FLAMELESS PRESSURIZED OXY-COMBUSTION LARGE PILOT DESIGN, CONSTRUCTION, AND OPERATION: PHASE I

Phase I Topical Report

Award Number: DE - FE0031580
SwRI® Project No. 18.23745

Principal Investigator:

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George Booras

Federal Agency to which the report is submitted:

U.S. Department of Energy (DOE)
National Energy Technology Laboratory (NETL), Pittsburgh, PA

Date of the Report:
March 29, 2019

Prime Recipient's DUNS Number: 00-793-6842

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Machinery Department

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1. TECHNICAL STATUS

The team of Southwest Research Institute® (SwRI®), ITEA, Electric Power Research Institute, Inc. (EPRI), General Electric Global Research (GE), Sargent & Lundy (S&L), and Peter Reineck Associates (PRA) are advancing Flameless Pressurized Oxy-Combustion (FPO), a novel coal technology. The sections below provide detail on the different accomplishments that have been made under the project.

A. PRE-FEED LARGE-SCALE PILOT DESIGN BASIS

A preliminary design basis was developed by the team for the chosen University of Wyoming (UW) Central Energy Plant (CEP) host location. The basic configuration of the facility is shown in Figure 1. The planned design emphasizes the combustion loop test at a large pilot scale of 25-MWth. This choice relates to scale up parameters that have been established for the combustion loop elements by ITEA. Further information on the choice of scale is available in Section 1.C.

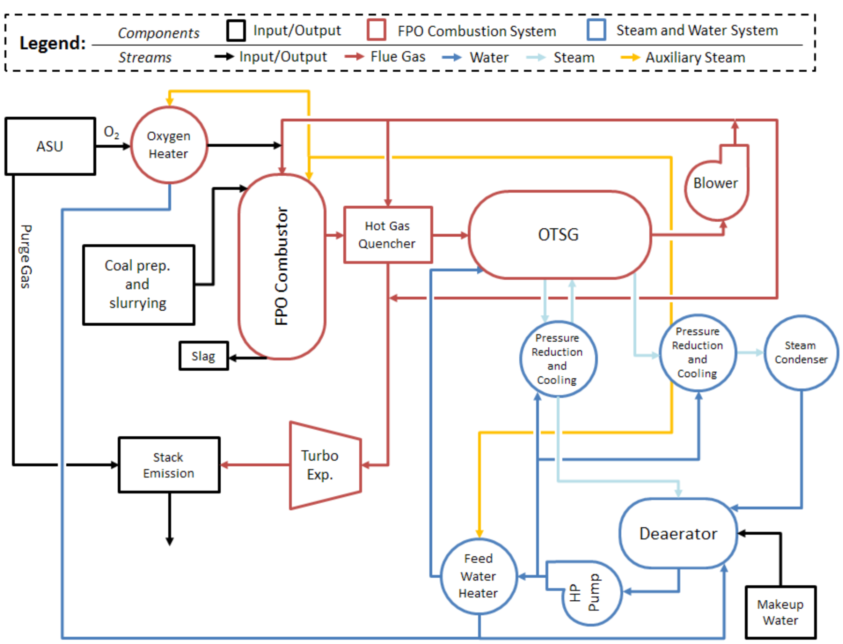


Figure 1. Block Diagram of the Large FPO Pilot

A major equipment list was generated to define the pieces of equipment that will take the largest space and cost. The list is recreated here in Table 1. The interconnectivity of the major equipment was defined with process flow diagrams (PFDs), which can be found in Appendix D: FPO Process Flow Diagrams. The sizing of equipment has led to a preliminary plant layout, shown in Figure 2. All of these elements will be built into the cost estimate by the conclusion of Phase I. The current cost estimate is discussed in greater detail in Section 1.D.

Table 1. Preliminary Sized Major Equipment List for the Pilot

Equipment No.	Description	Weight	Size
01 X01	Coal Slurry Bar Mill	30 tons	12' x 20' x 10'H
01 X08	Coal Slurry Bar Mill Recycle Conveyor	2 tons	1' x 20' x 1'H
01 X09	Coal Slurry Paddle Mixer	10 tons	6' x 15' x 3'H
02 P01A	Coal Slurry Feed Pump A	1,500 lbs	2' x 12' x 2'H
02 P01B	Coal Slurry Feed Pump B	1,500 lbs	2' x 12' x 2'H
02 E02	Combustor O_2 Feed Heat Exchanger		
02 R01	Oxy-combustor Vessel	90 tonnes	11' dia x 30'H
02 R01	Oxy-combustor Vessel Injection Set		11' dia x 15'H
02 J01A	Flue Gas Quencher A	19 tonnes	5' dia x 15'H
02 J01B	Flue Gas Quencher B	20 tonnes	5' dia x 15'H
	Refractory for Combustor/Quencher/Pipes	32 tonnes	~1' thick
02 E06	Once Through Steam Generator - OTSG	95 tonnes	12' dia x 42'L
02 F01	Recycle Flue Gas Glower Inlet Air Filter	1 ton	52" dia x 2 ft
02 C01A	Recycle Flue Gas Blower	5 tons	6' x 8' x 10'H
02 V01A	Refractory Lined Quencher Inlet Pipe A	4 tons	3.5' dia x 12'L
02 V01B	Refractory Lined Quencher Inlet Pipe B	4 tons	3.5' dia x 12'L
02 V01C	Refractory Lined Quencher Inlet Pipes C	4 tons	3.5' dia x 12'L
02 V01D	Refractory Lined Quencher Inlet Pipes D	4 tons	3.5' dia x 12'L
02 V02A	Refractory Lined Quencher Outlet Pipe A	4 tons	4' dia x 15'L
02 V02B	Refractory Lined Quencher Outlet Pipe B	4 tons	4' dia x 15'L
02V03	Refractory Lined Quencher Outlet Pipe - Common	5 tons	5.5' dia x 12'L
02 K01	Turbo-expander	5 tons	10' x 10' x 10'H
01 D01	Coal Storage Silo	150 tons	12' dia x 36'H
01 X03	Coal Feed Conveyor		

Equipment No.	Description	Weight	Size
01 X05	Coal Reclaim Conveyor		
01 X06	Coal Bucket Conveyor		
09 D04	Flush / Service Water Tank	125 tons	15' dia x 20'H
09 D07	Demineralized Water Storage Tank	125 tons	15' dia x 20'H
08 X01	Air Separator Unit		70' x 130' x 40'H
03 P02A	BFW Pump (HP) A	4 tons	5' x 10' x 5'H
03 P01	BFW Treatment Additive Pump	500 lb	3' x 3' x 3'H
03 D01	BFW Treatment Additive Tote	1 ton	300 gal (40" x 48" x 54")
09 P09A	Demineralized Water Pump A	1 ton	5' x 5' x 3'H
09 P07A	Flush / Service Water Pump A	1 ton	5' x 5' x 3'H
04 P05	Closed Cooling Water (CCW) Pump	2 tons	8' x 8' x 3'H
04 D08	Closed Cooling Water Head Tank	6 tons	1,000 gallons
09 X02	Air Compressor Package	4 tons	8' x 40' x 8.5'H
04 P02A	Slag Quench Water Pump A	2 tons	8' x 8' x 3'H
04 E01	Slag Quench Heat Exchanger	2 tons	3' x 20' x 4'H
04 V01A	Slag Settler A (ID:89)	20 tons	12' x 12' x 20'H
04 V01B	Slag Settler B (ID:92)	20 tons	12' x 12' x 20'H
04 P04	Slag Settlers Flush Water Pump	500 lbs	2' x 2' x 2'H
04 P03A	Slag Sump Pump A	500 lbs	2' x 2' x 4'H
03 X02	Super Critical Main Steam Attemperator		
03 X03	Reheat Steam Attemperator		
03 E04	Air Cooled Steam Pressure Condenser (ACC)		60' x 240' x 80'H
04 E03	Air Cooled Closed Cooling Water (CCW) Fin Fan Cooler		20' x 80' x 40'H
05 X01	Turbo-expander Dynamometer		
03 V01	Super Critical Steam Deaerator	30 tonnes	7' x 18' x 17'H
03 E05	Feedwater Heat Exchanger		
	HVAC Unit for Combustor Building	2 tons	8' x 8' x 4'H
	HVAC Unit for ASU Building	2 tons	8' x 8' x 4'H
	Fuel Gas Regulating Station		
	Combustor Building		150' x 200' x 40'H
	ASU Building		80' x 150' x 40'H
	Steel Flue Gas Stack		200'H
	Electrical PDC Building		
	13.8kV Substation Circuit Breaker		
	DCS		

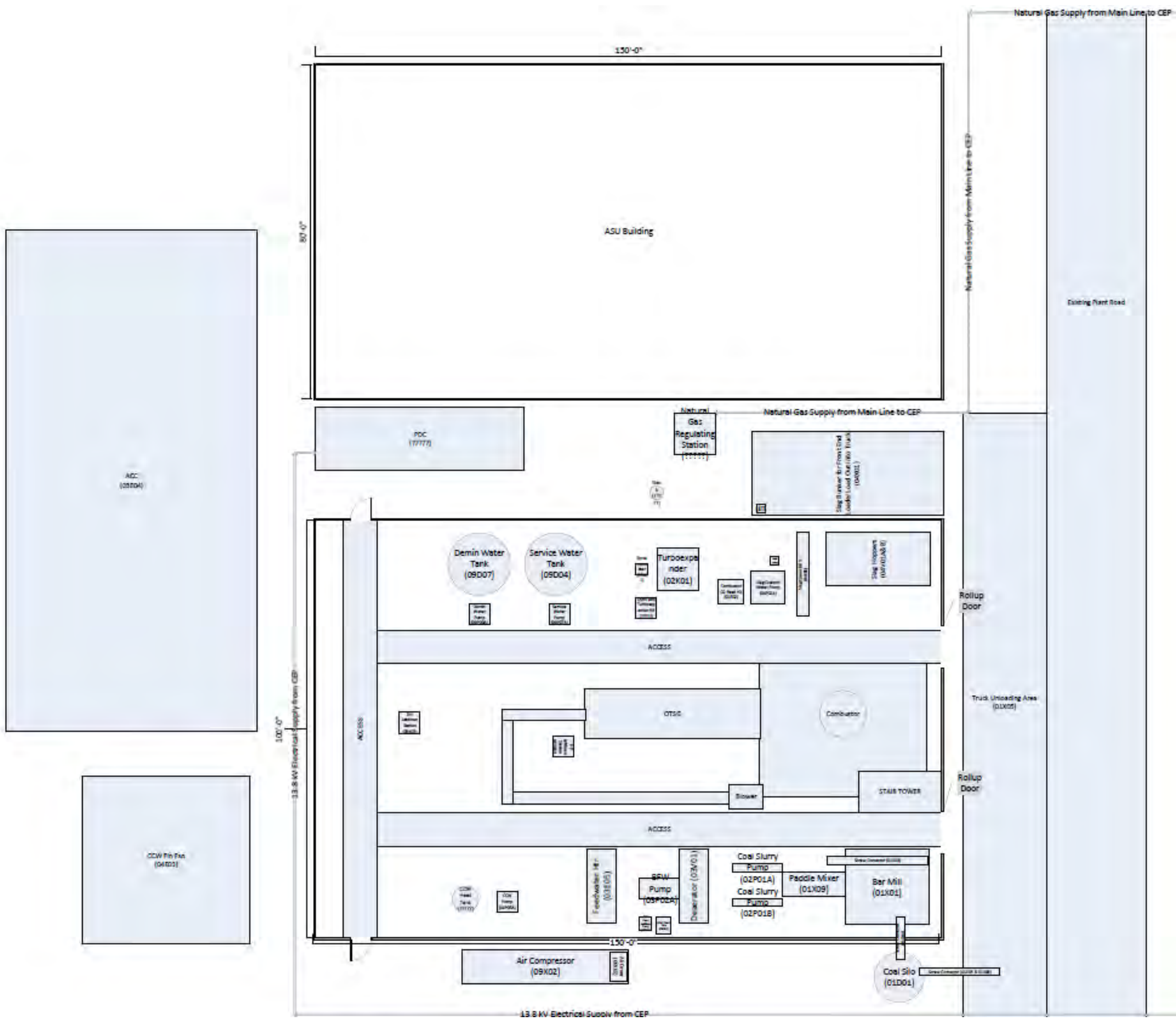


Figure 2. Layout of the Planned Pilot Facility at UW CEP

Further information on the environmental conditions expected at the site can be found in the Environmental Information Volume (EIV) in Section 2.D. The basis for the flow rates, the composition of streams, temperatures, and pressures in the pilot were extracted from a detailed Aspen Plus process model. The flowsheet of the Aspen Plus model is shown in Figure 3. Further improvement of the model including refinement of fuel feed, prediction of off-design, and other conditions will be incorporated in Phase II.

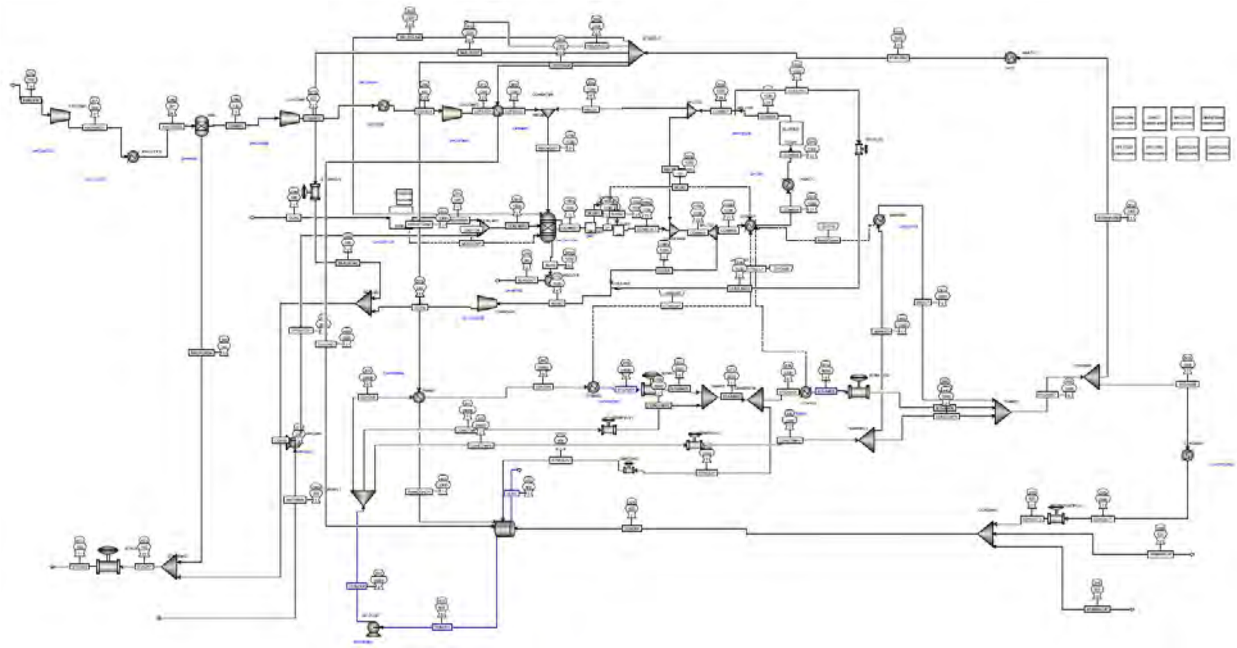


Figure 3. Flowsheet of the Pilot Aspen Plus Process Model

B. STATUS OF THE TECHNOLOGY DEVELOPMENT

I. FPO SMALL PILOT BACKGROUND OVERVIEW

FPO was originally conceived for the treatment of hazardous industrial wastes. It was reasoned that the benefit of reduced emissions could offset the cost of oxygen. Research and development (R&D), on a pressurized 5-MWth pilot erected in 2003, was conducted in parallel to a lab pilot at atmospheric pressure. Conceptual design of this 5-MWth pilot was based on the theoretical prediction that a suitable combustion parameter combination could achieve a uniform, flameless condition with a substantial emissions reduction.

By 2004, apparent emission results of the 5-MWth pilot were suggesting that the ambitious goal of flameless condition was attained not only with gas and vaporizable liquid feedings but also with non-vaporizable liquid and solid granular feedings.

The FPO pilot achieved excellent emissions reduction versus permit values. It was able to convert quantitatively all combustible species, producing zero soot. Dioxin Furan was close to the lower detection limit (1,000 to 10,000 times smaller). Carbon monoxide was 100 times lower than typical values. Zero thermal NOx was generated, and NOx from organic nitrogen was reduced. Ashes melted, coalesced, and separated from flue gas inside the combustor. The waste collected at the combustor bottom as zero-carbon, vitrified, non-leaching (neither organics nor heavy metals) slag. Flue gas post-treatment operations reduced to the neutralization of acidic components (halogen hydric acids, SO_2).

These results attracted the attention of Enel, the European utility co-leader. After a preliminary trial with coal, Enel decided to consider FPO for their “near zero” emissions, coal-fired power development program. They supported the refurbishment/adaption of the 5-MWth ITEA pilot to coal firing. The launch of a three-year technology development program (2007-2009) extended to different types of coals of use in its fleet and some low-rank solid fuels.

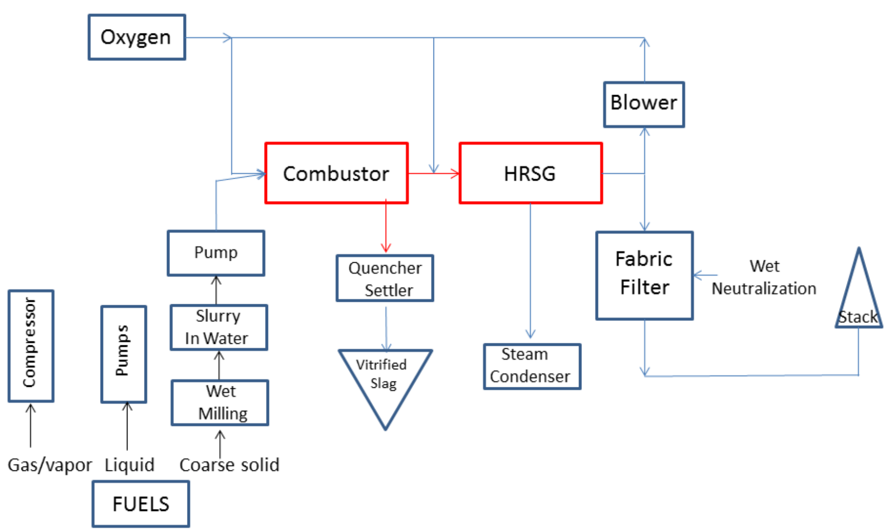


Figure 4. Block Diagram of the FPO 5-MWth Pilot

In autumn 2006, Enel and ITEA decided to perform further coal-firing developments in the 5-MWth pilot. An analysis uncovered some bottlenecks. For example, the manual handling times in the original design for the vitrified slag discharge system. More robust solutions were deemed necessary for the boiler (hot flue gas from 500°C to 800°C) and the molten slag discharge port (design temperature from 1,300°C to 1,450°C). The slurry pump was modified to pressurize like progressive cavity (warm) pumps.

After four trials in 2007, the unit was overhauled and improvements were engineered and implemented. This included the installation of wet-milling equipment, a ball mill, and a bar mill to alleviate numerous inconveniences associated with the supply of the already ground material. All modifications went on-stream in July 2008. The cycle diagram after the modifications of the FPO 5-MWth is shown in Figure 4, and to date, the configuration has not changed significantly.

Experimental runs demonstrated that the production of relatively clean flue gas from the combustor outlet could allow the operation of a compact pressurized flue gas boiler. Because no soot blower is required, the flue gas exiting the steam generator could be recycled for combustor and pre-boiler tempering. No significant fouling (sulfate), erosion, or acid dew was detected during and after firing runs.

Material and thermal balance data were collected and heat recovery efficiency was demonstrated. Enel received the support of Dr. Ahmed Ghoniem from the Massachusetts Institute of Technology (MIT) for process analysis and the elaboration of overall carbon capture and storage cycle efficiency and economic projections. The results of this analysis set FPO high among competitors, both for efficiency and levelized cost of electricity (LCOE).

Scale-up rules were analyzed, and a suitable combustor was designed to respond to major scale-up problems. A combustor numerical model, by Politecnico Bari at Enel

R&D, was tuned with experimental data from the once-through 5-MWth combustor. In 2009, the numerical model was applied for the initial design of a promising combustor setup where flow entered and exited from the same side. This model was conceived for a large pilot, which was to be installed in the Brindisi industrial coal-fired power station. ITEA developed the combustor concept and detailed the mechanical design to the proposed Brindisi large pilot. Extended validation for flue gas cleanliness allowed for a much more efficient supercritical once-through steam generator design.

In parallel to coal testing, numerous different applications were explored with the support of different industry leaders. Applications for power from oil heavies and oil residues treatment, power from high CO_2 gas, industrial and pharmaceutical waste treatment, and municipal waste-to-product treatment have been experimentally demonstrated on the 5-MWth pilot. ITEA demonstrated some of these on an industrial 15-MWth scale plant in Singapore.

Comprehensively, ITEA collected about 18,000 firing hours on the 5-MWth FPO pilot. ITEA has filed 10 international patent applications, some already granted, on this technology.

II. Pilot Coal Fired Tests Overview

This section will discuss all the components of the FPO 5-MWth pilot and will give a comprehensive overview of the testing methodology. Data was collected throughout the pilot loop. The numbers in boxes, as shown in Figure 5, represent locations where the flow was characterized by various sampling methods. The numbers in circles shown in Figure 5 represent a unique mass flow stream, which is useful when describing the cycle mass and thermal balance.

1) *Coal Slurrying*

Coal slurrying is an established technology already used in gasifiers. The FPO process is somewhat different from gasification, providing a quantitative conversion of fed combustible species in a once-through combustor. With FPO, there is no chance of particle classification or retention per diameter size. Therefore, the coal particle size parameter must be carefully investigated and validated on a case-by-case basis. It was experimentally apparent that fuel particle size, up to a few millimeters, does not affect FPO, so the burdensome coal pulverization step is excluded. In addition, there is experimental evidence that the broader the particle size distribution, the less likely the problem of erosion of piping systems will occur. From a cycle efficiency standpoint, the addition of water to allow the slurry to be pumped must be carefully managed to avoid undesirable drawbacks.

Each coal tested required a specific study to define the best compromise between firing requirement, hardware requirement, and slurry pumping. For each case, rheological lab study, tests in field pumping, and lance spray tests (no-clog test) were performed to optimize the slurry recipe prior to the firing test. Small slurry lots with particle size distributions progressively extended to coarser particles were fired during preliminary ITEA internal firing tests, which optimized particle size distribution.

The availability of milling units beginning in 2008 allowed for the customization of slurry preparation. It also avoided the inconvenience of unexpected feeding inconsistency and large particle contamination. Contamination had been experienced during two tests with ground material supplied by a toll manufacturer prior to the installation of milling equipment.

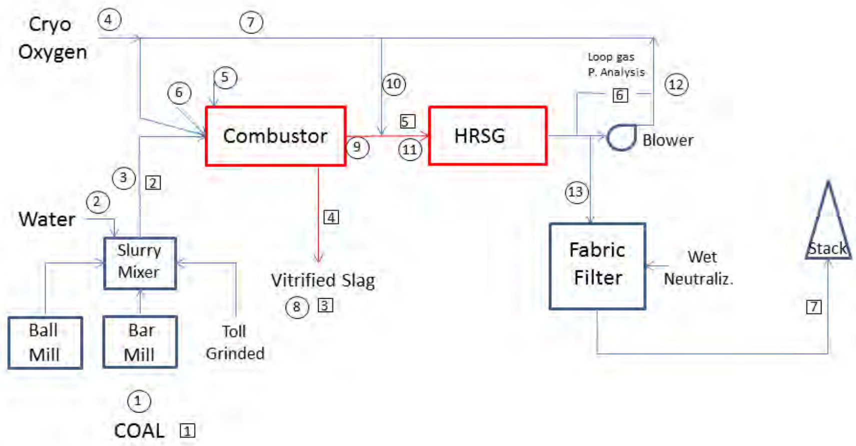


Figure 5. Sampling Points in the FPO 5-MWth Cycle Diagram

Sampling and characterization of coal and water streams at sample points 1 and 2 provided coal characteristics, slurry total water content, and mass flow rates during the trials.

2) The Firing Loop

Different from state-of-the-art conventional boiler systems, the FPO combustor is a refractory-lined vessel, without radiative heat exchange to steam. Temperature regulation is not affected by any external heat sink. Sensible heat recovery is performed in flue gas to water-steam heat exchanger downstream of the combustor.

Cool flue gas exiting the Heat Recovery Steam Generator (HRSG) is short-circuited back for combustor tempering and hot combustion gas tempering by the quencher. A blower provides the necessary head lost in the loop and HRSG. The combustor and HRSG are set in a pressurized flue gas loop. The gas composition downstream of the combustor is constant, which allows the sampling of gas from points at a manageable gas temperature (see sampling point 5 and 6 in Figure 5). Gas composition analysis is performed by a rack of continuous process analyzers, Non-Dispersive Infrared Sensor (NDIR) for CO, H_2O, CO_2, SO_2, Zirconia, and for oxygen excess. A Hydrogen Flame

Ionization Detector (HFID) is used for determining Total Organic Content (TOC). In some cases, SO_3 was monitored with a Teflon membrane at 120°C, by CESI technicians.

Residual particle content in the combustor outlet flue gas was continuously monitored by laser opacimeter before the HSRG inlet. This data is useful to console operators, but it is qualitative only. For quantitative characterization of residual particle content in the flue gas, a sample is taken at sampling point 5, just before HSRG. It has been characterized by microfiber filter (weight gain) filtration, which is collected in batches during the day shift. In parallel, and for most of the cases, the characterization was performed by an Electrical Low-Pressure Impactor (ELPI) continuous particle scanner, which was managed by ENEA technicians at all times. In some cases, a Direct Memory Allocation (DMA) scanner contributed by the University of Naples, magnified particle number distribution in the small diameters portion (7 to 50 nm). ELPI is equipped with a 10 µm cutoff at the flue gas inlet. ELPI particle integral value always tested lower than filter test values, around 20-40% less. The broadest deviations have been noticed for high filtration values, likely in circumstances in which insufficient melting-coalescence was occurring in the combustor.

The HRSG steam produced was metered by a shop calibrated orifice differential pressure (dP) cell. Steam was then condensed by an air fin and condensate was recycled to the HRSG at 35-40°C.

3) COMBUSTOR SLAG

Molten slag separates from the flue gas and drains to the combustor bottom and exits through an electrically heated port, falling into a quenching water bath. A water loop carries solidified beads to a settler and they are recorded in batches. There are two settlers so that one can be taken out of operation and emptied. The vitrified beads are manually shoveled into bags and tested, shown as sampling point 3 in Figure 5. The bags are weighed every 2-4 days, depending on the ash content of the used coal. This is how stream number 8 is given a calculated hourly value. Because the combustor is horizontal, the slag can accumulate at the bottom, as seen in Figure 6. This accumulation was collected and accounted for by inspection of the combustor after each trial.

Figure 6. Slag Residue Inside the Combustor

Even though the firing loop is simple, with compact piping pathways, ITEA alerted Enel that the pilot firing loop construction insulation standard was not very rigorous, neither for the combustor nor for hot flue gas piping. Thus, a blank test was performed at firing loop temperatures corresponding to those projected for the majority of coal trials. A steady condition at almost zero steam production was reached after firing 54 kg/hr of light oil (LHV 44,000 kJ/kg). From this test, it was deduced that 29 kW of sensible heat from the flue gas was released to the atmosphere at 238°C. The “pre-empty” load, which characterizes all unit losses (including pressurized air flushing to metal shells), was calculated to be 637 kW, of which 264 kW were combustor losses. This huge figure is due to the small scale and poor insulation of the pilot plant. However, Enel engineering estimated that, given hardware typical geometry, it could be reduced by a factor of 10 to 20 times with proper engineering at industrial scale. Pilot overhauling was evaluated, but Enel chose not to implement the overhaul, since it was not altering the scope of planned technology tests.

4) Flue Gas Treatment

ITEA adopted, for its hazardous waste-to-energy business, a dry, sodium acid carbonate (bicarbonate) injection into the flue gas. The flue gas at the pressurized loop outlet was laminated to a pressure slightly above atmospheric pressure. Gas-to-solid direct contact processing was performed in a tubular reactor. It was followed by flue gas filtration with a fabric filter. Neutralized flue gas was released to the stack.

No additional sensible heat recovery or water vapor condensation was implemented in the 5-MWth pilot, but can be included in future designs.

Enel considered pressurized alkali scrubbing and pressurized flue gas condensation, but traditional unit operations were manageable by the engineering department.

Pilot airborne emission was monitored by continuous Siemen’s analyzers. After a drier, NDIR was used for CO, SO_2, and NO_X, and HFID was used for TOC on the airborne emissions. Particulates were characterized by batch filtration and HCl by a wet batch method. Dioxin, Furan, and heavy metals were characterized by accumulation methods, sampling the gas for almost eight consecutive hours.

5) COAL TRIALS TESTING PROCEDURE

Enel and ITEA agreed to a testing procedure for each coal trial:

The coals were selected, acquired, and characterized by Enel. A preliminary, but extended, slurry production test and firing tests, were performed by ITEA, with Enel assistance, and monitored by internal characterization means for durations varying from 100 hours to 350 firing hours. A final, certified firing run was conducted with the presence of Regulatory Agency emission characterization technicians. The final run was supported by external certified bodies, technicians, and experts (CESI, University of Naples particulate experts, University of Bari experts) for a duration of about 120 hours. Detailed performance data and balances are provided for one of the coal trials.

An overview of trials 1 through 8 is presented in Table 2. These are Enel coal tests that ran from March of 2007 to May of 2009. Table 2 provides a summary of the results for each test, along with any issues that arose during testing.

Table 2. Coal Trials Summary

Enel-ITEA		Coal Firing Certified Trials					
Net Firing Hours	**Coal (tonne)**	**Heat in (MWth)**	**Rec. Heat (MWth)**	**Slurry Coal w%**	**Eff-iciency**	**Emiss-ions**	**Remarks**
Trial 1 - Coal Type: Fu-Kang, Indonesia Bituminous **Date:** March 14-22, 2007							
121	82	3.9	2.92	53	74.9%	Official test okay	Poor slagging, Iron III escapes, 8 downtime events, some flue gas ash
Trial 2 - Coal Type: Guasare, Venezuela Sub-Bituminous **Date:** June 4-22, 2007							
210	97	3.8	2.98	45	78.4%	Official test okay	Several lance clogging, Frequent load reduction

Trial 3 - Coal Type: Ukraine Anthracite **Date:** October 10-17, 2007							
96	53	3.3	2.4	39	72.7%	Official test okay	Slag hourly rate too high, Slow down on night shift, Liquid slag port clogged
Pilot Improvements Implemented							
Trial 4 - Coal Type: Ukraine Anthracite **Date:** June 18-26, 2008							
141	105	4.5	3.5	34	77.8%	Official test okay	High slag quantity handled, Slow down on night shift
Trial 5 - Coal Type: Adaro, Indonesia Bituminous **Date:** September 10-21, 2008							
183	135	4.9	3.85	50	78.5%	Official test okay	Iron Problem solved, no fouling
Trial 6 - Coal Type: Gordinne, Venezuela Sub-Bituminous **Date:** October 6-31, 2008							
349	291	4.9	3.97	41	81.1%	Official test okay	Peak capacity 5.3 MWth, minor operations problem
Trial 7 - Coal Type: KleinKopje, South Africa Sub-Bituminous **Date:** November 27-December 14, 2008							
187	125	4.7	3.73	39	79.4%	Official test okay	Lance clogging, muffle failure, unit down for 64 hrs.
Trial 8 - Coal Type: Ukraine Anthracite **Date:** May 11-15, 2009							
116	88	4.2	3.2	41	76.2%	Official test okay	Very high slag quantity handled, slow down during night shift
1,403 hours	**976 tonnes**	**Total Across All Trials**					

From all the above trials, Trial 6 was selected as a test with representative data for this report. The results of this trial are presented in the subsequent sections. A detailed overview of trial 6 is displayed in Table 3.

Table 3. Detailed Description of Coal Trial 6

Preliminary Firing Tests	
Trial Duration	241 hours net from October 6–31
Coal Fired	153 tonnes
Downtimes	Continuous-labor-hours limitation – 96 hours Emergency: Slag Muffle failure and replacement – 21 hours Lance tip clogging: 6 replacements – 18 hours Slow down at lower capacity – 32 hours equivalent
Emission Certified Firing Test	
Trial Duration	108 hours net from October 27–31
Coal Fired	68.5 tonnes
Power in	4.9 MWth
Downtimes	Lance tip clogging and replacement – 3 hours Lance tip clogging, and in place purging – 1.5 hours
Fuel	
Coal Type	Venezuela Gordinne
Ash Melting Temp. (Oxidizing)	1,329°C
Coal Slurry Feed Rate	932 kg/hr

6) *TRIAL 6 MATERIAL AND THERMAL BALANCE*

Table 4 displays the mean values of the materials at various stream points. The stream numbers correspond to the circled numbers shown in Figure 5. The balances for the streams were calculated and compared to metered values. The metered streams were acceptable (<1% deviation) with calculated values. Note that the temperature leaving the combustor was so high that it could not be measured before quenching, making stream number 9 a purely calculated value.

Table 4. Material and Balance

Stream	Coal – dry (kg/hr)	Vitrified ash (kg/hr)	Water (kg/hr)	Oxygen (kg/hr)	Nitrogen (kg/hr)	CO_2 (kg/hr)	SO_2 (kg/hr)	Total (kg/hr)
1	593		41					634
2			298					298
3	593		339					932

Stream	Coal – dry (kg/hr)	Vitrified ash (kg/hr)	Water (kg/hr)	Oxygen (kg/hr)	Nitrogen (kg/hr)	CO_2 (kg/hr)	SO_2 (kg/hr)	Total (kg/hr)
4				1,572				1,572
5				62	208			270
6			90					90
7			1,775	154	516	4,418	16	6,909
8		30						
9			2,471	221	732	6,322	23	9,769
10			3,239	289	968	8,287	30	12,813
11			5,710	510	1,700	14,609	53	22,582
12								19,753
13			717	63	214	1,835	7	2,829

Key temperatures, pressures, and heat rate balances are given in Table 5. When calculating the heat balance, the enthalpy was set to zero at 530K. Measured losses from the Enel study are also represented in Table 5. Some steam energy was recovered into the cycle in stream number 6, which is represented as a negative loss. The measured heat rise of steam is in agreement with the thermal balances presented above. Heat recovery in steam net efficiency for the pilot firing loop is measured to be 81.1 %. The net mass flow rate of steam generated was 4,570 kg/hr.

Table 5. Temperature, Pressure and Heat Balance for Relevant Streams

Stream	T (K)	P_{abs} (kPa)	Heat Rate Balance (kW)	Heat Losses (kW)
1				
2				
3	Ambient		-307	
4	Ambient		-93	
5	Ambient	800	17	
6	488	2,000		-4.0 (steam recovery)
7	533	470	33	
8	1,600			12
9	1,600	464	4,351	263 (combustor

Stream	T (K)	P_{abs} (kPa)	Heat Rate Balance (kW)	Heat Losses (kW)
				loss)
10	533	464	62	
11	1,030	463	4,052	
12	533	471	95	360 (piping loss)
13	530	440	0	

Enel R&D suggested technically achievable heat losses and heat recovered from flue gas water vapor condensation. The study calculated that the heat losses could be reduced to 75 kW (1.5% of the total load at an industrial scale). Flue gas heat recovery can provide 69 kW (cooling flue gas down to 460K) of sensible heat recovered from flue gas and 730 kW of heat recovered from flue gas condensation. The study also suggested that the injected steam recovery into the cycle could be improved to 5.3 kW. These cycle improvements would make the heat recovery efficiency close to 100%.

7) TRIAL 6 STREAM CHARACTERIZATION DATA

The sampling point data from trial 6 is presented in detail below.

Table 6. Trial 6 – Sampling Point 1 – Coal Feed Properties

Coal Characterization (as received)	
LHV	27.84 kJ/kg
C	79.0 % wt
H	5.07 % wt
O	3.19 % wt
N	1.4 % wt
S	0.53 % wt
Ash	4.39 % wt
Moisture	6.5 % wt
Ground Coal Particle Size Screening	
1,180 µm	2.1 % wt
500 µm	55.6 % wt
250 µm	26.9 % wt
150 µm	9.3 % wt
Res µm	6.1 % wt

The first sampling point is the coal feed, which was characterized at the laboratory scale in parallel with the 5-MWth testing. The coal characterization is displayed in Table 6.

Table 7. Trial 6 – Sampling Point 2 – Slurry Properties

Slurry Preparation	
Ground Coal Feed Rate	635 kg/hr
Water Added to Coal Feed	298 kg/hr
Percent Water in Slurry	36.4%
Melting Additive K_2SO_4	2 kg/hr
Slurry Feeding to Combustor	932 kg/hr mean (880 min. to 950 max.)
Slurry LHV	8.145 kJ/kg

The next point of sampling is after the slurry preparation. The slurry properties for trial 6 are in Table 7.

Table 8. Trial 6 – Sampling Point 3 – Vitrified Ash and Slag Properties

		21001	21001	21002	21002	21004	21007
		V2A R1	V2C R1	V3A P+/P-	V3C P+/P-	Additive	Residual Ash
Al	%	14.57	15.17	12.13	12.67	<0.02	4.21
Ca	%	2.85	2.93	2.73	2.85	0.05	1.18
Fe	%	9.61	8.81	7.56	7.93	0.05	5.85
K	%	8.68	8.25	11.84	11.65		24.56
Mg	%	1.19	1.22	1.12	1.18	0.06	0.50
Na	%	1.34	1.21	0.79	0.87	0.37	0.94
Si	%	21.04	22.96	25.47	26.77	0.37	8.79
Ti	%	0.49	0.58	0.57	0.58	<0.02	0.23
Ag	mg/kg	<13	<13	<13	<13	<12	<12
As	mg/kg	<13	<13	<13	<13	<12	40
Ba	mg/kg	776	763	868	830	<24	284
Be	mg/kg	<13	<13	<13	<13	<12	<12
Cd	mg/kg	<13	<13	<13	<13	<12	<12
Co	mg/kg	75	70	43	44	<12	21
Cr	mg/kg	5,818	5,431	1,277	1,348	45	3,790
Cu	mg/kg	119	116	174	174	<12	177
Hg	mg/kg	<13	<13	<13	<13	<12	<12
Mn	mg/kg	1,647	1,598	1,558	1,564	<12	673
Mo	mg/kg	<13	<13	<13	<13	<12	86
Ni	mg/kg	1,479	1,401	548	567	20	300
Pb	mg/kg	13	14	<13	14	<12	161
Sb	mg/kg	<13	<13	<13	<13	<12	15
Se	mg/kg	<13	<13	<13	<13	<12	<12
Sn	mg/kg	20	22	<13	<13	<12	37
Sr	mg/kg	637	587	631	614	<24	182
Te	mg/kg	<13	<13	<13	<13	<12	<12
Tl	mg/kg	<13	<13	<13	<13	<12	<12
V	mg/kg	577	574	674	689	< 24	457
Zn	mg/kg	6,327	5,998	1,222	1,300	< 24	3,705

Vitrified slag was removed from the cycle at sampling point 3 at a rate of 30 kg/hr. For trial 6, 9.37 kg of vitrified slag were collected in bags. Table 8 shows the composition of four samples of vitrified slag. Since ash accumulates in the combustor, as shown in Figure 6, the residuals are collected and analyzed after each trial. In Table 8 the additive composition is shown in the fifth column, and the composition of the residual ash for trial 6 is in the sixth column.

Slag composition was in line with ash composition, apart from Chromium. The high value is likely attributable to the failure of a brick of refractory lining. In fact, usual hardware inspection after the trial revealed that a big surface chunk of one of the manhole refractory bricks was missing. It is worth mentioning that carbon content is < 0.01%, both for vitrified slag and residual ashes; more precisely, it is non-detectable.

Table 9. Trial 6 – Sampling Point 4 – Water Metal Content

		21001	21001	21002	21002
		V2A R1	V2C R1	V3A P+/P-	V3C P+/P-
Ag	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Al	mg/L	0.0150	< 0.01	0.0880	0.1990
As	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Ba	mg/L	0.0140	0.0220	<0.01	<0.01
Be	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Ca	mg/L	0.3250	0.3210	0.8360	1.8840
Cd	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Co	mg/L	0.0009	0.0009	<0.0005	<0.0005
Cr	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Cu	mg/L	0.0007	0.0009	<0.0005	<0.0005
Fe	mg/L	<0.01	< 0.01	0.0180	0.1440
Hg	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
K	mg/L	0.1640	0.1340	0.2670	0.2260
Mg	mg/L	0.0630	0.0700	0.1450	0.1980
Mn	mg/L	0.0142	0.0153	0.0164	0.0045
Mo	mg/L	0.0592	0.0511	0.0255	0.0430
Na	mg/L	0.1700	0.1410	0.1270	0.1140
Ni	mg/L	0.0830	0.1013	0.0236	0.0052
Pb	mg/L	<0.0005	<0.0005	< 0.0005	<0.0005
Sb	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Se	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Si	mg/L	0.4990	0.5080	0.6320	0.9140
Sn	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Sr	mg/L	<0.01	<0.01	<0.01	0.0140

		21001	21001	21002	21002
		V2A R1	V2C R1	V3A P+/P-	V3C P+/P-
Te	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Ti	mg/L	<0.01	<0.01	<0.01	<0.01
Tl	mg/L	0.0005	< 0.0005	< 0.0005	<0.0005
V	mg/L	<0.01	<0.01	<0.01	<0.01
Zn	mg/L	<0.01	<0.01	<0.01	<0.01

Four samples of the slag-quenching water were analyzed for material content. The results of the metal content in the water are shown in Table 9. The methodology was a standard laboratory-leaching test, which produced results similar to the slag and ash results.

The quenching water was also assessed for other compounds, which are displayed in Table 10. For organic pyrolytic compounds analytical assessment, all regulated substances are below the detection limit concentration.

Table 10. Trial 6 – Sampling Point 4 – Water Properties

		21001	21002
		V2A R1	V3A P+/P-
pH		6.89	7
Cond	μS	5.5	10.1
F	mg/L	0.07	< 0.05
Cl	mg/L	0.06	0.09
NO_3	mg/L	0.90	0.24
SO_4	mg/L	1.48	0.24

The sampling and characterization, at point 5 of stream number 11, was performed with batch filtration onto silica microfibers. This test of the combustor outlet flue gas was performed 44 times within the final trial. The mean, minimum, and maximum values of these tests are presented in Table 11. ELPI continuous scanner results are also shown in Table 11. The results of this gave lower values, but the data was less scattered.

Table 11. Trial 6 – Sampling Point 5 – Residual Ash in Flue Gas

Batch Filtration	
Mean	83 mg/Nm^3
Maximum	112 mg/Nm^3
Minimum	42 mg/Nm^3
ELPI Continuous Scanner	
Mean	54 mg/Nm^3
Maximum	66 mg/Nm^3
Minimum	46 mg/Nm^3

Inspection of the 5-MWth pilot after the trial did not reveal any appreciable accumulation of particulate, neither in HRSG, nor along the piping. Some material was found accumulated at the quencher outlet pipe. The material was a very small chip with a green-violet color. This was sampled and analyzed with Inductively Coupled Plasma (ICP) spectrometry. The composition was very similar to the 8% alumina-chromia combustor refractory bricks.

Table 12. Trial 6 – Sampling Point 6 – Continuous Loop Gas Analysis

Emerson NDIR	
Mean H_2O	54% vol.
Mean CO_2	44% vol.
Range CO	1-2 ppv
Range SO_2	1,100 -1,300 ppv
HFID	
Total Organic Carbon	1 ppm (close to analyzer lower limit)
Mean Paramagnetic O_2	1.92 % vol.
Range Paramagnetic O_2	1.5-2.5 % vol.

Table 12 shows the composition of the gas that is sampled at point 6. This gas is recirculated back to the combustor and quencher for tempering.

Similar tests were performed on the airborne emissions at sampling point 7. Both NDIR and HFID analyses were performed and their results are shown in Table 13. On day 1 of the trial, a peak value of 867 mg/Nm^3 for the NO_X-NO_2 equivalent reading was recorded for 2.5 hours. This was corrected with a reduction in excess O_2 by 1.5-2%, and a staging of 15% of the oxygen supply at the mid length of the combustor. After these modifications, the continuous scanner produced the results in Table 13.

Table 13. Trial 6 – Sampling Point 7 – Stack Emissions Gas Analysis –Dry Gas

Siemens NDIR	Mean	Minimum	Maximum
NO_X-NO_2 equiv.	320 mg/Nm^3	320 mg/Nm^3	410 mg/Nm^3
CO_2	80% vol.	71% vol.	82% vol.
SO_2	36 mg/Nm^3	22 mg/Nm^3	41 mg/Nm^3
CO	2.2 mg/Nm^3	1.7 mg/Nm^3	3.5 mg/Nm^3
HFID			
Total Organic Carbon	1 mg/Nm^3		
Range O_2	3-6 % vol.		

Batch analysis was also conducted on stack emissions. With a microfiber filter, 37 samples were recorded and the results are shown in Table 14.

Table 14. Trial 6 – Sampling Point 7 – Stack Emissions Batch Filtration Analysis

Batch Analysis	
Number of Samples	37
Method	Filtration onto microfiber filter
Particulate D10	
Mean	0.35 mg/Nm^3
Minimum	0.085 mg/Nm^3
Maximum	2.7 mg/Nm^3 (isolated peak)
Heavy Metals	
Method	ICP (on absorbent solution with particulate)
Hg	Non-detectable
Cd	< 0.0001 mg/Nm^3
Tl	< 0.0001 mg/Nm^3
Others	0.022 mg/Nm^3

An accumulation study was also executed at the stack. This study sampled six total hours per day and was performed four times during trial 6. One of the sampling procedures was interrupted because of lance clogging. The results of the accumulation studies are shown in Table 15.

Table 15. Trial 6 – Sampling Point 7 – Stack Emissions Batch Accumulation

Batch Accumulation Analysis	
Number of Samples	4
Duration of Sample	6 hours daily
Mean Total Dioxin Furan	0.0076 ng/Nm^3
Mean Total PCBs	10.7 ng/Nm^3

The emissions analysts provided these comments: "Apart from mercury values, which are not significant because of the type of used coal (very low mercury in, Enel says), it is worth mentioning the low values of non-combusted species, together with heavy metals."

To translate concentration value (typical of air combustion analyses) into quantitative emission value, the airborne emission figures were converted, as shown in Table 16, and given a 48.5% projected gross efficiency. The heavy metals and organics were far below any emission limit and are not included in the table.

Table 16. Comparison of Results with U.S. Emission Limits

	FPO Pilot	FPO Projected	U.S. Targeted Emission Limit
SO_2	0.048 lb/MWh heat recovered	0.048 lb/MWh	1.0 lb/MWh
NO_X	0.41 lb/MWh	0.41 lb/MWh	0.7 lb/MWh
Particulate	0.09 lb/MWh	0.0004 lb/MWh	0.09 lb/MWh
HCl	< 0.00004 lb/MWh	<0.00004 lb/MWh	< 0.01 lb/MWh

8) *Enel Coal Trials Report to R&D and Engineering*

At the end of trial 8 in January 2010, the Enel team presented the coal trials report to its board. The firing trials with coals of Enel Italian coal fleet demonstrated the capability to convert quantitatively combustible species. Combining these results with other certified characterization firing tests conducted by ITEA on diversified fuels (industrial wastes, biomasses), it can be concluded that quantitative combustion is an intrinsic ITEA process performance. Also obtained was vitrified fully-inert slag, which is zero-carbon and zero-leaching.

Enel does not have any specific fundamental knowledge about the ash melting and coalescence slagging efficiency, which may impact residual ashes content in the flue gas, nor is there suitable information in the literature. The issue of some gas fowling arose in trials 1 and 2 from the fugitive Iron Oxide and high-melting temperature ash. However, ITEA developed with lab work (static crucible tests and dynamic lab pilot test) a rapid response via melting additives, which became a successful solution to this problem. This solution was demonstrated in trials 4 and 5. Therefore, ITEA demonstrated the capability to manage sophisticated high-temperature inorganic chemistry. Enel is confident that the ITEA process performance can be confirmed and, perhaps, extended to other coals different from the ones in the Italian fleet.

Enel-ITEA elaborated a list of apparent bottlenecks and hardware weak points for coal firing. They have been supplied in a priority list and the essential ones, for the scope of technology validation, were planned for implementation with Enel support. ITEA designed and implemented boiler replacement, improved slag discharge system, fabric filter de-bottlenecking, and other minor instrument improvements. These improvements were successfully tested in May 2008, just before trial 4.

Injection lance tip plugging, which impeded firing tests, was considered inherent to the small firing scale-small tip size. Cold tests, with geometrically larger tips, demonstrated that it is no longer an issue with a 50% diameter increase. Moreover, the addition of an in-line colloidal mill before the pump, along with slurry spraying cold tests, removed any clogging problem just before trial effort conclusion.

Suitable solutions have been selected and validated for slurry pumping. A progressive cavity (worm) pump provided good performance. The pump was positively cold tested for higher process pressure, up to 15 bar of absolute pressure. A direct flame heating device at the molten slag discharge port was designed (stoichiometric NG-Oxygen, in diluent CO_2) and implemented with positive results for high-temperature melting ashes.

The firing loop showed excessive turnaround heat losses. A final economizer on the flue gas discharged by the firing loop and a pressurized alkali scrubber have been analyzed and considered, but they were a lower priority for the scope of the trials and, thus, were excluded from implementation.

Enel R&D and Engineering conclude that ITEA's efficiency and cost of energy projections, elaborated in cooperation with the MIT Mechanical Engineering Department (Dr. Ghoniem), are now supported by experimental feasibility data.

Therefore, the preliminary engineering study, detailed design, and erection of a large pilot are recommended. In addition, the continuation of experimental effort for a technology application extension to low ranking fuels, to strengthen further economics and a competitive position outside the Italian coal fleet.

ITEA has been continuing the experimental application development effort on the 5-MWth pilot, firing different fuels:

- Low-rank coals (high water, high ash content and alkaline ash, lignite, and virgin lignite) for comprehensive 250 firing hours net
- Oil heavies and refinery residues for 750 hours net
- Municipal wastes for 620 hours net

Specific ash recipes have been tested to further compress residual ash in the flue gas. Recipes for high vanadium content slagging and neutralization have been validated. Patent applications have been filed for the novel solutions. Recipes for very high sodium ash have been validated and relevant patent filing is in the pipeline.

C. CHOICE OF SCALE FOR THE LARGE PILOT

I. CURRENT TECHNOLOGY READINESS

ITEA's FPO technology has advanced to TRL-6 according to NETL's definition. Here is a summary of each of the criteria associated with TRL-6 and how they were met:

- **A prototype has been validated in a relevant environment –** The size of the 5-MWth process development unit (PDU) qualifies as a prototypical scale for the combustor, which was validated under operating conditions that would be seen at a full-scale power plant using this technology. Key tests related to combustion efficiency, environmental performance, corrosion and erosion characteristics, and reliability were performed.

- **Component integration is like the final application in most respects, and input and output parameters resemble the target commercial application to the extent practical:** The novel aspects of a pressurized oxy-combustion system utilizing ITEA's technology were validated at the PDU test facility including the coal slurring process, pressurized conditions representative of the full-scale application, the unique FPO combustion system, and FGR. Components that would be needed for the commercial system including an ASU, power island, CO_2 purification, and compression island are already mature and can be plugged in relatively seamlessly.

- **Data sufficient to support the planning and design of the next TRL test phase have been obtained:** ITEA and Enel have obtained significant testing data at the PDU site over a multi-year period and these data have been used by ITEA and Enel to perform design and costing studies [1], [2] that were updated in cooperation with researchers at MIT [3], [4]. ITEA has performed a front-end engineering design study for the next-step pilot plant scale-up of the FPO combustor system based on data and experiences from the PDU test facility. This pilot plant and the associated testing program, the subject of this project, are sufficient to achieve the criteria to ultimately advance to TRL-7.
- **Performance attributes and requirements have been updated:** Significant testing was done to characterize and validate the design and operation of the combustor system over a long-term operating period. Lessons learned from the testing have been used by Enel and ITEA to update the design basis and perform detailed engineering and cost study for a full-scale 350-MWe pressurized oxy-combustion power plant using the technology [5].

II. PROPOSED WORK TO ADVANCE TRL

The goal of the current DOE project is to design the next-step 20–50-MWth pilot facility for ITEA's FPO technology that once constructed and operated will achieve TRL-7. Major technical uncertainties associated with the system that the project will attempt to address to attain TRL-7 are discussed below.

III. OVERALL PLANT DESIGN

Key aspects of the plant design will need to be verified during the pilot plant demonstration. Due to limited experience, there is uncertainty in pressurizing the coal feed. The slurry feed proposed by ITEA is probably the least uncertain of the options available but needs testing at a larger scale.

The system that ITEA is developing is dependent on the performance of the FPO combustion process. A single combustor is envisioned with a capacity of 400-MWth for the full-scale system, 80 times the size of the PDU. ITEA is proposing an intermediate-sized pilot plant with combustor capacity of 20–50-MWth, 4–10 times the size of the PDU, to reduce the risk of moving directly to commercial size. The pilot plant combustor geometry would change from a horizontal cylinder to a vertical down flow one, which is the same that would be used at full scale. The uncertainties associated with scale up and the geometry change will include:

- Required fuel preparation and combustion conditions and excess O_2 levels in the combustor exhaust that achieve acceptable carbon burn-out and NOx production resulting from these conditions.
- The ability of the new combustor design to capture 99%+ of the fuel ash in the combustor slag, obviating the need for a separate particulate control device.

- ITEA reported that at the 5-MWth PDU, metals in the fuel (excluding mercury, which was limited in tested coals) were captured to a high degree in the slag flowing from the combustor. This will need to be verified at pilot scale.
- The durability of the refractories used in the combustor. Refractory maintenance can be a significant cost / unit availability factor. The capability of the FPO technology to achieve and maintain low loads, reducing thermal cycling of the refractories, may minimize this uncertainty.
- New combustor design fuel flow required to maintain refractories at “standby” temperature, such that limits on refractory temperature rise rate, do not limit overall plant capacity increase rate.

The proposed pilot will provide experimental evidence required to develop and assess figures of merit designed to address the issues listed above, and validate that the projected scale-up rules are working and that any uncertainties identified for the commercial scale-up can be managed.

D. DETAILED COST ESTIMATE AND SCHEDULE FOR PHASE II (FEED)

For the Phase II continuation proposal, a detailed cost estimate and schedule was produced. A detailed program of tasks and subtasks was created to define all the necessary efforts in Phase II. A description of these tasks is contained within the Phase II continuation proposal under the Statement of Proposed Objectives.

I. DETAILED COSTS FOR PHASE II

The costs for Phase II were estimated by project managers based on the required labor for each effort. The breakdown of costs by task and selected subtasks is shown in Table 17. The bar graphs in Figure 7 also help illustrate the breakdown of Phase II costs. The majority of the project costs will be incurred under the front-end engineering and design (FEED) study. This is due to the level of definition required in the plant design to achieve the required AACE Class 3 cost estimate by the end of Phase II.

The expected monthly spend curve for Phase II is shown in Figure 8. The spending is evenly distributed throughout the project, but a higher rate is planned for the time prior to March 2020. This is to allow for some time to catch up by the end of the project if some tasks are falling behind their due dates.

Table 17. Table of Costs by Task with Selected Breakdown by Subtask

Task 1.0 - Project Management and Planning	**$54,506**
Task 2.0 - FEED Study	**$2,810,350**
Subtask 2.1 - Pilot Design Basis Refinement	$441,713
Subtask 2.2 - Equipment Development	$922,256
Subtask 2.3 - Facility Development	$814,051
Subtask 2.4 - Specification of Instrumentation	$67,185
Subtask 2.5 - Specification of Control Software and Equipment	$205,116
Subtask 2.6 - Refinement of the Phase III Cost Estimate	$360,029
Task 3.0 - NEPA and Permitting at Host Site	**$314,858**
Subtask 3.1 - NEPA Process	$176,298
Subtask 3.2 - Permitting Process	$138,560
Task 4.0 - Team and Cost Share Commitments	**$17,124**
Task 5.0 - Updated Techno-Economic Analysis	**$111,414**
Task 6.0 - Analytical Technical Risk Assessment	**$196,294**
Task 7.0 - Phase III Controlling Documents	**$188,309**
Task 8.0 - Updating the Technology Maturation Plan	**$56,695**
Total Project Cost	**$3,760,117**

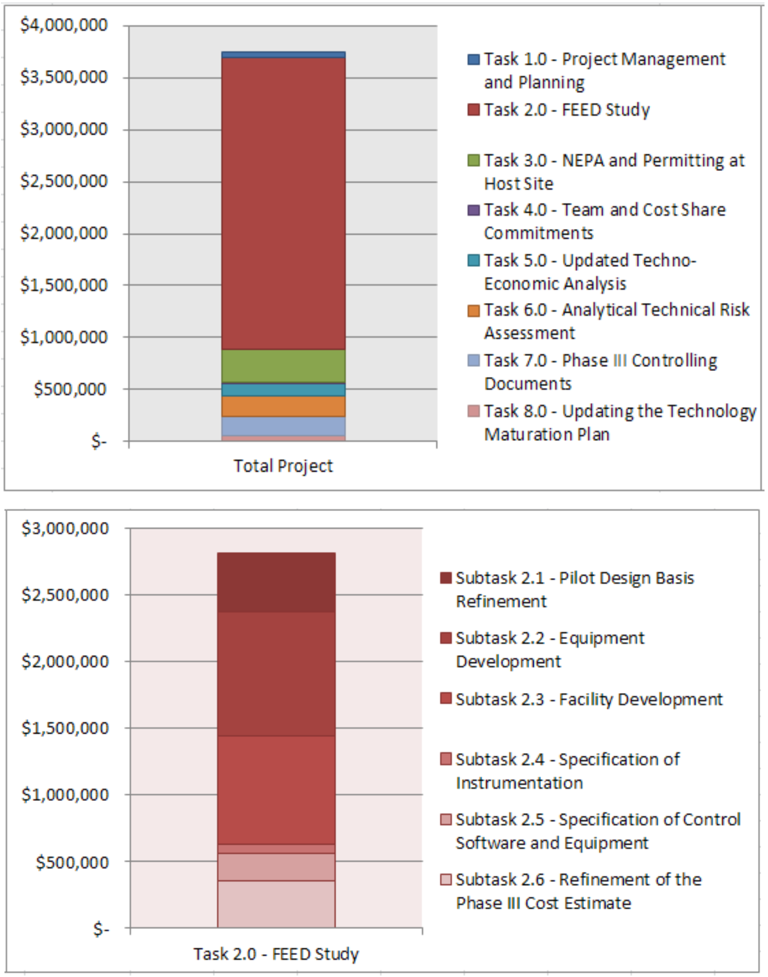


Figure 7. Bar Graphs of Total Project and FEED Study Task Breakdowns

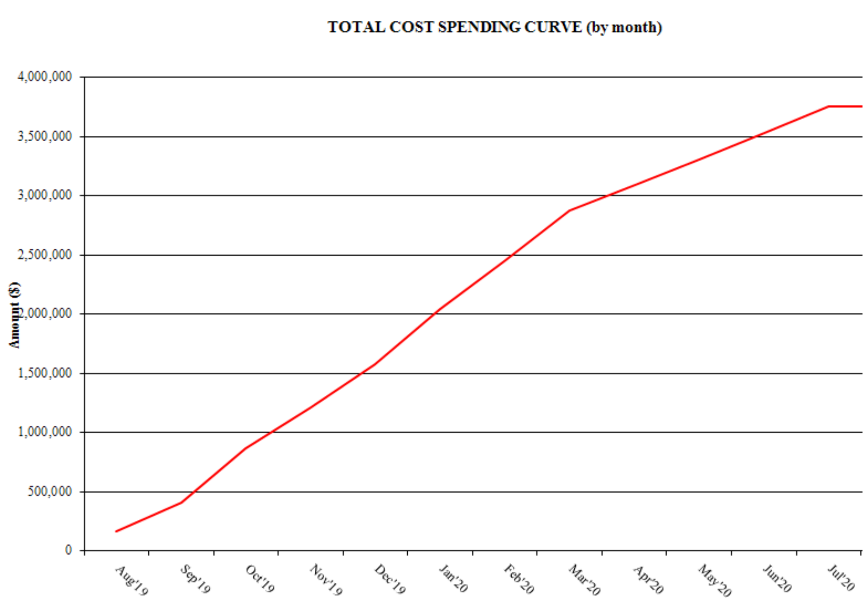
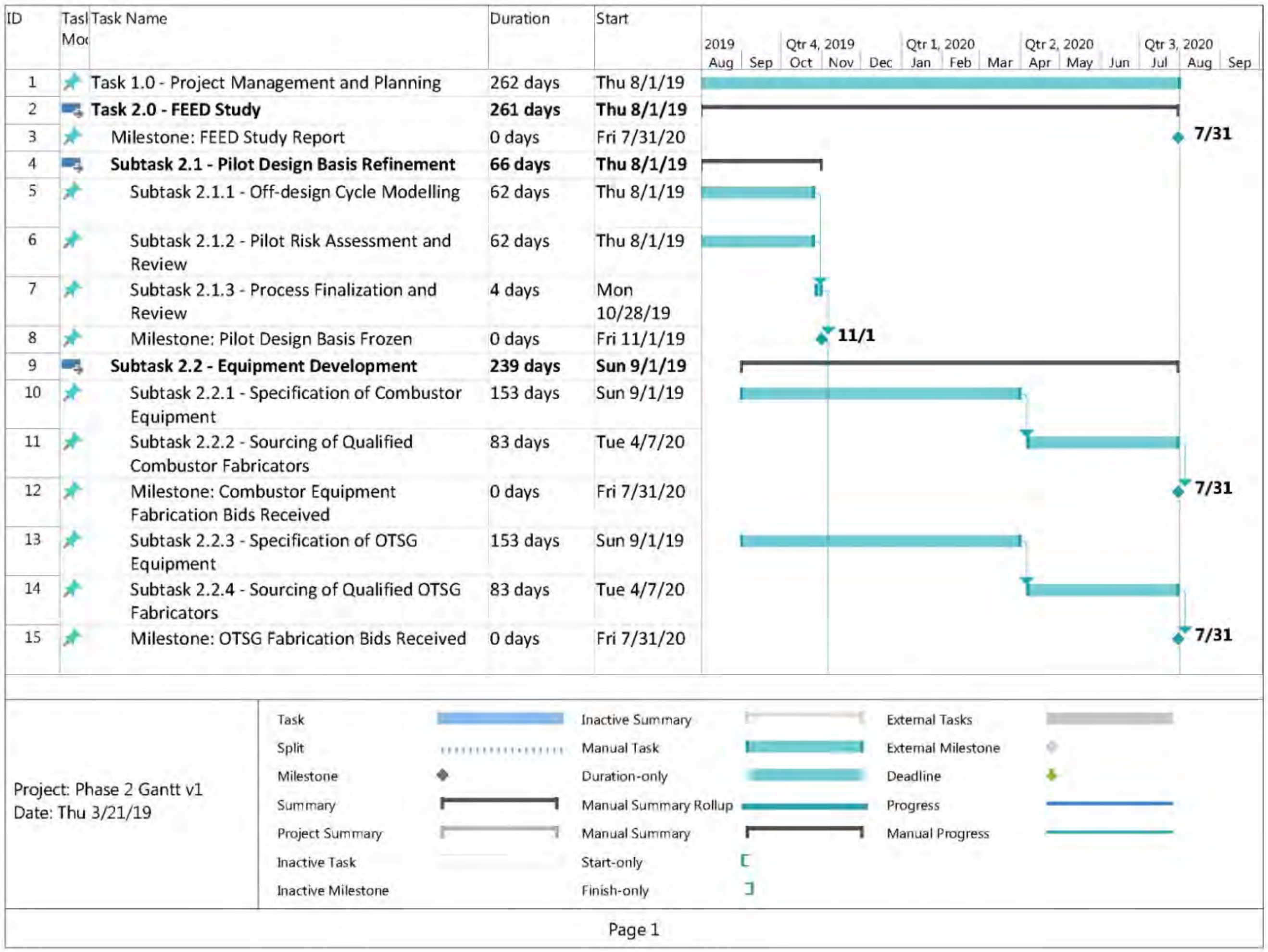


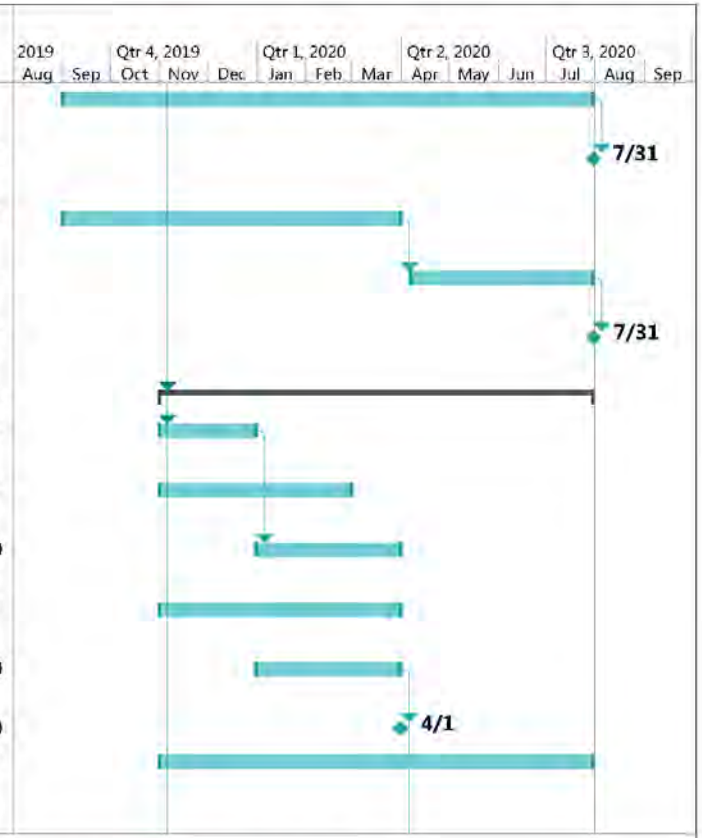
Figure 8. Monthly Spending Curve for Phase II

II. DETAILED SCHEDULE FOR PHASE II

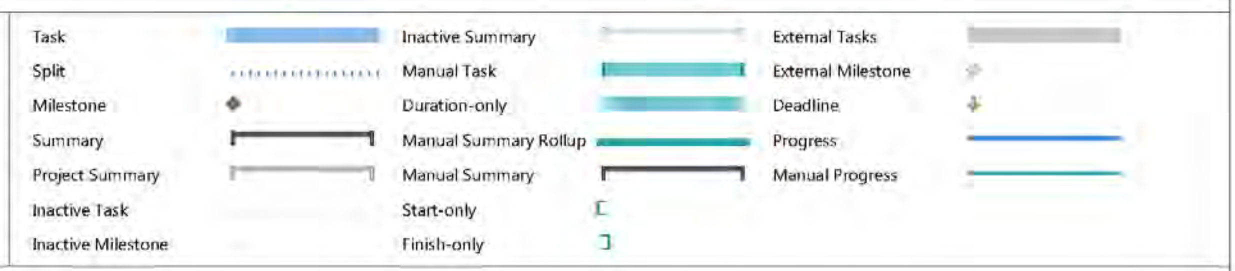
The expected schedule with associated milestones was built into a Gantt chart, as shown in Figure 9.



