
Integrated conductivity cell constant	—	Range	5.0 ± .70
pH mv Buffer 7	-19.9	Range	0 ± 50 mv
pH mv Buffer 4	144.6	Range	+180 ± 50 mv*
pH mv Buffer 10	-184.6	Range	-180 ± 50 mv *

***Note:** Millivolt span between pH 4 and 7 should be ≈ 165 to 180 mv

Millivolt span between pH 7 and 10 should be ≈ 165 to 180 mv

DO charge (RP only)	--	Range	25 to 75
DO gain	--	Range	0.7 to 1.4
ODO gain	--	Range	0.85 to 1.15

Turbidity standard used in calibration 0.0 / 12.7

Manufacturer and part number Distilled Water / YSI 6072

ME 467 YBA 5/2015

Barometric Pressure: 623 mmHg 8400

DO % Calculated – (BARO mmHg divided by 7.6) = % saturation

Example: 760 ÷ 7.6 = 100.0%

Record Calibration Values

	Standard	Pre Cal / Post Cal
Temperature	25.8	___ Sonde
Conductivity	4.49	4.60 / 4.49
pH 7	7.0	6.87 / 7.0
pH 4	4.0	4.16 / 4.0
pH 10	10.0	9.97 / 10.0
ORP	237.5	236 / —
Turbidity	0.0	0.2 / —
Turbidity	12.7	13.4 / 12.7
Turbidity 0.5	--	___ / ___
Chlorophyll	--	___ / ___
Chlorophyll	--	___ / ___
DO RP	--	___ / ___
DO ROX	82.0	82.3 / —
BGA PE/PC	--	___ / ___
BGA PE/PC	--	___ / ___
Rhodamine	--	___ / ___

Depth Calibration - If zero was entered, record barometric pressure at time of calibration N/A mmHg

Depth Calibration - If offset depth was entered, record value -- meters/feet and pressure N/A mmHg

Depth Calibration (Vented) – Acceptable calibration constant: 0.0 psig ± 0.15 N/A

Notes: Calibration Solution Manufacturer: YSI

Solution	Lot #	Expiration	Solution	Lot #	Expiration
pH 4.0	9256	10/2015	ORP	060114	8/2015
pH 7.0	10931	4/2015	Conuctivity	9256	10/2015
pH 10.0	10947	4/2015			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	LD02	Date:	8/21/2014
Sample ID:	LD02-08212014	Field Crew:	KGE, DMJ, JRH
QA/QC Sample IDs:		Purging Subcontractor:	N/A
MS/MSD for this Sample?		Weather:	
Location Description:	Well new driveway	FID/PID at Well Headspace (ppm):	~
Well Condition:	Unused. Cap on casing.		—

PURGING PARAMETERS

Casing Diameter (D, inches): 6

Approx. Screen Depth (feet bmp): — to 610

Depth to Water (H, feet bmp): 167.9 (0853)

Casing Volume (gallons): NA

Calculated Purge Volume (gallons): NA

Note if LPH (feet thickness): N/A

CASING VOLUME: V = 0.0408 X HD2

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☐	☐	
Dedicated Equipment?	☒ NA	☒ Hydrasleeve	

Intake Depth (feet bmp):

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temper-ature (degrees C)	Specific Conduct-ance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
	0	0								Start purge.
1205	—	—	—	—	—	—	—	—	—	Collect sample.
						None				
										End purge.

Other measurements (units): Ferrous Iron 0.01 mg/L (See notes on next page re filtering)

Time Samples Collected: 1205

Sample Appearance: Organic matter (2)

Laboratory: C&T, Precision, Isotech

Note Any Sampling Problem: ~~Reel only (1)~~

Equipment Decontamination: Reel only (1)

Purge Water Disposition: Lawn.

Water Meter Model/No: YSI 6920 v2.04 (Equipco) Hach DR 890 00194009422

Comments: Collect grab sample with Hydrasleeve and new heavy tubing. (1) Reel decon/disinfect - Liquinox solution wash and wipe with towels, second Liquinox rinse, DI water rinse, spray w/ 2% bleach solution. (2) Sample contains apparent black (<1cm) agglomerated particulate matter, brownish-black mostly with some yellowish green. Otherwise turbidity is low.

Signature: [signature]

Date: August 21, 2014

1405 Sample collected. Insufficient volume for field parameters

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	LD02	Date:	8/21/2014
Sample ID:	LD02-08212014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No (2)	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter *	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter *	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter *	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter *	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	46			

* Samples filtered by drawing water from Hydrasleeve into peristaltic pump with dedicated tubing. (2) Filled Isoflask concurrent with filtered samples using peristaltic pump.

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW05	Date:	8/18/2014 ✓
Sample ID:	PGDW05-08182014	Field Crew:	KGE, DMJ, JRH
QA/QC Sample IDs:		Purging Subcontractor:	N/A
MS/MSD for this Sample?		Weather:	Clear, calm, 65 °F
Location Description:	Tap on side of house in use in home	FID/PID at Well Headspace (ppm):	^
Well Condition:	In use		

PURGING PARAMETERS

Casing Diameter (D, inches)	7
Approx. Screen Depth (feet bmp):	— to 210
Depth to Water (H, feet bmp):	20 (Based on 45 and 60)
Casing Volume (gallons):	400
Calculated Purge Volume (gallons):	1200 (1)
Note if LPH (feet thickness):	N/A

CASING VOLUME: $V = 0.0408 \times HD^2$

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0826	0	13372 0	—							Start purge.
0833	4.2	13402		11.9	0.961	0.30	8.61	+96	2.0	0.48 (2)
0840	2.7	13421		11.4	0.963	0.27	8.87	+53	2.1	0.48
0845	1.6	13429		11.3	0.970	0.23	8.96	+22	2.1	0.48
0850	1.8	13438		11.4	0.967	0.21	9.00	~~-3~~ -4	2.6	0.48
0855	1.6	13446		11.3	0.967	0.20	9.03	-8	2.5	0.48
0859	2	13453		11.2	0.968	0.19	9.05	-33	2.4	0.48
09~~10~~03	2	13459		11.1	0.971	0.19	9.07	-45	2.2	0.48
09~~14~~07	2	13466		11.2	0.967	0.19	9.08	-63	2.4	0.48
09~~20~~10	2	13471		11.0	0.969	~~0.18~~ 0.17	9.09	-69	2.4	0.48
~~0911~~						pmk				
0910										End purge.

