Hot Springs Conservation District

Please see attached documents.

Boysen Dam Baseline Sampling Data

	GENERAL PARAMETERS				MAJOR IONS mg/L						METALS ug/L														
	Total Hardness as CaCO3 (mg/L)	Conductivity (uS/cm)	pH	TDS (mg/L)	Chloride (mg/L)	Fluoride (mg/L)	Sodium (mg/L)	Sulfate (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Aluminum (ug/L)	Arsenic (ug/L)	Beryllium (ug/L)	Cadmium (ug/L)	Chromium (ug/L)	Copper (ug/L)	Lead (ug/L)	Manganese (ug/L)	Mercury (ug/L)	Nickel (ug/L)	Silver (ug/L)	Thallium (ug/L)	Zinc (ug/L)	Selenium* (ug/L)	Count
Dec-2010		516	8.57	370	4.2	0.5	22	110			45	1.9	0.1	0.04	0.25	0.7	0.05	11	0.1	0.64	0.25	0.05	2.5	0.5	1
May-2011	310	617	8.6	350	11.0	0.2	71	140			43.9	0.25	0.1	0.04	0.25	0.25	0.05	0.25	0.1	0.25	0.25	0.05	2.5	0.5	2
Jun-2011	230	640	8.66	420	14.0	0.1	60.9	180			2	1.5	0.1	0.04	0.25	0.87	0.05	0.58	0.1	0.74	0.25	0.05	2.5	0.58	3
Jul-2011	130	256	8.25	240	7.2	0.1	26	85			2	0.25	0.1	0.04	0.25	0.25	0.05	0.25	0.1	5	0.25	0.05	2.5	0.5	4
Aug-2011	120	240	7.97	230	7.2	0.1	24	84			28	1.5	0.1	0.04	0.25	1.1	0.05	1.3	0.1	0.86	0.25	0.05	2.5	0.5	5
Sep-2011	110	403	8.34	240	6.2	0.1	21	85			9.4	1.6	0.1	0.04	0.25	0.72	0.05	1.2	0.1	0.56	0.25	0.05	2.5	0.5	6
Oct-2011	87	460	8.45	300	9.1	0.1	28	100			8.3	1.9	0.1	0.04	0.25	1.7	0.05	23.2	0.1	0.82	0.25	0.05	10.4	0.5	7
Nov-2011	140	449	8.27	280	7.7	0.1	29	110			5.5	1.8	0.1	0.04	0.68	0.97	0.14	2.9	0.1	0.68	0.25	0.05	2.5	0.5	8
Dec-2011	300	383	8.1	280	7.9	0.1	14	110			4.9	1.6	0.1	0.04	0.5	0.74	0.15	1.8	0.1	0.82	0.25	0.05	2.5	0.5	9
Jan-2012	210	386	8.36	300	9.5	0.1	28	110			4.3	1.7	0.1	0.04	0.25	1.2	0.05	2.8	0.1	0.75	0.25	0.05	2.5	0.5	10
Feb-2012	150	502	8.44	310	9.7	0.2	38	110			5	1.9	0.1	0.04	0.25	0.72	0.05	0.53	0.1	0.6	0.25	0.05	5.2	0.5	11
Mar-2012	190	510	8.38	310	9.9	0.1	32	110			2	1.8	0.1	0.04	3	0.61	0.05	1.5	0.1	12.9	0.25	0.05	2.5	0.5	12
Apr-2012	210	557	8.47	360	13.0	0.1	52	120			2	0.25	0.1	0.04	0.25	0.25	0.05	0.25	0.1	0.25	0.25	0.05	2.5	0.5	13
May-2012	130	567	8.54	340	11.0	0.3	29	130			2	0.25	0.1	0.04	0.25	0.25	0.05	0.25	0.1	0.25	0.25	0.05	2.5	0.5	14
Jun-2012	220	605	8.46	380	12.0	0.2	51	140			13.3	1.6	0.1	0.04	0.25	0.65	0.05	1.6	0.1	0.6	0.25	0.05	2.5	0.5	15
Jul-2012	95	561	8.43	350	11.0	0.3	32	140			2	0.25	0.1	0.04	0.25	0.25	0.05	0.25	0.1	0.25	0.25	0.05	2.5	0.5	16
Aug-2012	150	563	8.61	330	11.0	0.3	30	140			2	0.25	0.1	0.04	0.25	0.25	0.05	0.25	0.1	0.25	0.25	0.05	2.5	0.5	17
Sep-2012	200	580	8.25	354	10.0	0.2	46	140			2	2.3	0.1	0.04	0.25	0.25	0.05	8.8	0.1	0.25	0.25	0.05	2.5	0.5	18
Oct-2012	150	595	8.7	390	11.0	0.4	34	160			2	0.25	0.1	0.04	0.25	0.25	0.05	0.25	0.1	0.25	0.25	0.05	2.5	0.5	19
Nov-2012	190	597	9.54	360	16.0	0.1	46	170			2	2.4	0.1	0.04	0.25	0.25	0.05	2.9	0.1	0.25	0.25	0.05	2.5	0.5	20
Dec-2012	190	667	8.81	420	9.4	0.1	57	120			2	2.4	0.1	0.04	0.25	0.25	0.05	0.25	0.1	0.25	0.25	0.05	2.5	0.5	21
Jan-2013	200	665	8.67	340	13.7	0.5	50	240			2	0.25	0.1	0.04	0.25	0.25	0.05	1.1	0.1	0.25	0.25	0.05	2.5	0.5	22
Feb-2013	190	668	8.78	460	14.0	0.5	47	220			2	2.4	0.1	0.04	0.62	1.9	0.05	4.6	0.1	0.74	0.25	0.05	2.5	0.5	23
Mar-2013	220	691	8.71	440	12.0	0.5	51	220			2	2.2	0.1	0.04	0.25	0.54	0.05	8	0.1	0.7	0.25	0.05	2.5	0.5	24
Apr-2013	200	764	8.41	490	13.0	0.1	49	200			2	2	0.1	0.04	0.65	0.25	0.05	182	0.1	0.25	0.25	0.52	2.5	0.5	25
May-2013	210	684	8.51	430	1.7	0.1	46	12			2	1.8	0.1	0.04	1.1	2.2	0.05	0.25	0.1	0.25	0.25	0.05	2.5	0.5	26
Jun-2013	270	671	8.51	430	11.0	0.3	64	170			2	1.5	0.1	0.04	0.25	1	0.05	1.1	0.1	0.25	0.25	0.05	2.5	0.5	27
Nov-2013	211	628	8.75	409	9.0	0.3	59	152	56	17	1.5	2	0.5	0.5	2.5	2.5	0.5	0.5	0.05	0.25	0.5	0.25	5	1	28
Dec-2013	210	632	8.85	399	10.0	0.3	60	157	55	18	1.5	2	0.5	0.5	2.5	8	0.5	3	0.05	0.25	0.5	0.25	5	0.5	29
Jan-2014	214	675	8.8	412	10.0	0.3	61	158	56	18	1.5	2	0.5	0.5	2.5	2.5	0.5	25	0.05	0.25	0.5	0.25	5	0.5	30
Feb-2014	209	655	8.69	422	10.0	0.4	56	156	54	18	1.5	2	0.5	0.5	2.5	2.5	0.5	9	0.05	20	0.5	0.25	30	0.5	31
Mar-2014	215	653	8.6	420	13.0	0.4	56	152	56	18	1.5	2	0.5	0.5	2.5	2.5	0.5	14	0.05	0.25	0.5	0.25	5	0.5	32
Apr-2014	231	719	8.32	465	10.0	0.4	70	182	60	20	1.5	2	0.5	0.5	2.5	2.5	0.5	142	0.05	0.25	0.5	0.25	5	0.5	33
May-2014	221	653	8.52	427	10.0	0.3	61	163	58	18	1.5	2	0.5	0.5	2.5	2.5	0.5	15	0.05	0.25	0.5	0.25	5	0.5	34
Jun-2014	183	507		328	8.0	0.3	44	116	50	14														0.5	35
Jul-2014	165	505	8.41	319	7.0	0.2	42	113	44	13	1.5	2	0.5	0.5	2.5	2.5	0.5	0.5	0.05	0.25	0.5	0.25	5	0.5	36
Aug-2014	143	433	8.32	267	6.0	0.2	32	91	38	12	1.5	2	0.5	0.5	2.5	2.5	0.5	1	0.05	0.25	0.5	0.25	5	0.5	37
Sep-2014	157	492	8.15	303	8.0	0.2	38	104	43	12	1.5	3	0.5	0.5	2.5	7	0.5	175	0.05	0.25	0.5	0.25	5	1	38
Oct-2014	157	460	8.22	292	6.0	0.2	38	103	43	12	1.5	2	0.5	0.5	2.5	2.5	0.5	9	0.05	0.25	0.5	0.25	5	0.5	39
Nov-2014	167	487	8.54	307	7.0	0.3	42	104	45	13	1.5	2	0.5	0.5	2.5	2.5	0.5	17	0.05	0.25	0.5	0.25	5	0.5	40
Dec-2014	148	498	8.53	313	7.0	0.3	38	106	40	12	1.5	2	0.5	0.5	2.5	2.5	0.5	1	0.05	0.25	0.5	0.25	5	0.5	41
Jan-2015	174	523	8.48	329	7.0	0.3	42	111	48	13	1.5	2	0.5	0.5	2.5	39	1	11	0.05	0.25	0.5	0.25	80	0.5	42
Feb-2015	169	523	8.45	338	7.0	0.3	42	114	46	13	1.5	2	0.5	5	2.5	82	0.5	5	0.05	0.25	0.5	0.25	5	0.5	43
Mar-2015	190	543	8.39	316	7.0	0.3	46	116			1.5	2		0.5	2.5	2.5	0.5	5	0.05	0.25	0.5	0.25	5	0.5	44
Apr-2015	204	574	8.37	369	9.0	0.3	49	135	55	16	1.5	2	0.5	0.5	8	2.5	0.5	35	0.05	0.25	0.5	0.25	5	0.5	45
May-2015	194	564	8.34	374	8.0	0.3	48	125	52	15	1.5	2	0.5	0.5	2.5	2.5	0.5	6	0.05	0.25	0.5	0.25	5	0.5	46
Jun-2015	191	568	8.48	369	8.0	0.3	47	129	51	15	1.5	2	0.5	0.5	2.5	2.5	0.5	0.5	0.05	0.25	0.5	0.25	5	0.5	47
Jul-2015	134	426	8.26	265	6.0	0.2	31	90	36	11	1.5	1	0.5	0.5	2.5	2.5	0.5	2	0.05	0.25	0.5	0.25	5	0.5	48
Aug-2015	157	428	8.34	269	6.0	0.2	33	90	42	12	1.5	2	0.5	0.5	2.5	2.5	0.5	2	0.05	0.25	0.5	0.25	5	0.5	49
Sep-2015	152	440	8.32	276	7.0	0.2	37	94	42	12	50	2	0.5	0.5	2.5	2.5	0.5	3	0.05	0.25	0.5	0.25	5	0.5	50
Oct-2015	156	488	8.41	308	7.0	0.2	45	106	43	12	1.5	2	0.5	0.5	8	2.5	0.5	4	0.05	0.25	0.5	0.25	5	0.5	51
Nov-2015	171	496	8.39	311	7.0	0.2	44	116	47	13	1.5	2	0.5	0.5	2.5	2.5	0.5	6	0.05	0.25	0.5	0.25	5	0.5	52
Dec-2015	176	519	8.42	333	8.0	0.2	46	121	48	14	1.5	2	0.5	0.5	2.5	2.5	0.5	5	0.05	0.25		0.25	5	0.5	53
Jan-2016	185	551	8.4	353	8.0	0.3	46	125	50	15	1.5	2	0.5	0.5	2.5	2.5	0.5	4	0.05	0.25	0.5	0.25	5	0.5	54
Feb-2016	191	550	8.55	349	8.0	0.2	47	125	52	15	1.5	2	0.5	0.5	2.5	2.5	0.5	1	0.05	0.25	0.5	0.25	5	1	55
Mar-2016	205	560	8.61	364	8.0	0.2	48	127	54	17	1.5	2	0.5	0.5	2.5	2.5	0.5	2	0.05	0.25	0.5	0.25	5	2	56
Maximum	310	764	9.54	490	16.0	0.5	71	240	60	20	50	3	0.5	5	8	82	1	182	0.1	20	0.5	0.52	80	2	
Minimum	87	240	7.97	230	1.7	0.1	14	12	36	11	1.5	0.25	0.1	0.04	0.25	0.25	0.05	0.25	0.05	0.25	0.25	0.05	2.5	0.5	
Average	183	545	8.49	348	9.0	0.2	43	129	49	15	5.3	1.71	0.3	0.4	1.7	3.9	0.3	13.9	0.1	1.0	0.4	0.2	5.8	0.6	
Standard Deviation	43	105	0	60	2.6	0.1	12	38	6	2	11	1	0	1	2	12	0	37	0	3	0	0	11	0	

Reporting Limits Lab 1

Total Hardness as CaCO3	6.6	mg/L
Chloride	1	mg/L
Fluoride	0.2	mg/L
Sodium	1	mg/L
Sulfate	10	mg/L
Calcium	1	mg/L
Magnesium	1	mg/L
Total Dissolved Solids (TDS)	10	mg/L
Conductivity	10	uS/cm
pH	0.01	s.u.
Aluminum	4	ug/L
Arsenic	0.5	ug/L
Beryllium	0.2	ug/L
Cadmium	0.08	ug/L
Chromium	0.5	ug/L
Copper	0.5	ug/L
Lead	0.1	ug/L
Manganese	0.5	ug/L
Mercury	0.2	ug/L
Nickel	0.5	ug/L
Silver	0.5	ug/L
Thallium	0.1	ug/L
Zinc	5	ug/L
Selenium*	**0.03**	mg/L

Lab 2 Beginning November 2013

Hardness as CaCO3	mg/L	1
Chloride	mg/L	1
Fluoride	mg/L	0.1
Sodium	mg/L	1
Sulfate	mg/L	2
Calcium	mg/L	1
Magnesium	mg/L	1
Solids, Total Dissolved TDS @ 180 C	mg/L	10
Conductivity @ 25 C	uS/cm	5
pH	s.u.	0.01
Aluminum	ug/L	3
Arsenic	ug/L	1
Beryllium	ug/L	1
Cadmium	ug/L	1
Chromium	ug/L	5
Copper	ug/L	5
Lead	ug/L	1
Manganese	ug/L	1
Mercury	ug/L	0.1
Nickel	ug/L	.5
Silver	ug/L	1
Thallium	ug/L	0.5
Zinc	ug/L	10
Selenium	ug/L	1

	Avg	std Dev	Target	Max	WQ std. *(Cronic AL)*	EOP Mixed Concentration Limit
Aluminum (ug/L)	5	11	16	50	750	5.1 ug/L[3]
Arsenic (ug/L)	2	1	2	3	150	150
Chloride (mg/L)	9	3	12	16	2000[1]	2000
Chromium (ug/L)	2	2	3	8	126[2]	2.5 ug/L[3]
Copper (ug/L)	4	12	16	82	15.6[2]	2.5 ug/L[3]
Fluoride (mg/L)	0	0	0	0.5	N/A	N/A
Manganese (ug/L)	14	37	51	182	2083[2]	2083
Mercury (ug/L)	0	0	0	0.1	0.77	0.05 ug/L[3]
Nickel (ug/L)	2	3	5	20	90[2]	90
pH	8	0	9	9.54	6.5 - 9.0	6.5 - 9.0
Sodium (mg/L)	43	12	56	71	N/A	N/A
Calcium (mg/L)	49	6	55	60	N/A	N/A
Magnesium (mg/L)	15	2	17	20	N/A	N/A
Sulfate (mg/L)	129	38	167	240	3000[1]	3000
TDS (mg/L)	348	60	409	490	5000[1]	5000
Beryllium (ug/L)	0.3	0.2	0.5	0.5	N/A	0.05 ug/L[3]
Cadmium (ug/L)	0.4	0.7	1.0	5	0.4[2]	0.05 ug/L[3]
Selenium* (ug/L)	0.6	0.2	0.8	2	5	0.5 ug/L[3]
Silver (ug/L)	0.4	0.1	0.5	0.5	10.6	0.5 ug/L[3]
Thallium (ug/L)	0.2	0.1	0.3	0.52	N/A	0.25 ug/L[3]
Total Hardness as CaCO3 (mg/L)	183.3	43.0	226.3	310	N/A	N/A
Zinc (ug/L)	5.8	10.8	16.6	80	205[2]	16.8 ug/L[4]
Conductivity (uS/cm)	545.5	105.2	650.6	764	N/A	N/A
Lead (ug/L)	0.3	0.2	0.5	1	5.1[2]	0.5 ug/L[3]

Oil & Grease	N/A	N/A	N/A	N/A	10	10
Iron	N/A	N/A	N/A	N/A	300	1326
radium	N/A	N/A	N/A	N/A		
Sulfide-.Hhydrogen Sulfide	N/A	N/A	N/A	N/A		
Hardness	N/A	N/A	N/A	N/A		

(1) Based on an industry-specific effluent limit for oil & gas produced water

(2) Hardness Dependent Criterion based on 192 mg/L $CaCO_3$

(3) Limit is Non-detect, expressed as 1/2 the laboratory reporting limit to meet Class 1 antidegradation goals.

(4) Limit is Wind River Baseline plus 1 standard deviation at EOP because baseline was established, zinc is i

Monthly load Limit **(UNITS???)**
622
186
1438964
261
32
3316
4316
2
187
2852104
29848
29000
2145040
3575067
N/A
N/A
N/A
N/A
N/A
N/A
N/A
N/A
N/A

20714
1326
24155
207
152554

n discharge but the load was not modeled.

Memorandum

June 27, 2019

To: Dan Heilig, Wyoming Outdoor Council, Lander, WY

From: Harold Bergman, PhD, Professor Emeritus, University of Wyoming, Laramie, WY; and Joseph Meyer, PhD, Chief Scientist, Applied Limnology Professionals LLC, Golden, CO

Regarding: Analysis of, and comments on, proposed WDEQ Wastewater Discharge Permit for Aethon Energy Operating, LLC – WY0002062 Renewal

We have reviewed a series of documents including WDEQ-WQD's proposed WYPDES discharge permit WY0002062 renewal for Aethon Energy Operating, LLC; Aethon's application for this permit renewal dated August 8, 2016; portions of Environmental Resources Management's (ERM's) Water Quality Compliance Analysis report to Aethon Energy dated April 23, 2018; and ERM's Modeling Study Addendum (undated). We also have reviewed and used a number of peer-reviewed publications on the chemistry of produced waters from oil and gas operations and the toxicity of these waters to aquatic biota, and we have cited these references, as appropriate, in the text below.

In the text that follows, we present our analyses, conclusions and positions related to water chemistry and aquatic toxicity of Aethon's produced water and WDEQ's proposed issuance of a discharge permit renewal for Aethon's discharge. We then present a number of major concerns and recommendations related to this proposed permit renewal.

Water Chemistry

Untreated Produced Water Discharge. The WDEQ's proposed discharge permit for Aethon Energy's proposed Moneta Divide oil and gas field would allow discharge of a maximum of 8.274 MGD[1] (million gallons per day) of oil and gas field produced water, with 2.436 MGD untreated and approximately 5.838 MGD treated by reverse osmosis. Without an accompanying discharge of treated water, 2.856 MGD of untreated water would be allowed. The only measured water quality data presented in the Aethon permit application or the WDEQ proposed discharge permit are in Table 2 of Aethon's application, for a water sample collected on 3/2/2017 from Outfall 006 (see Aethon's Table 2 untreated water chemistry). Thus, this water sample is a raw produced water sample (treated only with a skim pond at Outfall 006) from the "Central Facility separators." This set of water quality analyses is offered by Aethon in their application as "representative of the quality of water being proposed for discharge" (question 14 on page 5 of the Aethon application).

There are several major inadequacies in Aethon's Table 2 "representative" water quality analysis results. In particular, there are no measurements or possibly misleading values for the following important water quality parameters:

[1] For comparison, the treated wastewater discharge for representative Wyoming cities are as follows: Riverton = 1.9 MGD for ~11,000 people, Laramie = 4.5 MGD for ~32,000 people, and Casper = 10 MGD for ~58,000 people.