ID	Task Mode	Task Name	Duration	Start
16		Subtask 2.2.5 - Specification of Turbo-Expander Equipment	240 days	Sun 9/1/19
17		Milestone: Turbo-Expander Basic Engineering Specification Complete	0 days	Fri 7/31/20
18		Subtask 2.2.6 - Specification of Other Major Equipment	153 days	Sun 9/1/19
19		Subtask 2.2.7 - Sourcing of Qualified Major Equipment Vendors	83 days	Tue 4/7/20
20		Milestone: Major Equipment Bids Received	0 days	Fri 7/31/20
21		**Subtask 2.3 - Facility Development**	**195 days**	**Fri 11/1/19**
22		Subtask 2.3.1 - Preliminary Facility Design	43 days	Fri 11/1/19
23		Subtask 2.3.2 - Development of Basic Engineering P&IDs	87 days	Fri 11/1/19
24		Subtask 2.3.3 - Development of Basic Engineering Layouts	65 days	Wed 1/1/20
25		Subtask 2.3.4 - Development of Facility Utilities	108 days	Fri 11/1/19
26		Subtask 2.3.5 - Creation of Material-Take-Offs	65 days	Wed 1/1/20
27		Milestone: Facility Basic Engineering	0 days	Wed 4/1/20
28		Subtask 2.3.6 - Development of Procurement, Contracting, and Commissioning	195 days	Fri 11/1/19



Project: Phase 2 Gantt v1
Date: Thu 3/21/19



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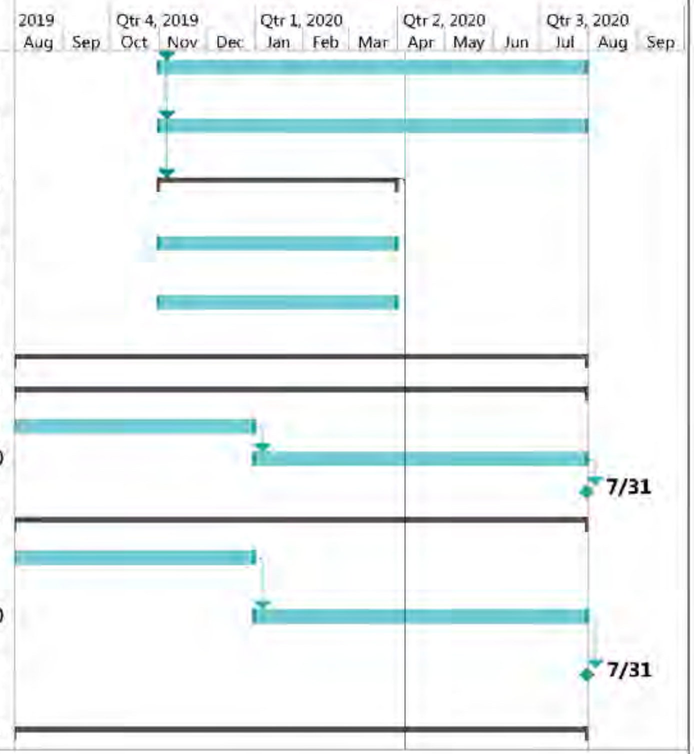
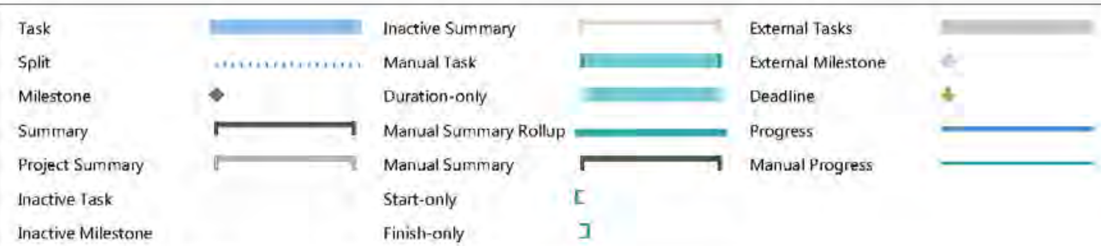
ID	Task Mode	Task Name	Duration	Start
29		Subtask 2.4 - Specification of Instrumentation	195 days	Fri 11/1/19
30		Subtask 2.5 - Specification of Control Software and Equipment	195 days	Fri 11/1/19
31		**Subtask 2.6 - Refinement of the Phase III Cost Estimate**	**108 days**	**Fri 11/1/19**
32		Subtask 2.6.1 - Validation of Phase III Capital Costs and Construction Schedule	108 days	Fri 11/1/19
33		Subtask 2.6.2 - Validation of Phase III Operating Costs and Test Plan	108 days	Fri 11/1/19
34		**Task 3.0 - NEPA and Permitting at Host Site**	**261 days**	**Thu 8/1/19**
35		**Subtask 3.1 - NEPA Process**	**261 days**	**Thu 8/1/19**
36		Subtask 3.1.1 - NEPA Proposal	109 days	Thu 8/1/19
37		Subtask 3.1.2 - NEPA Evaluation	152 days	Wed 1/1/20
38		Milestone: Final NEPA Documentation	0 days	Fri 7/31/20
39		**Subtask 3.2 - Permitting Process**	**261 days**	**Thu 8/1/19**
40		Subtask 3.2.1 - Address Existing Permit and Prepare Revision	109 days	Thu 8/1/19
41		Subtask 3.2.2 - Apply for New Permit and Participate in Reviews	152 days	Wed 1/1/20
42		Milestone: Permits for Phase III Applications Submitted	0 days	Fri 7/31/20
43		**Task 4.0 - Team and Cost Share Commitments**	**261 days**	**Thu 8/1/19**



Project: Phase 2 Gantt v1
Date: Thu 3/21/19



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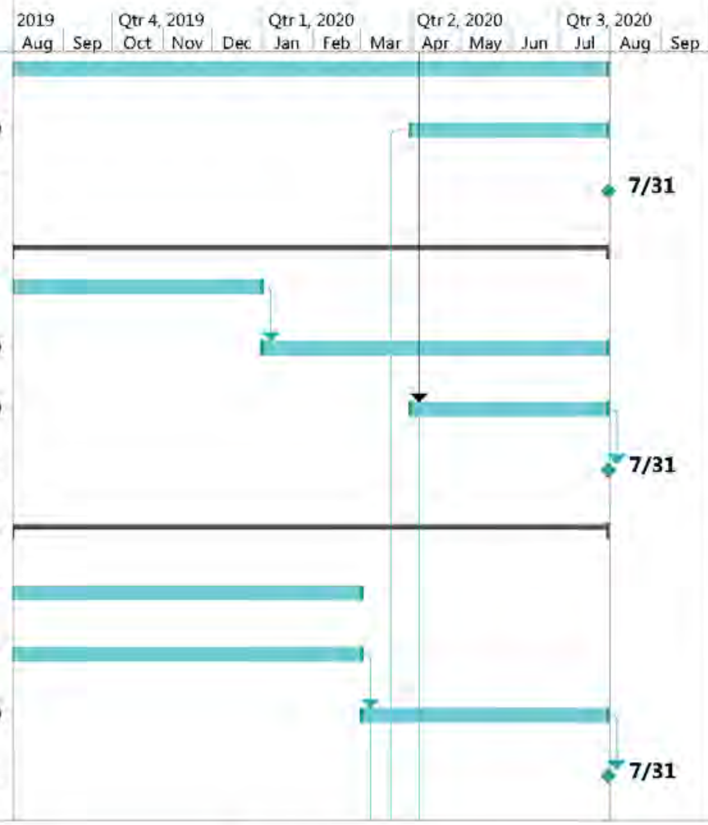
ID	Task Mode	Task Name	Duration	Start
44		Subtask 4.1 - Meetings with Potential Cost Share Partners	261 days	Thu 8/1/19
45		Subtask 4.2 - Negotiation of Cost Share Commitments	87 days	Wed 4/1/20
46		Milestone: Phase III Cost Share Commitment	0 days	Fri 7/31/20
47		**Task 5.0 - Updated Techno-Economic Analysis**	**261 days**	**Thu 8/1/19**
48		Subtask 5.1 - Update Previous Commercial Techno-Economic Analysis	109 days?	Thu 8/1/19
49		Subtask 5.2 - Add Pilot System Analysis to the Techno-Economic Analysis	152 days?	Wed 1/1/20
50		Subtask 5.3 - Add Pilot Refined Cost Estimate to the Techno-Economic Analysis	87 days?	Wed 4/1/20
51		Milestone: Updated Techno-Economic Analysis	0 days	Fri 7/31/20
52		**Task 6.0 - Analytical Technical Risk Assessment**	**261 days**	**Thu 8/1/19**
53		Subtask 6.1 - Modelling of the Pilot Combustion Reactor	153 days	Thu 8/1/19
54		Subtask 6.2 - Develop Detailed Pilot Heat and Mass Balance Model	153 days	Thu 8/1/19
55		Subtask 6.3 - Develop Technical Risk and Mitigation Plan	109 days?	Mon 3/2/20
56		Milestone: Technical Risk Analysis and Mitigation Plan	0 days	Fri 7/31/20



Project: Phase 2 Gantt v1
Date: Thu 3/21/19

Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

Page 4

ID	Task Mode	Task Name	Duration	Start
57		**Task 7.0 - Phase III Controlling Documents**	**261 days**	**Thu 8/1/19**
58		Subtask 7.1 - Phase III Data Collection, Processing, and Analysis Plan	261 days?	Thu 8/1/19
59		Subtask 7.2 - Phase III Control and Operations Philosophy	261 days?	Thu 8/1/19
60		Subtask 7.3 - Facility Safety Assessment and Guidelines	261 days?	Thu 8/1/19
61		Subtask 7.4 - Phase III Detailed Budget, Schedule, and Test Program	87 days?	Wed 4/1/20
62		**Task 8.0 - Updating the Technology Maturation Plan**	**261 days**	**Thu 8/1/19**
63		Subtask 8.1 - Development of FPO Data Book Requirement	261 days?	Thu 8/1/19
64		Subtask 8.2 - Define Performance Benchmarks Required in Phase III	153 days	Thu 8/1/19
65		Subtask 8.3 - Preliminary Validation of Performance Benchmarks	109 days?	Mon 3/2/20
66		Subtask 8.4 - Validate the Test Plan according to TRL Advancement Goals	87 days?	Wed 4/1/20
67		Milestone: Updated Technology Maturation Plan	0 days	Fri 7/31/20

Figure 9. Phase II Detailed Gantt Chart

E. PRELIMINARY COST ESTIMATE AND SCHEDULE FOR PHASE III

I. COSTS FOR PHASE III

The cost estimate for Phase III is an ongoing task that will be further refined by the completion of Phase I. The costs for major equipment for Phase III are shown in Table 18. These cost estimates are conservative and expected to be reduced before Phase II.

Table 18. Major Equipment Costs

Equipment No.	Description	25-MWth Pilot Estimated Price
01 X01	Coal Slurry Bar Mill	$798,000
01 X08	Coal Slurry Bar Mill Recycle Conveyor	$35,000
01 X09	Coal Slurry Paddle Mixer	$70,000
02 P01A	Coal Slurry Feed Pump A	$16,000
02 P01B	Coal Slurry Feed Pump B	$16,000
02 E02	Combustor O2 Feed Heat Exchanger	$20,930
02 R01	Oxy-combustor Vessel	$361,023
02 R01	Oxy-combustor Vessel Injection Set	$196,098
02 J01A	Flue Gas Quencher A	$101,500
02 J01B	Flue Gas Quencher B	$101,500
	Refractory for Combustor/Quencher/Pipes	$483,140
02 E06	Once Through Steam Generator - OTSG	$1,925,664
02 F01	Recycle Flue Gas Glower Inlet Air Filter	$7,000
02 C01A	Recycle Flue Gas Blower	$243,600
02 V01A	Refractory Lined Quencher Inlet Pipe A	$14,261
02 V01B	Refractory Lined Quencher Inlet Pipe B	$14,261
02 V01C	Refractory Lined Quencher Inlet Pipes C	$14,261
02 V01D	Refractory Lined Quencher Inlet Pipes D	$14,261
02 V02A	Refractory Lined Quencher Outlet Pipe A	$33,319
02 V02B	Refractory Lined Quencher Outlet Pipe B	$33,319
02V03	Refractory Lined Quencher Outlet Pipe - Common	$33,319
02 K01	Turbo-expander	$1,500,000
01 D01	Coal Storage Silo	$175,000
01 X03	Coal Feed Conveyor	$400,000
01 X05	Coal Reclaim Conveyor	$400,000
01 X06	Coal Bucket Conveyor	$400,000

Equipment No.	Description	25-MWth Pilot Estimated Price
09 D04	Flush / Service Water Tank	$29,100
09 D07	Demineralized Water Storage Tank	$162,300
08 X01	Air Separator Unit	$5,892,000
03 P02A	BFW Pump (HP) A	$900,000
03 P01	BFW Treatment Additive Pump	$29,300
03 D01	BFW Treatment Additive Tote	$1,000
09 P09A	Demineralized Water Pump A	$28,900
09 P07A	Flush / Service Water Pump A	$31,500
04 P05	Closed Cooling Water (CCW) Pump	$37,500
04 D08	Closed Cooling Water Head Tank	$18,750
09 X02	Air Compressor Package	$52,500
04 P02A	Slag Quench Water Pump A	$34,800
04 E01	Slag Quench Heat Exchanger	$13,400
04 V01A	Slag Settler A (ID:89)	$92,000
04 V01B	Slag Settler B (ID:92)	$92,000
04 P04	Slag Settlers Flush Water Pump	$5,000
04 P03A	Slag Sump Pump A	$28,800
03 X02	Super Critical Main Steam Attemperator	$172,500
03 X03	Reheat Steam Attemperator	$300,000
03 E04	Air Cooled Steam Pressure Condenser (ACC)	$4,500,000
04 E03	Air Cooled Closed Cooling Water (CCW) Fin Fan Cooler	$300,000
05 X01	Turbo-expander Dynamometer	$67,000
03 V01	Super Critical Steam Deaerator	$122,000
03 E05	Feedwater Heat Exchanger	$37,500
	HVAC Unit for Combustor Building	$85,000
	HVAC Unit for ASU Building	$85,000
	Fuel Gas Regulating Station	$25,000
	Combustor Building	$3,600,000
	ASU Building	$2,900,000
	Steel Flue Gas Stack	$1,000,000
	Electrical PDC Building	$1,200,000
	13.8kV Substation Circuit Breaker	$25,000
	DCS	$900,000
	Total	**$30,175,305**

Based on the projected equipment costs, a factored approach was taken for estimating the capital costs. These factors are based on experience by S&L in developing similar demonstration pilots. The Phase I task to refine the costs has the goal of further reducing the cost of equipment. The current Phase III capital costs and the estimated refined capital cost are shown in Table 19. By the completion of Phase I, a more detailed cost estimate will be produced that uses estimates of labor and materials.

The operating costs for the pilot were estimated based on information available at the site. The basis for the operating costs and the estimated costs of operating are shown in Table 20. Combining the projected capital cost of $85.5 million with the operating costs of the two year test plan of $21.1 million, the total projected cost for Phase III is $106.6 million. This indicates that $36.6 million in cost share will need to be committed to by the end of Phase II.

Table 19. Estimated Phase III Capital Costs for the 25-MWth Pilot Plant

	Current Capital Cost Estimate	Phase I End Projected Capital Cost	Factor
Equipment	$30,175,305	$25,649,009	30%
Materials	$5,029,218	$4,274,835	5%
Labor & Construction Equipment	$28,163,618	$23,939,075	28%
Site Overheads (CM, field office, scaffold, OT, freight, G&A, profit)	$20,116,870	$17,099,340	20%
Engineering	$9,052,592	$7,694,703	9%
S/U & Commissioning	$2,011,687	$1,709,934	2%
Escalation	$6,035,061	$5,129,802	6%
Total Capital Costs	$100,584,351	$85,496,698	100%

Table 20. Estimated Phase III Operating Costs for the 25-MWth Pilot Plant

Input Data	FPO 25-MWth Pilot	
Fuel Type	"Super-Compliance" PRB	
Nominal Plant Gross Capacity	MW	25
Capacity Factor (CF)	%	28.5
Heat Input to Boiler at Full Load	MMBtu/hr	88
Fuel Heating Value	Btu/lb	8,800
Fuel Ash Content	%	4.50
Ash Removal in Boiler	%	99.00
Fuel Sulfur Content	%	0.22
Solids Handling Analysis		
Fuel Firing Rate at Full Load	kg/s	1.27
Fuel Firing Rate at Full Load	lb/hr	10,056
Slag Production	kg/s	0.06
Slag Production	lb/hr	453
No. Waste Disposal Trucks per year		50
Auxiliaries Analysis		
Auxiliary Power Consumption	kW	3,688
Water Analysis		
Water Requirement	gpm	20
Economic Parameters		
Labor Rate	$/yr	1,703,000
Fuel Cost	$/MMBtu	5.0
Waste Disposal Cost	$/ton	20.00
Waste Disposal Trucking Cost	$/truck	104
Aux. Power Cost	$/kWh	0.74
Make up Water Cost	$/1000 gal	9.28
Water Treatment Cost	$/month	50,000
Variable O&M Cost		
Fuel Cost	$/yr	1,106,100
Limestone Reagent Cost	$/yr	0
Waste Disposal Cost (including Trucks)	$/yr	12,800
Auxiliary Power Cost	$/yr	6,859,700
Water with Treatment Cost	$/yr	627,900
Total Variable O&M Cost (w/ CF)	$/yr	8,006,500
Total Variable O&M Cost (@100% CF)	$/yr	28,055,000
Fixed O&M Cost		
Operating Labor	$/yr	1,703,000
Maintenance Material	$/yr	157,000
Maintenance Labor	$/yr	104,000
Total Fixed O&M Cost (w/ CF)	$/yr	1,964,000
Total Fixed and Variable O&M Costs(w/CF)	$/yr	10,570,500
Total O&M Costs for a 2 Year Test Plan		$21,141,000

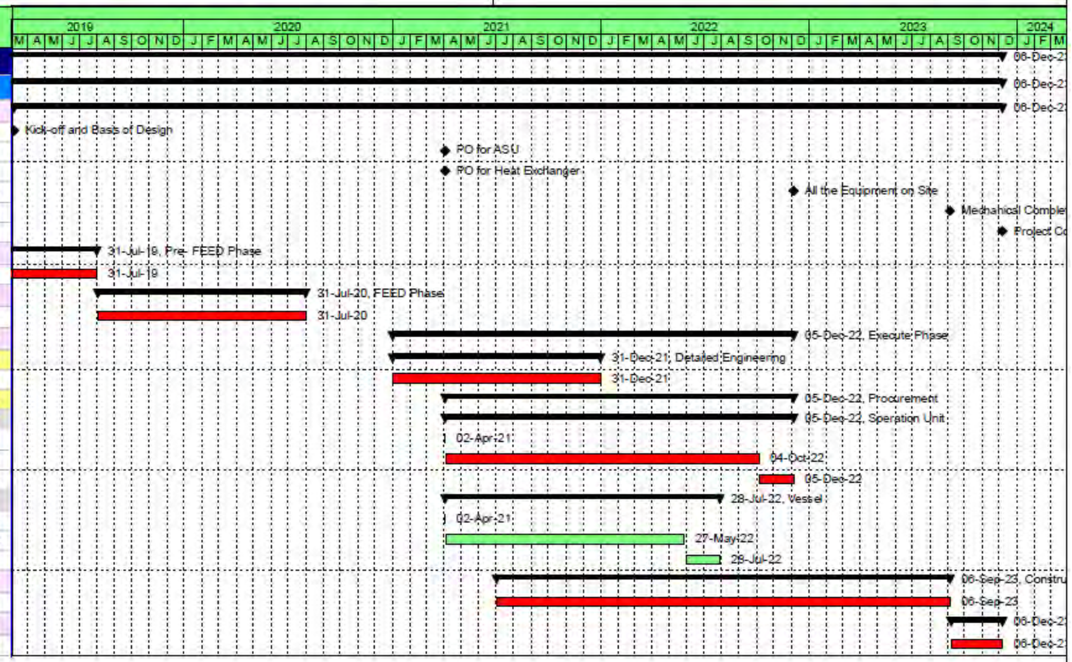
II. CONSTRUCTION AND COMMISSIONING SCHEDULE FOR PHASE III

A Level 1 project schedule was generated as shown in Figure 10. This schedule includes FEED and detailed engineering phases. It also highlights the projected lead times for major items. The detailed design, construction, and commissioning efforts will last approximately 3 years, ending in 2023.

Figure 10. Level 1 Project Schedule for the 25-MWth Pilot Plant

FPO DEMO PLANT | **LEVEL 1 PROJECT SCHEDULE** | **JACOBS ENGINEERING GROUB**

Activity ID	Activity Name	Original Duration	Start	Finish
FPO DEMO PLANT		1244	01-Mar-19	06-Dec-23
FPO DEMO PLANT		1244	01-Mar-19	06-Dec-23
Milestones		1240	07-Mar-19	06-Dec-23
A1160	Kick-off and Basis of Design	0	07-Mar-19	
A1110	PO for ASU	0		02-Apr-21
A1120	PO for Heat Exchanger	0		02-Apr-21
A1130	All the Equipment on Site	0		05-Dec-22
A1140	Mechanical Completion	0		06-Sep-23
A1150	Project Completion	0		06-Dec-23
Pre- FEED Phase		109	01-Mar-19	31-Jul-19
A1000	Feasibility Works (FEL2)	109	01-Mar-19	31-Jul-19
FEED Phase		262	01-Aug-19	31-Jul-20
A1010	Definition Works	262	01-Aug-19	31-Jul-20
Execute Phase		502	01-Jan-21	05-Dec-22
Detailed Engineering		261	01-Jan-21	31-Dec-21
A1020	Detailed Engineering Works	261	01-Jan-21	31-Dec-21
Procurement		437	02-Apr-21	05-Dec-22
Speration Unit		437	02-Apr-21	05-Dec-22
A1030	PO for ASU	1	02-Apr-21	02-Apr-21
A1040	Fabrication & Inspection Works for ASU	392	05-Apr-21	04-Oct-22
A1050	ASU - Ship & Delivery	44	05-Oct-22	05-Dec-22
Vessel		345	02-Apr-21	28-Jul-22
A1080	PO for Heat Exchanger	1	02-Apr-21	02-Apr-21
A1090	Fabrication & Inspection Works for Heat Exchanger	300	05-Apr-21	27-May-22
A1100	Heat Exchanger - Ship & Delivery	44	30-May-22	28-Jul-22
Construction Phase		570	01-Jul-21	06-Sep-23
A1060	Construction Works	570	01-Jul-21	06-Sep-23
Commissioning Phase		65	07-Sep-23	06-Dec-23
A1070	Commissioning Works	65	07-Sep-23	06-Dec-23



Remaining Level of Effort | Actual Work | Critical Remaining Work | Summary
Actual Level of Effort | Remaining Work | ◆ Milestone | WBS Summary Activity

Page 1 of 1

TASK filter: All Activities

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III. TEST PLAN AND OPERATIONS

The test plan includes commissioning, actual testing, and inspection work. Similar to the size and make-up of the pilot equipment, the test plan is dependent on the amount of funding available. If further funding is available, the pilot could perform a wide range of tests and be used as a permanent testing facility that could be useful even after the technology has gone commercial.

If funding is limited, there is a minimum amount of testing—both in terms of duration and type—required to accomplish the following:

- Determine the figures of merit (FOM) required to advance the technology to TRL.
- Give confidence to potential end-users that the technology can achieve its design targets and is safe, reliable, and less risky.
- Allow ITEA to update and finalize the design of the next system scale up in size.

In terms of the FOM, as discussed in Appendix C: FPO Pilot Testing Figures of Merit, most necessary accomplishments require relatively little operational time—perhaps as little as 100 hours—once the pilot has been commissioned and is operating at near-optimal, steady-state conditions, than the FOM related to longer-term endurance parameters.

In terms of the minimum time that end-users need to gain confidence in the potential viability of the technology, EPRI performed a survey of the power industry and posed the question “How many operating hours are necessary for the pilot project to be successful?” Out of the 20 organizations that responded to the survey, all of which are coal power producers in the U.S., the answers to this question ranged from 1,000 to 20,000 hours of operation. In addition, the majority stated that having the interested power industry directly involved in the testing could help facilitate acceptance if the technology would potentially reduce the amount of testing time required to achieve that. Additionally, understanding and identifying sequence of operations (e.g., startup and shutdown) and being able to run flexibly as most existing coal power plants are required to do, it will be important test parameters for the power industry.

The sequence of operations and operational flexibility, in particular, will challenge not only the equipment but also the underlying control system. The latter is a critical piece that ITEA wants to validate during the testing of this pilot. ITEA is also interested in vetting the “flexible fuel” nature of the technology by validating it can use low-ranking coals (the standard testing coal will be PRB), expanding its potential in the marketplace. Note that if funding and timing permits, GE, who is developing the turbo-expander component, would like to include high-temperature (up to 700°C inlet temperature) expander modifications for testing near the end of the program.

After the required commissioning phases, the minimum goals of the test plan were taken to be 3,000 hours of testing. This includes steady state and flexible testing along with performance and endurance testing. Several inspections will also be performed, one during and one after testing, to determine if operations have had deleterious impacts on the components.

Table 21 provides an overview of the testing phases and the anticipated time span for each phase for the required minimum testing. Figure 11 gives the overall schedule for commissioning and testing.

Table 21. Testing Phases and Timeline

Test Phase	Coal	Testing Time	Time Span
Cold Commissioning	---	---	2 months
Hot Commissioning and Startup	PRB	~100 hours	6 months
Steady-State, Flexible, and Load Testing	PRB	1,000 hours	6 months
Visual Inspection	---	1 week	1 week
Performance and Endurance Testing*	PRB (and possibly other coals**)	2,000 hours	10 months
Detailed Inspection	---	4 weeks	1 month
Totals	**---**	**~3,000 hours**	**25 months**

** Includes high-temperature turbo-expander testing, if time and funding permit.*
*** If funding and time permit.*

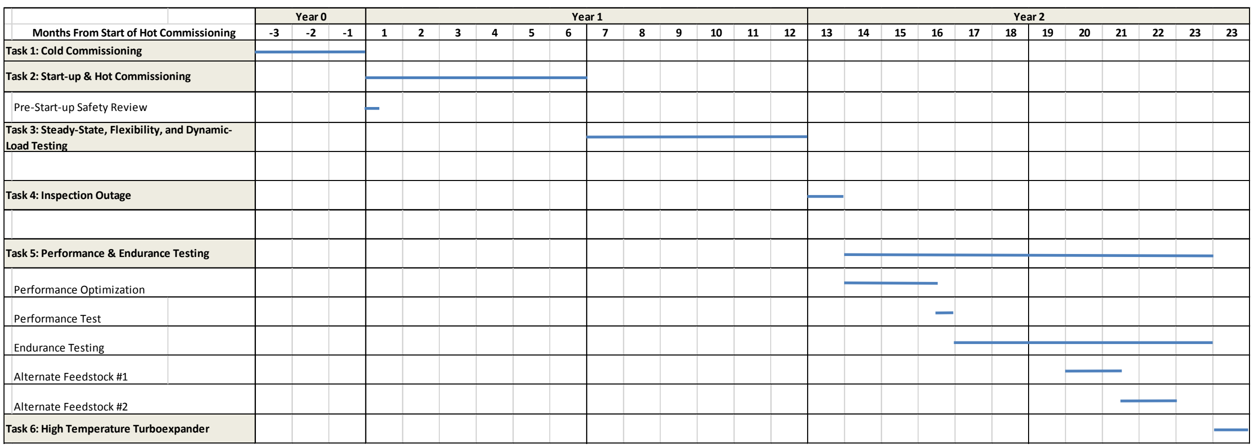

Figure 11. Overall Testing Schedule

F. PRELIMINARY TECHNO-ECONOMIC ANALYSIS

I. General Evaluation Basis

1) Introduction

The current design of the commercial-scale FPO system is as follows:

A cryogenic air separation unit (ASU) delivers oxygen to the combustor at the required pressure of approximately 189–203 psia (13–14 bara). Oxy-combustion then takes place in the patented, slagging “ISOTHERM PWR” combustor with slurry coal feed and the oxygen provided by the ASU. The combustion temperature is typically near 2,550°F (1,400°C). A flue gas recycle (FGR) system provides cooled flue gas to the combustor to dilute the combustor exhaust to an acceptable temperature. After that it enters the (convection) once-through steam generator (OTSG), which produces supercritical steam at 1,120°F (605°C),driving a steam-Rankine power cycle compatible with the OTSG. The OTSG waterside path is oriented in a counter-current flow configuration to the gas-side flow.

The environmental control system consists primarily of a direct-contact water wash to recover heat and scrub SO_2, SO_3, and residual particulates issuing from the combustor. Nearly all of the sulfur entering the combustor, organic or inorganic, leaves as either sulfate in the slag or as SO_2. The SO_3 content of the flue gas is reportedly at single ppmv levels. It is anticipated that NOx produced from fuel-bound nitrogen will be converted to HNO_3 at pressure, which will also be collected in the water wash; hence, no NOx removal technology is needed. A carbon-processing unit (CPU), within which water and any minor species are removed, meets the product CO_2 design-basis specification. The removed species include combustion byproducts such as carbon monoxide [CO], hydrogen chloride [HCl], hydrogen fluoride [HF], residual sulfur species like sulfur dioxide [SO_2] and sulfur trioxide [SO_3], and nitrogen dioxide [NO_2] or any byproducts from air separation like argon.

The remaining balance-of-plant systems are considered conventional.

The commercial FPO system employs a supercritical, single-reheat steam cycle. It is capable of supporting a dual-reheat system. However, a single-reheat OTSG was modeled to better compare with the performance of the NETL baseline cases, which are all single-reheat boilers. There are several notable features of this power system design:

- The pressurized combustor is fed with a coal and water slurry, fresh oxygen, and cooled FGR. Approximately 99% of the fuel ash leaves the combustor as a slag. The refractory-lined combustor pressure boundary is water-cooled, but it is not a significant contributor of heat to the power cycle. Products of combustion leave the combustor at a temperature typically between 2,460–2,820°F (1,350–1,450°C). The products of combustion are cooled by mixing FGR to a temperature near 1,470°F (800°C).
- Low-temperature feedwater heating is accomplished by heat recovery from flue gas leaving the OTSG.
- Low-temperature flue gas heat is recovered to the feedwater from an intermediate water loop that is sprayed into the flue gas leaving the OTSG. This direct-contact spray system is expected to remove most of the water-soluble trace gases: SO_2/SO_3, HCl, HF, NO_2, etc. Excess water condensed from the flue gas carries these dissolved contaminants to waste.
- Deaerator pressure is near 4.5 bar (65.3 psia). This pressure is set to maximize the low-temperature heat recovered from the flue gas.

2) SITE CHARACTERISTICS

The site characteristics were adopted from the NETL S12B case, which is contained in the reference document: “Cost and Performance Baseline for Fossil Energy Plants Vol. 3b: Low-Rank Coal Electricity: Combustion Cases” [6]. The site is a greenfield location in Montana and physical characteristics are shown in Table 22.

Table 22. Site Conditions for the Baseline Case

Elevation, m (ft.)	1,036 (3,400)
Barometric Pressure, MPa (psia)	0.09 (13.0)
Design Ambient Temperature, Dry Bulb, °C (°F)	5.6 (42)
Design Ambient Temperature, Wet Bulb, °C (°F)	2.8 (37)
Design Ambient Relative Humidity, %	62

The characteristics of the plant, shown in Table 23, are also taken from the NETL report [6].

Table 23. Plant Characteristics

Location	Greenfield site Montana, PRB coal
Topography	Level
Size, acres	300
Transportation	Rail
Ash/Slag Disposal	Off Site
Water	Municipal (50%) / Groundwater (50%)
Access	Land locked, having access by rail and highway
CO_2 Storage	Compressed to 15.3 MPa (2,215 psia), transported 80 kilometers (50 miles) and sequestered in a saline

3) Coal Characteristics

For this case, the Montana Rosebud PRB coal was used. This matches the input coal for the S12B case [6]. The characteristics of this coal are reproduced in Table 24.

Table 24. Characteristics of the Montana PRB Coal

Proximate Analysis		Dry Basis, %	As Received, %
Moisture		0.0	25.77
Ash		11.04	8.19
Volatile Matter		40.87	30.34
Fixed Carbon		48.09	35.70
	Total	100.0	100.0
Ultimate Analysis		**Dry Basis, %**	**As Received, %**
Carbon		67.45	50.07
Hydrogen		4.56	3.38
Nitrogen		0.96	0.71
Sulfur		0.98	0.73
Chlorine		0.01	0.01
Ash		11.03	8.19
Moisture		0.00	25.77
Oxygen[1]		15.01	11.14
	Total	100.0	100.0
Heating Value		**Dry Basis**	**As Received, %**
HHV, kJ/kg		26,787	19,920
HHV, Btu/lb		11,516	8,564
LHV, kJ/kg		25,810	19,195
LHV, Btu/lb		11,096	8,252
Hardgrove Grindability Index		57	
Ash Mineral Analysis			**%**
Silica	SiO_2		38.09
Aluminum Oxide	Al_2O_3		16.73
Iron Oxide	Fe_2O_3		6.46
Titanium Dioxide	TiO_2		0.72
Calcium Oxide	CaO		16.56
Magnesium Oxide	MgO		4.25
Sodium Oxide	Na_2O		0.54
Potassium Oxide	K_2O		0.38
Sulfur Trioxide	SO_3		15.08
Phosphorous Pentoxide	P_2O_5		0.35
Barium Oxide	Ba_2O		0.00
Strontium Oxide	SrO		0.00
Unknown	---		0.84
		Total	100.0
Trace Components			**ppmd**
Mercury[2]	Hg		0.081

4) *EMISSIONS LIMITS*

Emissions are bound by limits set at the project start. For comparison, the targets set forth in the NETL baseline [6] for new units are shown in Table 25. These values are federally regulated according to the New Source Performance Standards (NSPS). The FPO process slurries as-received coal with water without drying it. Therefore, the wet basis for mercury (Hg) emission is used.

Table 25. Standards of Performance for New Electric Utilities Built after February 28, 2015

Pollutant	New Units	
	NETL Baseline Limit	**Project Limit**
PM	0.015 lb./MMBtu	0.09 lb./MMBtu
SO_2	1.4 lb./MWh	1.0 lb./MWh
NOx	1.0 lb./MWh	0.7 lb./MWh
Hg Subbituminous (wet units)	66×10^{-6} lb./MWh	3×10^{-6} lb./MWh

The basis for the limiting of CO_2 emissions is to demonstrate the potential of FPO for carbon capture, utilization, and storage (CCUS) applications. CO_2 is not currently regulated, but there is a possibility that carbon limits will be enacted in the future. Per the guidelines in the NETL baseline reports [6], 90% of the CO_2 produced by the coal will be captured.

5) *CAPACITY FACTOR*

Following the expectation of the NETL baseline report, a capacity factor of 85% was used. This uses the assumption that the plant would be dispatched whenever it is available, and plant availability for the 400-599 MW size is typically 85% [6]. Like the NETL baseline, the CO_2 capture system was assumed to have no impact on plant availability.

6) *Raw Water Withdrawal and Consumption*

The water consumption was assumed to be provided as makeup for the cooling tower and steam systems, following the NETL baseline assumptions [6].

It should be noted that the usage of water is not required by the FPO system. In fact, a zero water consumption case is possible with a water treatment plant. The moisture within the PRB is not dried out of the feed but slurried with recycle water. Thus, there is a net production of water once it is removed from the CO_2 stream by the direct contact condenser (DCC). However, this scenario was not considered for this report, given that is a departure from the NETL assumptions about water use and consumption.

II. Cost Estimating Methodology

The total plant cost (TPC) and operation and maintenance (O&M) costs for the FPO supercritical power plant were estimated, following NETL's methodology, as follows.

1) *Capital Cost*

The baseline report for oxy-combustion cases "Cost and Performance for Low-Rank Pulverized Coal Oxy-combustion Energy Plants" [7] provides a cost estimate for the major subsystems of the Case S12F pulverized oxy-combustion plant with CO_2 capture and purification via cryogenic distillation. This case was chosen because the types of equipment being used in the FPO process are like the components in S12F. Using it as the main reference cost estimate, modifications to each subsystem's cost can be made either by cost scaling via capacity factor or by direct replacement with proprietary estimates. From this approach, the overall cost estimate for the nominal 550 MWe supercritical plant is estimated. For the subsystems in which capacity factoring is used to generate the cost estimates, appropriate scaling parameters, from the Cost Scaling Methodology Report [8], and exponents for capacity factoring, from the Cost Estimation Methodology Report [9], are used. NETL Case S4A, from "Cost and Performance Baseline for Fossil Energy Plants Vol. 3a: Low-Rank Coal Electricity" [10], was also used for cost estimates related to coal slurrying.

The list of the expected supercritical power plant systems and subsystems are shown in Table 26. Subsystems that are related to slurry-based coal handling and gasifier slag handling come from case S4A [10]. NETL Case S12F [7] informs the supercritical oxy-combustion and CO_2 capture subsystems. Finally, NETL Case S12B [6] is used for steam turbine subsystems. Subsystems that are grouped within the proprietary systems category are based on novel technologies and have no analogous counterparts within the S12F, S4A, or S12B plants. These subsystems are shown in ***bold, italicized blue font*** and are directly replaced with in-house estimates.

Table 26. List of Equipment and Basis of Estimate

Acct No.	Item/Description	Reference Case	Cost Estimate Basis	Cost Scaling Reference Parameter [8]
1	COAL & SORBENT HANDLING (GASIFICATION)			
1.1	Coal Receive & Unload	S4A	Cost Scaling	Coal Feed Rate, lb/hr
1.2	Coal Stackout & Reclaim	S4A	Cost Scaling	Coal Feed Rate, lb/hr
1.3	Coal Conveyors & Yard Crushing	S4A	Cost Scaling	Coal Feed Rate, lb/hr
1.4	Other Coal Handling	S4A	Cost Scaling	Coal Feed Rate, lb/hr
1.9	Coal & Sorbent Handling Foundations	S4A	Cost Scaling	Coal Feed Rate, lb/hr
2	COAL PREP & FEED SYSTEMS (GASIFICATION)			
2.1	Coal Crushing & Drying	S4A	Cost Scaling	Coal Feed Rate, lb/hr
2.2	Prepared Coal Storage & Feed	S4A	Cost Scaling	Coal Feed Rate, lb/hr
2.3	***Slurry Prep & Feed***	***N/A***	***Proprietary***	***N/A***
2.4	Misc. Coal Prep & Feed	S4A	Cost Scaling	Coal Feed Rate, lb/hr
2.9	***Slurry Prep and Feed Foundation***	***N/A***	***Proprietary***	***N/A***
3	FEEDWATER & MISC. BOP SYSTEMS			
3.1	Feedwater System	S12F	Cost Scaling	HP BFW Flow Rate, lb/hr
3.2	Water Makeup & Pretreating	S12F	Cost Scaling	Raw Water Makeup, gpm
3.3	Other Feedwater Systems	S12F	Cost Scaling	HP BFW Flow Rate, lb/hr
3.4	Service Water Systems	S12F	Cost Scaling	Raw Water Makeup, gpm
3.5	Other Boiler Plant Systems	S12F	Cost Scaling	HP BFW Flow Rate, lb/hr
3.6	FO Supply Sys & Nat Gas	S12F	Cost Scaling	Total Fuel Feed, lb/hr
3.7	Waste Treatment Equipment	S12F	Cost Scaling	Water to Treatment, lb/hr
3.8	Misc. Power Plant Equipment	S12F	Cost Scaling	Total Fuel Feed, lb/hr
4	BOILER & ACCESSORIES			
4.1	***ITEA FPO System***	***N/A***	***Proprietary***	***N/A***
4.2	ASU	S12F	Cost Scaling	O_2 Flow Rate, TPD
4.3	***O_2 Compression***	***N/A***	***Nexant***	***N/A***

Acct No.	Item/Description	Reference Case	Cost Estimate Basis	Cost Scaling Reference Parameter [8]
4.9	***FPO System Foundation***			
5A	FLUE GAS CLEANUP			
5.1	***Pressurized Flue Gas Desulfurization System***	***N/A***	***Proprietary***	***N/A***
5.9	***FGD System Foundation***	***N/A***	***Proprietary***	***N/A***
5B	CO_2 REMOVAL & COMPRESSION			
5B.1	CO_2 Condensing Heat Exchanger	S12F	Cost Scaling	CO_2 Captured, lb/hr
5B.2	CO_2 Compression & Purification	S12F	Cost Scaling	Compression Power Requirement, MWe
6	TURBO-EXPANDER			
6.1	***Turbo-expander***	***N/A***	***Proprietary***	***N/A***
6.9	***Turbo-expander Foundation***	***N/A***	***Proprietary***	***N/A***
7	OTSG, DUCTING & STACK			
7.3	Ductwork	S12F	Cost Scaling	Circulating Flue Gas Flow, acfm
7.4	Stack	S12F	Cost Scaling	Stack Flow, acfm
7.9	OTSG, Duct & Stack Foundations	S12F	Cost Scaling	Circulating Flue Gas Flow, acfm
8	STEAM TURBINE GENERATOR			
8.1	Steam TG & Accessories	S12B	Cost Scaling	Turbine Capacity, MW
8.2	Turbine Plant Auxiliaries	S12B	Cost Scaling	Turbine Capacity, MW
8.3a	Condenser & Accessories	S12B	Cost Scaling	Condenser Duty, MMBtu/hr
8.3b	Air Cooled Condenser	S12B	Cost Scaling	Condenser Duty, MMBtu/hr
8.4	Steam Piping	S12B	Cost Scaling	HP BFW Flow Rate, lb/hr
8.9	TG Foundations	S12B	Cost Scaling	Turbine Capacity, MW
9	COOLING WATER SYSTEM			
9.1	Cooling Towers	S12F	Cost Scaling	Cooling Tower Duty, MMBtu/hr

Acct No.	Item/Description	Reference Case	Cost Estimate Basis	Cost Scaling Reference Parameter [8]
9.2	Circulating Water Pumps	S12F	Cost Scaling	Circulating Water Flow Rate, gpm
9.3	Circ. Water Systems Auxiliaries	S12F	Cost Scaling	Circulating Water Flow Rate, gpm
9.4	Circ. Water Piping	S12F	Cost Scaling	Circulating Water Flow Rate, gpm
9.5	Makeup-Water System	S12F	Cost Scaling	Raw Water Makeup, gpm
9.6	Component Cooling Water System	S12F	Cost Scaling	Circulating Water Flow Rate, gpm
9.9	Circ. Water System Foundations	S12F	Cost Scaling	Circulating Water Flow Rate, gpm
11	COOLING WATER SYSTEM			
11.1	Generator Equipment	S12F	Cost Scaling	Turbine Capacity, MW
11.2	Station Service Equipment	S12F	Cost Scaling	Auxiliary Load, kW
11.3	Switchgear & Motor Control	S12F	Cost Scaling	Auxiliary Load, kW
11.4	Conduit & Cable Tray	S12F	Cost Scaling	Auxiliary Load, kW
11.5	Wire & Cable	S12F	Cost Scaling	Auxiliary Load, kW
11.6	Protective Equipment	S12F	Cost Scaling	Auxiliary Load, kW
11.7	Standby Equipment	S12F	Cost Scaling	Turbine Capacity, MW
11.8	Main Power Transformers	S12F	Cost Scaling	STG Rating, MVA
11.9	Electrical Foundations	S12F	Cost Scaling	Turbine Capacity, MW
12	INSTRUMENTATION & CONTROL			
12.6	Control Boards, Panels & Racks	S12F	Cost Scaling	Auxiliary Load, kW
12.7	Computer Accessories	S12F	Cost Scaling	Auxiliary Load, kW
12.8	Instrument Wiring & Tubing	S12F	Cost Scaling	Auxiliary Load, kW
12.9	Other I & C Equipment	S12F	Cost Scaling	Auxiliary Load, kW
13	IMPROVEMENTS TO SITE			
13.1	Site Preparation	S12F	Cost Scaling	BEC (Minus Acts 13 and 14)
13.2	Site Improvements	S12F	Cost Scaling	BEC (Minus Acts 13 and 14)
13.3	Site Facilities	S12F	Cost Scaling	BEC (Minus Acts 13 and 14)

Acct No.	Item/Description	Reference Case	Cost Estimate Basis	Cost Scaling Reference Parameter [8]
14	BUILDINGS & STRUCTURES			
14.1	***Boiler Building***	***N/A***	***Proprietary***	***N/A***
14.2	Turbine Building	S12F	Cost Scaling	BEC (Minus Acts 13 and 14)
14.3	Administration Building	S12F	Cost Scaling	BEC (Minus Acts 13 and 14)
14.4	Circulating Water Pump House	S12F	Cost Scaling	Circulating Water Flow Rate, gpm
14.5	Water Treatment Buildings	S12F	Cost Scaling	Raw Water Makeup, gpm
14.6	Machine Shop	S12F	Cost Scaling	BEC (Minus Acts 13 and 14)
14.7	Warehouse	S12F	Cost Scaling	BEC (Minus Acts 13 and 14)
14.8	Other Buildings & Structures	S12F	Cost Scaling	BEC (Minus Acts 13 and 14)
14.9	Waste Treating Building & Structures	S12F	Cost Scaling	Raw Water Makeup, gpm

a) *Proprietary Systems Capital Cost Estimate Criteria*

Costs were estimated from historical studies and updated figures for portions of the following proprietary systems:

- Coal slurry preparation and feed
- FPO firing system
- Pressurized flue gas desulfurization system
- Pressurized flue gas turbo-expander

The cost basis is for the current year (2018), but in Euros and for a location in Italy. ITEA provided the exchange rate (1.14 USD/Euro) and assumed a 10% location premium for Italy over the U.S. site. ITEA provided the bare erected costs (BEC) for the systems listed above, expressed as single line lump-sum turnkey costs for each proprietary system.

The lump-sum turnkey costs provided by ITEA excluded the foundation and building costs for these systems. These were estimated separately, expressed also as single line, lump-sum turnkey costs and added to the appropriate accounts consistent with NETL's cost accounting system.

The team performed a bottoms-up cost estimate based on equipment sizing for auxiliary, generic equipment that is not included in the technology licensor's package, such as the ASU oxygen compressor. Based on the equipment sizes defined by the process heat and material balance, the equipment cost for each piece of major equipment was estimated using commercial estimation software (ASPEN In-Plant Cost Estimator) with adjustments based on past quotes for similar equipment where necessary. Installation labor hours were factored from historical data for similar equipment types. Total equipment plus installation labor costs gives the major equipment cost (MEC) for a system.

Bulk material and installation costs were factored from and added to MEC to form the total direct cost (TDC) of a system. Bulk materials cover instrumentations, piping, structural steel, insulation, electrical, painting, concrete and site preparation works needed to complete the major equipment installations are factored from MEC based on historical data for similar services. Installation labor for each bulk commodity is factored from historical data by type.

Construction indirect costs were then factored from total direct labor costs based on historical data. Construction indirect costs cover the cost for setup, maintenance and removal of temporary facilities, warehousing, surveying and security services, maintenance of construction tools and equipment, consumables and utilities purchases, and field office payrolls. These elements were added to the system TDC to give the total field cost (TFC) for the system, which is analogous to the BEC in the NETL cost reporting format.

b) Non-Proprietary Systems Capital Cost Estimate Criteria

The non-proprietary systems category includes all of the common systems that, except for different capacities, have nearly identical flow schemes as the corresponding systems in either Case S12F [7] or Case S4A [10]. Capital costs for systems in the NPS category are scaled via capacity factor, using the appropriate scaling parameters as shown in Table 26 and exponents for capacity factoring from the Cost Scaling QGESS Report [8].

As the cost estimate bases for Case S12F and Case S4A are based on the years 2007 and 2011 respectively, it is necessary to escalate these costs to current year cost basis. It is possible to escalate subsystem costs directly from 2007 to current year cost basis uniformly using the ratios of the Chemical Engineering Plant Cost Indices (CEPCI) for the corresponding years. However, it was also noted from the 2007 Bituminous PC Baseline Report and 2015 Bituminous PC Baseline Report [11], whose plant system costs are reported in years 2007 and 2011 cost bases respectively, that the cost escalation for the various pulverized coal (PC) subsystems were not uniformly applied.

First, the costs for Case S12F were escalated to a 2011-cost basis first, using the factors established from the Bituminous PC Baseline Reports. Next, the 2011 cost basis was revised to the 2018-cost basis using the CEPCI ratio.

c) Home Office, Engineering Fees, and Project/Process Contingencies

Engineering and construction management fees, home office cost, project and process contingencies are factored from each subsystem's BEC. These were then added to the BEC to come up with the TPC of the system. Relevant factors from Case S12F and Case S4A were used to obtain these fees and contingencies. The engineering and construction management fees and home office costs were assumed at 10% of the BEC, while project contingencies varied between 7% and 20% for different subsystems, with the majority being at 15%. A process contingency of 15% of the BEC was applied to the FPO firing system, which is a novel process.

d) Owner's Cost

The owner's cost is then added to TPC to come up with the TOC for the system. Owner's costs, as defined in the NETL Cost Estimation QGESS Report [9] include the following:

- Preproduction Costs
    - 6 months of all labor cost
    - 1 month of maintenance materials
    - 1 month of non-fuel consumables
    - 1 month of waste disposal
    - 25% of 1 month fuel cost at 100% capacity factor (CF)
    - 2% TPC
- Inventory Capital
    - 60 day supply of fuel and consumable at 100% CF
    - 0.5% TPC
- Initial Cost for Catalyst and Chemicals per design
- Land Cost = $900,000 at 300 acres x $3,000/acre
- Other Owner's Costs at 15% TPC
- Financing Costs at 2.7% TPC

Capital cost levels and their elements are shown in Figure 12.

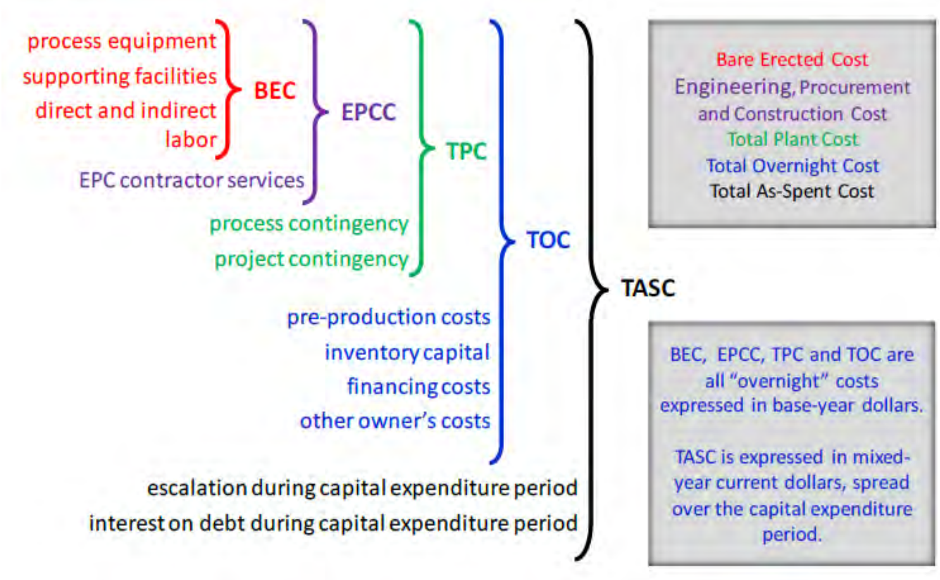

Figure 12. Capital Cost Levels and Buildup

2) O&M Costs

The O&M costs pertain to those charges associated with operating and maintaining the power plants over its expected life. These costs include:

- Operating labor
- Maintenance – material and labor
- Administrative and support labor
- Consumables
- Fuel
- Waste disposal

There are two components of O&M costs: fixed O&M, which is independent of power generation, and variable O&M, which is proportional to power generation.

a) Fixed Costs

Operating labor cost is determined based on the number of operators required to work in the plant. Other assumptions used in calculating the total fixed cost include:

- 2018 base hourly labor rate, \$39.70 \$/hr. (assumed that wages are flat since 2011)
- Length of workweek, 50 hrs.
- Labor burden, 30 %
- Administrative/support labor, 25 % O&M labor
- Maintenance material + labor, 1.74 % TPC
- Maintenance labor only, 40 % maintenance material + labor
- Property taxes and insurances, 2 % TPC

b) Variable Costs

The cost of consumables, including fuel, is determined based on the individual rates of consumption, the unit cost of each specific consumable commodity, and the plant annual operating hours. Waste quantities and disposal costs are evaluated similarly to the consumables. Available commodity unit costs from the Oxy-combustion Baseline Report [7] were escalated to 2018 dollars. Commodities not available in the Oxy-combustion Report but available in other NETL reports were identified and escalated to 2018 dollars. The existing unit costs in the oxy-combustion baseline are for the year 2007-cost basis and were first updated to 2011-cost basis from the Bituminous Baseline Report [11]. Following that, the unit costs were escalated to a 2018-cost basis using the CEPCI ratios.

III. PROCESS AREAS

The basic configuration of the commercial FPO cycle can be understood as shown in Figure 13. In addition, the ASU, the solids receiving and handling, CO_2 purification, balance of, plant, and other miscellaneous areas make up the commercial system.

Descriptions of the process areas and a full equipment list have been described but are not reproduced here for brevity. An update to the TEA added a second reheat to the system because the OTSG can support this addition within a single casing. This resulted in notably improved efficiency and economics.

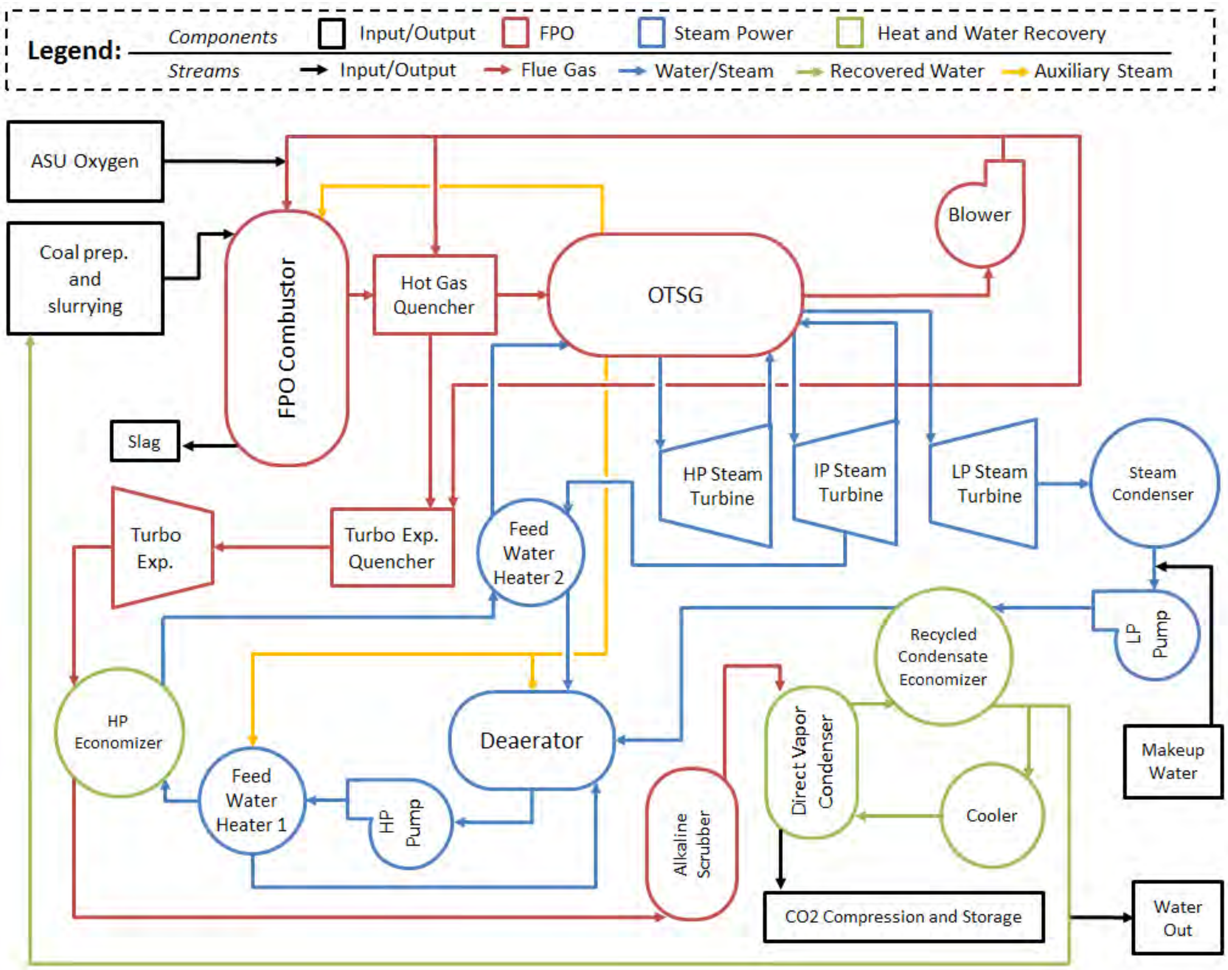

Figure 13. Commercial FPO Configuration

IV. FPO PLANT PERFORMANCE RESULTS

The FPO cycle was modeled in Aspen Plus and the results were compiled. Figure 14 shows the basic block flow of the cycle and the primary units that interact. Table 27 shows the stream information from Aspen Plus that corresponds to the streams in Figure 14.

Table 28 shows the power parasitic losses to achieve a 550 MWe net plant. The parasitic losses were derived from the Aspen Model, proprietary estimates of power requirements, and scaling flows relative to S12B [6] and S12F [7] where appropriate. The FPO plant achieved a 33.2% net efficiency relative to higher heating value (HHV) of coal with carbon capture. Without carbon capture, the net efficiency is 36.1% HHV.

Environmental performance and heat and mass balance were analyzed but not included in this document for brevity.

1) *PROCESS BLOCK DIAGRAM AND STREAM TABLE*

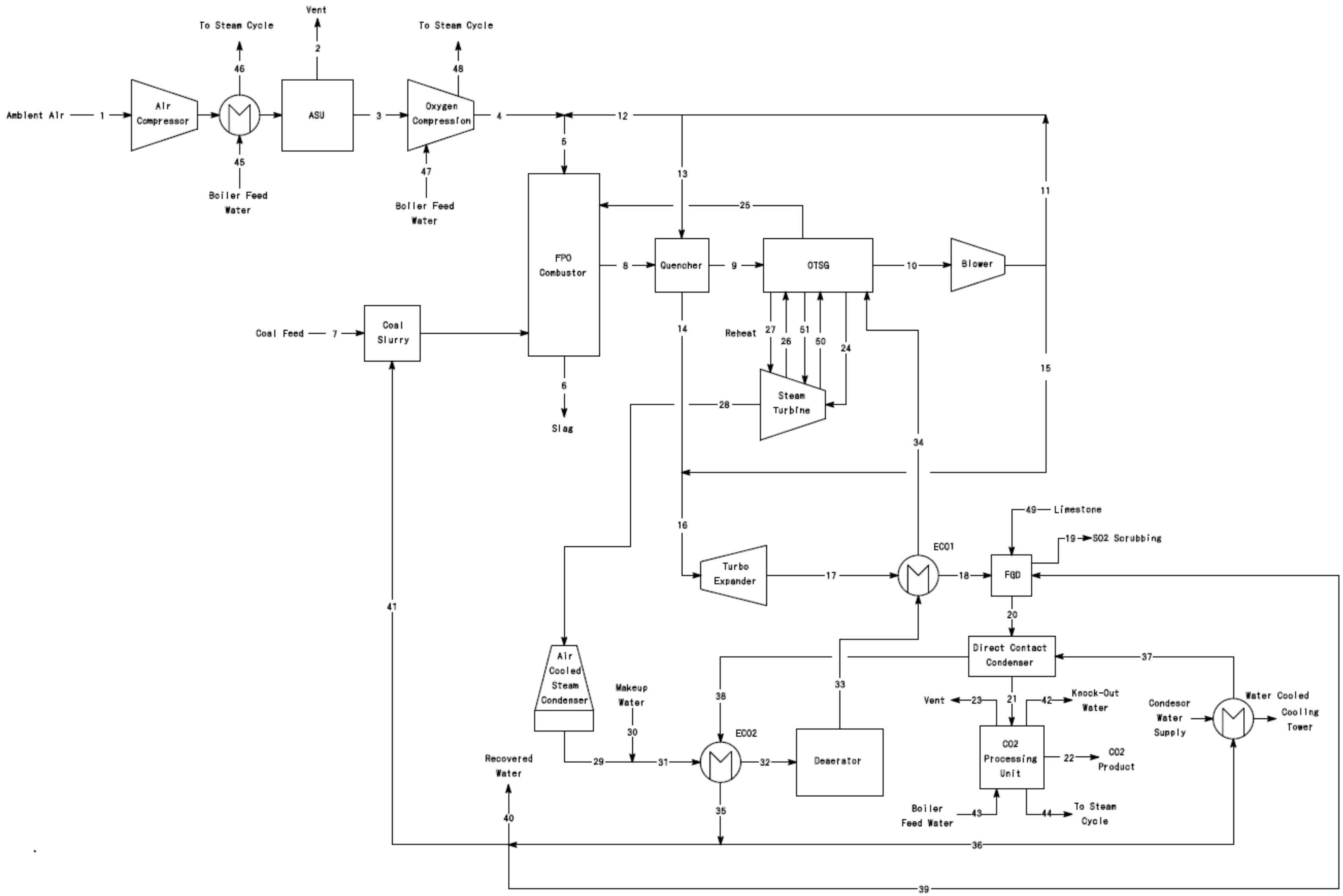

Figure 14. Plant Block Flow Diagram

Table 27. Plant Stream Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
V-L Mole Fraction																
H20	0.0064	0.0081	0.0000	0.0000	0.4636	0.0000	0.0000	0.5748	0.5748	0.5748	0.5748	0.5748	0.5748	0.5748	0.5748	0.5748
N2	0.7759	0.9826	0.0163	0.0163	0.0112	0.0000	0.0000	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099	0.0099
O2	0.2081	0.0064	0.9495	0.9495	0.1952	0.0000	0.0000	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143
AR	0.0093	0.0025	0.0342	0.0342	0.0195	0.0000	0.0000	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160	0.0160
SO2	0.0000	0.0000	0.0000	0.0000	0.0017	0.0000	0.0000	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
H2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0003	0.0004	0.0000	0.0000	0.3088	0.0000	0.0000	0.3829	0.3829	0.3829	0.3829	0.3829	0.3829	0.3829	0.3829	0.3829
CACO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CASO4-2H20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**0.0000**	**0.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**
V-L Flowrate (kmol/hr)	71313	56057	15256	15256	78863	0	0	96205	184075	184075	184075	63606	113797	25926	6672	32598
V-L Flowrate (kg/hr)	2060604	1569267	491337	491337	2317743	0	0	2762436	5285572	5285572	5285572	1826406	3267594	744458	191572	936030
Solids Flowrate (kg/hr)	0	0	0	0	0	24513	299390	0	0	0	0	0	0	0	0	0
Temperature (K)	279	290	288	416	510	288	298	1650	1079	525	529	529	529	1079	529	973
Pressure (Bar)	0.90	1.01	1.40	12.30	12.30	0.90	0.90	12.30	12.30	12.00	12.30	12.30	12.30	12.30	12.30	12.30
Enthalpy (kJ/kg)	-77.74	-84.81	-9.90	105.41	-7718.13	---	---	-8001.58	-8988.48	-9827.40	-9822.80	-9822.80	-9822.80	-8988.48	-9822.80	-9159.23
Density (kg/cum)	1.1	1.2	1.9	11.5	8.7	---	---	2.6	3.9	8.1	8.2	8.2	8.2	3.9	8.2	4.4
V-L Molecular Weight	28.8951	27.9941	32.2058	32.2058	29.3897	---	---	28.7142	28.7142	28.7142	28.7142	28.7142	28.7142	28.7142	28.7142	28.7142

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
V-L Mole Fraction																
H20	0.5847	0.5847	0.8786	0.5913	0.0112	0.0000	0.0048	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
N2	0.0097	0.0097	0.0000	0.0096	0.0232	0.0000	0.1323	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O2	0.0140	0.0140	0.0000	0.0129	0.0311	0.0000	0.1779	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR	0.0156	0.0156	0.0000	0.0154	0.0373	0.0000	0.2132	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SO2	0.0020	0.0020	0.0000	0.0001	0.0002	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.3739	0.3739	0.0001	0.3707	0.8969	1.0000	0.4702	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CACO3	0.0000	0.0000	0.0612	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CASO4-2H20	0.0000	0.0000	0.0600	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**
V-L Flowrate (kmol/hr)	33376	33376	1002	33839	13990	11392	2452	71225	2067	71225	71225	67445	67445	3178	23955	70623
V-L Flowrate (kg/hr)	950041	950041	32798	956660	599059	501360	95082	1283130	37246	1283130	1283130	1215040	1215040	57250	431556	1272289
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (K)	734	432	313	384	298	300	286	882	530	709	886	305	294	288	294	397
Pressure (Bar)	2.40	2.38	0.90	2.36	2.35	153.10	28.48	240.99	20.00	80.00	76.92	0.05	0.05	0.05	3.95	3.80
Enthalpy (kJ/kg)	-9567.47	-9991.03	- 12668.78	- 10113.68	-8306.64	-9196.06	- 4832.74	- 12443.33	- 13050.33	- 12738.66	- 12295.27	- 13567.49	- 15884.49	- 15910.03	- 15885.15	- 15450.05
Density (kg/cum)	1.1	1.9	18.2	2.1	4.1	691.0	50.9	66.7	8.8	27.3	19.5	0.0	998.0	999.1	998.3	939.9
V-L Molecular Weight	28.4649	28.4649	32.7351	28.2712	42.8217	44.0098	38.7718	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153

	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
V-L Mole Fraction																
H20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
N2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
O2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
H2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CACO3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CASO4-2H20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**	**1.0000**
V-L Flowrate (kmol/hr)	74262	71225	133157	113308	113308	133157	1488	11004	7358	145	19434	19434	22136	22136	5097	5097
V-L Flowrate (kg/hr)	1337855	1283130	2398954	2041353	2041353	2398954	26816	198251	132570	2616	350117	350117	398789	398789	91827	91827
Solids Flowrate (kg/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Temperature (K)	420	496	368	368	288	382	368	368	369	288	294	405	294	409	294	409
Pressure (Bar)	284.00	260.00	2.05	2.05	2.35	2.35	2.36	2.05	30.00	0.90	3.95	3.80	3.95	3.80	3.95	3.80
Enthalpy (kJ/kg)	-15336.28	-15006.82	-15652.38	-15652.38	-16018.95	-15589.93	-15652.34	-15652.38	-15648.60	-15908.26	-15885.15	-15414.87	-15885.15	-15397.79	-15885.15	-15397.79
Density (kg/cum)	935.2	856.1	923.3	923.3	1004.0	908.9	923.3	923.3	923.0	1000.0	998.3	933.0	998.3	929.5	998.3	929.5
V-L Molecular Weight	18.0153	18.0153	18.0160	18.0160	18.0160	18.0160	18.0160	18.0160	18.0160	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153	18.0153

	49	50	51
V-L Mole Fraction			
H20	0.0000	1.0000	1.0000
N2	0.0000	0.0000	0.0000
O2	0.0000	0.0000	0.0000
AR	0.0000	0.0000	0.0000
SO2	0.0000	0.0000	0.0000
H2	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000
CACO3	1.0000	0.0000	0.0000
CASO4-2H20	0.0000	0.0000	0.0000
Total	**1.0000**	**1.0000**	**1.0000**
V-L Flowrate (kmol/hr)	126	69473	69473
V-L Flowrate (kg/hr)	12600	1251580	1251580
Solids Flowrate (kg/hr)	0	0	0
Temperature (K)	288	717	886
Pressure (Bar)	2.38	26.00	25.00
Enthalpy (kJ/kg)	-12067.20	-12634.46	-12259.92
Density (kg/cum)	2714.3	8.1	6.2
V-L Molecular Weight	100.0872	18.0153	18.0153

2) PERFORMANCE RESULTS

Table 28. FPO Plant Performance Power Summary

Power Balance		
Heat Input		
Coal Feed Flowrate	299,390	kg/hr
Thermal input (HHV)	1,656,627	kWth
Thermal input (LHV)	1,596,083	kWth
Condenser Heat Duty	2,815	GJ/hr
Cooling water heat rejection	968	GJ/hr
Power Output		
Steam Turbine Power	662,992	kWe
Turbo Expander Power	91,201	kWe
Auxiliary Power Load		
HP Feedwater Pump	14,514	kWe
LP Feedwater Pump	182	kWe
Gas Recycle Blower	6,964	kWe
ASU Primary Fan	80,921	kWe
ASU Oxygen Compressor	32,651	kWe
ASU Auxiliaries	1,000	kWe
Air Condenser Fans (0.81% kWe/kWth)	6,334	kWe
Cooling Tower Fans (0.73% kWe/kWth)	1,962	kWe
Circulating Water Pumps (1.14% kWe/kWth)	3,064	kWe
Coal Bar Mill (18 kWe/kg/s coal)	1,497	kWe
Slurry Pump (7.7 kWe/kg/s coal)	640	kWe
Slag Handling (1.7 kWe/kg/s coal)	141	kWe
Steam Turbine Auxiliaries	329	kWe
Direct Contact Condenser Recycle Pump	34	kWe
Coal Handling and Conveying	629	kWe
FGD Auxiliaries (0.1% kWe/kWth)	16	kWe
Balance of Plant	2,000	kWe
Transformer Losses	2,629	kWe
CO2 Purification Loads		
CO2 LP Compressor Power	34,088	kWe
CO2 HP Compressor Power	14,390	kWe
Plant Performance		
Gross Power output	754,194	kWe
Net Auxiliary Load	155,508	kWe
Net CO2 Purification Load	48,478	kWe
Net Plant Power	550,208	kWe
Gross Power Efficiency (HHV)	45.5%	
Net Exported Power Efficiency (HHV)	33.2%	
Net Plant Heat Rate (HHV)	10,839	kJ/kWhr
Net Exported Power Efficiency without CO2 Capture (HHV)	36.1%	
Gross Power Efficiency (LHV)	47.3%	
Net Exported Power Efficiency (LHV)	34.5%	
Net Plant Heat Rate (LHV)	10,443	kJ/kWhr
Net Exported Power Efficiency without CO2 Capture (LHV)	37.5%	

V. PLANT COST

The TPC and O&M costs for the FPO supercritical power plant were estimated, following NETL's methodology, as follows.

1) *CAPITAL COST RESULTS*

a) FPO Power Plant Cost Estimation Results

The estimated capital cost for the commercial 550-MWe FPO supercritical power plant is summarized in Table 29 and is consistent with the code of accounts format as expressed in the Oxy-combustion Baseline Report [7]. The TPC costs for systems common to the Case S12F costs are capacity-factored from that report, with appropriate scaling parameters and exponents derived from the Cost Estimation Methodology QGESS Report [9].

Account lines that are in ***bold and italicized blue*** font are based on costs for novel technologies that have no analogous counterparts within the S12F oxy-combustion plant. These are:

- 2.3: Slurry Prep & Feed
- 4.1: FPO Boiler & Auxiliaries
- 4.3: ASU Oxygen Compressor
- 5.1: Pressurized Flue Gas Desulfurization System
- 6.1: Turbo-expander
- 10: Ash Handling System (cost included with FPO Boiler account)

With the exception of Account 4.3: ASU Oxygen Compressor, ITEA provided the BEC associated with these technology accounts, expressed as single-line lump-sum turnkey costs. The equipment cost for the ASU oxygen compressor was estimated based on equipment sizing per the process heat and material balance. The appropriate build-up factors were then applied from historical data to the compressor's equipment cost to calculate its BEC.

The relevant engineering and construction management, home office and fees, and process and project contingencies from the NETL reports were subsequently applied to the BEC to arrive at the 550-MWe FPO supercritical power plant TPC.

Table 30 shows the owner's costs breakdown and assumptions used to calculate the TOC for the 550-MWe FPO supercritical power plant. Table 31 shows the plant's annual O&M costs based on an 85% capacity factor. All costs were escalated to 2018 dollars.