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected: ~~1015~~ 0915 Note Any Sampling Problem: None

Sample Appearance: Small bubbles (3) Equipment Decontamination: None

Laboratory: C&T, Precision, Isotech Purge Water Disposition: Lawn

Water Meter Model/No: YSI 6920 v2.04 Equipto Hach PR890 00019 009442

Comments: (1) Owner reports well runs dry. Purge at 2-3 gpm and monitor parameters. (2) Adjust flow. 0950 Samples collected. (3) In bucket, water contained small amount of <4 mm pale translucent filamentaceous particulates.

Signature: [signature] Date: 08/18/2014 August 18, '14

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW05
Sample ID: PGDW05-08182014

Date: 8/18/2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	46			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW14
Sample ID: PGDW14-08142014
QA/QC Sample IDs:
MS/MSD for this Sample?
Location Description: Blue hydrant by vault
Well Condition: Off. Used for irrigation.

Date: 8/14/2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Overcast, 64°F, light NE
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 6
Approx. Screen Depth (feet bmp): — to 190
Depth to Water (H, feet bmp): Assume 100 ft
Casing Volume (gallons): 130
Calculated Purge Volume (gallons): 400
Note if LPH (feet thickness): N/A
CASING VOLUME: $V = 0.0408 \times HD^2$

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0830		11450								Start purge.
0843	6.0	11528		—	—	—	—	—	—	7gpm bucket.
0905	6.4	11669		11.2	4.00	0.28	7.55	+213	(1) —	2.13
0912	6.6	11715		10.9	4.04	0.20	7.57	+209	(1)	2.15
0923	6.6	11788		11.0	4.05	0.21	7.59	+204	(1) 10	2.16
0933	6.6	11854		11.4	4.08	0.19	7.61	+198	(1)	DO=0.55
0933	~	~ (2)	<	11.4	3.93	0.88	7.41	+167	2	2.09 (2) <>
0938		11879		11.3	4.07	0.19	7.61	+197	(1)	
0938	~	~(2)	<	11.6	3.92	0.53	7.43	+165	3	2.08 (2) >
0943		11911		11.2	4.09	0.19	7.62	+194	(1)	2.18
0947		11934		11.3	4.11	0.18	7.62	+194	(1)	2.19
~~0950~~										
0950										End purge.

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected: 0950
Sample Appearance: Gas bubbles.
Laboratory: C&T, Precision, Isotech
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Landscape

Water Meter Model/No:
Equipio YSI 6920V2.04
Hach DR890 00019 000944?

Comments: (1) Numerous gas bubbles turbidity readings.
(2) Duplicate meter reading Equipio YSI 6920V2.02 in series at second position. Fewer smaller gas bubble in second flow through cell.
Sampling completed at 1040

Signature: [signature]
Date: 8/14/2014

459 0934 0940 2

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW14
Sample ID: PGDW14-08142014

Date: 8/14/2014
Field Crew: KGE, DMJ, JRH

✓

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	46			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW20
Sample ID: PGDW20-08212014
QA/QC Sample IDs: —
MS/MSD for this Sample? —
Location Description: Hydrant by corral
Well Condition: Own has had hydrant ~~run~~ on since 0600

Date: 8/21/2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Sky 50%
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 5
Approx. Screen Depth (feet bmp): — to 380
Depth to Water (H, feet bmp): 168 (based on LD02)
Casing Volume (gallons): 220
Calculated Purge Volume (gallons): 650
Note if LPH (feet thickness): N/A
CASING VOLUME: V = 0.0408 X HD^2

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒ ~~N/A~~	☒	~~Hydrastle~~
Dedicated Equipment?	☒ ~~N/A~~	☒	
Intake Depth (feet bmp):	—		

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0630	(1) 5	— 0								Start purge. By owner.
0845	0		—							Set up man. fold
0848	(1) 5	15994	(2)							well on. (2)
0911	4.3	16093		12.18	2.94	0.20	8.32	-111	0.4	1.54
0919	4.1	16126		12.20	2.97	0.19	8.44	-120	1.7	1.56
0924	4.2	16147		12.19	2.98	0.21	8.50	-131	0.8	1.56
0929	4.2	16168		12.19	2.97	0.17	8.63	-145	0.8	1.56
0936	4.1	16197		12.19	2.97	0.17	8.60	-145	1.0	1.55
0940	4.3	16214		12.18	2.97	0.16	8.67	-144	1.0	1.56
0944	4	16230		12.20	2.97	0.16	8.71	-153	1.3	1.56
0949	4.2	16251		12.33	2.98	0.16	8.71	-170	1.2	1.56
0953	4	16268		12.29	2.99	0.16	8.75	-160	1.4	1.57
0957	4	16284		12.18	2.98	0.15	8.75	-148	1.5	1.56
										End purge.

Other measurements (units): Ferrous Iron 0.00 mg/L

Time Samples Collected: 10:00
Sample Appearance: Small gas bubbles
Laboratory: C&T, Precision, Isotech
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Behind corral
Water Meter Model/No: YSI-6920V2.04 (Equipico) Hach VR890 00019 0009422

Comments: Well not in use. (1) Owner turned on hydrant on at 0630. Bucket test approx 5 gpm flow. Off 0845 to 0848 to set up manifold. (2) Prior purge 0630-0845, 135 min x 4.3 gpm = 580 gal. 1050 Sample collected.