- Alkalinity and Bicarbonate ion concentration – Alkalinity and bicarbonate ion (HCO_3^-) measurements were not included in Aethon's Table 2 chemistry results. However, alkalinity (expressed as mg calcium carbonate/L) along with the reported pH of 7.31 (Table 2 from application) allows calculation of concentrations of bicarbonate, carbonate and hydroxide, that all contribute to total alkalinity. The bicarbonate ion (HCO_3^-) concentration is particularly important to know because bicarbonate is an important determinant for understanding and predicting toxicity to aquatic biota (see Aquatic Toxicity section, below). Because the Aethon Table 2 chemistry suffered from a very large charge imbalance (many fewer total negative charges than total positive charges per liter), and because the total charge of a water sample must be neutral, we were able to calculate the following estimate for the alkalinity and bicarbonate concentrations (assuming all of the deficiency of negative charges was due to alkalinity/bicarbonate): Alkalinity ~ 2,732 mg/L as $CaCO_3$; bicarbonate ~ 3,333 mg/L. These are quite high values not typical of most surface waters, but they are not uncommon for co-produced waters from deep oil and gas fields.
- Potassium (K^+) – No analyses of K^+ were included in Aethon's Table 2 chemistry results. However, based on a number of aquatic toxicity studies, K^+ can contribute more to aquatic toxicity than other constituents of typical saline produced waters when at similar concentrations (Mount et al., 1997). Thus, the K^+ concentration would be an important determinant for understanding and predicting toxicity of the produced waters to aquatic biota (see Aquatic Toxicity section, below). If K^+ was present in the Table 2 production water (which is highly likely) and its concentration had been reported, the estimated alkalinity and bicarbonate concentrations presented in the previous bullet would be even higher.
- Chloride (Cl^-) – The water chemistry for Aethon's "representative" discharge presented in Table 2 of Aethon's application shows a one-time analysis for chloride of 1840 mg/L. Yet the level allowed in WDEQ's proposed permit for an end-of-pipe chloride concentration is 2419 mg/L (based on an "historic effluent concentration" according to information in a footnote in WDEQ's proposed permit, though no supporting information is presented). And WDEQ-WQD's special end-of-pipe limit for chloride concentrations in oil and gas produced water discharges is 2000 mg/L (Chapter 2, Appendix H). But Appendix H also specifies that "[i]n no case shall any produced water discharge contain toxic materials in concentrations or combinations which are toxic to human, animal or aquatic life" (Appendix H(b)(i)). To assess the possibility of toxic effects on aquatic life, we need to consult Wyoming's water quality criteria for protection of aquatic life in receiving waters listed in WDEQ-WQD's Chapter 1 (Appendix B). Wyoming's aquatic life criteria for chloride are 860 mg Cl^-/L as an acute criterion (to protect for survival) and 230 mg Cl^-/L as a chronic criterion (to protect for reproduction and growth). These criteria are in agreement with EPA's recommended acute and chronic criteria listed in EPA's ambient water quality criteria document for chloride https://www.epa.gov/wqc/aquatic-life-ambient-water-quality-criteria-chloride-1988. Thus, to avoid adverse effects on fish and aquatic invertebrates, WDEQ's permitted end-of-pipe chloride discharge concentration of 2419 mg/L in the proposed permit would need to be diluted almost 3-fold to avoid in-stream acute effects (e.g., mortality of fish and aquatic invertebrates) and diluted more than 10-fold to avoid in-stream chronic effects (e.g., reproduction and growth of fish and aquatic invertebrates). Yet, no information is provided for dilution flow or water quality in Alkali or Badwater Creeks in

either Aethon's permit application or in WDEQ's proposed permit. (Also see comment on Alkali and Badwater Creeks, below.)

- Sulfide – Hydrogen Sulfide (H_2S) – The WDEQ's water quality standard for H_2S is 2 μg/L. However, the reported measurement in Table 2 of Aethon's application is listed as <40 μg/L (presumably the detection limit for the analytical method used by Aethon), which does not provide assurance that the H_2S concentration meets the water quality standard. [Note that the Required Detection Limit shown in Table 2 for H_2S is 0.1 mg/L (100 μg/L), which is far too high for Aethon and WDEQ to determine whether the discharge meets the 2 μg/L standard; thus we assume that the 0.1 mg/L detection limit for H_2S shown in Aethon's Table 2 is an error].
- Benzene and BTEX – No analytical results are presented for Benzene or BTEX (Benzene, Toluene, Ethylbenzene, Xylene). This is a serious shortcoming, because many oil and gas produced waters can contain quite high concentrations of these very toxic compounds.
- Chemicals associated with treatment of oil and gas wells – These well treatment chemicals often associated with completion or maintenance of oil and gas wells (such as hydraulic fracturing or "fracking" chemicals) can be highly toxic, and may be present in "flow back" water or produced waters from unconventional well completions. Reported effects from these kinds of chemicals can include endocrine disruption with potential adverse human health or environmental effects (Kassotis et al., 2018), yet no information is presented in either Aethon's application or WDEQ's draft permit on presence or potential presence of these chemicals in existing or future discharges from the Aethon facilities.
- pH – The pH value reported by Aethon in Table 2 is 7.31, which is within the acceptable range of pH 6.5 to 9.0 at the outfall. However, we used the reported pH value and other chemistry from Table 2 along with our estimate of the alkalinity concentration in the discharge water from Outfall 006 to determine that, using the Windermere Humic Aqueous Model (WHAM) geochemical-speciation software (Lofts, 2012), the partial pressure of carbon dioxide (pCO_2) is highly over-saturated at the elevation of the Aethon facility (note that over-saturated CO_2 would be expected from a deep-water well). With Table 2 chemistry, including a calculated alkalinity of 2,732 mg $CaCO_3$/L (see above) and assuming a temperature of 25 ^{o}C, the dissolved concentration of CO_2 in Aethon's discharge would be approximately 193.6 mg/L, while the concentration of CO_2 in water in equilibrium with the atmosphere at Aethon's elevation and 25 ^{o}C would be 0.52 mg/L. Thus, 193.6/0.52 yields approximately 372-fold over-saturation of CO_2 at the outfall, given the water chemistry listed in Table 2.

  This means that CO_2 will de-gas from the discharge water as it flows downstream in Alkali Creek and Badwater Creek. As CO_2 de-gasses from the stream water, the CO_2 concentration will approach equilibrium with the atmosphere, the H^+ concentration in the water will decrease as a consequence, and thus the pH of the water will increase. The table below demonstrates that the WHAM-predicted pH of the full-strength produced water listed in Table 2 would reach as high as approximately 9.6 if the produced water fully equilibrated with the atmosphere and was not diluted by air-equilibrated water (i.e., the pH values listed in the "Full strength" column of the table, below, are approximately 9.6). That pH would violate the current Wyoming water quality standard (i.e., the pH would exceed the upper limit of pH 9) and would cause toxicity concerns for most fish species and other aquatic biota. Even if diluted to only $1/10^{th}$ of full-strength water (i.e., 1 part produced water diluted by 9 parts air-equilibrated water), the WHAM-predicted pH in equilibrium with the atmosphere would still be at or near 9 (i.e., pH 8.8-9.0 in the "1/10 Full strength" column, below). Thus, although a 10-fold dilution of the produced water might decrease its salinity to an acceptable concentration for aquatic life in Badwater Creek and/or after subsequent dilution on entry into Badwater Bay on Boysen Reservoir, pH should be recognized as a potentially more important driver for water quality in Badwater Creek and Badwater Bay than is salinity (which is what ERM's acceptable-discharge calculations were based on).

Summary of WHAM calculations with Table 2 water chemistry for full-strength untreated produced water and produced water diluted with distilled water to 1/2, 1/5, and 1/10 of full strength

	Equilibrium pH					
Temp. (C)	Full strength	1/2 Full strength	1/5 Full strength	1/10 Full strength	pCO_2 that produces pH 7.31 (atm CO2)	CO_2 super-saturation ratio
0	9.59	9.38	9.05	8.79	0.104	306
10	9.57	9.37	9.06	8.80	0.109	321
20	9.58	9.39	9.09	8.84	0.122	359
30	9.61	9.43	9.15	8.91	0.148	435
40	9.66	9.50	9.24	9.00	0.193	568

These results demonstrate that (1) the alkalinity of the produced waters released from Aethon's operations should not be ignored in a discharge permit, given the type of water chemistry listed in Table 2 in Aethon's permit application; and (2) the pH of this type of produced water at its point of release might be considerably lower than the pH at distances downstream in the receiving drainage, even with (and sometimes especially without) mixing of the produced water with other, air-equilibrated water. Because we are unaware of any measurements of pH and alkalinity in Alkali Creek, Badwater Creek and Badwater Bay that would indicate the extent of pH increase downstream from current discharge points for produced water from the Moneta Divide, we strongly recommend that, at a minimum, the temperature, pH, alkalinity and flow of Alkali Creek and Badwater Creek should be monitored at least monthly immediately upstream and downstream of Aethon's current discharges and also in Badwater Bay. That monitoring should begin at least one year before a final permit is signed, so preliminary knowledge of annual variations of temperature, pH, and alkalinity in Alkali Creek, Badwater Creek and Badwater Bay can be used to better establish acceptable dilution factors for untreated produced water discharged by Aethon. A plume of elevated pH entering Badwater Creek and Badwater Bay could easily degrade the quality of those waterbodies as a nursery for young fish.

In addition to the recommended field monitoring, Aethon should also be required to incorporate these pH and alkalinity concerns into ERM's model that was used to calculate acceptable discharge and dilution rates (which were based on salinity concerns in Aethon's permit application, not on pH and alkalinity concerns). And as an extension, all inputs of produced water to Badwater Creek from both the Aethon and the Burlington operations should be combined in those calculations, to produce a cumulative-effects analysis.

Treated produced water using reverse osmosis. The proposed WDEQ permit specifies that of the maximum of 8.274 MGD ultimately allowed under this proposed permit, 5.838 MGD must be treated with reverse osmosis (RO-treated). Yet, we could find no water chemistry analysis results for discharge from the existing Neptune Water Treatment Facility that uses reverse osmosis; only a process flow diagram is presented in Appendix C of the application, and no water chemistry results are presented in the application or the proposed permit for the water discharged from this Neptune Facility at Outfall 001. Though no water chemistry measurements were presented for outflow from the Neptune Facility RO-treated water in Aethon's application or WDEQ's proposed permit, ERM's consulting report to Aethon presents operator-guaranteed treated Neptune effluent concentrations for several key parameters, as follows (ERM report, page 155):

- TDS = 350 mg/L (ppm)
- Chloride = 150 mg/L
- Sulfate = 40 mg/L
- Oil & Grease = 10 mg/L

Additionally, Aethon's measured post-treatment pH averaged from 3 years of daily measurements was 7.47 (ERM report, page 155).

This lack of actual water chemistry is important, because dilution of produced water with RO-treated water will result in higher salinity and alkalinity and a different pH than if the produced water would be diluted with distilled water. This means that the pH estimates in the table above (which assumed dilution of produced water with distilled water) likely differ from pH estimates that would be based on dilution with RO-treated water. But without reliable chemistry of Aethon's RO-treated water, the extent of the likely underestimates of the equilibrium pH in Badwater Creek is unknown.

Alkali Creek and Badwater Creek. No water chemistry or flow information is presented for Alkali Creek or Badwater Creek above and below the Aethon produced water discharges, and no thorough analysis of potential effects of Aethon's discharge on aquatic biota can be completed without this information. Moreover, monthly water chemistry and flow data for Alkali and Badwater Creeks would be needed for at least a 1-year monitoring period to account for variations in chemistry and flow, due to differences in dilution flows and water quality especially during low-flow periods of an annual hydrologic cycle.

Aquatic Toxicity

Highly saline co-produced waters from oil and gas operations typically have very poor water quality with very high concentrations of total dissolved solids (TDS) and other constituents. Adverse effects of discharging these saline production waters on aquatic biota have been reported from as early as 1924 (Wiebe, Burr and Faubion, 1924; Clemens and Jones, 1954).

In a study conducted by researchers at the University of Wyoming (UW) from 1988-1990 (Boelter et al., 1992), toxicity tests with larval Fathead Minnows (*Pimephales promelas*) and a water flea (*Ceriodaphnia dubia*) were conducted on water samples collected from Salt Creek and the Powder River below the Salt Creek oil field near Kaycee, Wyoming. Boelter et al. (1992) reported significantly decreased survival and reproduction in 7-day toxicity tests with *C. dubia* and significantly decreased growth in 7-day tests with Fathead Minnow larvae, as compared with reference water samples collected upstream from produced water discharges from the Salt Creek oil field. These significant toxic effects were measured in ambient water samples collected as far as 124 km downstream from produced water discharges in the Salt Creek oil field, particularly during low-flow periods in Salt Creek and the Powder River. It is important to note that analyzed concentrations of alkalinity, sodium, chloride and bicarbonate in Salt Creek and the Powder River producing significant reductions in survival, reproduction and growth of aquatic test organisms in the Boelter et al. (1992) study were approximately one-half to as little as one-tenth the concentrations of these same parameters reported (sodium and chloride concentrations reported in Table 2 in the Aethon application) or calculated for Aethon's untreated produced water at Outfall 6 (calculated alkalinity and bicarbonate concentrations as presented in the Water Chemistry section, above).

In part as a response to EPA's new effluent biomonitoring requirements implemented in the 1980's as Whole Effluent Toxicity (WET) tests, the Gas Research Institute (GRI) funded a series of studies to develop models that could be used to predict the toxicity of produced waters of varying quality from oil and gas operations. These studies were initiated at the University of Wyoming and then continued by former UW graduate students in a series of collaborations that included UW, ENSR Corporation, USEPA, and others (Gulley et al., 1992; Mount et al., 1992; Mount et al., 1997; and Tietge et al., 1997). In this series of studies, almost 3000 toxicity tests were conducted to measure survival of Fathead Minnows and two species of water fleas (*C. dubia* and *Daphnia magna*) exposed to different ionic mixtures that spanned the range of water chemistries typical of produced waters from oil and gas operations. Results from these toxicity tests were incorporated into multivariate logistic regression models that predict the acute (i.e., short-term) survival of the three test species (48-hour survival for the water fleas, 96-hour survival for the Fathead Minnow) based on the major-ion concentrations typical of oil and gas produced waters. The best-fit models for survival of all three species are presented in Table 4 of the paper by Mount et al. (1997), entitled *Statistical Models to Predict the Toxicity of Major Ions to Ceriodaphnia dubia, Daphnia magna and Pimephales promelas (Fathead Minnows)*. The utility of these models for reliably predicting acute lethality of oil and gas produced waters as well as other saline waters is amply illustrated or cited by Mount et al. (1992), Mount et al. (1997) and Tietge et al. (1997) using comparisons of actual measured toxicity from published studies and predicted toxicity using these models.

In addition to the ability to predict the acute lethality of various major-ion mixtures in produced waters to these three species, the researchers were also able to rank the relative toxicity of various ion constituents in typical produced waters (Mount et al., 1997), as follows:

$K^+ > HCO_3^- \sim Mg^{2+} > Cl^- > SO_4^{2+}$

These researchers also noted that Na^+ and Ca^{2+} were not significant variables in any of the models.

It is important to note that, in spite of this knowledge about relative contributions of various major ions in produced waters to aquatic toxicity, Aethon's reported produced water chemistry (Table 2 in Aethon's application) does not include analyses for K^+ or HCO_3^-; nor does it include analysis results for alkalinity, which would allow calculation of the HCO_3^- concentration. We presume that this is possibly because WDEQ does not have a water quality standard and monitoring requirements for potassium, bicarbonate or alkalinity. We strongly recommend that any permit that WDEQ issues for the Aethon facility, or for any other discharge of untreated or treated well-field produced water, should include a monitoring requirement and water quality standards for potassium, bicarbonate and alkalinity.

Based on the utility and proven reliability of the Mount et al. (1997) multivariate logistic-regression models for accurately predicting toxicity of saline produced waters, we ran these models using input chemistry from Table 2 in Aethon's permit application, which Aethon claims to be "representative of the quality of water being proposed for discharge" (Aethon permit application). We then supplemented the water chemistry data in Table 2 with our approximations of alkalinity and bicarbonate concentration necessary to achieve charge balance in the Table 2 chemistry (see the Water Chemistry section, above). Results of these model runs are shown in the table below. Note that these model runs with the undiluted, full-strength Aethon produced water predict zero percent (0%) survival for 48-hour lethality tests with *C. dubia* and *Daphnia magna* and zero percent (0%) survival for 96-hour lethality tests with Fathead Minnows. We also ran these models assuming dilution of the Aethon produced water in a series of up to a 10-fold dilution with distilled water. As shown in the table below, it was necessary to dilute Aethon produced water 10-fold with distilled water to achieve close to 100% survival for the three test species.

Model-predicted acute toxicity of Aethon produced water at full strength and after dilution with distilled water, based on model calculations using final regression equations presented in Table 4 in Mount et al. (1997).

Sample of Aethon produced water represented in Table 2 of application (Full Strength or Diluted)	Predicted Survival		
	C. dubia **48-hour survival (%)**	***D. magna*** **48-hour survival (%)**	**FHM 96-hour survival (%)**
Table 2 chemistry	0.0	0.0	0.0
Table 2 diluted 2x w/ dH2O	0.0	2.7	2.2
Table 2 diluted 3x w/ dH2O	2.4	34.8	27.6
Table 2 diluted 4x w dH2O	33.6	70.3	61.1
Table 2 diluted 5x w/ dH2O	75.6	85.2	78.6
Table 2 diluted 10x w/ dH2O	99.1	97.2	95.3

C. dubia = *Ceriodaphnia dubia*
D. magna = *Daphnia magna*
FHM = Fathead Minnow
dH2O = Distilled water

Note that longer-term effects on reproduction of *Ceriodaphnia* and growth of Fathead Minnows would occur at even greater dilutions of Aethon produced water than shown in the above table for short-term lethality. Thus, adverse effects on aquatic invertebrate communities in Alkali Creek and adverse effects on fish and aquatic invertebrates in Badwater Creek would be expected if untreated produced waters are not adequately diluted with good-quality water.

In fact, given the normal low flow in Alkali Creek (Class 3B with protected uses including aquatic life other than fish), defined in the draft permit (Statement of Basis, page 9) as "a low-flow stream, generally flowing only in response to storm events, snowmelt, or man-made discharges," and given our evaluation of likely pH increases in excess of pH 9 due to CO_2 de-gassing and given the predicted lethality of undiluted or modestly diluted historical produced water discharges, we are highly confident that a chemical and biological survey of Alkali Creek below Aethon's discharge would show existing (and likely future) violations of Wyoming water quality standards as well as lack of support of designated uses for aquatic life. Moreover, because Badwater Creek (Class 2AB with protected uses including a cold-water fishery) is also a "relatively low-flow, perennial stream" (Draft Permit, Statement of Basis, page 9), and given our assessment of (1) likely elevated pH exceeding 9 due to CO_2 de-gassing and (2) predicted lethality (as well as adverse effects on reproduction and growth of aquatic biota) with insufficient dilution of produced water discharges, we are highly confident that a chemical and biological survey of Badwater Creek would show existing (and likely future) violations of Wyoming water quality standards and lack of support for designated uses for aquatic communities and fish for a considerable distance downstream from the confluence with Alkali Creek.

Major Concerns and Recommendations

- The draft permit renewal for WY0002060 should not be approved – The permit renewal application and the draft permit, together, are severely inadequate and missing crucial information that would allow for evaluation of potential violations of end-of-pipe discharge limits, in-stream water quality standards, and effects on aquatic biota as a consequence of the discharges allowed under the proposed permit.
- Monitoring data necessary for evaluation of the proposed permit renewal – At a minimum, the temperature, pH, TDS, chloride, alkalinity, and flow of Alkali Creek and Badwater Creek should be monitored at least monthly immediately upstream and downstream of Aethon's current discharge in Alkali and Badwater Creeks and also in Badwater Bay. That monitoring should begin at least one year before a final permit is signed by WDEQ, so knowledge of annual variations of flow, temperature, pH, TDS, chloride and alkalinity in Alkali Creek, Badwater Creek and Badwater Bay can be used to better establish acceptable dilution factors for untreated produced water discharged by Aethon.
- Predicted elevation of pH above the pH 9 Wyoming water quality standard – The chemistry of untreated produced water discharged by Aethon will worsen as it flows down Badwater Creek (i.e., the pH of the water will increase and might exceed the in-stream Wyoming water quality standard for pH if not diluted adequately), thus posing a hazard for aquatic life in Alkali Creek, Badwater Creek and Badwater Bay. If pH becomes elevated in Badwater Creek and approaches or exceeds the Wyoming water quality standard's upper pH level of 9, Aethon's hydrologic analysis should be repeated to take into account the potential for adverse water chemistry changes downstream in Badwater Creek as the untreated produced water equilibrates with the atmosphere.