Table 29. Plant Capital Cost Estimate for 550-MWe FPO Supercritical Power Plant

SwRI FPO Total Plant Cost Details (Jun 2018 Basis) — Cost Updated for Improved Efficiency

SUPERCRITICAL OXYCOMBUSTION PC PLANT WITH CO2 CAPTURE AND PURIFICATION VIA CRYOGENIC DISTILLATION

Cost Basis 2018 ($x1000)
Plant Size 550 MWe, net

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Lump-sum Turnkey Cost	Sales Tax	Bare Erected Cost $	Eng'g CM H.O & Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
1	COAL & SORBENT HANDLING												
1.1	Coal Receive & Unload	$5,727	$0	$2,580	$0	$0	$0	$8,307	$831	$0	$1,371	$10,508	
1.2	Coal Stack out & Reclaim	$7,403	$0	$1,655	$0	$0	$0	$9,058	$906	$0	$1,495	$11,458	
1.3	Coal Conveyors & Yard Crushing	$6,883	$0	$1,636	$0	$0	$0	$8,519	$852	$0	$1,406	$10,777	
1.4	Other Coal Handling	$1,799	$0	$378	$0	$0	$0	$2,177	$218	$0	$359	$2,754	
1.5	Sorbent Receive & Unload	$88	$0	$26	$0	$0	$0	$115	$11	$0	$19	$145	
1.6	Sorbent Stackout & Reclaim	$1,422	$0	$260	$0	$0	$0	$1,681	$168	$0	$277	$2,127	
1.7	Sorbent Conveyors	$507	$110	$124	$0	$0	$0	$741	$74	$0	$122	$938	
1.8	Other Sorbent Handling	$307	$72	$160	$0	$0	$0	$538	$54	$0	$89	$681	
1.9	Coal & Sorbent Handling Foundations	$0	$6,643	$8,757	$0	$0	$0	$15,400	$1,540	$0	$2,541	$19,481	
	SUBTOTAL 1.	**$24,135**	**$6,825**	**$15,576**	**$0**	**$0**	**$0**	**$46,536**	**$4,654**	**$0**	**$7,678**	**$58,868**	**$107**
2	COAL & SORBENT PREP & FEED												
2.2	Prepared Coal Storage & Feed	$2,465	$592	$381	$0	$0	$0	$3,439	$344	$0	$757	$4,539	
2.3	*Slurry Prep & Feed*	$0	$0	$0	$0	$19,712	$0	$19,712	$1,971	$0	$4,337	$26,020	
2.4	Misc Coal Prep & Feed	$1,355	$991	$2,919	$0	$0	$0	$5,265	$526	$0	$1,158	$6,950	
2.5	Sorbent Preparation Equipment	$2,391	$103	$495	$0	$0	$0	$2,990	$299	$0	$493	$3,782	
2.6	Sorbent Storage & Feed	$288	$0	$110	$0	$0	$0	$398	$40	$0	$66	$504	
2.9	*Slurry Prep & Feed Foundation*	$0	$0	$0	$0	$10,989	$0	$10,989	$1,099	$0	$2,418	$14,506	
	SUBTOTAL 2.	**$6,500**	**$1,687**	**$3,905**	**$0**	**$30,702**	**$0**	**$42,793**	**$4,279**	**$0**	**$9,228**	**$56,300**	**$107**
3	FEEDWATER & MISC BOP SYSTEMS												
3.1	Feedwater System	$20,728	$0	$6,683	$0	$0	$0	$27,411	$2,741	$0	$4,523	$34,675	
3.2	Water Makeup & Pretreating	$5,559	$0	$1,758	$0	$0	$0	$7,317	$732	$0	$1,610	$9,659	
3.3	Other Feedwater Systems	$6,521	$0	$2,677	$0	$0	$0	$9,198	$920	$0	$1,518	$11,635	
3.4	Service Water Systems	$1,113	$0	$582	$0	$0	$0	$1,695	$169	$0	$373	$2,237	
3.5	Other Boiler Plant Systems	$8,541	$0	$8,073	$0	$0	$0	$16,614	$1,661	$0	$2,741	$21,017	
3.6	FO Supply Sys & Nat Gas	$352	$0	$410	$0	$0	$0	$762	$76	$0	$126	$963	
3.7	Waste Treatment Equipment	$3,513	$0	$2,034	$0	$0	$0	$5,547	$555	$0	$1,220	$7,322	
3.8	Misc Power Plant Equipment	$3,441	$0	$1,064	$0	$0	$0	$4,505	$451	$0	$991	$5,947	
	SUBTOTAL 3.	**$49,768**	**$0**	**$23,281**	**$0**	**$0**	**$0**	**$73,050**	**$7,305**	**$0**	**$13,102**	**$93,456**	**$170**
4	PC BOILER & ACCESSORIES												
4.1	*SwRI FPO Boiler & Auxiliaries*	$0	$0	$0	$0	$204,616	$0	$204,616	$20,462	$30,692	$25,577	$281,347	
4.2	ASU	$205,881	$0	$165,785	$0	$0	$0	$371,666	$37,167	$0	$40,883	$449,716	
4.3	*ASU Oxygen Compressor*	$14,592	$9,020	$21,244	$0	$0	$0	$44,856	$4,486	$0	$4,934	$54,276	
4.9	*Boiler Foundation*				*incl w/14.1*			*$0*	*$0*	*$0*	*$0*	*$0*	
	SUBTOTAL 4.	**$220,473**	**$9,020**	**$187,029**	**$0**	**$204,616**	**$0**	**$621,139**	**$62,114**	**$30,692**	**$71,394**	**$785,339**	**$1,428**

5	FLUE GAS CLEANUP												
5.1	***Pressurized Flue Gas Desulfurization System***	$0	$0	$0	$0	$33,295	$0	$33,295	$3,330	$0	$3,662	$40,287	
5.9	***Pressurized FGD Foundations***	$0	$0	$0	$0	$14,466	$0	$14,466	$1,447	$0	$3,183	$19,095	
	SUBTOTAL 5.	**$0**	**$0**	**$0**	**$0**	**$47,761**	**$0**	**$47,761**	**$4,776**	**$0**	**$6,845**	**$59,383**	**$108**
5B	CO2 REMOVAL & COMPRESSION												
5B.1	CO2 Condensing Heat Exchanger	$4,765	$0	$395	$0	$0	$0	$5,160	$516	$0	$851	$6,528	
5B.1	CO2 Compression & Purification	$65,828	$0	$63,775	$0	$0	$0	$129,602	$12,960	$0	$28,513	$171,075	
	SUBTOTAL 5B.	**$70,593**	**$0**	**$64,170**	**$0**	**$0**	**$0**	**$134,763**	**$13,476**	**$0**	**$29,364**	**$177,603**	**$323**
6	TURBOEXPANDER												
6.1	***Turboexpander***	$0	$0	$0	$0	$79,134	$0	$79,134	$7,913	$0	$8,705	$95,753	
6.9	***Turboexpander Foundation***			***incl w/14.1***				***$0***	***$0***	***$0***	***$0***	***$0***	
	SUBTOTAL 8B.	**$0**	**$0**	**$0**	**$0**	**$79,134**	**$0**	**$79,134**	**$7,913**	**$0**	**$8,705**	**$95,753**	**$174**
7	HRSG, DUCTING & STACK												
7.3	Ductwork	$4,902	$0	$3,094	$0	$0	$0	$7,996	$800	$0	$1,319	$10,114	
7.4	Stack	$1,732	$0	$1,007	$0	$0	$0	$2,739	$274	$0	$301	$3,314	
7.9	Duct & Stack Foundations	$0	$506	$601	$0	$0	$0	$1,107	$111	$0	$244	$1,461	
	SUBTOTAL 7.	**$6,634**	**$506**	**$4,701**	**$0**	**$0**	**$0**	**$11,841**	**$1,184**	**$0**	**$1,864**	**$14,889**	**$27**
8	STEAM TURBINE GENERATOR												
8.1	Steam TG & Accessories	$76,071	$0	$9,371	$0	$0	$0	$85,442	$8,544	$0	$9,399	$103,385	
8.2	Turbine Plant Auxiliaries	$479	$0	$1,019	$0	$0	$0	$1,499	$150	$0	$165	$1,813	
8.3a	Condenser & Auxiliaries	$6,021	$0	$3,785	$0	$0	$0	$9,805	$981	$0	$1,079	$11,865	
8.3b	Air Cooled Condenser	$56,160	$0	$11,185	$0	$0	$0	$67,345	$6,734	$0	$14,816	$88,895	
8.4	Steam Piping	$21,402	$0	$9,509	$0	$0	$0	$30,911	$3,091	$0	$5,100	$39,102	
8.9	TG Foundations	$0	$1,376	$2,271	$0	$0	$0	$3,647	$365	$0	$802	$4,814	
	SUBTOTAL 8.	**$160,132**	**$1,376**	**$37,140**	**$0**	**$0**	**$0**	**$198,649**	**$19,865**	**$0**	**$31,361**	**$249,874**	**$454**
9	COOLING WATER SYSTEM												
9.1	Cooling Towers	$8,686	$0	$2,686	$0	$0	$0	$11,372	$1,137	$0	$1,251	$13,760	
9.2	Circulating Water Pumps	$2,449	$0	$240	$0	$0	$0	$2,689	$269	$0	$296	$3,254	
9.3	Circ. Water System Auxiliaries	$717	$0	$96	$0	$0	$0	$813	$81	$0	$89	$984	
9.4	Circ. Water Piping	$0	$6,043	$5,473	$0	$0	$0	$11,517	$1,152	$0	$1,900	$14,569	
9.5	Make-up Water System	$609	$0	$782	$0	$0	$0	$1,391	$139	$0	$230	$1,760	
9.6	Component Cooling Water System	$584	$0	$448	$0	$0	$0	$1,032	$103	$0	$170	$1,306	
9.9	Circ. Water System Foundations	$0	$3,213	$5,335	$0	$0	$0	$8,548	$855	$0	$1,881	$11,284	
	SUBTOTAL 9.	**$13,044**	**$9,256**	**$15,062**	**$0**	**$0**	**$0**	**$37,362**	**$3,736**	**$0**	**$5,817**	**$46,915**	**$85**
10	ASH/SPENT SORBENT HANDLING SYS												
10.1	***Slag Dewatering & Cooling***			***incl w/ 4.1***				***$0***	***$0***	***$0***	***$0***	***$0***	
10.6	***Ash Storage Silos***			***incl w/ 4.1***				***$0***	***$0***	***$0***	***$0***	***$0***	
10.7	***Ash Transport & Feed Equipment***			***incl w/ 4.1***				***$0***	***$0***	***$0***	***$0***	***$0***	
10.8	***Misc. Ash Handling Equipment***			***incl w/ 4.1***				***$0***	***$0***	***$0***	***$0***	***$0***	
10.9	***Ash/Spent Sorbent Foundation***			***incl w/ 4.1***				***$0***	***$0***	***$0***	***$0***	***$0***	
	SUBTOTAL 10.	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**

11	ACCESSORY ELECTRIC PLANT												
11.1	Generator Equipment	$434	$0	$70	$0	$0	$0	$503	$50	$0	$39	$592	
11.2	Station Service Equipment	$7,982	$0	$2,676	$0	$0	$0	$10,658	$1,066	$0	$821	$12,545	
11.3	Switchgear & Motor Control	$9,161	$0	$1,591	$0	$0	$0	$10,752	$1,075	$0	$1,183	$13,010	
11.4	Conduit & Cable Tray	$0	$6,283	$20,298	$0	$0	$0	$26,581	$2,658	$0	$4,386	$33,625	
11.5	Wire & Cable	$0	$11,962	$21,386	$0	$0	$0	$33,348	$3,335	$0	$5,502	$42,186	
11.6	Protective Equipment	$318	$0	$1,105	$0	$0	$0	$1,423	$142	$0	$156	$1,721	
11.7	Standby Equipment	$442	$0	$10	$0	$0	$0	$452	$45	$0	$50	$547	
11.8	Main Power Transformers	$927	$0	$27	$0	$0	$0	$955	$95	$0	$105	$1,155	
11.9	Electrical Foundations	$0	$56	$142	$0	$0	$0	$198	$20	$0	$43	$261	
	SUBTOTAL 11.	**$19,264**	**$18,302**	**$47,304**	**$0**	**$0**	**$0**	**$84,870**	**$8,487**	**$0**	**$12,285**	**$105,642**	**$192**
12	INSTRUMENTATION & CONTROL												
12.6	Control Boards, Panels & Racks	$670	$0	$410	$0	$0	$0	$1,080	$108	$0	$178	$1,367	
12.7	Computer Accessories	$6,775	$0	$1,208	$0	$0	$0	$7,983	$798	$0	$878	$9,659	
12.8	Instrument Wiring & Tubing	$4,085	$0	$7,433	$0	$0	$0	$11,518	$1,152	$0	$1,900	$14,570	
12.9	Other I & C Equipment	$1,914	$0	$4,432	$0	$0	$0	$6,346	$635	$0	$698	$7,678	
	SUBTOTAL 12.	**$13,444**	**$0**	**$13,483**	**$0**	**$0**	**$0**	**$26,927**	**$2,693**	**$0**	**$3,655**	**$33,275**	**$60**
13	IMPROVEMENTS TO SITE												
13.1	Site Preparation	$0	$63	$1,337	$0	$0	$0	$1,400	$140	$0	$308	$1,847	
13.2	Site Improvements	$0	$2,087	$2,757	$0	$0	$0	$4,844	$484	$0	$1,066	$6,394	
13.3	Site Facilities	$3,740	$0	$3,924	$0	$0	$0	$7,664	$766	$0	$1,686	$10,117	
	SUBTOTAL 13.	**$3,740**	**$2,149**	**$8,018**	**$0**	**$0**	**$0**	**$13,908**	**$1,391**	**$0**	**$3,060**	**$18,358**	**$33**
14	BUILDINGS & STRUCTURES												
14.1	***Boiler Building***	$0	$0	$0	$0	$13,554	$0	$13,554	$1,355	$0	$2,236	$17,146	
14.2	Turbine Building	$0	$15,632	$14,559	$0	$0	$0	$30,190	$3,019	$0	$4,981	$38,191	
14.3	Administration Building	$0	$786	$829	$0	$0	$0	$1,615	$161	$0	$266	$2,043	
14.4	Circulating Water Pumphouse	$0	$254	$202	$0	$0	$0	$457	$46	$0	$75	$578	
14.5	Water Treatment Buildings	$0	$742	$611	$0	$0	$0	$1,353	$135	$0	$223	$1,711	
14.6	Machine Shop	$0	$525	$351	$0	$0	$0	$876	$88	$0	$145	$1,109	
14.7	Warehouse	$0	$355	$357	$0	$0	$0	$712	$71	$0	$117	$901	
14.8	Other Buildings & Structures	$0	$290	$247	$0	$0	$0	$538	$54	$0	$89	$680	
14.9	Waste Treating Building & Structures	$0	$548	$1,662	$0	$0	$0	$2,210	$221	$0	$365	$2,795	
	SUBTOTAL 14.	**$0**	**$19,133**	**$18,818**	**$0**	**$13,554**	**$0**	**$51,505**	**$5,151**	**$0**	**$8,498**	**$65,154**	**$118**
	CALCULATED TOTAL COST	**$587,727**	**$68,254**	**$438,489**	**$0**	**$375,768**	**$0**	**$1,470,238**	**$147,024**	**$30,692**	**$212,856**	**$1,860,810**	**$3,383**

Table 30. Owner's Costs for 550-MWe FPO Supercritical Power Plant

Description	$/1,000	$/kW
Preproduction Costs		
6 months All Labor	$12,355	$22
1 Month Maintenance Materials	$1,902	$3
1 Month Non-Fuel Consumables	$478	$1
1 Month Waste Disposal	$556	$1
25% of 1 Months Fuel Cost at 100% CF	$1,190	$2
2% of TPC	$37,216	$68
Total	**$53,698**	**$98**
Inventory Capital		
60 day supply of fuel at 100% CF	$9,386	$17
60 day supply of non-fuel consumables at 100% CF	$944	$2
0.5% of TPC (spare parts)	$9,304	$17
Total	**$19,634**	**$36**
Other Costs		
Initial Cost for Catalyst and Chemicals	$0	$0
Land	$900	$2
Other Owner's Cost	$279,122	$507
Financing Costs	$50,242	$91
Total Overnight Costs (TOC)	**$2,264,406**	**$4,117**

Table 31. Plant Operating Cost Estimate for 550-MWe FPO Supercritical Power Plant

INITIAL & ANNUAL O&M EXPENSES							
Case:	SwRI FPO Supercritical Oxycombustion Plant						
Plant Size (MWe)	**550**			**Heat Rate (Btu/kWh):**			10,839
Primary/Secondary Fuel:	**Wyoming PRB**			**Fuel Cost ($/MMBtu):**			
Design/Construction	5 years			**Book Life (yrs):**			20
TPC (Plant Cost) Year	Jun-18			**TPI Year:**			2018
Capacity Factor (%)	85			**CO2 Captured (TPD)**			13349
OPERATING & MAINTENANCE LABOR							
Operating Labor							
Operating Labor Rate (base):		$39.70	$/hr				
Operating Labor Burden:		30.0	% of base				
Labor Overhead Charge		25.0	% of labor				
Operating Labor Requirements per Shift		**units/mod**		**Total Plant**			
Skilled Operator		2.0		2.0			
Operator		9.0		9.0			
Foreman		1.0		1.0			
Lab Tech's etc		2.0		2.0			
TOTAL Operating Jobs		14.0		14.0			
						Annual Cost $	
Annual Operating Labor Cost						$6,329,450	
Maintenance Labor Cost						$12,935,374	
Administration & Support Labor						$4,756,908	
Property Taxes and Insurance						$37,216,208	
TOTAL FIXED OPERATING COSTS						**$61,237,941**	
VARIABLE OPERATING COSTS							
Maintenance Material Cost						$19,403,062	
Consumables	Consumption Initial	/Day	Unit Cost	Initial Fill Cost			
Water(/1000 gallons)	0	2,280	1.87	**$0**		**$1,236,360**	
Chemicals							
MU & WT Chem (lb)	0	11035	0.30	$0		**$957,541**	
Limestone (ton)	0	248	37.38	$0		**$2,685,793**	
Subtotal Chemicals				**$0**		**$3,643,334**	
Waste Disposal:							
Slag (ton)	0	698	28.03	$0		**$5,674,592**	
Subtotal Waste Disposal				**$0**		**$5,674,592**	
By-products & Emissions							
Gypsum (tons)	0	652	0.00	$0		$0	
Subtotal By-Products				**$0**		**$0**	
TOTAL VARIABLE OPERATING COSTS				**$0**		**$29,957,348**	
Fuel (tons)	**0**	**8520**	**19.63**	**$0**		**$48,533,941**	

b) S12B Air-Fired Supercritical Power Plant with CO_2 Capture in 2018-Cost Basis

The NETL Reference Case S12B cost estimates are presented here to compare with the oxy-combustion plant based on FPO technology. Both plants are a supercritical power plant, producing 550-MWe of power with 90 percent CO_2 capture. Case S12B from the Low-Rank Coal PC Baseline Report [6] is a 550-MWe air-fired supercritical power plant firing PRB coal with post-combustion capture using a conventional amine system to capture 90% of the CO_2 from the flue gas. Given that this plant uses the same coal (PRB), is at the same location, and produces the same amount of net power, it is useful for comparison.

The estimated capital cost for the S12B air-fired supercritical power plant with post-combustion capture is summarized in Table 32. As the original cost estimate basis for Case S12B is for year 2007, it was necessary to escalate these costs to the current year cost basis. Per the methodology stated in Section b), the S12B costs were escalated to year 2011-cost basis using escalation factors established from the Bituminous PC Baseline Reports [11] before revising to 2018-cost basis using the ratio of the corresponding CEPCI values.

Table 33 shows the owner's costs breakdown and assumptions used to arrive at the total overnight cost for the 550-MWe air-fired supercritical power plant firing PRB coal. Table 34 shows the plant's annual O&M costs based on an 85% capacity factor.

Table 32. Plant Capital Cost Estimate for 550-MWe Air-Fired Supercritical Power Plant

S12BTotal Plant Cost Details (Jun 2018 Basis)

AIR-FIRED SUPERCRITICAL PC PLANT WITH ECONAMINE-BASED CO2 CAPTURE

Cost Basis 2018 ($x1000)
Plant Size 550 MWe, net

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Sales Tax	Bare Erected Cost $	Eng'g CM H.O & Fee	Contingencies Process	TOTAL PLANT COST Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
1	COAL & SORBENT HANDLING											
1.1	Coal Receive & Unload	$6,459	$0	$2,910	$0	$0	$9,369	$937	$0	$1,546	$11,852	
1.2	Coal Stack out & Reclaim	$8,349	$0	$1,866	$0	$0	$10,215	$1,022	$0	$1,686	$12,922	
1.3	Coal Conveyors & Yard Crushing	$7,762	$0	$1,845	$0	$0	$9,608	$961	$0	$1,585	$12,154	
1.4	Other Coal Handling	$2,030	$0	$426	$0	$0	$2,456	$246	$0	$405	$3,107	
1.5	Sorbent Receive & Unload	$78	$0	$23	$0	$0	$101	$10	$0	$17	$128	
1.6	Sorbent Stackout & Reclaim	$1,264	$0	$229	$0	$0	$1,493	$149	$0	$246	$1,888	
1.7	Sorbent Conveyors	$451	$98	$109	$0	$0	$659	$66	$0	$109	$833	
1.8	Other Sorbent Handling	$272	$64	$141	$0	$0	$477	$48	$0	$79	$604	
1.9	Coal & Sorbent Handling Foundations	$0	$7,487	$9,870	$0	$0	$17,357	$1,736	$0	$2,864	$21,957	
	SUBTOTAL 1.	**$26,666**	**$7,650**	**$17,420**	**$0**	**$0**	**$51,735**	**$5,174**	**$0**	**$8,536**	**$65,445**	**$119**
2	COAL & SORBENT PREP & FEED											
2.1	Coal Crushing & Drying	$3,802	$0	$731	$0	$0	$4,533	$453	$0	$748	$5,735	
2.2	Prepared Coal Storage & Feed	$9,735	$0	$2,097	$0	$0	$11,832	$1,183	$0	$1,952	$14,968	
2.9	Coal & Sorbent Feed Foundation	$0	$1,026	$901	$0	$0	$1,926	$193	$0	$318	$2,437	
	SUBTOTAL 2.	**$13,538**	**$1,026**	**$3,728**	**$0**	**$0**	**$18,292**	**$1,829**	**$0**	**$3,018**	**$23,139**	**$42**
3	FEEDWATER & MISC BOP SYSTEMS											
3.1	Feedwater System	$28,717	$0	$9,260	$0	$0	$37,977	$3,798	$0	$6,266	$48,041	
3.2	Water Makeup & Pretreating	$7,936	$0	$2,510	$0	$0	$10,447	$1,045	$0	$2,298	$13,790	
3.3	Other Feedwater Systems	$9,034	$0	$3,709	$0	$0	$12,743	$1,274	$0	$2,103	$16,120	
3.4	Service Water Systems	$1,589	$0	$831	$0	$0	$2,420	$242	$0	$532	$3,194	
3.5	Other Boiler Plant Systems	$11,954	$0	$11,304	$0	$0	$23,258	$2,326	$0	$3,838	$29,422	
3.6	FO Supply Sys & Nat Gas	$370	$0	$431	$0	$0	$800	$80	$0	$132	$1,012	
3.7	Waste Treatment Equipment	$5,207	$0	$3,014	$0	$0	$8,220	$822	$0	$1,808	$10,851	
3.8	Misc Power Plant Equipment	$3,612	$0	$1,117	$0	$0	$4,730	$473	$0	$1,041	$6,243	
	SUBTOTAL 3.	**$68,420**	**$0**	**$32,175**	**$0**	**$0**	**$100,595**	**$10,060**	**$0**	**$18,018**	**$128,673**	**$234**
4	PC BOILER & ACCESSORIES											
4.1	PC Boiler & Accessories	$290,367	$0	$144,440	$0	$0	$434,807	$43,481	$0	$47,829	$526,117	
4.9	Boiler Foundation			w/14.1			$0	$0	$0	$0	$0	
	SUBTOTAL 4.	**$290,367**	**$0**	**$144,440**	**$0**	**$0**	**$434,807**	**$43,481**	**$0**	**$47,829**	**$526,117**	**$956**
5	FLUE GAS CLEANUP											
5.1	Flue Gas Desulfurization System	$127,947	$0	$34,614	$0	$0	$162,562	$16,256	$0	$17,882	$196,700	
5.2	Other FGD	$1,652	$0	$1,064	$0	$0	$2,716	$272	$0	$299	$3,286	
5.3	Bag House & Accessories	w/5.1	$0	w/5.1	$0	$0	$0	$0	$0	$0	$0	
5.4	Other Particulate Removal Materials	$30,569	$0	$20,710	$0	$0	$51,279	$5,128	$0	$5,641	$62,048	
5.5	Gypsum Dewatering System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
5.6	Mercury Removal System	w/5.1	$0	w/5.1	$0	$0	$0	$0	$0	$0	$0	
	SUBTOTAL 5.	**$160,168**	**$0**	**$56,388**	**$0**	**$0**	**$216,557**	**$21,656**	**$0**	**$23,821**	**$262,033**	**$476**

S12BTotal Plant Cost Details (Jun 2018 Basis)

AIR-FIRED SUPERCRITICAL PC PLANT WITH ECONAMINE-BASED CO2 CAPTURE

Cost Basis 2018 ($x1000)
Plant Size 550 MWe, net

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Sales Tax	Bare Erected Cost $	Eng'g CM H.O & Fee	Contingencies Process	Contingencies Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
5B	CO2 REMOVAL & COMPRESSION											
5B.1	CO2 Removal System	$276,197	$0	$83,229	$0	$0	$359,426	$35,943	$71,166	$93,307	$559,841	
5B.2	CO2 Compression & Drying	$53,669	$0	$19,937	$0	$0	$73,606	$7,361	$0	$16,193	$97,160	
	SUBTOTAL 5B.	**$329,866**	**$0**	**$103,166**	**$0**	**$0**	**$433,032**	**$43,303**	**$71,166**	**$109,500**	**$657,002**	**$1,194**
7	HRSG, DUCTING & STACK											
7.3	Ductwork	$13,033	$0	$8,226	$0	$0	$21,259	$2,126	$0	$3,508	$26,893	
7.4	Stack	$11,782	$0	$6,848	$0	$0	$18,630	$1,863	$0	$2,049	$22,542	
7.9	Duct & Stack Foundations	$0	$1,285	$1,525	$0	$0	$2,810	$281	$0	$618	$3,709	
	SUBTOTAL 7.	**$24,815**	**$1,285**	**$16,599**	**$0**	**$0**	**$42,699**	**$4,270**	**$0**	**$6,175**	**$53,144**	**$97**
8	STEAM TURBINE GENERATOR											
8.1	Steam TG & Accessories	$76,527	$0	$9,427	$0	$0	$85,954	$8,595	$0	$9,455	$104,004	
8.2	Turbine Plant Auxiliaries	$482	$0	$1,025	$0	$0	$1,508	$151	$0	$166	$1,824	
8.3a	Condenser & Auxiliaries	$4,043	$0	$2,542	$0	$0	$6,585	$658	$0	$724	$7,968	
8.3b	Air Cooled Condenser	$37,048	$0	$7,379	$0	$0	$44,427	$4,443	$0	$9,774	$58,643	
8.4	Steam Piping	$29,884	$0	$13,277	$0	$0	$43,161	$4,316	$0	$7,122	$54,599	
8.9	TG Foundations	$0	$1,437	$2,373	$0	$0	$3,810	$381	$0	$838	$5,029	
	SUBTOTAL 8.	**$147,984**	**$1,437**	**$36,023**	**$0**	**$0**	**$185,444**	**$18,544**	**$0**	**$28,079**	**$232,067**	**$422**
9	COOLING WATER SYSTEM											
9.1	Cooling Towers	$17,945	$0	$5,550	$0	$0	$23,494	$2,349	$0	$2,584	$28,428	
9.2	Circulating Water Pumps	$3,600	$0	$278	$0	$0	$3,877	$388	$0	$426	$4,691	
9.3	Circ. Water System Auxiliaries	$926	$0	$123	$0	$0	$1,050	$105	$0	$115	$1,270	
9.4	Circ. Water Piping	$0	$7,793	$7,059	$0	$0	$14,852	$1,485	$0	$2,451	$18,788	
9.5	Make-up Water System	$755	$0	$970	$0	$0	$1,725	$173	$0	$285	$2,182	
9.6	Component Cooling Water System	$754	$0	$579	$0	$0	$1,333	$133	$0	$220	$1,686	
9.9	Circ. Water System Foundations	$0	$4,123	$6,847	$0	$0	$10,970	$1,097	$0	$2,413	$14,480	
	SUBTOTAL 9.	**$23,979**	**$11,916**	**$21,405**	**$0**	**$0**	**$57,301**	**$5,730**	**$0**	**$8,495**	**$71,526**	**$130**
10	ASH/SPENT SORBENT HANDLING SYS											
10.6	Ash Storage Silos	$1,167	$0	$3,571	$0	$0	$4,738	$474	$0	$521	$5,733	
10.7	Ash Transport & Feed Equipment	$7,754	$0	$7,686	$0	$0	$15,440	$1,544	$0	$1,698	$18,683	
10.9	Ash/Spent Sorbent Foundation	$0	$264	$324	$0	$0	$588	$59	$0	$129	$776	
	SUBTOTAL 10.	**$8,921**	**$264**	**$11,581**	**$0**	**$0**	**$20,766**	**$2,077**	**$0**	**$2,349**	**$25,192**	**$46**
11	ACCESSORY ELECTRIC PLANT											
11.1	Generator Equipment	$2,190	$0	$350	$0	$0	$2,540	$254	$0	$196	$2,990	
11.2	Station Service Equipment	$6,254	$0	$2,097	$0	$0	$8,351	$835	$0	$643	$9,829	
11.3	Switchgear & Motor Control	$7,177	$0	$1,247	$0	$0	$8,424	$842	$0	$927	$10,193	
11.4	Conduit & Cable Tray	$0	$4,923	$15,904	$0	$0	$20,827	$2,083	$0	$3,436	$26,346	
11.5	Wire & Cable	$0	$9,373	$16,755	$0	$0	$26,128	$2,613	$0	$4,311	$33,052	
11.6	Protective Equipment	$328	$0	$1,140	$0	$0	$1,468	$147	$0	$161	$1,776	
11.7	Standby Equipment	$1,661	$0	$38	$0	$0	$1,699	$170	$0	$187	$2,056	
11.8	Main Power Transformers	$14,814	$0	$236	$0	$0	$15,050	$1,505	$0	$1,656	$18,211	
11.9	Electrical Foundations	$0	$411	$1,047	$0	$0	$1,459	$146	$0	$321	$1,925	
	SUBTOTAL 11.	**$32,424**	**$14,707**	**$38,816**	**$0**	**$0**	**$85,947**	**$8,595**	**$0**	**$11,838**	**$106,379**	**$193**

S12BTotal Plant Cost Details (Jun 2018 Basis)

AIR-FIRED SUPERCRITICAL PC PLANT WITH ECONAMINE-BASED CO2 CAPTURE

Cost Basis 2018 ($x1000)
Plant Size 550 MWe, net

Acct No.	Item/Description	Equipment Cost	Material Cost	Labor Direct	Labor Indirect	Sales Tax	Bare Erected Cost $	Eng'g CM H.O & Fee	Contingencies Process	TOTAL PLANT COST Project	TOTAL PLANT COST $	TOTAL PLANT COST $/kW
12	INSTRUMENTATION & CONTROL											
12.6	Control Boards, Panels & Racks	$623	$0	$381	$0	$0	$1,004	$100	$55	$174	$1,333	
12.7	Computer Accessories	$6,298	$0	$1,124	$0	$0	$7,422	$742	$408	$857	$9,429	
12.8	Instrument Wiring & Tubing	$3,796	$0	$6,908	$0	$0	$10,704	$1,070	$589	$1,854	$14,217	
12.9	Other I & C Equipment	$1,779	$0	$4,120	$0	$0	$5,899	$590	$324	$681	$7,495	
	SUBTOTAL 12.	**$12,496**	**$0**	**$12,532**	**$0**	**$0**	**$25,028**	**$2,503**	**$1,377**	**$3,567**	**$32,474**	**$59**
13	IMPROVEMENTS TO SITE											
13.1	Site Preparation	$0	$65	$1,392	$0	$0	$1,457	$146	$0	$320	$1,923	
13.2	Site Improvements	$0	$2,171	$2,869	$0	$0	$5,040	$504	$0	$1,109	$6,653	
13.3	Site Facilities	$3,890	$0	$4,081	$0	$0	$7,971	$797	$0	$1,754	$10,522	
	SUBTOTAL 13.	**$3,890**	**$2,236**	**$8,342**	**$0**	**$0**	**$14,468**	**$1,447**	**$0**	**$3,183**	**$19,098**	**$35**
14	BUILDINGS & STRUCTURES											
14.1	Boiler Building	$0	$12,145	$10,673	$0	$0	$22,817	$2,282	$0	$3,765	$28,864	
14.2	Turbine Building	$0	$16,000	$14,902	$0	$0	$30,902	$3,090	$0	$5,099	$39,091	
14.3	Administration Building	$0	$802	$846	$0	$0	$1,648	$165	$0	$272	$2,084	
14.4	Circulating Water Pumphouse	$0	$367	$292	$0	$0	$659	$66	$0	$109	$833	
14.5	Water Treatment Buildings	$0	$990	$902	$0	$0	$1,893	$189	$0	$312	$2,394	
14.6	Machine Shop	$0	$535	$359	$0	$0	$894	$89	$0	$148	$1,131	
14.7	Warehouse	$0	$362	$364	$0	$0	$725	$73	$0	$120	$918	
14.8	Other Buildings & Structures	$0	$296	$252	$0	$0	$548	$55	$0	$90	$693	
14.9	Waste Treating Building & Structures	$0	$568	$1,721	$0	$0	$2,289	$229	$0	$378	$2,896	
	SUBTOTAL 14.	**$0**	**$32,065**	**$30,311**	**$0**	**$0**	**$62,376**	**$6,238**	**$0**	**$10,292**	**$78,905**	**$143**
	CALCULATED TOTAL COST	**$1,143,534**	**$72,586**	**$532,927**	**$0**	**$0**	**$1,749,047**	**$174,905**	**$72,543**	**$284,700**	**$2,281,194**	**$4,147**

Table 33. Owner's Costs for 550-MWe Air-Fired Supercritical Power Plant

Description	$/1,000	$/kW
Preproduction Costs		
6 months All Labor	$14,358	$26
1 Month Maintenance Materials	$2,295	$4
1 Month Non-Fuel Consumables	$1,671	$3
1 Month Waste Disposal	$935	$2
25% of 1 Months Fuel Cost at 100% CF	$1,455	$3
2% of TPC	$45,624	$83
Total	**$66,339**	**$121**
Inventory Capital		
60 day supply of fuel at 100% CF	$11,484	$21
60 day supply of non-fuel consumables at 100% CF	$2,903	$5
0.5% of TPC (spare parts)	$11,406	$21
Total	**$25,792**	**$47**
Other Costs		
Initial Cost for Catalyst and Chemicals	$3,357	$6
Land	$900	$2
Other Owner's Cost	$342,179	$622
Financing Costs	$61,592	$112
Total Overnight Costs (TOC)	**$2,781,354**	**$5,057**

Table 34. Plant Operating Cost Estimate for 550-MWe Air-Fired Supercritical Power Plant

INITIAL & ANNUAL O&M EXPENSES

Case:	Air-Fired Supercritical PC Plant		
Plant Size (MWe)	**550**	**Heat Rate (Btu/kWh):**	12,634
Primary/Secondary Fuel:	**Wyoming PRB**	**Fuel Cost ($/MMBtu):**	
Design/Construction	5 years	**Book Life (yrs):**	20
TPC (Plant Cost) Year	Jun-18	**TPI Year:**	2018
Capacity Factor (%)	85	**CO2 Captured (TPD)**	16110

OPERATING & MAINTENANCE LABOR

Operating Labor

Operating Labor Rate (base):	$39.70	$/hr		
Operating Labor Burden:	30.0	% of base		
Labor Overhead Charge	25.0	% of labor		
Operating Labor Requirements per Shift	**units/mod**		**Total Plant**	
Skilled Operator	2.0		2.0	
Operator	11.3		11.3	
Foreman	1.0		1.0	
Lab Tech's etc	2.0		2.0	
TOTAL Operating Jobs	16.3		16.3	
				Annual Cost $
Annual Operating Labor Cost				$7,369,289
Maintenance Labor Cost				$15,603,922
Administration & Support Labor				$5,743,303
Property Taxes and Insurance				$45,623,885
TOTAL FIXED OPERATING COSTS				**$74,340,399**

VARIABLE OPERATING COSTS

Maintenance Material Cost	**$23,405,883**

Consumables	Consumption Initial	Consumption /Day	Unit Cost	Initial Fill Cost	
Water(/1000 gallons)	0	5,502	1.87	**$0**	**$3,189,900**
Chemicals					
MU & WT Chem (lb)	0	26631	0.30	$0	$2,470,528
Lime (ton)	0	147	90.73	$0	$4,137,946
Carbon (Mercury Removal) (lb)	0	3216	1.27	$0	$1,267,394
MEA Solvent (ton)	1144	1.62	2721.80	$3,113,735	$1,367,989
NaOH (tons)	74	11.60	524.64	$38,824	$1,888,137
H2SO4 (tons)	82	7.70	165.47	$13,568	$395,293
Corrosion Inhibitor	0	0.00	0.00	$191,347	$9,112
Activated Carbon (lb)	0	1935	1.27	$0	$762,564
Ammonia (19% NH3) (ton)	0	32	157.03	$0	$1,558,945
Subtotal Chemicals				**$3,357,474**	**$13,857,908**
Other					
SCR Catalyst	0	0.49	6987.42	$0	$1,062,246
Subtotal Other				**$0**	**$1,062,246**
Waste Disposal:					
Flyash (ton)	0	937	28.03	$0	$8,149,028
Bottom Ash (ton)	0	160	28.03	$0	$1,391,510
Subtotal Waste Disposal				**$0**	**$9,540,537**
By-products & Emissions					
Gypsum (tons)	0	0	0.00	$0	$0
Subtotal By-Products				**$0**	**$0**
TOTAL VARIABLE OPERATING COSTS				**$3,357,474**	**$51,056,474**
Fuel (tons)	**0**	**9750**	**19.63**	**$0**	**$59,379,523**

2) *COST ESTIMATE COMPARISON*

Compared to the S12B air-fired supercritical power plant with CO_2 capture, the FPO supercritical power plant has a total plant cost that is about 18.4% lower at $3,383/kW vs. $4,147/kW. Substantial savings have been realized in the FPO firing system, flue gas cleanup, and CO_2 recovery and compression systems compared to Case S12B. This is more than enough to offset the major additional costs associated with the ASU, oxygen compressor, and pressurized flue gas turbo-expander units for the 550-MWe FPO power plant.

After factoring in pre-production, inventory capital, and other costs, the 550-MWe FPO supercritical plant has a lower TOC ($4,117/kW vs. $5,057/kW) compared to the air-fired S12B case. Note that the variable O&M and fuel cost in are based on 100% capacity factor.

For O&M costs, the FPO plant has lower fixed operating costs at $61.2MM/year compared to the S12B power plant at $74.3MM/year. This is due to the FPO plant having lower operating labor requirements and lower fixed operating costs associated with the overall plant capital costs (maintenance labor and property taxes and insurance). Its variable operating cost is also substantially lower ($48.5MM/year vs $59.4MM/year at 100% capacity factor), due to the higher chemical costs associated with amine-based capture. Finally, as the FPO plant has a lower heat rate than the S12B case (110,839 Btu/kWh vs. 12,634 Btu/kWh) it uses less coal and thus has a lower fuel cost.

3) *Cost of Electricity*

The first-year power cost is the cost of electricity (COE), calculated as revenue received by the generator per net MWh during the first year of operation. It is assumed that the COE escalates at a nominal annual rate equal to the general inflation rate, remaining constant in real terms over the operational period of the plant. The LCOE is the revenue received by the generator per net MWh during the first year of operation assuming that the COE escalates at a nominal annual rate of 0% (i.e., remains constant in nominal terms over the operation period of the plant). NETL's Power Systems Financial Model (PSFM) provides a reference for COE calculations. The model accepts all the economic assumptions outlined in Table 35 as well as the specific information on capital and fixed/variable O&M costs as outlined in Table 36.

Table 35. Model Economic Assumptions

Type of Security	% of Total	Current (Nominal) Dollar Cost	Weighted Current (Nominal) Cost	After Tax Weighted Cost of Capital
		LOW RISK		
Debt	50	4.50%	2.25%	
Equity	50	12%	6%	
Total			8.25%	7.39%
		HIGH RISK		
Debt	45	5.50%	2.48%	
Equity	55	12%	6.60%	
Total			9.08%	8.13%

Table 36. Model Economic Assumptions (Continued)

Parameter	Value
TAXES	
Income Tax Rate	38% Effective (34% Federal, 6% State)
Capital Depreciation	20 years, 150% declining balance
Investment Tax Credit	0%
Tax Holiday	0 years
CONTRACTING AND FINANCING TERMS	
Contracting Strategy	Engineering Procurement Construction Management (owner assumes project risks for performance, schedule and cost)
Type of Debt Financing	Non-Recourse (collateral that secures debt is limited to the real assets of the project)
Repayment Term of Debt	15 years
Grace Period on Debt Repayment	0 years
Debt Reserve Fund	None
ANALYSIS TIME PERIODS	
Capital Expenditure Period	5 Years
Operational Period	30 years
Economic Analysis Period (used for IRROE)	35 Years (capital expenditure period plus operational period)
TREATMENT OF CAPITAL COSTS	
Capital Cost Escalation During Capital Expenditure Period (nominal annual rate)	3.6%
Distribution of Total Overnight Capital over the Capital Expenditure Period (before escalation)	5-Year Period: 10%, 30%, 25%, 20%, 15%
Working Capital	zero for all parameters
% of Total Overnight Capital that is Depreciated	100% (this assumption introduces a very small error even if a substantial amount of TOC is actually non-depreciable)
ESCALATION OF OPERATING REVENUES AND COSTS	
Escalation of COE (revenue), O&M Costs, Fuel Costs (nominal annual rate)	3.0%

A nominal average annual rate of 3.6% is assumed for escalation of capital costs during construction. This rate is equivalent to the nominal average annual escalation rate for process plant construction costs between 1947 and 2008 according to the CEPCI. An average annual inflation rate of 3.0% is assumed. This rate is equivalent to the average annual escalation rate between 1947 and 2008 for the U.S. Department of Labor's Producer Price Index for Finished Goods. This is used instead of the Producer Price

Index for Electric Power Generation Industry because that data does not provide long-term historical perspective, dating only back to December 2003.

The approaches used to calculate both first-year power costs and LCOE are described below.

a) First-Year Power Cost

A simplified method provided in the NETL Financial Model User's Guide was used to calculate the first-year power cost. A first-year capital charge factor (CCF) can be used to calculate the COE with this simplified equation:

$$COE = [\ (CCF)(TOC) + OC_{FIX} + (CF)\ OC_{VAR}\ ]\ /\ (CF)\ (MWh)$$

- COE is the revenue received by the generator ($/MWh) during the power plant's first year of operation (expressed in 2018 dollars), assuming that the COE escalates at a nominal annual rate equal to the general inflation rate; i.e., that it remains constant in real terms over the operational period of the power plant.
- CCF is the first-year CCF that matches the applicable finance structure and capital expenditure period.
- TOC is the Total Overnight Capital in 2018 dollars.
- OCFIX is the sum of all fixed annual operating costs in 2018 dollars.
- OCVAR is the sum of all variable annual operating costs, including fuel at 100% capacity factor, in 2018 dollars.
- CF is the plant capacity factor, assumed to be constant over the operational period.
- MWh is the annual net megawatt-hours of power generated at 100% capacity factor.

Based on the economic factors specified by the DOE, the CCF for a low-risk IOU and five-year capital expenditure period is 0.116 (such as a commercial project like case S12A). The CCF for a high-risk IOU and five-year capital expenditure period is 0.124 (such as a novel system like cases S12B or the FPO case).

b) LCOE

The PSFM provides the LCOE on a current dollar basis over a levelization period equal to the plant's operational life; i.e., the LCOE is constant in current dollars over this period. The model provides a levelization factor that can be multiplied by the COE to give the LCOE in base-year dollars. The levelization factor for NETL-defined economic inputs is 1.268.

c) Costs of CO_2 Captured and Avoided

The cost of CO_2 captured was calculated both from the standpoint of the cost of CO_2 removed and the cost of CO_2 avoided.

The cost of CO_2 captured or removed in $/ton or $/tonne is given by:

$$\text{Cost of } CO_2 \text{ Captured} = (COE_{\text{with removal}} - COE_{\text{w/o removal}}) / (CO_2 \text{ Captured})$$

- COE is the cost of electricity ($/MWhnet)
- CO_2 Captured is the CO_2 captured (tonnes/MWhnet or tons/MWhnet)

Note that for cost of CO_2 captured, the COE does not include the cost of CO_2 transport and storage (T&S). The equation used to calculate the cost of CO_2 avoided in $/ton or $/tonne is given by:

$$\text{Cost of } CO_2 \text{ Avoided} = (COE_{\text{with removal}} - COE_{\text{w/o removal}}) / (CO_{2\text{w/o removal}} - CO_{2\text{with removal}})$$

- COE is the cost of electricity ($/MWhnet)
- CO_2 is CO_2 emissions (tonnes/MWhnet or tons/MWhnet)

d) Costs of CO_2 Transport and Storage

The cost of CO_2 T&S is included in the COE to derive the complete cost of capturing and storing CO_2. The updated NETL Baseline Report [12] specified the conditions and T&S costs to be used. The costs are based on transporting high-pressure (15.17 MPa) CO_2 from the power plant through a 100-km pipeline to the sequestration or enhanced oil recovery site. The CO_2 leaves the pipeline at a pressure of 8.27 MPa still in a supercritical state. For either a Midwest or Wyoming plant location used for this study, the T&S value specified by NETL is $10/tonne-$CO_2$.

e) First-Year Power Costs and LCOE Summary

Table 37 compares the first-year power costs, broken down into their components, for the NETL baseline cases S12A, S12B [6], and the FPO case. The first-year power cost for the FPO case only increases by 53.4% over that of the NETL-based case without CO_2 capture (S12A), compared to a 92.3% increase in first-year power cost for NETL's amine scrubbing based case with CO_2 capture (S12B). The FPO case shows potential cost reductions over Case S12B in capital (18.5%), operating and maintenance cost (26.9%), and fuel cost (18.6%). The O&M cost reduction is primarily due to elimination of amine solvent expense, while the fuel cost reduction is due to the improved net plant efficiency.

Table 37. LCOE Comparisons (in 2018$)

	NETL Case S12A	NETL Case S12B	FPO
Capital	44.7	84.2	68.6
Fixed O&M	11.1	18.2	15.0
Variable O&M	6.9	12.5	7.3
Fuel Cost	10.1	14.5	11.8
CO_2 T&S Cost	0.0	11.1	9.0
First Year Power Cost, $/MWh	**72.8**	**140.4**	**111.7**
LCOE, $/MWh	**92.3**	**178.1**	**141.6**

Table 37 also compares the LCOE for the base and test cases. The FPO case is 20.5% reduced when compared to the S12B case. Similar conclusions can be drawn to those for the first-year power costs, as relative differences between the NETL baseline cases and the FPO case are similar.

f) Cost of CO_2 Avoided and Captured Summary

Table 38 shows the CO_2 avoided and captured costs for the NETL baseline cases S12B [6], and the FPO case. The costs are relative to the NETL supercritical PC without CCS (Case S12A) [6] and for the cost of CO_2 captured does not include T&S.

The cost of CO_2 avoided is 44.6% less for the FPO case than for NETL baseline capture case S12B. On a cost of CO_2 captured basis, the FPO case advantage decreases by a 35.3% reduction relative to baseline case S12B.

Table 38. CO_2 Avoided and Captured Costs (in 2018$)

	NETL Case S12A	NETL Case S12B	FPO
Cost of CO_2 Avoided, $/tonne	Base	92	51
Cost of CO_2 Captured, $/tonne (excludes T&S Cost)	Base	51	33

2. TEAM STATUS

A. HOST SITE SELECTION

I. DESCRIPTION OF HOST SITE AND EVIDENCE OF COMMITMENT

A highly detailed description of the host site can be found in the Environmental Information Volume (EIV), contained in Section 2.D. The University of Wyoming demonstrated its commitment by providing a signed commitment letter, which is reproduced below in Figure 15.

1) UNIVERSITY OF WYOMING COMMITMENT LETTER

UNIVERSITY OF WYOMING
School of Energy Resources
Dept. 3012 • 1000 E. University Ave. • Laramie, WY 82071
(307) 766-2663 • fax: (307) 766-6701
www.uwyo.edu/SER

March 13, 2019

Joshua Schmitt
Research Engineer
Southwest Research Institute
6220 Culebra Road
San Antonio, Texas 78238

Subject: Letter of Commitment: Support for Awarded U.S. Department of Energy (DOE) Project DE-FE0031580: concerning the Southwest Research Institute's Development Project titled "Coal-Fired Flameless Pressurized Oxy-Combustion (FPO) Technology".

Dear Mr. Schmitt,

Please accept this non-binding letter of commitment from the School of Energy Resources, University of Wyoming in support of the subject proposed project submitted under the stated DOE award. Concerning the design, construction and operation of a test facility to show-case Itea SpA proprietary coal-fired Flameless Pressurized Oxy-fuel (FPO) combustion technology; we propose locating this at the University of Wyoming Central Energy Plant, in Laramie, Wyoming.

The University of Wyoming (UW) through the School of Energy Resources offers to host the FPO show-case facility on a site adjacent to and connected with the UW Central Energy Plant (CEP), which currently supplies steam and cooling water for the UW campus. It is our intention to continue operation of the FPO show-case as a going commercial entity once the technology test program is complete assuming successful performance and following agreement with DOE and the project Prime Recipient. In this event, Federal disposition regulations, will be followed on the assumption that agreed upon assets will move to University of Wyoming ownership to permit continued operation of the FPO show-case facility beyond the envisaged test campaign expectations covered by the subject project.

SER agrees to participate in FPO development project activities at its own in-kind cost contribution related to the designated work plan, which includes pre-FEED engineering, scope of work definition for construction and commissioning, design of the experimental program, technology evaluation and development planning, and compilation of safe-operational practices including commissioning and decommissioning.

In addition to providing the host site and assuming successful completion of FPO development project activities, and further DOE award funding to fully engineer, construct and operate the FPO show-case facility at the UW campus CEP, SER is willing to contribute cost-share toward this phase of work. Availability of cost-share funding is conditional on the State of Wyoming Legislator appropriating sufficient funds at the time of award and assuming an agreeable FPO technology development and evaluation work plan that can lead to commercialization.

A preliminary assessment of the proposed site location has confirmed that a suitably sized plot of land is available and sufficient to host the FPO technology show-case facility envisioned by the project team. This includes considerations and provisions such as availability of utility systems (e.g. waste-treatment, water and electric supply), integration into existing electric, power schemes and load considerations together with logistical needs including coal supply and handling.

We confirm willingness to provide field operations and research and technology development support professionals to the project and to facilitate environmental risk assessment and permitting processes including provision of information and advice. Practiced at infrastructure and project support in connection with operation, growth and expansion to the existing campus resident 40 MWth of coal-fired boilers, we further verify that there exists within SER, professionals familiar with managing and conducting major technology evaluation projects awarded and funded by DOE in the past.

This project is viewed as being highly valuable to the state of Wyoming and supports creation of local community projects, with the expectation that the project, if successful, will lead to the creation of an engineering data package/book suitable for commercialization of the FPO technology. Appealingly, FPO technology offers the potential for integrated CO_2 capture with associated significant technical performance and economic benefits, when benchmarked against alternative clean-coal combustion technologies available.

We look forward to hosting, supporting, promoting, and showcasing this FPO evaluation project and working with the project team to assure success and commercialization of a most promising technology.

Sincerely,

R. A. Horner 3/13

Richard A. Horner
Director of Special Projects & Emerging Technology
Tel: (307) 766 4301
E-mail: rhorner@uwyo.edu

Figure 15. UW Commitment Letter

II. DISCUSSION OF SITE SELECTION CRITERIA

The potential sites were reduced to the candidate host site through a checklist developed so that the information collected could be compared on a relative basis and each site could then be assessed based on its application to the design basis. The checklist has been divided into four major categories that group the collected information:

- Business and Financing
- Physical Attributes
- Environmental and Permitting
- Operations and Safety

A weighting system has been developed for every item in the checklist, since some have a greater impact on the suitability of a particular host site. The preliminary weighting, labeled as "Importance" for each item was given based on the team's assessment of its relative importance. A relative score of "High," "Medium," or "Low" was given for each item with high scores given a 9, medium a 3, and low scores a 1. Each host site will then be evaluated for each item getting a score from 5 (best) to 0 (worst). This score will then be multiplied by the weighted importance to get a numerical value for the site for the item (for example, if the item has an importance of "High" and the site scores a 5, its score for this item is then 45). The values for every item are then summed up to give the final score for the host site, which is then non-dimensionalized into a percentage. In this way, each host site will be given a quantitative score between 0 and 100% relative to each of the other potential sites. Those with the highest scores advance to the final step of the deeper-dive assessment. The list of items selected to assess the host sites and their relative preliminary importance is given in Table 39**.**

Table 39. Scoring Criteria and Associated Weighting Factors

Item	Importance
Business and Financing	
Is the organization operating the host site and the host site itself financially stable?	Medium
Are there perceived schedule risks for getting the site ready according to the schedule?	Medium
Does the host site organization have a track record working / contracting with DOE?	Low
Does the organization have a successful track record with doing DOE projects?	Low
Does the organization have a well laid out plan for performing the project and supporting the bid?	High
Does the power industry support the site?	Medium
Does the site have proximity to an international airport and accommodations?	Low
Does the site have special labor limitations or issues (e.g., union labor agreements)?	Medium
Does the site have suitable insurance to cover normal operational risks?	Low
Does the site have the support of the local and / or state governments?	Low
Is the host willing to provide cost share?	High
Is the organization willing to and capable of contracting with other organizations?	Low
Is there a perceived risk of the host site withdrawing from the project?	High
Is there available local or state government funding for the site?	Low
Is there risk associated with the cost share, e.g., is it from a source that may be hard to verify or has contingencies?	High
What is the perceived total cost of the site compared to others?	High
Physical Attributes	
Are there perceived construction risks / access issues?	Medium
Does the host site have the ability to use different coals?	Low
Does the site have a potential need for process steam?	Medium
Does the site have an existing air separation unit or excess oxygen?	Medium
Does the site have existing infrastructure that can be used?	High
Does the site have ready access to coal?	High
Does the site have ready availability to all required utilities?	High

Item	Importance
Does the site have sufficient plot space and are there no space restrictions?	High
Does the site have the ability to provide power to the grid?	Low
Does the site have the ability to utilize CO_2 or access to a nearby CO_2 pipeline?	Low
Environmental, Permitting, and Safety	
Are there any other concerns with accessing / providing consumables?	Low
Are there any perceived health, safety, and environment issues?	High
Are there concerns around air permitting for the site?	Medium
Are there concerns around water permitting for the site?	Medium
Does the site have National Environmental Policy Act Environmental Assessment and Categorical Exclusion?	High
Operations	
Are there any noise restrictions at the site that could limit the hours of operation?	Low
Are there any security risks for the host site?	Medium
Cost of operating the site?	High
Does the organization have a successful track record in doing pilot-scale testing?	Medium
Does the organization have experience with any of the core components of the system?	Low
Does the site have existing staff to support the project through all phases?	Medium
Does the site have the ability to support full 24/7 operations?	High
Does the site location have weather-related or altitude concerns?	Low
Does the site, its existing equipment (if any), and its staff support long-term operations?	Medium
Is the skillset needed to perform maintenance available from the site or nearby organizations?	Medium
Is there a risk of changes in future operations of host site that could impact the test plan?	Low

In the first stage of the work, stakeholders who are owners (and potential sponsors/funders of approximately 12 prospective host sites) were contacted in order to develop a long list of candidate sites. Long-list sites will be assessed in more detail in the next stage of the process, with the objective to develop a short-list of up to five sites by June 30th for a full evaluation during the second half of 2017.

To make the long-list, prospective host sites will have to meet the following minimum requirements:

- Does the host site have ready access to coal?
- Does the host site have the ability to receive different coals in the quantities required?
- Does the site have sufficient plot space and are there any space restrictions?
- Are there any noise restrictions at the site that could limit the hours of operation?
- Does the site have the ability to support full 24/7 operations?

Also, the following issues are critical if they would seriously impede or prevent the construction or operation of the pilot plant, and if there is no realistic possibility that they can be resolved:

- Any special labor limitations or issues (e.g., union labor agreements)
- Any perceived HSE issues
- Any perceived Air or Water Permitting issues

With respect to the items above, it would be helpful if there was an NEPA - Environmental Assessment (EA) - Categorical Exclusion (CX) determination applicable to the site or its activities. Using these selection criteria, the University of Wyoming (UW) Central Energy Plant (CEP) was chosen to host the pilot. The full detail on the selection process and determining factor can be found in Appendix G: Excerpts from DE-FE0027771 Site Selection Report.

III. ENVIRONMENTAL ANALYSIS OF THE HOST SITE

Environmental Analysis was performed on the selected host site at the UW CEP. This information was compiled into the EIV, which is contained in Section 2.D.

B. TEAM STATUS FOR PHASES II AND III

1) Team Structure for Phase II

The structure of the team will take a single PI delegating the management of efforts to Technical Lead Investigators. As the prime contractor, SwRI will track the progress of the partners, keeping regular communication with the subcontractors and vendors. The partners have agreed to a scope of work, budget, and associated schedule. The structure of the team and the responsibilities of each team member within the proposed objectives are illustrated in Figure 16.

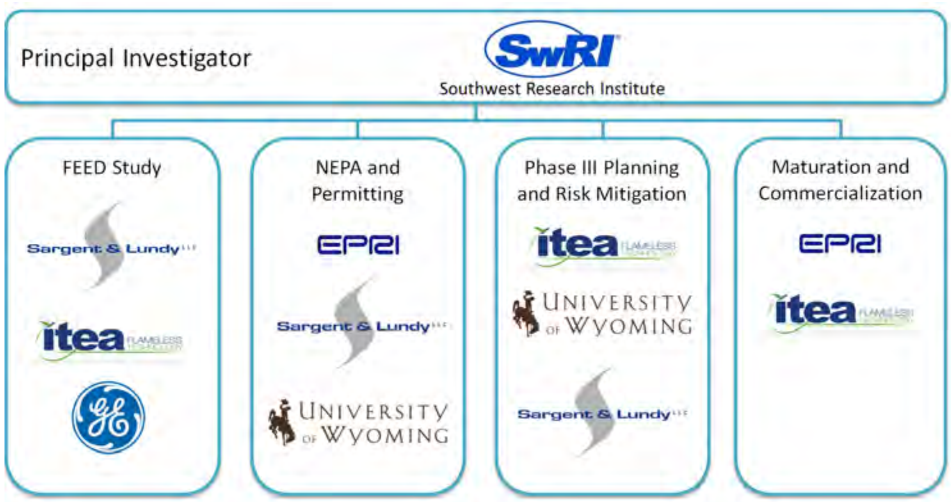

Figure 16. Team Structure for Phase II

Part of the scope for Phase II is to secure any further team members that will be needed for Phase III. The team will target industry partners to help cover costs associated with Phase III. These industry partners will also represent a significant step towards improvement of the commercialization strategy of the FPO technology.

2) EPC Selection for Phase II and III

Sargent & Lundy was approached during the proposal process for Phase I. They have provided cost share for their efforts in Phase I, and they will be providing cost share in

Phase II, which is evidence of commitment to the project. They have extensive experience with CO_2 capture projects. A summary of Sargent & Lundy's work is below in Table 40.

Table 40. Sargent & Lundy Experience with CO_2 Capture Projects

Carbon Dioxide (CO_2) Capture Experience

Testing, Studies, Implementations

Sargent & Lundy

Client	Project/ Location	Project Type	Scope Summary	Date
Carbon Capture Machine (UK) Limited	X-Prize Carbon Capture Competition	Test Skid Design	As subcontractor to CCM, S&L is supporting design of pilot skid carbon capture system to be installed at the Wyoming ITC as part of X-Prize's Carbon Capture Competition. S&L's role on the project includes equipment design, balance-of-plant engineering and design, and construction oversight.	2018-ongoing
Confidential Client	Confidential	Test Skid Design	Owner's Engineering for design of test skid for new carbon capture technology. The skid will be installed at various industrial applications.	2018-ongoing
Confidential Client	Confidential	Oxy-Combustion and Carbon Capture Study	Supporting confidential client in developing study to evaluate conversion of existing coal-fired unit to oxy-combustion, in conjunction with installing a CO_2 capture system. Coordinating efforts of multiple subcontractors, as well as performing balance-of-plant engineering and cost estimating.	2018-ongoing
ION Engineering, LLC (ION)/ Nebraska Public Power District (NPPD)/DOE	Gerald Gentleman 2, Nebraska	Nebraska	As a subcontractor to ION, S&L is supporting development of a commercial carbon capture design and costing study for a 300-MW (equivalent) carbon capture system. S&L's role includes performing studies, balance-of-plant engineering and design, constructibility review, and cost estimating.	2018-ongoing
Basin Electric Power Cooperative	Dry Fork Station 1, Wyoming	Integrated Test Center (ITC) - Capture Technology Evaluation	Conducted engineering and developed costs to support development of ITC using 20-MWe (87,500-ACFM) slip stream of flue gas from Dry Fork Station, divided amongst six test sites. First scheduled tests ITC evaluated six different CO_2 capture technologies for X-Prize's Carbon Capture Competition to demonstrate beneficial utilization of the recovered CO_2.	2015-2018
University of Utah	Hunter, Utah	Carbon Capture and Sequestration (CCS) Implementation	Assisting client in evaluating feasibility and economics of integrating CO_2 capture technologies at existing plant for sequestration in nearby geological sites. Evaluation included comparison of traditional amine-based technology and emerging cryogenic technology. As part of this project, S&L defined the balance-of-plant impacts and estimated the associated costs for the station for each technology.	2017
University of Wyoming	Jim Bridger, Wyoming	Carbon Capture and Sequestration (CCS) Implementation	High-level evaluation of station as a potential candidate for CO_2 capture technology to provide a concentrated CO_2 stream for sequestration. Evaluation was conducted as part of the DOE-funded CarbonSAFE project.	2017

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Client	Project/ Location	Project Type	Scope Summary	Date
CARBON 360/Petra Nova/ NRG Energy	W.A. Parish 8, Texas	Carbon capture and sequestration (CCS) Implementation	Primary scope: 1) Owner's Engineer during development and design phase of project. Included design reviews and HAZOP participation in addition to detailed drawing review. 2) Detailed design of Hastelloy and fiberglass reinforced plastic (FRP) ductwork system capable of handling a 240 MWe slipstream (646,800 SCFM) of flue gas that is interconnected to the host unit (Unit 8) and the carbon capture island. This design included a computational fluid dynamic (CFD) model, ductwork design, support steel design, and foundation design. 3) Performed evaluation of MHI's amine based process producing 1.6 million tons of CO_2 per year (4776 tons/day).	2013-2017
Confidential Client	Confidential	Carbon Capture for Enhanced Oil Recovery (EOR) Economic Evaluation	Assisted client in evaluating feasibility and economics of integrating CO_2 capture technologies at existing plant for use in EOR at nearby oil fields. As part of this project, S&L defined the balance-of-plant impacts and estimated the associated costs for the station.	2016-2017
Confidential Client	Confidential	Carbon Capture for Enhanced Oil Recovery (EOR) Economic Evaluation	Assisted client in evaluating feasibility of installing a CO_2 capture system at existing plant for use in EOR at nearby oil fields. This project included an evaluation of the permitting requirements for both the onsite capture equipment and the associated CO_2 pipeline. Subsequent to the permitting evaluation, S&L is evaluated the technical feasibility of integrating various configurations of CO_2 capture technology within the limitations of the existing station.	2016
Confidential	Novel CO_2 Solvent Technical and Economic Assessment	--	A developer of a second-generation CO_2 capture solvent contracted S&L to perform a technical and economic assessment of a CO_2 capture facility based on the use of their proprietary solvent as part of a DOE-funded project. Assessment evaluated the incremental cost of CO_2 capture using this solvent based on installation at a theoretical greenfield power plant. Included development of conceptual design for the base plant and capital and O&M costs for the entire facility, including the CO_2 capture island.	2015-2016
Confidential Client	Confidential	Novel CO_2 Capture Technology Evaluation	A major U.S. utility company contracted S&L to perform a FEED study, in conjunction with the technology developer, to determine how to integrate the technology into an existing power plant; provide preliminary design information, identify risks and unknowns; and to conduct capital and O&M cost estimates to help the client evaluate the economics of developing the project further. The system was designed to capture 100,000 tons per year of CO_2, roughly equivalent to a 15-MWe slipstream of flue gas.	2014-2015

Client	Project/ Location	Project Type	Scope Summary	Date
NRG Energy	W.A. Parish 8, Texas	Carbon capture and sequestration (CCS) FEED Study	Work described below at W.A. Parish 7 evolved to Unit 8 and was expanded in size to a 240-MWe slipstream. Owner's engineering services and balance-of-plant (BOP) design for a 240-MWe Carbon Capture Utilization and Storage (CCUS) demonstration project. Project received a funding grant from the U.S. DOE. S&L was heavily involved in the development of the proposal to the DOE. As owner's engineer, S&L reviewed all technical aspects of the project, including HAZOP reviews for the facility.	2010-2013
U.S. DOE	Indiana and Mississippi	Gasification projects	Perform due diligence analyses on the projects for the U.S. DOE Loan Guarantee Program. Projects intended to produce substitute natural gas (SNG) from coal and petroleum coke to power two plants ranging in size from 300 to 400 MW. Sale of CO_2 is beneficial to use in enhanced oil recovery (EOR) applications.	2010-2014
U.S. DOE	Generic	Efficiency study	Develop conceptual design for a new 500 MW PC power plant equipped with CO_2 recovery that is fully thermally integrated. Determined overall efficiency improvements that are possible due to integration and compared these to existing concepts.	2009-2013
NRG Energy	W.A. Parish 7, Texas	Carbon capture and sequestration (CCS) DOE Proposal	Supported proposal development to DOE for Clean Coal Power Initiative (CCPI) 3 for 60-MWe slipstream (161,700-SCFM) demonstration facility on Unit 7. Facility would remove SO_2 and capture 1,194 tons per day of CO_2 using Fluor Econamine Plus and wet limestone scrubbing technology. The captured CO_2 would be used for EOR in nearby oil fields. As owner's engineer, S&L provided all BOP engineering, including CO_2 compression.	2008-2010
Confidential	Western U.S.	Repowering/CCS	Compared costs for repowering several existing steam turbines totaling approximately 500 MW with natural gas combined-cycle power systems with installations of retrofit carbon capture system technologies on existing boilers.	2010
US/EPA	Generic	Pulverized coal and IGCC plants	Developed cost estimating workbook for applying efficiency enhancement technologies at existing power plants. Assessed reduction in CO_2 footprint possible for each technology. Compared the enhancements to installation of new pulverized coal and IGCC power plants.	2009-2010
Confidential	--	Due diligence	Performed due diligence analysis of the FutureGen project for a prospective participant in the FutureGen Alliance.	2009

Carbon Dioxide (CO_2) Capture Experience

Testing, Studies, Implementations

Sargent & Lundy

Client	Project/ Location	Project Type	Scope Summary	Date
ENMAX Corporation	Canada	Feasibility study	Worked with Hatch on studies of combined-cycle and IGCC projects, including evaluation of variations to syngas for combustion turbines: • NGCC to IGCC retrofit prefeasibility study • High-hydrogen content Syngas combustion effects on CTGs prefeasibility study • IGCC/SNG/CO_2 EOR plant prefeasibility financial/market analysis	2007-2009
NRG Energy	W.A. Parish and Limestone, Texas	SO_2 and CO_2 capture	Evaluated SO_2 and CO_2 capture using Powerspan's ammonia based ECO-SO_2 and ECO_2 technology. Powerspan's system was designed to use a 125-MWe slipstream of flue gas to produce 3000 tons per day of CO_2.	2007-2009
Nebraska Public Power District	Generic	CO_2 utilization	Evaluated CO_2 utilization using CO_2 captured from a 700 MW power plant.	2008
Duke Energy	Confidential	Carbon management	Carbon capture and compression retrofit feasibility study for a 600 MW coal plant.	2007-2008
Midwest Generation	Generic	CO_2 control pre-feasibility studies, carbon management	CO_2 control prefeasibility studies and carbon management: • FGD technology selection, cost analysis, and site layout (SDA wet FGD, Powerspan technology) • FGD technology selection and CO_2 retrofit impacts • CO_2 transportation retrofit pre-feasibility study • CO_2 technology for capture and compression site constraint pre-feasibility study • CO_2 technology site selection, site layout, and performance impacts	2007-2008
Confidential client	Confidential	Site selection	Site selection, feasibility studies, and carbon management.	2007
IP&L	Generic	Carbon capture	Prepared white paper on carbon capture.	2007
OG&E	Fleetwide	Carbon management	Provided emissions data and costs for 25 units.	2007-2008

C. STATUS OF COST SHARE FOR PHASES II AND III

The breakdown of cost share for Phase II by percentage of the total project is shown in Table 41. Each organization will provide a commitment letter as part of the Phase II continuation proposal.

Table 41. Cost Share for Phase II by Organization

Participant	Type	Project Budget	Cost Share
Southwest Research Institute®	Not for Profit	$370.2k	0.0%
Sargent & Lundy	For Profit	$1,869k	9.9%
ITEA S.p.A.	For Profit	$840.0k	5.6%
General Electric Global Research Center	For Profit	$211.8k	1.1%
Electric Power Research Institute, Inc.	Not for Profit	$191.0k	1.0%
University of Wyoming	Not for Profit	$277.5k	2.7%

The University of Wyoming has indicated that it can procure as much as $19 million for Phase III work. This amount is subject to project approval and appropriation from the State of Wyoming. The Phase II organizations will also be providing cost share for portions of their work. Any additional cost share required to fund a successful Phase III program will be developed with additional organizations as part of the Phase II scope.

D. UNIVERSITY OF WYOMING EIV

I. EIV ABBREVIATIONS AND ACRONYMS LIST

Term	Description
°C	degrees Celsius
°F	degrees Fahrenheit
A	amp
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ASU	air separation unit
Bar(g)	Bar gauge
BMP	best management practice
BOP	balance-of-plant
Btu	British thermal unit
CCS	carbon capture and sequestration
CEP	University of Wyoming Central Energy Plant
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CO	carbon monoxide
CO_2	carbon dioxide
db(A)	adjusted decibels
DEQ	Department of Environmental Quality
DOE	U.S. Department of Energy
EIV	environmental information volume
EPA	U.S. Environmental Protection Agency
EPC	engineering, procurement, and construction
EPRI	Electric Power Research Institute
ESA	environmental site assessment
DOE	U.S. Department of Energy
FEED	front end engineering design
FGD	flue gas desulfurization
FIRM	Flood Insurance Rate Map
FOM	figures of merit
FPO	flameless pressurized oxy-combustion
ft	foot/feet
ft3	cubic foot/feet
GE	General Electric
GEP	good engineering practice
gpm	gallons per minute

Term	Description
GWC	general work contractor
H2O	water
Hg	mercury
hp	horsepower
hr	hour
iPaC	Information for Planning and Conservation
kg	kilogram
km	kilometer
kPaG	kilopascal gauge
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
lb	pound
lb/hr	pound per hour
m	meter
MMBtu	million British thermal unit
mm	millimeter
MW	megawatt
MWh	megawatt-hour
MWth	megawatt-thermal
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NOx	nitrogen oxides
NRHP	National Register of Historic Places
NWI	National Wetlands Inventory
O&M	operations and maintenance
O_2	oxygen
OEM	original equipment manufacturer
OTSG	once through steam generator
P&ID	piping and instrumentation diagram
PCC	power control center
PFD	process flow diagram
PM	particulate matter
ppm	parts per million
ppmvd	parts per million volume dry
PRB	Powder River Basin
psig	pounds per square inch gauge
REC	recognized environmental conditions
S&L	Sargent & Lundy
SO_2	sulfur dioxide
SwRI	Southwest Research Institute
TCLP	toxicity characteristic leaching procedure
TPH	tons per hour

Term	Description
TRL	technology readiness level
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UW	University of Wyoming
V	volt/voltage
VOC	volatile organic compounds
WAAQS	Wyoming Ambient Air Quality Standards
WYNDD	Wyoming Natural Diversity Database

II. INTRODUCTION

1) *BACKGROUND*

The purpose of this document is to present a site-specific EIV for a pilot plant to demonstrate the technical feasibility of FPO technology, a technology developed and patented by ITEA. The FPO pilot project is supported by the U.S. DOE's Project DE-FE0027771 to advance coal carbon capture and sequestration (CCS) technologies in response to the recent DOE FOA: DE-FOA-0001788 for large-scale pilots for transformational coal technologies. Southwest Research Institute, in cooperation with ITEA, the UW, EPRI, S&L, and GE (collectively referred to as "SwRI") is proposing to construct and operate a 25-MWth FPO pilot unit at the UW's existing CEP in Laramie, Wyoming. Plans call for the construction of the FPO pilot to begin in 2022 and be in operation by December 2023.

SwRI engaged S&L to provide engineering and technical support to the project team, and to prepare this EIV. S&L will participate in all phases of the project, as needed, in the capacity as a technical subcontractor to SwRI to provide technical assistance and engineering guidance. The enclosed EIV was prepared in accordance with 40 CFR Parts 1500-1508 and U.S. DOE Regulations for the implementation of the National Environmental Policy Act (NEPA) (10 CFR Part 1021). This document evaluates potential impacts to environmental resources addressed in an EIV, and identifies potentially significant adverse environmental impacts, if any, related to the proposed project. DOE, will review the EIV as the lead agency, to identify the level of NEPA documentation required.

2) *DESCRIPTION OF THE PROPOSED PROJECT*

FPO can be described as a next-generation oxy-combustion technology that improves upon existing atmospheric-pressure oxy-combustion technologies. The proposed FPO pilot project will demonstrate the technical feasibility of the FPO technology, validate performance of FPO, and identify potential risks in the path to commercialization of the technology as a transformative 2nd generation coal technology capable of providing high-efficiency, low-emissions power generation.

The primary difference between the FPO system and conventional coal-fired power generation is the method of coal combustion. In the FPO system, coal and water slurry is fed to a pressurized combustor where it reacts (i.e., combusts) at high pressure with oxygen provided by an air separation unit (ASU) and recirculated flue gas from the once-through steam generator (OTSG). Flue gas from the combustion process primarily consists of carbon dioxide (CO_2) and water, with minimal, or no, emissions of other criteria air pollutants such as nitrogen oxides (NOx) and sulfur dioxide (SO_2). The high concentration of CO_2 in the resulting flue gas simplifies downstream CO_2 capture, allowing for CO_2 greater than 90% CO_2 capture and compression to 2,200 psig for sale or sequestration. Potential benefits of the FPO system include smaller and less expensive boiler equipment and the ability to provide latent heat recovery at temperatures that are useful for power generation, resulting in improved efficiencies.

The performance of the FPO unit's novel pieces of equipment, including the coal preparation and pressurized slurrying equipment, the FPO combustor or "Oxy-combustor", the hot fumes quencher located immediately after the combustor, the OTSG, the turbo-expander quencher, and the turbo-expander will be evaluated in detail as part of the demonstration. SwRI will run tests on the pilot unit for approximately two years. Following successful completion of the pilot project, the FPO unit will be turned over to UW.

3) FPO TECHNOLOGY BACKGROUND

ITEA began developing the FPO technology in 2003 on its 5-MWth pilot unit in Gioia del Colle, Italy. The technology was initially designed to destroy hazardous industrial waste. In 2007, ITEA, in cooperation with Enel, modified the 5-MWth facility to tailor it for coal-firing. In 2018, a pilot flue gas desulfurization (FGD) scrubbing column was retrofit to the facility, and continues to operate and collect operating data. The technology was deployed in 2009 at the 15-MWth scale at the Jurong Island petrochemical cluster in Singapore for waste incineration.

EPRI evaluated the readiness level of the ITEA FPO technology and determined that the current technology readiness level (TRL) is TRL-6.[1] One of the goals of the proposed pilot project is to advance the technology to TRL-7 so it can be ready for commercial demonstration (TRL-8). To achieve TRL-7, the proposed pilot plant must be scaled up from the previous 5-MWth pilot by a factor of 5 to 10 in capacity (e.g., 25 to 50-MWth), and must encompass all the novel equipment associated with the process.

4) SUMMARY OF IMPACTS

The majority of potential environmental or socioeconomic impacts resulting from the installation, operation, and testing of the FPO pilot can be categorized as insignificant

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[1] TRL are based on a scale of 1 to 9, with TRL-9 equivalent to the most mature technology. See https://swdev.epri.com/softwaretrls.asp for TRL definitions.

and/or positive. Environmental impacts can be considered neutral or minimal, while socioeconomic impacts can be considered overall to be positive.

The FPO pilot plant will not take up significant land, will recycle water to the greatest extent practical, and no wastewater discharges are expected that could impact surface or ground water quality. Storm water will be directed to the existing storm water pond and storm sewers, and will be controlled using the proper sediment and erosion controls. There are no streams, floodplains, or wetlands at the proposed site; therefore, there are no anticipated impacts to water resources. There are no known sensitive habitat areas; therefore, the construction and operation of the FPO plant is unlikely to affect listed species. The FPO pilot plant will result in some increase to air emissions, and an increase in waste to an off-site location in Wyoming, but these impacts are expected to be minimal considering the size of the project and will meet regulatory requirements.

The FPO project is expected to have a positive influence on local employees, contractors, and vendors. New jobs will be created to support the operation of the plant, and a construction crew will be hired to build the plant. The project will also demonstrate the technical feasibility of a new technology, which if scaled up for commercial demonstration, would provide an economic benefit to coal producing regions.

Some potential challenges that may be encountered include designing the FPO pilot plant to be critically silenced in order to meet the local noise ordinance for residential areas. Additionally, the UW host site has indicated that the city’s building permit process can be slow, and may impact the schedule of the project. Further, the design for the plant will need to be reviewed and approved by UW’s internal design review committee.