Signature: [signature]
Date: August 21, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW20
Sample ID: PGDW20-082I2014

Date: 8/21/2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	46			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW23
Sample ID: PGDW23-08152014
QA/QC Sample IDs: Dupe-1-08152014
MS/MSD for this Sample?
Location Description: Tank shed near house
Well Condition: Used for irrigation

Date: 8/15/2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Clear
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 5
Approx. Screen Depth (feet bmp): 445 to 465
Depth to Water (H, feet bmp): 120 (drillers log)
Casing Volume (gallons): 350 gal
Calculated Purge Volume (gallons): 1,100
Note if LPH (feet thickness): N/A
CASING VOLUME: $V = 0.0408 \times HD^2$

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0830	8.5	— 0	—	—	—	—		—	—	Start purge. (1)
0832		12575								
0848	7.0	12687		12.6	1.11	0.50	7.61	14	0.1	0.55
0852	6	12712		12.4	1.11	0.31	8.21	36	0.2	0.56
0856	6	12737		12.4	1.11	0.27	8.57	-32	0.1	0.56
0900	6	12762		12.4	1.11	0.23	8.73	-67	0.1	0.56
0904	6	12788		12.4	1.11	0.21	8.88	-92	~~2.8 (2)~~	0.55 NTU 0.1
0908	6	12813		12.3	1.11	0.21	8.94	-96	0.2	0.55
0912	5	12833		12.3	1.11	0.19	8.98	-105	0.2	0.55
0916	5	12855		12.4	1.11	0.18	9.01	-110	0.2	0.55
0920	5	12882		12.4	1.11	0.17	9.06	-116	0.2	0.55
0924		12898	—	12.4	1.11	0.17	9.07	-119	0.2	0.55
0928	5	12920	—	12.4	1.11	0.17	9.10	-115	0.2	0.55
0932	5	12942	—	12.4	1.15	0.16	9.09	-104	0.3	0.55
										End purge.

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected: 0935
Sample Appearance: Clear
Laboratory: C&T, Precision, Isotech

Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Trees landscape Hach DR 890

Water Meter Model/No: Equipco 9516920V2.04

Comments: Total depth 475 ft bgs and 5-inch casing per drillers log. (1) Owner has been running well since ca. ~0600. Total 1,300 gallons ~~was~~ purged.
~~(2) Scattered fine bubbles after purge~~ JM
10:05 Primary sample collected, 1015 collect Dupe-1-08152014
10:38 Duplicate sample collected

Signature: JM

Date: August 15, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW23	Date:	8/15/2014
Sample ID:	PGDW23-08152014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	8	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	6	No	HCl	C&T
Glycols	8015B	VOA	40	6	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	2	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	6	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	6	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	2	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	2	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	4	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	2	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	2	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	4	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	4	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	2	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	2	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	2	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	2	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	2	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	2	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	2	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	2	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	2	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	2	No	HCl	C&T
Radon	NS	VOA	40	4	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	2	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	2	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	2	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	2	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	2	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	2	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	2	No	Cold	Precision; 30-hr hold time call Sat
			Count:	92			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW30
Sample ID: PGDW30-08122014
QA/QC Sample IDs:
MS/MSD for this Sample? **Yes**
Location Description: Tap outside well house
Well Condition: Owner ran well at 0600

Date: 8/12/2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Clear, calm, 70s F, 0 mph 70°F.
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 6
Approx. Screen Depth (feet bmp): — to 260
Depth to Water (H, feet bmp): Assume 100 feet
Casing Volume (gallons): 235
Calculated Purge Volume (gallons): 700
Note if LPH (feet thickness): N/A
CASING VOLUME: $V = 0.0408 \times HD^2$

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0600	0	0								Start purge. (1)
0822	5	—	—							710 gallons (2)
0835		9800	—							
0850		9863	—	10.6	1.05	0.75	8.46	135	0.8	
0855	4.8	9887	—	10.6	1.05	0.71	8.62	94	0.6	
0900		9919	—	10.6	1.05	0.67	8.70	63	1.1	
0907		9948	—	10.6	1.05	0.72	8.80	13	1.0	
0911		9955	—	10.6	1.05	0.70	8.82	9.0	1.0	0.52
0915	4.5	9973	—	10.6	1.04	0.68	8.83	3.7	1.4	0.52
0919		9988	—	10.6	1.04	0.66	8.82	2.0	1.0	0.52
0922		10001	—	10.6	1.04	0.69	8.82	~~1.0~~	1.0	-10 ORP
0925	4.7	10015	—	10.6	1.04	0.71	8.84	-22	1.6	(4) 0.52
0925										End purge.

Other measurements (units): Ferrous Iron 0.0 mg/L (0930)

Time Samples Collected: 0930 (5)
Sample Appearance: Clear, small bubbles
Laboratory: C&T, Precision, Isotech
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Landscape trees

Water Meter Model/No:
YSI 6920V2 Equipco, 02 (3)
Hach DR890 Equipco, 06 (6)

Comments: (1) Owner turned on well on full at 0600.
(2) 710 gallons purged by 0822 (142 min x 5 gpm)
(3) Equipco meter YSI 6920V2.02
(4) Gas bubbles appear to affect stability of DO readings. Will jump down 0.2 to 0.3 mg/L.
Trip Blank TB-1-08122014 0920

Signature: [signature]
Date: August 12, 2014

(5) End 0955 (6) Hach DR890 00019000 9442

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW30
Sample ID: PGDW30-08122014

Date: 8/12/2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	9	No	HCl	C&T
Glycols	8015B	VOA	40	9	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	3	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	9	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	9	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	3	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	6	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	3	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	3	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	6	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	6	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	3	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	3	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	3	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	3	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	3	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	3	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	3	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	3	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	106			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW32	Date:	8/13/2014
Sample ID:	PGDW32-08132014	Field Crew:	KGE, DMJ, JRH
QA/QC Sample IDs:	—	Purging Subcontractor:	N/A
MS/MSD for this Sample?	—	Weather:	78°F, variable breeze
Location Description:	Red hydrant	FID/PID at Well Headspace (ppm):	—
Well Condition:	Running ~1.5 gpm since 0600		

PURGING PARAMETERS

Casing Diameter (D, inches)	6
Approx. Screen Depth (feet bmp):	~ to 900
Depth to Water (H, feet bmp):	271.8 (0852)
Casing Volume (gallons):	930
Calculated Purge Volume (gallons):	2800
Note if LPH (feet thickness):	N/A
CASING VOLUME: V = 0.0408 X HD^2	

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	
Intake Depth (feet bmp):	—		

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0600	1.5 0	— 0								Start purge. (1)
0830	9	(230)(2)								Increased rate.
0852	9	(430)(2)	271.8	—	—	—	—	—	—	
0916	9	(640)(2)	276.6	—	—	—	—	—	—	
1050	9	(1490)(2)	283.4	—	—	—	—	—	—	
1105	9	10451		—	—	—	—	—	—	Add flowmeter (3)
1145	6.5	10710		14.3	1.11	0.25	9.87	-116	13	0.55 (4)
1210	6.4	10870		13.7	1.12	0.15	9.91	-128	6.	0.56
1231	6.0	10996		13.8	1.11	0.14	9.89	-128	5.	0.56
1238	6.4	11041	283.6	13.8	1.15	0.14	9.88	-130	5.	0.56
1244	6.7	11081		13.6	1.11	0.14	9.86	-132	5.	0.55
1249	6	11110		13.6	1.12	0.14	9.89	-133	5.	0.56
1255	6.5	11149		13.7	1.12	0.14	9.88	-133	3.	Salinity = 0.56 (5)
1300										End purge.