Averting such water chemistry changes might necessitate even greater dilution of the untreated produced water than the currently-planned-for salinity constraint in the Wind River downstream of Boysen Reservoir necessitates.

- Predicted toxicity of Aethon's untreated produced water – Based on a published model of the toxicity of saline oil and gas industry produced water to freshwater fish and invertebrates, Aethon's untreated produced water would have to be diluted at least 10-fold to avoid decreasing short-term survival of aquatic organisms; and it is likely that even more dilution would be needed to avoid longer-term, sublethal impairment (e.g., decreased growth and/or reproduction). Thus, averting such adverse effects in Alkali Creek, Badwater Creek and possibly in Badwater Bay might necessitate even greater dilution of the untreated production water than the currently-planned-for salinity constraint necessitates (which is based on projected salinity changes in the Wind River downstream of Boysen Reservoir).
- Contributions of potassium to the toxicity of Aethon's produced water discharge – The lack of an analysis for potassium in the water chemistry reported by Aethon means we have no way of knowing if the reportedly most-toxic major ion in the water (K^+) will be present at a high enough concentration to impair survival, growth, or reproduction of fish and other aquatic organisms.
- Inadequate hydrogen sulfide analyses in the permit application – The analytical method used for sulfides in the water chemistry reported by Aethon was not sensitive enough to determine whether the Wyoming water quality standard for sulfide will be exceeded and thus impair survival, growth, or reproduction of fish and other aquatic organisms.
- Cumulative effects of all discharges – Any analysis of the potential effects of Aethon's discharge of produced water should include the cumulative effects of all discharges into the Badwater Creek drainage (i.e., Aethon, Burlington, and any other discharges, current and future). And when evaluating the potential effects in the Wind River downstream of Boysen Reservoir, the cumulative effects of all discharges (current and future) in the entire Boysen Reservoir drainage should be considered.
- Toxicity testing requirements in the permit – To test whether Aethon's produced water discharges might adversely affect fish and/or other aquatic organisms in Alkali Creek, Badwater Creek and Badwater Bay, stricter toxicity testing requirements will be needed in a final discharge permit. Whole Effluent Toxicity (WET) tests should be required quarterly (rather than annually), include each outfall rather than a flow-weighted composite sample, include acute 48-hour lethality tests with *Daphnia magna* and acute 96-hour lethality tests with Fathead Minnows, and include chronic toxicity tests for 7-day larval Fathead Minnow growth and 7-day *Ceriodaphnia magna* reproduction (this *Ceriodaphnia* chronic test is now not included in the draft permit but would be important in evaluating potential effects of the discharge in Alkali Creek and Badwater Creek). Additionally, WDEQ should require Aethon to conduct a preliminary toxicity study before the discharge permit is finalized, to ensure the required dilution of untreated produced water is sufficient to avoid long-term toxicity downstream. To evaluate the possible effects of pH shifts to greater than pH 9 due to CO_2 de-gassing, these tests should include testing of both "fresh" untreated produced water and "aged" untreated produced water, with the length of the "aging" determined by the longest projected transit time for water between its discharge into Alkali Creek and its entry into Badwater Bay.

References Cited

Boelter, A.M., F.N. Lamming, A.M. Farag and **H.L. Bergman.** 1992. Environmental effects of saline oil-field discharges on surface waters. *Environ. Toxicol. Chem.* **11**:1187–1195.

Clemens, H.P. and **W.H. Jones.** 1954. Toxicity of brine water from oil wells. *Trans. Am. Fish. Soc.* **84:**97- 109.

Gulley, D.D., D.R. Mount, J.R. Hockett and H.L. Bergman. 1992. A statistical model to predict toxicity of saline produced waters to freshwater organisms. In J.P. Ray and F.R. Engelhardt, eds., *Produced Water: Technological/Environmental Issues and Solutions.* Plenum, New York, NY, USA, pp. 89–96.

Kassotis, C.D., D.C. Vu, P.H. Vo, C.H. Lin, J.N. Cornelius-Green, S. Patton and S.C. Nagel. 2018. Endocrine-disrupting activities and organic contaminants associated with oil and gas operations in Wyoming groundwater. *Arch. Of Environ. Contam. And Toxicol.* **75**: 247-258.

Lofts, S. 2012. User's Guide to WHAM7: Windermere Humic Aqueous Model, Version 7. Centre for Ecology and Hydrology, Natural Environment Research Council, UK.

Mount, D.R., K.R. Drottar, D.D. Gulley, J.P. Fillo and **P.E. O'Neil.** 1992. Use of laboratory toxicity data for evaluating the environmental acceptability of produced water discharge to surface waters. In J.P. Ray and F.R. Engelhardt, eds., *Produced Water: Technological/Environmental Issues and Solutions.* Plenum, New York, NY, USA, pp. 175–185.

Mount, D.R., D.D. Gulley, J.R. Hockett, T.D. Garrison and **J.M. Evans.** 1997. Statistical models to predict the toxicity of major ions to *Ceriodaphnia dubia, Daphnia magna* and *Pimephales promelas* (fathead minnows). *Environ. Toxicol. Chem.* **16**:2009–2019.

Tietge, J.E., J.R. Hockett and **J.M. Evans.** 1997. Major ion toxicity of six produced waters to three freshwater species: Application of ion toxicity models and TIE procedures. *Environ. Toxicol. Chem.* **16**:2002–2008.

Wiebe, A.H., J.G. Burr and **H.E. Faubion.** 1924. The problem of stream pollution in Texas with special reference to salt water from the oil fields. *Trans. Am. Fish. Soc.* **64:**231-85.

<u>**Curriculum Vitae for Bergman and Meyer**</u>

Harold L. Bergman
Emeritus Professor of Zoology and Physiology
University of Wyoming
bergman@uwyo.edu • (307) 460-0015

EDUCATION
Eastern Michigan University Biology B.A., 1968
Eastern Michigan University Biology M.S., 1971
Michigan State University Fisheries Biology Ph.D., 1973

PROFESSIONAL POSITIONS
2011-2013 Department Head, Department of Zoology and Physiology, University of Wyoming
1995-2016 J.E. Warren Distinguished Professor of Energy and Environment, University of Wyoming
1998-2008 Director, William D. Ruckelshaus Institute and Helga Otto Haub School of
 Environment and Natural Resources, University of Wyoming
1988 Visiting Scientist, U.S. Environmental Protection Agency, Duluth, Minnesota
1986-1987 Acting Director, Wyoming Water Research Center, University of Wyoming
1984-2016 Professor, Department of Zoology and Physiology, University of Wyoming (Retired 2016)
1984-1999 Director, Red Buttes Environmental Biology Laboratory, University of Wyoming
1975-1984 Asst. & Assoc. Professor, Dept. of Zoology and Physiology, University of Wyoming

PROFESSIONAL AWARDS AND DISTINCTIONS (Selected)
Founder's Award, Society of Environmental Toxicology and Chemistry, 2018
Distinguished Faculty Graduate Mentor Award, University of Wyoming, 2014
Extraordinary Merit in Advising, Arts & Sciences College, University of Wyoming, 2014
Elected Fellow, American Association for the Advancement of Science, 1995
George Duke Humphrey Distinguished Faculty Award, University of Wyoming, 1995
Conservation Educator of the Year, Wyoming Wildlife Federation, 1986
President of the Society of Environmental Toxicology and Chemistry, 1984-85
President of the Water Quality Section, American Fisheries Society, 1982-83
Editorial Board, Environmental Toxicology and Chemistry, 1981-84
EPA Doctoral Traineeship, Michigan State University, 1971-73

STATE, NATIONAL AND INTERNATIONAL ADVISORY & REVIEW PANELS (Selected)
Wyoming Environmental Quality Council, 1983-95; Chairman, 1985-87
National Research Council - National Academy of Sciences Committees/Board
 Ecological Risk Assessment, 1986-87
 Animals as Monitors of Environmental Hazards, 1987-91
 NRC Board of Agriculture and Natural Resources, 2009-2016
Environmental Protection Agency, ORD, Peer Review Panels/Review Committees
 Exploratory Grants Program, Environmental Biology Panel, 1986-96
 National Acid Precipitation Assessment Program, Aquatic Effects Program, Panel Chair, 1987
 Graduate Fellowship Review Panel, 1995-98, 2009-12
 Environmental Protection Agency, Science Advisory Panel for Pesticides (FIFRA), 1984-87
 Science and Technology Achievement Awards, 1986-87
 Water Quality Standards Research Review, 1986
 Ecological Risk Assessment Research Review, 1986
 Environmental Protection Agency, Board of Scientific Councilors, 1996-97
The Royal Society (London), Surface Water Acidification Program Review Panel, 1990
Private Sector Board and Advisory Positions
 PacifiCorp, Inc., Environmental Forum, Portland, OR, 2000-04
 Wyoming Outdoor Council Board, Lander, WY, 2009-2015; 2017-present

SELECTED RELEVANT PUBLICATIONS (Selected from over 100 publications)

Johnson, E.O., B.D. Cherrington and H.L. Bergman. 201_. Assessment of endocrine disrupting compounds in Wyoming surface waters. Environ. Toxicol. Chem. (In Preparation).

Firkus, T., F.J. Rahel, H.L. Bergman and B.D. Cherrington. 2017. Warmed winter water temperatures alter reproduction in two fish species from the South Platte River, Colorado. Environmental Management 61(4) https://doi.org/10.1007/s00267-017-0954-9.

Pham, D.T., H.M. Nguyen, T.Boivin, A. Zajacova, S.V. Huzurbazar and H.L. Bergman. 2015. Predictors for dioxin accumulation in residents living in Da Nang and Bien Hoa, Vietnam, many years after Agent Orange use. Chemosphere 118:277-283.

Godwin, B.L., S.E. Albeke, H.L. Bergman, A. Walters and M. Ben-David. 2015. Density of river otters (*Lontra canadensis*) in relation to energy development in the Green River Basin, Wyoming. Science of the Total Environment 532: 780-790.

Wood, C.M., H.L. Bergman, A. Bianchini, P. Laurent, J. Maina, O.E. Johannsson, L. Bianchini, C. Chevalier, G.D. Kavembe, M.B. Papah and R.O. Ojoo. 2012. Transepithelial potential in the Magadi tilapia, a fish in extreme alkalinity. J. Comp. Phyiol. B 182: 247-258.

Bergman, H.L. (ed.). 2009. Research and Development Concerning Coalbed Natural Gas. Final Report to the NETL, U.S. Department of Energy, Ruckelshaus Institute of Environment and Natural Resources, University of Wyoming, Laramie, Wyoming. 177pp.

Bergman, H.L., A.M. Boelter, and K.S. Parady (eds.). 2008. Research needs and management strategies for pallid sturgeon recovery. Final Report to the U.S. Army Corp of Engineers, Ruckelshaus Institute of Environment and Natural Resources, University of Wyoming, Laramie, Wyoming. 36pp. + App.

Bergman, H.L. (ed.). 2005. Water Production from Coalbed Methane Development: A Summary of Quantity, Quality and Management Options. Ruckelshaus Institute of Environment and Natural Resources, University of Wyoming, Laramie, Wyoming. 64 pp. + App.

Lease, H.M., J.A. Hansen, H.L. Bergman and J.S. Meyer. 2003. Structural changes in gills of Lost River suckers exposed to elevated pH and ammonia concentrations. Comp. Biochem. Phys. Part C, 134: 491-500.

Bergman, A.N., P. Laurent, G. Otiang'a-Owiti, H.L. Bergman, P.J. Walsh, P.W. Wilson, and C.M. Wood. 2003. Physiological adaptations of the gut in the Lake Magadi tilapia, *Alcolapia grahami*, in an alkaline- and saline-adapted teleost fish. Comp. Biochem. Phys. Part A, 136. 701-715.

DiToro, D.M., H.E. Allen, H.L. Bergman, J.S. Meyer, P.R. Paquin and R.C. Santore. 2001. Biotic ligand model of the acute toxicity of metals. 1. Technical basis. Environ. Toxicol. Chem. 20:2383-2396.

Hansen, J.A., D.F. Woodward, E.E. Little, A.J. DeLonay and H.L. Bergman. 1999. Behavioral avoidance: Possible mechanism for explaining abundance and distribution of trout species in a metals-impacted river. Environ. Toxicol. Chem. 18: 126-130.

MacRae, R.K., D.E. Smith, N. Swoboda-Colberg, J.S. Meyer and H.L. Bergman. 1999. Copper binding affinity of rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*) gills: Implications for assessing bioavailable metal. Environ. Toxicol. Chem. 18:1180-1189.

Meyer, J.S., R.C. Santore, J.P. Bobbitt, L.D. DeBrey, C.J. Boese, P.R. Paquin, H.E. Allen, H.L. Bergman and D.M. DiToro. 1999. Binding of nickel and copper to fish gills predicts toxicity when water hardness varies, but free-ion activity does not. Environ. Sci. Technol. 33:913-916.

Bergman, H.L. and E.J. Dorward-King. (eds.). 1997. Reassessment of Metals Criteria for Aquatic Life Protection: Priorities for Research and Implementation. SETAC Press, Pensacola, FL. 114 pp.

Boelter, A.M., F.N. Lamming, A.M. Farag, and H.L. Bergman. 1992. Environmental effects of saline oil-field discharges on surface waters. Environ. Toxicol. Chem. 11:1187-1195.

Gulley, D.D., D.R. Mount, J.R. Hockett and H.L. Bergman. 1992. A statistical model to predict toxicity of saline produced waters to freshwater organisms. pp 89-96 In: J.P. Ray and F.R. Engelhardt (eds.). Produced Water: Technological/Environmental Issues and Solutions. Plenum Press, New York.

Bergman, H.L., R.A. Kimerle and A.W. Maki (eds.). 1986. Environmental Hazard Assessment of Effluents. Pergamon Press, Elmsford, N.Y. 366 pp.

Joseph S. Meyer
Chief Scientist
Applied Limnology Professionals LLC
jsmeyer@ALPsColorado.com • (303) 524-4373

EDUCATION

Lehigh University, Chemical Engineering B.S., 1973
University of Wyoming, Zoology and Physiology Ph.D., 1986

PROFESSIONAL POSITIONS

2016-Present	Chief Scientist, Applied Limnology Professionals LLC, Golden, CO
2012-Present	Affiliated Faculty Member, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, CO
2007-2016	Technical Expert and Principal Scientist, Arcadis, Lakewood, Colorado
2005-2007	Professor, Department of Zoology and Physiology, University of Wyoming
1999-2005	Associate Professor, Department of Zoology and Physiology, University of Wyoming
1999 2004	Director, Red Buttes Environmental Biology Laboratory, University of Wyoming
1994-1999	Assistant Professor, Department of Zoology and Physiology, University of Wyoming
1991-1993	Coordinator, Wastewater Utilization Graduate Program, Humboldt State University, Arcata, CA
1990-1993	Lecturer, Department of Fisheries, Humboldt State University, Arcata, CA
1989-1990	Postdoctoral Researcher, University of Wyoming-National Park Service Research Center, University of Wyoming
1988-1989	Postdoctoral Researcher, Lake Research Laboratory, Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG/ETH), Kastanienbaum, Switzerland
1987-1988	NATO Postdoctoral Research Fellow, Lake Research Laboratory, Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG/ETH), Kastanienbaum, Switzerland
1987	Research Scientist, Department of Zoology and Physiology, University of Wyoming
1986	Graduate Research and Teaching Assistant, Department of Zoology and Physiology, University of Wyoming
1980-1983	Associate Scientist, Western Aquatics, Inc., Laramie, WY [part-time]
1976-1985	Research Scientist, Department of Zoology and Physiology, University of Wyoming
1972	Student Participant, NASA Summer Institute for Biomedical Engineering, Howard University and Goddard Space Flight Center, Greenbelt, MD

PROFESSIONAL AWARDS AND DISTINCTIONS (Selected)

Fellow of Society of Environmental Toxicology and Chemistry, 2018-Present
President of Rocky Mountain Chapter of Society of Environmental Toxicology and Chemistry, 2004-2005
Member of Editorial Board, *Environmental Toxicology and Chemistry*, 1997-2000
Member of Board of Directors of Rocky Mountain Association of Environmental Professionals, 1983-1984

STATE, NATIONAL AND INTERNATIONAL ADVISORY & REVIEW PANELS (Selected)

U.S. Environmental Protection Agency: Member, Aquatic Life Criteria Consultative Panel of the Science Advisory Board of the U.S. Environmental Protection Agency. 2005.

U.S. Environmental Protection Agency: Member, Health and Ecological Effects Subcommittee of the Advisory Council on Clean Air Compliance Analysis of the Science Advisory Board (SAB) of the U.S. Environmental Protection Agency. 1998-2002.

Environment Canada: Member, Environmental Resource Group for the Assessment of Chloramine under the Canadian Environmental Protection Act. 1996-1999.

U.S. Environmental Protection Agency: Member, Advisory Council on Clean Air Compliance Analysis Physical Effects Review Subcommittee of the Science Advisory Board of the U.S. Environmental Protection Agency. 1994-1997.

U.S. Department of Energy: Review of documents addressing damages and benefits of various fuel cycles. 1992-1993.

SELECTED RELEVANT PUBLICATIONS (Selected from 100 publications)

Meyer, J.S. and D.K. DeForest. 2018. Protectiveness of copper water quality criteria against impairment of behavior and chemo/mechanosensory responses: An update. *Environmental Toxicology and Chemistry* 37:1260-1279.

Traudt, E.M., J.F. Ranville and J.S. Meyer. 2017. Acute toxicity of ternary Cd-Cu-Ni and Cd-Ni-Zn mixtures to *Daphnia magna*: Dominant metal pairs change along a concentration gradient. *Environmental Science and Technology* 51:4471-4481.

Müller, B., J.S. Meyer and R. Gächter. 2016. Alkalinity regulation in calcium carbonate-buffered lakes. *Limnology and Oceanography* 61:341-352.

Traudt, E.M., J.F. Ranville, S.A. Smith and J.S. Meyer. 2016. A test of the additivity of acute toxicity of binary-metal mixtures of Ni with Cd, Cu, and Zn to *Daphnia magna*, using the inflection point of the concentration-response curves. *Environmental Toxicology and Chemistry* 35:1843-1851.

Farley, K.J. and J.S. Meyer. 2015. Metal mixtures modeling evaluation: 3. Lessons learned and steps forward. *Environmental Toxicology and Chemistry* 34:821-832.

Farley, K.J., J.S. Meyer, L.S. Balistrieri, Y. Iwasaki, M. Kamo, S. Lofts, C.A. Mebane, W. Naito, A.C. Ryan, R.C. Santore and E. Tipping. 2015. Metal mixtures modeling evaluation: 2. Comparison of four modeling approaches. *Environmental Toxicology and Chemistry* 34:741-753.

Meyer, J.S., K.J. Farley and E.R. Garman. 2015. Metal mixtures modeling evaluation: 1. Technical background. *Environmental Toxicology and Chemistry* 34:726-740.

Meyer, J.S., J.F. Ranville, M. Pontasch, J.W. Gorsuch and W.J. Adams. 2015. Acute toxicity of binary and ternary mixtures of Cd, Cu, and Zn to *Daphnia magna*. *Environmental Toxicology and Chemistry* 34:799-808.

Fulton, B.A. and J.S. Meyer. 2014. Development of a regression model to predict copper toxicity to *Daphnia magna* and site-specific copper criteria across multiple surface-water drainages in an arid landscape. *Environmental Toxicology and Chemistry* 33:1865-1873.