III. PROPOSED PROJECT & ALTERNATIVES

1) *PROPOSED PROJECT*

This section of the EIV describes: (1) the proposed location of the FPO pilot project and existing site conditions; (2) existing operation of the UW CEP; (3) the construction and operation of the FPO unit; and (4) associated project requirements, including anticipated changes to the existing site (e.g., land requirements, fuel and water requirements, and environmental discharges).

a) Site Location

The FPO pilot unit will be located west of UW's existing CEP site in Laramie, Wyoming. Figure 17 shows the location of the pilot project and the local topography for the site, as depicted on the relevant U.S. Geological Survey (USGS) topographic map. The USGS Topographic Map for the entire Laramie Quadrangle, Wyoming – Albany County, 7.5-Minute Series in provided in Appendix A: USGS Laramie Quadrangle, Wyoming – Albany County, 7.5-Minute Series Topographic Map. The site is located in an area of minimal flood hazard, outside the 100-year floodplain, and no wetlands are located on or adjacent to the site based on a review of the National Wetlands Inventory (NWI). Soils in the area of the pilot project consist of a mixture of urban land, Alogia soil, and Wycolo soils[2]. In addition to UW buildings located in the vicinity of the pilot project, several landmarks are located within 1 mile of the proposed project including Buchanan

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[2] From Custom Soil Resource Report for Albany County Area, Wyoming. Alogia, and Wycolo soils are described as well or moderately well drained.

Center for the Performing Arts, Greenhill Cemetery, Labonte Park, Laramie Park, Laramie Plains Museum, and War Memorial Stadium.

b) Existing Plant

UW's existing CEP is located adjacent to the proposed location of the FPO pilot project. The CEP consists of four units that supply steam, chilled water, and compressed air for heating and cooling of the UW campus buildings. Unit 1 is an E. Keeler D.S. boiler capable of firing oil and gas (37.5 MMBtu/hr). Units 2 through 4 are identical IBW VSG-60 stoker boilers, capable of firing coal in addition to oil and gas (73.17 MMBtu/hr). Each unit is equipped with a baghouse for particulate control. Units 2 through 4 currently fire bituminous coal from Colorado ("Twenty Mile Coal") and have fired Powder River Basin (PRB) coal in the past from Wyoming ("Decker Coal"). As a starting point for Analysis, the NETL PRB coal analysis is used [13], and is included in Appendix B: CEP & FPO Pilot Coal Analyses. During pilot development activities, the coal used for the design basis will be adjusted to represent regional coals. Off-design analysis of using different coals from the design PRB will be performed. Coal is delivered to site by truck and loaded into silos. Water required for various site operations is provided by the City of Laramie. The plant is permitted to discharge wastewater, including steam-cycle blowdown and cooling water, to the City of Laramie Wastewater Utility.

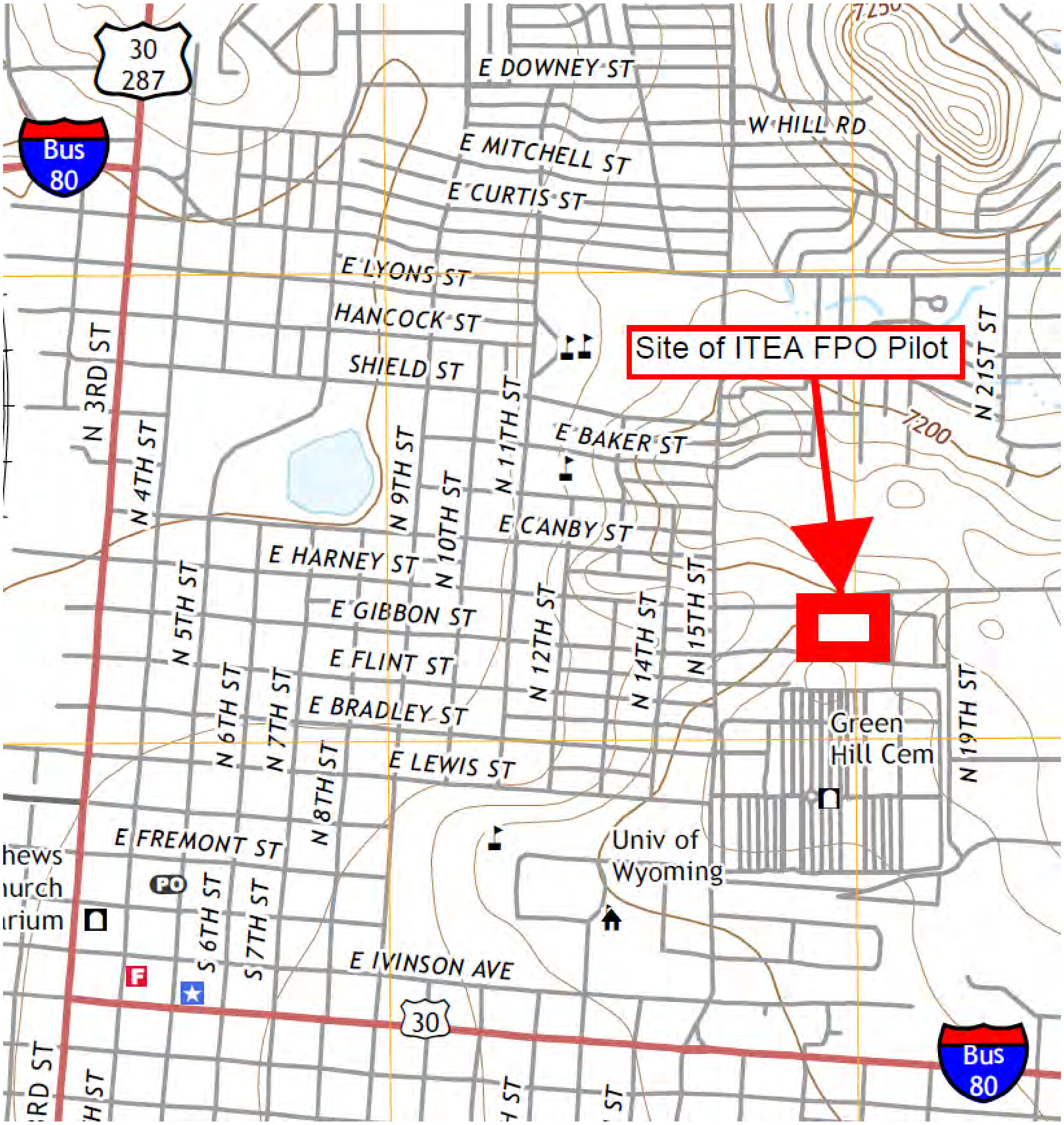


Figure 17. Site Detail from Laramie Quadrangle, Wyoming – Albany County 7.5-Minute Series

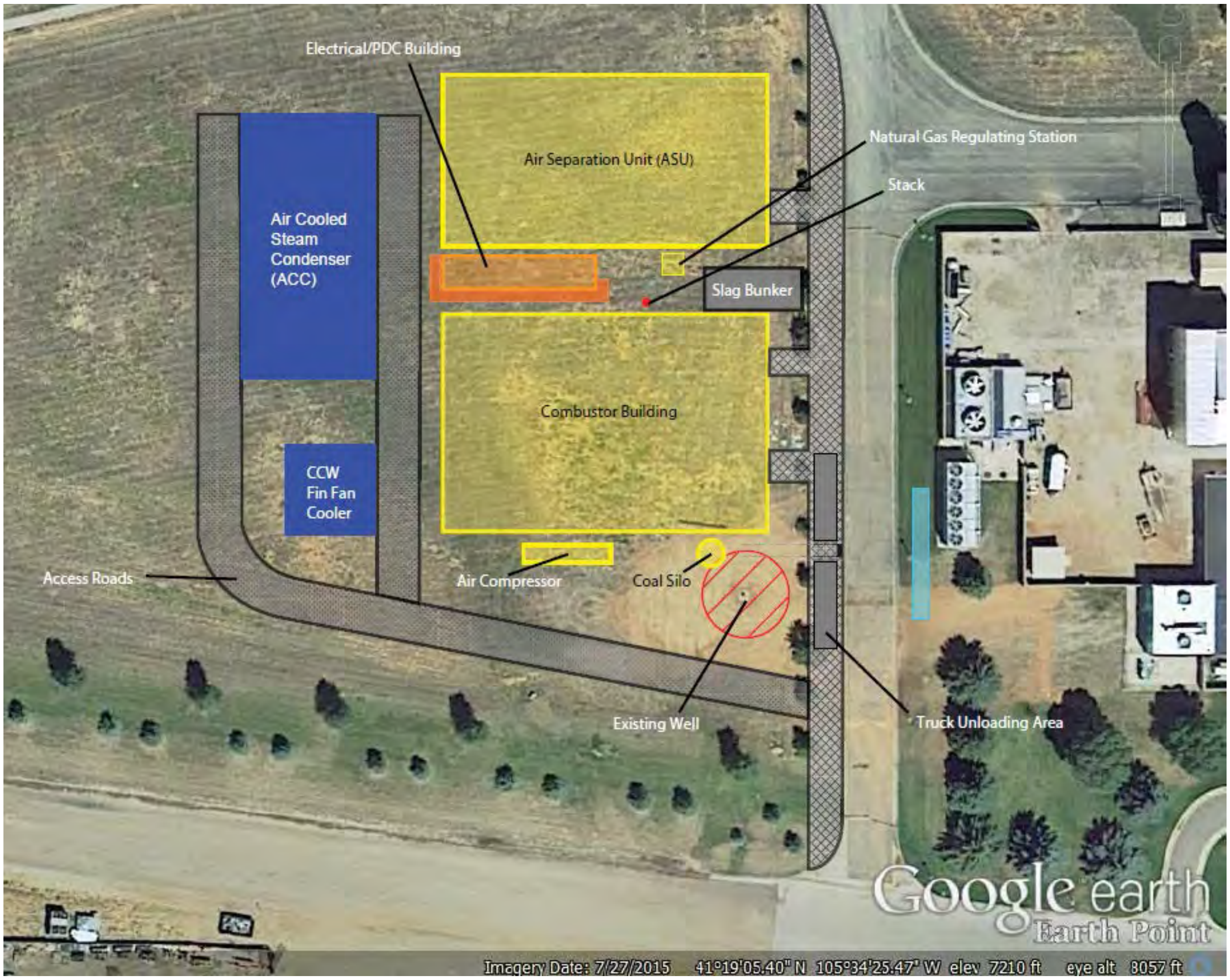


Figure 18. CEP Aerial View

c) Construction and Operation

i) Description of FPO Project

The primary objective of this project is to install, test, and demonstrate the performance of ITEA's FPO technology at a 25-MWth pilot unit. This project will be the first North American demonstration of the FPO technology and the first application of this technology utilizing PRB coal. The pilot project is designed to validate performance of FPO, demonstrate production of a high CO_2 concentration flue gas stream, and develop data to evaluate the costs and cost effectiveness of the FPO system. Equipment and operating data developed through execution of this project will be used for future commercialization of the technology. Results of the operation and experimental testing will be used to further improve the FPO design and operation.

Specific technical objectives of the FPO demonstration include, but are not limited to:

- Determine the Figures of Merit (FOM) required to advance the technology to the next TRL (an outline of the FOM items that will be evaluated is included in Appendix C: FPO Pilot Testing Figures of Merit):
- Give confidence to potential end-users that the technology can achieve its design targets and is a low risk, safe, and reliable process; and
- Allow ITEA to update and finalize the design of the next system scale up in size.

ii) Description of FPO Project Phases

The proposed project will advance through three phases including conceptual design and project development (Phase I), Front End Engineering Design (FEED)/preliminary engineering (Phase II), followed by detailed design, construction and operation of a pilot scale facility (Phase III). The TRL of all elements of the FPO technology will be advanced at the end of Phase III to meet criteria allowing for larger scale commercialization. The phases, along with the scheduled beginning and completion dates and tasks are shown below:

Phase I – Conceptual Design and Project Development (04/01/18 – 07/31/19)

1. Project Management and Planning
2. Site Selection and Securing Commitments
3. Environmental Analysis

Phase II – FEED/Preliminary Engineering (08/01/19 – 07/31/20)

Phase III – Detailed Design, Construction, and Operation (01/01/21 – 12/06/23)

1. Engineering Design
2. Procurement and Furnish Material
3. Construction and Commissioning
4. Start-up and Training
5. Test Campaign

SwRI, acting as the general contractor, will take the lead in all efforts required for the execution of the demonstration project. SwRI will be performing all the major tasks throughout the entire period of the project, and will actively participate in the operation and testing activities that are expected to last two (2) years. ITEA, GE, and UW (the test site host), will assist SwRI with technology aspects needed and inputs of site related information during the phases of the project, and will be actively involved in the start-up, training, and experimental testing of the pilot unit. S&L will participate in all phases of the project, as needed, in the capacity as a technical subcontractor to SwRI to provide technical assistance and engineering guidance throughout the entire project.

iii) Process Description

Process flow diagrams (PFDs) for the proposed FPO pilot unit are included in Appendix D: FPO Process Flow Diagrams. In the FPO process, a coal slurry fuel is fed into the Oxy-combustor where it is combusted with oxygen to generate useful heat. Pre-crushed, low sulfur, PRB fuel will be utilized for the demonstration. Trucks will deliver coal to the site where it will be transferred via conveyors to a dedicated coal silo. The coal feed silo will feed directly into the wet slurry rotary rod mill by a weigh screw feeder. A separate screw conveyor will feed crushed limestone into the rod mill, as needed. In the rod mill, the coal is wet milled and slurried to maximum particle size of 0.841 mm via a rotating classifier screen. Recycled process water transferred from the flush water tank is used for slurry preparation. A paddle mixer immediately downstream of the mill controls the solids content of the crushed coal slurry to approximately 60% before the slurry is transferred directly to the Oxy-combustor. Service steam from the OTSG is injected to the coal slurry at the burner to aide atomizing the slurry.

An Air Separation Unit (ASU) will produce O_2 for the Oxy-combustor. Oxygen is delivered to the Oxy-combustor at ambient temperature and 14 bar(g) at a purity of approximately 96%, with the balance being primarily argon with some nitrogen. The O_2 product stream is preheated to 104°C with attemperated reheat steam in an Oxy Preheater, prior to being mixed with recycled flue gas to produce a synthetic air stream before entering the Oxy-combustor vessel.

The coal slurry is combusted with O_2 in the Oxy-combustor vessel. The Oxy-combustor vessel is refractory lined with the burner mounted at the top and a slag tap at the bottom. Oxygen flow to the Oxy-combustor is controlled to ensure complete combustion, and a small quantity of oxygen will be present in the flue gas. Recirculated flue gas is used to moderate the combustion process. Temperatures in the Oxy-combustor vessel are sufficient to melt ash particles in the coal to form a liquid slag.

Previous FPO testing demonstrates that approximately 99% of the ash will be captured as slag. Molten slag runs down the walls of the Oxy-combustor and flows through a slag tap in the bottom of the vessel into a quenching vessel or water bath mounted beneath the Oxy-combustor. Slag solidifies when it contacts the water and is slurried within the quench vessel. The Oxy-combustor and quench vessel are elevated so that the solidified slag can flow via gravity from the bottom of the vessel into one of two slag settlers.

The slag settlers act as a pressure lock hopper, filtration, and primary dewatering for the slag. When the on-line slag settler is full, the empty off-line settler is brought online, the full settler is isolated and depressurized allowing the slag to fall from the settler into a concrete slag bunker or sump for further dewatering (by gravity). A front-end loader will be used to transfer slag to the trucks for transport to a landfill. A slag sump pump will be used to transfer any collected water back to the flush water tank for reuse within the process.

Sulfur in the coal is converted primarily to sulfur dioxide (SO_2) in the Oxy-combustor and exits in the flue gas stream. The flue gas is withdrawn from four ports on the sides of the vessel. Flue gas from the Oxy-combustor is split between two quenchers where it is mixed with a colder recycled flue gas to control the mixed temperature to approximately 777°C. Flue gas exiting the two quenchers is combined and then divided to two lines; the main flow feeds the OTSG and the flow feeds the Turbo-expander.

The Turbo-expander is similar to a turbine that would be located downstream of the combustion section on a typical combustion turbine. The Turbo-expander receives flue gas from the Oxy-combustor at approximately 500°C and a pressure of about 14 Bar(g). The hot flue gas is expanded through the turbine section, which converts the energy to mechanical work to drive a generator or in this case, a dynamometer. Use of the dynamometer, in lieu of an electrical generator, avoids the costs of the associated electrical gear needed to distribute the electrical power generated. The dynamometer will also provide operation flexibility of the FPO pilot by allowing the unit to startup, shutdown, and vary load as necessary for testing activities without disruption to the electrical grid. The dynamometer rejects the energy in the form of thermal energy (heat) to the closed cooling water system and ultimately the fin-fan cooler.

Flue gas leaving the OTSG flows to the flue gas recycle blower. Flow from the flue gas recycle blower is split into five lines. Two flue gas recycle lines are directed to the quenchers; a third line flows to the combustor burner to make the synthetic air; a fourth line flows via temperature control for mixing with the flue gas from the quenchers and fed to the Turbo-expander; and the fifth line flows to the shell side of the OTSG, which is used for shell pressurization. From the Turbo-expander, flue gas is mixed with reject gases from the ASU before the combined stream is discharged to the atmosphere via a new stack.

An air-cooled system will condense steam from the OTSG after letdown stations and return pressurized condensate to the cycle deaerator. The closed cooling water system will have a closed loop to circulate cooling water from the each of the heat exchangers to a fin-fan cooler. This loop will have a corrosion inhibitor to stabilize the water and prevent corrosion that could cause damage to the cooling system. This loop will include an expansion/head tank to accommodate thermal expansion as the system operates and will accept makeup water as needed to account for losses within the process. Makeup water required for the process will be supplied by portable ion-exchange resin vessels.

d) Project Requirements

Resource requirements for the FPO demonstration pilot, and the modifications required to the UW CEP host site, are described in the following subsections.

i) Land Requirements

The FPO project, including temporary construction, would occupy approximately 2.3 acres of land located to the west of the UW CEP. The site should be adequate to include laydown areas, construction trailers, and construction equipment. Although the majority of the land for the pilot facility is currently not developed, it has been disturbed in the past by construction and grading activities at UW, and there are areas containing underground infrastructure and piping that are to be avoided.

ii) Fuel Requirements

Coal for the 25-MWth pilot unit will also be delivered to site by truck. The process will require low-sulfur, crushed coal with “lumps” that are 30 mm to 40 mm in size (1.2” to 1.6”). The ultimate analyses for proposed coals to be used are included in Appendix B: CEP & FPO Pilot Coal Analyses. In order to avoid the cost of a coal crusher for the pilot plant, a pre-crushed PRB fuel will be utilized for the demonstration. In the event that it is not available, coal will be crushed at the Transpro-Burgner coal storage location in Laramie, Wyoming prior to being transported via truck to the site. Due to the FPO fuel requirements, in lieu of utilizing the existing CEP plant’s coal unloading facilities, a separate system dedicated to the FPO pilot will be installed. The pilot unit will be designed to operate at a design feed rate of approximately five (5) tons per hour (TPH) of PRB sub-bituminous coal when operated.

Crushed limestone may also be added to the coal in order to lower the slag melting temperature to help facilitate metal capture from the slag quenching water. Crushed limestone would be sourced from local suppliers near Laramie, Wyoming. The need for limestone addition will be based on the quality of the coal used during the demonstration. When required, limestone would be added at a rate of approximately 0.0033 tons (3 kilograms) of limestone per ton of coal fired.

Natural gas required for the FPO start-up operations to preheat the FPO and downstream equipment will be supplied to the FPO by a tie-in to UW's gas distribution grid.

iii) Water Requirements

The FPO pilot unit will recycle water to the greatest extent practical. This practice reduces the estimated total water demand for the FPO pilot plant to less than 20 gpm. The two largest water demands are condensate make-up and fuel slurry preparation. In order to meet these water demands, the FPO project will draw make-up water from the City of Laramie Utility Division via a tap in the CEP's water main. A portion of the city water will be added to the clarified water from slag dewatering, recycled slag sump runoff, and rain water runoff captured in the slag bunker and other project areas. As needed, city water will be used to make up for water lost to evaporation, moisture in the flue gas exiting the stack, and water entrained in the dewatered slag.

The majority of the city water will be demineralized in order to provide sufficient quality for condensate makeup. Demineralization for supercritical steam generation will be accomplished with portable ion-exchange resin vessels. If needed later for trimming purposes, sodium zeolite softened boiler FEED water has been noted to be available from the existing CEP facility; however, the existing volumetric capacity is unknown.

Potable water is also supplied by the UW water main tie-in at the CEP.

iv) Waste Disposal Requirements

All water collected for various project areas will be collected and reused within the processes to the greatest extent possible. The air-cooled systems should not generate a wastewater stream. Therefore, there should not be a liquid wastewater discharge from the FPO pilot facility. In the event any discharge is needed, the water will meet the discharge limits provided by the City of Laramie Industrial Wastewater Contribution Permit, included in Appendix E: CEP City of Laramie Industrial Wastewater Contribution Permit, for the discharge of industrial wastewater into the City of Laramie Wastewater Utility. Therefore, no additional wastewater treatment is required and any potential wastewater from the FPO will be discharged from the site using the existing CEP's water discharge point (city sanitary sewer). A FPO wastewater flow meter will be installed at a location upstream of tie-in point for sub-metering.

The ion-exchange resin vessels that will be utilized for the demineralized water needs for the FPO pilot will remove hardness and other dissolved solids without the need to produce a wastewater stream on site. Once the resin vessels are exhausted, a service agreement for the resin vessels will include vessel replacement and removal of exhausted resin vessels for regeneration at an off-site facility.

Dewatered slag from the Oxy-combustor is a glass-like solid waste, which is expected to pass a Toxicity Characteristic Leaching Procedure (TCLP) and paint-filter test, making it suitable for disposal in a non-hazardous solid waste landfill. The dewatered slag will be loaded into trucks using a front-end loader for transport to a landfill for disposal.

v) Power Requirements

An estimate of the FPO unit's power consumption is included in Appendix F: FPO Pilot Auxiliary Power Load List. The electrical system is connected to the UW's 13.8 kV electrical power supply from the existing CEP site electrical transformer area.

vi) Labor Requirements

The FPO pilot is expected to require six full-time employees, four two-person crews to cover three 8-hour shifts and a backup crew, and two part-time employees. The labor required for FPO operation will be shared with CEP Operations personnel as indicated in Table 42.

Table 42. Labor Requirements

Position	Full Time/ Part Time	No.	Remarks
Pilot Plant Project Manager (PM)	Full Time	1	Provided by UW
Data Analysis Support Engineer	Full Time	1	UW Post-Graduate Researcher
Design Test Engineer	Full Time	1	Local Hire
Administrator	Full Time	1	Local Hire
Operations Manager (OM)	Full Time	1	CEP OM to split time 50%
Maintenance Specialist	Full Time	1	Local Hire
Control Room Operator (CRO)	Shift Work	4	CEP CRO to split time 50% each shift
Infield Operator (IO)	Shift Work	4	CEP IO to split time 50% each shift
EHS Support	Part Time	1	Local Contractor
Analyst/Chemist	Part Time	1	Local Contractor

2) Assessment of Alternatives

This section describes the alternatives to the proposed action including (1) a no-action alternative, (2) alternative sites considered, and (3) alternative process/design configurations. Note that as the FPO process is an ITEA patented technology, no other FPO processes exist and, therefore, no other alternative technologies were considered.

a) No-Action Alternative

In this scenario, the proposed FPO technology demonstration would not be granted financial assistance from the DOE and would result in failure to demonstrate the viability of the project through the achievement of TRL-7 and, therefore, the FPO technology would not be scaled up for commercial demonstration, TRL-8. This no-action alternative would also result in a significant loss of investment.

b) Alternative Sites

A summary of the site selection for the FPO demonstration is included in Appendix G: Excerpts from DE-FE0027771 Site Selection Report. As described in Appendix G, several locations were considered to be feasible for the FPO demonstration. The University of Wyoming site was selected as it was considered to have good available infrastructure and the highest opportunity for cost sharing in the event the project proceeds to Phase III.

c) Alternative Process/Design Configurations

Several alternative process and design configurations were considered over the development of this project. The following lists the major alternative configurations and the reasoning why they were not considered appropriate or were not selected:

- <u>50-MWth Pilot Unit</u>: A larger scale, 50-MWth FPO pilot unit was initially considered to further enhance the scale up abilities of the pilot demonstration. However, after it was found to be cost prohibitive, the smaller 25-MWth pilot unit was selected to reduce project costs.

- Flue Gas Desulfurization (FGD): Initially, several coals were considered as part of the demonstration pilot, including low sulfur PRB, mid-sulfur bituminous (Twenty Mile Coal) and a higher sulfur lignite. A wet, pressurized FGD process, consisting of a crushed limestone reagent preparation system, an alkali scrubbing tower, a direct contact cooler/demister tower, and a wet FGD solids dewatering system was included as part of the demonstration to allow for fuel flexibility. However, after reducing the pilot unit scale to 25-MWth, it was found that the proposed project cost would still exceed the allotted budget, with the FGD process being one of the largest capital and operating cost items. Therefore, the FGD process was removed from the scope and it was determined that the fuel would be limited to low sulfur PRB to mitigate SO_2 emissions from the pilot unit.
- Propane Startup Fuel: Propane would be used during startup for heating up the Oxy-combustor/OTSG and then continuously heating the slag tap heater, in the event the natural gas available at the CEP site did not meet the pressure requirements during startup. Later, it was determined that a tie-in location on the CEP natural gas supply line, at a location upstream of the existing units, would supply higher pressure conditions needed for startup. Therefore, it was determined that the longer pipe routing and use of natural gas would be more economical than the use of propane tanks, pumps, vaporizers, and associated electrical loads. Additionally, the

existing CEP plant is already familiar with operation and maintenance of natural gas systems/equipment.

- Wet Cooling: A forced draft cooling tower consisting of three (3) cells, each with its own water pump, was previously considered for the supply of cooling water for the various FPO process needs. However, it was determined that an air-cooled condenser system would be used instead in order to reduce the system complexity and eliminate cooling tower makeup, blowdown disposal, and chemical treatment needs. Overall, the use of an air-cooled system will provide significant water savings for the site. In addition, an air-cooled system eliminates the amount of water that would be lost due to evaporation and drift, which can create a large plume throughout the year and sometimes can cause icing concerns (depending on ambient conditions).
- Steam Turbine: The steam turbine was eliminated as a means to reduce project cost and keeping with the key goals of the pilot project (prove scaling ability of the Oxy-combustor and OTSG technology). Instead of a steam turbine, a series of letdown stations are used to reduce the steam temperature and pressure accordingly to maintain OTSG operation without the steam turbine.

IV. EXISTING ENVIRONMENT

This section discusses the existing environment at the proposed site of the FPO pilot plant and the general project area, including a 0.5-mile buffer around the project site.

1) *Land Use*

The site proposed for the FPO plant is an approximately 7-acre site owned by UW, which is adjacent to the existing CEP. Land at the proposed site is currently used for snow storage and storm water. The site contains a storm water pond, which will remain after the construction of the FPO plant. The site is a grassy area, with decorative trees for landscaping.

With the exception of the CEP, land use in the vicinity around the site is largely residential, including housing for university students. The Green Hill Cemetery lies approximately 200 feet to the south of the site. The nearest park is located approximately 0.7 miles away. Utilities beneath the north and west sides of the CEP include low voltage power (480 V), a natural gas line, a water well, and irrigation lines, see Appendix H: CEP Site Utility General Arrangement for more details. The site is bordered by E Harney Street to the north, the access drive to the CEP to the east, E Gibbon Street to the south, and N 15th Street to the west.

2) *Atmospheric Conditions/ Air Quality*

The proposed site is located in the City of Laramie, Wyoming. The nearest air quality monitor is the Cheyenne NCore monitor located in the City of Cheyenne Community Park, part of the Environmental Protection Agency's (EPA) NCore Network of monitors. The nearest National Oceanic and Atmospheric Administration (NOAA) Weather Station is the Laramie Regional Airport (KLAR) station. Laramie is in American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Climate Zone 6B. The following sections describe the local climate and air quality for the City of Laramie.

a) *Local Climate*

Most of Wyoming, including Laramie, is in Climate Zone 6B, which is characterized by generally cold and dry conditions. Based on data from the KLAR station, the annual average temperature is 41.0°F, with an average minimum of 27.5°F, and an average maximum of 54.5°F for the years 1981 through 2010. Maximum precipitation occurs in spring and early summer, and is generally greater over mountain ranges and higher elevations. The elevation at the site is approximately 7,220 feet above mean sea level. Precipitation totals approximately 11 inches annually (1981-2010); however, 2018 was drier than normal with precipitation totals close to 7 inches for the year. Table 43 shows the most recent temperature and precipitation data for Laramie, Wyoming.

Wind roses for the period 2006-2015 show that the average wind direction for October through April is generally WSW. Average wind direction May through September is generally SSE.

Figure 19 shows the annual wind rose for Laramie, Wyoming.

Table 43. Climate Data for Laramie, Wyoming[1]

Month	Average Temperature (°F)		1981-2010 Normal Temperature (°F)		Precipitation Totals (in)	1981-2010 Normal Precipitation Totals (in)
	Maximum	Minimum	Maximum	Minimum		
February 2019	35.2	13.0	35.2	11.9	0.06	0.34
January 2019	33.5	8.4	33.3	10.1	0.13	0.27
December 2018	32.5	8.7	32.2	10.0	0.09	0.32
November 2018	38.1	16.0	41.3	17.4	0.33	0.54
October 2018	53.5	27.0	55.7	28.0	0.61	0.80
September 2018	76.4	39.2	68.6	37.9	0.07	1.11
August 2018	80.0	45.8	77.9	46.7	0.72	1.23
July 2018	83.3	48.2	80.1	48.0	0.89	1.43

Month	Average Temperature (°F)		1981-2010 Normal Temperature (°F)		Precipitation Totals (in)	1981-2010 Normal Precipitation Totals (in)
	Maximum	Minimum	Maximum	Minimum		
June 2018	79.2	43.1	72.5	41.9	1.12	1.54
May 2018	66.5	35.8	61.5	33.7	1.66	1.69
April 2018	54.8	24.3	51.1	24.6	0.30	1.07
March 2018	45.4	17.9	43.0	18.7	0.91	0.58

[1] Data from the Laramie Regional Airport (KLAR) Weather Station.

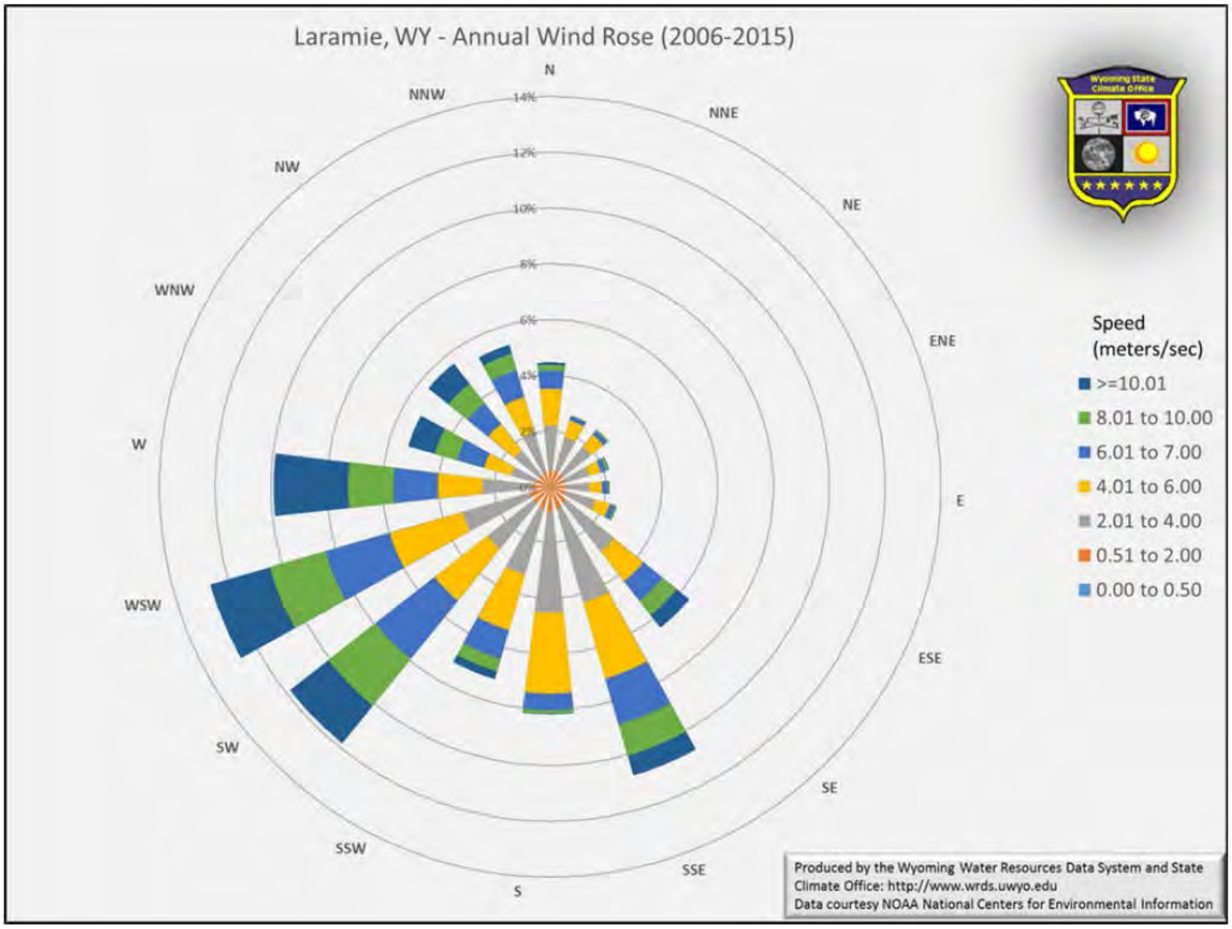


Figure 19. Annual Wind Rose for Laramie, Wyoming

b) Existing Air Quality

Based on the Annual Data Summary for the Cheyenne NCore monitor for 2017, there have been no exceedances of the National Ambient Air Quality Standards (NAAQS) or Wyoming Ambient Air Quality Standards (WAAQS). Table 44 presents air quality data for the air quality monitor nearest to the proposed site.

Overall air quality for the area has not changed considerably compared to 2011 when the monitor was first installed. The UW CEP also reports emissions of PM, PM_{10}, $PM_{2.5}$, CO, NO_X, SO_2, and VOC annually to the Wyoming DEQ, and may also affect the ambient air quality in the vicinity of the proposed site.

Table 44. Annual Ambient Air Quality Data

NAAQS/WAAQS	Standard	Cheyenne NCore Monitor 2017 [1]	Cheyenne NCore Monitor 2011
8-hr Ozone [2]	0.070 ppm (70 ppb)	4th Highest Daily Max: 65 ppb	4th Highest Daily Max: 67 ppb
1-hr NO_2 [3]	100 ppb	2nd Highest Daily Max: 40.6 ppb	2nd Highest Daily Max: 38.9 ppb
Annual NO_2	53 ppb	Arithmetic Mean: 4 ppb	Arithmetic Mean: 3.6 ppb
8-hr CO [4]	9 ppm	2nd Highest Daily Max: 0.408 ppm	2nd Highest Daily Max: 0.2 ppm
1-hr CO [4]	35 ppm	2nd Highest Daily Max: 0.734 ppm	2nd Highest Daily Max: 0.358 ppm
1-hr SO_2 [5]	75 ppb	2nd Highest Daily Max: 7.3 ppb	2nd Highest Daily Max: 8.9 ppb
3-hr SO_2 [6]	0.5 ppm (540 ppb)	2nd Highest Daily Max: 3.5 ppb	2nd Highest Daily Max: 4.4 ppb
Annual $PM_{2.5}$	12.0 $\mu g/m^3$	Arithmetic Mean: 3.4 $\mu g/m^3$	Arithmetic Mean: 4.8 ppb
24-hr $PM_{2.5}$ [7]	35 $\mu g/m^3$	2^{nd} Highest Max: 34.3 $\mu g/m^3$	2nd Highest Max: 32.1 $\mu g/m^3$
Annual PM_{10} [6]	50 $\mu g/m^3$	Arithmetic Mean: 2 $\mu g/m^3$	--
24-hr PM_{10} [8]	150 $\mu g/m^3$	2^{nd} Highest Max: 57 $\mu g/m^3$	--

[1] 2018 data not available until May 1, 2019.
[2] To attain the ozone standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations must not exceed the standard.
[3] To attain the NO_2 standard, the 3-year average of the 98th percentile value must not exceed the standard.
[4] The CO standard is not to be exceeded more than once per year.
[5] To attain the 1-hour SO_2 standard, the 3-year average of the 99th percentile value must not exceed the standard.
[6] Wyoming Ambient Air Quality Standards (WAAQS).
[7] To attain the $PM_{2.5}$ standard, the 3-year average of the weighted annual mean must not exceed the annual standard, and the 3-year average of the 98th percentile 24-hour average must not exceed the 24-hour standard.
[8] To attain the PM_{10} standard, the average cannot exceed the standard more than once per year on average over 3 years.

3) *HYDROLOGIC CONDITIONS/ WATER QUALITY*

The proposed site lies within the Woodhouse Reservoir-Laramie River Watershed (HUC12- 101800100603), which drains to the Soap Holes-Laramie River Watershed (HUC12- 101800100605). Both of these watersheds are part of the larger Spring Creek-Laramie River Watershed (HUC10- 1018001006). The following sections describe the surface water and ground water resources in the vicinity of the proposed site.

a) Surface Water Quality

There are no surface water features on or within 0.5 miles of the site, with the exception of the storm water pond on the west side of the proposed site. The nearest waterbodies are Spring Creek, approximately one (1) mile to the south, an unnamed stream approximately one (1) mile to the east, and a pond approximately 0.5 miles to the west. According to the National Wetlands Inventory (NWI), there are no mapped wetlands for the proposed site, see Appendix I: National Wetlands Inventory Map for more details. No floodplains, floodways or floodway fringes were mapped for the proposed site. The Flood Insurance Rate Map (FIRM) of Laramie, Wyoming is provided in Appendix J: Flood Insurance Rate Map. Since there are no waterbodies or wetlands on the proposed site, there are no unique aquatic habitats or recreational areas.

b) Ground Water Quality

According to the geotechnical investigation that was done for the adjacent CEP, there is groundwater below the CEP site. Free water was encountered below the CEP site at a depth of approximately 36 feet below the existing ground surface, see Appendix K: 1979 CEP Geotechnical Report. Assuming groundwater resources for the proposed FPO site are similar to the adjacent CEP site, ground water would be expected below the site;

however, at this time there is no data available for aquifers or ground water below the proposed FPO site. If needed, this data can be acquired at a later phase of the project.

Public water supplies include water from the City of Laramie Utility Division, which will be the source of water for the FPO pilot plant. Based on information from the host site, there should be adequate water from the city, and there are no known constraints on water availability, see Appendix L: DE-FE0027771 Detailed Site Assessment Questions, UW CEP Responses. Test data for the City of Laramie water supply is available for various water quality parameters, and is provided in Appendix M: City of Laramie Water Analysis.

According to information from the host site, the sanitary sewer operated by the City of Laramie Utility Division is available for wastewater disposal from the site. The existing storm water pond and the Harney Street storm sewer are available for storm water discharges from the site.

4) Geologic/ Soil Conditions

According to the geotechnical investigation that was completed for the adjacent CEP, subsoil conditions at the CEP site varied from loose to dense. The first foot of soil consisted of loose silty sand topsoil. At a depth of up to 21 feet, soil consisted of loose to very dense silty sand dispersed with gravel and cobble. Bedrock was also encountered for multiple borings at various depths. More details and figures are available from the boring logs in the CEP geotechnical report; see Appendix K: 1979 CEP Geotechnical Report. Soil conditions are expected to be similar at the proposed FPO site.

The U.S. Department of Agriculture (USDA) web-based soil survey was reviewed to identify soil resources for the proposed FPO site. A copy of the soil map is included in Appendix N: USDA Albany County Area, Wyoming Soil Report for FPO Pilot Site. Two (2) soil types were identified for the proposed site: Alogia-Urban land complex and Wycolo-Alcova complex. Alogia-Urban land complex is characterized by a profile including loam and clay loam. Wycolo-Alcova complex is characterized by a profile including fine sandy loam, sandy clay loam, loam, clay loam, and bedrock. Neither soil types are considered to be prime farmland. More detailed site-specific information on soil characteristics is not available at this time, and can be acquired at a later phase of the project.

5) Vegetation and Wildlife Resources

A list of threatened and endangered species that may occur in the proposed project area has been received from the U.S. Fish and Wildlife Service (USFWS) via an online request through the Information for Planning and Conservation (iPaC) project planning tool. According to the iPaC report, there are several federally listed threatened and endangered species that have historical ranges within the project area, which are summarized in Table 45. According to the iPaC report, no designated critical habitat for any federally threatened or endangered species occurs within the project area, see Appendix O: USFWS Wyoming Ecological Services Field Office List of Threatened and Endangered Species.

State rare, threatened, and endangered species data was obtained from the Wyoming Natural Diversity Database (WYNDD). WYNDD maintains a database of species of concern, including rare, endemic, disjunt, threatened, or biologically sensitive species.

Unlike the iPaC report, the WYNDD is not site-specific and includes information statewide. Animal species of concern are included in Appendix P: UW Wyoming Natural Diversity Database Animal Species of Concern, and plant species of concern are included in Appendix Q: UW Wyoming Natural Diversity Database Plant Species of Concern. Note that the species of concern list has no status under state legislation while federally listed species are protected by the Endangered Species Act.

Table 45. Federally Listed Threatened and Endangered Species in the Project Area

Species Type	Common Name	Scientific Name	Federal Status
Mammal	Preble's Meadow Jumping Mouse	*Zapus hudsonius preblei*	Threatened
Bird	Least Tern	*Sterna antillarum*	Endangered
Bird	Piping Plover	*Charadrius melodus*	Threatened
Bird	Whooping Crane	*Grus americana*	Endangered
Amphibians	Wyoming Toad	*Bufo hemiophrys baxteri*	Endangered
Fishes	Pallid Sturgeon	*Scaphirhynchus albus*	Endangered
Plants	Western Prairie Fringed Orchid	*Platanthera praeclara*	Threatened

Preferred habitat for the Preble's Meadow jumping mouse includes well-developed plains riparian vegetation with nearby grasslands and a water source. Habitat areas for the Least Tern include sea beaches, bays, large rivers, and salt flats. Piping plovers use wide, flat, and open sandy beaches and nest in small creeks or wetlands. Preferred habitat for whooping cranes includes grassy wetlands, shallow river flats, and coastal marshes and estuaries. Habitat for the Wyoming toad includes floodplains, ponds, and small lakes. The Pallid sturgeon is historically known in the Missouri and Mississippi River drainages, and prefers the bottom of large, silty rivers. The Western prairie fringed orchid occurs in tallgrass prairies and meadows, but have also been known to occur in old fields and roadside ditches.

Although a site-specific Rare, Threatened and Endangered Species assessment has not been conducted for the proposed site, it is unlikely that the site would be considered suitable habitat for these threatened and endangered species. Wyoming is not a coastal state and there are no waterbodies, wetlands, or floodplains at the proposed site. Therefore, there are no known sensitive habitat areas located at the FPO site. There is also a lack of vegetation at the site that would be characteristic of a prairie or meadow, as the site is predominately grass with decorative trees.

6) SOCIOECONOMIC CONDITIONS

Census data has been received from the U.S. Census Bureau via an online request through the U.S. Census Bureau QuickFacts tool. The QuickFacts report may be found in Appendix R: U.S. Census Bureau Albany County, WY QuickFacts. According to the QuickFacts report, the population of Albany County, Wyoming, where the proposed FPO site is located, has a population of 38,332 as of July 1, 2017. Over 96% of the population has graduated high school and 49.8% has attained a bachelor's degree or higher. The percentage of the population participating in the civilian labor force is 68.7%. The largest sector of the local economy is retail sales, with $480 million in 2012 revenue, followed by 2012 healthcare and social assistance receipts/revenue, $178 million. The median household income (in 2017 dollars) is $45,816, and the percentage of people living in poverty is 19.5%.

7) Cultural Resources

According to the National Park Service National Historic Landmarks Program, there are no National Historic Landmarks within 0.5 miles of the proposed site. There are 27 National Historic Landmarks in the State of Wyoming, but only one in Albany County, the Ames Monument. The Ames Monument is located more than 15 miles away from the proposed FPO site.

There are 41 properties and districts listed on the National Register of Historic Places (NRHP) in Albany County. The nearest NRHP property listed is the Cooper Mansion, located approximately 0.5 miles from the proposed site. The William Goodale House, Old Main, and the University Neighborhood Historic District are also located approximately 0.6 miles from the proposed FPO site.

There is a cemetery located within 0.5 miles of the proposed site. The Green Hill Cemetery lies approximately 200 feet to the south of the site. At this time, there is no information available on archaeological resources that may be present at the proposed site. If needed, this data can be acquired at a later phase of the project through a site-specific study.

8) Visual Resources

There are no known scenic vistas, wild and scenic rivers, or wildlife areas near the proposed FPO site. The proposed site and surrounding area are part of the University of Wyoming campus, which has landscaping and buildings that were designed with aesthetics in mind.

9) *Health and Safety Factors*

The proposed site is currently not developed; therefore, current emissions, effluents, and noise near the proposed site are largely from the adjacent CEP. The CEP is currently permitted to emit criteria pollutants, hazardous air pollutants, and greenhouse gas emissions as allowed under their current Title V permit, see Appendix R: U.S. Census Bureau Albany County, WY QuickFacts. The CEP is also authorized to discharge industrial wastewater into the City of Laramie Wastewater Utility, as allowed under their Industrial Wastewater Contribution Permit, see Appendix E: CEP City of Laramie Industrial Wastewater Contribution Permit. Ash from the CEP site is collected by a collection service and is disposed of off-site, See Appendix U: CEP Landfill Disposal Agreement.

The CEP plant also utilizes various chemicals for boiler treatment. Safety data sheets are available in Appendix T: CEP Plant Safety Data Sheets. Noise data for the CEP is not available at this time, but would be expected to meet the City of Laramie Local Ordinance for residential noise, permissible level of level 55 db(A) 7:00 a.m. to 7:00 p.m., and 50 db(A) 7:00 p.m. to 7:00 a.m.

V. Environmental Impacts of the Proposed Project

This section discusses the anticipated environmental impacts of the FPO project on the general project area, including a 0.5-mile buffer around the project site.

1) *Land Use*

Of the 7-acre parcel, the FPO equipment and buildings are expected to occupy approximately 2.3 acres of land to the west of the CEP. During construction, a portion of this area will be graded for building and equipment foundation installation and parking for plant employees. The total area affected by the project is 4.3 acres and includes the laydown areas, trailers, and equipment used during construction.

Waste disposal is not expected to be an issue at the site. Liquid wastewater discharge is not anticipated from the FPO pilot plant. The FPO plant will utilize air-cooled systems; therefore, no cooling or effluent ponds are planned for the site. During construction, portable toilets will be employed; therefore, no sewer connections will be required. Solid waste will be collected by a collection service and disposed off-site.

2) ATMOSPHERIC CONDITIONS/ AIR QUALITY

The FPO pilot plant is expected to contribute to minor increases in air emissions to the surrounding area. Estimated emissions from the FPO pilot plant are provided in Table 46. This FPO pilot plant is expected to be permitted as a synthetic minor source under Title V of the Clean Air Act, as emissions are expected to be below major source thresholds. Estimated emissions for the FPO pilot plant are based on calculated operating conditions provided by SwRI, with input from ITEA's other pilot FPO demonstrations.

Atmospheric dispersion modeling has not yet been conducted for the project, so it is not yet known how emissions from the plant will contribute to air quality in the area, and attainment of the NAAQS. However, at this stage of the project in order to be conservative, the FPO pilot unit stack is assumed to be designed to meet the U.S. 40 CFR, part 51.100 (ii) good engineering practice (GEP) stack height, which ensures that the emissions from a stack do not result in excessive concentrations of any air pollutant as a result of atmospheric downwash, wakes, or eddy effects created by the source itself, nearby structures or nearby terrain features. Atmospheric dispersion modeling is expected to be completed at a later phase of the project, in which an economic stack height may be determined.

After the required commissioning phases, the minimum goal for the FPO pilot demonstration testing is estimated to be 3,000 to 5,000 hours, which will likely occur over a period of 25 months, which includes steady-state and flexible testing along with performance and endurance testing. However, due to staffing limitations, the testing of the unit will only be completed during the normal business days, unless specifically planned in advance.

Table 46. FPO Pilot Plant Emissions

Pollutant	Estimated FPO Emissions (lb/hr) [1]	Estimated Annual FPO Emissions (tons/year)[2]
PM	0.0023	0.003
SO_2	43.7	55
NO_X	2.5	3.1
CO	1.07	1.34
GHGs (CO_2e)	18,541	23,176

[1]The preliminary estimated FPO emissions are based on the low-sulfur, FPO pilot coal included in Appendix B: CEP & FPO Pilot Coal Analyses.
[2]Due to the unknown manner in which the unit is expected to operate over the approximate 2-year test period, estimated annual emissions are based on hourly emission rate × 5,000 hours of pilot operation total ÷ 2 years ÷ 2,000 lbs/ton.

Add-on control technology is not expected for the FPO pilot plant. Based on testing by ITEA, FPO results show that 99% of ash is captured in the slag, resulting in minimal particulate emissions. Hg is removed through the slag system, and based on ITEA testing, no Hg was found in gas emissions. SO_2 emissions will be minimized by using low sulfur, PRB fuel.

Impacts to air quality, during the construction phase of the project, will be temporary in nature and include VOC emissions due to solvents and/or paints, emissions from vehicle exhaust and construction equipment, and fugitive dust during transportation and excavation. During construction, the general work contractor (GWC) will employ the appropriate best management practices (BMPs) to control fugitive dust emissions from the various construction traffic and activities.

Fugitive dust during operation is expected to be controlled with dust suppression methods similar to what is currently used at the CEP. Fugitive dust from the coal handling equipment will be mitigated through the use of water sprays, and fugitive emissions are not anticipated during the slag truck loading.

3) HYDROLOGIC CONDITIONS/ WATER QUALITY

The FPO pilot unit will recycle water to the greatest extent practical. Liquid wastewater discharge is not anticipated from the FPO pilot plant, as the FPO will utilize air-cooled systems. Coal unloading is anticipated to occur directly adjacent to the FPO pilot unit and will be transferred directly into a FPO coal feed silo; therefore, no coal storage piles are expected to be needed on the FPO site. Also, no wastewater discharges or storage pile runoff is expected from the proposed project that could impact surface water or ground water quality.

During construction, the GWC will employ the appropriate BMPs to control storm water runoff. With proper BMPs in place, no discharges to downstream surface waters are anticipated. During operation, non-contact storm water runoff will be directed towards the Harney Street West Storm Sewers and collected in the 15th Street and Harney Street South Detention Pond.

4) *GEOLOGIC/ SOIL CONDITIONS*

Assuming that the soil conditions for the FPO site are similar to CEP site, there should be no subsidence or erosion. Erosion will be prevented during construction using appropriate BMPs, and construction activities will avoid existing irrigation and wells on site. There are no streams, floodplains, or wetlands at the proposed site; therefore, no stream diversion, floodplain intrusion, or wetland intrusion is anticipated.

5) *VEGETATION AND WILDLIFE RESOURCES*

As discussed in the previous section, the proposed site is characterized by grass and decorative trees is located in a residential area, and therefore lacks the vegetation and water sources needed to support local flora and fauna. It is unlikely that the site would be considered suitable habitat for threatened and endangered species, therefore, the construction and operation of the FPO plant is unlikely to affect listed species. Further, there are no known sensitive habitat areas located at the FPO site.

According to the iPaC Report received from USFWS, no designated critical habitat for any federally threatened or endangered species occurs within the project area, and USFWS does not anticipate project-related adverse impacts to listed or proposed threatened or endangered plant or animal species.

6) *SOCIOECONOMIC CONDITIONS*

The capital expenditure for the proposed project would have a positive influence on local employees, contractors, and vendors. Up to 10 additional jobs, including 5 local hires and contractors, will be required to operate the FPO after construction. Jobs that are not filled by local hires and contractors will be filled by the UW Human Resources Department or CEP employees. Due to the size of the project, no employees are expected to relocate to the City of Laramie to support the project. In addition to operation of the plant, a construction crew will be hired to complete the construction phase of the project.

7) Cultural Resources

There are four NRHP properties and a cemetery located within the vicinity of the FPO site. These areas are expected to be avoided during construction, and no impacts are expected. In addition, the operation of the FPO pilot plant is not expected to impact these properties.

At this time, there is no information available on archaeological resources that may be present at the proposed site. A cultural resource survey will be conducted at the site of the proposed FPO plant in accordance with Section 106 of the National Historic Preservation Act (NHPA). Archeological or historical resources are not expected to be impacted by the project. If any archaeological material is encountered during construction, work will cease until a field evaluation has been conducted.

8) Visual Resources

The design of the plant will be required to meet the 2017 UW Design Guidelines, which will be approved by an internal UW design review committee to ensure new building designs follow the recommendations of the UW's Long Range Development Plan (LRDP). It is anticipated that the project architecture will employ the same aesthetics as other nearby UW buildings and the existing CEP plant to reduce the visual impacts of the structures.

9) *Health and Safety Factors*

The FPO facility will share operations personnel with the existing CEP facility. These operators will be trained in the safe operation and emergency procedures for the pilot FPO equipment. Occupational hazards are expected to be similar to the CEP, and the FPO will employ similar environmental health and safety procedures as the existing CEP facility. Inventories of hazardous chemicals will be minimized, and the plant will be designed to meet the local noise ordinance for the residential areas.

10) *Solid and Hazardous Wastes*

Dewatered slag from the Oxy-combustor is a glass-like solid waste, which should pass a Toxicity Characteristic Leaching Procedure (TCLP) and paint-filter test, making it suitable for disposal in a non-hazardous landfill. The dewatered slag will be loaded into trucks using a front-end loader for transport to a land farm facility owned by TDS Collection Services Inc. near Torrington, Wyoming for disposal. TDS confirmed that their facility has enough capacity for the disposal of the FPO slag. Upon confirmation from the Wyoming Department of Environmental Quality (DEQ) that the slag material is non-hazardous, the existing UW CEP’s Service Agreement (see Appendix U: CEP Landfill Disposal Agreement) for the other CEP’s coal combustion residues (ash and clinkers) would be amended to include the FPO slag material. The transfer and disposal of the FPO slag will be handled in accordance with the applicable state and federal regulations.

Any other miscellaneous spent catalysts or absorbents that cannot be reclaimed will be treated as hazardous wastes and disposed of accordingly.

11) *IMPACTS ON REGIONAL OR LOCAL PLANS*

The majority of the potential impacts to the local region resulting from the installation, operation, and testing of the FPO pilot can be categorized as insignificant and/or positive. The FPO project will bring a significant amount of capital to the county for construction and new jobs that will be created for administration and operation of the pilot unit. The FPO pilot plant will not take up significant land; will recycle water to the greatest extent practical; and no wastewater discharges are expected that could impact surface or ground water quality. The FPO pilot plant will result in some increase to air emissions, and an increase in waste to an off-site location in Wyoming, but these impacts are expected to be minimal considering the size of the project.

Power, water, and natural gas for the FPO site will be supplied from UW's utility distribution system. If required, additional power can be provided from existing CEP standby generators or be imported from the local power utility, Rocky Mountain Power, at a local substation. There should be adequate natural gas, electricity, sanitary and storm sewer capacity for this project with minimal modification. Therefore, the project is not expected to impact the availability of resources to the local region.

VI. POTENTIAL LIABILITY TO DOE OF EXISTING CONDITIONS

As described in *Section a) Site Location*. FPO pilot project will occupy approximately 2.3 acres of land located adjacent west of the UW CEP. The CEP is the UW's main energy plant, and consists of four coal, oil, or gas-fired boilers that supply steam, chilled water and compressed air for heating and cooling the UW campus buildings. The location of the pilot project is shown in Figure 18.

The proposed project site is largely undeveloped land owned by UW. Information provided by UW indicates that underground infrastructure, including a natural gas line, a water well, and irrigation lines, are located beneath the north and west sides of the adjacent CEP. Storm water and sanitary conveyance, is located along the northern and southern boundaries of the site, and a storm water detention pond occupies the western portion of the property. Harney Street parallels the northern boundary of the project, and additional undeveloped land owned by UW is located north of the site. Additional campus buildings are located adjacent south of the project site, and the City of Laramie Green Hill Cemetery is located approximately 200 feet south of the project site. The nearest residential development is located approximately 700 feet west of the project site.

Based on a limited review of available historical aerial photographs, dating back to 1994, it does not appear that the proposed project location has previously been developed. Aerial photography does not suggest prior use of the property for industrial/commercial activities, solid waste disposal, or material storage.

Although the risk of potential environmental liabilities associated with existing conditions at the project site appear to be minimal, UW has not completed similar construction activities in the recent past that would trigger NEPA review, and has not carried out a NEPA study of the subject property for a similar DOE project. Furthermore, S&L is not aware of, and has not reviewed, any prior Phase I Environmental Site Assessments (ESAs) of the subject property conducted in conformance with ASTM Practice E1527-13-Standard Practice for Environmental Site Assessments. The objective of a Phase I ESA is to identify Recognized Environmental Conditions (RECs) in connection with the subject property, defined in the standard as “the presence or likely presence of any hazardous substances or petroleum products in, on, or at a property: (1) due to any release to the environment; (2) under conditions indicative of a release to the environment; or (3) under conditions that pose a material threat of a future release to the environment.” A Phase I ESA, prepared in conformance with the ASTM standard, is generally required to qualify for the innocent landowner, contiguous property owner, or bona fide prospective purchaser limitations on Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) liability as part of an “all appropriate inquires” assessment as defined in 42 U.S.C. §1601(35)(B).

VII. Regulatory Compliance

This section identifies federal, state, and local environmental regulations with which the FPO pilot plant project must comply. This section also addresses required permits and modifications to existing permits.

1) Resource Conservation and Recovery Act (RCRA)

The Resource Conservation and Recovery Act (RCRA) of 1976 allows the EPA to regulate hazardous waste including the generation, transportation, treatment, storage, and disposal of hazardous waste. Under the regulation, there are three separate programs: (1) the solid waste program under RCRA Subtitle D, (2) the hazardous waste program under RCRA Subtitle C, and (3) the underground storage tank program under RCRA Subtitle I.

Dewatered slag from the Oxy-combustor is expected to pass a Toxicity Characteristic Leaching Procedure (TCLP) and paint-filter test, making it suitable for disposal in a non-hazardous landfill. The dewatered slag will be loaded into trucks using a front-end loader for transport to a land farm facility for disposal. This slag is a coal combustion residual, which must be disposed of in a landfill that meets the requirements of subtitle D of the RCRA. The slag will be contained in an impermeable concrete bunker with provisions to control rainfall contacting the slag.

2) COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund, provides federal funding to clean up uncontrolled or abandoned hazardous waste sites, or other releases of pollutants and contaminants. This regulation gives EPA the power to identify responsible parties and engage them for cleanup assistance.

Based on a search of the National Priorities List (NPL) for Superfund sites, the proposed FPO site is not on the NPL list; therefore, CERCLA does not apply to the FPO site.

3) TOXIC SUBSTANCE CONTROL ACT

The Toxic Substances Control Act of 1976 provides EPA with authority to require reporting, recordkeeping and testing requirements, and restrictions relating to chemical substances and/or mixtures. These chemicals include, but are not limited to asbestos, formaldehyde, lead, mercury, polychlorinated biphenyls (PCBs), per- and polyfluoroalkyl substances (PFAS), and spray polyurethane foam (SPF) insulation.

The FPO plant will not import, export or manufacture any of the chemicals governed by the Toxic Substances Control Act; therefore, the act does not apply to the FPO plant.

4) CLEAN AIR ACT

a) *New Source Review (for Pilot Plant)*

New Source Review is required for new or modified sources that may cause emissions of air pollutants or increase emissions of air pollutant from existing sources. In accordance with Wyoming Air Quality Standards and Regulations (WAQSR) Chapter 6, Section 2(a)(i): “Any person who plans to construct any new facility or source, modify any existing facility or source, or to engage in the use of which may cause the issuance of or an increase in the issuance of air contaminants into the air of this state shall obtain a construction permit from the State of Wyoming, Department of Environmental Quality before any actual work is begun on the facility.”

Sources located in an area meeting the NAAQS are subject to the Prevention of Significant Deterioration (PSD) regulations in WAQSR Chapter 6, Section 4, while sources located in areas that do not meet the NAAQS are subject to the non-attainment area regulations in WAQSR Chapter 8. Projects subject to the NSR program must receive a permit from the Wyoming Department of Environmental Quality (WDEQ) prior to commencement of construction activities.

The FPO plant is located in Albany County, Wyoming. Albany County is currently designated as “unclassifiable/attainment” for all NAAQS; therefore, the plant is subject to the PSD regulations. It is anticipated that the project will apply for a permit from the WDEQ and will comply with PSD regulations by meeting the emission limitations and requirements set forth in the permit.

b) Title V Permit Program (for Pilot Plant)

Title V of the Clean Air Act Amendments of 1990, and the implementing regulations in 40 CFR, Part 70, required Wyoming to establish an Operating Permit Program. This program is codified in Chapter 6, Section 3 of the Wyoming Air Quality Standards and Regulations (WAQSR).

Any major source, which has actual or potential emissions at or above the major source thresholds, is subject to the requirements of the Operating Permit Program. In areas designated as attainment with the NAAQS, the major source threshold is 100 tons per year for criteria pollutants, 25 tons per year for combined HAPs, and 10 tons per year for a single HAP.

The FPO pilot plant is expected to be permitted as a synthetic minor source and could potentially receive an Operating Permit waiver because actual emissions will be below major source thresholds. Although the unit has the potential to operate more, the pilot demonstration testing is expected to be limited to 3,000 to 5,000 hours over a period of 25 months, and the FPO pilot unit will be designed to target emission levels to 80% of the major source thresholds.

The adjacent CEP is considered a major source, subject to the Operating Permit Program. Due to the contiguous location of the FPO pilot plant, the FPO pilot unit will likely be rolled into UW CEP's Title V permit, which will require a permit modification to CEP's current Title V permit.

c) Air Permit Modifications (for Standby Generators)

CEP has a pair of two 1,250 kW standby generators. Currently, the standby generation plan is to only operate one 1,250 kW generator with a second 1,250 unit installed as a standby in case the first does not start. They both are capable of running at the same time, but the air quality permit for those does not currently permit this mode of operation.

The UW CEP's peak load could be as high as 1.5 MW, but typically is less than 1 MW. Some outage startup procedures could be changed to limit the peak load during an outage to no more than 1 MW. The FPO plant will require more standby power than the 250 kW margin on a single standby generator; therefore, the CEP air permit will require modification if the FPO uses the existing standby generators for emergency power.

5) CLEAN WATER ACT

The National Pollutant Discharge Elimination System is a permit program that addresses water pollution from point sources to waters of the U.S. Liquid wastewater discharge is not anticipated from the FPO pilot plant, as the FPO will utilize air-cooled systems. Therefore, an NPDES permit will not be required for surface water discharge.

6) OCCUPATIONAL SAFETY AND HEALTH ACT

The proposed project would be covered under the appropriate Occupational Health and Safety Act (OSHA) regulations as well as applicable Wyoming state health and safety regulations. Examples of major applicable regulations are described in the following paragraphs.

a) OSHA General Industry Standards, 29 CFR 1910

The standards of 29 CFR 1910 will be followed during the design of equipment and buildings for the FPO plant. Examples of standards included in 29 CFR 1910 are the following: walking and working surfaces, emergency action plans, environmental controls, handling of hazardous materials, personal protective equipment, fire protection, machine guarding, “hot work” (such as welding and cutting of metal), electrical equipment and wiring, and hazard communication.

b) OSHA Construction Standards, 29 CFR 1926

The standards of 29 CFR 1926 will be followed during the construction of the FPO plant. Examples of standards included in 29 CFR 1926 are the following: safety training, first aid, housekeeping, illumination, personal protective equipment, fire protection, tools, “hot work” (such as welding and cutting of metal), fall protection, excavations, concrete and masonry, steel erection, confined spaces, cranes, and hazard communication.

7) State of Wyoming

a) Industrial Siting Division

Facilities with an estimated construction cost of $216,383,802 or more are required to obtain a permit from the Wyoming Department of Environmental Quality, Industrial Siting Council, and projects costing less than $173,107,041 are exempt from obtaining an Industrial Siting Permit. The current estimate of the installed cost for the FPO project is less than $100,000,000; therefore, an Industrial Siting Permit is not required.

b) State Department of Fire Prevention and Electrical Safety

Facilities within the City of Laramie are not regulated by the Wyoming Department of Fire Prevention and Electrical Safety, but are within the jurisdiction of the City of Laramie Department of Life Safety and Fire Prevention, which will be discussed below.

8) City of Laramie Local Ordinances

a) Building Permit

A City of Laramie building permit is required for all new construction within the city. SwRI will submit a complete list of plans including, but not limited to, specifications, site plan, footing and foundation plans, soils report, geotechnical report, plumbing and electrical layouts, and other information as needed to show compliance with codes.

b) City of Laramie Department of Life Safety and Fire Protection

In addition to the City of Laramie building permit, the project must also apply to obtain an Electrical, Mechanical, and Plumbing permit from the City of Laramie Department of Life Safety and Fire Protection demonstrating compliance with local, national, and international building codes.

c) Noise

Noise from the project must comply with Laramie, Wyoming Code of Ordinances, Chapter 8.40, Article I – Noise Pollution – General. The permissible noise levels are listed in Section 8.40.30. Due to the proximity of residential zones to the project, the residential sound limits are applied to this project: 55 db(A) during the hours of 7:00 a.m. to the next 7:00 p.m. and 50 db(a) from 7:00 p.m. to the next 7:00 a.m. A residential zone includes educational facilities, hospitals, nursing homes, and similar institutions. Noise at the FPO pilot plant shall be measured at a distance of at least 25 feet at or beyond the property line. To comply with the local noise ordinance, equipment will be critically silenced by utilizing hospital grade acoustical design.

During construction, the project shall be subject to the maximum permissible noise levels, specified for industrial zones for the period within, which construction is to be completed pursuant to any applicable construction permit issued by proper authority. If no time limitation is imposed, then for a reasonable time for completion of the project, provided that during the hours between 8:00 p.m. to the next 7:00 a.m., maximum noise levels shall not exceed fifty db(A), measured at the property line of the nearest occupied dwelling, except for emergency operations.

VIII. Experience and Approach to Environmental Issues

1) Education and Experience of Key Project Members

Upon receipt of project funding, key project members for (1) air quality management; (2) surface water and ground water management; (3) solid and liquid waste management and disposal practices; (4) noise, land use, ecological and cultural resource management; and (5) environmental permit applications, amendments and renewals will be identified.

2) Environmental Policies, Procedures, and Plans

A written plan will be developed at a later phase of the project, which will outline how environmental issues and concerns that come up during the project will be addressed.

3. REFERENCES

[1] "Pressurised Oxy-Coal Combustion Rankine-Cycle for Future Zero Emission Power Plants: Process Design and Energy Analysis," *Energy Sustainability,* August 2008.

[2] M. Gazzino and et al., "Pressurised Oxy-Coal Combustion Rankine-Cycle for Future Zero Emission Power Plants: Technological Issues," *Energy Sustainability,* July 2009.

[3] J. Hong, R. Field, M. Gazzino and A. Ghoniem, "Performance of the Pressurized Oxy-Fuel Combustion Power Cycle with Increasing Operating Pressures," in *34th Clearwater Coal Conference*, May 2009.

[4] J. Hong and et al., "Analysis of Oxy-fuel Combustion Power Cycle Utilizing a Pressurized Coal Combustor," *Energy,* vol. 34, 2009.

[5] J. Hong, A. Ghoniem, R. Field and M. Gazzino, "Techno-Economic Evaluation of Pressurized Oxy-Fuel Combustion Systems," *ASME-IMECE2010-38002,* 2010.

[6] National Energy Technology Laboratory, "Cost and Performance baseline for Fossil Energy Plants Volume 3b: Low Rank Coal to Electricity: Combustion Cases," March 2011.

[7] National Energy Technology Laboratory, "Cost and Performance for Low-Rank Pulverized Coal Oxy-combustion Energy Plants," September 2010.

[8] National Energy Technology Laboratory, "QGESS: Capital Cost Scaling Methodology," January 2013.

[9] National Energy Technology Laboratory, "QGESS: Cost Estimation Methodology for NETL Assessments of Power Plant Performance," April 2011.

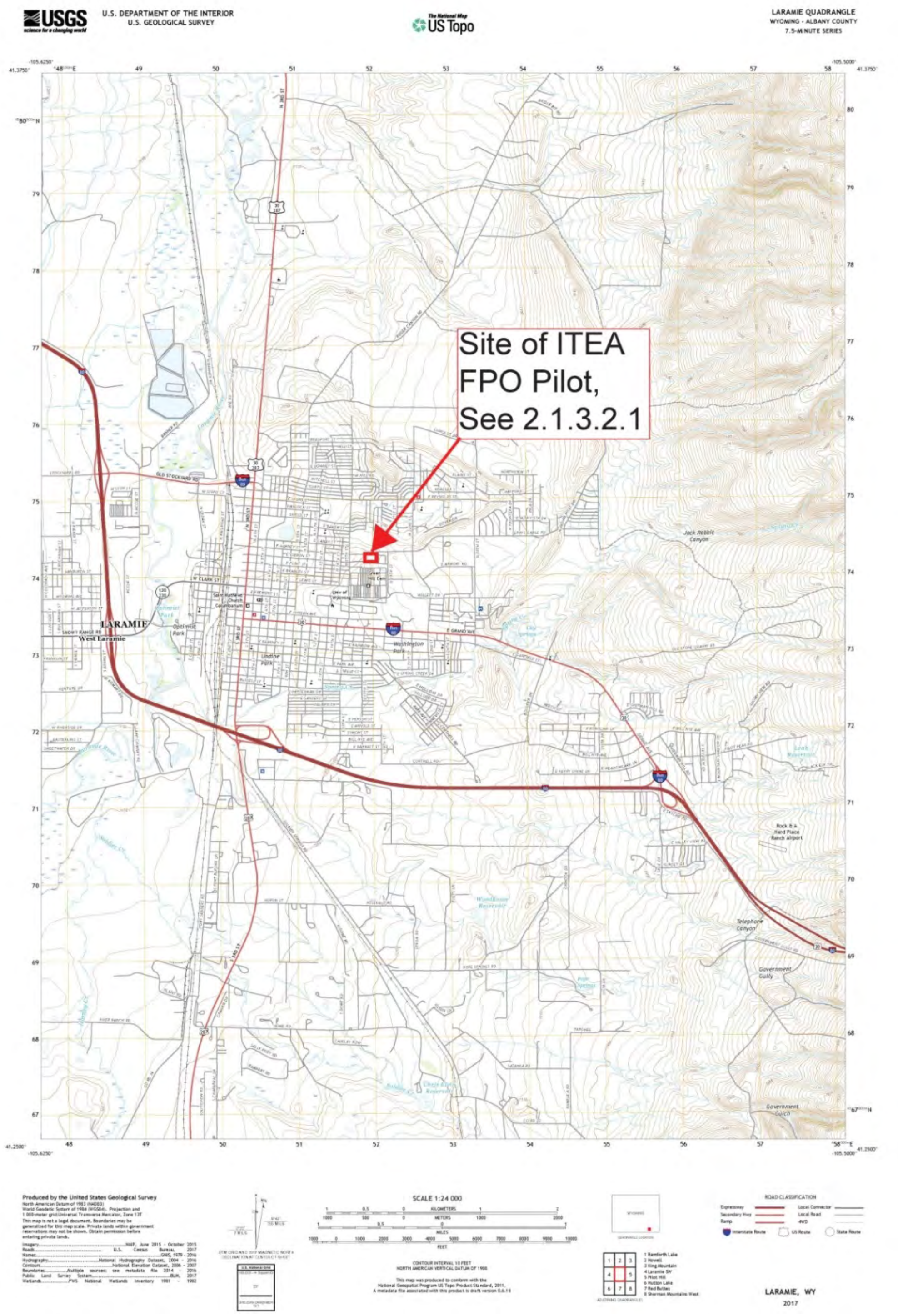
[10] National Energy Technology Laboratory, "Cost and Performance Baseline for Fossil Energy Plants Vol 3a: Low Rank Coal Electricity: IGCC Cases," May 2011.

[11] National Energy Technology Laboratory, "Cost and Performance Baseline for Fossil Energy Plants Volume 1a: Bituminous Coal (PC) and Natural Gas to Electricity Revision 3," July 2015.