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected:	1300	Note Any Sampling Problem:	None
Sample Appearance:	Fine bubbles	Equipment Decontamination:	None
Laboratory:	C&T, Precision, Isotech	Purge Water Disposition:	Landscape

Water Meter Model/No: YSI-6920V2.04 Equipco Hach DR890-00019 0009442

Comments: (1) Owner ran well at approximately 1.5 gpm since 0600
(2) Increase flowrate to 9 gpm (bucket test) with larger hose. Reading in totalizer column in (230) is total purged gal.
(3) 1105 add flow meter. Purge volume total now 1625 gallons.
(4) Small ~~bubbles~~ bubbles affect turbidity readings.
(5) Total purge volume 2,200 gal. Sampling completed 1325

Signature: [signature]

Date: August 13, 2014

(1250) (1255) 721 & 0852

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW32
Sample ID: PGDW32-08132014

Date: 8/13/2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	46			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW33	Date:	8/13/2014
Sample ID:	PGDW33-08132014	Field Crew:	KGE, DMJ, JRH
QA/QC Sample IDs:	FB-1-08132014	Purging Subcontractor:	N/A
MS/MSD for this Sample?		Weather:	74°F Breeze
Location Description:	Blue hydrant	FID/PID at Well Headspace (ppm):	—
Well Condition:	Running w/ gpm since 0600		

PURGING PARAMETERS

Casing Diameter (D, inches)	6
Approx. Screen Depth (feet bmp):	— to 30
Depth to Water (H, feet bmp):	Assume 20
Casing Volume (gallons):	15
Calculated Purge Volume (gallons):	45
Note if LPH (feet thickness):	N/A

CASING VOLUME: $V = 0.0408 \times HD^2$

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0600	1	0								Start purge. (1)
0825	0	10440								145 gal (1)
0845	—	10440	—							Restart (2)
0851	2	10451	—		1.51					Set low (2)
0854	0.5	—	—	18.2	~~1.50~~	4.95	7.41	221	0.3	
0903	0.3	—	—	17.5	1.57	4.88	7.31	219	0.6	
0907	0.3	—	—	17.2	1.60	4.85	7.29	219	1.2	
0915	0.3	—	—	17.2	1.65	4.65	7.25	219	3.4	
0922	0.3	—	—	17.2	1.67	4.47	7.22	217	2.1	Salinity 0.85
0930	0.3	—	—	17.0	1.68	4.36	7.21	216	2.0	" 0.86
0936	0.3	—	—	17.1	1.69	4.28	7.21	215	6.1 (3)	" 0.86
0939	0.3	—	—	17.1	1.70	4.30	7.21	214	2.0	" 0.86
0942	0.3	—	—	17.1	1.70	4.29	7.21	213	2.3	Salinity 0.86
										End purge.

0918

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected:	0945	Note Any Sampling Problem:	None
Sample Appearance:	Bubbles	Equipment Decontamination:	None
Laboratory:	C&T, Precision, Isotech	Purge Water Disposition:	Lawn

Water Meter Model/No: YSI-6920V2.04 Equipco Hach DR890-0019000944 2

Comments: (1) 145 gallons ~~un~~purged as of 0825. Stopped temporarily.
(2) Reset pump and flow so all goes through meter and none through flow meter for minimum flow
(1) Continued -- owner ran well ~ 1gpm starting at 0600
(3) Some bubbles in water. Minor effect on turbidity.
Sampling completed 1023.

Signature: [signature] Date: August 13, 2014

TB 0915

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW33
Sample ID: PGDW33-08132014

Date: 8/13/2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	~~6~~ 3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	~~2~~ 1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	~~6~~ 3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP I75	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	~~4~~ 2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	~~2~~ 1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	~~2~~ 1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	~~2~~ 1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	~~58~~ 46			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW41A
Sample ID: PGDW41A-08202014
QA/QC Sample IDs:
MS/MSD for this Sample?
Location Description: 8 feet southwest of vault
Well Condition: Owner notes is in use as cistern is dry.

Date: 8/20/2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather:
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches) 6
Approx. Screen Depth (feet bmp): ~ to 370
Depth to Water (H, feet bmp): Assume 50
Casing Volume (gallons): 470
Calculated Purge Volume (gallons): 1,400
Note if LPH (feet thickness): N/A
CASING VOLUME: $V = 0.0408 \times HD^2$

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

(1)

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
1046	0	1573	~	—	—	—	—	—	—	Start purge.
1056	2.8	1579		10.32	7.28	0.83	7.42	+61		4.02
1101	2.6	1577		10.51	7.69	0.67	7.17	+64	6.2	4.31
1108	2.9	1579		10.51	7.84	0.60	7.15	+73	2.7	4.40
1114	2.8	1580		10.52	7.90	0.57	7.12	+79	12	4.40
1120	2.7	1582		10.54	8.07	0.57	7.15	+82	2.8	4.49
1125	2.8	1583		10.36	8.08	0.60	7.06	+88	3.0	4.50
1129	3	1585		10.44	8.07	0.61	7.04	+91	1.7	4.49
1133	3	1586		10.44	8.06	0.71	7.04	+92	2.3	4.49
1137	3	1587		10.46	8.10	0.86	7.06	+92	1.8	4.51
1141	3	1588		10.47	8.08	0.91	7.07	+93	1.6	4.50 (2)
										End purge.

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected: 1145
Note Any Sampling Problem:
Sample Appearance: A few gas bubbles
Equipment Decontamination: None
Laboratory: C&T, Precision, Isotech
Purge Water Disposition: Cottonwoods.
Water Meter Model/No: YSI 6920V2.04 (Equipto) Hach DR890 00019 000 9442

Comments: Pump #1 on breaker panel.
(1) Well purged at low rate to prevent water level from reaching pump intake.
(2) Will sample now, DO is starting to increase; water level may be nearing pump intake.
1222 Samples collected.