Meyer, J.S. and GG. Pyle. 2013. Effects of anthropogenic chemicals on chemosensation and behavior in fish: Organismal, ecological, and regulatory implications. *Fisheries* 38:283-284.

Meyer, J.S., S.J. Clearwater, T.A. Doser, M.J. Rogaczewski and J.A. Hansen. 2007. *Effects of Water Chemistry on the Bioavailability and Toxicity of Waterborne Cadmium, Copper, Nickel, Lead, and Zinc to Freshwater Organisms*. SETAC Press, Pensacola, Florida, USA.

Meyer, J.S., W.J. Adams, K.V. Brix, S.N. Luoma, D.R. Mount, W.A. Stubblefield and C.M. Wood (eds.). 2005. *Toxicity of Dietborne Metals to Aquatic Organisms*. SETAC Press, Pensacola, Florida, USA.

Meyer, J.S. and J.A. Hansen. 2002. Subchronic toxicity of low dissolved oxygen concentrations, elevated pH, and elevated ammonia concentrations to Lost River suckers. *Transactions of the American Fisheries Society* 131:656-666.

Dare, M.R., W.A. Hubert and J.S. Meyer. 2001. Influence of stream flow on hydrogen sulfide concentrations and distributions of two trout species in a Rocky Mountains tailwater. *North American Journal of Fisheries Management* 21:971-975.

Di Toro, D.M., H.E. Allen, H.L. Bergman, J.S. Meyer, P.R. Paquin and R.C. Santore. 2001. Biotic ligand model of the acute toxicity of metals. 1. Technical basis. *Environmental Toxicology and Chemistry* 20:2383-2396.

Goldstein, J.N., W.A. Hubert, D.F. Woodward, A.M. Farag and J.S. Meyer. 2001. Naturalized salmonid populations occur in the presence of elevated trace element concentrations and temperatures in the Firehole River, Yellowstone National Park, Wyoming. *Environmental Toxicology and Chemistry* 20:2342-2352.

Santore, R.C., D.M. Di Toro, P.R. Paquin, H.E. Allen and J.S. Meyer. 2001. Biotic ligand model of the acute toxicity of metals. 2. Application to acute copper toxicity in freshwater fish and *Daphnia*. *Environmental Toxicology and Chemistry* 20:2397-2402.

Meyer, J.S., D.A. Sanchez, J.A. Brookman, D.B. McWhorter and H.L. Bergman. 1985. Chemistry and aquatic toxicity of raw oil shale leachates from Piceance Basin, Colorado. *Environmental Toxicology and Chemistry* 4:559-572.

Woodward, D.F., R.G. Riley, M.G. Henry, J.S. Meyer and T.R. Garland. 1985. Leaching of retorted oil shale: Assessing the toxicity to Colorado squawfish, fathead minnows, and two food-chain organisms. *Transactions of the American Fisheries Society* 114:887-894.

Hot Springs Conservation District

601 Broadway, Suite A

Thermopolis, WY 82443

307-864-3488

July 3, 2019

Jason Thomas
WYPDES Permitting Supervisor
Wyoming Department of Environmental Quality
Water Quality Division
200 West 17th Street
Cheyenne, Wyoming 82002

Submitted online: http://wq.wyomingdeq.commentinput.com/?id=f4gaH and email jason.thomas@wyo.gov

RE: Aethon Energy (Moneta Divide) Proposed Discharge Permit WY0002062

Dear Mr. Thomas:

The Hot Springs Conservation District submits the following comments with regard to the proposed renewal of WYPDES permit number WY0002062, for Aethon Energy's Frenchie Draw/Moneta Divide. We thank you for extending the deadline for comments and providing public meetings to help our communities become better informed.

Many citizens of Hot Spring County utilize the waters of Boysen Reservoir for fishing and recreation, additionally, as the first county below Boysen Dam, we take conservation of this Class 1 water resource very seriously. Not only do we gain a significant economic boost from the scenic value, recreation, fishing and agricultural industries these waters support, but they also provides our drinking water.

Class 1 Antidegradation:

The requirement for Class 1 water is stated clearly on page 2, Statement of Basis (SOB) of this permit, "'…the water quality and physical and biological integrity which existed on the water at the time of *designation* will be maintained and protected.' The Wind River below Boysen Reservoir was designated as a Class 1 water in 1979." The baseline water quality data, below Boysen Dam, used in Environmental Resources Management's (ERM) modeling study was collected beginning thirty one years after its designation, from 2010 to 2016. The USGS has recorded data below Boysen Dam for many of the constituents modeled (https://nwis.waterdata.usgs.gov/wy/nwis/qwdata/?site_no=06259000). The use of new data where historic data exists, violates the antidegradation law of Section 303(d)(4)(B) of the Clean

Water Act, as well as, WDEQ's, Implementation Policies for Antidegradation Mixing Zones and Dilution Allowances Turbidity Use Attainability Analysis of 2013.

As presented on SOB page 3, this permit allows concentrations of monitored constituents to increase by up to one standard deviation. The allowance of the one standard deviation came from WDEQ's Interim Policy on Establishing Effluent Limits for Permitted Point Source Discharges to Class 1 Water Tributaries of 2007. To our understanding, this policy was not reviewed by the EPA per 303(c)(2)(A) nor is it a Wyoming law or binding policy; it is merely the opinion of the WDEQ administrator. It did not follow the Water Quality Divisions procedures (W.S. 35-11-114), for public comment, review by the Water Quality Advisory Board nor was it reviewed by the Environmental Quality Council (W.S. 35-11-112). **As such the one standard deviation utilized in reaching concentration limits should not be used.**

The standard deviations (std Dev) shown in the Model Output – Baseline Concentrations and Permit Limits table on SOB page 3, suggest great variations in the values reported in the lab samples. Upon reviewing the file, Boysen Dam Baseline Sampling Data (BDBSD) [2018_11_13_Boysen Dam Baseline_ND_reporting limits_BD2_Nickel], provided by WDEQ's Bill DiRienzo, it is apparent that outliers were not excluded. Not removing outliers creates baseline averages which misrepresent what the actual Wind River Baseline averages (utilizing the 2010-2016 data) would be, and distort the std Dev values. Additionally, there are many examples of inconsistencies between the two documents e.g., sometimes values are rounded and sometimes they are not. While the BDBSD showed a std Dev of 11 ug/L, the Model Output table reports 10.8 ug/L for Zinc.

Taking Zinc as the example, there were three outliers: 10.4 ug/L, 30ug/L, and the highest 80 ug/L which is over <u>13 times</u> the average of 5.8 ug/L listed on table as being the baseline average; all other reported values were between 2.5 and 5.2 (with the 5.2 being an outlier itself within the 2010-2013 data). Outlier removal would have significantly changed the std Dev, as well as the baseline average. The Model Output table reports 10.8 ug/L as the std Dev. Utilizing a std Dev that is 5 points higher than the baseline average, generates an Anti-deg Target <u>3 times</u> greater than the baseline average. **Removal of the three outliers moves the baseline average of 5.8 ug/L down to 3.8 ug/L and the std Dev down 10 points to 1 ug/L.**

Six constituents listed in the Model Output table show a std Dev above the Wind River Baseline Concentration averages; Manganese, Copper, Nickel, Zinc, and Cadmium. The std Dev recomputed with outliers removed, causes changes anywhere from 1 point to 30 points, in the case of Manganese. Baseline average changes are: Manganese 14 ug/L (file - 13.9 ug/L) to 5.1 ug/L; Copper 4 ug/L to 2.9 ug/L; Nickel 2 ug/L (file - 1ug/L) to .4 ug/L; Zinc 5.8 ug/L to 3.8 ug/L; Cadmium .4 ug/L to .3 ug/L.

For Mercury, the numbers listed in the BDBSD file are not even the data used on SOB page 3. Sometimes data are rounded, sometimes not and in this case it is unclear were data even came from. There are additional issues with the Model Output – Baseline Concentrations and Permit Limits table on SOB page 3 in relation to the Boysen Dam Baseline Sampling Data file. They need serious review in their entirety.

Not removing outliers creates Wind River baseline averages which are, in some instances significantly misrepresentative of what the true baseline (utilizing the 2010-2016 data) would be and a significant degradation from actual 2010-2016 levels. The SOB page 10, states that WDEQ does not believe waters below Boysen Dam would ever reach these thresholds.

If this permit were accepted as it stands, the numbers WDEQ/ERM used for the Wind River Baseline would become erroneously established. Additionally, these numbers were used by ERM for modeling and used by WDEQ for setting the Standards and Effluent Limits in this permit.. **This inaccurate data compiling constitutes a clear violation of Antidegradation of Class 1 water as well as begging the question of the reliability of the ERM model as a whole.**

Category 1 pollutants: If the chloride contaminant amounts evaluated in this permit (SOB page 5) are sent downstream in the allowed zero treated flow of 2.856 MGD, which the permit maintains is, "just below the antidegradation target," (this statement implies a level between 11 and 12) again, degradation already exists. This also means that if Aethon's reverse osmosis (RO) system should be offline for *any* amount of time, and the flows of up to 8.274 MGD are released, chloride limits rise quickly well above present averages and antidegradation targets. WDEQ states in the permit SOB page 10, "Any increase in downstream pollutant levels within Badwater Creek would be expected only during short periods of servicing or malfunction of the treatment unit, if at all. During such times, the permit still requires full compliance with all established effluent limits." Our concern lies in these waters reaching beyond Badwater Creek, on into Badwater Bay, Boysen Reservoir and potentially the Class 1 water and below. WDEQ does not address this in its discussion, except in Badwater Creek. **While the requirement that Aethon maintains, "full compliance" is stated, the reality is, as confirmed by the BLM's 2019 Draft EIS page 3-81 showing 33 violation by Aethon, and WDEQ's public meeting presentation (depicting severe erosion), violations of significant magnitude do occur and it only takes one misstep to cause down-stream catastrophe.**

For pH SOB page 3, shows no standard deviation and yet WDEQ is proposing increasing the Anti-deg Target from a pH of 8 to a pH of 9 in a system which is already at the upper end of the alkalinity scale. This is of great concern to those who use waters below Boysen Dam for irrigation, as they already struggle with alkaline soils. We do not believe that a status of no degradation can be maintained when the pH average is allowed to be increased so significantly.

Frenchie Draw was established prior to the Clean Water Act of 1972, however, the amount of discharge water from the field at that time was relatively small (1 MGD), due to the minimum amount of development. The WDEQ has the authority/obligation to regulate pollutant levels. They also have the authority to allow or disallow the grandfathering of those pollutant levels. The proposed Moneta Divide field expansion will allow produced water of 8.27 MGD, however, discharge water at full development are estimated at 58.8 MGD (BLM 2019 Draft EIS pg. 2-70). Grandfathering in higher pollutant levels for an increasing field development of this size is contrary to the mission of WDEQ "To protect, conserve and enhance the quality of Wyoming's environment for the benefit of current and future generations," as well as the value to be, "…consistent by fairly applying and implementing regulatory requirements." Allowing the huge volume of water containing pollutants to be discharged into state park and recreational waters goes counter to your mission. No facility coming into existence after the Clean Water Act is given such an economic advantage. Aethon is not being required to take care of their own environmental pollutants by meeting current limits associated with their discharge water. They are passing along any possible damages to the public. Does WDEQ have a bond in place for Aethon to ensure monies are in place to remediate any potential damages they may cause?

The modeling accounted for, "all other sources of water flowing into Boysen Reservoir" and implies that it accounted for all current pollutants being added to Boysen Reservoir. If with ERM's modeling you set their Effluent Limits at the highest level possible for the lowest flow month, then no other operator would be allowed any future development or pollutant additions. Any additional pollutant inflows would be added to the existing levels and would then exceed downstream Class 1 water antidegradation targets. To counter the permit states, "assuming that all modeled constituents will pass through the reservoir" which DEQ does not believe will occur. However, nothing in this permit addresses issues of future weather extremes, which can be expected to include extreme drought. **Natural inflows could be decreased to well below historic levels, and this scenario is not accounted for in ERM's modeling.**

Discharge Water Used for Agriculture, Livestock and Wildlife:

Water Quality for Wyoming Livestock and Wildlife, Raisbeck et. al., 2007 sets short exposure and chronic exposure levels for some of the constituents listed in this permit's WQ Standards and Effluent Limits, SOB table on page 3. The EOP Mixed Concentration Limit for Sulfate is 3000 mg/L. However, according to the report, "a water SO_4 concentration of 1125 mg/L will meet or exceed the NRC's *(National Research Council)* maximum tolerance limit for S in cattle." It goes on to say, "In practice, water SO_4 concentrations as low as 2000 mg/L have caused PEM *(Polioencefphalomalacia)* and/or sudden death in cattle." The permit addresses, "Historical Beneficial Use" and "Agricultural and wildlife use of water," but does not address the safety of the proposed effluent limits in this regard.

The EOP Mixed Concentration Limit for TDS is 6400 mg/L and while the report states, "We do not recommend relying upon TDS to evaluate water quality for livestock and wildlife; however, if no other information is available, TDS concentrations less than 500 mg/L should ensure safety from almost all inorganic constituents. Above 500 mg/L, the individual constituents contributing to TDS should be identified, quantified, and evaluated." **This analysis should be done to assist in determining if TDS constituents could pose additional hazards to livestock and wildlife.**

The suitability of the proposed discharge water for use by livestock and wildlife based on the very high Sulfate and TDS limits proposed in this permit need greater review or are in direct conflict with the Water Quality for Wyoming Livestock & Wildlife, A Review of the Literature Pertaining to Health Effects of Inorganic Contaminants, a study funded by WDEQ.

As stated in Texas A&M AgriLife Extensions publication, Irrigation Water Quality Standards and Salinity Management Strategies, "As water evaporates, the dissolved salts remain, resulting in a solution with a higher concentration of salt . The same process occurs in soils. Salts as well as other dissolved substances begin to accumulate as water evaporates from the surface and as crops withdraw water." pg. 2. The report goes on to say, "High concentrations of salt in the soil can result in a "physiological" drought condition. That is, even though the field appears to have plenty of moisture, the plants wilt because the roots are unable to absorb the water." pg. 3 https://aglifesciences.tamu.edu/baen/wp-content/uploads/sites/24/2017/01/B-1667.-Irrigation-Water-Quality-Standards-and-Salinity-Management-Strategies.pdf pg. 2. Our concern is that farmers and ranchers utilizing the discharged water in the Moneta Divide area, for irrigation, may in the long term, cause soils to become so salinized that they are no longer suitable for agricultural or wildlife purposes.

Concentration of constituents due to evaporation:

The evaporation effect along Alkali and Badwater Creeks which are known to be ephemeral at times, will deposit sodium, chloride and other pollutant constituents in the stream and streambank sediment. A significant rain event, will carry sediment downstream in mass; just as we saw in the 2015 event which closed Wind River Canyon. Has WDEQ evaluated the effect of this accumulation of polluted sediment on the downstream systems? ERM's modeling did not. Have streambed samples been taken to determine the current level of constituents in the sediment and does it have a monitoring program for future testing to determine build up? If you will review the "mixing zone" slides presented in your public meetings, in Riverton and Thermopolis, you will notice the plume of darker colored water moving out into Boysen Reservoir. It distinctly shows that solids are moving well beyond the "mixing zone" and on into Boysen Reservoir. **The permit does not address extreme flood events where evaporated crystalized pollutant deposits are picked up and rapidly carried downstream and well beyond the "mixing zone."**

Level and frequency of monitoring:

Permit page 2 states, "This permit does not cover activities associated with discharges of drilling fluids, acids, stimulation water or other fluids derived from the drilling or completion of the wells." The permit only covers end of pipe (EOP) mixed concentration limits for 12 of the 105 Priority Pollutants listed in Appendix B of the Wyoming Surface Water Quality Standards. **How do you intend to monitor for the other 93 priority pollutants to ensure they do not exceed human health and safety levels for skin contact, drinking water, fish and fish consumption in Boysen Reservoir and below Boysen Dam?**

A much more in-depth and frequent level of monitoring and testing must be put into place. This is crucial to the status and nature of the Class 1 water resource being protected. Quarterly testing of BWC1, BWB1 and WRC1 should be monitored and reported at least on a monthly interval and those results need to be used for regulation. Monitoring and testing must be done by an independent firm and facility, not by the operator (Aethon) or one of their agents.

Modeling:

As previously mentioned with regards to the Wind River Baseline Data file and the SOB page 3 Model Output – Baseline Concentrations and Permit Limits table, the ERM modeling report is of questionable soundness. The report contains 22 uses of the word assumed and twelve references to insufficient, most referencing assumptions made to do the modeling or insufficient data for modeling input. For example on page 4 of Hydros Consulting's, Review of ERM Water-Quality Modeling Study of Boysen Reservoir dated July 1, 2018 they state:

"… only collected tributary inflow water-quality data on one day in April of 2017. These often-single data points are the basis for many of the inflow WQ assumptions. And yet, in the case of Badwater Creek, ERM used the one sample from Tough Creek, as a surrogate for conditions upstream of produced water discharges. There is no reason to believe that the water quality in Tough Creek is similar to that of Badwater Creek and no reason is provided as to why sampling did not occur at such a critical location."

This is just one example of the serious concerns we have with the data used in ERM's modeling. **We do not believe modeling done by ERM is of sufficient quality for WDEQ to safely rely upon it to determine the actual effects of using Badwater Bay and Boysen Reservoir as a filtration system for Aethon's pollution discharges.**

Fisheries:

We are greatly concerned that the protection of the aquatic life zone located at Badwater Bay has not been fully evaluated. Many species utilize Badwater Bay and Boysen Reservoir as habitat. The Sauger fish in Boysen Reservoir are the last native population of Sauger in Wyoming. This means we have allowed situations to occur throughout the state which make it unsuitable for Sauger. Young Sauger (as well as Walleye) utilizes Badwater Bay as a nursery habitat as young fry (per phone conversation with WG&F, Fisheries Biologist, Craig Amadio). Were Badwater Bay to become unsuitable for these fish they would have to move out of the bays protective shallows and place themselves at greater risk to predation. We also draw your attention to the analysis done by, "Harold Bergman, PhD, Professor Emeritus, University of Wyoming, Laramie, WY; and Joseph Meyer, PhD, Chief Scientist, Applied Limnology Professionals LLC, Golden, CO," dated June 27th, 2019. This review points out serious failures on the part of ERM's model and the effluent limits being set, to ensure aquatic biota protection.

While we are in support of the development of Aethon's Moneta Divide field, and the economic value it has for both Wyoming and associated communities, we do not believe the discharge water permit, as proposed, is validated in such a way as to ensure the valuable natural resources of Badwater Bay, Boysen Reservoir, Wind River Class 1 water and downstream users are protected. Thank you for considering our comments.

Respectfully Submitted,

Sonja L. Becker
Chairwoman
Hot Spring Conservation District
601 Broadway, Suite A
Thermopolis, WY 82443
sonja.becker.hscd@gmail.com

CC: Governor Mark Gordan
Hot Springs County Commissioners
Thermopolis Town Mayor

Enclosures:

Bergman – Fisheries Review
Boyer – ERM Modeling Review
Boysen Dam Baseline Data

FINAL TECHNICAL MEMORANDUM

TO: Dan Heilig, Wyoming Outdoor Council and
Jill Morrison, Powder River Basin Resource Council
FROM: Jean Marie Boyer, PhD, PE, Hydros Consulting Inc.
SUBJECT: Review of ERM Water-Quality Modeling Study of Boysen Reservoir
DATE: July 1, 2018

BACKGROUND

Per your request, I have reviewed the report entitled "Water Quality Compliance Analysis for the Long Range Development Plan at Moneta Divide, Wyoming. A Hydrologic, Hydrodynamic and Water Quality Study of the Boysen Reservoir Watershed" written by Environmental Resources Management (ERM), dated April 23, 2018 (Report). My review focused on the development of the Boysen Reservoir Water-Quality Model developed using GEMSS and the analysis of results. I did not focus on the SWAT modeling, which was conducted to develop daily flows for use in the reservoir model.

My staff and I also briefly reviewed reservoir modeling files, sent to us by ERM. These files provided more detail than what was described in the Report. Given the lack of model documentation and time / resource constraints, model files have not been thoroughly reviewed. However, the review resulted in the identification of several severe and alarming issues, and there may be more.