[12] National Energy Technology Laboratory, "Updated Costs (June 2011 Basis) for Selected Bituminous Baseline Cases," August 2012.

[13] National Energy Technology Laboratory, "Detailed Coal Specifications," in *Quality Guidelines for Energy System Studies*, DOE/NETL-401/012111, January 2012.

4. APPENDIX A: USGS LARAMIE QUADRANGLE, WYOMING – ALBANY COUNTY, 7.5-MINUTE SERIES TOPOGRAPHIC MAP



5. APPENDIX B: CEP & FPO PILOT COAL ANALYSES

SwRI
25-MWTH FPO DEMONSTRATION EIV

SL-014916
Draft
Appendix

Proximate Analysis (As Received)	Unit	FPO Pilot "Super-Compliance" PRB Coal Note 1	CEP Plant Twenty Mile Coal
Moisture	wt%	27.42	7.3
Ash	wt%	4.5	12.01
Volatile Matter	wt%	31.65	35.34
Fixed Carbon	wt%	36.43	45.35
Total	wt%	100	100
Ultimate Analysis (Moisture Free)			
Carbon	wt%	69.21	69.28
Hydrogen	wt%	4.7	5.32
Nitrogen	wt%	0.89	5.32
Sulfur	wt%	0.3	0.5
Oxygen	wt%	18.67	6.62
Ash	wt%	6.2	12.96
Chlorine	wt%	0.03	0
Higher Heating Value (As Received)	BTU/lb	8,800	
Lower Heating Value (As Received)	BTU/lb	8,486	
Hardgrove Grinding Index		52	
Sulfur Analysis			
Total Sulfur	wt%	0.89	0.5
Pyritic Sulfur	wt%	0.4	0.23
Sulfate Sulfur	wt%	0.09	0.04
Organic Sulfur	wt%	0.4	0.23

Note 1 - PRB analysis based on National Energy Technology Laboratory Detailed Coal Specifications, excerpt attached.

SwRI FPO Demonstration DOE EIV
Project No. 13846-001

Sargent & Lundy

“Super-Compliance” Subbituminous PRB Coal [13]

7.4 “Super-Compliance” Subbituminous PRB Coal

“Super-compliance” subbituminous coal analysis is based on a coal sample reported by the Sheldon Station power plant for an energy system study conducted in 2003 [17], and is presented in Exhibit 7-5.

Exhibit 7-5 “Super-compliance” subbituminous coal analysis

Coal name	PRB
Coal seam nomenclature	Wyodak/Anderson
Mine	Rochelle Coal Co.
ASTM D388 Rank	Subbituminous C

Proximate Analysis[5]	**As-Received**	**Dry**
Moisture	27.42%	0.00%
Volatile Matter	31.65%	43.61%
Ash	4.50%	6.20%
Fixed Carbon	36.43%	50.19%
Total	100.00%	100.00%

Ultimate Analysis[5]	**As-Received**	**Dry**
Carbon	50.23%	69.21%
Hydrogen	3.41%	4.70%
Nitrogen	0.65%	0.89%
Sulfur	0.22%	0.30%
Chlorine	0.02%	0.03%
Ash	4.50%	6.20%
Moisture	27.42%	0.00%
Oxygen	13.55%	18.67%
Total	100.00%	100.00%

Heating Value[2,5]	**As-Received (Reported)**	**Dry (Dulong calc.)**
HHV (Btu/lb)	8,800	11,546
LHV (Btu/lb)	8,486	11,113
HHV (kJ/kg)	20,469	26,856
LHV (kJ/kg)	19,738	25,850

Hardgrove Grindability Index	52 HGI

Coal name		PRB
Coal seam nomenclature		Wyodak/Anderson
Ash Mineral Analysis		
Silica	SiO_2	33.40%
Aluminum Oxide	Al_2O_3	16.30%
Titanium Dioxide	TiO_2	1.20%
Iron Oxide	Fe_2O_3	5.20%
Calcium Oxide	CaO	21.50%
Magnesium Oxide	MgO	6.40%
Sodium Oxide	Na_2O	1.90%
Potassium Oxide	K_2O	0.35%
Phosphorus Pentoxide	P_2O_5	1.20%
Sulfur Trioxide	SO_3	11.70%
Barium Oxide	Ba_2O	0.56%
Strontium Oxide	SrO	0.27%
Manganese Dioxide	MnO2	0.02%
Total		100.00%

Ash Fusion Temperatures (°F)		
Reducing		
Initial - Limited deformation		2,170 °F
Softening	H=W	2,190 °F
Hemispherical	H=1/2W	2,200 °F
Fluid		2,230 °F
Oxidizing		
Initial - Limited deformation		2,200 °F
Softening	H=W	2,220 °F
Hemispherical	H=1/2W	2,250 °F
Fluid		2,290 °F

Trace element composition, dry basis, ppm[1,3]

		Reported	WY Average
Antimony	Sb	0.62	<0.4
Arsenic	As	1.5	<3
Barium	Ba	N/A	300
Boron	B	43	70
Beryllium	Be	0.4	N/A
Cadmium	Cd	0.56	<0.15
Cerium	Ce	N/A	<20
Cobalt	Co	N/A	2
Chromium	Cr	6	7
Copper	Cu	12	8
Fluorine	F	76	N/A
Gallium	Ga	N/A	3
Germanium	Ge	N/A	<2
Lanthanum	La	N/A	<7
Lead	Pb	5	<3
Lithium	Li	N/A	4.6
Manganese	Mn	9	N/A
Mercury[4]	Hg	0.1	0.1
Molybdenum	Mo	N/A	1
Neodymium	Nd	N/A	<15
Nickel	Ni	5	5
Niobium	Nb	N/A	1.5

Coal name		PRB	
Coal seam nomenclature		Wyodak/Anderson	
Phosphorus	P	N/A	N/A
Thorium	Th	N/A	2.7
Tin	Sn	N/A	N/A
Selenium	Se	0.3	<0.8
Scandium	Sc	N/A	1.5
Silver	Ag	0.24	N/A
Strontium	Sr	N/A	100
Uranium	U	N/A	<0.9
Vanadium	V	17	15
Ytterbium	Yb	N/A	0.5
Yttrium	Y	N/A	5
Zirconium	Zr	N/A	15
Zinc	Zn	8	17.9

Notes:

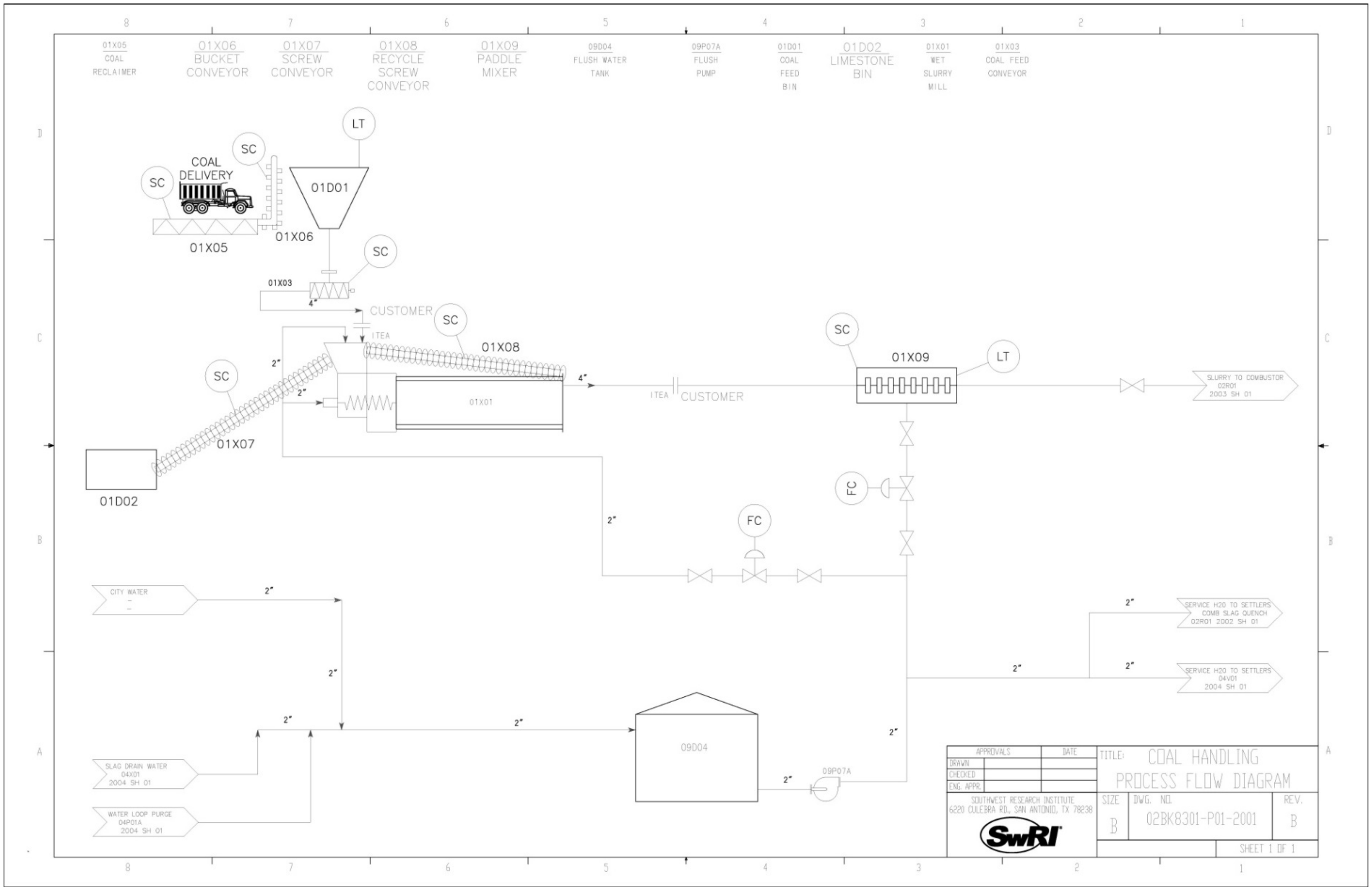
1. *N/A = not available*
2. *Calculated Dulong HHV As-Received - 8,380 Btu/lb*
3. *Average trace element composition found in Wyoming coals is based on 48 published analyses in the 2004 Keystone Coal Industry Manual [11]*
4. *Mercury values for other coal analyses used in previous system studies were the mean plus one standard deviation*
5. *The system studies using this coal type are documented in Exhibit 5-1*

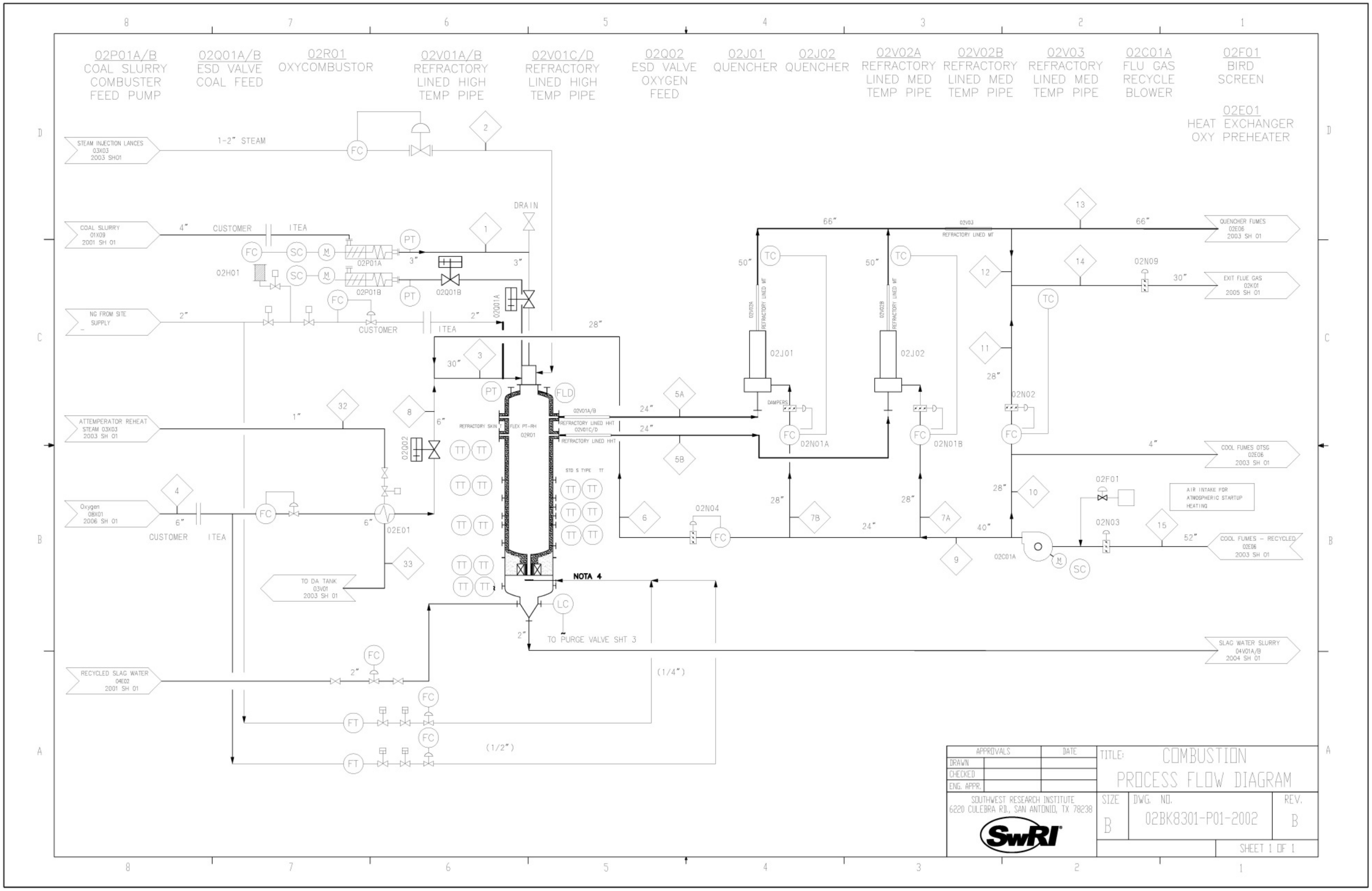
6. APPENDIX C: FPO PILOT TESTING FIGURES OF MERIT

Environmental Performance	
CO_2 Capture, %	% of Carbon in CO_2 Stream vs. Carbon-in-Fuel (based on measurements) **Note:** Dry CO_2 stream composition (O_2 concentration + inerts)
Emissions	CO, mercury, NOx, particulate matter, and SOx outlet concentrations
Slag Properties	Carbon content, composition, density, and reachability
Solids Production	Slag, fly ash, and scrubber solids weight measurement
Water Production	Quantity Produced - Recycle for Auxiliary Steam Generation and Slurry Use
Heat Exchange	
Combustor Efficiency, %	Feed stream energy [oxygen (m, H) + coal (m, H, GCV)] - Heat to Steam **Note:** Enthalpy flow of product gas stream is excluded
Cooler Effectiveness, %	Circulation ratio, total dissolved solids, and cooling effectiveness (cooling water temperature vs. gas outlet temperature)
Feedwater Heat Recovery	OTSG Feedwater m x h (T, P) - Condensate Feedwater m x h (T, P) **Note:** Heat to Steam and Feedwater Recovery converted to electrical output and added to expander output for the total gross generation
Heat to Steam	Main Steam m x h (T, P) - OTSG Feedwater m x h (T, P)
OTSG Effectiveness, %	
Oxygen Heater Effectiveness, %	Oxygen outlet temperature vs. steam supply temperature
Quencher Controllability	Mixing efficiency (maximum temperature / average temperature) and turndown performance
Mills	
Mill Effectiveness	Inspection for prevention of significant deterioration during an outage
System Performance	
Auxiliary Power, MWe	MW use of blowers, mills, pumps, cooling systems, etc
Maximum Net Power, MWe	
Minimum Stable Load, MWth	
Net Efficiency, % Lower Heating Value	
Plant Operations	Measured total operating hours and availability, startup time, ramp rates, stable load range, and longest continuous operation
Turbo Expander	
Efficiency, %	(Inlet Gas Enthalpy - Outlet Gas Enthalpy) / (Inlet Gas Enthalpy - Isentropic Expansion Enthalpy) **Note:** Turbo expander output to be monitored for total output evaluation.
Operability	Measured startup time, load range, efficiency at reduced load, and noise
Power, MWe	

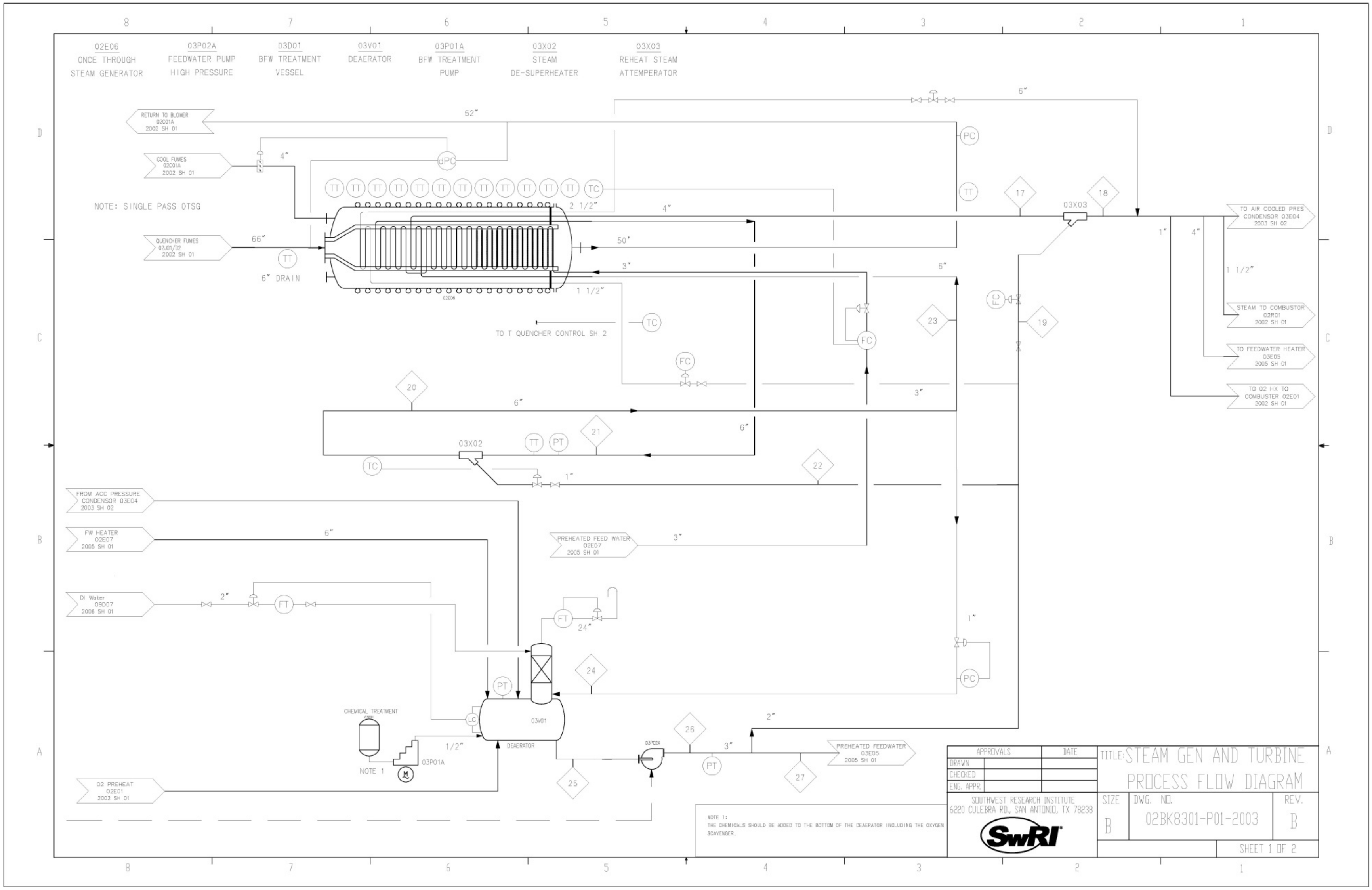
Pre-Project Planning for a Flameless Pressurized Oxy-Combustion Pilot Plant – Test Plan, Operations, Controls, and Instrumentation Page 9
SwRI Project No. 18.22423; DE-FE0027771 January 31, 2019

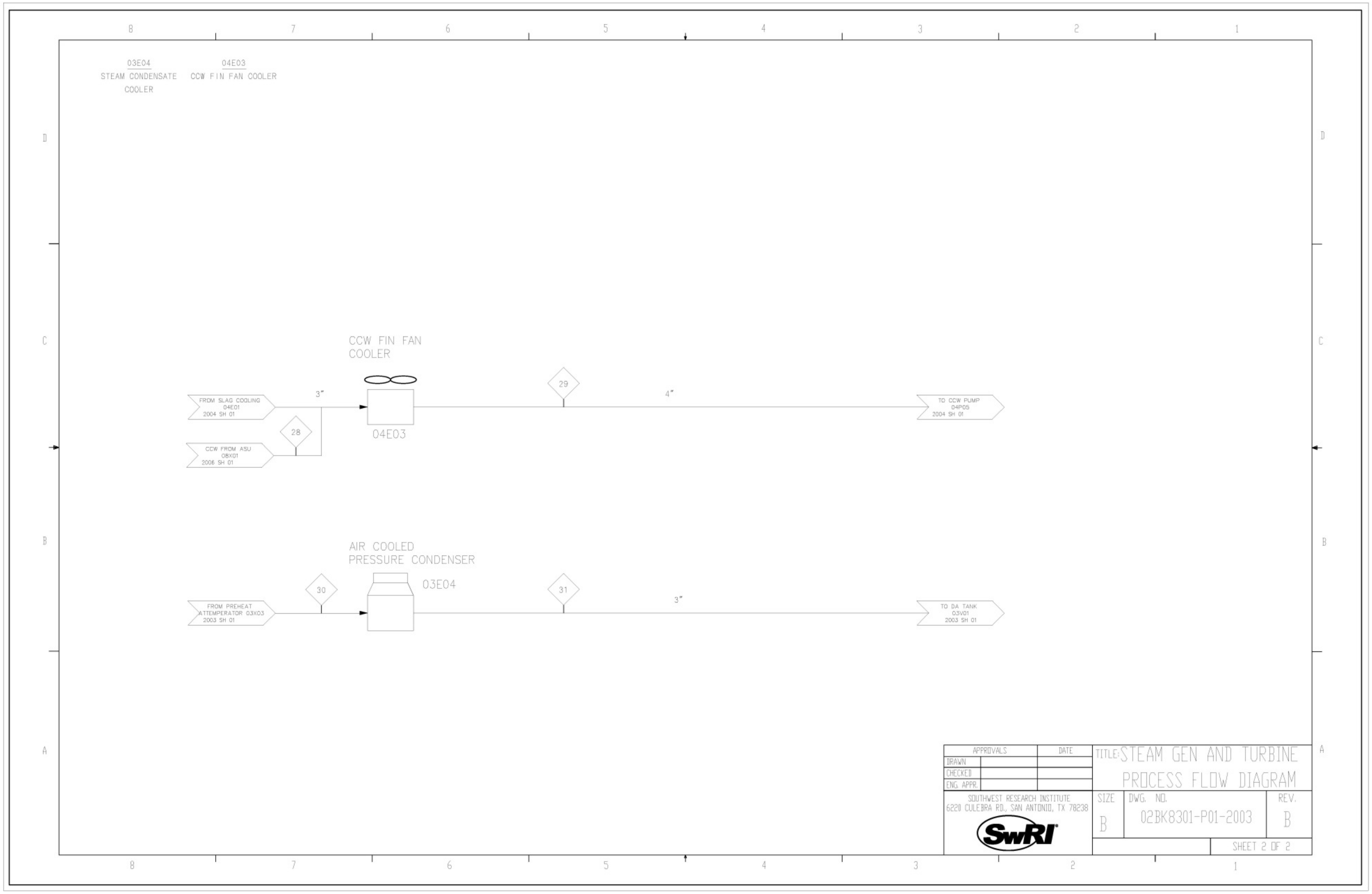
7. APPENDIX D: FPO PROCESS FLOW DIAGRAMS





02P01A/B COAL SLURRY COMBUSTER FEED PUMP
02Q01A/B ESD VALVE COAL FEED
02R01 OXYCOMBUSTOR
02V01A/B REFRACTORY LINED HIGH TEMP PIPE
02V01C/D REFRACTORY LINED HIGH TEMP PIPE
02Q02 ESD VALVE OXYGEN FEED
02J01 QUENCHER
02J02 QUENCHER
02V02A REFRACTORY LINED MED TEMP PIPE
02V02B REFRACTORY LINED MED TEMP PIPE
02V03 REFRACTORY LINED MED TEMP PIPE
02C01A FLU GAS RECYCLE BLOWER
02F01 BIRD SCREEN
02E01 HEAT EXCHANGER OXY PREHEATER
1-2" STEAM
DRAIN
CUSTOMER
ITEA
TO PURGE VALVE SHT 3
NOTA 4
TITLE: COMBUSTION PROCESS FLOW DIAGRAM
SOUTHWEST RESEARCH INSTITUTE
6220 CULEBRA RD., SAN ANTONIO, TX 78238
DWG. NO. 02BK8301-P01-2002
SIZE B
REV. B
SHEET 1 OF 1


02E06 ONCE THROUGH STEAM GENERATOR
03P02A FEEDWATER PUMP HIGH PRESSURE
03D01 BFW TREATMENT VESSEL
03V01 DEAERATOR
03P01A BFW TREATMENT PUMP
03X02 STEAM DE-SUPERHEATER
03X03 REHEAT STEAM ATTEMPERATOR
NOTE: SINGLE PASS OTSG
RETURN TO BLOWER 02C01A 2002 SH 01
COOL FUMES 02C01A 2002 SH 01
QUENCHER FUMES 02J01/02 2002 SH 01
6" DRAIN
TO T QUENCHER CONTROL SH 2
TO AIR COOLED PRES CONDENSOR 03E04 2003 SH 02
STEAM TO COMBUSTOR 02R01 2002 SH 01
TO FEEDWATER HEATER 03E05 2005 SH 01
TO 02 HX TO COMBUSTER 02E01 2002 SH 01
FROM ACC PRESSURE CONDENSOR 03E04 2003 SH 02
FW HEATER 02E07 2005 SH 01
PREHEATED FEED WATER 02E07 2005 SH 01
DI Water 09D07 2006 SH 01
CHEMICAL TREATMENT
NOTE 1
DEAERATOR
PREHEATED FEEDWATER 03E05 2005 SH 01
02 PREHEAT 02E01 2002 SH 01
NOTE 1:
THE CHEMICALS SHOULD BE ADDED TO THE BOTTOM OF THE DEAERATOR INCLUDING THE OXYGEN SCAVENGER.
APPROVALS
DATE
DRAWN
CHECKED
ENG. APPR.
SOUTHWEST RESEARCH INSTITUTE
6220 CULEBRA RD., SAN ANTONIO, TX 78238
TITLE: STEAM GEN AND TURBINE PROCESS FLOW DIAGRAM
SIZE B
DWG. NO. 02BK8301-P01-2003
REV. B
SHEET 1 OF 2


03E04
STEAM CONDENSATE COOLER
04E03
CCW FIN FAN COOLER
CCW FIN FAN COOLER
FROM SLAG COOLING 04E01 2004 SH 01
3"
CCW FROM ASU 08X01 2006 SH 01
28
04E03
29
4"
TO CCW PUMP 04P05 2004 SH 01
AIR COOLED PRESSURE CONDENSER
03E04
FROM PREHEAT ATTEMPERATOR 03X03 2003 SH 01
30
31
3"
TO DA TANK 03V01 2003 SH 01
APPROVALS
DATE
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ENG APPR.
SOUTHWEST RESEARCH INSTITUTE
6220 CULEBRA RD., SAN ANTONIO, TX 78238
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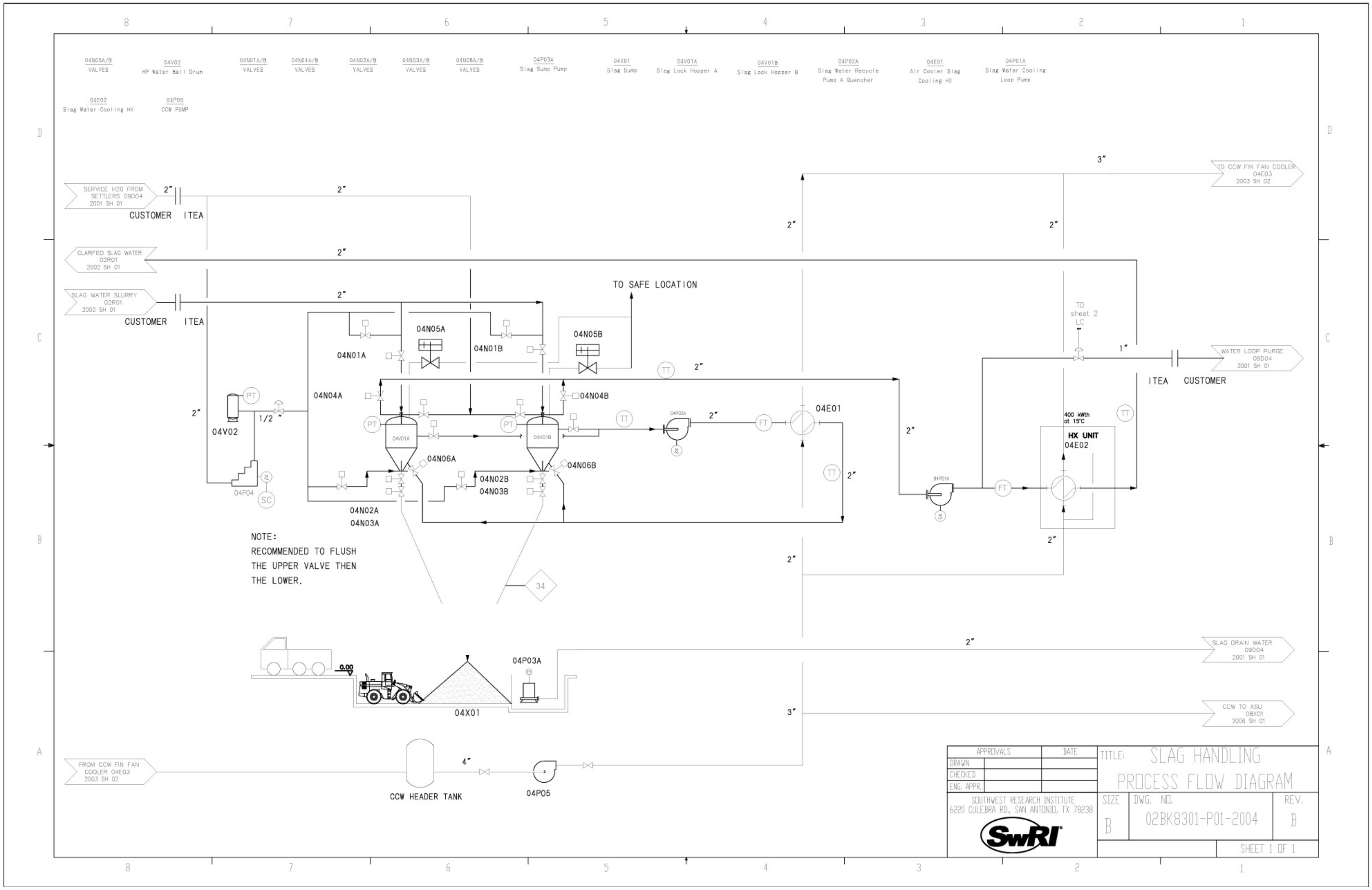
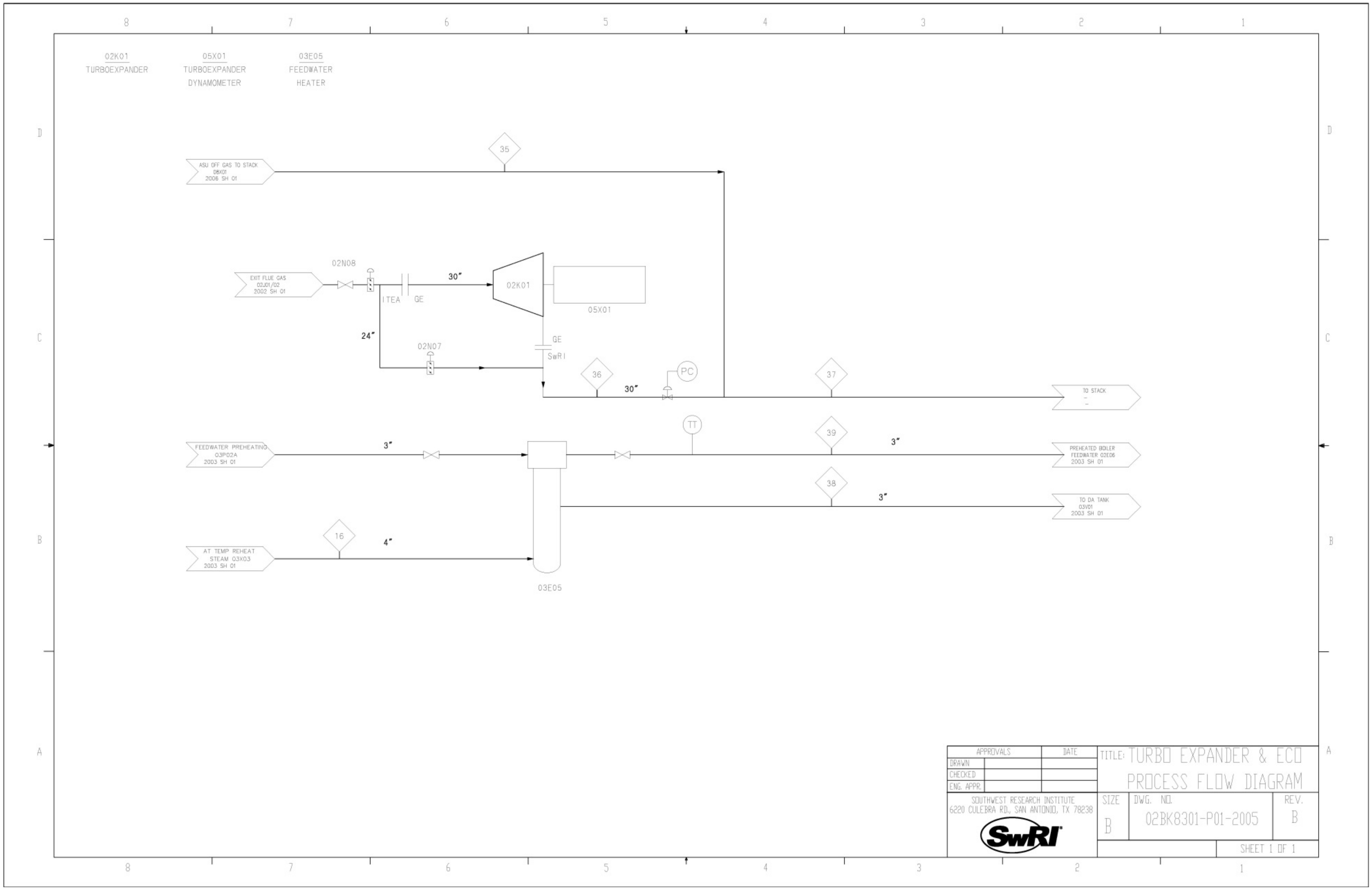
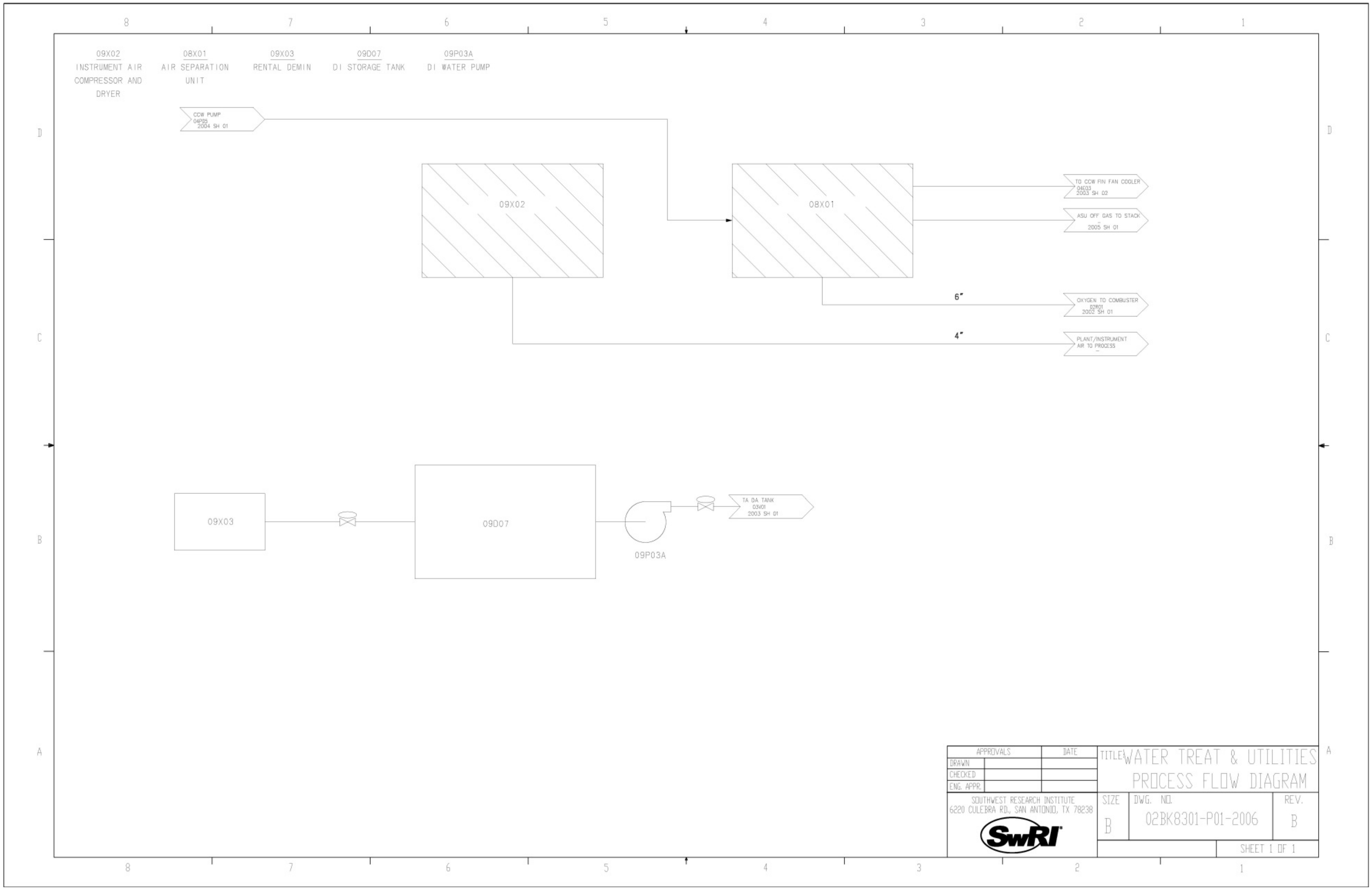


SERVICE H20 FROM SETTLERS 09D04 2001 SH 01
CUSTOMER
ITEA
CLARIFIED SLAG WATER 02R01 2002 SH 01
SLAG WATER SLURRY 02R01 2002 SH 01
TO SAFE LOCATION
TO CCW FIN FAN COOLER 04E03 2003 SH 02
WATER LOOP PURGE 09D04 2001 SH 01
04N05A
04N05B
04N01A
04N01B
04N04A
04N04B
04N06A
04N06B
04N02A
04N03A
04N02B
04N03B
04V02
04P04
04E01
HX UNIT
04E02
400 kWth at 15°C
NOTE:
RECOMMENDED TO FLUSH THE UPPER VALVE THEN THE LOWER.
04P03A
04X01
SLAG DRAIN WATER 09D04 2001 SH 01
CCW TO ASU 08X01 2006 SH 01
FROM CCW FIN FAN COOLER 04E03 2003 SH 02
CCW HEADER TANK
04P05
TITLE: SLAG HANDLING PROCESS FLOW DIAGRAM
SOUTHWEST RESEARCH INSTITUTE
6220 CULEBRA RD., SAN ANTONIO, TX 78238
SIZE B
DWG. NO. 02BK8301-P01-2004
REV. B
SHEET 1 OF 1


02K01
TURBOEXPANDER
05X01
TURBOEXPANDER
DYNAMOMETER
03E05
FEEDWATER
HEATER
35
ASU OFF GAS TO STACK
08X01
2006 SH 01
EXIT FLUE GAS
02J01/02
2002 SH 01
02N08
ITEA
GE
30"
02K01
05X01
24"
02N07
GE
SwRI
36
30"
PC
37
TO STACK
TT
39
3"
FEEDWATER PREHEATING
03P02A
2003 SH 01
3"
PREHEATED BOILER
FEEDWATER 02E06
2003 SH 01
38
3"
TO DA TANK
03V01
2003 SH 01
16
4"
AT TEMP REHEAT
STEAM 03X03
2003 SH 01
03E05
APPROVALS
DATE
DRAWN
CHECKED
ENG. APPR.
TITLE: TURBO EXPANDER & ECO
PROCESS FLOW DIAGRAM
SOUTHWEST RESEARCH INSTITUTE
6220 CULEBRA RD., SAN ANTONIO, TX 78238
SIZE
B
DWG. NO.
02BK8301-P01-2005
REV.
B
SHEET 1 OF 1



09X02
INSTRUMENT AIR COMPRESSOR AND DRYER
08X01
AIR SEPARATION UNIT
09X03
RENTAL DEMIN
09D07
DI STORAGE TANK
09P03A
DI WATER PUMP
CCW PUMP 04P05 2004 SH 01
09X02
08X01
TO CCW FIN FAN COOLER 04E03 2003 SH 02
ASU OFF GAS TO STACK 2005 SH 01
6"
OXYGEN TO COMBUSTER 02R01 2002 SH 01
4"
PLANT/INSTRUMENT AIR TO PROCESS
09X03
09D07
09P03A
TA DA TANK 03V01 2003 SH 01
APPROVALS
DATE
DRAWN
CHECKED
ENG. APPR.
TITLE WATER TREAT & UTILITIES PROCESS FLOW DIAGRAM
SOUTHWEST RESEARCH INSTITUTE
6220 CULEBRA RD., SAN ANTONIO, TX 78238
SIZE
B
DWG. NO.
02BK8301-P01-2006
REV.
B
SHEET 1 OF 1

8. APPENDIX E: CEP CITY OF LARAMIE INDUSTRIAL WASTEWATER CONTRIBUTION PERMIT

LARAMIE

CITY OF LARAMIE
INDUSTRIAL PRETREATMENT
P.O. Box C
Laramie, WY 82073

Public Works 721-5230
Utility Division 721-5280
Wastewater Treatment Plant 721-5204
FAX (307) 721-3077
TDD (307) 721-5295

CITY OF LARAMIE
INDUSTRIAL WASTEWATER CONTRIBUTION PERMIT
Permit Number: UW2018

Under the authority of the provisions of City of Laramie Enrolled Ordinance 1687 amending Chapter 13.78 of the Laramie Municipal Code:

Mailing Address: University Of Wyoming
Environmental Health and Safety
Department 4305
1000 E. University Ave.
Laramie, Wyoming, 82071

is hereby authorized to discharge industrial wastewater from the outfalls specified herein, into the City of Laramie Wastewater Utility in accordance with the conditions set forth in this permit. Compliance with this permit does not relieve the permittee of its obligation to comply with any or all applicable pretreatment standards, regulations, or requirements under local, State, or Federal law, including any regulations, standards, requirements or laws that may become effective during the term of this permit.

Noncompliance with any term or condition of this permit shall constitute a violation of the Laramie Industrial Pretreatment Ordinance.

This permit is effective the date it is signed and is effective for five (5) years. The permittee shall apply for permit reissuance ninety (90) days prior to the expiration date of the existing permit.

Chris Claymore
POTW Supervisor
City of Laramie, Wyoming

X

Issue Date: 12/03/2018

Expiration Date: 12/03/2023

SECTION A. EFFLUENT LIMITS

1. **Permitted Outfalls**
During the effective period of the permit the Permittee is authorized to discharge industrial process wastewater to the City of Laramie Wastewater Utility from the outfalls listed below. Discharge from a point source other than those listed below and hence specifically authorized is prohibited.

Outfall	Description
01	(Classroom Building): 9th and Fremont, manhole located in the lawn area west of the building.
03	(Engineering Building): 12th and Lewis, manhole located in the driveway, northeast corner of the building.
04	(Steam Plant) RMMC/Power Plant/Animal Science: Manhole located west of 19th and Gibbon in the alley.
05	(Vet Lab) UW Ag Sciences: 1174 Snowy Range Road, manhole in the lawn on the northeast side.
06	(ART) Visual Arts Building: 22nd and Willet, manhole located at the east corner of the building in the lawn.
07	(Transpark) EIC Building: 9 1/2 and Lewis, manhole is in the alley north of Lewis.
08	(STEM) Building (Science, Technology, Engineering, and Mathematics): Manhole is on 11th Street between Lewis and Bradley

2. **Permit Limits**
During the effective period of the permit, the discharge from each outfall shall not exceed the effluent limitations set forth in Table 1 below.

Table 1 Permit Limits

Parameter	Daily Max	Collection Method
Arsenic	3.151 mg/l	24 hr Time Composite
Cadmium	0.061 mg/l	24 hr Time Composite
Chromium, Total	1.160 mg/l	24 hr Time Composite
Chromium III	0.673 mg/l	Grab
Chromium VI	0.486 mg/l	Grab
Copper	1.603 mg/l	24 hr Time Composite
Lead	0.296 mg/l	24 hr Time Composite
Mercury	0.002 mg/l	24 hr Time Composite
Molybdenum	3.443 mg/l	24 hr Time Composite
Nickel	3.733 mg/l	24 hr Time Composite
Selenium	0.017 mg/l	24 hr Time Composite
Silver	1.006 mg/l	24 hr Time Composite
Zinc	8.568 mg/l	24 hr Time Composite
TPH	250 mg/l	Grab
pH, standard units	> 5.0 and < 12.0	Grab

3. **Sampling Frequency**
The Permittee shall sample each Outfall by February 28th (February 29th if it is a leap year), by June 30th, and by October 31st every year.

SECTION B. MONITORING REQUIREMENTS

1. **Sample Parameters**
Parameters which shall be monitored at the discharge sites are as follows:
Arsenic, Cadmium, Chromium (Total), Chromium (III), Chromium (VI), Copper, Lead Hydrocarbons Mercury, Molybdenum, Nickel, Selenium, Silver, Zinc, TPH (Total Petroleum) and pH. The only exception is TPH does not have to be monitored at Outfall 01.

2. **Representative Sampling**
All samples and measurements shall be representative of the volume and nature of the monitored wastewater discharge. All samples shall be taken from the sampling outfalls specified in Section A of this permit and outfalls shall not be changed without notification and approval by the permit issuing authority.

3. **Chromium Requirements**
If the analytical results for total chromium exceed the permit limit of 1.160 mg/l, the permittee shall be required to sample for chromium III and chromium VI within ten (10) days of receipt of analytical data. The sampling method for chromium is the grab method by a single dip and take.

4. **Analyses Reporting**
The permittee shall be provided with a Self-Monitoring Report Form on which to report the sampling results. Copies of the laboratory analytical report shall be submitted with the Self-Monitoring Report Form.

5. **Sampling Event**
One sampling event shall consist of five (5) separate twenty-four (24) hour composite samples on five (5) consecutive weekdays. TPH (total petroleum hydrocarbons) and pH will be sampled on the 5th day of the 5-day sampling event for all outfalls excluding TPH for outfall 01.

SECTION C. REPORTING REQUIREMENTS

1. **Monitoring results.**
Results obtained from the outfalls shall be submitted with a Self-Monitoring Report Form (SMR). The reports are due by the 20th of the month following the last day of the monitoring month. If the monitoring month is March, the SMR is due between April 1st and April 20th. The report shall indicate the nature and concentration of all pollutants in the effluent for which sampling and analysis were performed. The reports shall contain all the required information per Section F (6).

2. **24-Hour Notification of Violations.**
If sampling performed by the permittee indicates a violation, the permittee shall notify the City of Laramie Wastewater Treatment Facility (POTW) within twenty-four (24) hours of becoming aware of the violation. The permittee shall also repeat the sampling and analysis and submit the results of the repeat analysis to the POTW within thirty (30) days after becoming aware of the violation.

3. **Notification of Changed Discharge.**
The permittee shall promptly notify the City of Laramie POTW at least forty-five (45) days prior to any facility expansion, production increase, or process modifications or discharge of any previously unreported hazardous wastes. All Industrial Users shall promptly notify the Control Authority (and the POTW if the POTW is not the Control Authority) in advance of any substantial change ten percent (10%) in the volume or any change in the character of pollutants in their Discharge, including the listed or characteristic hazardous wastes for which the Industrial User has submitted initial notification under 40 CFR Part 403.12(p). In addition, the permittee shall give advance notice of any planned changes in the permitted facility or activity that may result in noncompliance with permit requirements.

4. **Accidental Discharge Report.**
The permittee shall notify the POTW immediately upon knowing of, or when the permittee reasonably should have known, of the occurrence of an accidental discharge of substances prohibited by the City of Laramie Ordinance 1687 or any slug loads or spills that may enter the public sewer. The notification shall include the location of the discharge, date and time thereof, type of discharge, including concentration and volume, and corrective action taken. The permittee's notification of accidental releases in accordance with this section does not relieve it from other reporting requirements or from liabilities that arise under local, state or federal law.

   Within five (5) days following an accidental discharge, the permittee shall submit a detailed written report. The report shall specify:
   a. Description and cause of the upset, slug load or accidental discharge and the impact on the permittee's compliance status. The description should include location of the discharge, type, concentration and volume of discharge.
   b. Duration of the discharge, including exact dates and times of the event and, if the discharge is continuing, the time by which the event is reasonably expected to terminate.
   c. All steps taken, or to be taken, to reduce, eliminate and/or prevent recurrence of the upset, slug load or accidental discharge.

5. **Hazardous Waste Discharge.**
   a. The Industrial User shall notify the POTW, the EPA Regional Waste Management Division Director, and State hazardous waste authorities in writing of any discharge into the POTW of a substance, which, if otherwise disposed of, would be a hazardous waste under 40 CFR Part 261. Such notification must include the name of the hazardous waste as set forth in 40 CFR Part 261, the EPA hazardous waste number, and the type of discharge (continuous,

batch, or other). If the Industrial User discharges more than one hundred (100) kilograms (which is equivalent to 220.46 lbs) of such waste per calendar month to the POTW, the notification shall also contain the following information to the extent such information is known and readily available to the Industrial User: An identification of the hazardous constituents contained in the wastes, an estimation of the mass and concentration of such constituents in the waste stream discharged during that calendar month, and an estimation of the mass of constituents in the waste stream expected to be discharged during the following twelve (12) months. All notifications must take place within one hundred and eighty (180) days of the effective date of this rule. Industrial users who commence discharging after the effective date of this rule shall provide the notification no later than one hundred and eighty (180) days after the discharge of the listed or characteristic hazardous waste. Any notification under this paragraph need be submitted only once for each hazardous waste discharged. However, notifications of changed discharges must be submitted under 40 CFR 403.12(j). The notification requirement in this section does not apply to pollutants already reported under the self-monitoring requirements of 40 CFR 403.12(b), (d), and (e).

b. Discharges are exempt from the requirements of paragraph 40 CFR 403.12 (p)(1) during a calendar month in which they discharge no more than fifteen (15) kilograms of hazardous wastes, unless the wastes are acute hazardous wastes as specified in 40 CFR 261.30(d) and 261.33(e). Discharge of more than fifteen (15) kilograms of non-acute hazardous wastes in a calendar month, or of any quantity of acute hazardous wastes as specified in 40 CFR 261.30(d) and 261.33(e), requires a one-time notification.
c. Subsequent months during which the Industrial User discharges more than such quantities of any hazardous waste do not require additional notification.
d. In the case of any new regulations under section 3001 of RCRA identifying additional characteristics of hazardous waste or listing any additional substance as hazardous, the Industrial User must notify the POTW, the EPA Regional Waste Management Waste Division Director, and State hazardous waste authorities of the discharge of such substance within ninety (90) days of the effective date of such regulations.
e. In the case of any notification made under paragraph 40 CFR 403.12 (p), the Industrial User shall certify that it has a program in place to reduce the volume and toxicity of hazardous waste generated to the degree it has determined to be economically practical.

6. **Duty to Provide Information.**
The permittee shall furnish to the POTW, within thirty (30) days, any information which the POTW may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit. The permittee shall also, upon request, furnish to the POTW, within thirty (30) days, copies of any records required to be kept by this permit.

7. **Signatory Requirements.**
All applications, reports, or information submitted to the POTW must contain the following certification statement and be signed as required in Sections (a), (b), (c), or (d) below:

"I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

a. A responsible corporate officer, if the Industrial User submitting the reports required by Section 8 of the City of Laramie Ordinance 1687 is a corporation. For the purpose of this paragraph, a responsible corporate officer means:
   1. A president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy or decision-making functions for the corporation, or
   2. The manager of one or more manufacturing production, or operating facilities, provided, the manager is authorized to make management decisions which govern the operation of the regulated facility including having the explicit or implicit duty of making major capital investment recommendations, and initiate and direct other comprehensive measures to assure long-term environmental compliance with environmental laws and regulations, can ensure that the necessary systems are established or actions taken to gather complete and accurate information for control mechanism requirements; and where authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures.
b. A general partner or proprietor if the Industrial User submitting the reports required by Section 8 of the City of Laramie Ordinance 1687 is a partnership, or sole proprietorship respectively.
c. A duly authorized representative of the individual designated in Section 4 of the City of Laramie Ordinance 1687 if:
   1. The authorization is made in writing by the individual described in Section 4 of the City of Laramie Ordinance 1687;
   2. The authorization specifies either an individual or a position having responsibility for the overall operation of the facility from which the Industrial Discharge originates, such as the position of plant manager, operator of a well, or well field Superintendent, or a position of equivalent responsibility, or having overall responsibility for environmental matters for the company; and
   3. The written authorization is submitted to the Control Authority.
d. If an authorization under Section 4 of the City of Laramie Ordinance 1687 is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, or overall responsibility for the environmental matters for the company, a new authorization satisfying the requirements of Section 4 of the City of Laramie Ordinance 1687 must be submitted to the Control Authority prior to or together with any reports to be signed by an authorized representative. The City may at any time require the production of written evidence of authority.

8. **Operating Upsets. (Limited to categorical users only)**
Any permittee that experiences an upset in operations that places the permittee in a temporary state of noncompliance with the provisions of this permit or the City of Laramie Ordinance 1687 shall inform the POTW within twenty-four (24) hours of becoming aware of the upset.

A written follow-up report of the upset shall be filed by the permittee with the POTW within five (5) days. The report shall specify:
a. Description of the upset, and cause(s) thereof and the upsets impact on the permittee's compliance status;
b. Duration of noncompliance, including exact dates and times of noncompliance, and if not corrected, the anticipated time the noncompliance is expected to continue; and
c. All steps taken or to be taken to reduce, eliminate, and prevent recurrence of such an upset.

The report must also demonstrate that the treatment facility was being operated in a prudent and workmanlike manner. A documented and verified operating upset shall be an affirmative defense to any enforcement action brought against the permittee for violations attributable to the upset event.

SECTION D. STANDARD CONDITIONS

1. **Severability.**
The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

2. **Duty to Comply.**
The permittee must comply with all conditions of this permit. Failure to comply with the requirements of this permit may be grounds for administrative action, or enforcement proceedings including civil or criminal penalties and injunctive relief.

3. **Duty to Mitigate.**
The permittee shall take all reasonable steps to minimize or correct any adverse impact to the public treatment plant or the environment resulting from noncompliance with this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the non-complying discharge.

4. **Permit Modification.**
The Superintendent may modify an individual wastewater discharge permit for good cause, including, but not limited to, the following reasons:
a. To incorporate any new or revised Federal, State, or local Pretreatment Standards or Requirements;
b. To address significant alterations or additions to the User's operation, processes, or wastewater volume or character since the time of the individual wastewater discharge permit issuance;

c. A change in the POTW that requires either a temporary or permanent reduction or elimination of the authorized discharge;
d. Information indicating that the permitted discharge poses a threat to the City's POTW, City personnel, or the receiving waters;
e. Violation of any terms or conditions of the individual wastewater discharge permit;
f. Misrepresentations or failure to fully disclose all relevant facts in the wastewater discharge permit application or in any required reporting;
g. Revision of or a grant of variance from categorical Pretreatment Standards pursuant to 40 CFR 403.13;
h. To correct typographical or other errors in the individual wastewater discharge permit; or
i. To reflect a transfer of the facility ownership or operation to a new owner or operator where requested in accordance with Section 7(3) of the City of Laramie Ordinance 1687.

5. **Permit Termination.**
This permit may be terminated for the following reasons:
a. Falsifying compliance reports
b. Tampering with monitoring equipment
c. Refusing access to facility premises and records
d. Failure to meet effluent limitations
e. Failure to pay fines
f. Failure to pay sewer charges
g. Failure to meet compliance schedules
h. Violation of any permit condition

6. **Permit Appeals.**
The permittee has the right to appeal the denial of permit, certain conditions in the permit, or permit termination if the permittee believes that the permit itself, certain conditions, or decisions made are contrary to law, arbitrary, capricious, or not supported by substantial evidence. The local sewer use ordinance sets forth the procedures by which appeals may be implemented.
The City of Laramie shall not stay the effectiveness of this permit pending reconsideration.

7. **Property Rights.**
The issuance of this permit does not convey any property rights of any sort, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any violation of federal, state, or local laws or regulations.

8. **Permit Transfer.**
Wastewater discharge permits are issued to a specific user for a specific operation at a specific location. A wastewater discharge permit is void if it is assigned or transferred; or if the permittee is sold or leased to a new owner or new user, or is moved to different premises, without, at a minimum, prior notification the POTW and provision of a copy of the existing control mechanism to the new owner or operator". A wastewater discharge permit may not be used for a new or changed process or operation without the advance approval of the superintendent in writing.

9. **Duty to Reapply.**
Assuming no early termination, if the permittee wishes to continue an activity regulated by this permit after the expiration date of this permit, the permittee must submit an application for a new permit at least ninety (90) days before the expiration date of this permit.

10. **Continuation of Expired Permits.**
There is no continuation of permits that have reached the expiration date.

11. **Dilution.**
Dilution prohibited as substitute for treatment. Except where expressly authorized to do so by an applicable Pretreatment Standard or Requirement, no Industrial User shall ever increase the use of process water, or in any other way attempt to dilute a Discharge as a partial or complete substitute for adequate treatment to achieve compliance with a Pretreatment Standard or Requirement. The Control Authority may impose mass limitations on Industrial Users which are using dilution to meet applicable Pretreatment Standards or Requirements, or in other cases where the imposition of mass limitations is appropriate.

12. **Accidental Discharge/Slug Discharge Control Plans**.
The Superintendent shall evaluate whether each SIU needs an accidental discharge/slug discharge control plan or other action to control Slug Discharges. The Superintendent may require any User to develop, submit for approval, and implement such a plan or take such other action that may be necessary to control Slug Discharges. Alternatively, the Superintendent may develop such a plan for any User. An accidental discharge/slug discharge control plan shall address, at a minimum, the following:
    a. Description of discharge practices, including non-routine batch discharges.
    b. Description of stored chemicals;
    c. Procedures for immediately notifying the Superintendent of any accidental or Slug Discharge, as required by Section 7 of the City of Laramie Ordinance 1687; and
    d. Procedures to prevent adverse impact from any accidental or Slug Discharge. Such procedures include, but are not limited to, inspection and maintenance of storage areas, handling and transfer of materials, loading and unloading operations, control of plant site runoff, worker training, building of containment structures or equipment, measures for containing toxic organic pollutants, including solvents, and/or measures and equipment for emergency response.

Whenever the facility changes its operations in such a way as to change the potential for Slug Discharge, the plan must be updated.

13. **Definitions**
    a. Bypass: Bypass means the intentional diversion of waste streams from any portion of the Industrial User's treatment facility. Bypass is prohibited.
    b. Composite Method: It is recommended that effluent operational data be obtained through twenty-four (24) hour flow proportional composite samples. Sampling may be done manually or automatically, and discretely or continuously. If discrete sampling is employed, at least twelve (12) aliquots should be composited. Discrete sampling may be flow proportioned either by varying the time interval between each aliquot or the volume of each aliquot. All composites should be flow proportional to either the stream flow at the

time of collection of the influent aliquot or to the total influent flow since the previous influent aliquot.

c. Daily Maximum: The maximum allowable discharge quantity of a pollutant during a calendar day.
d. Grab Sample: A single "dip and take" sample collected at a representative point in the discharge stream without regard to flow or time.
e. Interference: A discharge which, alone or in conjunction with another discharge inhibits or disrupts the POTW, its treatment process or operations, or its sludge processes, use or disposal and therefore is a cause of or contributes to a violation of any requirement of the POTW NPDES permit.
f. Instantaneous measurement: A single reading, observation, or measurement using existing monitoring facilities.
g. Local Limit: maximum pollutant concentrations set by the City of Laramie.
h. NPDES Permit: National Pollutant Discharge Elimination System Permit is the permit issued to the POTW by the State of Wyoming allowing the POTW to discharge treated wastewater to the Laramie River.
i. Pass-through: A discharge which exits the POTW into the Laramie River in quantities or concentrations which cause a violation of the POTW NPDES permit.
j. POTW: City of Laramie Publicly Owned Treatment Works as the wastewater treatment facility or utility. The term also means the municipality as defined in section 502 (4) of the Act, which has jurisdiction over the Indirect Discharges to and the discharges from such a treatment works.
k. Significant Noncompliance: For the purposes of this provision, a Significant Industrial User (or any Industrial User which violates Section 7 of the City of Laramie Ordinance 1687) is in significant noncompliance if its violation meets one or more of the following criteria:
   1. Chronic violations of wastewater Discharge limits, defined here as those in which sixty-six percent (66%) or more of all of the measurements taken for the same pollutant parameter during a six (6) month period exceed (by any magnitude) a numeric Pretreatment Standard or Requirement, including instantaneous limits, as defined by 40 CFR Part 403.3(1);
   2. Technical Review Criteria (TRC) violations, defined here as those in which thirty-three percent (33%) or more of all of the measurements taken for the same pollutant parameter during a six (6) month period equal or exceed the product of the numeric Pretreatment Standard or Requirement including instantaneous limits, as defined by 40 CFR Part 403.3(1) multiplied by the applicable TRC (TRC=1.4 for BOD, TSS, fats, oil and grease, and 1.2 for all other pollutants except pH).
   3. Any other violation of a Pretreatment Standard or Requirement as defined by 40 CFR Part 403.3(1) (daily maximum, long-term average, instantaneous limit, or narrative Standard) that the POTW determines has caused, alone or in combination with other Discharges, Interference or Pass Through (including endangering the health of POTW personnel or the general public);
   4. Any discharge of a pollutant that has caused imminent endangerment to human health, welfare or to the environment or has resulted in the POTW's exercise of its emergency authority under Section 12(I)(A)(viii) of the City of Laramie Ordinance 1687 to halt or prevent such a discharge;

5. Failure to meet, within ninety (90) days after the schedule date, a compliance schedule milestone contained in a local control mechanism or enforcement order for starting construction, completing construction, or attaining final compliance;
6. Failure to provide, within forty-five (45) days after the due date, required reports such as baseline monitoring reports, ninety (90) day compliance reports, periodic self-monitoring reports, and reports on compliance with compliance schedules.
7. Failure to accurately report noncompliance;
8. Any other violation or group of violations, which may include a violation of Best Management Practices, which the POTW determines will adversely affect the operation or implementation of the local Pretreatment program.

l. Slug Load or Slug Discharge: For purposes of this permit, a Slug Discharge is any Discharge of a non-routine episodic nature, including but not limited to an accidental spill or a non-customary batch Discharge, which has a reasonable potential to cause Interference or Pass Through, or in any other way violate the POTW's regulations, local limits or Permit conditions.

m. Superintendent: For the purposes of this permit, refers to the person designated by the city manager as public works director or designee.

14. **Right of Entry**

Representatives of the POTW, the state, and EPA, upon showing proper identification, shall be permitted to enter and inspect the premises of any user who may be subject to the requirements of the City of Laramie Industrial Pretreatment Ordinance 1687 with amendments to determine whether the permittee is in compliance with all requirements of the ordinance, this permit or other order. Industrial users shall allow representatives of the POTW, the state, and EPA access to all premises at all times for the purposes of inspecting, sampling, examining or copying records in the performance of their duties. EPA, state, and representatives of the POTW shall have the right to install on the industrial user's property devices, equipment, and access locations necessary or convenient to conduct sampling and monitoring.

15. **General and Prohibitive Standards**

The permittee may not introduce into the POTW any pollutant(s) which cause pass-through or interference or which may otherwise cause the POTW to violate its NPDES permit. Namely, the industrial user shall not discharge wastewater to the sewer system that contains:

a. Gasoline, benzene, naphtha, fuel oil or other liquids, solids, or gases which either alone or by interaction with other substances cause fire or explosion in the collection system or treatment facility. In no case shall pollutants be discharged having a closed cup flashpoint of less than one-hundred and forty degrees Fahrenheit (140°F) or sixty degrees Centigrade (60°C), or pollutants which cause an exceedance of five percent (5%) of the Lower Explosive Limit (LEL) at any point within the POTW;
b. Solid or viscous substances that cause obstruction to the flow in the City of Laramie sewer;
c. Having a pH less than or equal to five (5.0) or greater than or equal to twelve (12.0) or having any other property capable of causing damage or hazards to structures, equipment, or personnel of the sewer system;
d. Containing toxic pollutants in sufficient quantity to injure or interfere with any wastewater treatment process, to constitute a hazard to humans or animals, to create any hazard in waters that receive treated effluent from the POTW. Toxic wastes shall include, but are

not limited to, wastes containing arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, silver, and zinc ions;

e. Containing any substance which would cause the treatment plant to be in noncompliance with the sludge use, recycle or disposal criteria pursuant to guidelines or regulations developed under Section 405 of the Federal Act, the Solid Waste Disposal Act, the Clean Air Act, the Toxic Substances Control Act or other regulations or criteria for sludge management and disposal as required by the State;
f. Containing noxious or malodorous gases or substances capable of creating a public nuisance; including pollutants which result in the presence of toxic gases, vapors, or fumes which may be in sufficient quantity to cause acute worker health or safety hazards, or are sufficient to prevent entry into the public sewer for maintenance or repairs;
g. Containing any substance that may affect the treatment plant's effluent and cause a violation of NPDES permit requirements;
h. Containing heat in amounts which will inhibit biological activity in the POTW resulting in interference, but in no case in such quantities that the wastewater temperature entering the treatment plant exceeds one-hundred and four degrees Fahrenheit (104°F) or forty degrees Centigrade (40°C) unless the approval authority approves an alternate temperature limit;
i. Any grease or oil of petroleum or animal fat origin that alone or in conjunction with other pollutants could potentially cause pass-through or interference;
j. Containing color which is not removed in the treatment process;
k. Containing any medical or infectious wastes;
l. Containing any radioactive wastes or isotopes;
m. Containing any pollutant, including BOD pollutants, released at a flow rate and/or pollutant concentration that would cause interference with the treatment plant;
n. Trucked or hauled pollutants except at discharge points designated by the POTW;
o. Containing solids, sludges, filter backwash or other pollutants removed in the course of pretreatment prior to entering the POTW.

16. **Compliance with Applicable Pretreatment Standards and Requirements.**
Compliance with this permit does not relieve the permittee from its obligations regarding compliance with any and all applicable local, state and federal pretreatment standards and requirements including any such standards or requirements that may become effective during the term of this permit.

SECTION E. OPERATION AND MAINTENANCE OF POLLUTION CONTROLS

1. **Proper Operation and Maintenance.**
The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the conditions of this permit. Proper operation and maintenance includes, but is not limited to, effective performance, adequate funding, adequate operator staffing and training, and adequate laboratory and process controls, including appropriate quality assurance procedures.
This provision requires the operation of back-up or auxiliary facilities or similar systems only when necessary to achieve compliance with the conditions of this permit.

2. **Duty to Halt or Reduce Activity.**
Upon reduction of efficiency of operations, or loss or failure of all or part of the treatment facility, the permittee shall, to the extent necessary to maintain compliance with its permit, control its production of discharges until operation of the treatment facility is restored or an alternative method of treatment is provided. This requirement applies, for example, when the primary source of power of the treatment facility fails or is reduced. It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

3. **Bypass of Treatment Facilities.**
Bypass is prohibited unless it is unavoidable to prevent loss of life, personal injury, or severe property damage or no other feasible alternatives exist. The permittee may allow bypass to occur which does not cause effluent limitations to be exceeded, but only if it is also for essential maintenance.
   a. Notification of Anticipated Bypass: If the permittee knows in advance of the need for a bypass, it shall submit prior written notice at least ten (10) days before the date of bypass to the POTW. This report shall specify:
      1. A description of the bypass, and its cause, including its duration;
      2. Whether the bypass has been corrected; and
      3. The steps being taken to reduce, eliminate and prevent a reoccurrence of the bypass.
   b. Notification of Unanticipated Bypass: The permittee shall immediately notify the POTW and submit a written notice to the POTW within five (5) days. This report shall specify:
      1. A description of the bypass, and its cause, including its duration;
      2. Whether the bypass has been corrected; and
      3. The steps being taken to reduce, eliminate and prevent a reoccurrence of the bypass.

SECTION F. MONITORING AND RECORDS

1. **Representative Sampling.**
Samples and measurements taken as required herein shall be representative of the volume and nature of the monitored discharge. All samples shall be taken at the monitoring points specified in this permit and, unless otherwise specified, before the effluent joins or is diluted by any other waste stream, body of water or substance. All equipment used for sampling and analysis must be routinely calibrated, inspected, and maintained to ensure their accuracy. Monitoring points shall not be changed without notification to and the approval of the POTW.

2. **Flow Measurements.**
If flow measurement is required by this permit, the appropriate flow measurement devices and methods consistent with approved scientific practices shall be selected and used to ensure the accuracy and reliability of measurement of the volume of monitored discharges. The devices shall be installed, calibrated, and maintained to ensure that the accuracy of the measurements is consistent with the accepted capability of that type of device. Devices selected shall be capable of measuring flows with a maximum deviation of less than ten percent (10%) from true discharge rates throughout the range of expected discharge volumes.

3. **Analytical Methods to Demonstrate Continued Compliance.**
All handling, preservation, sampling and analysis required by this permit shall be performed in accordance with 40 CFR 136 and the City of Laramie Ordinance 1687.

4. **Additional Monitoring by the Permittee.**
If the permittee monitors any pollutant more frequently than required by this permit, using approved test procedures, the results of this monitoring shall be included in the permittee's self-monitoring reports.

5. **Retention of Records.**
The permittee shall retain records of all monitoring information; including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation if used. The permittee shall retain copies of all reports required by the permit. These records shall be kept for a period of at least five (5) years from the date of the sample, measurement, report, or application. This period may be extended by request of the POTW. Any records associated with best management practices shall be retained for at least (3) three years.

6. **Records Contents.**
Records of sampling and analysis shall include:
   a. The date, exact place, time, and methods of sampling or measurements, and sample preservation;
   b. Who performed the sampling or measurements;
   c. The date(s) and time(s) analyses were performed;
   d. Who performed the analyses;
   e. The analytical techniques and methods used; and
   f. The results of the analyses.

7. **Falsifying Information.**
Knowingly making any false statement on any report or other document required by this permit or knowingly rendering any monitoring device or method inaccurate is a crime and may result in the imposition of criminal sanctions and/or civil penalties.

SECTION G. ANNUAL PUBLICATION

40 CFR Part 25. Enforcement of National Pretreatment Standards:

Requires at least annual public notification by the authority in a newspaper(s) of general circulation that provides meaningful public notice within the jurisdiction(s) served by the POTW of Industrial Users, which at any time during the previous twelve (12) months, were in significant noncompliance with applicable Pretreatment requirements.

SECTION H. CIVIL AND CRIMINAL LIABILITY

Nothing in this permit shall be construed to relieve the permittee from civil and/or criminal penalties for noncompliance with federal, state or local laws or regulations.

City of Laramie Municipal Ordinance 13.78.120.B **Enforcement**

1. **Penalties for Violations of Permit Conditions.**
   Any person who violates a permit condition is subject to a civil penalty of up to one thousand dollars ($1000) per day of such violation.