Signature: [signature]
Date: August 20, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW41A
Sample ID: PGDW41A-08202014

Date: 8/20/2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	46			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW41B
Sample ID: PGDW41B-08202014
QA/QC Sample IDs:
MS/MSD for this Sample?
Location Description: 4 feet southwest of vault
Well Condition: Owner notes is in use as cistern is dry.

Date: 8/20/2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: 70°F, SW 4 mph, Sky 70%
FID/PID at Well Headspace (ppm): –

PURGING PARAMETERS

Casing Diameter (D, inches): 8
Approx. Screen Depth (feet bmp): – to 70
Depth to Water (H, feet bmp): Assume 30
Casing Volume (gallons): 100
Calculated Purge Volume (gallons): 300
Note if LPH (feet thickness): N/A
CASING VOLUME: V = 0.0408 X HD²

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒

Intake Depth (feet bmp): ~

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0836	0	15091 0								Start purge.
0851	6.5	15188	–	10.7	5.31	0.25	7.44	-72	9.8	2.88 (0836)
0900	6.0	15242		~~11.8~~	~~5.24~~	~~0.24~~	~~7.49~~	~~-46~~	~~16~~	~~2.84~~ (1)
0905	6.0	15272		~~13.3~~	~~5.26~~	~~0.26~~	~~7.49~~	~~-54~~	~~8.6~~	~~2.85~~ (1)
0911	6.2	15309		10.5	5.28	0.17	7.54	-78	61 (2)	2.87 (0911)
0916	6.2	15340		10.6	5.29	0.16	7.62	-71	68 (2)	2.86
0920	6	15365		10.5	5.28	0.16	7.60	-69	68 (2)	2.86
0925	6.2	15396		10.5	5.29	0.15	7.62	-67	70 (2)	2.86
0930	6.0	15426		10.7	5.27	0.16	7.62	-63	59 (2)	2.86
										End purge.

Other measurements (units): Ferrous Iron 0.74 mg/L Duplicate reading 0.75

Time Samples Collected: 0935
Sample Appearance: Small gas bubbles, turbid (3)
Laboratory: C&T, Precision, Isotech

Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Cottonwoods.

Water Meter Model/No: YSI 6920V2.04 (Equipio) Hach DR890 000 19 000 9442

Comments: Pump #2 on breaker panel. (1) Readings at 0900 and 0905 no good. Flow through meter cell had stopped. Adjust meter flow. (2) Small gas bubbles affect turbidity readings, but sample IS visibly turbid > 20 NTU. (3) Particulate turbidity visible in samples - appears to be fine sand. 1018 Samples collected. Did NOT collect unfiltered metals as NTU > 20.

Signature: [signature]
Date: August 20, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW41B
Sample ID: PGDW41B-08202014

Date: 8/20/2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
~~Metals~~	~~6010B/6020 & 7470~~	~~P~~	~~500~~	~~1~~	~~No~~	~~HNO3~~	~~C&T; see list~~ } Not collected.
~~Lithium (Li) and Uranium (U)~~	~~6010B/6020~~	~~P~~	~~250~~	~~1~~	~~No~~	~~HNO3~~	~~C&T/ TBD~~ } Turbidity > 20 NTU.
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	46			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW44
Sample ID: PGDW44-08142014
QA/QC Sample IDs: —
MS/MSD for this Sample? —
Location Description: Hydrant near converted tank
Well Condition: In use for stock / irrigation

Date: 8/14/2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Scattered CLD, 75° NW 5
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches): 9
Approx. Screen Depth (feet bmp): — to 750
Depth to Water (H, feet bmp): 45.9 @ 0934
Casing Volume (gallons): 2,300
Calculated Purge Volume (gallons): 6,900
Note if LPH (feet thickness): N/A
CASING VOLUME: V = 0.0408 X HD^2

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒

Intake Depth (feet bmp): —

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0940	~2	— 0	45.9	—	—	—	—	—	—	Start purge.
1135	0									Add flow meter.
1140	~2	12290	84.9	—	—	—	—	—	—	
1150	4	12330	—	11.9	5.90	0.22	8.18	-262	(1)	3.22
1154	5.5	12352	~	11.8	5.88	0.19	8.20	-263	(1) 5	3.23
1158		12366	~	11.7	5.91	0.18	8.21	-262	(1)	3.22
1203	3.2	12382	~	11.8	5.90	0.17	8.24	-253	(1)	3.22
1209		12406	—	11.9	5.93	0.16	8.27	-278	(1)	3.21
1214	2.6	12419	~	11.8	5.90	0.16	8.28	-279	(1)	3.22
1220		12438	—	11.9	5.90	0.15	8.28	-278	12	3.21
(1220)										
1225										End purge.

Other measurements (units): Ferrous Iron 3.3 mg/L

Time Samples Collected: 1225
Sample Appearance: Gas bubbles
Laboratory: C&T, Precision, Isotech
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Ground
Water Meter Model/No: Equipco YSI 6920V2.04 Hach VIC890 00019 0009442

Comments: Owner states pump set at approximately 150 feet below ground surface. Purge at 2 gpm to prevent the well from going dry.
(1) Gas bubbles interfere with NTU readings.
Sampling completed at 1305

Signature: [signature]
Date: August 14, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW44
Sample ID: PGDW44-08142014

Date: 8/14/2014
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	46			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW45
Sample ID: PGDW45-08182014
QA/QC Sample IDs:
MS/MSD for this Sample?
Location Description: Wellhead in yard
Well Condition: Used for stock.