My comments are summarized in this memorandum and organized under two broad categories:

- The Reservoir Model Cannot be Used for Decision Making; and
- The Compliance Analysis Methods and Findings are Incorrect.

Many of the comments are supported with detailed examples and they are not in order of most important to least important. An overall summary can be found at the end of this document, where the most important concerns are highlighted.

MAJOR POINT: RESERVOIR MODEL CANNOT BE USED FOR DECISION MAKING

It is very clear that the model developed by ERM cannot be used for decision making. Several comments are made below and they are divided into two categories of reasoning.

1. The Model Was Not Developed Properly; and
2. Model Performance Was Not Appropriately Evaluated.

Reason 1: Model Was Not Developed Properly

Numerical reservoir water-quality models require numerous types of detailed inputs. This is especially true if one uses a 3-dimensional (3-D) representation of the reservoir, as was chosen by ERM. Issues associated with data inputs, assumptions made, and "adjustments" used in model development are highlighted below and grouped by type of assumption.

Water Balance Assumptions

A complete and representative water balance for a reservoir is important when modeling its water quality. Boysen Reservoir outflow records are good and the best inflow records are for Wind River above the reservoir and Five-Mile Creek. Distributing the inflows correctly is a critical aspect of modeling water quality in Boysen Reservoir, given the wide range of inflow water quality characteristics in the watersheds of this very large reservoir. A tributary with a low flow and poor concentrations can add a significant load to the reservoir, relative to other sources.

1. Little Data, Yet No Flow Data Collection

Aethon spent 5+ years collecting data to support the analyses needed for project approval, yet chose to focus water-quality data collection at a location with a significant amount of data (below Boysen Reservoir)[1]. Aethon did not collect any flow data to ground-truth the distribution of flows among the 9 simulated tributaries. Therefore, many of the tributaries represented by SWAT-generated flows were uncalibrated and highly uncertain. This could have been avoided.

2. Reservoir Evaporation was Ignored in the Water Balance

Evaporation is an important component of the water balance, especially for Boysen Reservoir. Given its surface area and location, evaporation is significant (on the order of 50,000 AF/year[2]). Correctly accounting for evaporation is important when modeling reservoir water quality in that the process of evaporation tends to increase in-reservoir concentrations (constituents are not removed with the water that is evaporated). If a modeler lumps this into other outflows, the model will unrealistically remove constituents with the outflow. The model as delivered to Hydros by ERM is set up to not include evaporation, as indicated by the model setting in Figure 1.

[1] Aethon did take tributary water quality samples on one day in April 2017
[2] Based on reservoir surface area and NOAA (1982)

Figure 1. Screen Capture from Model Setup Interface Sent to Hydros

3. Flow Adjustments Made to Badwater Creek

Because the flows simulated by the SWAT model for Badwater Creek (above the produced water discharges) were so poor, they were decreased and re-distributed (described in Appendix D of the Report). This redistribution was based on comparisons made to historic data and a basin-wide water resources planning model. The differences with respect to the planning model were added to four other tributaries (Birdseye, Cottonwood, Tough, and Unnamed Creeks) – apparently selected since "they have the greatest uncertainty compared to larger creeks that were previously well-calibrated with reliable flow."

- Note that there are two other tributaries with no flow data - Poison Creek and Muddy Creek. ERM chose not to re-distribute flow to these tributaries, yet they also have the same level of uncertainty.
- The four tributaries chosen for flow increases as a result of this adjustment have the best water quality (using ERM assumed concentrations.

Also, ERM notes "the amount of flow redistributed and load increases were considered small."

- If the redistributed loads were "considered small", they would not have had the effect mentioned in Appendix D of the Report. ERM notes "These changes highly benefitted the overall water quality calibration of Wind River Below Boysen Reservoir."

In addition, simulated flows from other ungaged tributaries, were not compared to the planning model and adjusted in the same manner. Thus, tributary flows were treated inconsistently.

4. "Adjustments" Made to Reservoir Inflows from Wind River

The model was set up to "auto-calibrate" the water balance to user-provided surface water elevations (SWEs). Thus, model inflows were adjusted so that the observed SWEs were simulated. When flow adjustments were needed to complete the water balance, flows were from the Wind River above the reservoir were adjusted. This is the site with the most certainty for inflows (along with Five Mile Creek), yet ERM made adjustments at this location.

Meteorology Assumptions

Meteorological model inputs are important for correctly simulating reservoir hydrodynamics and mixing. Of the several meteorological inputs to the model, wind plays a particularly key role and needs to be characterized correctly.

5. <u>Wind Speeds Were Significantly and Unrealistically Capped</u>

The Wind River basin experiences high wind conditions, as displayed in Figure 2 where wind speed is reported in knots. The model as delivered to Hydros by ERM is set up to "cap" wind speeds to a maximum of 5 m/s (9.7 knots) during the simulation, as indicated by the model setting in Figure 1 above.

Artificially reducing the wind speed serves to reduce mixing and increase stratification (something the model has troubles simulating). It appears that the modeler used this cap to make up for other important model development problems. This significant adjustment was not described anywhere in the Report and the reader is led to believe that the values shown in Figure 2 were used.

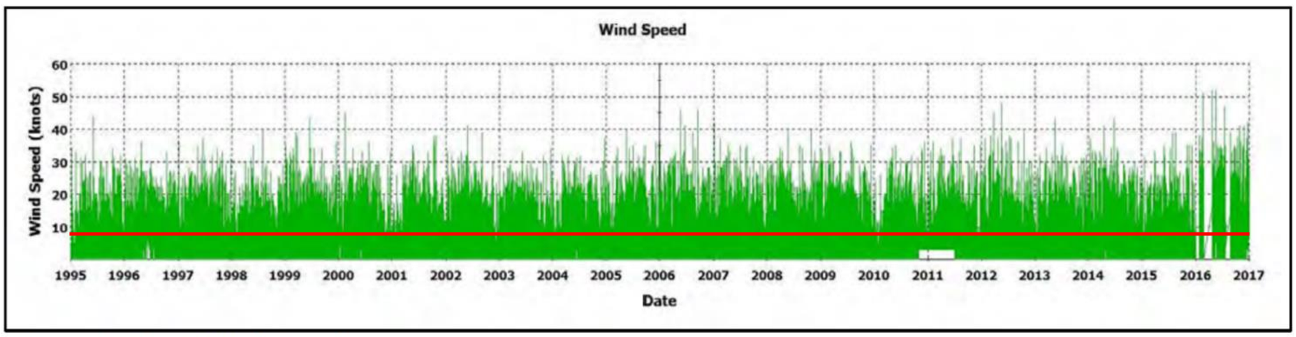

Figure 4-18 Wind Speed

Figure 2. Wind Speed Figure from the ERM Report. Red line added at 5 m/s (9.7 knots)

Inflow Water-Quality Assumptions

It is clear that the water quality of the various inflow sources varies considerably. Thus, it is important to base inflow water-quality assumptions on the best available data. Sometimes, additional data collection is necessary to develop a useable model. This should have occurred for this effort. Some of the assumptions made to make up for the lack of data are described below.

6. <u>Surrogate for Badwater Creek and Lack of Data Collection</u>

Water-quality characteristics of water flowing into the reservoir from Badwater Creek are obviously critical for this effort. It is surprising to know that Aethon spent 5+ years collecting data to support the analyses needed for project approval, yet only collected tributary inflow water-quality data on one day in April of 2017. These often-single data points are the basis for many of the inflow WQ assumptions. And yet, in the case of Badwater Creek, ERM used the one sample from Tough Creek, as a surrogate for conditions upstream of produced water discharges. There is no reason to believe that the water quality in Tough Creek is similar to that of Badwater Creek and no reason is provided as to why sampling did not occur at such a critical location. Again, this could have been avoided. Inflow water quality at numerous locations over time needs to be measured to be able to consider the impacts of the project. Current available data are insufficient.

7. Questionable Use of Method for Quantifying Inflow Concentrations

For some constituents, ERM used the WRTDS (Weighted Regressions on Time, Discharge, and Season) method to describe inflow concentrations for Wind River above the reservoir, 5-Mile Creek, and Muddy Creek (see Appendix F of the Report). The results from using this methodology are questionable and unrealistic in some cases. ERM subjectively capped what was determined to be excessively high concentrations. In addition, odd results sometimes occurred due to extreme values in a single or few data points and certain trends were created that are not described or justified. Examples are shown in Figures 3 and 4. Note that Wind River provides the majority of the inflow into the reservoir (over 70% according to Appendix C of the Report) and its water quality is an important driver of in-reservoir dynamics.

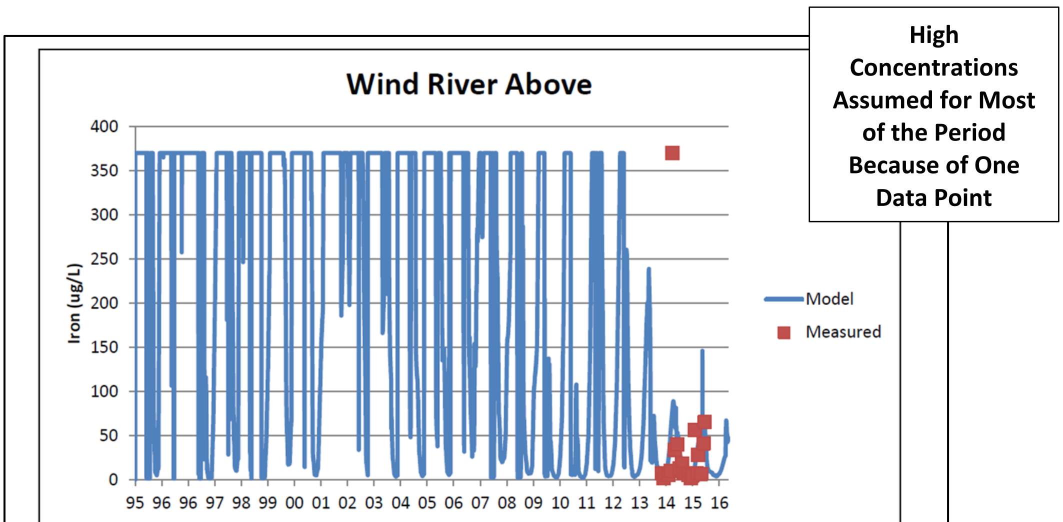

Figure F 12 WRTDS Model Compared to Measured Values for Iron in Wind River Above

Figure 3. Assumed Iron Concentrations at the Wind River Above Boysen Reservoir (from Report)

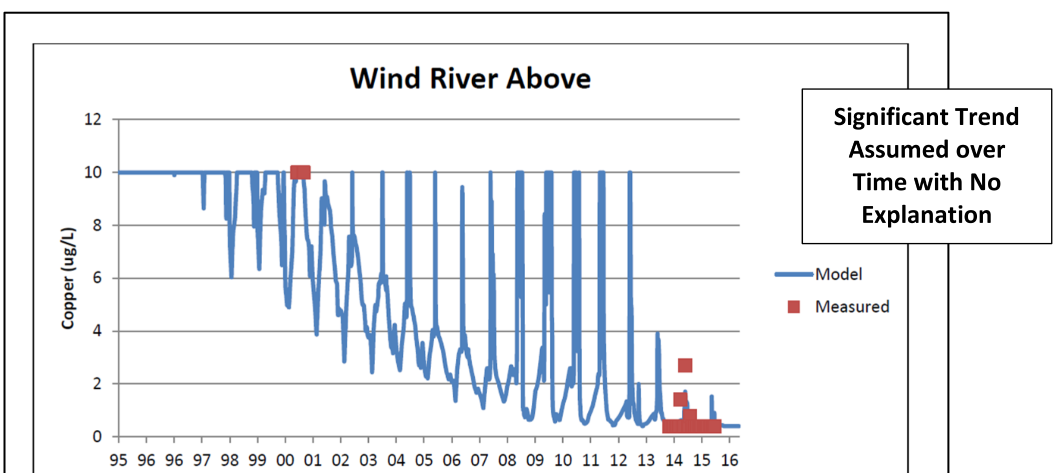

Figure F 9 WRTDS Model Compared to Measured Values for Copper in Wind River Above

Figure 4. Assumed Copper Concentrations at the Wind River Above Boysen Reservoir (from Report)

8. Assumption of Permit Concentrations

In several instances, ERM assumed that the water quality of the produced water was at permit limits for the calibration and validation period. This could be far from actual conditions during the 22-year period. The purpose of calibration and validation is to recreate what actually happened. Using permit limits for calibration needs justification.

9. Dividing up Badwater Creek into Four Sources

It is very odd that ERM chose to separate the flows into Badwater Bay into four distinct sources (Badwater Creek above Alkali Creek, Burlington, Aethon, and Neptune) and have them all entering the same location of the model grid. It is even more confusing to know that some level of treatment at Neptune has been occurring historically but treatment details and flow amounts over time are not described in the Report. Nor can this information be inferred from the model input files. In addition, samples exist for Badwater Creek ~ 5 miles above the reservoir (where the sources are already mixed and is more representative of what is actually flowing into the reservoir) and these samples are not considered by ERM. For calibration, it is important to capture the blended source of water entering the reservoir at this location. It is unclear why ERM developed the model in this manner, when it could have been considered in a more straight-forward way.

Inflow Placement into the Reservoir

Tributaries can enter a particular reservoir differently depending on the density of the inflowing water (Figure 5). The higher the salinity, the higher the density of the inflowing water. Since produced water has very high salinity, it is important to capture inflow placement dynamics correctly for this effort, given:

- the increase in density of the inflow water at Badwater Creek Bay with the proposed project;
- the potential for the diving of inflows as an underflow; and
- the low-level outlet works at the dam.

<u>Thus, there is the potential for impacts to the releases downstream that exceed average impacts in the reservoir.</u> Most commonly-used hydrodynamic reservoir water-quality models simulate these types of dynamics.

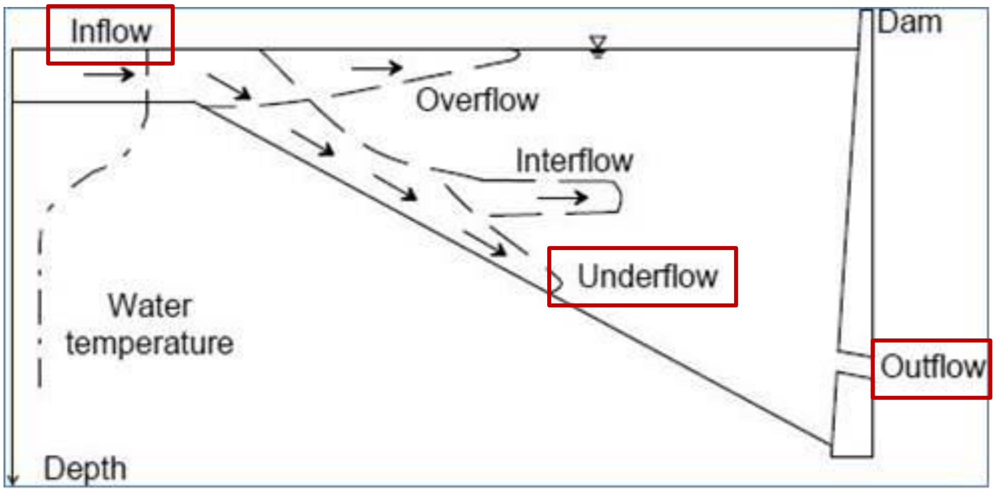

Figure 5. Generic Reservoir Graphic Showing Density Currents and Possible Inflow Patterns

10. <u>Mischaracterization of Inflow Placement</u>

Although ERM describes the importance of water density and transport processes, the model was not set up to distribute inflows vertically based on the density of the inflow and the density profile of the water in the reservoir. Instead, tributary inflows enter each 2-foot layer of the model grid uniformly[3]. Thus, changes to the density of the inflows (through salinity and temperature changes) from the project <u>do not</u> correspondingly change the vertical distribution of the inflows in the model. This is a serious flaw to the model as flows into Badwater Bay will tend to enter the reservoir lower in the reservoir with the project. This may affect water released at the dam through the low-level outlet differently than it has historically. Also, inflow placement assumptions made by ERM are not described in the Report (as they should have) and were only determined based on review of model files.

Representation of Reservoir Releases

Releases from Boysen Reservoir to the Wind River occur at two different locations. Flow through the low-level outletworks (at 4,657 feet; USDOI, 1981) provides water to the penstocks for power production. This is the dominant means of withdrawal due to the potential to generate power. Spilling of water near the top of the reservoir can occur if the SWE is above 4,700 feet.

Water leaving through the outletworks (OLW) can have very different characteristics from water leaving via the spillway, due to vertical variations in water quality characteristics, especially during the stratified period (Figure 6). Thus, outlet operations have a direct impact on water quality in the Wind River below Boysen Reservoir (Class I). Most 2-dimensional (2D) and 3-dimensional (3D) reservoir models (including

[3] The control file specifies that for each inflow, the vertical limits are the bottom of the reservoir at the location of the inflow and the water surface. There are no options in the user interface for setting up the control file to select or determine if the placement of the inflows within these boundaries is uniform or density-based. However, based on review of the snapshot output files (e.g., the file received for the calibration run output named "Final Calibration_Restart.snp"), it was clear that the flows output by the model in the "Discharge Boundary Condition" section of the snapshot file that correspond to the inflows are uniformly distributed in the vertical direction.

GEMSS) have the capability to compute a withdrawal zone from which only certain layers contribute to the outflow, based on each structure, each outlet flowrate, and in-reservoir water density. This methodology has been developed to replicate how water is physically discharged from a reservoir. The model can then take that information and output the resulting water quality in the downstream river.

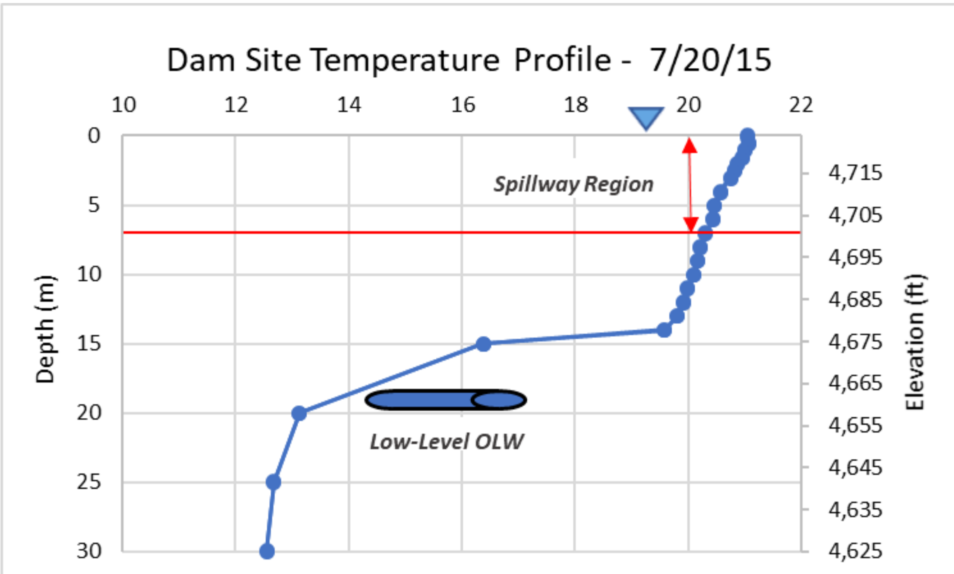

Figure 6: Temperature Profile Showing Stratification and Elevations of Releases (OLW = Outletworks)

11. Mischaracterization of Reservoir Release

Although the GEMSS model software includes the ability to characterize different structures and compute withdrawal zones, the modelers chose to release water uniformly in the vertical direction within each column - from the top layer of the reservoir to the bottom layer[4]. Thus, there is no differentiation between the outletworks and the spillway and outlet operations that control downstream water quality are completely ignored. Again, this is a serious flaw. Also, the assumptions made are not described in the Report and were only determined based on review of model files.