2. **Criminal Prosecution**

   a. Violations Generally. Any industrial user who willfully or negligently violates any provision of this chapter or any order or permit issued hereunder is guilty of a misdemeanor, and upon conviction shall be punished by a fine not to exceed seven hundred fifty dollars or imprisonment not exceeding six months, or both.
   b. Falsifying Information. Any industrial user who knowingly makes any false statements, representations, or certifications in any application, record, report, plan or other document filed or required to be maintained pursuant to this chapter or any permit issued under this chapter, or who falsifies, tampers with, or knowingly makes inaccurate any monitoring device or method required under this chapter or any permit, shall, upon conviction, be punished by a fine not exceeding seven hundred fifty dollars or imprisonment not exceeding six months, or both.
   c. Persons Liable. If the industrial user is a corporation, any director, any officer, and any employee or agent with managerial authority is punishable as a principal. If the industrial user is a partnership, any general partner and any employee or agent with managerial authority is punishable as a principal. If the industrial user is a limited liability company, any owner of units in the company and any employee or agent with managerial authority is punishable as a principal.

3. **Recovery of Cost Incurred.**
   In addition to civil liability, the permittee violating any of the provisions of this permit or the City of Laramie Ordinance 1687 or causing damage to or otherwise inhibiting the wastewater disposal system, shall indemnify and hold harmless the POTW and the City of Laramie, including but not limited to any and all expenses, costs, fines, penalties (civil and/or criminal), losses, costs of repair, replacement, or cleaning, testing and monitoring expenses, damages, including personal injury and property damage, and reasonable attorney fees caused by the Permittee as a result of violation of this permit, the City of Laramie Ordinance 1687, or of any applicable categorical standard, or violation of any federal or state law, rule or regulation.

9. APPENDIX F: FPO PILOT AUXILIARY POWER LOAD LIST

Equipment No.	Description	FPO Pilot Motor Size/ Aux Power Draw	Estimated Auxiliary Power Consumption
01 X01	Coal Slurry Bar Mill (ID:18)	150 hp	112.5 kW
01 X08	Coal Slurry Bar Mill Recycle Conveyor	25 hp	18.8 kW
01 X09	Coal Slurry Paddle Mixer	15 hp	11.3 kW
02 P01A	Coal Slurry Feed Pump A(ID:29)	15 hp	11.3 kW
02 P01B	Coal Slurry Feed Pump B(ID:36)	15 hp	11.3 kW
02 R01	Oxycombustor Injection Lance (52AQM21X)	2 hp	1.5 kW
02 R01	Oxycombustor Injection Lance (52AQM22X)	2 hp	1.5 kW
02 R01	Oxycombustor Injection Lance (52AQM51X)	2 hp	1.5 kW
02 R01	Oxycombustor Injection Lance (52AQM61X)	2 hp	1.5 kW
02 R01	Oxycombustor Injection Lance (52AQM62X)	2 hp	1.5 kW
02 C01A	Recycle Flue Gas Blower (ID:40)	157 hp	117.9 kW
01 X03	Coal Feed Conveyor	10 hp	7.5 kW
01 X05	Coal Reclaim Conveyor	40 hp	30.0 kW
01 X06	Coal Bucket Conveyor	50 hp	37.5 kW
08 X01	Air Separator Unit (ID:142)	2,132 kW	2,132.0 kW
03 P02A	BFW Pump (HP) A (ID:68)	350 hp	262.5 kW
03 P01	BFW Treatment Additive Pump (ID:67)	0.75 hp	0.6 kW
09 P09A	Demineralized Water Pump A (ID:138)	5 hp	3.8 kW
09 P07A	Flush / Service Water Pump A (ID:7)	10 hp	7.5 kW
04 P05	Closed Cooling Water (CCW) Pump	50 hp	37.5 kW
09 X02	Air CompressorPackage (ID:151)	75 hp	56.3 kW
04 P02A	Slag Quench Water Pump A (ID:83)	50 hp	37.5 kW
04 P04	Slag Settlers Flush Water Pump (ID:88)	2 hp	1.5 kW

Equipment No.	Description	FPO Pilot Motor Size/ Aux Power Draw	Estimated Auxiliary Power Consumption
04 P03A	Slag Sump Pump A (ID:86)	5 hp	3.8 kW
03 E04	Air Cooled Steam Pressure Condenser (ACC)	4 x 200 hp	600.0 kW
04 E03	Air Cooled Closed Cooling Water (CCW) Fin Fan Cooler	4 x 60 hp	180.0 kW
		Total[1]	**3,688 kW**

[1] – Note that auxiliary power consumption does not include building and building HVAC power consumption. The auxiliary power consumption for the FPO pilot demonstration will be updated through the end of Phase I and into Phase II.

10. APPENDIX G: EXCERPTS FROM DE-FE0027771 SITE SELECTION REPORT

1. INITIAL SELECTION AND ASSESSMENT

In the beginning of 2017, the search for candidate host sites began. Under this task, members of the team reviewed interested sites and began talks with organizations about the feasibility of building the 50 MWth pilot plant at their locations. The locations were categorized and graded based on a set of criteria developed by the team.

1.1 SEARCH FOR POTENTIAL HOST SITES

The team has identified numerous potential host sites that may be a fit for the location of the pilot. Sites were identified and high-level information was obtained for each to prioritize the sites for a deeper assessment.

The sites were selected based on the knowledge of the team about locations and organizations that would be potentially interested in hosting such a pilot, either because it would benefit them by providing steam (or potentially power) and/or carbon dioxide (CO_2) for use in the short term or they have a long-term interest in owning or facilitating lower-cost, low-carbon coal-based power. Organizations that already have an established relationship with the team [e.g., power utilities that are members of the Electric Power Research Institute, Inc. (EPRI)] were among the first contacted, as the prior history facilitated information gathering. The list of the dozen organizations' sites under consideration, along with a high-level description of each site, including its location, is in Table 1.

Table 1. Initial Potential Hosts Assessed

Organization	Description
Archer Daniels Midland Company (ADM)	Located in Decatur, Illinois (IL), this ADM site under a Department of Energy (DOE) project, already captures and stores CO_2 from ethanol production on a large scale and may be able to use steam on-site as well as transport the CO_2 for sequestration.
CPS Energy	Located nearby Southwest Research Institute (SwRI) in San Antonio, Texas (TX), CPS Energy owns several coal-fired power plants that could potentially host the pilot.
Denbury Resources	Denbury has a long history in using CO_2 for enhanced oil recovery (EOR) and has potential sites in both Wyoming (WY) and in the Gulf Coast region that might be close to an existing CO_2 EOR pipeline and be able to use steam.
Great River Energy (GRE) and the Lignite Energy Council (LEC)	GRE has several potential coal-fired sites located in North Dakota (ND) that might be a fit for the pilot. LEC could potentially be interested in being part of the project commensurate with their interest in advancing technology for lignite use.
LG&E and Kentucky University (KU)	LG&E and KU, with several coal-fired power plants located in Kentucky (KY), has a long history in doing CO_2 research and have been actively involved with the University of Kentucky's Center for Applied Energy Research.

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Organization	Description
Midland-Odessa and Permian Basin	This region in TX may have multiple oil- and gas-based (as well as several coal-fired power plant) host site opportunities with considerable interest and need for steam or power and anthropogenic CO_2 for EOR.
National Carbon Capture Center (NCCC)	The NCCC, located in Alabama, has hosted multiple CO_2 capture technologies through the DOE over its nine-year history. The site is next to Southern Company's Gaston coal-fired power-plant and may be a fit for the pilot, given their expertise and experience in working on such research projects.
PacifiCorp	PacifiCorp's Wyodak Coal Power Plant, located in Utah (UT), has expressed an interest in potentially being a host site for the pilot.
Southern Illinois Power Cooperative (SIPC)	The IL region has significant ongoing CO_2 capture and storage-related work and research, and the Advanced Coal and Energy Research Center (ACERC) at Southern Illinois University at Carbondale (SIU-C) could be a location for the host site.
Tata Chemicals	Located in WY, the Green River Soda Ash Plant has been identified as a potential host site that might benefit from steam and be close by CO_2 pipelines.
University of Wyoming (UW)	The Central Energy Plant (CEP), which supplies steam and power to the UW, has been identified as a potential host site with the university interested in partaking in the research on the pilot technology.
Youngstown Thermal (YT)	Located in Ohio (OH), this site provides district heating and has been under consideration for other DOE pilots, which would facilitate the site assessment. The site is interested in hosting the pilot and may bring funding from the Energy Industries of Ohio (EIO).

High-level information has been obtained via teleconferences with appropriate resources from each site or, in some cases, based on face-to-face meetings. E-mail exchanges have also been used to request and obtain information. Several of the most likely sites were also visited by the team to get more detailed, preliminary information.

The information obtained has been used to narrow down the list to the two or three most viable candidates, which will then undergo a more rigorous assessment, including a more in-depth site visit and a more thorough estimation of the costs, benefits, and risks.

1.2 ASSESSMENT AND SELECTION OF SITES

A ranking system was developed to eliminate candidates and provide a merit-based approach to host site selection.

1.2.1 Establishing Initial Selection Criteria

The next step was to reduce the number of remaining potential host sites by utilizing an assessment chart that could be used to compare the information collected on a relative basis. The assessment chart was divided into these four major categories:

1. Business and Financing
2. Physical Attributes
3. Environmental and Permitting
4. Operations and Safety

A weighting system was developed for every item in the assessment chart, since some have a greater impact on the suitability of a particular host site. The preliminary weighting, labeled as "Importance" for each item was given based on the team's assessment of its relative importance. A relative score of "High," "Medium," or "Low" was given for each item with "High" scores given a 9, "Medium" a 3, and "Low" scores a 1. Each host site was then evaluated for each item getting a score from 5-to-0 (best-to-worst). This score was multiplied by the weighted importance to get a numerical value for the site for each item (for example, if the item has an importance of "High" and the site scores a 5, its score for this item is then 45). The values for every item were then summed up to give the final score for the host site, which was then non-dimensionalized into a percentage. In this way, each host site was given a quantitative score between 0 and 100%, relative to each of the other potential sites. Those with the highest scores advanced to the final step of the deeper-dive assessment. The list of items selected to assess the host sites and their relative preliminary importance is given in Table 2.

Table 2. Scoring Criteria and Associated Weighting Factors

Item	Importance
Business and Financing	
Is the organization operating the host site and the host site itself financially stable?	Medium
Are there perceived schedule risks for getting the site ready according to the schedule?	Medium
Does the host site organization have a track record working or contracting with the DOE?	Low
Does the organization have a successful track record with undertaking DOE projects?	Low
Does the organization have a well laid out plan for performing the project and supporting the bid?	High
Does the power industry support the site?	Medium
Does the site have proximity to an international airport and accommodations?	Low
Does the site have special labor limitations or issues (e.g., union labor agreements)?	Medium
Does the site have suitable insurance to cover normal operational risks?	Low
Does the site have the support of the local and/or state governments?	Low
Is the host willing to provide cost share?	High
Is the organization willing to and capable of contracting with other organizations?	Low
Is there a perceived risk of the host site withdrawing from the project?	High
Is there available local or state government funding for the site?	Low
Is there risk associated with the cost share, e.g., is it from a source that may be hard to verify or has contingencies?	High
What is the perceived total cost of the site compared to others?	High
Physical Attributes	
Are there perceived construction risks or access issues?	Medium
Does the host site have the ability to use different coals?	Low
Does the site have a potential need for process steam?	Medium
Does the site have an existing air separation unit or excess oxygen?	Medium
Does the site have existing infrastructure that can be used?	High
Does the site have ready access to coal?	High
Does the site have ready availability to all required utilities?	High
Does the site have sufficient plot space and are there no space restrictions?	High
Does the site have the ability to provide power to the grid?	Low
Does the site have the ability to utilize CO_2 or access to a nearby CO_2 pipeline?	Low
Environmental, Permitting, and Safety	
Are there any other concerns with accessing or providing consumables?	Low
Are there any perceived health, safety, and environment issues?	High
Are there concerns around air permitting for the site?	Medium
Are there concerns around water permitting for the site?	Medium
Does the site have National Environmental Policy Act (NEPA) Environmental Assessment and Categorical Exclusion?	High
Operations	
Are there any noise restrictions at the site that could limit the hours of operation?	Low

Item	Importance
Business and Financing	
Are there any security risks for the host site?	Medium
Cost of operating the site?	High
Does the organization have a successful track record in doing pilot-scale testing?	Medium
Does the organization have experience with any of the core components of the system?	Low
Does the site have existing staff to support the project through all phases?	Medium
Does the site have the ability to support full 24/7 operations?	High
Does the site location have weather-related or altitude concerns?	Low
Does the site, its existing equipment (if any), and its staff support long-term operations?	Medium
Is the skillset needed to perform maintenance available from the site or nearby organizations?	Medium
Is there a risk of changes in future operations of host site that could impact the test plan?	Low

In the first stage of the work, owners (and potential sponsors or funders) of the 12 prospective host sites were contacted to develop a list of candidate sites.

To make the list, prospective host sites had to meet the following minimum requirements:

a. Does the host site have ready access to coal?
b. Does the host site have the ability to receive different coals in the quantities required?
c. Does the site have sufficient plot space and are there any space restrictions?
d. Are there any noise restrictions at the site that could limit the hours of operation?
e. Does the site have the ability to support full 24/7 operations?

Also, the following issues were seen as critical if they would seriously impede or prevent the construction or operation of the pilot plant, and if there was no realistic possibility that they could be resolved:

f. Any special labor limitations or issues?
g. Any perceived Health, Safety, and Environment (HSE) issues?
h. Any perceived air or water permitting issues?

With respect to g and h above, it was helpful if there was a NEPA Environmental Assessment (EA) Categorical Exclusion (CX) determination applicable to the site or its activities.

1.2.2 Reducing Candidates for Detailed Review

During the selection process, the weighted criteria in Section 1.2.1 clarified which sites from the initial search were more desirable than others. The results of this review are shown in Table 3.

Table 3. Score for a Set of Candidate Sites

Organization	No. of 5s	No. of 4s	No. of 3s	No. of 2s	No. of 1s	No. of 0s	Average	No of High Wins	Total Score
NCCC, AL	23	6	4	6	1	2	3.90	5	82.5%
Tata, WY	14	14	12	1	0	1	3.90	1	81.0%
Coal Creek, ND	9	19	10	3	0	1	3.74	2	79.1%
UW CEP, WY	10	15	13	3	0	1	3.69	0	78.7%
Wyodak, WY	10	12	13	1	5	1	3.43	3	74.3%
Youngstown, OH	8	18	9	0	5	1	3.51	0	67.0%

1.2.3 Sites that were Eliminated from Candidacy

Of the approached sites, some were eliminated based on telephone discussions. Below are the sites and a description of the scenarios leading to their elimination:

ADM in Decatur, IL: An exploratory telephone conversation found that there was no interest in hosting the pilot plant and was confirmed by the ACERC at SIU-C.

CPS Energy in San Antonio, TX: CPS is already involved in a large-DOE project and was not prepared to consider another one at this time.

Denbury Resources: Potentially interested in some form of involvement in a pilot plant that would demonstrate the ability to supply CO_2 in WY or U.S. Gulf Coast; however, they could not offer a site for a project based on coal.

LG&E and KU, KY: This site has a 15-year history of looking at CO_2 mitigation projects and concerns about regulatory requirements for waste water. Discussions around specific water contamination issues at a possible site were not held to a conclusion, as a number of other potential sites did not have these issues, and, hence, the site was eliminated from consideration.

Midland-Odessa in Permian Basin Region (West, TX): Considered Xcel Energy's Tolk Plant as the coal plant nearest the Midland-Odessa CO_2 pipeline system, and also, the NRG Limestone lignite-fired Plant at Jewett, TX which has now switched to Powder River Basin (PRB) coal; however, there was insufficient time to establish contact with either of these plants.

Three additional sites were also eliminated during the preliminary assessment process, based on visits to candidate sites, interviews with management in June 2017, and recent developments.

GRE, Coal Creek, ND: As of May 2018, GRE removed themselves from candidacy for being considered as a host site.

SIPC, Marion, IL: ACERC at SIU-C arranged a meeting with SIPC at the Lake of Egypt site in April 2017, and a second visit was made in June 2017 to make a preliminary assessment. As a result and because of a lack of experience with DOE projects and concerns about the availability of financial support from the state being significant drawbacks, this site was eliminated.

Tata Chemicals, Green River, WY: Tata Chemicals removed themselves from candidacy in August 2017. They cited concerns that the capital and time for this project would take away from other areas that have been identified as critical. They were also concerned about the need to take one of the existing boilers offline to have an outlet for the steam produced by the pilot plant. The 50 MWth sizing of the pilot plant is not adequate to replace their largest coal-fired boiler. They stated that any future boiler installation on site would need to be at least as large as their current largest boiler to allow them to decommission that unit.

Wyodak, WY (PacifiCorp/Rocky Mountain Power): Management in Salt Lake City, UT, expressed interest in possibly hosting the pilot plant at the Wyodak plant. The results of a review of key criteria in April 2017 were positive, and a site visit was made in June 2017. As a result of the preliminary assessment, this site was rated fifth out of six. Although the state could be expected to provide some financial support, lack of experience with DOE or pilot projects, weather-related and altitude concerns, and the fact that the pilot plant would have no commercial value long term on this site were significant disadvantages.

YT and EIO: YT expressed strong interest in locating the pilot plant at its Youngstown District Heating site in Youngstown, OH, where EIO already did soil borings and a full environmental study for another DOE project. Meetings with YT in Youngstown, OH were held in April and June 2017. It was decided to eliminate this site based on its ranking of sixth out of six in the assessment chart.

2. FINAL SITE SELECTION

The following three sites were selected for a more thorough assessment of the costs, benefits, and risks during the second half of 2017 based on their merits.

2.1 SITE VISITS AND IN-PERSON ASSESSMENTS

During October 2017, several trips were made to assess each site in person. These visits were used to characterize the capability, willingness, and feasibility in choosing the final candidate host site.

NCCC (Southern Company), Wilsonville, AL: NCCC has the interest and talent required to support the project at the Wilsonville, AL site. The site was rated in the top three remaining candidates, based on the preliminary assessment, which was conducted by teleconference. The wealth of experience and successful track record with DOE projects at this site were significant advantages. This site's position regarding environmental and permitting issues, infrastructure, and project management is also well established. Southern Company, the site owner, has expressed interest in hosting the pilot plant and in contributing cost share.

UW CEP, Laramie, WY: UW's School of Energy Resources (SER) suggested locating the pilot plant on a site adjacent to its CEP, which currently supplies all steam and cooling water for the Laramie campus. The results of a preliminary review of key criteria were positive, and a second site visit was made in June 2017. In the preliminary assessment, this site was rated in the top three remaining candidates that were not eliminated. UW has a successful track record with DOE projects and doing pilot-scale testing. CEP is also experienced with environmental and permitting issues for the site, and can provide infrastructure and project support based on its existing business, which includes approximately 40 MWth of coal-fired boilers.

UW is interested in the supply of steam and electric power to the Laramie campus on a long-term basis as an eventual replacement for the existing coal boilers and supply of power from the grid. UW has expressed interest in hosting the pilot plant and in contributing cost share in-kind. Furthermore, the state could provide financial support for coal with CO_2 capture.

Coal Creek, ND (GRE): Following positive discussions with GRE and LEC, a meeting took place with GRE and other LEC members in Bismarck, ND in June 2017. A visit was made to the Spiritwood site afterwards. However, GRE subsequently offered the Coal Creek site for preliminary assessment, which was conducted by telephone and as a result the site was rated third in the top three candidates that were not eliminated. This site has a successful track record with DOE projects (e.g., the Lignite DryFining project). This site is also experienced with environmental and permitting issues, infrastructure, and project management for its existing business, which includes operating a large lignite-fired power plant.

There is interest in a supply of steam to the site and the adjacent ethanol plant on a long-term basis. GRE has expressed interest in hosting the pilot plant and in contributing cost share in-kind, for which GRE proposes to leverage via LEC and EPRI. Furthermore, the State of ND could be expected to contribute cash via the LEC up to 50% of a 20% cost share (approximately $7 million) for lignite with CO_2 capture.

As of May 2018, GRE requested that they be removed from candidacy for the pilot plant. At this point a detailed assessment had already been conducted, so Coal Creek is included in the following sections for completeness. It is however, no longer being considered as a primary or backup candidate site.

2.1.1 UW CEP, Laramie, WY

Summary

UW and SER propose to host the pilot on a site adjacent to the UW CEP, which currently supplies steam and cooling water for the Laramie campus. A visit to the site by EPRI and Peter Reineck Associates (PRA) on September 12, 2017 confirmed that a suitable plot could be made available, and that environmental and permitting issues for the pilot are likely to be manageable.

UW is interested in supply of steam from the pilot as an eventual replacement for existing coal boilers. As such, revenues could potentially be available from steam and power supplied to UW to offset costs.

UW indicated an interest to attract the project to Laramie and is considering contributing in-kind cost share. Furthermore, the State of WY could also potentially provide financial support for the project based on its energy-from-coal with CO_2 capture ability.

Proposed Site, Physical Infrastructure, and Schedule

The pilot would require 2.3 acres, including large spaces between equipment, which is considerably larger than the existing CEP. However, potential plots are available west of the CEP, where the main units (highlighted in green in Figure 1), including the vacuum-pressure swing adsorption (VPSA) air separation unit (ASU), would be sited, and to the north, where new coal handling facilities would sit close to the existing coal scale and grizzly.

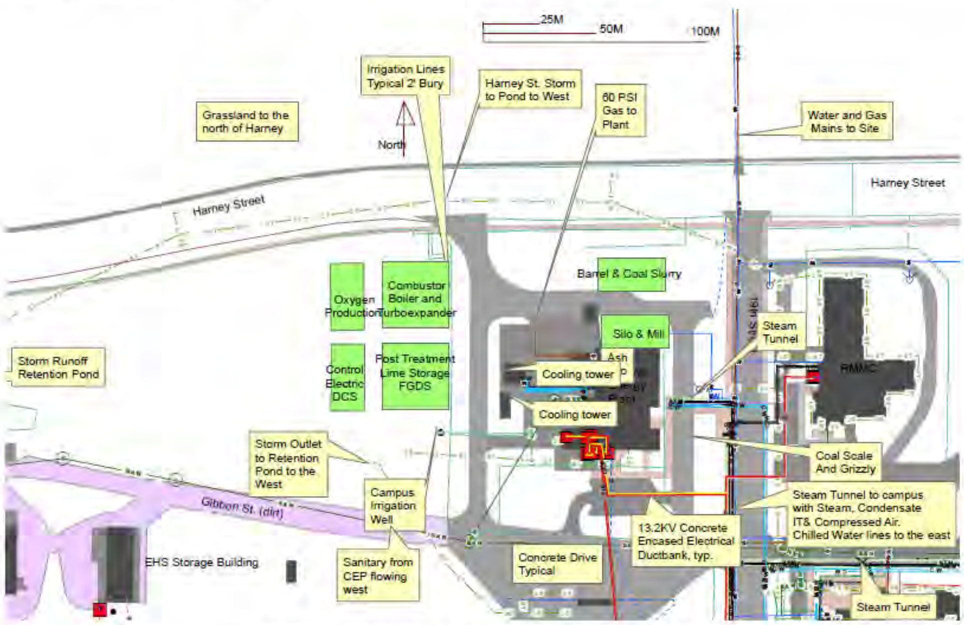


Figure 1. University of Wyoming Proposed Site

Coal is received in trucks and loaded into silos at the site. The pilot could use the existing grizzly for unloading and coal handling, but would need a separate 1,000-ton coal silo (3-4 days' supply) and coal slurry equipment, which would be sited north of the CEP. The slurry would be pumped to the combustor on the west side. There are minimal underground structures or utilities beneath the north and west sides of the CEP. There is a natural gas line, a water well, and some irrigation lines.

Using PRB as the main coal for the test program would be highly desirable for obtaining cost share from WY sources. Each of the two alternate coals, lignite and Twenty-mile (bituminous), would be run for demonstration purposes.

5.4 MWe of power could be purchased from Rocky Mountain Power (RMP). Spare breakers are available and, hence, the pilot may not need new electrical service. The local grid has reliability issues. Two diesel generator sets are available that would provide stand-by backup power generation for the on-site equipment.

UW would take steam from the pilot during the test program to supplement steam from the CEP. However, since UW cannot take all the steam produced during the summer, a steam turbine (ST) would need to be included. The ST and associated electrical interconnections will add cost, but in turn will provide power revenue.

UW has a need for 6-10 MWe, which is broadly similar to the net power that would be produced by the pilot. Balancing supply with demand by exporting any excess power to RMP would incur additional cost for connecting to the grid, so other options, such as turning down the pilot plant at times when UW steam and power demand are low will be explored.

Boiler water quality requirements are different (existing plant vs. pilot), so a heat exchanger will be needed to isolate the supercritical-steam system of the pilot from condensate returning from the campus system.

The project budget should include extra costs associated with winterization, and possibly building cladding. While UW has a requirement for visual aesthetics, exemptions may be possible.

The UW Board of Trustees would need to approve participation in the project.

Host Organization Resources

Training of UW staff will be needed on new equipment, which includes a ST, turbo-expander, VPSA ASU, and others. Coal slurry needs some human interaction, but most of the remaining system is automated, and will be incorporated within the existing distributed control system (DCS) (currently by Emerson).

UW would plan to provide infrastructure and project support based on existing CEP operations, sharing existing and additional operators and maintenance staff. UW would strongly prefer to hire staff, and then sub-contract them to the project. Graduate students would be a good fit for several roles in the project. UW would welcome visits by outside entities to observe operations.

Environmental and Permitting

The NEPA review process would be required for a DOE federally funded project on this site, including an Environmental Impact Volume to decide which of the three levels of NEPA review is required. This effort is to be included and budgeted as part of a continuation of this project.

The site has noise abatement requirements in place. UW advised that "hospital-grade" noise reduction is required, which will likely add to the project costs. Neighbor concerns about noise, any visible emissions during startup, and a number of coal trucks could be an issue for this site. This may create costs for potentially noisy cooling solutions, such as air coolers.

A new stack (approximately 83' tall) will be required, which will release moist CO_2. This stack needs to be designed to minimize the water vapor plume in cold conditions and address CO_2 corrosion of stack. A new permit would be required.

2.1.2 NCCC (Southern Company), Wilsonville, AL

Summary

A visit to NCCC by EPRI and PRA on September 15, 2017 confirmed a suitable plot could be made available by the end of FY2019. NCCC's infrastructure and project management capabilities would be more than adequate to support the project.

Cost-share options to be investigated include collaborative funding through EPRI from Southern Company and other EPRI members. Clear Path and other project partners may be interested. Seeking cash and/or co-funding from Southern Company may be worthwhile. However, it should be noted that the Southern Company has been developing a competing oxy-combustion technology. No known state or local funding sources would be available to support the pilot project at this site, and there will be no revenues from steam or power supplied to offset costs.

Proposed Site, Physical Infrastructure, and Schedule

The proposed plot, which is approximately two-plus acres in size, is now occupied by gasification test equipment. Figure 2 shows the layout and terrain of the existing infrastructure at NCCC. However, all the above-ground structures, along with any existing on-site underground utilities, will be demolished by October 1, 2019. Foundation pilings may be left in place, and the control room will remain. There is a possibility to save the existing foundation, curbing, and groundwater drainage system, if the timing can be synchronized, which would reduce pilot-project costs.

Existing coal crushing equipment would be demolished, but covered shed storage (approximately 1,000-tons coal capacity) and a conveyor could remain. Options for delivery of coal include rail-car delivery in 100-car trains to the adjacent Plant Gaston, where some of the coal could be used, and the balance transported by truck to the NCCC. Another option would be to truck coal from Plant Miller (located in North Birmingham, AL). Support by coal mining companies could help to develop creative train delivery options.

An electric (15 MWe) feed exists, whereas the pilot needs only 5.6 MWe. On-site backup capacity is provided by a 1.7 MWe diesel generator, which allows for controlled shutdown. Three existing 30,000-gallon propane tanks are scheduled to be removed, but could be saved to enable the pilot to use propane for startup instead of natural gas, which would require a one-mile pipeline from Plant Gaston. Demineralized water and other utilities are available on site.

Steam produced by the pilot would have to be condensed, as it is not feasible to supply steam or power from the pilot to the NCCC or Plant Gaston. An air-cooled condenser is recommended as the best solution to demonstrate the once-through steam generator (OTSG).

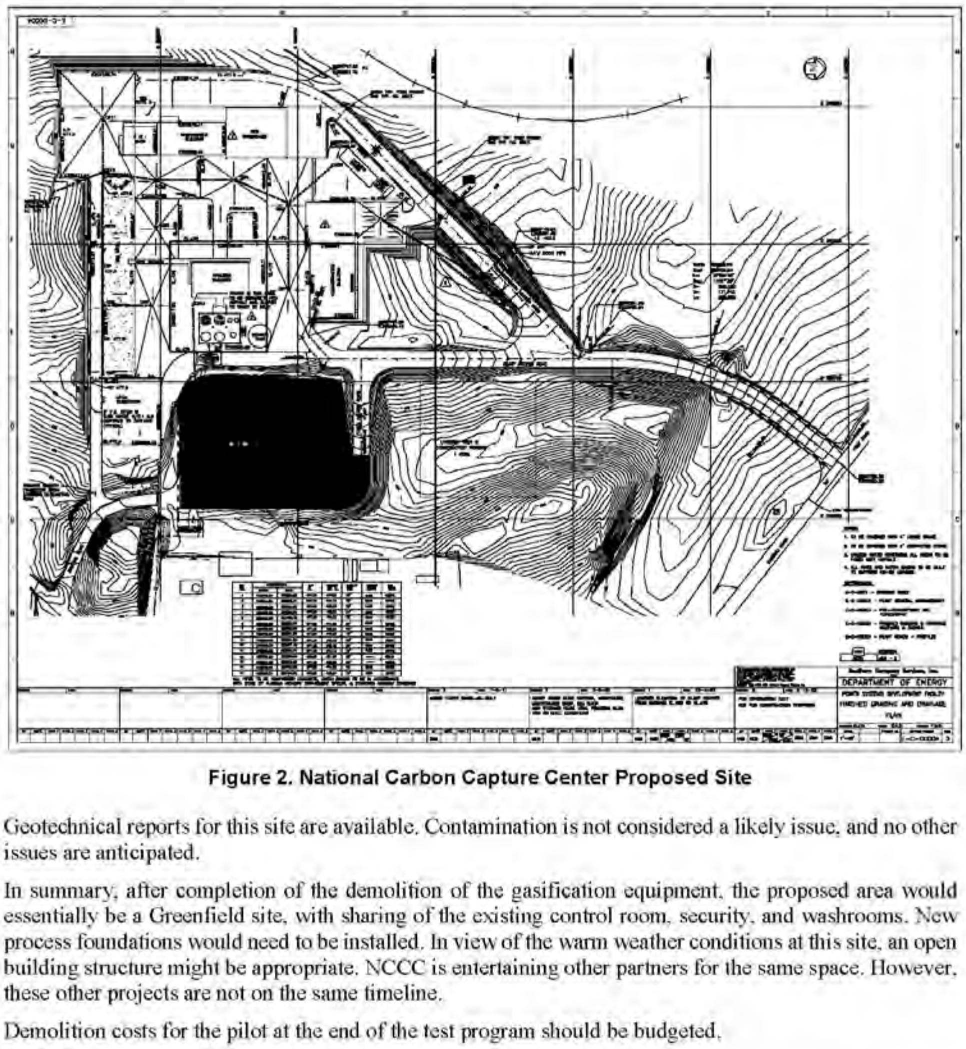


Figure 2. National Carbon Capture Center Proposed Site

Geotechnical reports for this site are available. Contamination is not considered a likely issue, and no other issues are anticipated.

In summary, after completion of the demolition of the gasification equipment, the proposed area would essentially be a Greenfield site, with sharing of the existing control room, security, and washrooms. New process foundations would need to be installed. In view of the warm weather conditions at this site, an open building structure might be appropriate. NCCC is entertaining other partners for the same space. However, these other projects are not on the same timeline.

Demolition costs for the pilot at the end of the test program should be budgeted.

Host Organization Resources

The project would need to buy everything, except sharing of the control room and utilization of DCS system may be possible, subject to DOE agreement.

Staffing from the NCCC is available to support all defined roles [project manager (PM), operators, maintenance, chemist lab, etc.]. Fractional people power can be accommodated readily at the NCCC.

Rent is not charged for site use. Since NCCC is a guest on the Alabama Power property, and hence, does not pay rent. Process costs are direct pass through with no mark-up. The project would pay a mark-up on utilities. Office costs are not charged separately.

Environmental and Permitting

A recent NEPA study (2014) was performed, as an EA, with a finding of no significant impact. This study will need to be repeated for this project.

There are no local ordinances regarding noise, and no nearby neighbors. However, NCCC has a hearing conservation program in place. There is no need for zero water discharge. Water discharges would be handled via Plant Gaston. Permits would be handled by Southern Company Services (SCS), but other resources may be needed, which are available within SCS.

2.1.3 Coal Creek, ND (GRE)

Summary

A visit to Coal Creek by EPRI and PRA on September 13, 2017 confirmed a suitable plot could be made available. There are several potential cost share options at this site, which may be investigated further. These include GRE in-kind cost share, which GRE proposes to leverage via the LEC. There is also the option of using collaborative funding through the GRE and other EPRI members. North Dakota is likely to contribute cash (from a coal severance tax) via the LEC of up to 50% of a 20% cost share (approximately $10 million) for lignite with CO_2 capture.

There will be no revenues available from steam or power supplied to offset costs.

Proposed Site, Physical Infrastructure, and Schedule

Two potential plots for locating pilot equipment are available at the Coal Creek plant, each with two-plus acres available. The preferred plot, shown in Figure 3, is approximately 3.1 acres on former railroad sidings, and is located closer to the coal supply. The second potential plot, a current laydown storage area (bottom center of aerial view below), may be used for a future ammonium sulfate scrubber project. There are limited underground structures (e.g., water) in the proposed plot. It was noted that other projects may be run concurrently, so there may be some competition for the laydown area on the site.

No coal unloading facility (from railcars) is available at the Coal Creek site (which receives virgin lignite from a nearby mine via a conveyor), and this would need to be added to receive other coals (PRB or bituminous) by railcar. The project would need to budget for this, including dust control. Support by coal mining companies could help to support train delivery options.

Sufficient electricity (5.4 MWe) to operate the pilot could be purchased from the host site. The Coal Creek plant could supply power from the switchyard. GRE has minimal stand-by backup power generation (2 x 3 MWe), but this would not be available for the pilot.

Natural gas capacity may already be consumed by existing plant uses. The pilot would need to arrange for propane to be trucked in for startup, which could trigger an additional safety study. Alternatively, the project could consider adding additional natural gas pipeline capacity, to fuel the pilot during startup.

Steam produced by the pilot would have to be condensed, since high costs make it infeasible to supply steam or power from the pilot to Coal Creek or any nearby facilities. (Supplying steam to the ethanol plant on the Coal Creek site, in place of waste steam supplied by GRE, was also not economically feasible.) An air-cooled condenser is recommended as the best solution.

Demolition costs for the pilot at the end of the test program should be budgeted. GRE would expect the pilot site to be restored to pre-construction conditions. There is no interest by GRE in keeping any parts.

GRE senior staff approvals would be required, followed by approval by the Board of the Cooperative.

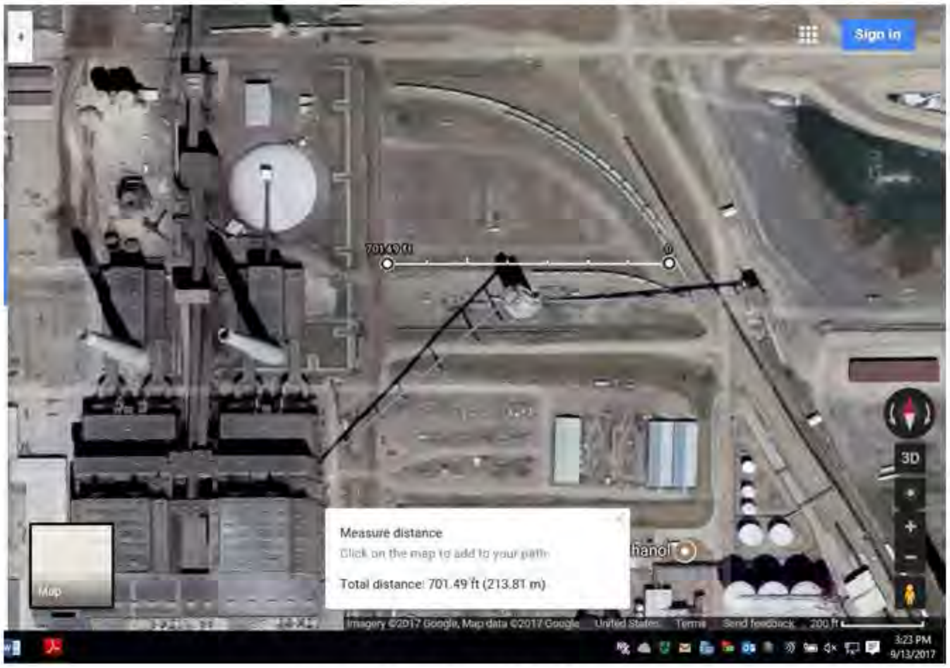


Figure 3. Aerial View of Coal Creek Site

Host Organization Resources

GRE could provide engineering support, supplementing maintenance with shared staff, although training may be needed. GRE is not willing to share operator staffing; however, partial staffing integration with a separate control room could be possible. GRE has a chemical lab on site.

Environmental and Permitting

GRE did a NEPA study for the coal drying (DryFining) demonstration in 2009. It is unclear at this point whether this was a CX, EA, or Environmental Impact Statements (EIS). However, GRE indicated that it was a quick process, which suggests that it may have been a CX.

There appears to be no environmental show-stoppers, but the permitting processes can sometimes take longer than expected. Air permitting is through the North Dakota Health Department and noise is covered under the Occupational Safety and Health Administration (OSHA). Slag produced would need to be evaluated. Environmental issues could be supported in-house by GRE and supplemented by consultants. Slurry from the sulfur scrubber could produce more water than consumed. GRE would need to review river water permit.

- Host Site in Kind (CAPEX-related) $340k in BP 1 is estimated
- Host Site in Kind (OPEX-related) highlighted in green:
  - $456k over 5 years (BP 1-5) for staff
  - $1,778k over 5 years (BP 1-5) for utilities supplied by the site [de-ionized water, slag disposal, waste (gypsum settler) water disposal and site fees]
- Coal Producer or Producers In Kind – $1,320k support for PRB coal based on $10 per ton credit against cost of PRB free on truck mine. Coal producers are being approached.

3.2 VARIABILITY IN THE PRELIMINARY COST ESTIMATION

The likely ranges of cost with probabilities are included in the tables of this section in order to quantify the likelihood of costs changing, including the availability of cost share, as "Probability of a Risk Occurring" and "Impact as a Percentage of the Cost if the Risk Occurs." The potential for an increase in costs, or a decrease in cost share, was calculated by multiplying the probability of a risk occurring by the impact as a percentage of the cost, if that risk occurs.

3.2.1 Potential Increase in Project Cost

The potential increase in the cost of the major items and categories of project cost is $4.0 million in total, as shown in Table 14.

Staffing: The estimated potential for an increase in staffing costs is confined to a pay increase halfway through the project.

Coal: If the cost of coal is higher than expected, the potential for an increase assumes that the higher cost of coal can't be offset by using less.

Utilities: The estimated costs are based on estimates provided by UW and others. The potential for an increase assumes higher than expected cost.

FPO Loop, Turbo-expander, and ASU: These CAPEX estimates include an allowance of 15-20%, so no additional provision is necessary.

Other CAPEX: Estimates for these items, primarily additional equipment required at this site, are approximate.

Building Winterization: No provision for a potential increase in costs was made as Jacobs' estimates appear conservative.

OSBL and Civil Works: Estimates for these items are approximate and did not include any allowances. It is considered likely that these costs will increase as the existing site may have unexpected costs.

Table 14. Risk of Project Cost Increases

Item/ Category	BP 1-5	Probability of Risk Occurring	Impact as % of Cost if Risk Occurs	Value ($k)
Staffing	$4,101	30%	3%	$37
Coal	$13,067	20%	10%	$261
Utilities	$3,458	20%	20%	$98
TOTAL OPEX	$30,360			$402
FPO Loop and Turbo-expander	$24,680	0%	0%	$0
ASU	$16,500	0%	0%	$0
Other CAPEX	$13,116	50%	40%	$2,443
Building Winterization	$7,200	0%	0%	$0
OSBL	$1,700	70%	50%	$595
Civil Works	$1,700	70%	50%	$595
TOTAL CAPEX	$64,896			$3,633
Detailed Engineering	$6,490	0%	0%	$0
TOTAL PROJECT COST	$101,746			$4,035
Potential Increase in Project Cost	$4,035			
Total PROJECT COST Including Potential Increase	$105,780			

3.2.2 Potential Decrease in Cost Share Available

The potential decrease in the major items of cost share is $9.1 million in total, as shown in Table 15.

Cost Share Co-Funding (Cash): The calculation assumes it is 50% probable that only 50% of the CAPEX equipment for power production and transmission is contributed by UW.

Revenue from Sale of Outputs: Power and steam pricing may be conservative, as they are based on current cost information provided by UW, and volumes are realistic. It is assumed that a further 20% discount is 50% probable.

Cost Share in Kind

CAPEX-related: The cost estimate is equal to 10% OSBL and civil works, and is considered realistic.

OPEX-related Staff: The cost estimate is equal to the costs of 1.25 persons and consider realistic.

OPEX-related Utilities: It is assumed that securing the full amount is 50% probable since the amount has to be negotiated.

LEC: It is considered likely that LEC will contribute this level of funding as a minimum.

Phase 3 Award Recipients

ITEA FPO Loop: Considered a given that ITEA will contribute this level of in-kind contribution.

GE Turbo-expander: Considered reasonable to expect 20% in-kind contribution from a project partner for a relatively standard item.

ASU Provider: A 20% in-kind contribution is considered a maximum for an industrial gas company.

Coal Producer: The project may be unsuccessful in negotiating any contribution.

Table 15. Risk of Cost Share Decreasing

Cost Share Item/ Category	BP 1-5	Probability of Risk Occurring	Impact as % of Cost if Risk Occurs	Value ($k)
Co-Funding (Cash) CAPEX/Equipment-related [1]	$18,396	50%	50%	$4,599
Revenue from Sale of Outputs	$12,940	50%	20%	$1,294
Cost Share In Kind				
CAPEX-related	$340	0%	0%	$0
OPEX-related Staff	$456	0%	0%	$0
OPEX-related Utilities	$1,778	50%	100%	$889
Total Host Site	$33,909			$6,782
LEC	$3,500	0%	0%	$0
Phase 3 Award Recipients				
ITEA FPO Loop	$6,440	0%	0%	$0
GE Turbo-expander	$336	0%	0%	$0
ASU Provider	$3,300	50%	100%	$1,650
Coal Producer	$1,320	50%	100%	$660
TOTAL COST SHARE	$48,805			$9,092
Potential Decrease in Cost Share	-$9,092			
Total COST SHARE Including Potential Decrease	$39,713			

[1] Assume 100% in BP 1.

3.3 PERMIT PLAN FOR UW CEP SITE

There are a variety of permits, ordinance compliances, and interconnection issues that would apply to the construction, commissioning, and operation of the pilot plant, if located at the UW CEP site. While the detailed requirements for each component of this permit plan section are not yet fully understood, a budget estimate of $100,000 for the permitting costs is considered reasonable based on prior experience in other demonstration projects. The currently available information for each of the permits, ordinance compliance, and interconnection issues is summarized below.

3.3.1 Local Permits and Ordinances

The City of Laramie's local ordinances should be followed. While the City of Laramie building permit process can be long, it is well understood by the UW, and will have to start in the early phases of the project to ensure that it does not hinder the project progression. Generally, permits have to be approved before new facilities can be commissioned. There may be scope to incorporate the proposed project facility under the existing permits for the CEP; however, this has not yet been fully explored. The university also has an internal design review committee that would need to approve the plant design. The project team would need to understand how this proposed pilot plant would work within the overall scheme of the campus master and campus utility master plans.

The plans for the proposed facility would need to be reviewed by the city and state for international building code compliance, and to identify any issues with zoning or local City of Laramie ordinances. At least three weeks should be allocated from receipt of the plan and specification set, as this process can take some time. There may be a possibility of using a "Construction Manager At-Risk" method of contracting, which could allow for construction to start earlier. When the UW has used this method in the past, typically the foundation package was the first to be released so that work could begin, while other parts of the design were being finalized. In such cases, it has been typical that three stages of bid packages were released at separate times.

3.3.2 Sound Issues, Permits

While there may not be specific permits required for acoustic emissions, it has been identified that there is a need to keep all plant equipment at certain noise levels (i.e., hospital-grade acoustical design) as there are residential areas nearby. Consequently, it is understood that the equipment design must take sound issues into account, and that the project would likely incur additional equipment costs. The City of Laramie ordinance (8.40.030 – permissible noise levels) provides limits on noise levels for four different specified zones. If the proposed facility is deemed to be adjacent to a residential zone, the night-time operational noise levels would be restricted to 50 dB(A). If the noises emitted from the proposed facility are deemed to be "periodic, impulsive, or shrill," then a limit of 5 dB(A) would apply. There are less restrictive noise limits, which would apply during construction as well.

3.3.3 Air Quality and Emissions Permits

The proposed pilot plant would have to be permitted through the Wyoming Department of Environmental Quality's Air Quality Division (AQD). Depending on the situation, the plant would need a new source review and could end up with a permit wavier, if the emission numbers were low enough. The plant would most likely be tied to the UW CEP's Title V permit, which would require a new permit, as well as a public input period. This would be the case, even if the plant only planned to operate for three years. AQD recommends a pre-application meeting to shorten the AQD permitting process. Title V permits usually take 18-12 months. In general, a Title V permit is needed for any major source, if:

- Any major source has actual or potential emissions at or above the major source threshold for any air pollutant.
- The major source threshold for any air pollutant is 100 tons per year (this is the default value).
- Lower thresholds apply in non-attainment areas (but only for the pollutant that are in non-attainment).
- Major source thresholds for hazardous air pollutants (HAP) are 10 tons per year for a single HAP or 25 tons per year for any combination of HAP.
- The Environmental Protection Agency generally has not required non-major sources to get permits.
- There is also a possibility that the permit might become a wavier, if emission levels are minimal.

Air Permit Modifications for Standby Generators

CEP has a pair of two 1,250 kW standby generators. The current setup is to let only one run at a time. If both are needed, a new air quality permit will be needed and control changes would have to be made. Standby generation is currently one 1,250 kW generator with a second 1,250 unit as a standby in case the first does not start. They both can run at the same time, but the air quality permit for them would then have to change.

The UW CEP's peak load could be as high as1.5 MW, but typically is less than 1 MW. Additionally, some outage startup procedures could be changed to limit the peak load during an outage to no more than 1 MW. The generators would need to be reprogrammed and the permit changed. The 1,250 kW generators tie into a 4,000 A, 480 V, 3-phase distribution panel that is separated into two halves, with a tiebreaker. Each section has an 800 A spare breaker, which could be upgraded to 1,600 A, if necessary. Loads beyond that will need more investigation and design.

3.3.4 Water Permits

There is no need for zero liquid discharge at the site. It should be considered to polish the blowdown for cooling tower use. The City of Laramie has a high cost for water and there is no de-ionization plant in place. These systems are costly to run and increase water consumption by at least 25%, driving up the raw water costs. A new city water tap can be pricey, if needed.

The CEP facility is fed with a 4" line that has a 3" size meter that is rated for approximately 150 gpm at a 5 psig pressure drop. The meter can be upgraded to a 4" size, which would increase the flow to approximately 220 gpm at 5 psig pressure drop. The increase in meter size increases the monthly base water fee by approximately $200 per month.

3.3.5 Electricity Interconnection

Unique issues at the site include being close to residential areas, limited to trucking coal from the mine or an off-loading facility in town, and issues with cogeneration with RMP, as cogeneration could have a major impact for them. The revenue to RMP for the two main service points for the campus (where the proposed pilot plant would tie in) is presently over $4 million per year.

Also, existing public service commission tariffs are an issue. A special agreement may need to be set up with RMP, as this Schedule 33 can have cost implications to the University, if the cogeneration scheme is not done correctly. Subsequent discussions between the University and RMP have confirmed that the utility will do what is needed to insure project success.

3.3.6 NEPA Study

Since the proposed pilot plant would be built using federal funding, the NEPA process would apply, and a study would be required. The federal funding agency (e.g., U.S. Department of Energy) would need to make a determination on the appropriate level of study, given the details of the planned pilot plant, and the proposed site. In increasing order of cost and level of effort, the possible options include: CX, EA, or EIS. Given that the proposed pilot plant would be sited at an existing operating plant facility, rather than on undisturbed land, it is likely that either a CX or EA type of study would apply, rather than the more costly and lengthy EIS.

3.3.7 Other Permits

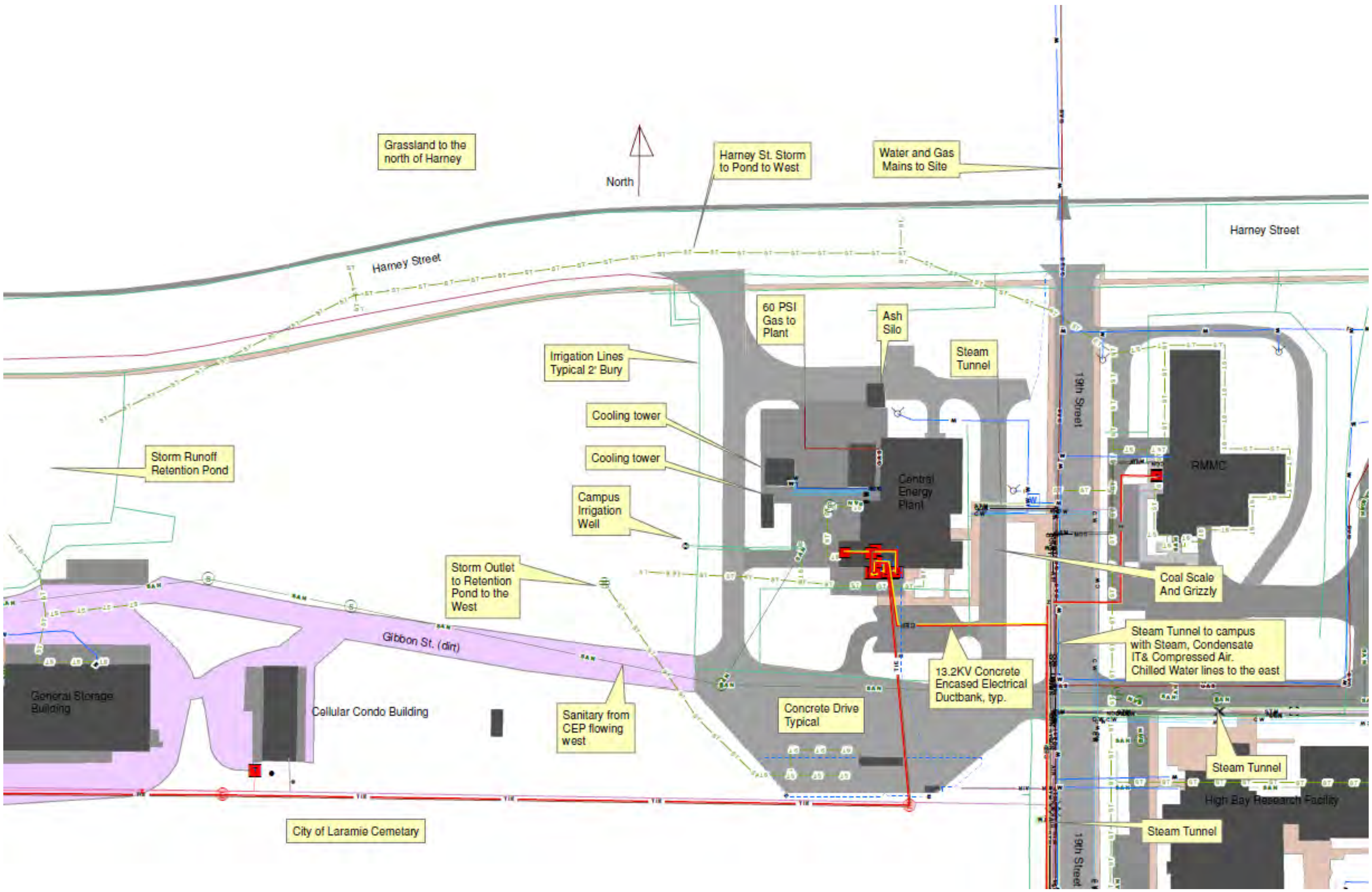
A variety of other permits may be needed:

- Industrial Siting Division
- City of Laramie Building
- State Department of Electrical Safety and Fire Prevention

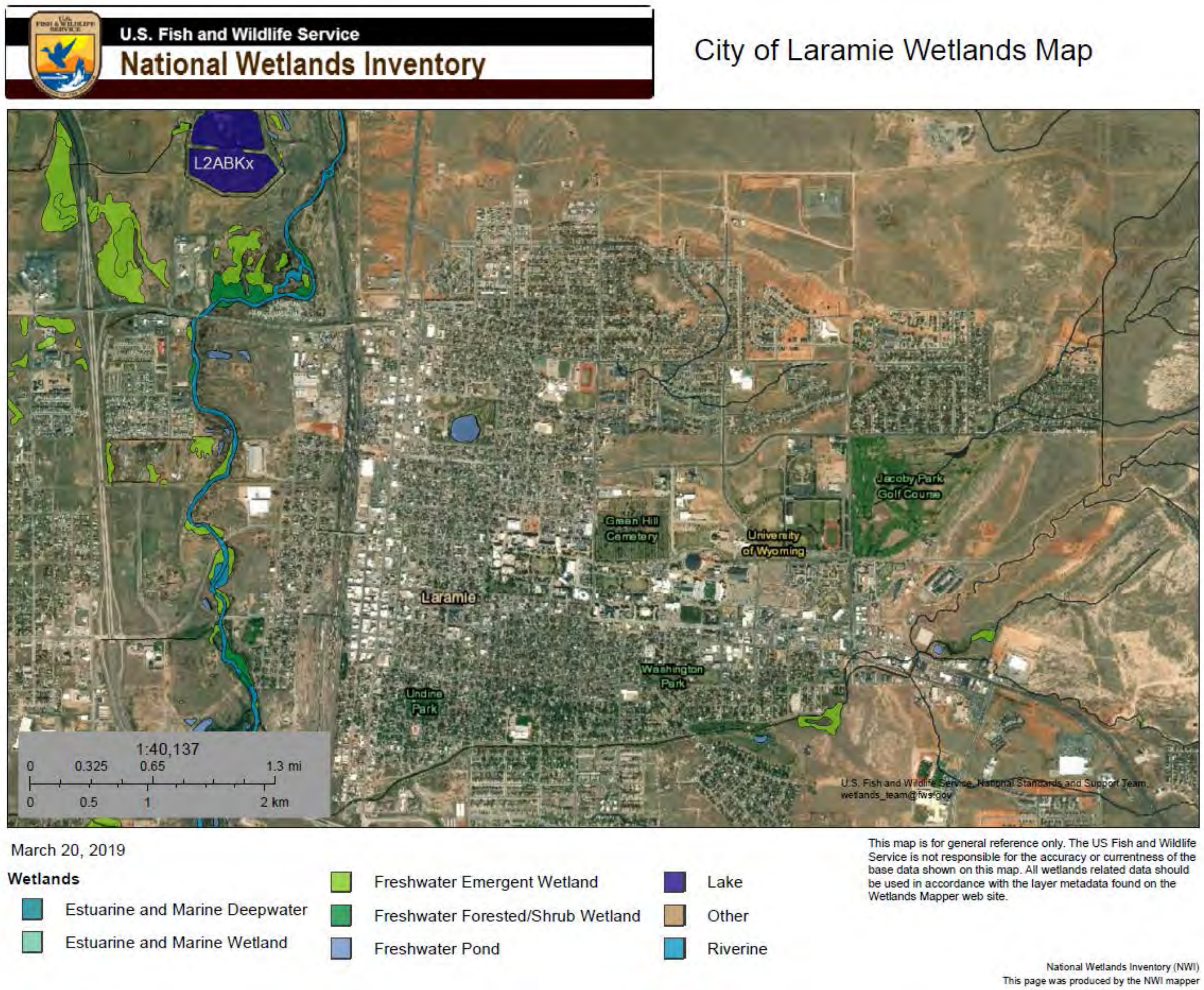
3.3.8 UW Support for the Permitting Process

UW would most likely employ an environmental or engineering consultant for this process. If the pilot project is simpler, it may not require a new operating permit and the modified permit could be done in-house.

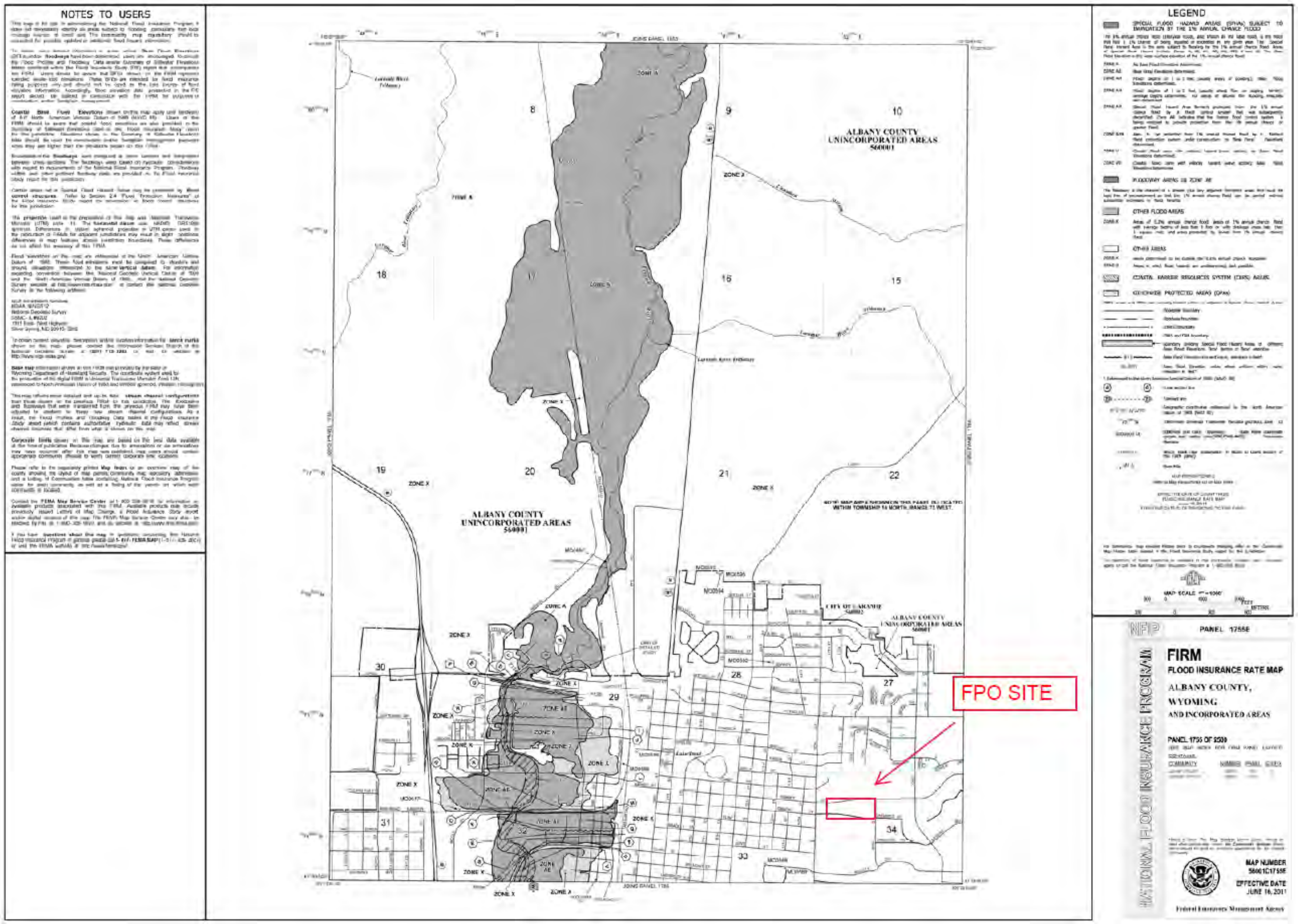
11. APPENDIX H: CEP SITE UTILITY GENERAL ARRANGEMENT



12. APPENDIX I: NATIONAL WETLANDS INVENTORY MAP



13. APPENDIX J: FLOOD INSURANCE RATE MAP



14. APPENDIX K: 1979 CEP GEOTECHNICAL REPORT

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GEOTECHNICAL INVESTIGATION
FOR THE PROPOSED COAL FIRED, CENTRAL
HEATING AND CHILLED WATER PLANT AND
SUPPORT FACILITIES AT THE UNIVERSITY
OF WYOMING, LARAMIE, WYOMING

Prepared For:

THE UNIVERSITY OF WYOMING
MR. ROBERT C. ARNOLD,
DIRECTOR OF PHYSICAL PLANT
UNIVERSITY STATION
LARAMIE, WYOMING 82071

Job No. 5980W

June 20, 1979

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CONCLUSIONS

(1) The proposed coal fired, Central Heating and Chilled Water Plant and support facilities should be founded with straight-shaft piers drilled into bedrock designed for a maximum end pressure of 40,000 psf, a skin friction of 4,000 psf, and a minimum dead load pressure of 10,000 psf.

(2) A satisfactory foundation alternative for the lighter, smaller support facilities, which include the weigh scale, truck hoppers, and transformers, is spread footings placed on the silty sands and weathered bedrock designed for a maximum soil pressure of 2,000 psf or placed on the competent siltstone bedrock designed for a maximum soil pressure of 10,000 psf.

(3) The pavement structure should consist of 6½ inches of asphalt for a full depth asphalt structure or 4 inches of asphalt and 6 inches of base course for an asphalt-base course structure.

(4) Other design details and precautions are discussed in the body of the report.

SCOPE

This report presents the results of a geotechnical investigation for the proposed coal fired, Central Heating and Chilled Water Plant and support facilities at the University of Wyoming, Laramie, Wyoming. This report presents the most desirable type foundation, foundation alternative, allowable soil pressures, water table conditions, and design and construction details.

PREVIOUS INVESTIGATIONS

We previously conducted geotechnical investigation for various facilities on the University of Wyoming campus. Geotechnical investigations have been conducted for the fine arts building as reported under our Job No. 3531W dated December 12, 1968; the reconstruction of the football stadium as reported under our Job No. 3532 dated December 9, 1968; the physical education building as reported under our Job No. 4364W dated July 19, 1972; the law building as reported under our Job No. 4653W dated May 20, 1974; and for the athletic facilities as reported under our Job No. 5802 dated November 6, 1978. The results of those previous investigations have been utilized in evaluating the data from this investigation.

PROPOSED CONSTRUCTION

It is proposed to construct a coal fired, central heating and chilled water plant with support facilities with approximate plan dimensions and locations as shown in Fig. 1. The main structure will house the 60,000 pounds per hour coal fired boilers, the existing relocated gas fired boiler, the electric generators, chillers, and office and control rooms. This structure will be a steel framed structure approximately 145 feet in height. Support facilities will include cast-in-place concrete storage silos, a weigh scale, truck hoppers, ash silo, dust collectors, cooling tower, and transformers. Construction details have not been finalized.

SITE CONDITIONS

At the time of our investigation, the site was vacant. The ground surface sloped downward from the northeast to the southwest with a difference in elevation on the order of 7.5 feet across the proposed site.

SUBSOIL CONDITIONS

Subsoil conditions at the site were erratic. In general, they consisted of 0 to 1 foot of loose, silty sand topsoil, 0 to 21 feet of loose to very dense, silty to very silty sand with scattered gravel and cobble, and 0 to 8.5 feet of weathered siltstone bedrock overlying hard to very hard siltstone bedrock to the depth investigated, 49 feet 6 inches. A 4-foot layer of hard sandstone bedrock was encountered in Test Hole 8 immediately beneath the weathered siltstone bedrock. The silty sand settles moderately to excessively under load and when wetted as indicated by the Swell-Consolidation Test Results presented in Figs. 6, 8, and 9. Gradations for typical samples of the very silty sands are presented in Figs. 12 through 17. The siltstone bedrock varies from being non-expansive to possessing a low swell potential as indicated by the Swell-Consolidation Test Results presented in Figs. 5, 6, 7, 9, 10, and 11. Gradations for typical samples of the siltstone bedrock are presented in Figs. 12 and 14. The sandstone bedrock is non-expansive as indicated by the Swell-Consolidation Test Results presented in Fig.

10. A gradation for a typical sample of the sandstone bedrock is presented in Fig. 15. The strength parameters for a typical sample of the siltstone bedrock were determined by the direct shear test method. These test results are presented in Fig. 18. The siltstone bedrock was found to have an angle of internal friction of 59.5 degrees and a cohesion of 0.9 ksf.

Free water was encountered in all of the exploratory holes except Test Holes 3 and 4 at a depth of 32 to 39 feet below the existing ground surface at the time of drilling.

FOUNDATION RECOMMENDATIONS

We believe the most desirable type foundation for the proposed coal fired, Central Heating and Chilled Water Plant and support facilities is straight-shaft piers drilled into bedrock. The following design and construction details should be observed:

(1) Piers should be designed for a maximum end pressure of 40,000 psf and a skin friction of 4,000 psf for the portion of pier in bedrock.
(2) All piers should be designed for a minimum dead load pressure of 10,000 psf based on pier end area only.
(3) All piers should penetrate a minimum of 4 feet into the unweathered bedrock (darkened portion of Logs of Exploratory Holes, Figs. 2 and 3).
(4) Piers should have a minimum length of 10 feet.
(5) Piers should be reinforced their full length with at least two #5 bars to resist tension.
(6) A 4 inch void should be provided beneath the grade beams to prevent the soils from exerting uplift forces on the grade beams and to concentrate the pier loadings.

(7) Piers should be properly cleaned and dewatered prior to the placement of concrete. Groundwater was not encountered during our investigation, and we do not believe it will present a problem to pier drilling. In no case should concrete be placed in more than 6 inches of water.

(8) Foundation walls should be designed to resist the lateral forces exerted by an equivalent fluid pressure of 50 pcf. This assumes the on-site soils will be utilized for backfill material.

FOUNDATION ALTERNATIVE

We believe a satisfactory foundation alternative for the smaller and lighter structures, which would include the weigh scale, truck hoppers and transformers, is spread footings placed on either the silty sand, weathered siltstone bedrock or siltstone bedrock. The following design and construction details should be observed:

(1) Footings placed on the silty sand or weathered siltstone bedrock should be designed for a maximum soil pressure of 2,000 psf. Footings placed on the more competent siltstone bedrock should be designed for a maximum soil pressure of 10,000 psf. Under these pressures we estimate that total settlement will be on the order of 1 inch and maximum differential settlement across the proposed structures will be less than 3/4 of an inch.

(2) Continuous foundation walls should be reinforced top and bottom to span an unsupported length of 10 feet.

(3) Local soft pockets of soil found within the loaded depth of the footings should be removed and the footings extended to the lower firm soils.

(4) Exterior footings should be provided with adequate soil cover above their bearing elevation for frost protection. We recommend that at least 3 feet of soil cover be used at this site.

FOUNDATION CONCRETE

The water soluble sulfate content of the silty sands and siltstone bedrock was found to range from 0.01 to 0.24 percent. The conditions, therefore, range from negligible to severe for the potential sulfate attack of concrete. We recommend that Type II modified low C3A or Type V cement be used for all concrete which will be in contact with the ground.

GROUND FLOORS

Both the silty sands and siltstone bedrock are suitable to support slab-on-grade construction. All slabs should be separated from bearing members with a positive expansion joint and adequately reinforced. A 4 inch layer of free draining gravel should be provided beneath the floor slabs to distribute the floor loadings. The gravel should consist of aggregate having a maximum size of 1½ inches, at least 50% retained on the #4 sieve, and less than 10% passing the #200 sieve.

UNDERDRAIN SYSTEM

Although free water was encountered at a depth considerably below proposed construction elevations, we believe the basement in the area of the coal fired boilers should be protected by an underdrain system. It has been our experience in areas such as this where excavations are made into an impervious bedrock that local perched water tables can develop within the excavation after irrigation of the landscaping has started.

Therefore the lower level of the structure should be protected by an underdrain system. The underdrain system should consist of drain tile installed in a gravel filled trench around the perimeter of the structure at least 2 feet below the lower floor slab leading to a sump where water may be removed by pumping or gravity flow. The gravel beneath the floor slab should connect into the underdrain system.

PAVEMENT STRUCTURE

The required pavement section for the proposed streets will depend upon the soils used in construction, the amount of traffic, type of traffic, and overall drainage. It is essential that positive drainage be provided for the paved areas. We anticipate the subgrade soils will consist of either the silty sands or the siltstone bedrock. The moisture-density relationships for a typical sample of the very sandy clay-silt soils was determined in accordance with ASTM D698-70. Test results are presented in Fig. 19. The California Bearing Ratio was determined for a remolded specimen of this typical sample. The material was remolded at optimum moisture content and compacted in the test cylinder to approximately 100% standard Proctor density. The specimen was tested after soaking for 96 hours. The load-penetration curve for the CBR test is presented in Fig. 20 and summarized in Table II. Test results indicate the material has a CBR value on the order of 5.

The pavement structure should consist of either 6½ inches of asphalt for a full depth asphalt structure or 4 inches of asphalt and 6 inches of base course for an asphalt-base course structure. The granular base course should meet the requirements of Section 304 of the Specifications for Road and Bridge Cosntruction of the Wyoming Highway Department and be compacted to at least 100% standard Proctor density. The asphalt should meet the requirements of Section 403 of the same specifications and placed to at least 98% Marshall density. Subgrade soils should be scarified for a minimum depth of 18 inches and be recompacted to 100% standard Proctor density.

SURFACE DRAINAGE

The following drainage precautions should be observed during construction and maintained at all times after the structures have been completed:

(1) Excessive wetting or drying of the foundation excavation should be avoided during construction.

(2) Backfill around the structures should be moistened and compacted to at least 85% standard Proctor density.

(3) The ground surface surrounding the exterior of the structures should be sloped to drain away from the structures in all directions. We recommend a minimum slope of 6 inches in the first 10 feet.

(4) Roof downspouts and drains should discharge well beyond the limits of all backfill.

(5) Landscaping which requires excessive watering and lawn sprinkler heads should be located at least 10 feet from the foundation walls of the residence.

MISCELLANEOUS

Our exploratory borings were spaced as closely as feasible in order to obtain a comprehensive picture of the subsoil conditions; however, erratic soil conditions may occur between test holes. If such conditions are found in the exposed excavation, it is advisable that we be notified to inspect the foundation excavation.

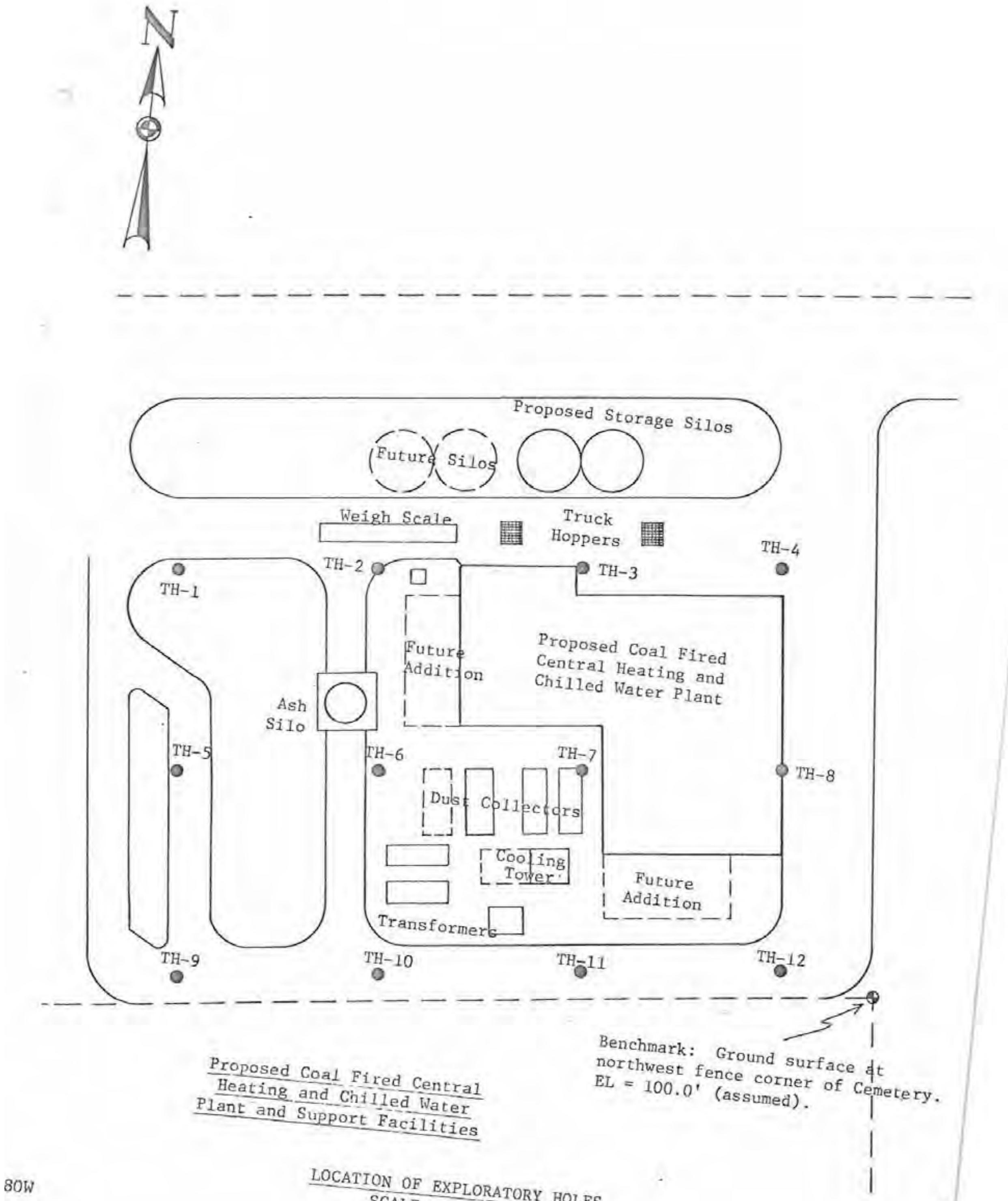
CHEN AND ASSOCIATES, INC.