Date: 8/18/2014
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: Clear, calm, 2mph, 76°F SEJ
FID/PID at Well Headspace (ppm):

PURGING PARAMETERS

Casing Diameter (D, inches): 6
Approx. Screen Depth (feet bmp): ~ to 48
Depth to Water (H, feet bmp): 10.3 10:12 (1)
Casing Volume (gallons): 56
Calculated Purge Volume (gallons): 170
Note if LPH (feet thickness): N/A
CASING VOLUME: $V = 0.0408 \times HD^2$

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	☒	☒	
Dedicated Equipment?	☒	☒	

Intake Depth (feet bmp): ~

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
1026	– 0	13513 0	10.3							Start purge.
1030	3(2)	13527		9.40	1.03	1.55	7.19	+103	-0.1	0.52
1033	3(2)	13539		9.16	1.06	1.56	7.09	-42	-0.1	0.53
1037	7	13555		9.44	1.08	3.49	7.04	-40	36	0.55 (2)
1041	9	13590		9.22	1.11	1.73	7.03	+105	-0.1	0.55
1044	9	13617		9.22	1.11	1.56	7.04	+107	-0.1	0.56
1047	9	13644		9.20	1.12	1.49	7.03	+109	-0.1	0.56
1051	9	13679		9.24	1.13	1.45	7.03	+113	-0.1	0.57
1054	9	13706		9.22	1.14	1.42	7.02	+115	-0.1	0.57
1057	9	13734		9.20	1.15	1.40	7.01	+117	-0.2	0.57
1102	–	–	20.6	–	–	–	–	–	–	–
1057										End purge.

Other measurements (units): Ferrous Iron 0.0 mg/L

Time Samples Collected: 11:00
Sample Appearance: Clear
Laboratory: C&T, Precision, Isotech
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Lawn
Water Meter Model/No: Envirpro YSI 6920V2.04 Hach DR890 0019 000 9442

Comments: Water from pump is used for stock. (1) Opening on well head 1/4-3/8 inch; DTW may not be accurate. (2) Closed 2 valves on yard hydrants down line so all flow now goes through meter. Earlier readings show only part of flow. 1139 Samples collected.

Signature: [signature]
Date: August 18, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.		Project Name:	Pavillion, Wyoming
1107 Investment Blvd., Suite 290		Facility/ Address:	Fremont County, Pavillion, Wyoming
El Dorado Hills, CA 95762		Project Number:	90081.05s
Well/ Sample Location:	PGDW45	Date:	8/18/2014
Sample ID:	PGDW45-08182014	Field Crew:	KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	4	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	3	No	HCl	C&T
Glycols	8015B	VOA	40	3	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	1	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	3	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	3	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	1	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	1	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	2	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	1	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	1	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	2	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	2	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	1	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	1	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	1	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	1	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	1	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	1	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	1	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	1	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	1	No	HCl	C&T
Radon	NS	VOA	40	2	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	1	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	1	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	1	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	1	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	1	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	1	No	Cold	Precision; 30-hr hold time call Sat
			Count:	46			

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Page 1 of 2

Well/ Sample Location: PGDW49
Sample ID: PGDW49-08192014
QA/QC Sample IDs: Dupe-2-08192014
MS/MSD for this Sample?
Location Description: Well near cattle shed
Well Condition: Not in use

Date: 8/19/204
Field Crew: KGE, DMJ, JRH
Purging Subcontractor: N/A
Weather: 69°F, SW 0-1.7mph, P/C
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches) 6
Approx. Screen Depth (feet bmp): ~ to 50
Depth to Water (H, feet bmp): 18.7 @ 0825
Casing Volume (gallons): 46
Calculated Purge Volume (gallons): 140
Note if LPH (feet thickness): N/A
CASING VOLUME: V = 0.0408 X HD²

V = volume in gallons, H = height of water column in ft, D = inside diameter of casing in inches.

PURGING/SAMPLING METHODS

	Purging	Sampling Notes
Low Flow	☐	☐
Peristaltic Pump	☐	☐
Submersible Pump	☐	☐
Bailer	☐	☐
Tap/ Other	☒	☒
Dedicated Equipment?	☒	☒

Intake Depth (feet bmp): ~

PURGING AND WATER QUALITY DATA

Time	Purge Rate (gpm) or Increment (gal)	Totalizer Water Meter Readings (gal)	Depth to Water (feet bmp)	Temperature (degrees C)	Specific Conductance (mS/cm)	Dissolved Oxygen (mg/L)	pH (units)	ORP (mV)	Turbidity (NTU)	Notes (e.g. pump adjustments) Salinity (ppt)
0838	0	14120	18.7	—	—	—	7.00	—	—	Start purge.
0845	9.1	14184	(4)	9.75	6.08	0.39	6.10	-97	54	3.33 (1)
0855	8.6	14270		9.85	6.10	0.25	7.07	-26	8.5 (2)	3.33 (2)
0901	8.7	14322		9.86	6.13	0.20	6.99	-24	7.1 (2)	3.35
0906	8.6	14365		9.93	6.12	0.18	6.99	-21	10 (2)	3.34
0912	8.7	14417		9.92	6.12	0.17	7.00	-23	5 (2)	3.34
0917	8.6	14460	(4)	9.95	6.15	0.17	7.00	-36	20 (2)	3.36
0923		14512	14.9	10.04	6.16	0.44	7.03	-8		3.36 (0823)
0926		14539	(3)						(3)	Decrease flow
0931	7.6	14577		10.26	6.16	0.48	7.02	+5	19 (5)	3.37
0935	+/-	14565								Decrease flow (3)
0940		14627		10.55	6.16	0.38	7.04	+17	14 (5)	3.37
0944	4	14644		10.69	6.17	0.86	7.09	+13	14 (5)	3.37
0946	0	14652								Pump off (6)
			<see	page	2>					
										End purge.

Other measurements (units): Ferrous Iron 0.12 mg/L

Time Samples Collected: 1045
Sample Appearance: Clear, gas bubbles
Laboratory: C&T, Precision, Isotech
Note Any Sampling Problem: None
Equipment Decontamination: None
Purge Water Disposition: Pasture
Water Meter Model/No: Equipmo YSI 6920V2.04, Hach DR 890

Comments: Well not in use. (1) Purge water initially reddish and turbid. (2) ~~Sam~~ Small gas bubbles in sample. Affect turbidity readings. (3) 0926 adjust flow downward. Suspect water level near pump intake based on DO readings. (4) Water level readings may not be accurate. (5) Increased gas bubbles. NTU readings affected. (6) Pump off to allow well to recover. Fluctuating DO may indicate that water level is near pump intake.
1030 Primary sample collected. (1130). 1145 Begin to collect duplicate. 1228 Duplicate sample collected.