Reason 2: Model Performance Was Not Appropriately Evaluated – Erroneous Conclusions Reached

After the model was completed, ERM compared the results to certain targets to show that the model was calibrated, validated, and adequate for use to prediction of future conditions with the project. There are several instances where misleading information is provided. The reservoir model cannot be

[4] For the outflow, the control file specifies that the vertical limits are the bottom of the reservoir at the location of the outflow and the water surface. There is an option to choose either density placement or area-based placement of the outflow within these vertical boundaries. The area-based option was chosen in the control file, as provided. Review of the snapshot output also reveals that the area-based option is equivalent to the vertical uniform distribution of flow for each column of cells where the outflow takes place. Because the outflow takes place in two columns of cells located at the dam of the reservoir, and one column is deeper than the other one, the net vertical distribution of flow is not completely uniform. It is uniform from the water surface to the bottom of the shallowest column and between the bottom of the shallowest column and the bottom of the deepest column. However, overall, there is more flow coming from the upper layers than from the bottom layers, when in reality, more water is likely to flow out from deeper sections due to the low-level outlet location.

considered to be calibrated or adequate for simulating water quality in-reservoir or downstream in the Wind River.

Evaluation and Reporting of Wind River Simulation Results

The focus of the work conducted by ERM is to ensure protection of the downstream Class I segment of the Wind River. Analyses were conducted to determine produced water flows that would meet antidegradation requirement at that location. Thus, a very critical part of the analysis involves the quantification of model results for release water quality.

12. Evaluation and Reporting of Wind River Results are Wrong and Misleading

Through review of the model files, our team determined that the graphs displaying calibration and validation results for the Wind River below the reservoir are misleading and severely flawed. An example graph for temperature is shown in Figure 7. The top of the graph is labeled as "Outflow" and the caption says "Wind River Below Boysen Reservoir." The data (green markers) are reportedly Aethon's temperature measurements in the Wind River below the dam. The reader is led to believe that the blue line represents the temperature of the water released from the reservoir (via the low-level outlet and/or the spillway) and delivered to the river.

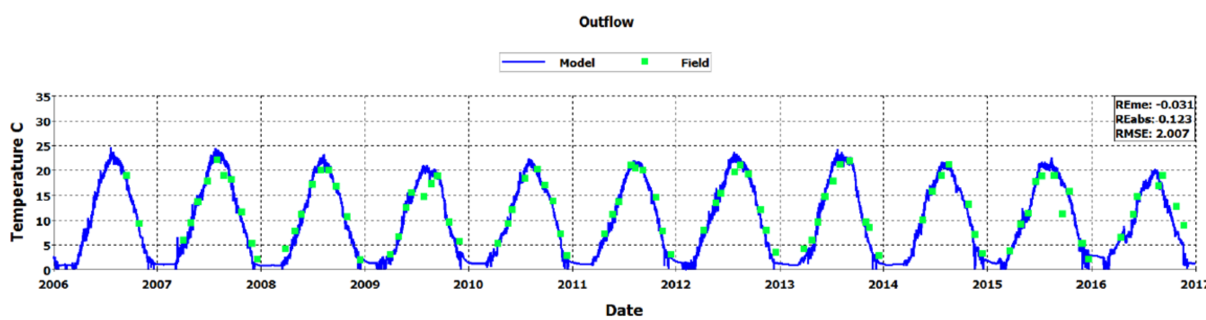

Figure J 3 Wind River Below Boysen Reservoir Temperature Calibration at Surface Level

Figure 7: Temperature Calibration Figure for Outflow (from Report)

According to the model files, the blue line actually represents the simulated temperature at the top model layer (~top 2 feet) of the most downstream location (at the dam). This is wrong and misleading and it is unclear why this was done. Note that ERM added "at Surface Level" at the end of the caption (Figure 7) and perhaps thinking this makes it not misleading, even though there is a low-level outlet used for power production?

This is a very serious problem since the water quality at the top two feet of the reservoir is being represented as Wind River water quality and there are observed (but not simulated) vertical variations in the reservoir. In reality, the water quality at the top of the reservoir is often different from the bottom of the reservoir[5] (see Figure 6). Since water is removed predominantly through the low-level

[5] See Figure 6 as an example for temperature. Many other constituents (e.g. iron, manganese, arsenic) often show significant differences in top versus bottom concentrations in a reservoir, especially during stratification.

outlet, Wind River water quality would generally reflect the water flowing through that outlet or a combination of lower level releases and spills[6].

An example of temperature variations in a stratified reservoir is provided in Figure 8. The location of the outlet is an important factor in determining the water quality of the river downstream. ERM mistakenly compared the simulated reservoir surface temperature (top 2 feet) to the samples in the Wind River.

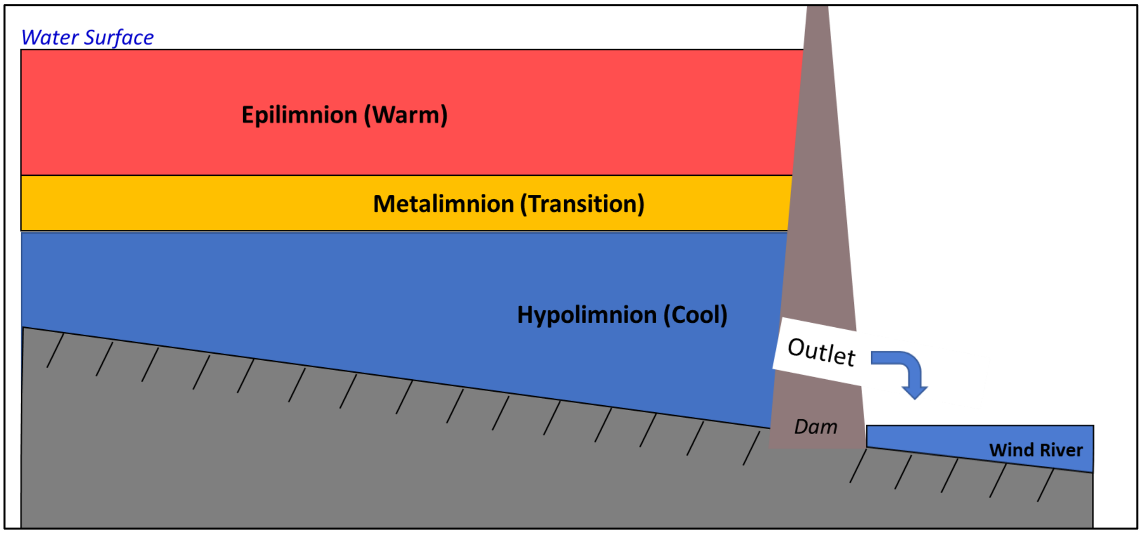

Figure 8. Temperature Differences in a Stratified Reservoir

If the modeler had differentiated between the outlets and simulated withdrawal zones, the release water quality output file would have reflected these dynamics. This was not done by ERM and incorrect and very misleading comparisons were made.

Choice of Observed Dataset Used for Comparisons

During calibration/validation, comparisons are made between observations and simulation results. Thus, the observed dataset used is important when evaluating model performance.

13. <u>ERM Removed Numerous Observed Data Points from Analysis without Justification</u>

There are several cases where measured data were removed from the analysis without justification. A few examples are highlighted below:

Removal of In-Reservoir Data

Table 5-2 of the Report includes a list of all available data for calibration and validation in Boysen Reservoir (Figure 9). A footnote at the bottom indicates that more than 300 data points were excluded after "thorough QA/QC." There is no discussion to justify the exclusion of all data associated with 15 constituents in the reservoir. The only data that were kept and considered were profile data (conductivity, pH, and temperature).

[6] Unless an outage or maintenance resulted in flow restrictions through the low-level outlet.

As a result, for the reservoir, there is absolutely no calibration or any ground-truthing of numerous constituents, including TDS, chloride, sulfate, and numerous metals.

Table 5-2 Available Data for Calibration and Validation within the Reservoir

Parameter	Total # of Stations	Total # of Data Points	Date Range	Vertical Profiles Available
Aluminum (µg/L)	0	0	N/A	No
Arsenic (µg/L)	1	4*	1999 only	No
Barium (µg/L)	0	0	N/A	No
Boron (µg/L)	0	0	N/A	No
Calcium (mg/L)	1	32*	1999-2001	No
Chloride (mg/L)	1	59*	1999-2006	No
Chromium (µg/L)	0	0	N/A	No
Conductivity (uS/cm)	10	1226	2002-2016	Yes
Copper (µg/L)	1	4*	1999 only	No
Fluoride (mg/L)	1	32*	1999-2000	No
Iron (µg/L)	1	4*	1999 only	No
Magnesium (mg/L)	1	32*	1999-2000	No
Manganese (µg/L)	1	4*	1999 only	No
Mercury (µg/L)	1	4*	1999 only	No
Nickel (µg/L)	1	4*	1999 only	No
Oil and Grease (mg/L)	0	0	N/A	No
pH	11	1404	1999-2016	Yes
Total Petroleum Hydrocarbons mg/L)	0	0	N/A	No
Total Suspended Solids (mg/L)	1	33*	1999-2001	No
Radium-226 (pCi/L)	0	0	N/A	No
Sodium (mg/L)	1	32*	1999-2000	No
Sulfates (mg/L)	1	32*	1999-2001	No
Sulfides (µg/L)	0	0	N/A	No
Total Dissolved Solids (mg/L)	1	61*	1999-2006	No
Temperature (°C)	10	1343	2002-2016	Yes
Total Hardness (mg/L)	1	33*	1999-2001	No

*These data points were excluded from the analysis after a thorough QA/QC process was performed

Figure 9: ERM Table Indicating that Over 300 Data Points were Excluded

Removal of Winter Data

Although water-quality impacts in the spring through fall period are very important, the winter period is critical. Due to low tributary flows in the winter, any produced water added will result in the highest % effluent in Badwater Creek (and highest changes in salinity, etc.), as it enters the reservoir. ERM chose to exclude winter data, with no valid justification. ERM states:

> *"temperature data overlapping with model predicted periods of non-zero ice thickness were excluded from the calibration and validation comparisons to field data. This is because grab sample measurements recorded during predicted periods of ice cover are highly uncertain. The uncertainty arises because these samples could have been taken from localized areas that may not have ice or may have been collected from below the ice cover. These field measurements did not contain such information and were deemed unsuitable for comparison to model results."*

The reasons given for exclusion do not make sense and this is unconventional. In fact, several studies focus on accurate modeling under ice-cover conditions and/or simulated conditions over a number of years and include data collected during ice cover (e.g., Brodzeller and McGinley, 2016; LimnoTech, 2016; Hydros Consulting, 2017). It is suspect that ERM chose to remove data from a critical period for this project.

The percent of produced water in the inflow from Badwater Creek into the reservoir (using flows from ERM input files) is displayed in Figure 10. Results from the calibration model run are shown along with the three compliance analysis cases considered by ERM. Large increases are seen in July and August and maximum levels are reached in December and January. The highest percentages occur in the winter months and reach values of over 90% produced water under Case 03 (the case considered in the Statement of Basis). These periods are when “maximum concentrations entering Boysen Bay and the reservoir” occur, as noted by ERM. We acknowledge that a portion of the water is to be treated, but also note that concentrations of several constituents are not reduced via treatment (examples include arsenic, chromium, nickel, magnesium, manganese, copper, sulfide, and mercury – Table 6-4 in the Report).

Winter conditions are critical for this analysis and ERM’s exclusion of winter data is unwarranted and wrong.

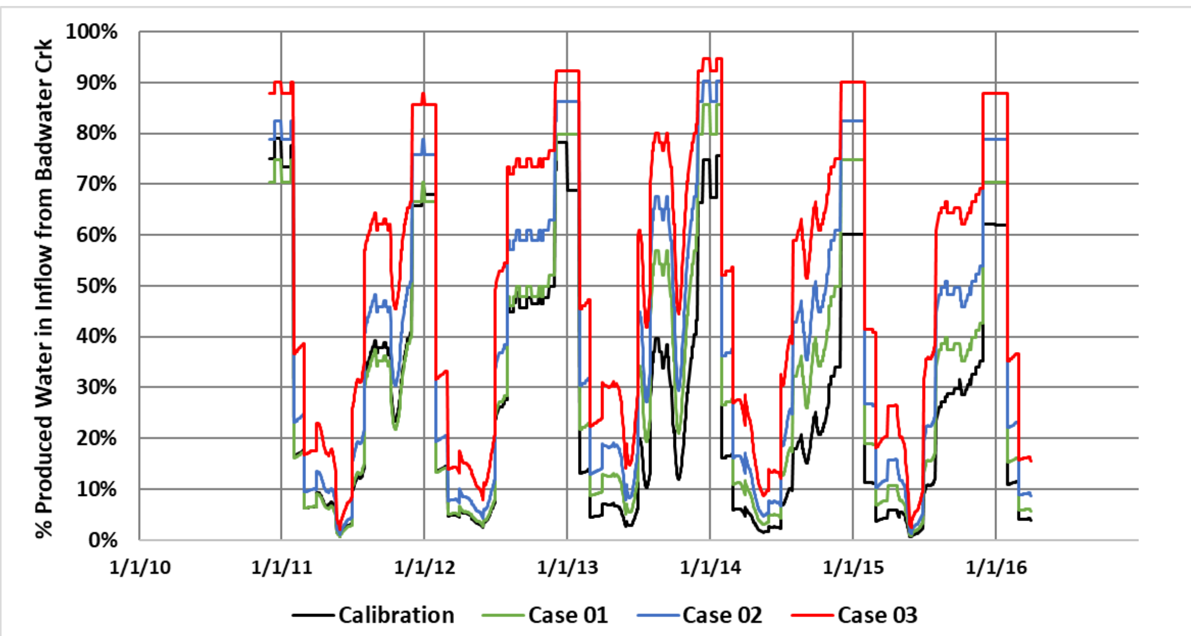

Figure 10: Proportion of Produced Water in the Inflow from Badwater Creek into the Reservoir

Reservoir Model Calibration Targets

Calibration targets are used to evaluate model performance and to determine if the model can be used for desired purposes. This is an important aspect of model development.

14. ERM Used Overly-Lenient Calibration Targets

In Section 5.4 of the Report, ERM describes the calibration targets used to evaluate the reservoir water-quality model.

> *"EPA-based metrics for evaluating watershed model performance (Donigian 2000) were used to evaluate the GEMSS model performance for important water quality parameters to the study."*

Although they are evaluating a reservoir model, ERM chose to use targets that were developed for watershed modeling, specifically HSPF. It is easier to more accurately simulate reservoir dynamics than watershed dynamics, due to the smaller spatial scale and greater homogeneity of the physical environment represented. Thus, calibration targets used for reservoir modeling are more stringent and should have been used for this effort. For example, developers of the well-used CE-QUAL-W2 model (from which GEMSS is reportedly based on) note that temperature simulations (important for simulating flow patterns accurately) should have an average mean absolute error within 1 °C. This means that the simulated model value is, on average, within 1 °C of the measured temperature. This target is met by numerous model applications of CE-QUAL-W2 (Cole and Wells, 2016 lists 70 applications in Table 4).

Given that the Boysen Reservoir is developed in 3 dimensions (versus a using 2-dimension assumption for CE-QUAL-W2 applications), one could expect the targets for Boysen Reservoir could be more stringent than the ones used in W2. Note that the commonly-used temperature target for reservoirs is not met by the Boysen Reservoir application (at least at the dam). This indicates that the model is not performing well enough to be called calibrated or adequate for making predictions.

In addition, ERM represents "% differences" in a manner that is highly unusual, dividing the mean of the RMSE by the average model prediction. It is unclear why this metric was created and used for this effort. In addition, ERM does not present the % differences computed. Only the final categories are presented (fair, poor, etc.) for a particular constituent. Thus, the actual % differences computed are not disclosed anywhere in the text, which results in lack of transparency.

Display of Results

Modeling results need to be complete and transparent. This is not the case for the Report reviewed.

15. Information Was Concealed by Limiting Bottom Elevations Displayed on Profile Graphs

In-reservoir observed and simulated results are shown in the Report in Appendices J and K for temperature, TDS, and pH with depth. All of the graphs provide data and results for elevations above 4,680 feet. This elevation is not at the bottom of the reservoir (at least near the dam) and cutting off the elevations in the figures leads the reader to assume that the reservoir is typically well-mixed summer and does not stratify or have much vertical variation. In addition, the model results show something similar. An example is shown in ERM's Figure K 39 (Figure 11) for July 30, 2002 near the dam, where the reservoir appears to be well-mixed with good model predictions (and hot from top to bottom).

However, the full profile of observed data indicates stratified conditions (Figure 12). In addition, Figure 12 shows that ERM failed to display about 90% of the observed profile. The bottom of ERM's model grid at the calibration location is also indicated, showing that the model grid is not deep enough near the dam. Nor is it deep enough to reach the lower-level outlet. This also highlights significant issues with the development of the model grid (which isn't deep enough to reach the lower-level outlet).

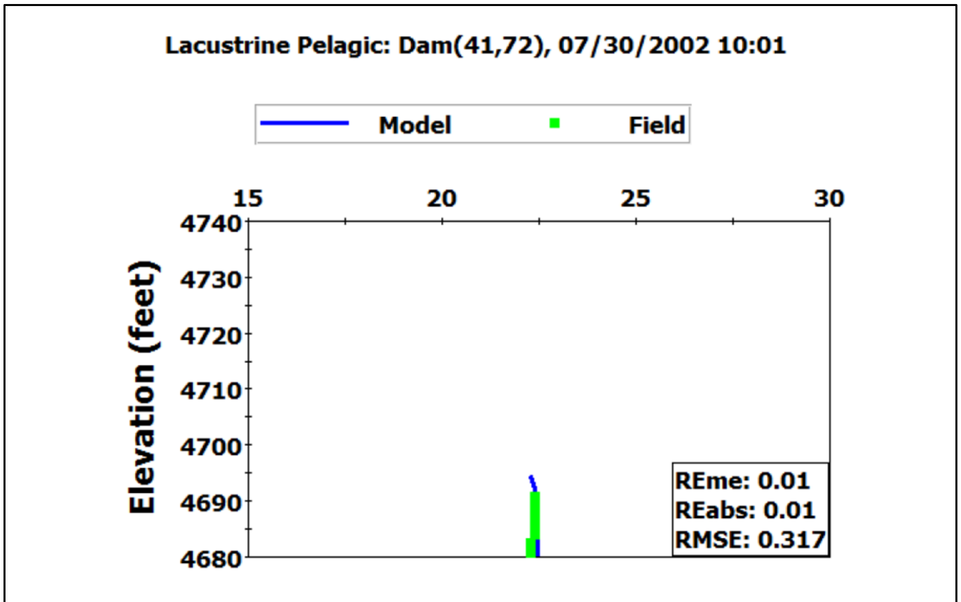

Figure K 39 Vertical Profile Temperature Validation at Lacustrine Pelagic on July 30, 2002

Figure 11. ERM's Figure Showing Observed and Simulated Temperature Profiles

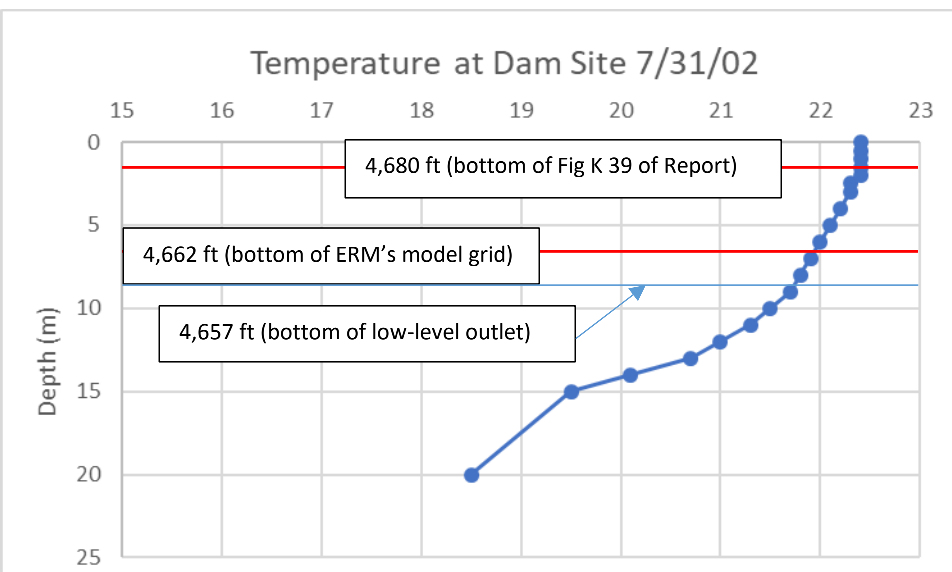

Figure 12. Full Profile at the Calibration Site Closest to the Dam

16. <u>Information Was Omitted by Failing to Include All Profile Dates</u>

In-reservoir observed and simulated results are shown in the Report in Appendices J and K for temperature, TDS, and pH. Several profiles were omitted, including temperature profiles near the dam for 2014-2016. It is not clear why this is the case.