BY ______________________
Kenneth E. Temme, P.E.

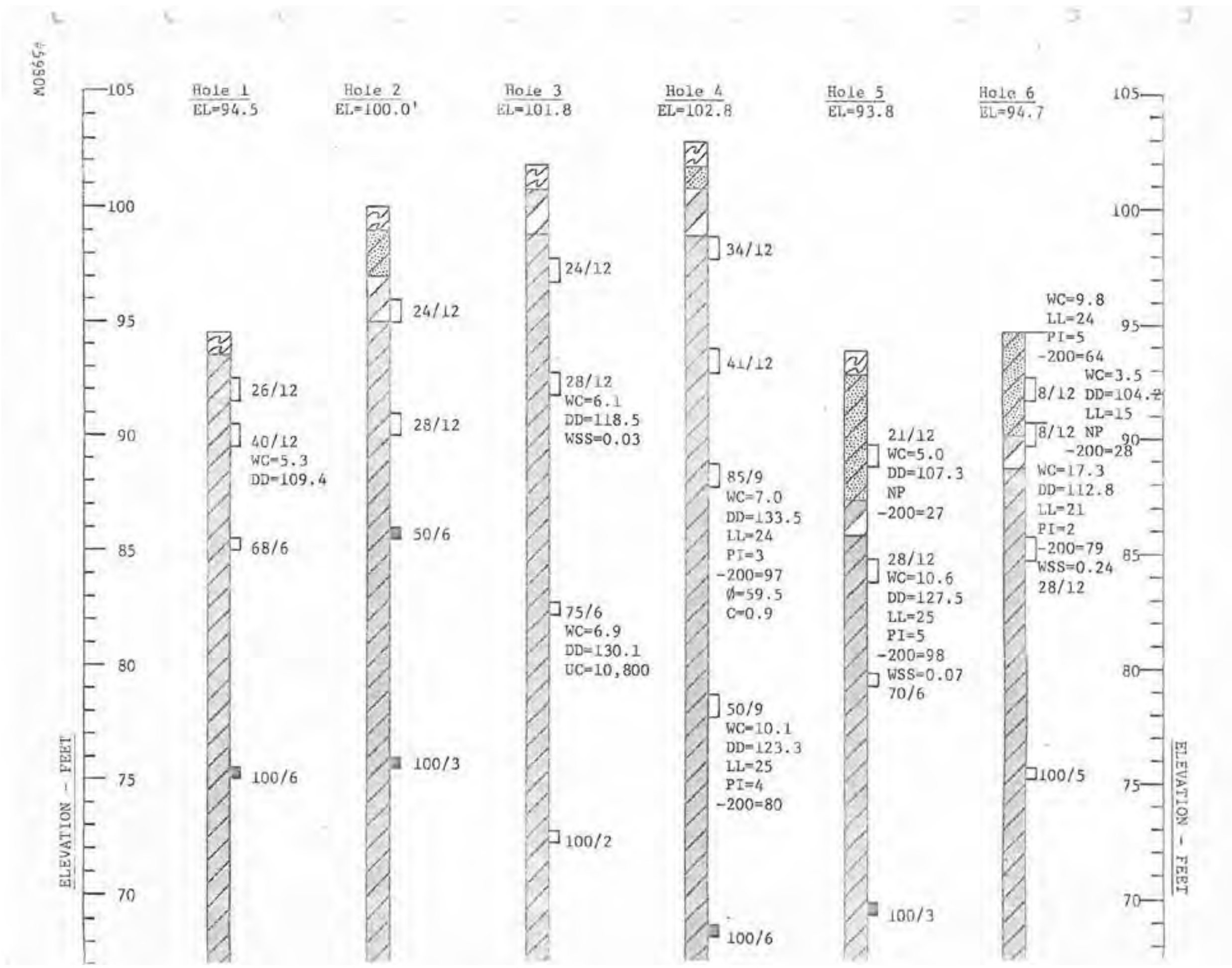
KENNETH E. TEMME
REGISTERED
2196
PROFESSIONAL ENGINEER
STATE OF WYOMING

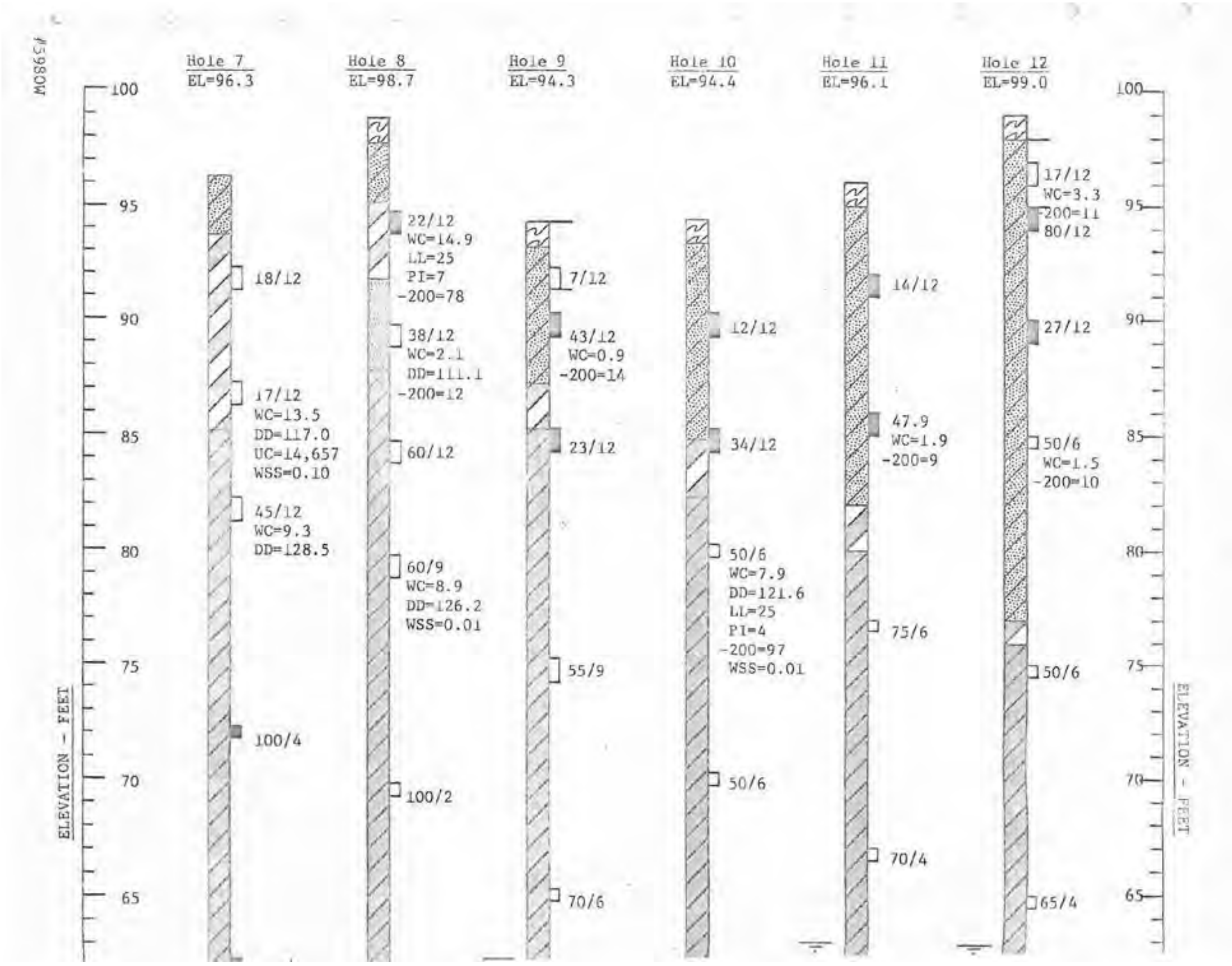
REVIEWED BY ______________________
Harold Hollingsworth, Jr., P.E.

KET:bec
cc: Volk and Harrison



LOCATION OF EXPLORATORY HOLES
SCALE: 1" = 30'


M0865A
Hole 1
EL=94.5
Hole 2
EL=100.0'
Hole 3
EL=101.8
Hole 4
EL=102.8
Hole 5
EL=93.8
Hole 6
EL=94.7
105
100
95
90
85
80
75
70
ELEVATION - FEET
26/12
40/12
WC=5.3
DD=109.4
68/6
100/6
24/12
28/12
50/6
100/3
24/12
28/12
WC=6.1
DD=118.5
WSS=0.03
75/6
WC=6.9
DD=130.1
UC=10,800
100/2
34/12
41/12
85/9
WC=7.0
DD=133.5
LL=24
PI=3
-200=97
Ø=59.5
C=0.9
50/9
WC=10.1
DD=123.3
LL=25
PI=4
-200=80
100/6
21/12
WC=5.0
DD=107.3
NP
-200=27
28/12
WC=10.6
DD=127.5
LL=25
PI=5
-200=98
WSS=0.07
70/6
100/3
WC=9.8
LL=24
PI=5
-200=64
WC=3.5
8/12 DD=104.2
LL=15
8/12 NP
-200=28
WC=17.3
DD=112.8
LL=21
PI=2
-200=79
WSS=0.24
28/12
100/5


WO896#
Hole 7
EL=96.3
Hole 8
EL=98.7
Hole 9
EL=94.3
Hole 10
EL=94.4
Hole 11
EL=96.1
Hole 12
EL=99.0
ELEVATION - FEET
18/12
17/12
WC=13.5
DD=117.0
UC=14,657
WSS=0.10
45/12
WC=9.3
DD=128.5
100/4
22/12
WC=14.9
LL=25
PI=7
-200=78
38/12
WC=2.1
DD=111.1
-200=12
60/12
60/9
WC=8.9
DD=126.2
WSS=0.01
100/2
7/12
43/12
WC=0.9
-200=14
23/12
55/9
70/6
12/12
34/12
50/6
WC=7.9
DD=121.6
LL=25
PI=4
-200=97
WSS=0.01
50/6
14/12
47.9
WC=1.9
-200=9
75/6
70/4
17/12
WC=3.3
-200=11
80/12
27/12
50/6
WC=1.5
-200=10
50/6
65/4

Legend:

Topsoil, silty sand, loose, scattered gravel, red to reddish brown, moist.

Sand (SM), silty to very silty, loose to very dense, scattered gravel and cobble, red to reddish brown, moist.

Weathered Siltstone Bedrock, firm, red to reddish brown, moist.

Siltstone Bedrock, medium hard to very hard, moderate to highly cemented, red to reddish brown, moist to wet.

Sandstone Bedrock, hard, red to reddish brown, moist.

26/12 Undisturbed drive sample. The symbol 26/12 indicates that 26 blows of a 140 lb. hammer falling 30 inches were required to drive the sampler 12 inches.

100/6 Standard drive sample. The symbol 100/6 indicates that 100 blows of a 140 lb. hammer falling 30 inches were required to drive a standard 2-inch O.D. split spoon sampler 6 inches.

Indicates free water level measured at the time of drilling.

Notes:

(1) Test holes were drilled May 11 through 15, 1979 using a 4-inch diameter continuous flight power auger.

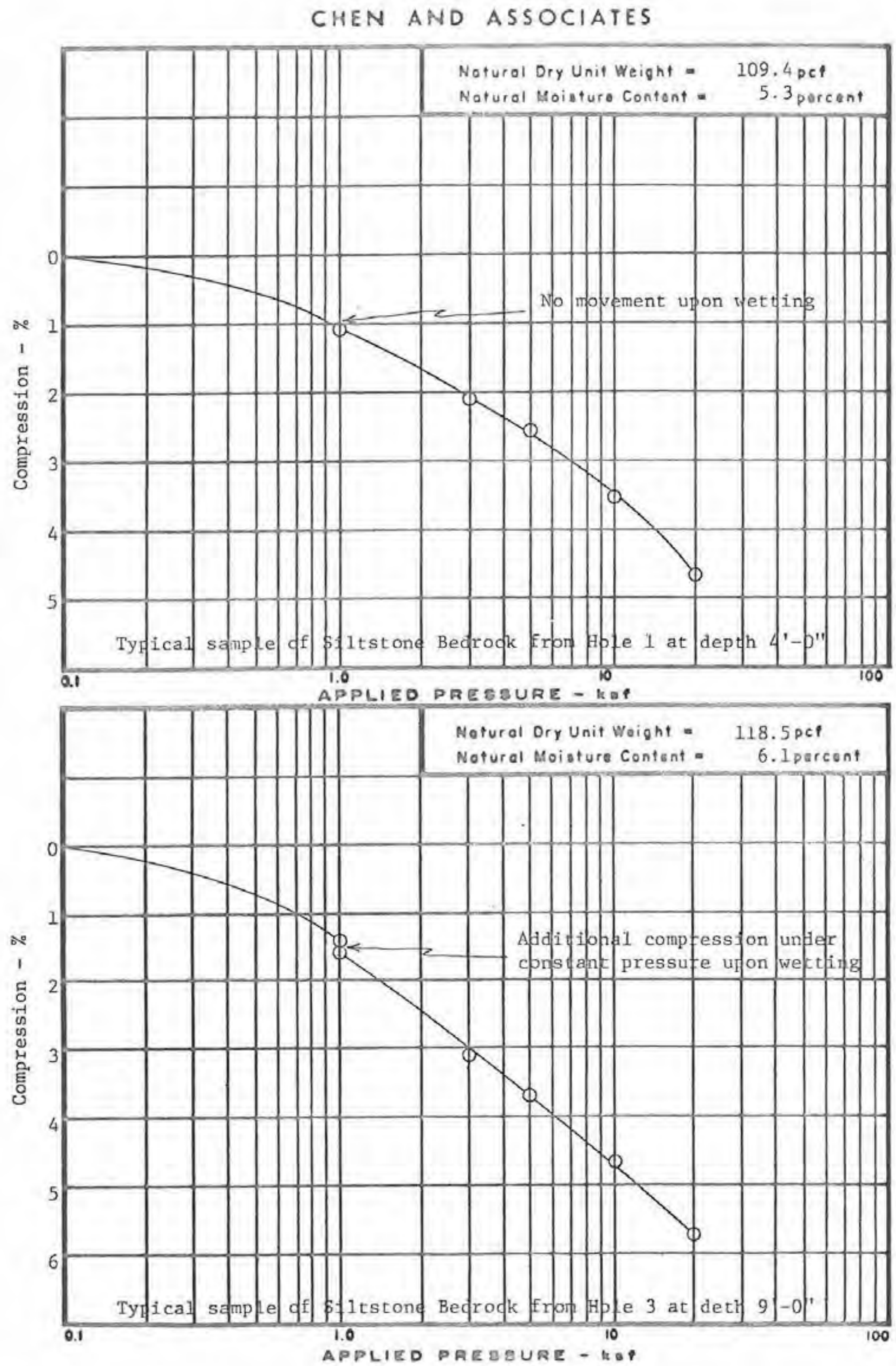
(2) Elevations of test holes refer to the existing ground surface at the northeast fence corner of the cemetery. EL = 100.0' (assumed).

(3) WC = Water Content (%)
DD = Dry Density (pcf)
LL = Liquid Limit (%)
PI = Plasticity Index (%)
NP = Non-plastic
UC = Unconfined Compressive Strength (psf)
-200 = Passing No. 200 Sieve (%)
WSS = Water Soluble Sulfate Content (%)
Ø = Angle of Internal Friction (degrees)
C = Cohesion (ksf)

LEGEND AND NOTES

#5980W

Fig. 4



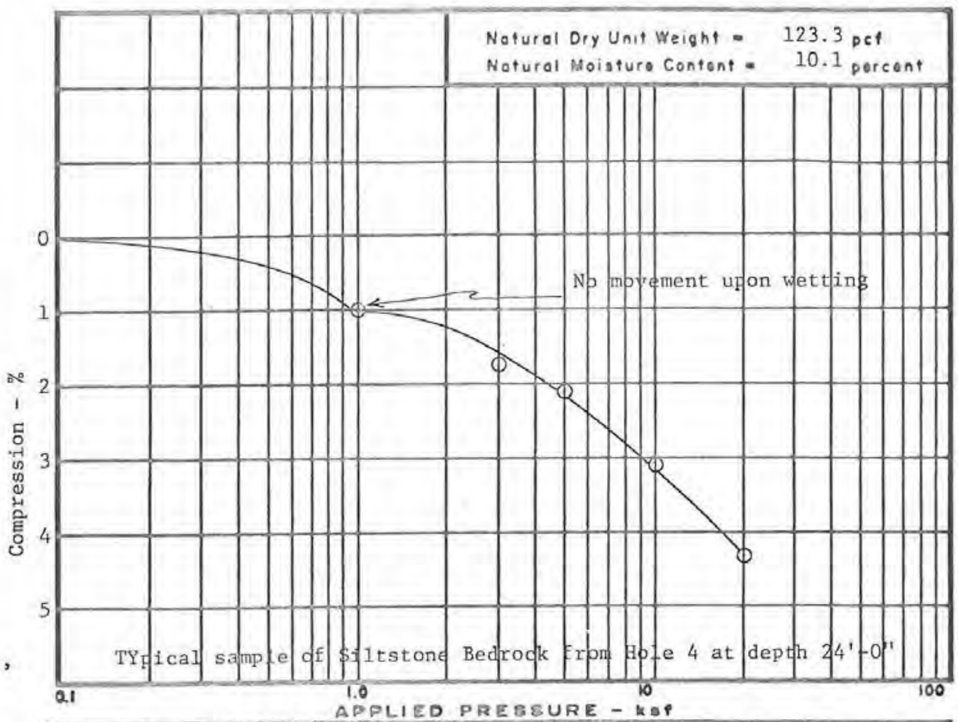
#5980W

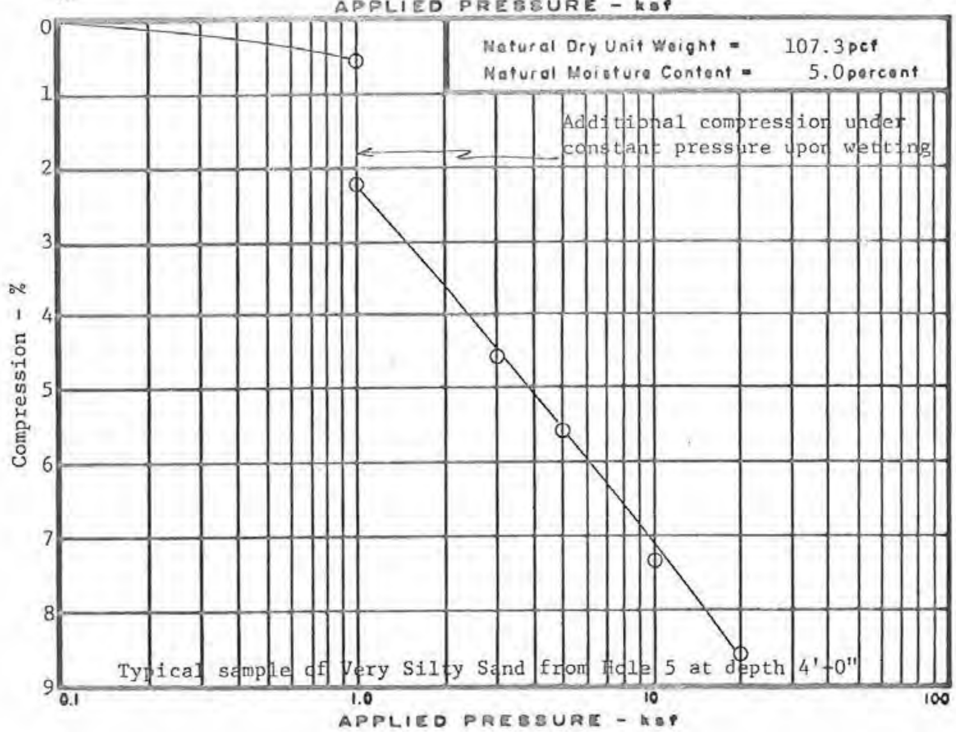
Swell-Consolidation Test Results

Fig. 5

CA-1

CHEN AND ASSOCIATES





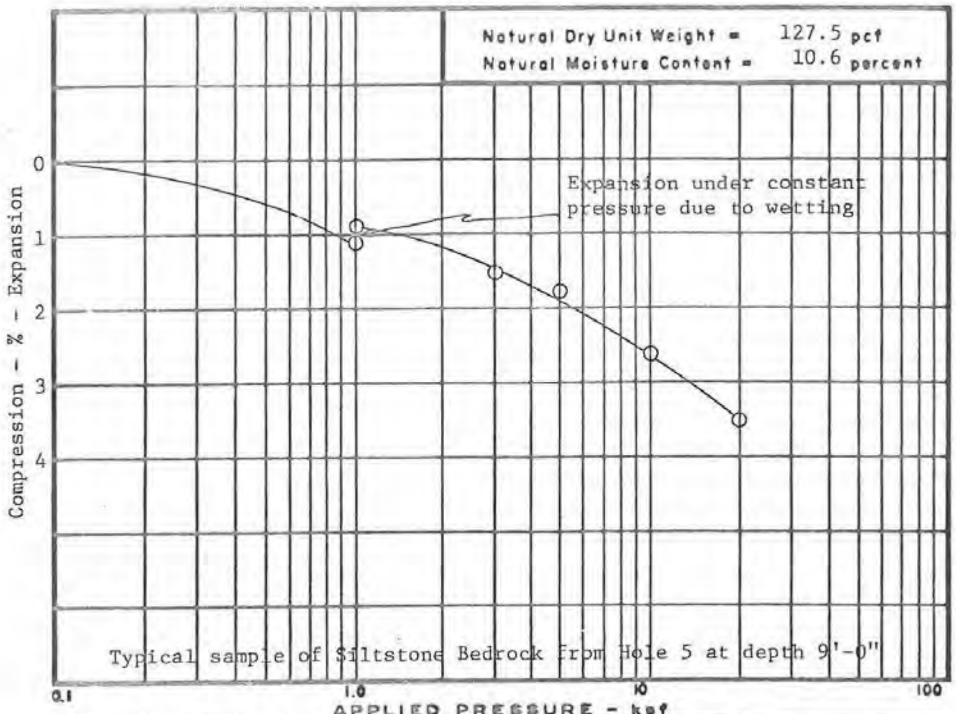
#5980W

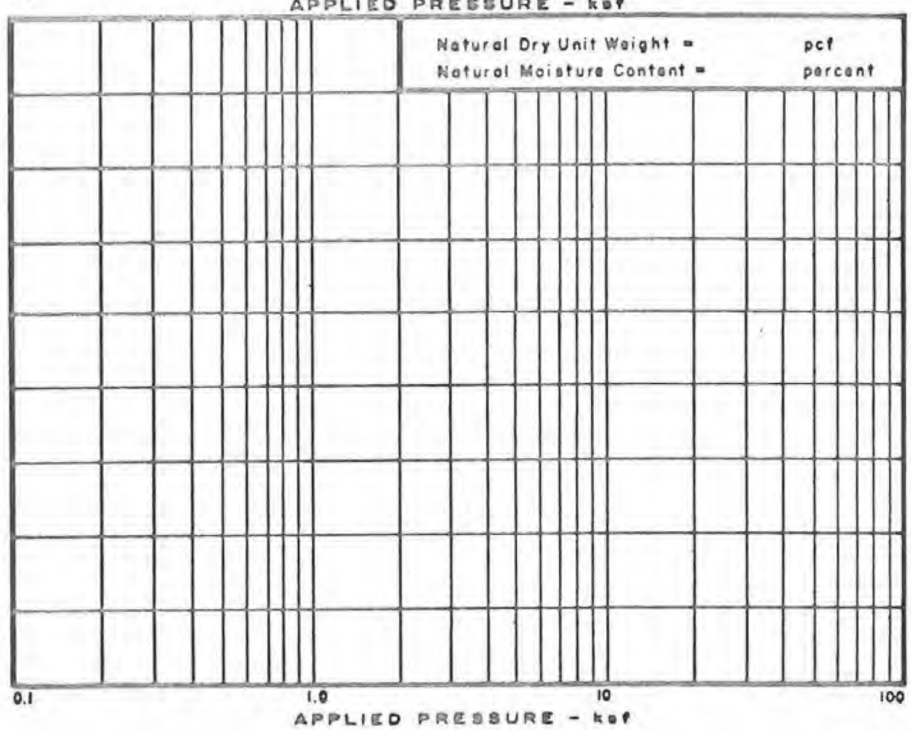
Swell-Consolidation Test Results

Fig. 6

CA-1

CHEN AND ASSOCIATES





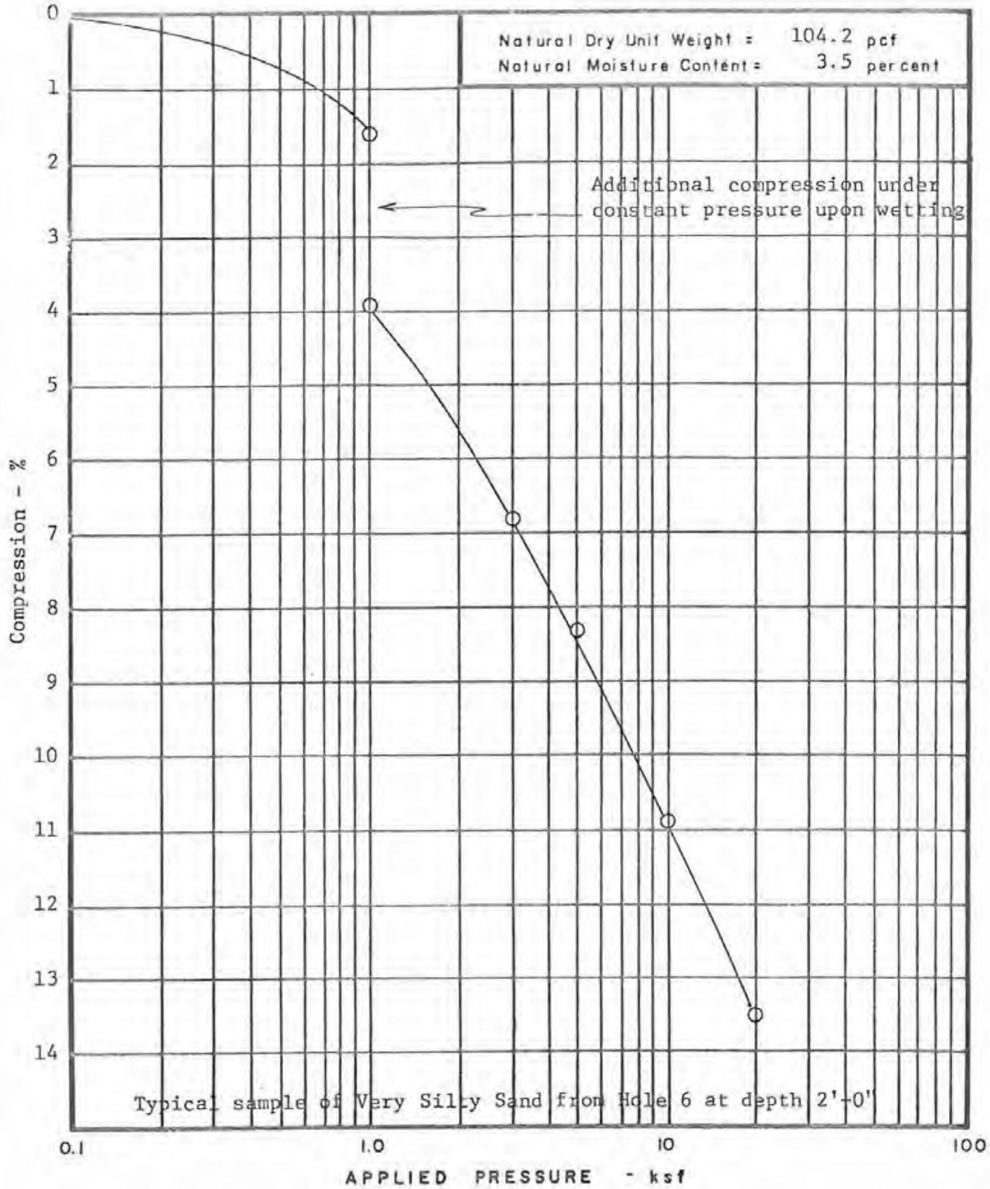
#5980W

Swell-Consolidation Test Results

Fig. 7

CA-1

CHEN AND ASSOCIATES



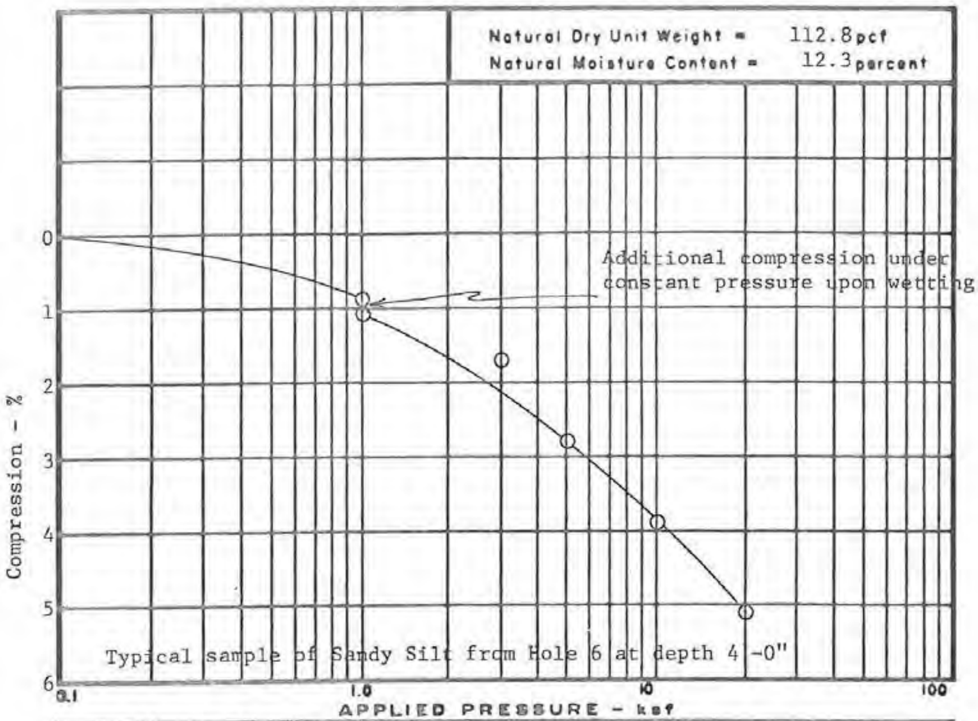
Swell - Consolidation Test
Results

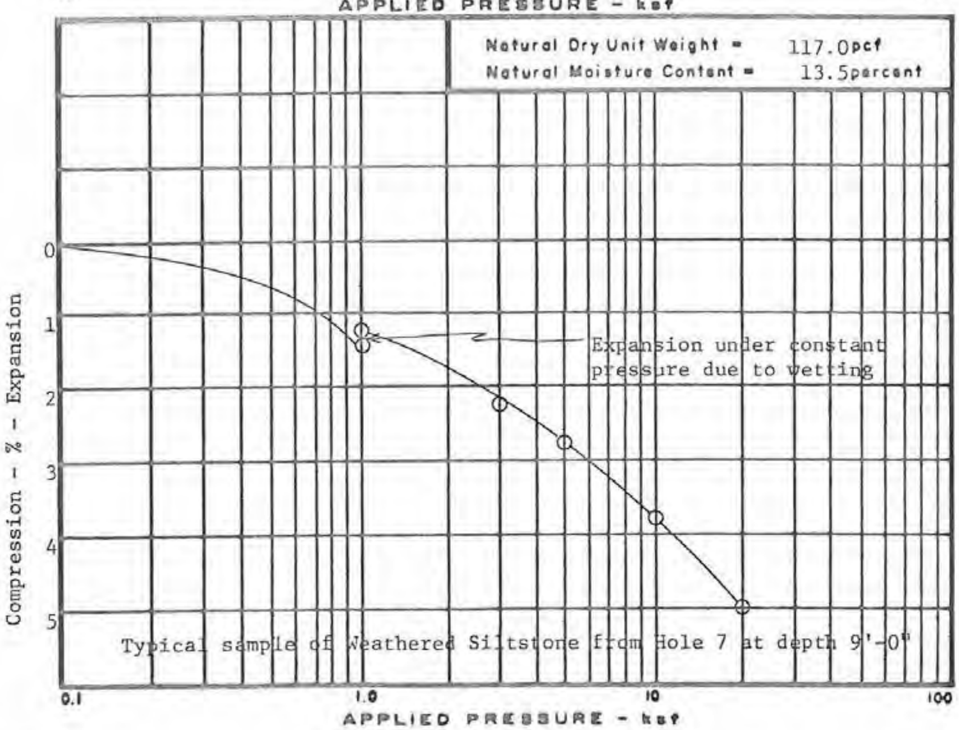
#5980W

Fig. 8

CA-1A

CHEN AND ASSOCIATES





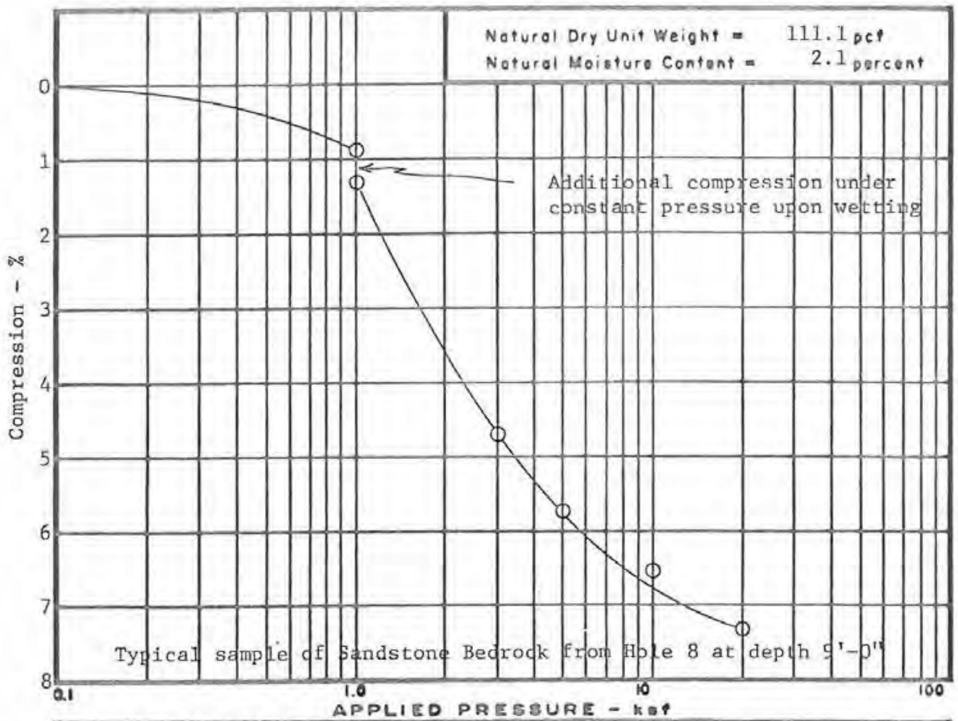
#5980W

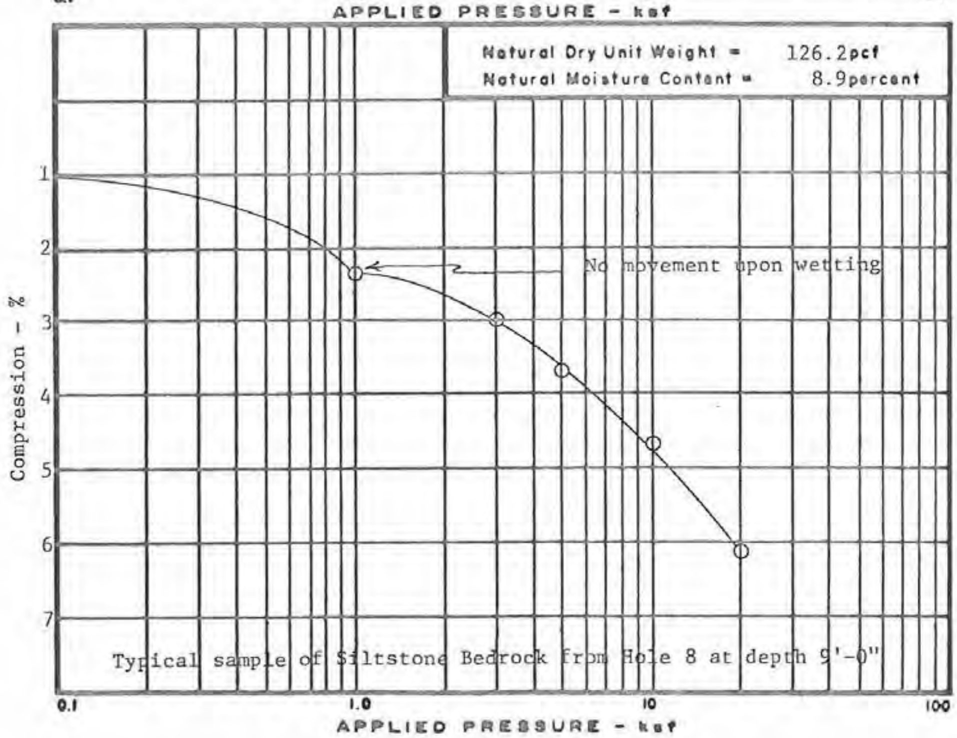
Swell-Consolidation Test Results

Fig. 9

CA-1

CHEN AND ASSOCIATES



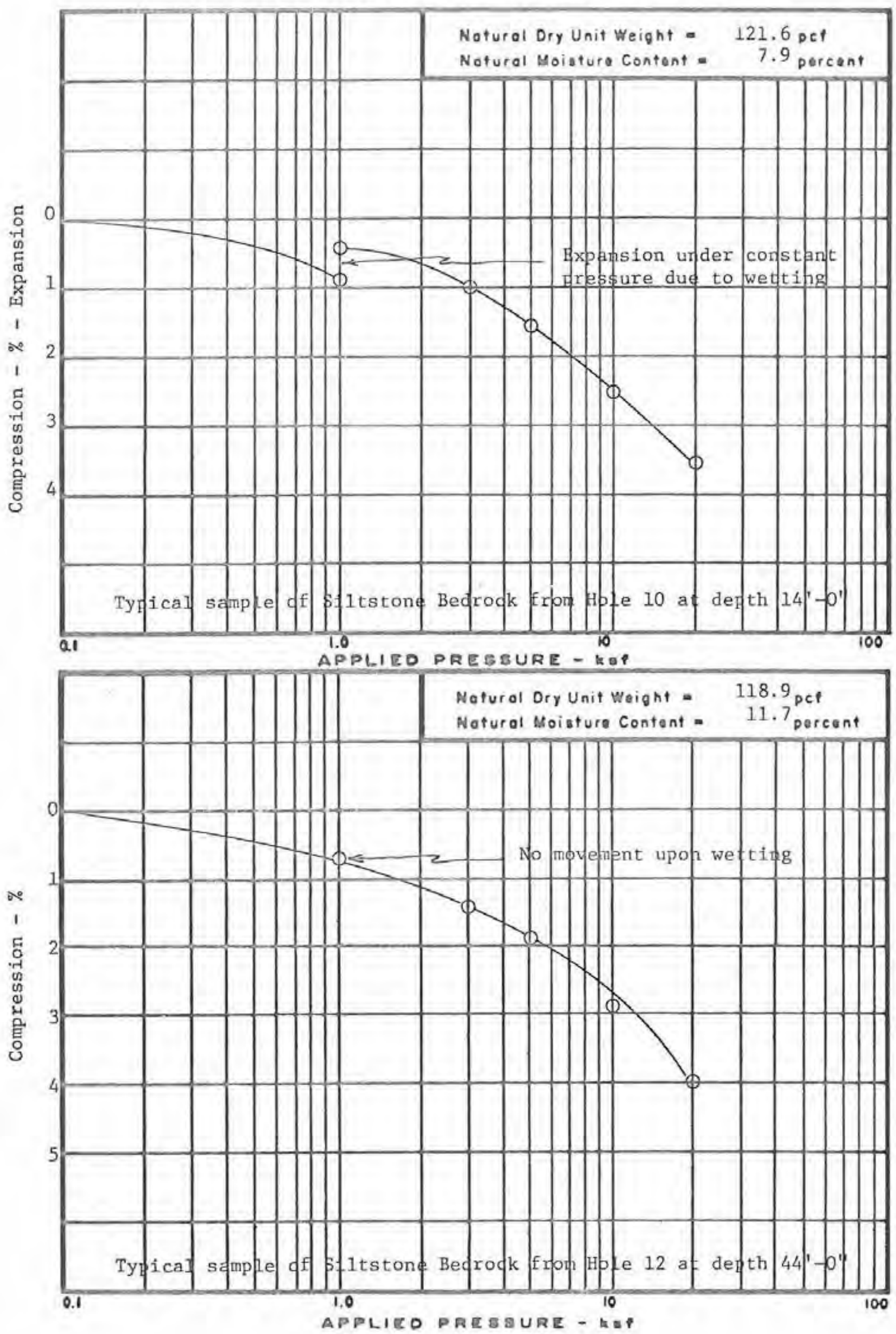


Swell-Consolidation Test Results

#5980W

Fig. 10 CA-1

CHEN AND ASSOCIATES



Swell-Consolidation Test Results

#5980W Fig. 11 CA-1

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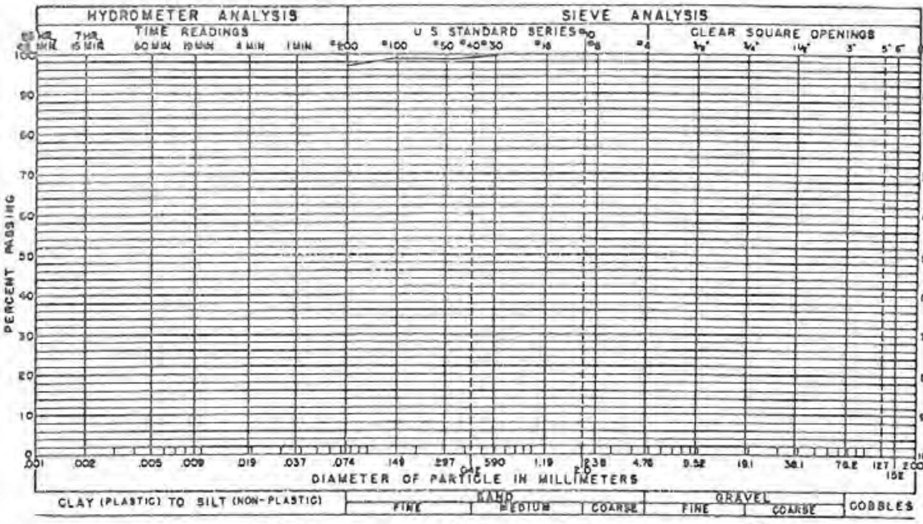
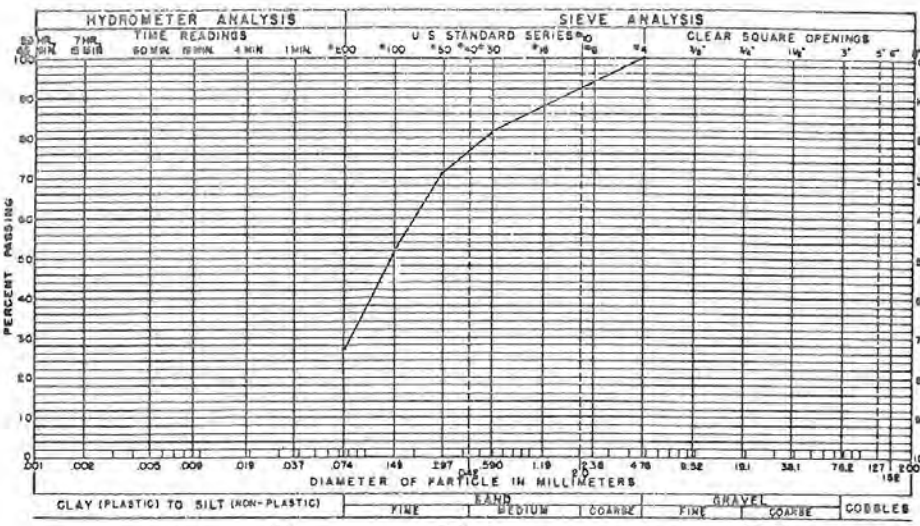


GRAVEL 0 % SAND 3 % SILT AND CLAY 97 %

LIQUID LIMIT 24% PLASTICITY INDEX 3 %

SAMPLE OF Siltstone Bedrock FROM Hole 4 at depth 14'-0"



GRAVEL 0% SAND 73 % SILT AND CLAY 27 %

LIQUID LIMIT % PLASTICITY INDEX NP %

SAMPLE OF Very Silty Sand FROM Hole 5 at depth 4'-0"

#5980W

GRADATION TEST RESULTS

Fig. 12

CA-2

CHEN AND ASSOCIATES

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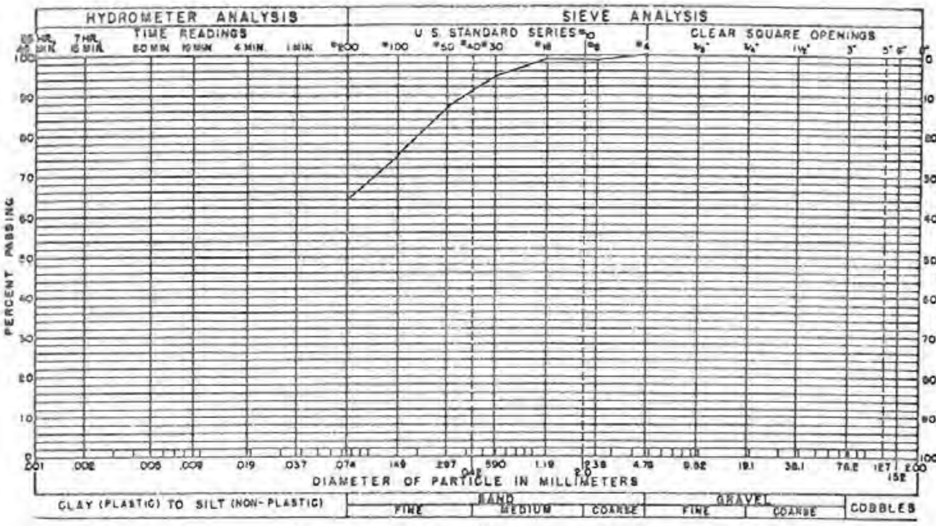
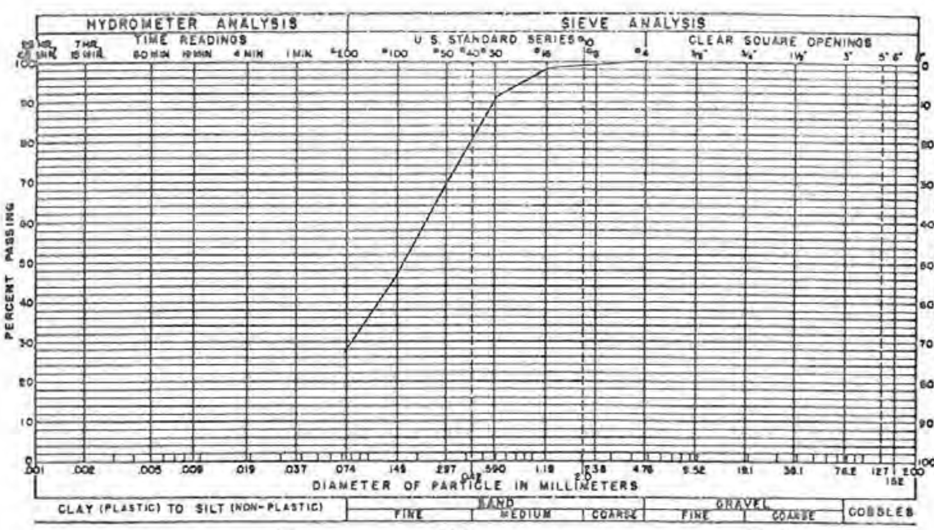


GRAVEL 0 % SAND 36 % SILT AND CLAY 64 %

LIQUID LIMIT 24 % PLASTICITY INDEX 5 %

SAMPLE OF Very Sandy Clay-Silt FROM Hole 6 at depth 0'-0" to 4'-0"



GRAVEL 0% SAND 72% SILT AND CLAY 28 %

LIQUID LIMIT 15 % PLASTICITY INDEX NP %

SAMPLE OF Very Silty Sand FROM Hole 6 at depth 2'-0"

GRADATION TEST RESULTS

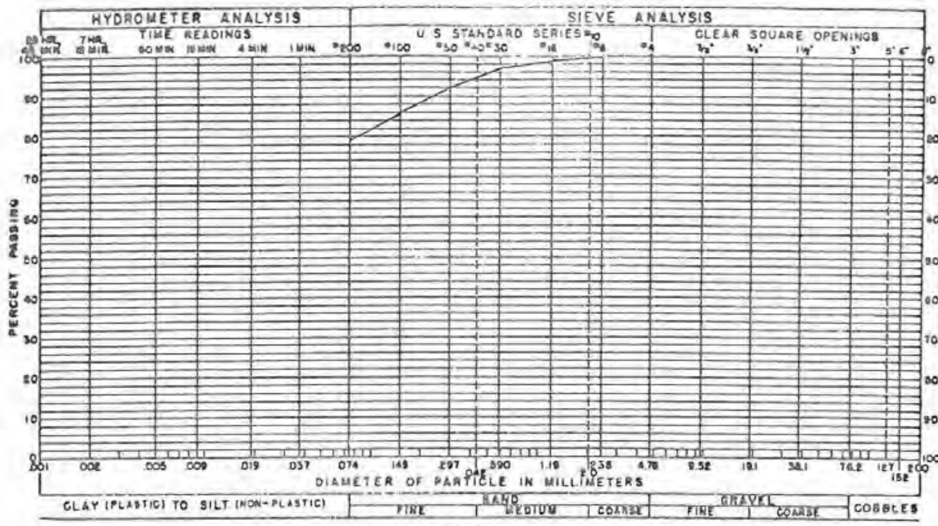
#5980W

Fig. 13

CA-2

CHEN AND ASSOCIATES

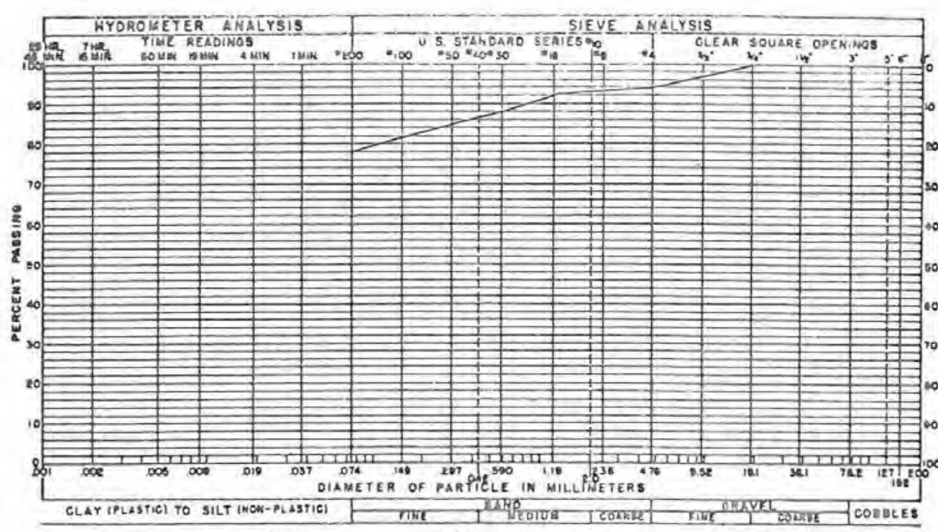
Consulting Soil and Foundation Engineers



GRAVEL 0 % SAND 21 % SILT AND CLAY 79 %

LIQUID LIMIT 21% PLASTICITY INDEX 2 %

SAMPLE OF Sandy Silt FROM Hole 6 at depth 4'-0"



GRAVEL 6 % SAND 16 % SILT AND CLAY 78 %

LIQUID LIMIT 25 % PLASTICITY INDEX 7 %

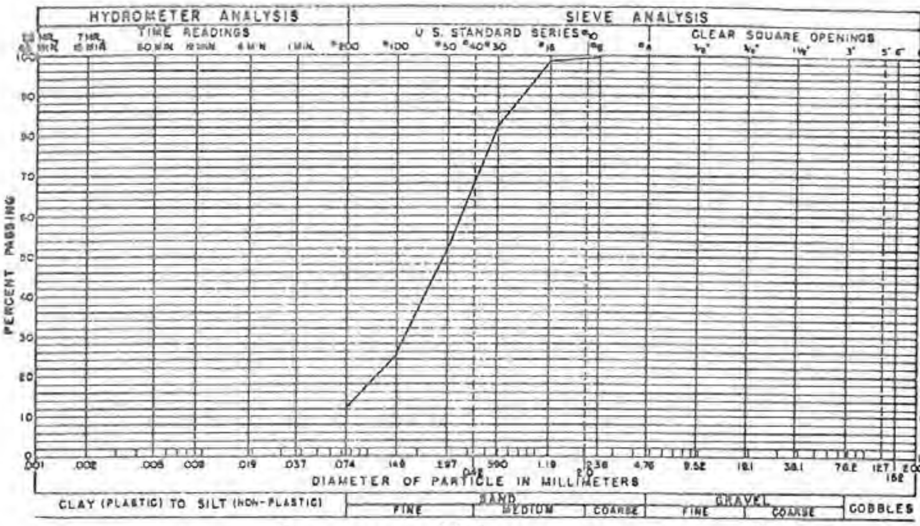
SAMPLE OF Weathered Siltstone FROM Hole 8 at depth 4'-0"

GRADATION TEST RESULTS

#5980W Fig. 14

CA-2

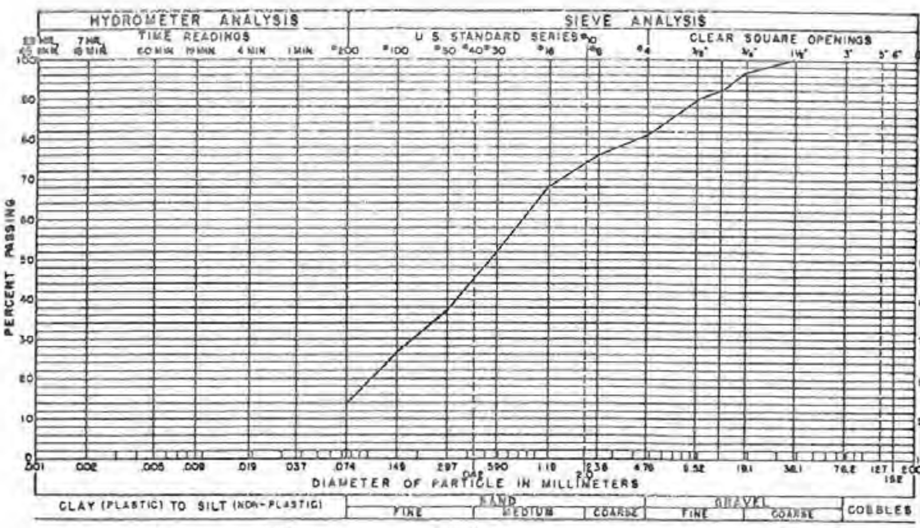
CHEN AND ASSOCIATES
Consulting Soil and Foundation Engineers



GRAVEL 0 % SAND 88 % SILT AND CLAY 12 %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF Sandstone Bedrock FROM Hole 8 at depth 9'-0"



GRAVEL 19% SAND 67% SILT AND CLAY 14 %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF Silty, Gravelly Sand FROM Hole 9 at depth 4'-0"

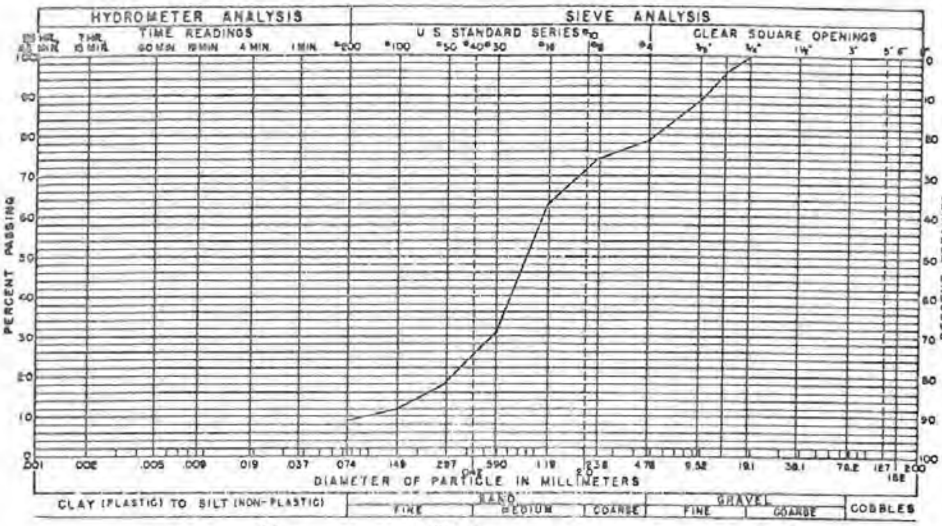
GRADATION TEST RESULTS

#5980W

Fig. 15

CA-2

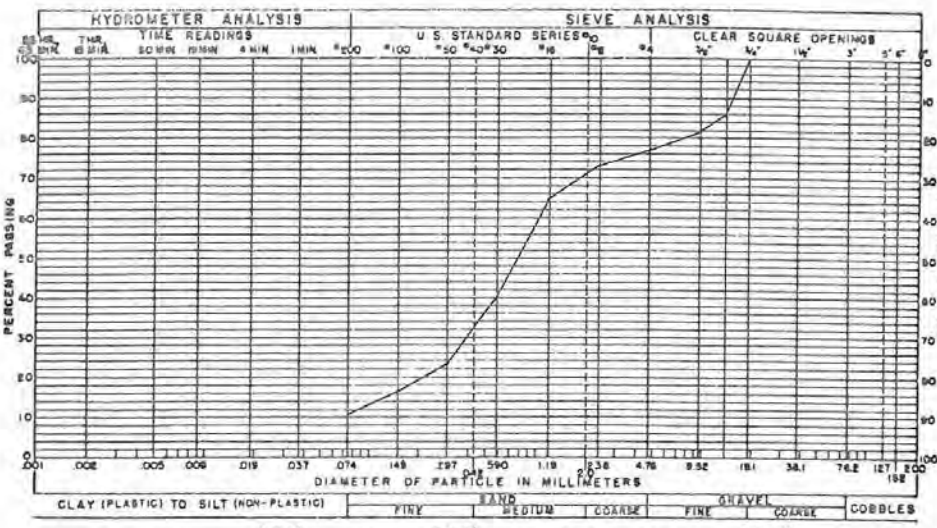
CHEN AND ASSOCIATES
Consulting Soil and Foundation Engineers



GRAVEL 21 % SAND 70 % SILT AND CLAY 9 %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF Slightly Silty, Gravelly Sand FROM Hole 11 at depth 9'-0"



GRAVEL 23 % SAND 66 % SILT AND CLAY 11 %

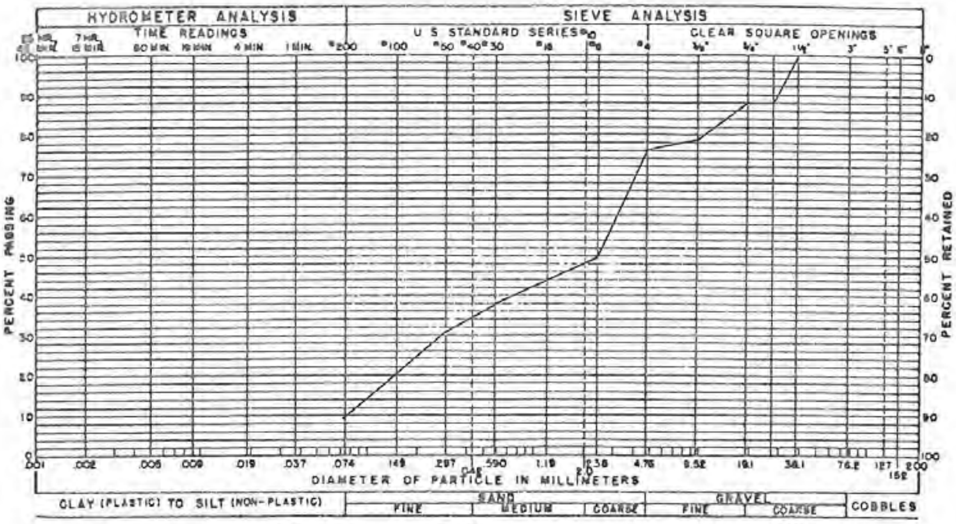
LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF Slightly Silty, Gravelly Sand FROM Hole 12 at depth 2'-0"

GRADATION TEST RESULTS

#5980W

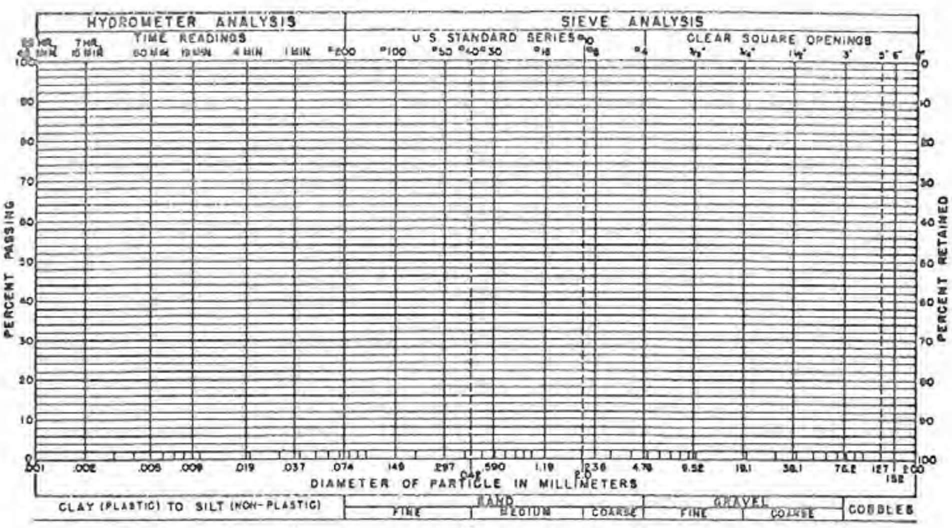
Fig. 16 CA-2



GRAVEL 24 % SAND 66 % SILT AND CLAY 10 %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF Slightly Silty, Gravelly Sand FROM Hole 12 at depth 14'-0"



GRAVEL % SAND % SILT AND CLAY %

LIQUID LIMIT % PLASTICITY INDEX %

SAMPLE OF FROM

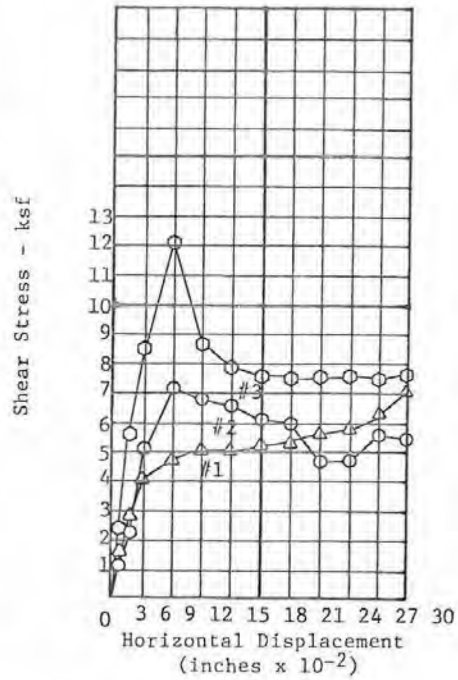
#5980W

GRADATION TEST RESULTS

Fig. 17

CA-2

TEST NUMBER	1	2	3
LOCATION	TH-4 at 14'-0"	TH-4 at 14'-0"	TH-4 at 14'-0"
HEIGHT - INCH	1	1	1
DIAMETER - INCH	1.94	1.94	1.94
WATER CONTENT - %	7.3	7.0	7.3
DRY DENSITY - pcf	130.7	133.5	137.9
CONSOL. LOAD - ksf	2	4	6
NORMAL LOAD - ksf	2	4	6
SHEAR STRESS - ksf	4.1	7.7	12.1

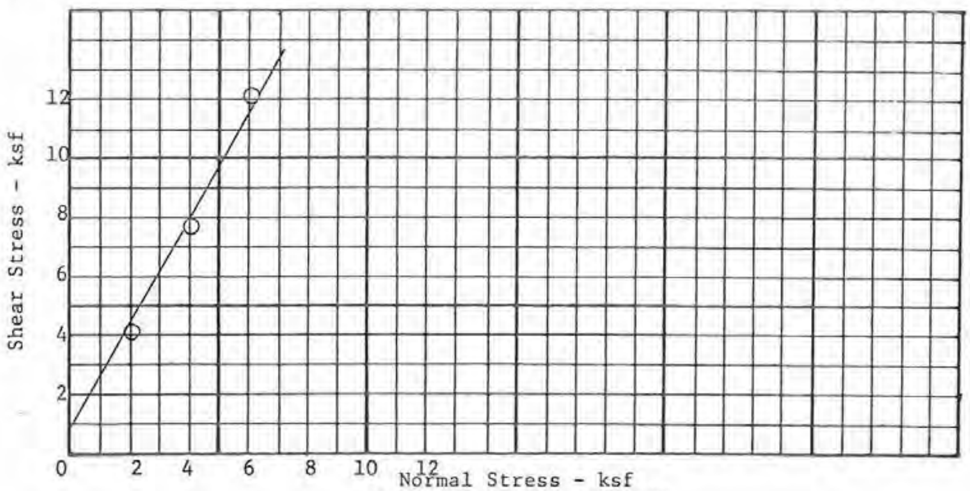


TYPE OF SPECIMEN Undisturbed

SOIL DESCRIPTION Siltstone Bedrock

TYPE OF TEST Consolidated-Undrained

TAN Ø 1.700 Ø 59.5° COHESION - ksf 0.9



DIRECT SHEAR TEST RESULTS

#5980W

Fig. 18

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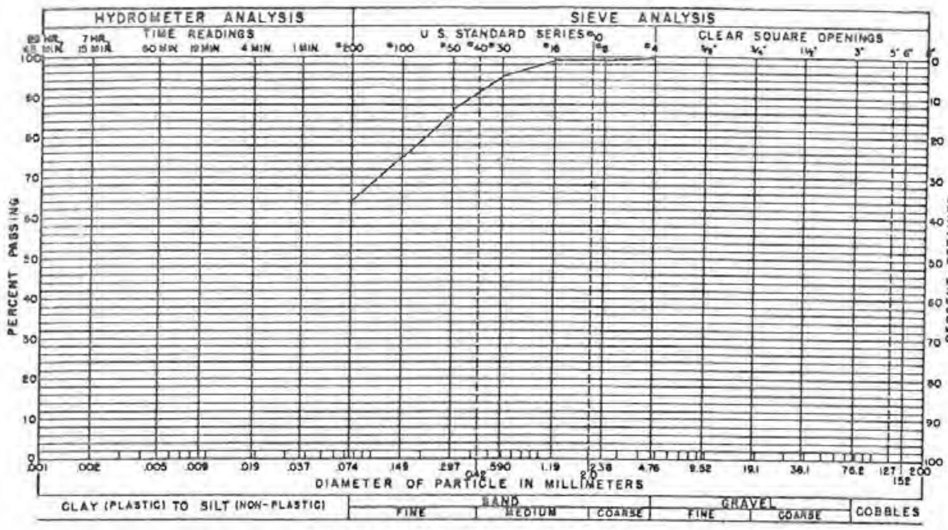
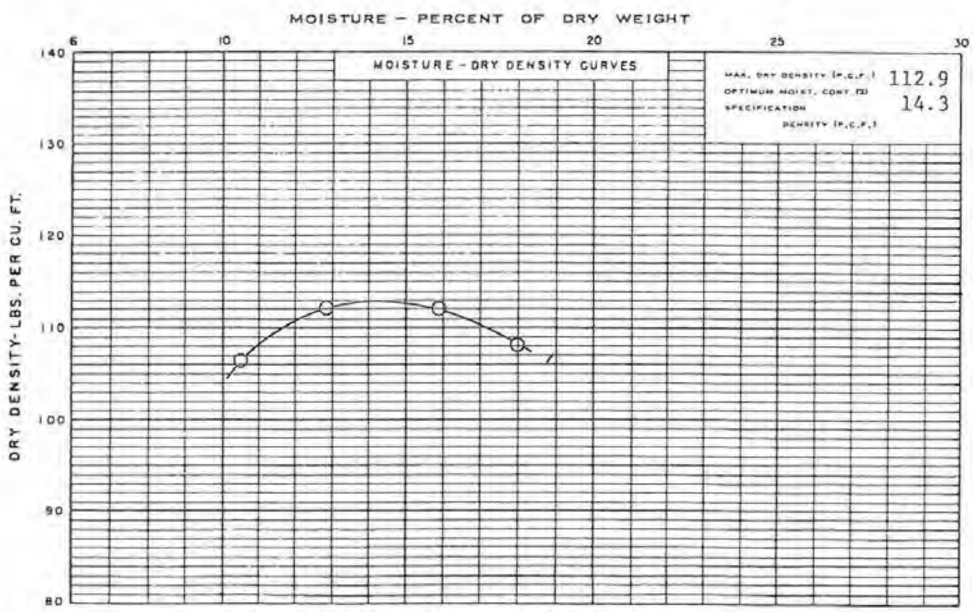


GRADATION TEST RESULTS

GRAVEL 0 % SAND 36 % SILT AND CLAY 64%

LIQUID LIMIT 25 % PLASTICITY INDEX 5 %



COMPACTION TEST RESULTS

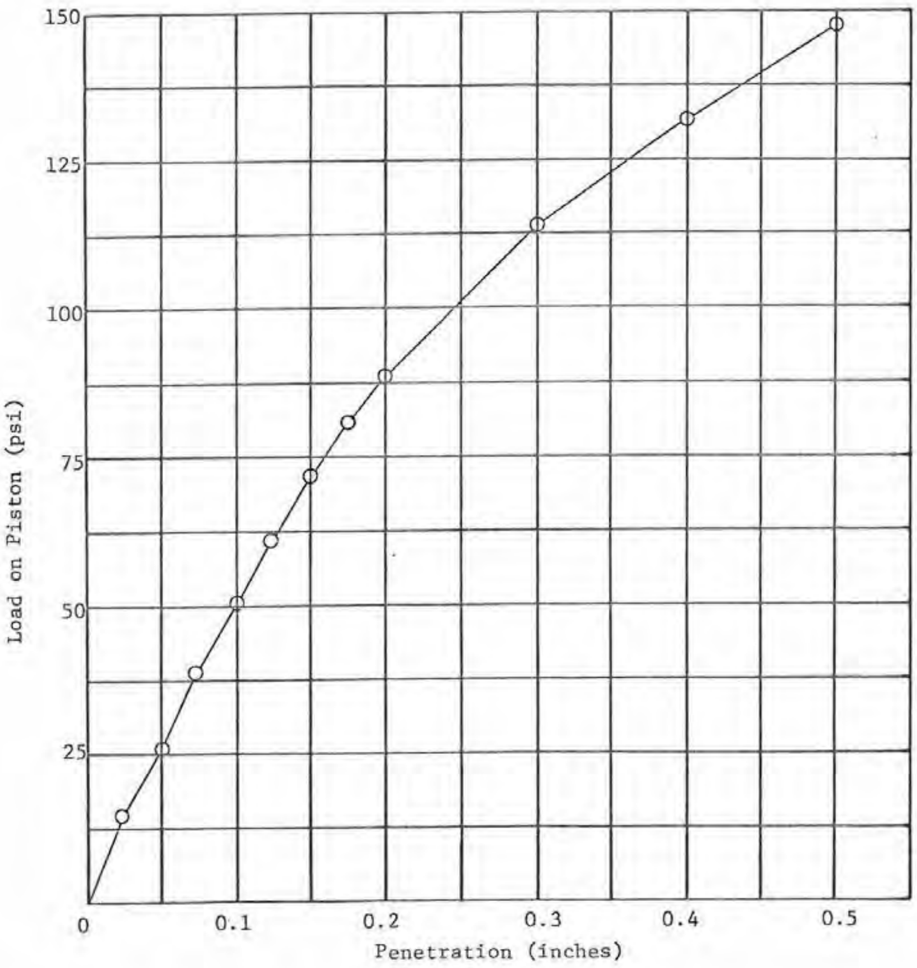
COMPACTION TEST PROCEDURE ASTM D698-70, Method A

SAMPLE OF Very Sandy Clay-Silt

#5980W FROM Hole 6 DEPTH 0'-0" to 4'-0"

Fig. 19 CA-3

Hole	6
Depth	0'-0" to 4'-0"
Soil Type	Very Sandy Clay-Silt
Remolded Moisture Content	14.3%
Remolded Density	112.5 pcf



LOAD-PENETRATION CURVE

#5980W

Fig. 20

JOB NO. 5980W

CHEN AND ASSOCIATES

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS LIQUID LIMIT (%)	ATTERBERG LIMITS PLASTICITY INDEX (%)	UNCONFINED COMPRESSIVE STRENGTH (PSF)	WATER SOLUBLE SULFATE (%)	GRADATION ANALYSIS +#4 (%)	GRADATION ANALYSIS -#4 +#200(%)	GRADATION ANALYSIS -#200 (%)	SOIL TYPE
1	4	5.3	109.4								Siltstone Bedrock
3	9	6.1	118.5				0.03				Siltstone Bedrock
	19	6.9	130.1			10,800					Siltstone Bedrock
4	14	7.0	133.5	24	3			0	3	97	Siltstone Bedrock
	24	10.1	123.3	25	4					80	Siltstone Bedrock
5	4	5.0	107.3		NP			0	73	27	Very Silty Sand
	9	10.6	127.5	25	5		0.07			98	Siltstone Bedrock
6	0 - 4	4.8		24	5			0	36	64	Very Sandy Clay-Silt
	2	3.5	104.2	15	NP			0	72	28	Very Silty Sand
	4	12.3	112.8	21	2		0.24	0	21	79	Sandy Silt
7	9	13.5	117.0			14,657	0.10				Weathered Siltstone
	14	9.3	128.5								Siltstone Bedrock
8	4	14.9		25	7			6	16	78	Weathered Siltstone
	9	2.1	111.1					0	88	12	Sandstone Bedrock
	19	8.9	126.2				0.01				Siltstone Bedrock
9	4	0.9						19	67	14	Silty, Gravelly Sand

HOUSE OF PRINTING — CASPER

CA-4

JOB NO. 5980W

CHEN AND ASSOCIATES

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	WATER SOLUBLE SULFATE (%)	GRADATION ANALYSIS			SOIL TYPE
				LIQUID LIMIT (%)	PLASTICITY INDEX (%)			+#4 (%)	−#4 +#200(%)	−#200 (%)	
10	14	7.9	121.6	25	4		0.01			97	Siltstone Bedrock
11	9	1.9						21	70	9	Slightly Silty, Gravelly Sand
12	2	3.3						23	66	11	Slightly Silty, Gravelly Sand
	14	1.5						24	66	10	Slightly Silty, Gravelly Sand
	44	11.7	118.9								Siltstone Bedrock

HOUSE OF PRINTING — CASPER

CA-6

JOB NO. 5980W

CHEN AND ASSOCIATES

TABLE II

SUMMARY OF CBR TEST DATA

SAMPLE LOCATION		ATTERBERG LIMITS			Unified Soil	ASTM D698		MOLDED			MOISTURE CONT. AFTER SOAKING		
Hole	Depth (ft)	Liquid Limit (%)	Plasticity Index (%)	-200 Content (%)	Classification	Optimum Moisture Content (%)	Maximum Dry Density (pcf)	Moisture Content (%)	Dry Density (pcf)	Swell (%)	Top 1" (%)	Average (%)	CBR Value (%)
6	0 - 4	24	5	64	CL-ML	14.3	112.9	14.3	112.5	0.17	15.6	15.3	5.0

15. APPENDIX L: DE-FE0027771 DETAILED SITE ASSESSMENT QUESTIONS, UW CEP RESPONSES

DOE Project DE-FE0027771 - Detailed Site Assessment Questions

1. **Proposed Site, Physical Infrastructure, and Schedule**

   1.1. Maps of proposed site and plot plan, including laydown areas, crane locations, easements, roadways, reserved spaces, and structures, etc. See the attached FPO Site utility Aerial 1.1. and FPO site plot plan

   1.2. Recent available civil site survey, including site drawings that identify property boundary limits, topographical features, and underground utilities (e.g. ground penetrating radar). See the attached HARNEY ST SITE PLAN, 22&HarneySt_StormSewer_Site Plan, CEP Site Survey.jpg and CEP Survey 2.jpg for survey information for this site.