Signature: [signature]
Date: August 19, 2014

~~Water Meter 37.4.2~~

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, WY
Facility/ Address: Fremont County, Pavillion, WY
Project Number: 90081.05 S

Page 2 of 2

Well/ Sample Location: PGDW49
Sample ID: PGDW49-08192014
QA/QC Sample IDs: Dupe-2-08192014
MS/MSD for this Sample? —
Location Description: Well near cattle shed.
Well Condition: Not in use.

Date:
Field Crew: KGE, DMS, JRH
Purging Subcontractor: —
Weather: Overcast
FID/PID at Well Headspace (ppm): —

PURGING PARAMETERS

Casing Diameter (D, inches) 6
Approx. Screen Depth (feet bmp): — to 50
Depth to Water (H, feet bmp):
Casing Volume (gallons): ~~NA~~ 46
Calculated Purge Volume (gallons): ~~NA~~ 140
Note if LPH (feet thickness):

CASING VOLUME: ([TD-H]*[3.14*(D/24)2]*[7.48 gallons/ft3
0.65*[TD-H] for 4-inch well; 0.16*[TD-H] for 2-inch wel

PURGING/SAMPLING METHODS

	Purging	Sampling	Notes
Low Flow	☐	☐	
Peristaltic Pump	☐	☐	
Submersible Pump	☐	☐	
Bailer	☐	☐	
Tap/ Other	X	X	
Dedicated Equipment?	X	X	

Intake Depth (feet bmp): —

(CONTINUED FROM PAGE 1) **PURGING AND WATER QUALITY DATA**

Time	Purge Rate (gpm) (lpm) or Increment (gal) (l)	Cumulative Water Removed (gal) (l)	Depth to Water (feet bmp)	pH (units)	Specific Conductance (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/L)	Temperature (degrees C)	Other (circle): Fe+2 (mg/L) Eh (mV) ORP ( )	Notes (e.g. pump setting, adjustments) Salinity (ppt)
1013	0	0								Start purge.
1020	—	14682	—	7.09	6.18	—(5)	1.69	11.92	+25	3.38
1024	~~4~~	14696	—	7.09	6.17	—(5)	1.39	11.92	+24	3.38
1029 (1030)	4	14717	—	7.06	6.18	13(5)	1.45	11.91	+30	3.37
1033	4	14727	—	7.07	6.17	12(5)	1.45	11.94	+34	3.37
1036	4	14738	—	7.09	6.16	12(5)	1.48	11.93	+37	3.37
1039	4	14748	—	7.09	6.19	12(5)	1.55	11.89	+38	3.39
										End purge.

Time Samples Collected:
Note Any Sampling Problem:
Sample Appearance:
Equipment Decontamination:
Laboratory:
Purge Water Disposition: <See page 1>
Water Meter Model/No:

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
					☐		
					☐		
					☐		
					☐		
					☐		
					☐		
					☐		

Comments:

Signature: [signature]
Date: August 19, 2014

SAMPLING/DEVELOPMENT INFORMATION

ACTON • MICKELSON • ENVIRONMENTAL, INC.
1107 Investment Blvd., Suite 290
El Dorado Hills, CA 95762

Project Name: Pavillion, Wyoming
Facility/ Address: Fremont County, Pavillion, Wyoming
Project Number: 90081.05s

Well/ Sample Location: PGDW49
Sample ID: PGDW49-08192014

Date: 8/19/204
Field Crew: KGE, DMJ, JRH

LABORATORY SAMPLE INFORMATION

Analysis	Analysis Method	Container Type	Volume (ml)	Number of Containers	Sample Filtered?	Preservative	Notes
Sulfide	EPA 376.2	VOA	40	8	No	Cold	Precision
Gasoline range organics	8015D	VOA	40	6	No	HCl	C&T
Glycols	8015B	VOA	40	6	No	Cool	C&T/ Weck
Volatile organic acids	NS	P	500	2	No	Cold	C&T/ Microbac
VOCs w/ TICs	8260B	VOA	40	6	No	HCl	C&T
Methane, ethane, ethene	RSK-SOP 175	VOA	40	6	No	HCl	C&T
Gas comp; d13C & dD in gases	GC; GC/MS	Isoflask	750	2	No	Bactericide	Isotech
Acrylamide	8032A / 8316	G	500	2	No	Cold	C&T/TBD
Diesel range organics	8015D	G	500	4	No	Cold	C&T; w/ & w/o SGCU
N- and P- pesticides	507	G	1000	2	No	Cold	C&T/ APPL
Organochlorine pesticides	8081	G	1000	2	No	Cold	C&T/ APPL
Organophosphorus compounds	8141B	G	1000	4	No	Cold	C&T/ APPL
SVOCs w/ TICs	8270D	G	1000	4	No	Cold	C&T
Metals	6010B/6020 & 7470	P	500	2	No	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	2	No	HNO3	C&T/ TBD
Metals	6010B/6020 & 7470	P	500	2	Filter	HNO3	C&T; see list
Lithium (Li) and Uranium (U)	6010B/6020	P	250	2	Filter	HNO3	C&T/ TBD
d13C in DIC	NS	P	125	2	Filter	Cold	Isotech
d15N&d180 in NO3	NS	P	1000	2	Filter	Cold	Isotech
Anions; alkalinity; MBAS, TDS	300.0; SM 2320B; 5540C; 2540C	P	1000	2	No	Cold	C&T; 48-hr hold time call Sat
Cyanide	SM 4500-Cn-E	P	250	2	No	NaOH	C&T
Ammonia; TOC; DOC	SM 4500NH3-D; 5310C	G	500	2	No	H2SO4	C&T
Oil and grease, non-polar	EPA1664A	G	1000	2	No	HCl	C&T
Radon	NS	VOA	40	4	No	Cold	C&T/ GEL; 4-day hold time
Gross alpha w/ Ra-226 no Rn, U	NS	P	500	2	No	HNO3	C&T/ GEL
Radium-226	EPA 903.1	P	1000	2	No	HNO3	C&T/ GEL
Radium-228	EPA 904.0	P	1000	2	No	HNO3	C&T/ GEL
Strontium-90	NS	P	1000	2	No	HNO3	C&T/ GEL
E. Coli	SM 9223B	P	125	2	No	Na2S2O3	Precision; 30-hr hold time call Sat
Total coliform	SM 9223B	P	125	2	No	Na2S2O3	Precision; 30-hr hold time call Sat
IRB, SRB (bacteria)	BART™	P	1000	2	No	Cold	Precision; 30-hr hold time call Sat
			Count:	92			