Actual Model Performance

17. <u>Simulation Results are Poor</u>

Capturing observed flow patterns and hydrodynamics with the model is important. This is necessary to be able to use the model to predict conditions with increased flows at higher concentrations at Badwater Creek. Fortunately, a few temperature and specific conductivity profiles are available. Both of these constituents are good indicators of flow and thermal patterns and hydrodynamics.

Even though a number of adjustments were made during model development and calibration, the model results are very poor. Temperature profiles near the dam (Figure 13) show that the model is not capturing observed stratification in the summer and shows very little variation top to bottom. Reservoir temperature calibration is an initial and very important step in modeling. Recall that water in Boysen Reservoir is released to the Wind River via a low-level outlet (elevation 4,657 ft) and an upper spillway, at times. This makes it even more critical to be able to capture the vertical variations. As described earlier, using commonly-accepted calibration targets, the ERM model is not adequate for use. Also note that the bottom of the model grid at this calibration location is so high that water in the bottom 35 feet of the reservoir is ignored. Thus, water quality in this region (near the lower level OLW) is not even simulated.

Instances where modeled outflow temperatures to the Wind River correspond closely with observed temperatures downstream are strong indications of poor reservoir model performance. This is because the observed temperatures were compared to the temperatures at the top 2 feet of the reservoir near the dam, as described previously. The observed downstream temperatures should be the result of outflows that depend on release location (low level outlet, spillway), amount released at that location, and vertical density distribution. Thus, even when the reported model results seem to be acceptable, they are not generated as a result of a physically realistic simulation. <u>This renders modeled predictions at the Wind River Class I segment unreliable.</u>

Specific conductivity profiles are shown in Figure 14. Again, the vertical variations are not captured and sometimes the magnitudes are overestimated by 100's of uS/cm. Note that most of these are in mid-summer, when the % produced water increases (see Figure 10).

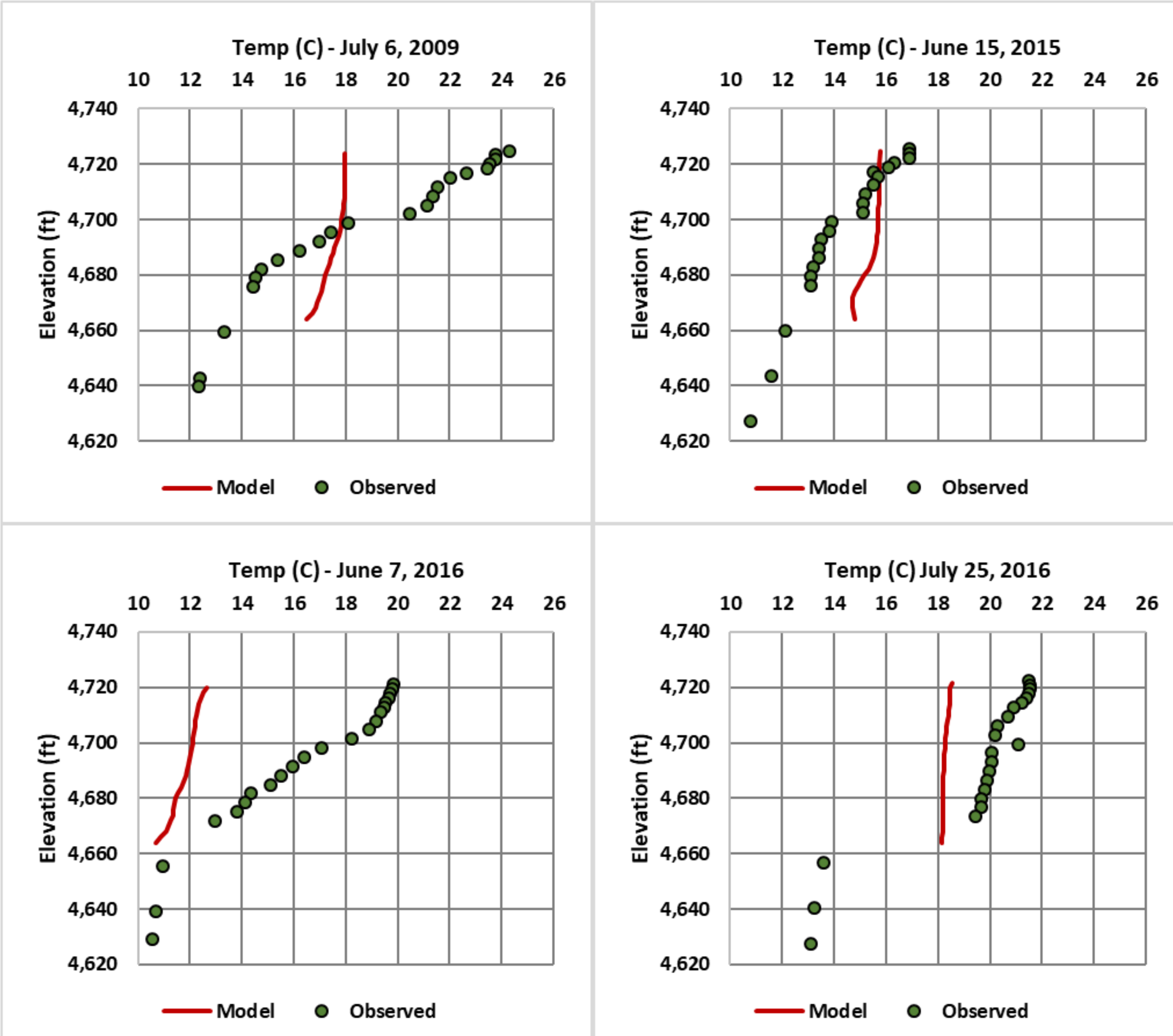

Figure 13. Example Temperature Profiles Displaying All Observations and Model Results from Top to Bottom of the Reservoir. Data from Lacustrine Pelagic: Dam Site

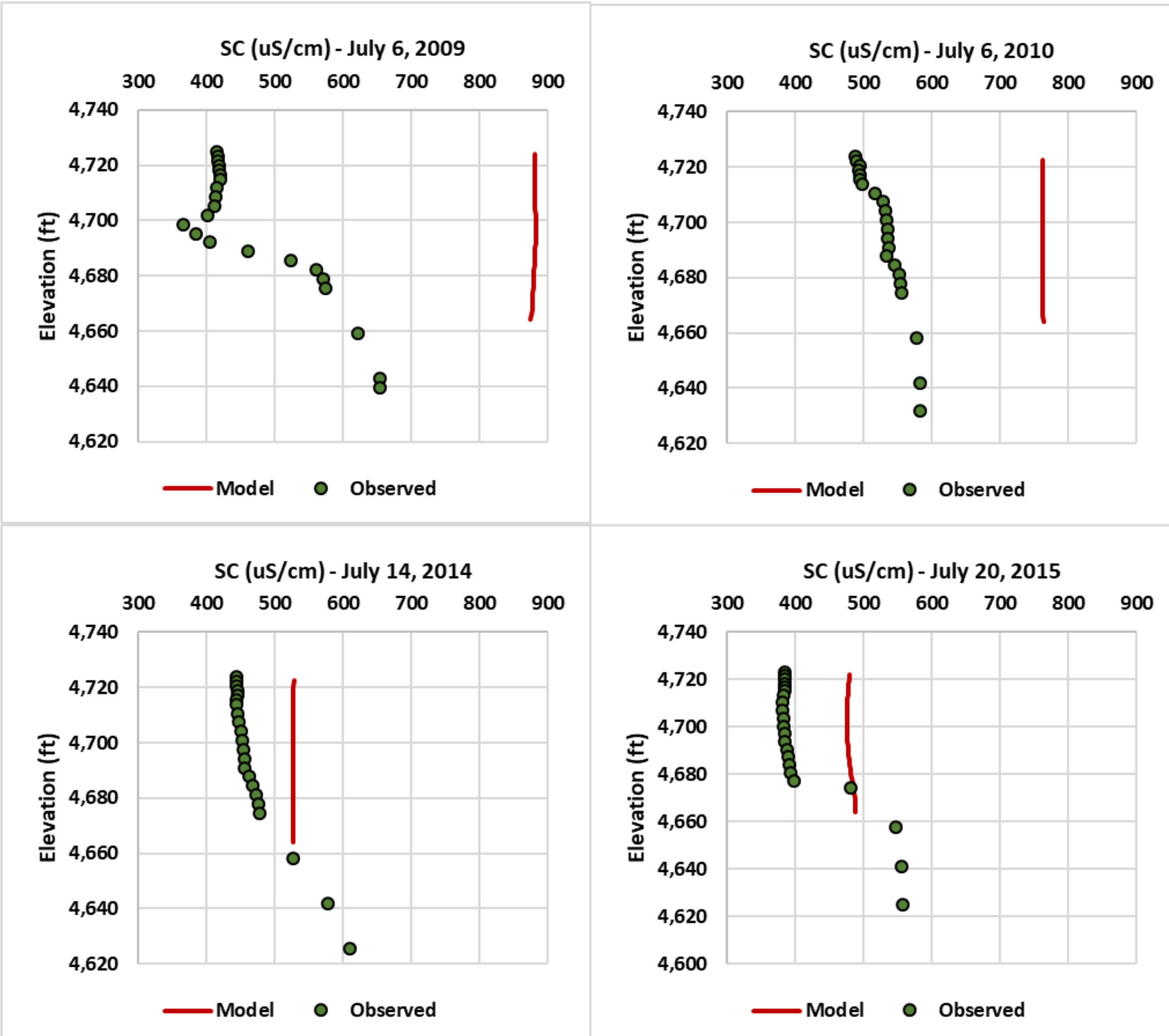

Figure 14. Example Specific Conductivity Profiles Displaying All Observations and Model Results from Top to Bottom. Data from Lacustrine Pelagic: Dam Site

MAJOR POINT: "COMPLIANCE ANALYSIS" METHODS AND FINDINGS ARE INCORRECT

Even if the reservoir model was developed adequately, the methodology used by ERM to evaluate compliance is severely flawed and is biased. Comments below are considered in 3 areas:

1. Data Used to Define Baseline Conditions in Class 1 Section;
2. How ERM Shows Compliance; and
3. Boysen Reservoir Antidegradation.

Data Used to Define Baseline Conditions in Class 1 Section

Baseline conditions in the Wind River are very important because these conditions are the basis for protection.

18. ERM Failed to Use USGS Data for Defining Baseline in Class I Segment

Only Encana/Aethon-collected data were considered when defining baseline conditions for the Class I segment of the Wind River. Yet, there are hundreds of approved water-quality measurements from the USGS below the reservoir for the period ERM defined as baseline (December 2010 – March 2016). Approved USGS data are considered to be of very high quality. In some instances, there are more data from the USGS in this period (Encana/Aethon did not report data for 8 months of the baseline period; Figure 15). In addition, there is much more variability in much of the data collected by Encana/Aethon than the USGS (see Figure 15 as an example). This variability would serve to increase a standard deviation.

In addition, the Encana / Aethon baseline data provided to Hydros Consulting did not appear to be raw data. The forms of the constituents were not noted (dissolved or total). The dates were often the 1st of the month and appear to be reported as a monthly value. The values could be averages or single points, and this is not clear. Aethon switched labs (going from "Lab 1" to "Lab 2") in November 2013. This resulted in an increase in detection limit for 12 of 14 metals, most of which were already below detection limits.

Baseline conditions should be defined using USGS data which is of higher quality and more complete, in most cases.

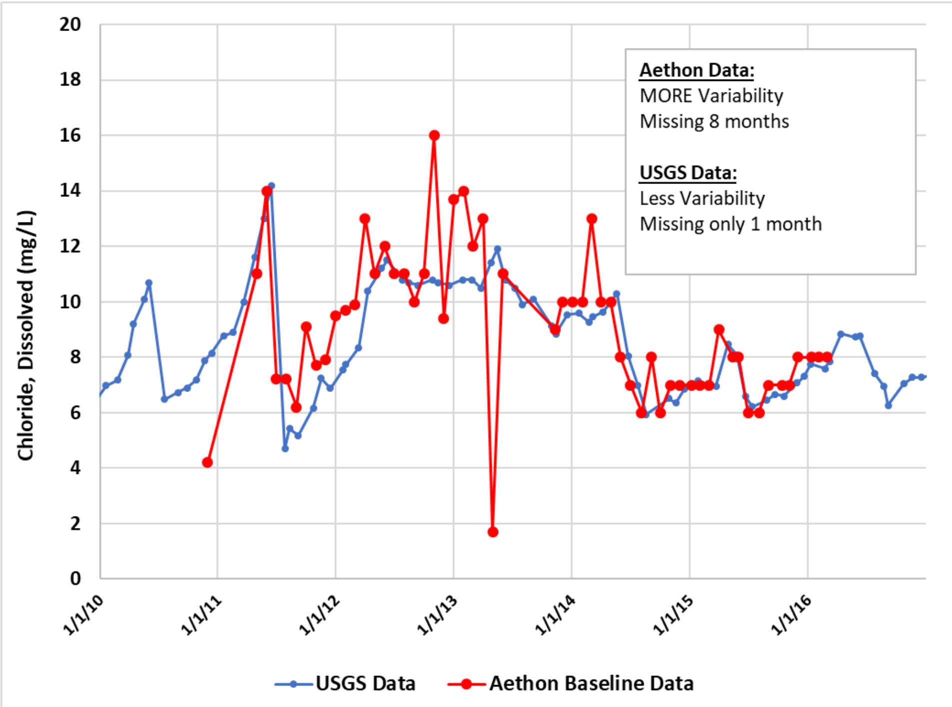

Figure 15: Chloride Observations in the Wind River below Boysen Reservoir (2010-2016)

How ERM Shows Compliance in Class I Segment

19. <u>Used Monthly Averages, Obscuring Results</u>

ERM chose to complete the compliance analysis on an average monthly basis. So, all Januarys are averaged together, Februarys are averaged together etc. This method lumps the data, reduces observed variability, and also serves to hide important differences that occur year-to-year, especially since time-series of the results are not displayed. This point is illustrated for chloride in Figure 16.

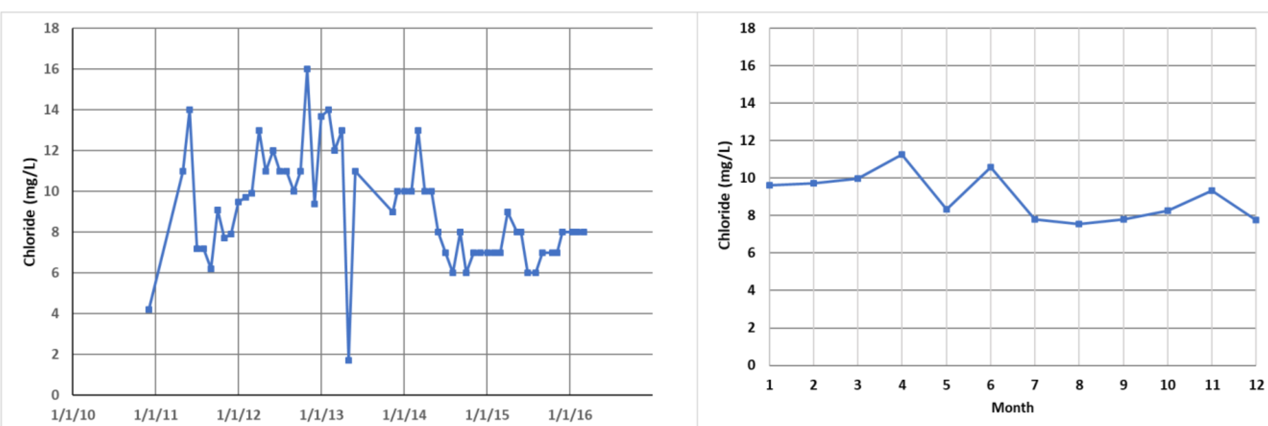

Figure 16: Chloride Measurements, Wind River Below Boysen Reservoir, Aethon Data. Individual Measurements (Left); Lumped Average Monthly Values (Right); Illustration of Reduction in Variability.

ERM did display chloride results in an attempt to justify the model "spin-up" period and to only focus on model results from December 2010 – March 2016 (Figure 17). Note that the project results in lower chloride concentrations in the "outflow" (top 2 feet of the reservoir) in 2010-2011.

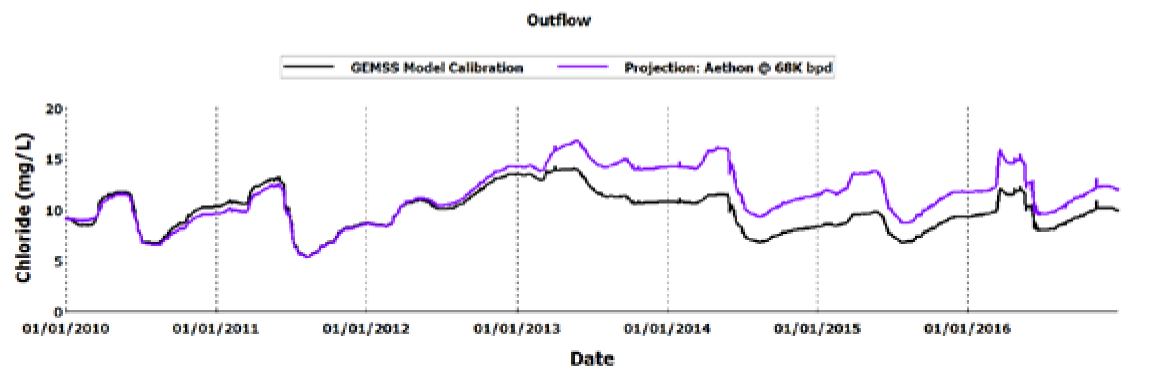

Figure 6-4 Projected Chloride Concentrations Compared to the Calibrated Model to Demonstrate the Model Spin-Up Period

Figure 17. Model Output for "Outflow" (Top 2 ft of the Reservoir); Model Calibration and Case 01

The results are clearly not due to "spin-up" if one considers the flow inputs into the model (Figure 18).

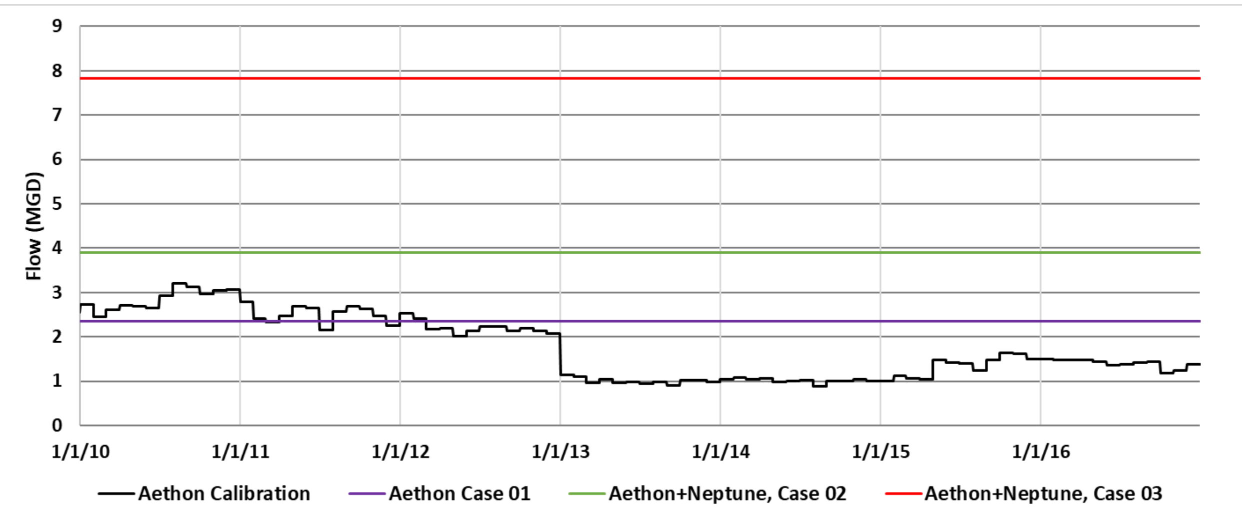

Figure 18. Aethon Produced Water Flowrate Assumptions

Because the projection flows (68,000 bpd; Case 01) are lower than what actually occurred in 2010 and 2011, the model shows an improvement (lower concentrations) with the project. Starting in 2013, when the projection flows are much higher than the actual, the model shows some significant increases in concentrations (Figure 17).