APPENDIX P

Stable Isotope Data

APPENDIX P

STABLE ISOTOPE DATA

Pavillion, Wyoming Area Domestic Water Wells

Final Report and Palatability Study

Location	Sample Date	Type	Field Sample ID	Legend	Location in Report	d13C1	dDC1 VSMOW	C1/ (C2+C3)	C1 Methane	C2 Ethane	C2H4 Ethene	C3 Propane	iC4 Isobutane	nC4 n-Butane	iC5 Isopentane	nC5 n-Pentane	C6+ Hexanes +	Argon	Carbon Dioxide	Carbon Monoxide	Hydrogen	Nitrogen	Oxygen
PGDW20	6/20/2014	N	PGDW20-06202014	AME, 2014	PGDW20	-31.80		32.27	4.97E-01	1.45E-02	0.00E+00	9.00E-04	0.00E+00	0.00E+00	1.40E-03	0.00E+00	0.00E+00	1.44	0.11	0.00	0.00	87.42	10.52
PGDW23	8/15/2014	FD	DUPE-1-08152014	AME, 2014	PGDW23 Dup	9.10	146.90	567.50	6.81E-01	1.20E-03	0.00E+00	0.00E+00	4.00E-03	0.00E+00	0.00E+00	0.00E+00	9.00E-04	1.51	0.02	0.00	0.00	89.58	8.20
PGDW23	8/15/2014	N	PGDW23-08152014	AME, 2014	PGDW23	9.00	146.20	555.45	6.11E-01	1.10E-03	0.00E+00	0.00E+00	3.40E-03	0.00E+00	0.00E+00	0.00E+00	6.00E-04	1.42	0.02	0.00	0.00	88.51	9.44
PGDW30	6/18/2014	N	PGDW30-06182014	AME, 2014	PGDW30	-26.37	-129.40	5842.86	4.09E+00	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.45	0.05	0.00	0.00	84.12	10.29
PGDW30	8/12/2014	N	PGDW30-08122014	AME, 2014	PGDW30	-27.40		4271.43	2.99E+00	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.28	0.03	0.00	0.00	84.05	11.65
Tribal Pavillion 14-6	1/1/1993	N	Tribal Pavillion 14-6(g) (WR)	Johnson and Rice, 1993		-39.24		30.44	9.53E+01	2.83E+00		3.00E-01	1.10E-01	1.80E-01	5.00E-02	2.00E-02							
Govt 21-5	1/1/1993	N	Govt 21-5(g) (WR)	Johnson and Rice, 1993		-40.20		20.81	9.32E+01	3.75E+00		7.30E-01	3.30E-01	2.20E-01	1.60E-01	9.00E-02							
Tribal Pavillion 41-09	1/1/1993	N	Tribal Pavillion 41-09(g) (FU)	Johnson and Rice, 1993		-38.04		23.77	8.82E+01	3.35E+00		3.60E-01	1.40E-01	9.00E-02	0.00E+00	0.00E+00							
Tribal Pavillion 14-11	1/1/1993	N	Tribal Pavillion 14-11(g) (FU)	Johnson and Rice, 1993		-38.40		32.67	6.60E+01	1.96E+00		6.00E-02	5.40E-02	6.00E-03	6.00E-03	2.00E-03							
Blankenship 4-8	1/1/1993	N	Blankenship 4-8(g) (FU)	Johnson and Rice, 1993		-38.08		21.17	9.34E+01	4.00E+00		4.10E-01	5.00E-02	6.00E-02	7.00E-02	1.00E-02							
Tribal Pavillion 14-10	1/21/2010	N	Tribal Pavillion 14-10(g) (WR)(PGPP01)	EPA, 2010		-38.75	-203.40	17.61	9.25E+01	4.04E+00	1.00E-03	1.21E+00	4.15E-01	3.72E-01	1.83E-01	1.14E-01	4.86E-01						
Tribal Pavillion 43-10	1/21/2010	N	Tribal Pavillion 43-10(g) (FU)(PGPP02)	EPA, 2010		-39.07	-212.90	24.73	9.49E+01	3.48E+00	1.00E-04	3.56E-01	1.43E-01	6.18E-02	5.01E-02	1.94E-02	1.80E-01						
Tribal Pavillion 24-2	1/21/2010	N	Tribal Pavillion 24-2(g) (WR)(PGPP04)	EPA, 2010		-39.26	-204.90	14.78	9.02E+01	4.64E+00	1.70E-03	1.46E+00	5.81E-01	5.12E-01	3.35E-01	2.11E-01	1.39E+00						
Tribal Pavillion 33-10	1/21/2010	N	Tribal Pavillion 33-10(g) (FU)(PGPP05)	EPA, 2010		-39.05	-207.30	23.59	9.47E+01	3.64E+00	0.00E+00	3.73E-01	1.31E-01	5.50E-02	4.27E-02	1.40E-02	1.07E-01						
Tribal Pavillion 14-2	1/21/2010	N	Tribal Pavillion 14-2(g) (FU)(PGPP06)	EPA, 2010		-39.28	-215.30	19.29	9.32E+01	3.93E+00	1.20E-03	9.03E-01	3.21E-01	2.50E-01	1.51E-01	9.05E-02	5.06E-01						
PGDW20	4/18/2011	N	PGDW20(w)	EPA, 2010-2011		-33.10	-175.00	28.70	2.21E-01	7.00E-03	0.00E+00	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00						
PGDW30	1/19/2010	N	PGDW30(w)	EPA, 2010-2011		-28.77	-143.60		5.99E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00						
PGDW30	5/10/2010	N	PGDW30(w)	EPA, 2010-2011		-28.76	-145.80		1.19E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00						
PGDW30	4/18/2011	N	PGDW30(w)	EPA, 2010-2011		-27.80	-133.00		1.46E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00						
PGDW32	4/18/2011	N	PGDW32(w)	EPA, 2010-2011		-34.20			7.52E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.90E-03						
PGDW32	4/18/2011	FD	PGDW32(w)-dup	EPA, 2010-2011		-34.00			5.22E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.30E-03						

APPENDIX Q

Water Treatment Requirements