This is an additional illustration as to why the method of lumping into monthly averages is inappropriate. In this case, the conclusion reached depends on the period analyzed. If one only considered the period 2010 – 2012, the results would show an improvement with the project. If, on the other hand, one only considered the period 2013-2016, the results would show a greater impact than reported in the Report.

The analysis should be presented on a daily basis so that periods of larger impact are transparent. For example, from Figure O 1 (Figure 19), the reader could assume that April concentrations may only increase by up to 2.7 mg/L chloride, while the time-series data (Figure 17) show increases of up to 4.6 mg/L at times.

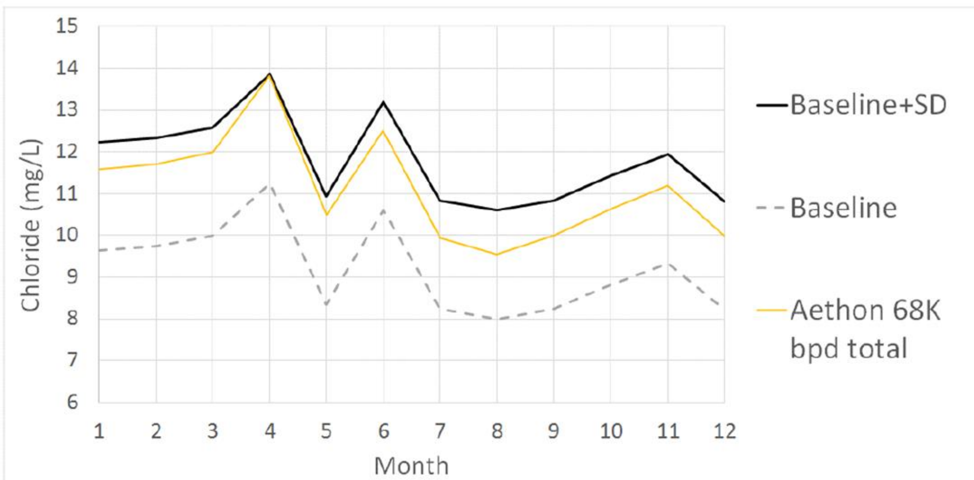

Figure O 1 Chloride Resulting in Wind River Below Boysen Dam from Aethon's Projected Discharge of 68,000 bpd Total (Modeling Case 01)

Figure 19. ERM Figure Showing Impact of the Project for Case 01

20. <u>Used Inflated Standard Deviation</u>

As described above, ERM chose to conduct the analysis on a monthly basis. If this is done to quantify the baseline and if the analysis is to be based on a standard deviation, the estimate of the baseline + 1 standard deviation (SD) must be performed using the SD of the lumped monthly data. ERM chose to use the SD of the original data points. This is incorrect and results in allowing a greater load to the reservoir.

For the example above (Figure 16), the SD for the un-lumped data (left) is 2.7 mg/L, while the SD for the lumped data (right) is 1.2 mg/L. This makes a considerable difference in the antidegradation analysis, since the larger SD allows for larger decreases in water quality (Figure 20).

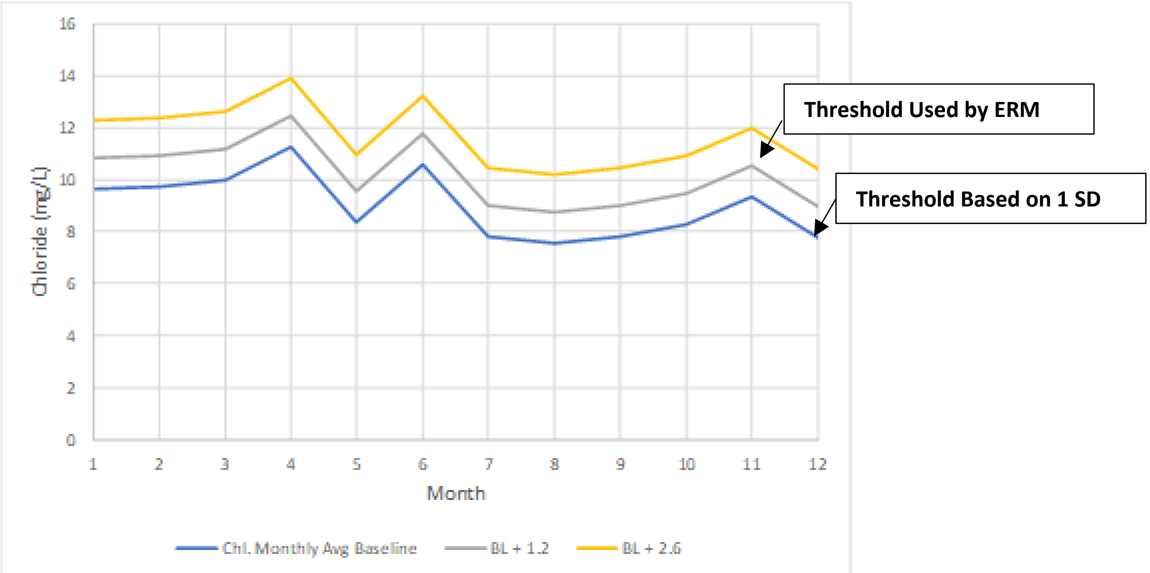

Figure 20. Impacts of Different Standard Deviations

21. Favorable Assumptions Made for Category III Constituents

ERM created an analysis category to include constituents that are present in Aethon's discharge above required detection limits, yet are often below detection limits (more than 50% of the time) in the Wind River below the reservoir. This was called Category III and includes total chromium, dissolved copper, dissolved nickel, dissolved aluminum, and dissolved mercury. ERM chose to evaluate these constituents for compliance by:

- Taking the model results simulated at the top 2 feet of the reservoir near the dam. (which is not representative of the outflow)
- Lumping the results together on a monthly basis and averaging (thus removing observed variability and eliminating the need to display a time series of results and changes each year)
- Comparing the results to the detection limit.

ERM noted that the detection limits varied over time (since they changed labs in 2013, most often resulting in an increased detection limit for some reason), so the decision was made to use the maximum detection limit. Issues associated with this decision include:

- It makes it easier to show compliance; and
- It is inconsistent with use of ½ the DL in the rest of the analyses.

As an example, more detail is provided here for dissolved nickel. For the Aethon sampled Wind River data (which was exclusively used to determine baseline versus using USGS data), the detection limit was 0.5 ug/L from December 2010 through June 2013. Then a different lab was used for November 2013 – March 2016[7] and reported a 5 ug/L detection limit. It is not clear why the detection limit would

[7] No data were collected for the 4-month period between July 2013 – October 2013.

increase, in light of the fact that of the 27 samples collected before the lab change, 13 were below the detection limit[8].

Using the approach developed by ERM, the results are displayed as Figure O 28 in Appendix O (see Figure 21). Using the threshold of 5 ug/L (based on the 2nd lab's detection limit), it appears that the project will not result in degradation in the Class I section. However, if the lab change had not occurred (or if the minimum DL was chosen), then the conclusion would be that degradation would occur.

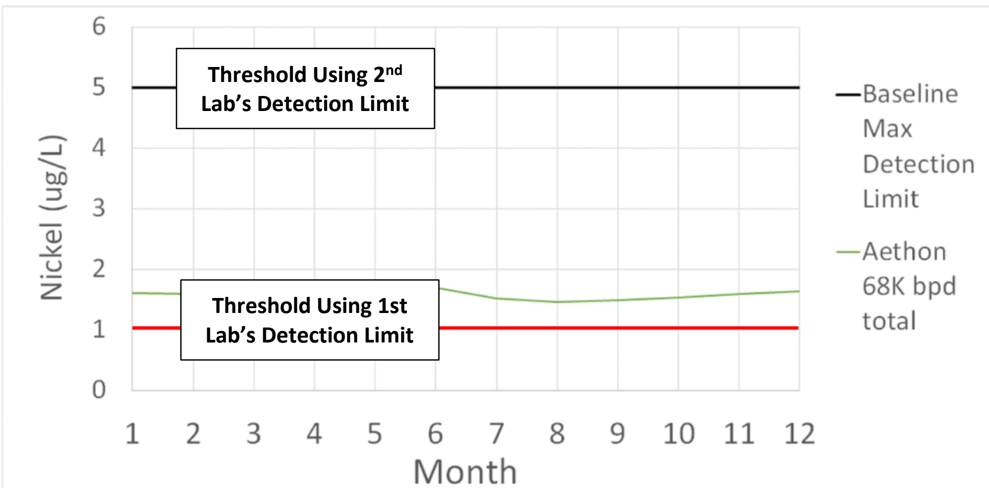

Figure O 28 Nickel Resulting in Wind River Below Boysen Dam from Aethon's Projected Discharge of 68,000 bpd Total (Modeling Case 01)

Figure 21. ERM Results for the Compliance Analysis for Dissolved Nickel (Red Line and Two Text Boxes Added)

Overall, this method and its implementation are flawed.

22. Created Alternative Threshold for Aluminum

Extending the discussion for Comment 22 for an in-depth look at how dissolved aluminum was evaluated (another Category III constituent), it appears that an alternative tactic was used. For this constituent, the 1st lab's detection limit was 4 ug/L and the 2nd lab's detection limit was actually lowered to 3 ug/L. The observed data are shown in Figure 22, along with USGS data for comparison (which were not considered to quantify baseline conditions).

[8] Although it is interesting that the 50% threshold for Category III constituents was being approached.

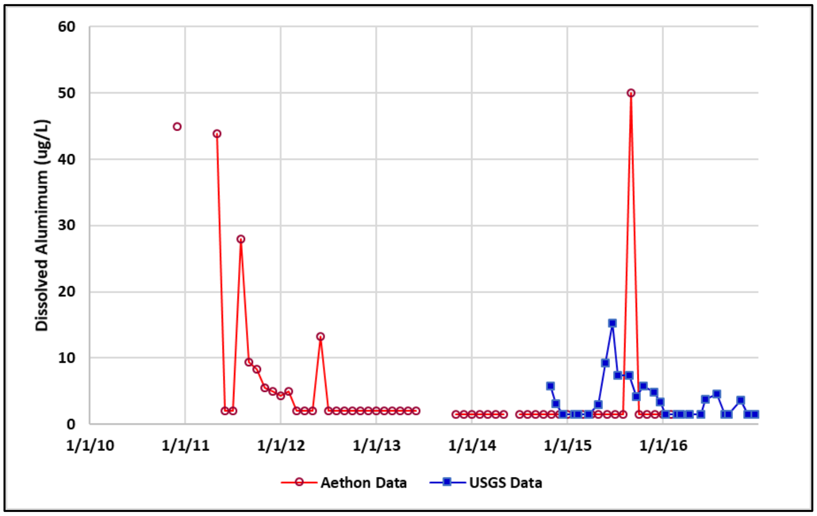

Figure 22. Dissolved Aluminum Data for Wind River below Boysen Reservoir

After lumping the model results and applying the adjustment factor (described above), the monthly model results are in the range of ~22-33 ug/L (Figure 23). This would show a problem if one compares these values to the 3-4 ug/L detection limits. ERM chose to set an alternative threshold of 50 ug/L and using that threshold, the project would not result in degradation.

The source of the 50 ug/L threshold appears to be the required detection limit for dissolved aluminum at the end of the pipe (WDEQ, 2019a). This 50 ug/L detection limit does not apply to the Class I segment of the Wind River (since it is not effluent) and use of this value by ERM for compliance is wrong.

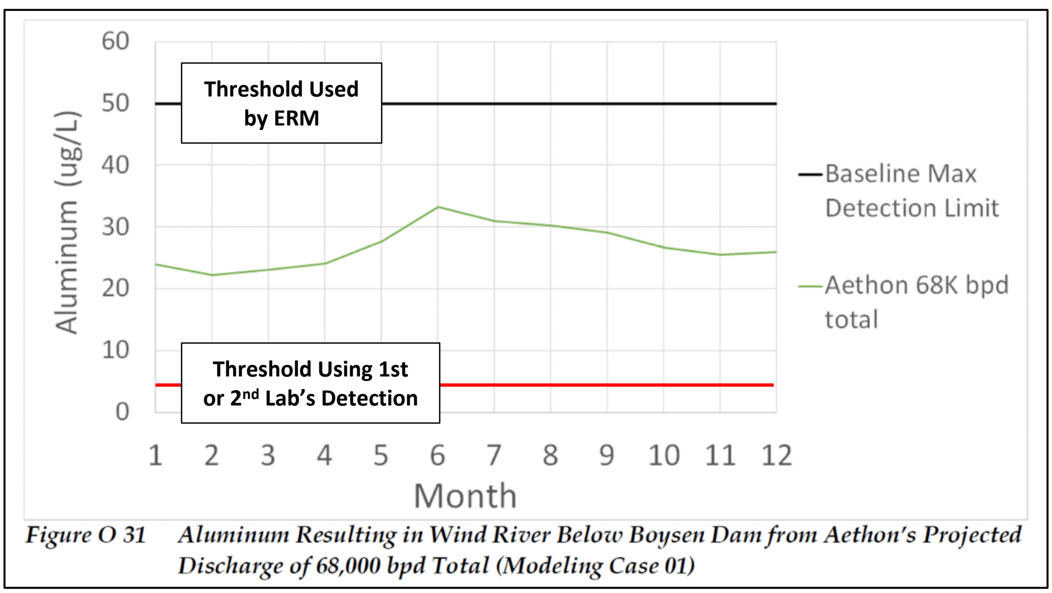

Figure 23. ERM Results for the Compliance Analysis for Dissolved Aluminum (Red Line and Two Text Boxes Added)

Boysen Reservoir Antidegradation

23. <u>ERM Did Not Conduct an Antidegradation Analysis for Boysen Reservoir</u>

For Boysen Reservoir, which is classified as a High Quality Water (Class 2AB), "a lowering of water quality may be allowed if it is determined that the amount of degradation is insignificant" (WDEQ, 2013). The determination of significance of the degradation is to be determined using either of the following tests:

- The increased loading is less than 10% of the existing total load for critical constituents; or
- The increased loading will consume, after mixing, less than 20% of the assimilative capacity for critical constituents.

The only time loading to the reservoir is described in the Report is in Chapter 8, which focuses exclusively on chloride. ERM assumes that Aethon can discharge 23.8 tons/day of chloride to the reservoir, based on a flow of 68,000 bpd (Case 01 – no treatment) and a concentration of 2,000 mg/L end-of-pipe limit. ERM states *"This resulting load is the total allowable chloride load that can be discharged by Aethon's operations while complying with the Antidegradation criteria."* This is <u>not</u> based on Boysen Reservoir antidegradation, but on the Wind River below. ERM did not consider the 10% load increase criterion for Boysen Reservoir.

The only time project impacts to the water in Boysen Reservoir were considered in the Report is in Chapter 7, the Mixing Zone Study. ERM describes a mixing zone and claims that *"Chronic water quality criteria outside the mixing zone within the reservoir is (sic) met in all three flow conditions."* Thus, ERM considered it to be acceptable to consume all of the assimilative capacity in the reservoir for this project. ERM did not consider the 20% limit for assimilative capacity.

Thus, ERM failed to conduct an antidegradation analysis for Boysen Reservoir.

SUMMARY

ERM developed a mechanistic hydrodynamic water-quality model of Boysen Reservoir to support permitting and to determine conditions for Aethon's project that would "protect downstream surface water quality in Badwater Creek, Boysen Reservoir and the downstream Class 1 segment of the Wind River Below Boysen Reservoir, as well as require Aethon to uphold Wyoming's antidegradation policies."

There are very serious issues related to the development, evaluation, and use of the Boysen Reservoir Model. Our review of the reservoir model documentation and reservoir model files revealed critical concerns. Highlights include:

<u>The Model was not Developed Properly and Does not Account for Factors Important for this Project</u>

- Density changes anticipated in the future for water flowing into Badwater Bay, (important for flow patterns) were completely ignored.
- Releases to the Wind River (low-level outlet vs. spills) were not differentiated.
- Releases to the Wind River were not density based.
- Wind speeds were severely and unrealistically reduced without discussion.
- Reservoir evaporation was not considered.

- Several water balance and water quality input assumptions and adjustments were made without justification.

Model Performance was Not Evaluated Appropriately and is Misleadingly Communicated

- ERM misleadingly claims that the reservoir model is calibrated and adequately simulates Wind River (Class I segment) water quality. This is done by comparing water-quality measurements in the river to water quality simulated in the top two feet of the reservoir. This is disturbing, wrong, and was done even though the reservoir stratifies and has a low-level outlet.
- There are numerous instances of excluding meaningful data during the calibration/validation process (including all non-profile reservoir data and all data during periods of highest percent produced water).
- Information was misleadingly concealed from the reader by only displaying the top portion of profile results and observations.
- The model is not calibrated and the results are poor.

"Compliance Analysis" Methods and Findings are Flawed and Incorrect

- Baseline conditions for the Class I segment excluded valid USGS data.
- Methods used to show compliance for the Class I segment:
    - Used monthly averages, leading to the conclusion of reduced impacts
    - Used inflated and incorrect values for standard deviation
    - Relied on favorable assumptions for Category III constituents
- An antidegradation analysis for Boysen Reservoir was not conducted.

Based on how the model was developed and the results, the reservoir model cannot be used for projections or decision making. In addition, even if the model adequately simulated water quality, the methods used to determine compliance are inadequate, sometimes wrong, and several assumptions were made to show favorable results.

According to the WDEQ (2019b), "Model was designed to ensure compliance with WQS applicable to Boysen and to maintain existing quality in the Wind River below Boysen." Unfortunately, this is not a true statement.

REFERENCES

Brodzeller, J. and P. McGinley. 2016. A CE-QUAL-W2 Model for Dissolved Oxygen in the Big Eau Pleine Reservoir, Wisconsin to Understand and Manage Winter Anoxia. Center for Watershed Science and Education at the University of Wisconsin-Stevens Point. June 2016.

Cole, T.M., and S.A. Wells. 2016. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydro-dynamic and Water Quality Model, Version 4.0. Department of Civil and Environmental Engineering. Portland State University. Portland, OR. June 2016.

ERM (Environmental Resources Management). 2018. Water Quality Compliance Analysis for the Long Range Development Plan at Moneta Divide, Wyoming. A Hydrologic, Hydrodynamic and Water Quality Study of the Boysen Reservoir Watershed. Prepared for Aethon Energy. April 23, 2018.

Hydros Consulting. 2017. Three Lakes Water-Quality Model Documentation. Submitted to Grand County, Northern Water, and the U.S. Bureau of Reclamation. November 27, 2017.

LimnoTech. 2016. CE-QUAL-W2 Lake Response Modeling of Petenwell and Castel Rock Reservoirs for the Wisconsin River TMDL. Prepared for U.S. EPA Region 5. June 2016.

NOAA (National Oceanic and Atmospheric Administration). 1982. Technical Report NWS 33: Evaporation Atlas for the Contiguous 48 United States.

WDEQ (Wyoming Department of Environmental Quality). 2013. Wyoming Surface Water Quality Standards. Implementation Policies for Antidegradation, Mixing Zones and Dilution Allowances, Turbidity, Use Attainability Analysis. September 24, 2013.

WDEQ (Wyoming Department of Environmental Quality). 2019a. Wyoming Pollutant Discharge Elimination System Application for Permit to Surface Discharge Produced from Oil and Gas Production Unit Discharges. DEQ_WQD SHORT FORM C.pdf. January 2019.

WDEQ (Wyoming Department of Environmental Quality). 2019. Moneta-Public-Meeting-Presentation_2019-0521.pdf. May 21, 2019.

USDOI (U.S. Department of Interior). 1981. Project Data. Water and Power Resources Service.