   1.3. Recent available site geotechnical evaluation, including dynamic field testing results to be used to determine dynamic parameters of soil and seismic site classification. See the attached CEP Geotech RPT_1979. For seismic info, see the attached IMB_2690.JPG.

   1.4. Recent available site NEPA study (Categorical Exclusion or Environmental Assessment) to help identify any environmental concerns or limitations. No records of a NEPA study carried out for the Central Energy Plant. See response to question 4.5 below

   1.5. Is there any specific site preparation work that must be done before the project construction may begin? If so, who would be responsible for this work? This would be part of the project. However, expect it to be minimal.- civil grading works and exposing integration needed fixtures.

   1.6. Is sufficient additional space available on the host site, beyond the area used by the test facility, to accommodate laydown areas, construction trailers, and construction equipment? If there are any potential concerns, what options exist to overcome the potential limitation? Space should be adequate. See the FPO Site Utility Aerial 1.1 for the proposed areas. The north-south drive on the west side of the Central Energy Plant (CEP) will need to be kept open.

   1.7. Perceived construction risks / access issues? Does the host site foresee any other future operations, operational limitations, construction plans, or testing activities, which may limit the ability of the project testing to proceed as planned? Are there any local ordinances or policies (e.g. noise limits) that would place limits on construction activities? Are there any site-specific rules or policies that may impair access to the site during the construction or testing phases of the project? Need to keep equipment critically silenced (i.e. hospital grade acoustical design) as there are residential areas nearby. Also, the City of Laramie's local ordinances should be followed. City building permit process may slow the project. The University also has an internal design review committee which the plant design would have to be approved by. Need to see how this plant would work in the grand scheme of the Campus Master and Campus Utility Master Plans.

   1.8. Identify any weather issues (winterization / construction issues / storms), worker productivity - risk assessment. Laramie is in an ASHRAE Climate Zone 6 Dry (B) with typical winter lows of -40°F.

   1.9. Provide a definitive statement on site's existing infrastructure that can be made available for use. The site should have adequate natural gas, water, sanitary, storm services with minimal modifications. The site is next to the CEP steam plant which has coal unloading facility with 3 day bunkers and 3 storage silos. A separate silo is recommended if the integrated scheme is used. System has a truck scale, grizzly to dump the coal into via belly dump trucks where it the can be pneumatically conveyed to any of the 3 storage silos or one of the day bunkers (see the attached CEP Equipment Diagram.pdf). The electrical service for the CEP is 2500 KVA, 13.2-480V three phase with a current plant max load of

~1242KW. Standby generation is current one 1250KW generator with a second 1250 unit as a standby in case the first doesn't start. They both can run at the same time, but the air quality permit for them would have to change. Boiler feed water is softened and goes through a de-aerator. Main campus steam supply and condensate return lines are either in the CEP or in the east steam tunnel.

1.10. Would there be a need to modify any existing buildings, structures, or work around any underground utilities on the host site? If so, please explain. Depends if the integrated scheme of standalone scheme is used.

- Integrated: can use existing coal handling equipment (scale, grizzly dump, pneumatic and chain conveying systems) and extend to serve the FPO unit. Could also connect to the north end of the CEP for water, gas, steam header, electrical, and unit enclosure to keep it above freezing. Other equipment would still have to be located west of the plant, but would be connected.
- Standalone: all services would pretty much have to be new and separate which would entail modifications to the campus electrical distribution system.

1.11. Would the host site be able to accommodate an extension to the project testing schedule, beyond the currently planned end date? If so, are there any specific limitations (e.g. subsequent planned uses for the testing site)? Yes, shouldn't be a problem. The CEP does have an annual team shutdown that lasts ~4 weeks from mid-July through mid-August. Extension to R&D and technology programs would need to be reviewed to be consistent with researcher availability.

1.12. Define the existing utilities that are available for use by the project, including power (capacity on existing transformer), natural gas (volume and pressure), demineralised water and water for cooling (any limit on thermal loading without tripping environmental permitting?)

- Available Utilities are:

1.12..1. Natural gas, 60 psig to the plant, 30 psig within the plant. Current capacity is ~ 130,000 MMBTU but could be modified by black Hills energy, the locat gas distribution company. Also, UW purchases gas on a transport basis which the FPO plant could also be a part of.

1.12..2. CEP power 2500 KVA transformer with a second unit for back up. Current KW demand at ~1242KW. CEP also has 2 - 1250 KW generators. Current set up is to only let one run at a time. If both are needed, a new air quality permit will be needed and control changes would have to be made.

1.12..3. The CEP uses softened city water for boiler makeup. Is also goes through a de-aerator. The FPO would need to take the softened water from the CEP and run it through a new DI system.

1.12..4. Water dumping has to be below ~105°F to go to the City sanitary sewer.

- The same applies to Consumables (if any)

1.12..5. Coal could be purchased through the University contract for coal supply, same with natural gas.

1.12..6. If integrated scheme is used, the existing real time gas meter, water meter and electric meter could be used. The FPO plant needs submetering for all its equipment, including blowdown and other waste water discharges.

1.13. Does the host site have stand-by backup power generation available? Yes, see 1.12..2 above.

1.14. Would any of the host site main operations need to be shut down in order to facilitate any utility tie-ins for the test project? If so, what is the planned outage schedule? See 1.11 above and also, this outage could easily be extended one or two weeks.

1.15. Define the expectations of demolition, equipment removal, and site restoration at the conclusion of the project activities, or at the end of the plant's useful life. Expect site to be restored to pre-construction conditions. If economical and reliable, FPO plant would continue to be used after project.

2. Host Financials, Cost-Share by Host, State and Other Stakeholders, and Project Economics

2.1. Audited financial statements for last 2 years

See attached latest 2016 audit report and compliance report. Other preceding reports available from http://www.uwyo.edu/research/sponsored-programs-post-award-management/audit-reports.html

2.2. Detailed statement of Cost Share by Host / Site and associated risk, e.g., is it from a source that may be hard to verify or has contingencies?

The University is a land Grant Institution and is funded through Block Grant award from the State Legislator covering the biennium expenditure. Separately the School of Energy resources receives a special appropriation to fund energy related projects and initiatives across campus. In addition one off biennium appropriations are awards for particular priories and missions. One of these relates to the future of coal, which the FPO pilot project would fall under. Information sessions with University leadership and legislators have informed strong firm support behind funding the FPO pilot should the award be made to Wyoming.

2.3. Identify sources and amounts of any available state or local government funding for the site, along with associated risk.

In addition to attracting State funding, with a very successful record, the School of Energy resources has developed very strong relationships with primary and secondary energy producing industry and in this regard expects that private funding of the project could very well emerge from such sources too. The State separately provides matching dollars (1:1) for any private investment in the University research programs

2.4. Are additional sources of cash, or in-kind, cost share available from other stakeholders? If so, please explain.

See response to 2.3 above

2.5. Provide details on potential requirements for steam - intermittent or continuous etc. – and/or power if appropriate. Hopefully, unit would provide steam for campus. Steam demand ranges from 12,000 pounds per hour (pph) to 130,000 pph with a yearly consumption of ~ 328,000,000 to 372,000,000 pounds. Hourly consumption numbers are available, if needed. If cogeneration is used, it can be simple of complex. Simple would be to generate electricity for the CEP & FPO, or even possibly adding other buildings that are all fed off a radial in that area (High Bay, RMMC, Visual Arts, Animal Sciences and Centennial Complex). Complex would be doing East and/or West Campus distribution center(s). In the complex scenario, Rocky Mountain Power, the local electric utility, would need to be involved as it would severely affect their operations. Also, smarter sectionalizers and other distribution equipment may be needed. See the attached pdf's of

Load Profiles for E&W Campus, Typical Weekly Load Profile E&W Campus, SummaryStatistics_East&West Campus Elect, Load Profiles for E campus, Load Profiles for W campus and Schedule 33 RMP for information concerning this. The yearly MWH consumption for the two substations is ~58,000.

2.6. Describe any investment in facilities and operating cost required for supply, and/or storage, of coals to be used during the testing. For either the integrated or stand-alone schemes, there would have to be a dedicated coal storage silo. However, with the integrated scheme, existing off loading and handling systems can be used.

2.7. What, if any, staffing can the host site organization provide to support the project? The current CEP staff could monitor and operate the steam generation unit as part of the CEP. Also they would do routine maintenance on the miscellaneous equipment. The specialized equipment would require training. Steam to electric turbine(s) would also require training. More staff (~1-2 additional) most likely would be required. Maintenance and utility costs would undoubtedly be much higher so more financial support would be required. The University has FPO technology expertise within the College bof Engineering and as it is already supporting FPO research would make these tangible and intangible assets available to the project. The School of Energy resources would make available an in kind contribution of a project coordinator who has considerable experience in technology scale up in Europe and China.

2.8. Provide detailed information on staff cost for operators, management, and support staff. The current staff of 13 (one position down) average has a payroll of ~$1,060,000/year with benefits or ~$700,000 without. Two additional high technical staff would be ~$300,000/yr. ($150K each) with benefits.

2.9. Is the project free to supply its own staffing, or are there existing site labor agreements that may limit the project staffing options? If so, do the labor agreements cover only on-site construction, or also testing phase activities, etc.? Yes, through the University Human Resources Department. The School of Energy Resources uses at-will-contract mechanisms to recruit professional staff.

2.10. Are there existing labor agreements, or site specific policies, which would impact the project test staffing plan (e.g. minimum number of operators, or supervisors, or minimum number of hours per year)? At the CEP, 2 persons are required to be there 24 hours/day, every day of the year.

2.11. Current and projected future costs of any pass though utility costs (e.g. electricity, natural gas, water, etc.). As of August, 2017, average electrical costs for the plant are ~0.744/KWH including energy and demand. Demand charges are ~$20.13/KW with energy charges at ~$0.03162/KWH. Natural gas will vary depending on the market. However, in the past, this has ranged from $4.08-$6.22/MMBTU delivered to the plant. We expect the cost to drop ~5-10% with the current transport agreement in place, but the market is still the driver for gas cost. Water is through the City of Laramie and for FY 2017, averaged $8.44/KGal. This will increase ~4-5%/year for the foreseeable future. Coal costs for 20 Mile coal from Colorado are averaging ~3.56/MMBTU and for Powder River Basin Coal, it is in the $4.90-$5.20/MMBTU range. Coal is bid out for a 1 year, extendable to 3 year contract. The CEP also has a compressed air plant that could be used.

2.12. Would the project obtain utilities through the host site, or directly from another provider? Does the host site have any utility discounts, below normal market pricing, which could be passed through to the project? If so, provide details on pricing structure. Through the host site. See 2.11 for pricing. Pricing is generally market driven. The transportation agreement for natural gas lowers the normal distribution costs.

2.13. Does the host site organization intend to charge the project any rental fees for the usage of the site? NO, providing net benefits from the project can be demonstrated. In this case there is clear evidence of intangible and tangible net benefits.

2.14. Are there any anticipated host site changes, which would likely have a significant impact (either positive or negative) upon the expected operating cost of the testing? Depends on the level of cogeneration. PRB coal will be more expensive due to its low BTU and high moisture content along with the long trucking distance to the CEP. Costs to bring in other solid fuels (not routinely consumed on a cost competitive basis) to evaluate could also give rise to higher feedstock costs.

2.15. Identify potential interest by the host site in any of the equipment or improvements associated with this project. Is it assumed that all equipment and improvements will be removed at the conclusion of the project? Does the host site see value in retaining any of the equipment at the conclusion of the project? If so, would the host site agree to a residual value, in advance? If the FPO plant proves to be reliable and economic, the University would likely continue the operation of the plant. Such actions would be subject to DOE (owner?) satisfactory turnover of the as-built assets.

2.16. Is the project free to supply its own supporting equipment, or are there any areas for which the host site prefers, or requires, that it retain equipment ownership and/or control?

YES: providing it confirms to in-place safety/environmental / engineering design standards and guidelines in place at the time for the University of Wyoming. If the integrated design is chosen, the University anticipates it would retain ownership of any Assets required to assure a safe reliable operation of the non FPO project assets, before/after and during the pilot project.

2.17. Are any capital improvements needed to supply the project with the necessary utilities? If so, who will pay for and own these improvements? Any modifications to the existing equipment and infrastructure or new services for a standalone FPO plant would be borne by the grant. There may be instances where University net benefits, if demonstrated would result in some cost share. Commitments could not be made until the full engineering design / package is known.

2.18. Is the host site organization free to negotiate a host site agreement with the project team, or are there additional investment partners, or other stakeholders, who would need to approve any agreements? The University can negotiate with various entities required, but probably would have to go through a Request for Qualifications process to short list the possibilities and stay within State and Federal requirements. The University Administration would approve any type of these agreement(s). The University Board of Trustees would need to be informed and approve the project notion. Providing these approvals were started in a timely manner, they would be unlikely no cause to disrupt the project.

3. **Host Organization Resources**

3.1. Evidence of previous DOE projects – Has the host organization worked on previous DOE projects? Does the host organization have a successful track record in doing pilot-scale testing?

See attachment Horner DOEawards

3.2. Does the site, its existing equipment (if any), and its staff have experience in supporting long-term operations? The CEP runs continuously since it was built. The University has operated its own steam generation system since original construction. For ~30 years, they also cogenerated. Existing staff includes engineering and maintenance personnel to keep the campus running. Facilities management group are conversant with project management and working and negotiating with engineering contractors

3.3. Identify any host site organization experience with any of the core components of the system being tested. The University is well versed in steam generation, electrical driven chilled water generation and compressed air systems and their associated maintenance and operational costs.

3.4. Describe the availability of existing host site staff to support the project through all phases. The University is prepared to make available operational, maintenance and facilities management and School, of Energy Resources professionals to support the pilot project, to include some of the CEP staff. The CEP has a 3-8 hour shift system for 24/7 coverage.

3.5. Does the host site organization have its own internal engineering resources to address technical questions? If not, is there an owner's engineer available, who is familiar with the site? Will the project be billed for local engineering support? To a point, as the University does manage the CEP and all the utilities for the campus. Project would be billed for support. Activities' where net tangible benefit can be demonstrated, the University is willing to consider absorbing or contributing to costs.

3.6. Does Site have ability to do maintenance on pilot plants that may be fundamentally different to current systems on the site? If not, are there specific contractors that the host site recommends, or requires that the project use? The FPO plant would need specialized training, which could be done for University staff. Expertise for power plant projects would come from contractors and engineers from either in or out of the state through various contracts. The University does have annual agreements with engineering firms that work in the power plant field that could be brought on board.

3.7. Write-up of proposed implementation plan for performing the project and supporting the bid.

Implementation plan can and will be provided once the engineering design package is frozen and the choice of a stand-alone or integrated scheme is known. Historic project implementation plans can be provided on request to show University competence in this space.

3.8. Describe any perceived risk of changes in future operations of host site that could adversely impact the test plan (e.g. use of shared human resources or utilities). For example, is there a risk of not operating if host site staff have other obligations, or limited utilities are needed for production operations? The highest priority is to maintain steam to campus so its operations can continue with minimal freeze up risk to the campus buildings. If cogeneration is used, having a stable and reliable source would be necessary along with it being economical. Chilled water production also has to continue 24/7 throughout the year. Issues with low and high demands periods (seasons) for both steam and electricity (if cogeneration is used) will need to be managed and some strategies to ensure reliable operation without disruption to the pilot project have been crafted. .

4. **Environmental and Permitting**

4.1. HSE – Describe the host site track record for conducting projects and proposed HSE planning? Provide OSHA benchmarks? Describe any noise limit concerns? Yes, all OSHA, Worker's Comp and Injury reports are tracked by the University. Since the plant will be in a residential setting, noise levels will be an issue. Plant needs to be designed with hospital grade silencing.

4.2. Air permitting – Describe state permitting procedures. Identify any specific state interests in coal power, and how they may impact the permitting process. Are there any unique issues due to the host site's proximity to population or environmentally sensitive areas etc.? What are the site threshold limits that would trigger additional air, water, or noise permitting requirements? The plant would have to be permitted through the Wyoming Department of Environmental Quality's (DEQ) Air Quality Division (AQD). Depending on the situation, the plant would need a new source review and could end up with a permit wavier if the emission numbers worked out. In General, a Title V Permit is needed for any major source if;

- Any major source has actual or potential emissions at or above the major source threshold for any "air pollutant."
- The major source threshold for any air pollutant is 100 tons/year (this is the "default value").
- Lower thresholds apply in non-attainment areas (but only for the pollutant that are in non-attainment).
- Major source thresholds for "hazardous air pollutants" (HAP) are 10 tons/year for a single HAP or 25 tons/year for any combination of HAP.
- The EPA generally has not required non-major sources to get permits.

See https://www.epa.gov/title-v-operating-permits/who-has-obtain-title-v-permit for more info. There is also a possibility that the permit might become a wavier if emission levels are minimal.

Coal interests are high in the state, so I would expect support from all levels of industry and government. Unique issues due to site include, being very close to residential areas, limited to trucking coal from the mine or an off loading facility in town, issues with cogeneration with Rocky Mountain Power, the local electrical utility, as cogeneration could be a major impact to them. Also, existing Public Service Commission tariffs are an issue (see the attached Schedule 33 RMP pdf). A special agreement may need to be set up with Rocky Mountain Power as this Schedule 33 can have huge cost implications to the University if the cogeneration scheme is not done correctly.

4.3. Water permitting – Is there a need for zero liquid discharge at this site? No, only if it saves money with a good pay back. It should be considered to polish the blowdown for cooling tower use. Describe any costs associated with special water treatment requirements? The high cost of Laramie's water and there is no DI plant in place. These systems as costly to run and increase water consumption by at least 25% driving up the raw water costs.

A new City water tap can be pricey, if needed.

4.4. If additional permits are needed, would the host site organization be able to support this effort? If so, are there any specific limitations, which would present a challenge? The University would most likely employ an environmental/engineering consultant for this process. If the FPO project is simpler, it may not require a new operating permit and the modified permit could be done in-house.

Industrial Siting Division permit may be required. See link: http://deq.wyoming.gov/isd/resources/jurisdiction/

City of Laramie building permitting process.

https://www.cityoflaramie.org/index.aspx?nid=432

State Dept. of Electrical Safety and Fire Prevention permit.

http://wsfm.wyo.gov/electrical-safety

4.5. NEPA – [Environmental Assessment (EA) - Categorical Exclusion (CX)] – Did the host site complete similar construction activities in the recent past, and has it carried out a NEPA study for a DOE project? NEPA is not applicable – on state land. The University has to renew the CEP's Operating Permit every 5 years and has worked with DEQ's AQD on several matters, from new source permits to operating permit requirements.

16. APPENDIX M: CITY OF LARAMIE WATER ANALYSIS

WYOMING DEPARTMENT OF AGRICULTURE
ANALYTICAL SERVICES
1174 Snowy Range Road, Laramie, WY 82070
Phone: (307) 742-2984

Internet: http://wyagric.state.wy.us/divisions/asl
E-mail: analytical.lab@wyo.gov

Customer
City of Laramie
P.O. Box C
Laramie, WY 82073

Sample ID : AA24988
Date Collected : 11/27/2018 09:00
Date Received : 11/27/2018 12:01
Date Authorized : 12/18/2018
Sample Collector : BAUMAN/PALM

Phone : 742-8521 | **Email** : pumpswells@cityoflaramie.org

Official or Service : Official

Sample Description : Soldier

Temperature : 7.2 °C

Sample Comments:

Test Report

Analyte	Method	Units	Results	Comments	Date Completed
Nitrate (as N)	EPA 300.0	mg/L	2.1		12/03/2018
Nitrite (as N)	EPA 300.0	mg/L	< 0.20		12/03/2018
Chloride	EPA 300.0	mg/L	7.9		12/03/2018
Fluoride	EPA 300.0	mg/L	< 0.50		12/03/2018
Sulfate	EPA 300.0	mg/L	12.1		12/03/2018

Sample Number: **AA24988** **Page 1 of 3**

Authorized by: Laboratory Supervisor or Manager

T JARVIS 12/18/2018
Authorizer **Date**

12/18/2018 15:53

Analyte	Method	Units	Results	Comments	
Nitrate + Nitrite - N	Calculation	mg/L	2.1		
Calcium Hardness	Calculation	mg/L	140		12/10/2018
Total Hardness	Calculation	mg/L	200		12/10/2018

Analyte	Method	Units	Results	Comments	Date Completed
Conductivity	2510 B	uS/cm	391		11/29/2018

Analyte	Method	Units	Results	Comments	Date Completed
TDS by Summation	2540 C	mg/L	200		12/10/2018

Sample Number: **AA24988** **Page 2 of 3**

Authorized by: Laboratory Supervisor or Manager

12/18/2018 15:53

T JARVIS 12/18/2018

Authorizer **Date**

Analyte	Method	Units	Results	Comments	Date Completed
Alkalinity	2320 B	mg/L	184		11/29/2018
Bicarbonate	2320 B	mg/L	184		11/29/2018
Calcium	WC.016	ppm	54.6		12/10/2018
Carbonate	2320 B	mg/L	< 2.0		11/29/2018
Copper	WC.004	ppm	< 0.010		12/14/2018
Corrosivity	2330 B		0.57	Non-aggressive	12/10/2018
Iron	WC.016	ppm	< 0.079		12/10/2018
Lead	WC.004	ppm	< 0.005		12/14/2018
Magnesium	WC.016	ppm	18.5		12/10/2018
Manganese	WC.004	ppm	< 0.005		12/14/2018
pH	4500-H+ B		8.1		11/29/2018
Potassium	WC.016	ppm	0.80		12/10/2018
Sodium	WC.016	ppm	3.83		12/10/2018
Zinc	WC.004	ppm	< 0.005		12/14/2018

The results issued on this report only reflect the analysis of the sample submitted.

The laboratory will only maintain testing results for 7 years. Copies must be requested within 7 years of result date.
Sample received for testing was acceptable unless otherwise stated on report.

Sample Number: AA24988

Authorized by: Laboratory Supervisor or Manager

12/18/2018 15:53

T JARVIS	12/18/2018
Authorizer	**Date**

17. APPENDIX N: USDA ALBANY COUNTY AREA, WYOMING SOIL REPORT FOR FPO PILOT SITE

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Albany County Area, Wyoming

March 12, 2019

Custom Soil Resource Report
Soil Map

9

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Albany County Area, Wyoming
Survey Area Data: Version 15, Sep 14, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jul 8, 2012—Nov 19, 2016

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
109	Alogia-Urban land complex, 0 to 3 percent slopes	1.5	35.0%
241	Wycolo-Alcova complex, 3 to 10 percent slopes	2.8	65.0%
Totals for Area of Interest		**4.3**	**100.0%**

Albany County Area, Wyoming

109—Alogia-Urban land complex, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: jtzk
Mean annual precipitation: 10 to 14 inches
Mean annual air temperature: 39 to 43 degrees F
Frost-free period: 85 to 110 days
Farmland classification: Not prime farmland

Map Unit Composition

Alogia and similar soils: 70 percent
Urban land: 15 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Alogia

Setting

Landform: Fan remnants, alluvial fans
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from sandstone and shale

Typical profile

A - 0 to 3 inches: loam
Btk - 3 to 21 inches: clay loam
Bky - 21 to 41 inches: loam
C - 41 to 60 inches: clay loam

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 36 to 60 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 20 percent
Gypsum, maximum in profile: 20 percent
Salinity, maximum in profile: Slightly saline to moderately saline (4.0 to 8.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 5.0
Available water storage in profile: Moderate (about 8.7 inches)

Interpretive groups

Land capability classification (irrigated): 4s
Land capability classification (nonirrigated): 4s
Hydrologic Soil Group: B
Hydric soil rating: No

Minor Components

Joemre

Percent of map unit: 9 percent
Hydric soil rating: No

Unnamed mod deep soils

Percent of map unit: 5 percent
Hydric soil rating: No

Seeps

Percent of map unit: 1 percent
Landform: Depressions
Hydric soil rating: Yes

241—Wycolo-Alcova complex, 3 to 10 percent slopes

Map Unit Setting

National map unit symbol: jv5m
Mean annual precipitation: 10 to 14 inches
Mean annual air temperature: 39 to 43 degrees F
Frost-free period: 85 to 110 days
Farmland classification: Not prime farmland

Map Unit Composition

Wycolo and similar soils: 45 percent
Alcova and similar soils: 35 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Wycolo

Setting

Landform: Hills, ridges
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Residuum weathered from sandstone and shale and/or alluvium derived from sandstone and shale

Typical profile

A - 0 to 6 inches: fine sandy loam
Bt - 6 to 12 inches: sandy clay loam
Bk1 - 12 to 25 inches: loam
Bk2 - 25 to 36 inches: clay loam
Cr - 36 to 60 inches: unweathered bedrock

Properties and qualities

Slope: 3 to 10 percent
Depth to restrictive feature: 20 to 40 inches to paralithic bedrock
Natural drainage class: Well drained

Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 25 percent
Gypsum, maximum in profile: 1 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: Low (about 5.3 inches)

Interpretive groups

Land capability classification (irrigated): 4e
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: C
Ecological site: LOAMY (10-14SE) (R034XY322WY)
Hydric soil rating: No

Description of Alcova

Setting

Landform: Hills
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Convex
Parent material: Alluvium derived from igneous and metamorphic rock

Typical profile

A - 0 to 4 inches: gravelly sandy loam
Bt - 4 to 24 inches: gravelly sandy clay loam
Bk - 24 to 60 inches: very gravelly sandy clay loam

Properties and qualities

Slope: 3 to 10 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum in profile: 15 percent
Gypsum, maximum in profile: 1 percent
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 5.0
Available water storage in profile: Moderate (about 6.4 inches)

Interpretive groups

Land capability classification (irrigated): 4e
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Ecological site: LOAMY (10-14SE) (R034XY322WY)
Hydric soil rating: No

Minor Components

Joemre

Percent of map unit: 7 percent
Hydric soil rating: No

Rohonda

Percent of map unit: 7 percent
Hydric soil rating: No

Pilotpeak

Percent of map unit: 3 percent
Hydric soil rating: No

Tieside

Percent of map unit: 3 percent
Hydric soil rating: No

18. APPENDIX O: USFWS WYOMING ECOLOGICAL SERVICES FIELD OFFICE LIST OF THREATENED AND ENDANGERED SPECIES

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Wyoming Ecological Services Field Office
5353 Yellowstone Road, Suite 308a
Cheyenne, WY 82009-4178
Phone: (307) 772-2374 Fax: (307) 772-2358
http://www.fws.gov/wyominges/

In Reply Refer To: March 18, 2019
Consultation Code: 06E13000-2019-SLI-0182
Event Code: 06E13000-2019-E-00472
Project Name: FPO Pilot Plant Location

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (ES) of 1973, as amended (16 U.S.C. 1531 *et seq.*).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the ESA, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

Please feel free to contact us if you need more information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. We also encourage you to visit the Wyoming Ecological Services website at https://www.fws.gov/wyominges/species_endangered.php.

The purpose of the ESA is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the ESA and its implementing regulations (50 CFR 402 *et seq.*), federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2)(c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at: http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF.

We also recommend you consider the following information when assessing impacts to federally listed species, as well as migratory birds, and other trust resources:

Colorado River and Platte River Systems: Federal agencies must consult with the Service under section 7 of the ESA for projects in Wyoming that may lead to water depletions or have the potential to impact water quality in the Colorado River system or the Platte River system, because these actions my affect threatened and endangered species inhabiting the downstream reaches of these river systems. In general, depletions include evaporative losses and/or consumptive use of surface or groundwater within the affected basin, often characterized as diversions minus return flows. Project elements that could be associated with depletions include, but are not limited to: ponds, lakes, and reservoirs (e.g., for detention, recreating, irrigation, storage, stock watering, municipal storage, and power generation); hydrostatic testing of pipelines; wells; dust abatement; diversion structures; and water treatment facilities. For more information on consultation requirements for the Platte River species, please visit https://www.fws.gov/platteriver/.

Migratory Birds: The Migratory Bird Treaty Act (16 U.S.C. 703-712; MBTA) prohibits the taking of any migratory birds, their parts, nests, or eggs except as permitted by regulations. Except for introduced species and some upland game birds, almost all birds occurring in the wild in the United States are protected (50 CFR 10.13). On December 22, 2017, the Department of the Interior Solicitor's Office issued an opinion that the MBTA's prohibitions on pursuing, hunting, taking, capturing, killing, or attempting to do the same apply only to affirmative actions that have as their purpose the taking or killing of migratory birds, their nests, or their eggs.

While the opinion (M-37050) states that the MBTA prohibition on the taking or killing of migratory birds applies only to deliberate acts, project activities should avoid, to the extent possible, sensitive periods and habitats to conserve healthy populations of migratory birds. See our website for more information and example conservation measures at https://www.fws.gov/wyominges/species_migratory.php. Guidance for minimizing impacts to migratory birds for projects that include communication towers can be found at https://www.fws.gov/birds/management/project-assessment-tools-and-guidance/guidance-documents/communication-towers.php.

The Bald and Golden Eagle Protection Act (16 U.S.C. 668-668d; Eagle Act) prohibits knowingly taking, or taking with wanton disregard for the consequences of an activity, any bald or golden eagles or their body parts, nests, or eggs, which includes collection, molestation, disturbance, destruction, or killing. Eagle nests are protected whether they are active or inactive. Removal or destruction of nests, or causing abandonment of a nest could constitute a violation of the Eagle Act. Projects affecting eagles may require development of an eagle conservation plan (https://www.fws.gov/ecological-service/es-library/pdfs/Eagle_Conservation_Guidance-Module%201.pdf). Additionally, wind energy projects should follow the wind energy guidelines (https://www.fws.gov/ecological-service/energy-develpment/wind.html) for minimizing impacts to migratory birds and bats.

In addition to MBTA and the Eagle Act, Executive Order 13186: *Responsibilities of Federal Agencies to Protect Migratory Birds*, obligates all federal agencies that engage in or authorize activities that might affect migratory birds, to minimize those effects and encourage conservation measures that will improve bird populations. Executive Order 13186 provides for the protection of both migratory birds and migratory bird habitat. For information regarding the implementation of Executive Order 13186, please visit https://www.fws.gov/birds/policies-and-regulations/executive-orders/e0-13186.php.

We appreciate your concern for threatened and endangered species. The Service encourages federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the ESA. Please include the Consultation Code in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries
- Migratory Birds
- Wetlands

Official Species List

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

Wyoming Ecological Services Field Office
5353 Yellowstone Road, Suite 308a
Cheyenne, WY 82009-4178
(307) 772-2374

Project Summary

Consultation Code: 06E13000-2019-SLI-0182

Event Code: 06E13000-2019-E-00472

Project Name: FPO Pilot Plant Location

Project Type: POWER GENERATION

Project Description: The Southwest Research Institute (SwRI) is proposing to construct and operate a 25-MWth FPO demonstration system at the University of Wyoming (UW) in Laramie, Wyoming. This will allow SwRI to evaluate the FPO unit performance including novel pieces of equipment, such as, coal preparation and slurrying, FPO combustor, hot fumes quencher, once-through steam generator (OTSG), the turbo-expander quencher, and the turbo-expander. SwRI will run tests on the unit for approximately two years; afterwards the FPO unit will be turned over to UW.

Project Location:

Approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/place/41.318147351454904N105.57380944490433W

Counties: Albany, WY

Endangered Species Act Species

There is a total of 7 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

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1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

Mammals

NAME	STATUS
Preble's Meadow Jumping Mouse *Zapus hudsonius preblei* There is **final** critical habitat for this species. Your location is outside the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/4090	Threatened

Birds

NAME	STATUS
Least Tern *Sterna antillarum* Population: interior pop. No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/8505	Endangered
Piping Plover *Charadrius melodus* Population: [Atlantic Coast and Northern Great Plains populations] - Wherever found, except those areas where listed as endangered. There is **final** critical habitat for this species. Your location is outside the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/6039	Threatened
Whooping Crane *Grus americana* Population: Wherever found, except where listed as an experimental population There is **final** critical habitat for this species. The location of the critical habitat is not available. Species profile: https://ecos.fws.gov/ecp/species/758	Endangered

Amphibians

NAME	STATUS
Wyoming Toad *Bufo hemiophrys baxteri* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6889	Endangered

Fishes

NAME	STATUS
Pallid Sturgeon *Scaphirhynchus albus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7162	Endangered

Flowering Plants

NAME	STATUS
Western Prairie Fringed Orchid *Platanthera praeclara* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/1669	Threatened

Critical habitats

THERE ARE NO CRITICAL HABITATS WITHIN YOUR PROJECT AREA UNDER THIS OFFICE'S JURISDICTION.

USFWS National Wildlife Refuge Lands And Fish Hatcheries

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

THERE ARE NO REFUGE LANDS OR FISH HATCHERIES WITHIN YOUR PROJECT AREA.

Migratory Birds

Certain birds are protected under the Migratory Bird Treaty Act[1] and the Bald and Golden Eagle Protection Act[2].

Any person or organization who plans or conducts activities that may result in impacts to migratory birds, eagles, and their habitats should follow appropriate regulations and consider implementing appropriate conservation measures, as described below.

1. The Migratory Birds Treaty Act of 1918.
2. The Bald and Golden Eagle Protection Act of 1940.
3. 50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)

The birds listed below are birds of particular concern either because they occur on the USFWS Birds of Conservation Concern (BCC) list or warrant special attention in your project location. To learn more about the levels of concern for birds on your list and how this list is generated, see the FAQ below. This is not a list of every bird you may find in this location, nor a guarantee that every bird on this list will be found in your project area. To see exact locations of where birders and the general public have sighted birds in and around your project area, visit the E-bird data mapping tool (Tip: enter your location, desired date range and a species on your list). For projects that occur off the Atlantic Coast, additional maps and models detailing the relative occurrence and abundance of bird species on your list are available. Links to additional information about Atlantic Coast birds, and other important information about your migratory bird list, including how to properly interpret and use your migratory bird report, can be found below.

For guidance on when to schedule activities or implement avoidance and minimization measures to reduce impacts to migratory birds on your list, click on the PROBABILITY OF PRESENCE SUMMARY at the top of your list to see when these birds are most likely to be present and breeding in your project area.

NAME	BREEDING SEASON
Bald Eagle *Haliaeetus leucocephalus* This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities. https://ecos.fws.gov/ecp/species/1626	Breeds Jan 1 to Aug 31
Cassin's Finch *Carpodacus cassinii* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/9462	Breeds May 15 to Jul 15

NAME	BREEDING SEASON
Clark's Grebe *Aechmophorus clarkii* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds Jan 1 to Dec 31
Golden Eagle *Aquila chrysaetos* This is not a Bird of Conservation Concern (BCC) in this area, but warrants attention because of the Eagle Act or for potential susceptibilities in offshore areas from certain types of development or activities. https://ecos.fws.gov/ecp/species/1680	Breeds Jan 1 to Aug 31
Lesser Yellowlegs *Tringa flavipes* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/9679	Breeds elsewhere
Long-billed Curlew *Numenius americanus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/5511	Breeds Apr 1 to Jul 31
Marbled Godwit *Limosa fedoa* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/9481	Breeds May 1 to Jul 31
Mountain Plover *Charadrius montanus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/3638	Breeds Apr 15 to Aug 15
Olive-sided Flycatcher *Contopus cooperi* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/3914	Breeds May 20 to Aug 31
Rufous Hummingbird *selasphorus rufus* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska. https://ecos.fws.gov/ecp/species/8002	Breeds Apr 15 to Jul 15
Willet *Tringa semipalmata* This is a Bird of Conservation Concern (BCC) throughout its range in the continental USA and Alaska.	Breeds Apr 20 to Aug 5

Probability Of Presence Summary

The graphs below provide our best understanding of when birds of concern are most likely to be present in your project area. This information can be used to tailor and schedule your project activities to avoid or minimize impacts to birds. Please make sure you read and understand the FAQ "Proper Interpretation and Use of Your Migratory Bird Report" before using or attempting to interpret this report.

Probability of Presence (■)

Each green bar represents the bird's relative probability of presence in the 10km grid cell(s) your project overlaps during a particular week of the year. (A year is represented as 12 4-week months.) A taller bar indicates a higher probability of species presence. The survey effort (see below) can be used to establish a level of confidence in the presence score. One can have higher confidence in the presence score if the corresponding survey effort is also high.

How is the probability of presence score calculated? The calculation is done in three steps:

1. The probability of presence for each week is calculated as the number of survey events in the week where the species was detected divided by the total number of survey events for that week. For example, if in week 12 there were 20 survey events and the Spotted Towhee was found in 5 of them, the probability of presence of the Spotted Towhee in week 12 is 0.25.
2. To properly present the pattern of presence across the year, the relative probability of presence is calculated. This is the probability of presence divided by the maximum probability of presence across all weeks. For example, imagine the probability of presence in week 20 for the Spotted Towhee is 0.05, and that the probability of presence at week 12 (0.25) is the maximum of any week of the year. The relative probability of presence on week 12 is 0.25/0.25 = 1; at week 20 it is 0.05/0.25 = 0.2.
3. The relative probability of presence calculated in the previous step undergoes a statistical conversion so that all possible values fall between 0 and 10, inclusive. This is the probability of presence score.

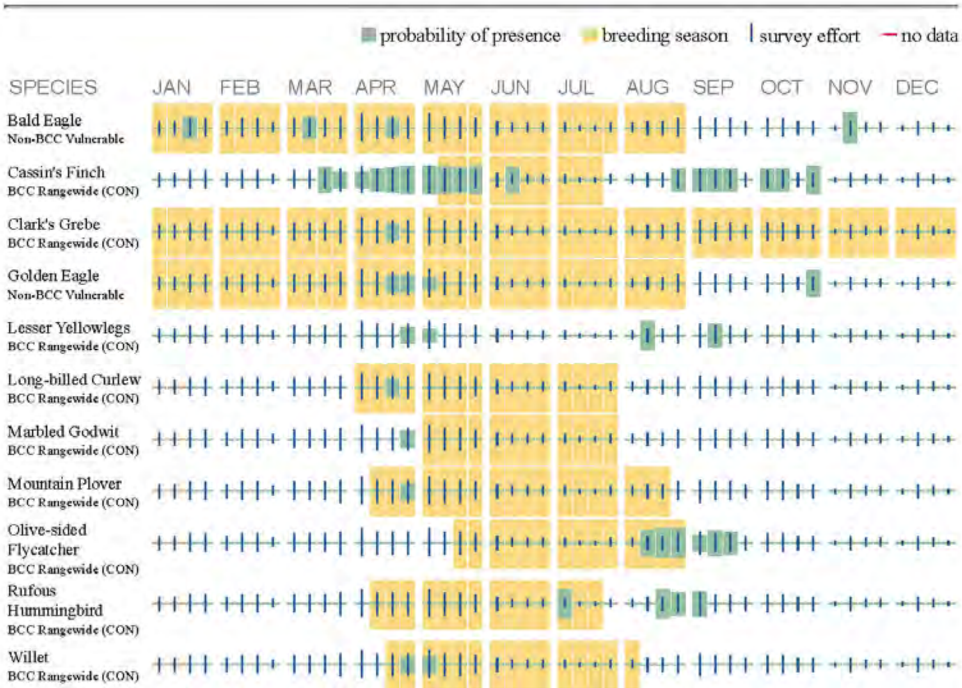
Breeding Season (■)
Yellow bars denote a very liberal estimate of the time-frame inside which the bird breeds across its entire range. If there are no yellow bars shown for a bird, it does not breed in your project area.

Survey Effort (|)
Vertical black lines superimposed on probability of presence bars indicate the number of surveys performed for that species in the 10km grid cell(s) your project area overlaps. The number of surveys is expressed as a range, for example, 33 to 64 surveys.

No Data (−)
A week is marked as having no data if there were no survey events for that week.

Survey Timeframe

Surveys from only the last 10 years are used in order to ensure delivery of currently relevant information. The exception to this is areas off the Atlantic coast, where bird returns are based on all years of available data, since data in these areas is currently much more sparse.



Additional information can be found using the following links:

- Birds of Conservation Concern http://www.fws.gov/birds/management/managed-species/birds-of-conservation-concern.php
- Measures for avoiding and minimizing impacts to birds http://www.fws.gov/birds/management/project-assessment-tools-and-guidance/conservation-measures.php
- Nationwide conservation measures for birds http://www.fws.gov/migratorybirds/pdf/management/nationwidestandardconservationmeasures.pdf

Migratory Birds FAQ

Tell me more about conservation measures I can implement to avoid or minimize impacts to migratory birds.

Nationwide Conservation Measures describes measures that can help avoid and minimize impacts to all birds at any location year round. Implementation of these measures is particularly important when birds are most likely to occur in the project area. When birds may be breeding in the area, identifying the locations of any active nests and avoiding their destruction is a very helpful impact minimization measure. To see when birds are most likely to occur and be breeding in your project area, view the Probability of Presence Summary. Additional measures and/or permits may be advisable depending on the type of activity you are conducting and the type of infrastructure or bird species present on your project site.

What does IPaC use to generate the migratory birds potentially occurring in my specified location?
The Migratory Bird Resource List is comprised of USFWS Birds of Conservation Concern (BCC) and other species that may warrant special attention in your project location.

The migratory bird list generated for your project is derived from data provided by the Avian Knowledge Network (AKN). The AKN data is based on a growing collection of survey, banding, and citizen science datasets and is queried and filtered to return a list of those birds reported as occurring in the 10km grid cell(s) which your project intersects, and that have been identified as warranting special attention because they are a BCC species in that area, an eagle (Eagle Act requirements may apply), or a species that has a particular vulnerability to offshore activities or development.

Again, the Migratory Bird Resource list includes only a subset of birds that may occur in your project area. It is not representative of all birds that may occur in your project area. To get a list of all birds potentially present in your project area, please visit the E-bird Explore Data Tool.

What does IPaC use to generate the probability of presence graphs for the migratory birds potentially occurring in my specified location?
The probability of presence graphs associated with your migratory bird list are based on data provided by the Avian Knowledge Network (AKN). This data is derived from a growing collection of survey, banding, and citizen science datasets .

Probability of presence data is continuously being updated as new and better information becomes available. To learn more about how the probability of presence graphs are produced and how to interpret them, go the Probability of Presence Summary and then click on the "Tell me about these graphs" link.

How do I know if a bird is breeding, wintering, migrating or present year-round in my project area?
To see what part of a particular bird's range your project area falls within (i.e. breeding, wintering, migrating or year-round), you may refer to the following resources: The Cornell Lab of Ornithology All About Birds Bird Guide, or (if you are unsuccessful in locating the bird of interest there), the Cornell Lab of Ornithology Neotropical Birds guide. If a bird on your migratory bird species list has a breeding season associated with it, if that bird does occur in your

project area, there may be nests present at some point within the timeframe specified. If "Breeds elsewhere" is indicated, then the bird likely does not breed in your project area.

What are the levels of concern for migratory birds?
Migratory birds delivered through IPaC fall into the following distinct categories of concern:

1. "BCC Rangewide" birds are Birds of Conservation Concern (BCC) that are of concern throughout their range anywhere within the USA (including Hawaii, the Pacific Islands, Puerto Rico, and the Virgin Islands);
2. "BCC - BCR" birds are BCCs that are of concern only in particular Bird Conservation Regions (BCRs) in the continental USA; and
3. "Non-BCC - Vulnerable" birds are not BCC species in your project area, but appear on your list either because of the Eagle Act requirements (for eagles) or (for non-eagles) potential susceptibilities in offshore areas from certain types of development or activities (e.g. offshore energy development or longline fishing).

Although it is important to try to avoid and minimize impacts to all birds, efforts should be made, in particular, to avoid and minimize impacts to the birds on this list, especially eagles and BCC species of rangewide concern. For more information on conservation measures you can implement to help avoid and minimize migratory bird impacts and requirements for eagles, please see the FAQs for these topics.

Details about birds that are potentially affected by offshore projects
For additional details about the relative occurrence and abundance of both individual bird species and groups of bird species within your project area off the Atlantic Coast, please visit the Northeast Ocean Data Portal. The Portal also offers data and information about other taxa besides birds that may be helpful to you in your project review. Alternately, you may download the bird model results files underlying the portal maps through the NOAA NCCOS Integrative Statistical Modeling and Predictive Mapping of Marine Bird Distributions and Abundance on the Atlantic Outer Continental Shelf project webpage.

Bird tracking data can also provide additional details about occurrence and habitat use throughout the year, including migration. Models relying on survey data may not include this information. For additional information on marine bird tracking data, see the Diving Bird Study and the nanotag studies or contact Caleb Spiegel or Pam Loring.

What if I have eagles on my list?
If your project has the potential to disturb or kill eagles, you may need to obtain a permit to avoid violating the Eagle Act should such impacts occur.

Proper Interpretation and Use of Your Migratory Bird Report
The migratory bird list generated is not a list of all birds in your project area, only a subset of birds of priority concern. To learn more about how your list is generated, and see options for identifying what other birds may be in your project area, please see the FAQ "What does IPaC use to generate the migratory birds potentially occurring in my specified location". Please be aware this report provides the "probability of presence" of birds within the 10 km grid cell(s) that

overlap your project; not your exact project footprint. On the graphs provided, please also look carefully at the survey effort (indicated by the black vertical bar) and for the existence of the "no data" indicator (a red horizontal bar). A high survey effort is the key component. If the survey effort is high, then the probability of presence score can be viewed as more dependable. In contrast, a low survey effort bar or no data bar means a lack of data and, therefore, a lack of certainty about presence of the species. This list is not perfect; it is simply a starting point for identifying what birds of concern have the potential to be in your project area, when they might be there, and if they might be breeding (which means nests might be present). The list helps you know what to look for to confirm presence, and helps guide you in knowing when to implement conservation measures to avoid or minimize potential impacts from your project activities, should presence be confirmed. To learn more about conservation measures, visit the FAQ "Tell me about conservation measures I can implement to avoid or minimize impacts to migratory birds" at the bottom of your migratory bird trust resources page.

Wetlands

Impacts to NWI wetlands and other aquatic habitats may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal statutes.

For more information please contact the Regulatory Program of the local U.S. Army Corps of Engineers District.

Please note that the NWI data being shown may be out of date. We are currently working to update our NWI data set. We recommend you verify these results with a site visit to determine the actual extent of wetlands on site.

THERE ARE NO WETLANDS WITHIN YOUR PROJECT AREA.

19. APPENDIX P: UW WYOMING NATURAL DIVERSITY DATABASE

ANIMAL SPECIES OF CONCERN

WYOMING NATURAL DIVERSITY DATABASE

Animal Species of Concern

The table below includes vertebrate and invertebrate animals with conservation ranks or agency statuses (of *conservation concern*) within the state of Wyoming. All speci
extinction within Wyoming (see Keinath and Beauvais 2003 (../../_files/docs/reports/WYNDDReports/U04KEI02WYUS.pdf)). WYNDD species of concern (SOC) include tho
high Wyoming Contribution Rank (../../codes-and-definitions/wy-contribution-rank/index.html) or are experiencing substantial threats (see Heritage Rank Definitions (../.
(SOPC) are generally those that currently appear secure in Wyoming but exhibit some vulnerability that suggests they could become a conservation priority in the future,
row highlighting and text. The status of species are periodically reviewed and updated as appropriate.

This list has no status under state legislation, though S-rank values are sometimes cited in policies, and referenced in development of sensitive species lists by federal lar
and more geographically restricted than criteria used for inclusion on the Wyoming Species of Concern List. The list contents and S-rank values are based on factors cons
contribution ranks are calculated as an alternative score that represents the relative contribution of species' status in Wyoming over its rangewide status.

WYNDD has generated species assessments for many species on these lists, which provide detailed discussions of their biology and conservation concerns (see the Specie
the process of creating brief Species Abstracts for all tracked species that will concisely state major biological information (e.g. habitat) and conservation concerns.

Also, check out the Wyoming Bat Call Library (../../data-dissemination/priority-data-comp/wyoming-bat-call-library/index.html), a central distribution site for the exchang

Submit Sensitive Animal Data (http://www.uwyo.edu/wyndd/species-of-concern/subm

Class	Sciname	Comname	WY occur	SOC (http://www.uwyo.edu/wyndd/species-of-concern/)	S Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	G Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	USFWS (http://www.uwyo.edu/wyndd/codes-and-definitions/federal-status/#USFWS)
Amphibians	Ambystoma mavortium	Western Tiger Salamander	Resident	SOPC	S4	G5	
Amphibians	Anaxyrus baxteri	Wyoming Toad	Resident	SOC	S1	G1	LE
Amphibians	Anaxyrus boreas	Western Toad	Resident	SOC	S1	G4	
Amphibians	Anaxyrus boreas - Eastern Clade	Eastern Clade Western Toad	Resident	SOC	S1	G4T2T3	NW
Amphibians	Anaxyrus cognatus	Great Plains Toad	Resident	SOPC	S2	G5	
Amphibians	Lithobates pipiens	Northern Leopard Frog	Resident	SOC	S3	G5	NW
Amphibians	Lithobates sylvaticus	Wood Frog	Resident	SOC	S1	G5	
Amphibians	Lithobates sylvaticus - Bighorn Mountains	Bighorn Mountains Wood Frog	Resident	SOC	S1	G5T1Q	
Amphibians	Lithobates sylvaticus - Southern Rockies	Southern Rockies Wood Frog	Resident	SOC	S1	G5T3Q	
Amphibians	Rana luteiventris	Columbia Spotted Frog	Resident	SOC	S3	G4	
Amphibians	Rana luteiventris - Bighorn Mountains	Bighorn Mountains Spotted Frog	Resident	SOC	S1	G4T1Q	
Amphibians	Spea bombifrons	Plains Spadefoot	Resident	SOC	S4	G5	
Amphibians	Spea intermontana	Great Basin Spadefoot	Resident	SOC	S3	G5	
Birds	Accipiter gentilis	Northern Goshawk	Resident	SOC	S2S3BS3N	G5	NW
Birds	Aechmophorus clarkii	Clark's Grebe	Resident	SOC	S2S3	G5	
Birds	Aechmophorus occidentalis	Western Grebe	Resident		S3S4	G5	
Birds	Aegolius funereus	Boreal Owl	Resident	SOC	S2	G5	
Birds	Ammodramus bairdii	Baird's Sparrow	Resident	SOC	S1	G4	NW
Birds	Ammodramus savannarum	Grasshopper Sparrow	Resident	SOPC	S4	G5	
Birds	Anthus rubescens	American Pipit	Resident		S2	G5	
Birds	Anthus spragueii	Sprague's Pipit	Resident	SOPC	SNA	G4	NW

Class	Sciname	Comname	WY occur	SOC (http://www.uwyo.edu/wyndd/species-of-concern/)	S Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	G Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	USFWS (http://www.uwyo.edu/wyndd/codes-and-definitions/federal-status/#USFWS)
Birds	Antigone canadensis	Sandhill Crane	Resident	SOPC	S3BS5N	G5	
Birds	Aphelocoma woodhouseii	Woodhouse's Scrub-Jay	Resident	SOC	S1	G5	
Birds	Aquila chrysaetos	Golden Eagle	Resident	SOPC	S5BS4S5N	G5	
Birds	Archilochus alexandri	Black-chinned Hummingbird	Resident		S3	G5	
Birds	Ardea herodias	Great Blue Heron	Resident		S4	G5	
Birds	Artemisiospiza nevadensis	Sagebrush Sparrow	Resident	SOC	S3S4	G5	
Birds	Asio flammeus	Short-eared Owl	Resident	SOC	S1S2	G5	
Birds	Athene cunicularia	Burrowing Owl	Resident	SOC	S3	G4	
Birds	Aythya collaris	Ring-necked Duck	Resident	SOPC	S4B	G5	
Birds	Baeolophus ridgwayi	Juniper Titmouse	Resident	SOC	S1S3	G5	
Birds	Bartramia longicauda	Upland Sandpiper	Resident		S4B5	G5	
Birds	Botaurus lentiginosus	American Bittern	Resident	SOC	S2S3	G4	
Birds	Bucephala albeola	Bufflehead	Resident	SOPC	S2B	G5	
Birds	Bucephala clangula	Common Goldeneye	Resident	SOPC	S3B	G5	
Birds	Buteo regalis	Ferruginous Hawk	Resident	SOC	S4S5BS3N	G4	NW
Birds	Buteo swainsoni	Swainson's Hawk	Resident		S5	G5	
Birds	Calcarius ornatus	Chestnut-collared Longspur	Resident	SOC	S3	G5	
Birds	Calidris canutus rufa	Rufa Red Knot	Accidental		SNA	G4T2	LT
Birds	Catherpes mexicanus	Canyon Wren	Resident	SOPC	S4	G5	
Birds	Centrocercus urophasianus	Greater Sage-Grouse	Resident	SOC	S4	G3G4	NW
Birds	Chaetura pelagica	Chimney Swift	Resident	SOPC	S3B	G5	
Birds	Charadrius melodus	Piping Plover	Accidental	SOPC	SNA	G3	LT
Birds	Charadrius montanus	Mountain Plover	Resident	SOC	S3	G3	NW
Birds	Charadrius nivosus	Snowy Plover	Resident	SOC	S1	G3	
Birds	Chlidonias niger	Black Tern	Resident	SOC	S1	G4	
Birds	Chordeiles minor	Common Nighthawk	Resident		S5	G5	
Birds	Cinclus mexicanus	American Dipper	Resident	SOPC	S4	G5	
Birds	Cinclus mexicanus - Black Hills	Black Hills Dipper	Resident	SOC	S1	G5TNR	NW
Birds	Circus hudsonius	Northern Harrier	Resident		S4BS5N	G5	
Birds	Coccyzus americanus	Yellow-billed Cuckoo	Resident	SOC	S1	G5	
Birds	Coccyzus americanus - Western U.S. DPS	Western Yellow-billed Cuckoo	Accidental	SOC	SNA	G5T2T3	LT
Birds	Coccyzus erythropthalmus	Black-billed Cuckoo	Resident	SOC	S2S3	G5	
Birds	Colinus virginianus	Northern Bobwhite	Resident	SOPC	S1	G5	
Birds	Contopus cooperi	Olive-sided Flycatcher	Resident	SOPC	S4B	G4	
Birds	Cygnus buccinator	Trumpeter Swan	Resident	SOC	S3	G4	NW
Birds	Cygnus columbianus	Tundra Swan	Resident	SOPC	S2N	G5	

Class	Sciname	Comname	WY occur	SOC (http://www.uwyo.edu/wyndd/species-of-concern/)	S Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	G Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	USFWS (http://www.uwyo.edu/wyndd/code-and-definitions/federal-status/#USFWS)
Birds	Cypseloides niger	Black Swift	Potential Occupier		SU	G4	
Birds	Dolichonyx oryzivorus	Bobolink	Resident	SOC	S2S3	G5	
Birds	Egretta thula	Snowy Egret	Resident	SOPC	S1S2	G5	
Birds	Empidonax hammondii	Hammond's Flycatcher	Resident	SOPC	S4	G5	
Birds	Empidonax traillii	Willow Flycatcher	Resident		S5	G5	
Birds	Falco columbarius	Merlin	Resident	SOPC	S4	G5	
Birds	Falco peregrinus	Peregrine Falcon	Resident	SOC	S2BS2S3N	G4	DM
Birds	Falco sparverius	American Kestrel	Resident		S5	G5	
Birds	Gavia adamsii	Yellow-billed Loon	Resident		SNA	G4	NW
Birds	Gavia immer	Common Loon	Resident	SOC	S1BS3N	G5	
Birds	Geothlypis tolmiei	MacGillivray's Warbler	Resident		S4	G5	
Birds	Geothlypis trichas	Common Yellowthroat	Resident		S5	G5	
Birds	Glaucidium gnoma	Northern Pygmy-Owl	Resident	SOC	S1S2	G4G5	
Birds	Grus americana	Whooping Crane	Historic	SOC	SH	G1	LE,LEXN
Birds	Haliaeetus leucocephalus	Bald Eagle	Resident	SOC	S4BS5N	G5	DM
Birds	Himantopus mexicanus	Black-necked Stilt	Resident	SOPC	S3B	G5	
Birds	Histrionicus histrionicus	Harlequin Duck	Resident	SOC	S1	G4	
Birds	Hydroprogne caspia	Caspian Tern	Resident	SOC	S1	G5	
Birds	Icterus parisorum	Scott's Oriole	Resident	SOC	S1	G5	
Birds	Ixobrychus exilis	Least Bittern	Resident	SOPC	SNA	G5	
Birds	Junco hyemalis	Dark-eyed Junco	Resident	SOC	S5BS5N	G5	
Birds	Junco hyemalis aikeni	White-winged Junco	Resident	SOC	S3BS3N	G5T4	
Birds	Junco hyemalis caniceps	Gray-headed Junco	Resident	SOC	S5BS5N	G5T5	
Birds	Junco hyemalis hyemalis	Slate-colored Junco	Resident	SOC	S5BS5N	G5T5	
Birds	Junco hyemalis mearnsi	Pink-sided Junco	Resident	SOC	S5BS5N	G5T5	
Birds	Junco hyemalis oreganus	Oregon Junco	Resident	SOC	S5BS5N	G5T5	
Birds	Lagopus leucura	White-tailed Ptarmigan	Accidental	SOC	SNA	G5	UR
Birds	Lanius ludovicianus	Loggerhead Shrike	Resident	SOC	S4S5	G4	
Birds	Larus argentatus	Herring Gull	Resident	SOPC	SNA	G5	
Birds	Larus californicus	California Gull	Resident	SOPC	S2B	G5	
Birds	Larus delawarensis	Ring-billed Gull	Resident	SOPC	S2	G5	
Birds	Larus fuscus	Lesser Black-backed Gull	Resident	SOPC	SNR	G5	
Birds	Leucophaeus pipixcan	Franklin's Gull	Resident		S1	G4G5	
Birds	Leucosticte atrata	Black Rosy-Finch	Resident	SOC	S1BS2N	G4	
Birds	Leucosticte australis	Brown-capped Rosy-Finch	Resident	SOC	S1	G4	
Birds	Loxia curvirostra	Red Crossbill	Resident		S5	G5	
Birds	Loxia leucoptera	White-winged Crossbill	Resident	SOPC	S2	G5	
Birds	Megascops asio	Eastern Screech-Owl	Resident	SOPC	S3	G5	
Birds	Megascops kennicottii	Western Screech-Owl	Resident	SOPC	S2	G5	
Birds	Melanerpes erythrocephalus	Red-headed Woodpecker	Resident		S2S3	G5	
Birds	Melanerpes lewis	Lewis's Woodpecker	Resident	SOC	S2	G4	

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Birds	Myiarchus cinerascens	Ash-throated Flycatcher	Resident	SOPC	S1S2	G5	
Birds	Nucifraga columbiana	Clark's Nutcracker	Resident		S3S4	G5	
Birds	Numenius americanus	Long-billed Curlew	Resident	SOC	S3S4	G5	
Birds	Nycticorax nycticorax	Black-crowned Night-Heron	Resident	SOPC	S3S3	G5	
Birds	Oreoscoptes montanus	Sage Thrasher	Resident	SOPC	S5	G5	
Birds	Oreothlypis virginiae	Virginia's Warbler	Resident	SOC	S1	G5	
Birds	Pandion haliaetus	Osprey	Resident	SOPC	S3B	G5	
Birds	Passerina caerulea	Blue Grosbeak	Resident	SOPC	S1	G5	
Birds	Passerina cyanea	Indigo Bunting	Resident	SOPC	S3B	G5	
Birds	Pelecanus erythrorhynchos	American White Pelican	Resident	SOC	S3S4	G4	
Birds	Peucaea cassinii	Cassin's Sparrow	Resident	SOPC	SNA	G5	
Birds	Phalaropus lobatus	Red-necked Phalarope	Resident	SOPC	S3N	G4G5	
Birds	Pheucticus ludovicianus	Rose-breasted Grosbeak	Resident	SOPC	S1	G5	
Birds	Picoides albolarvatus	White-headed Woodpecker	Accidental		SNA	G4	
Birds	Picoides arcticus	Black-backed Woodpecker	Resident	SOC	S2	G5	
Birds	Picoides arcticus - Black Hills	Black Hills Black-backed Woodpecker	Resident	SOC	S2	G5T1	NW
Birds	Picoides dorsalis	American Three-toed Woodpecker	Resident	SOC	S3	G5	
Birds	Picoides dorsalis - Black Hills	Black Hills Three-toed Woodpecker	Resident	SOC	S3	G5T3	
Birds	Plegadis chihi	White-faced Ibis	Resident	SOC	S1	G5	
Birds	Polioptila caerulea	Blue-gray Gnatcatcher	Resident		S3S4	G5	
Birds	Progne subis	Purple Martin	Resident		S1	G5	
Birds	Psaltriparus minimus	Bushtit	Resident	SOC	S2S3	G5	
Birds	Psiloscops flammeolus	Flammulated Owl	Resident	SOPC	S1	G4	
Birds	Rallus limicola	Virginia Rail	Resident	SOPC	S2S4	G5	
Birds	Recurvirostra americana	American Avocet	Resident	SOPC	S3B	G5	
Birds	Regulus satrapa	Golden-crowned Kinglet	Resident	SOPC	S3BS4N	G5	
Birds	Rhynchophanes mccownii	McCown's Longspur	Resident	SOC	S3	G4	
Birds	Sayornis phoebe	Eastern Phoebe	Resident	SOPC	SNA	G5	
Birds	Selasphorus calliope	Calliope Hummingbird	Resident	SOC	S2	G5	
Birds	Selasphorus rufus	Rufous Hummingbird	Resident		S3	G5	
Birds	Setophaga nigrescens	Black-throated Gray Warbler	Resident	SOC	S2	G5	
Birds	Setophaga townsendi	Townsend's Warbler	Resident	SOPC	SNA	G5	
Birds	Sialia sialis	Eastern Bluebird	Resident	SOPC	S2	G5	
Birds	Sitta pygmaea	Pygmy Nuthatch	Resident	SOC	S2S3	G5	
Birds	Sphyrapicus thyroideus	Williamson's Sapsucker	Resident	SOC	S3S4	G5	
Birds	Spiza americana	Dickcissel	Resident	SOPC	S1	G5	
Birds	Spizella breweri	Brewer's Sparrow	Resident	SOPC	S5	G5	
Birds	Spizella pallida	Clay-colored Sparrow	Resident	SOPC	S3B	G5	
Birds	Sterna forsteri	Forster's Tern	Resident	SOC	S1	G5	

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Birds	Sterna hirundo	Common Tern	Resident	SOPC	S1	G5	
Birds	Sternula antillarum	Least Tern	Accidental		SNA	G4	LE
Birds	Streptopelia roseogrisea	African Collared-Dove	Resident	SOPC	SNR	G5	
Birds	Strix nebulosa	Great Gray Owl	Resident	SOC	S2	G5	
Birds	Thryomanes bewickii	Bewick's Wren	Resident		S3	G5	
Birds	Troglodytes hiemalis	Winter Wren	Resident	SOPC	SNA	G5	
Birds	Tympanuchus cupido	Greater Prairie Chicken	Resident	SOPC	SNA	G4	
Birds	Tympanuchus phasianellus columbianus	Columbian Sharp-tailed Grouse	Resident	SOC	S1	G5T3	NW
Birds	Tyto alba	Barn Owl	Resident	SOPC	S3	G5	
Birds	Vireo olivaceus	Red-eyed Vireo	Resident	SOPC	S2	G5	
Birds	Vireo vicinior	Gray Vireo	Resident		S1	G4	
Crayfish, Scuds and Sow Bugs	Cambarus diogenes	Devil Crayfish	Resident	SOC	S3	G5	
Crayfish, Scuds and Sow Bugs	Orconectes immunis	Calico/Papershell Crayfish	Resident		SNR	G5	
Crayfish, Scuds and Sow Bugs	Orconectes neglectus	Ringed Crayfish	Resident	SOC	S3	G5	
Crayfish, Scuds and Sow Bugs	Pacifastacus gambelii	Pilose Crayfish	Resident	SOC	S3	G4G5	
Fishes	Catostomus discobolus	Bluehead Sucker	Resident	SOC	S3	G4	
Fishes	Catostomus latipinnis	Flannelmouth Sucker	Resident	SOC	S3	G3G4	
Fishes	Catostomus platyrhynchus	Mountain Sucker	Resident	SOPC	S5	G5	
Fishes	Chasmistes muriei	Snake River Sucker	Resident	SOC	SX	GX	
Fishes	Chrosomus neogaeus	Finescale Dace	Resident	SOC	S2	G5	
Fishes	Couesius plumbeus	Lake Chub	Resident	SOPC	S5	G5	
Fishes	Etheostoma exile	Iowa Darter	Resident	SOPC	S3S4	G5	
Fishes	Etheostoma spectabile	Orangethroat Darter	Resident	SOC	S1	G5	
Fishes	Fundulus kansae	Northern Plains Killifish	Resident		S5	G5	
Fishes	Fundulus sciadicus	Plains Topminnow	Resident	SOPC	S3?	G4	NW
Fishes	Gila cypha	Humpback Chub	Accidental	SOC	SX	G1	LE
Fishes	Gila elegans	Bonytail	Accidental	SOC	SX	G1	LE
Fishes	Gila robusta	Roundtail Chub	Resident	SOC	S3	G3	
Fishes	Hiodon alosoides	Goldeye	Resident	SOC	S2	G5	
Fishes	Hybognathus argyritis	Western Silvery Minnow	Resident	SOC	S3	G4	
Fishes	Hybognathus hankinsoni	Brassy Minnow	Resident		S5	G5	
Fishes	Hybognathus placitus	Plains Minnow	Resident	SOPC	S3	G4	
Fishes	Lepidomeda copei	Northern Leatherside Chub	Resident	SOC	S1	G3	NW
Fishes	Lota lota	Burbot	Resident	SOPC	S3S4	G5	
Fishes	Luxilus cornutus	Common Shiner	Resident	SOPC	S3S4	G5	
Fishes	Macrhybopsis gelida	Sturgeon Chub	Resident	SOC	S1	G3	UR
Fishes	Margariscus nachtriebi	Northern Pearl Dace	Resident	SOC	S1	G5	
Fishes	Nocomis biguttatus	Hornyhead Chub	Resident	SOC	S1	G5	

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Fishes	Notropis dorsalis	Bigmouth Shiner	Resident		S5	G5	
Fishes	Oncorhynchus clarkii	Cutthroat Trout	Resident	SOC	S2S3	G4	
Fishes	Oncorhynchus clarkii bouvieri	Yellowstone Cutthroat Trout	Resident	SOC	S2	G4T4	NW
Fishes	Oncorhynchus clarkii lewisi	Westslope Cutthroat Trout	Resident	SOC	S1	G4T4	NW
Fishes	Oncorhynchus clarkii pleuriticus	Colorado River Cutthroat Trout	Resident	SOC	S1	G4T3	NW
Fishes	Oncorhynchus clarkii - Snake River	Snake River Fine-spotted Cutthroat Trout	Resident	SOC	S1	G4T1T2Q	
Fishes	Oncorhynchus clarkii stomias	Greenback Cutthroat Trout	Accidental	SOC	SX	G4T2T3	LT
Fishes	Oncorhynchus clarkii utah	Bonneville Cutthroat Trout	Resident	SOC	S1	G4T4	NW
Fishes	Phenacobius mirabilis	Suckermouth Minnow	Resident	SOC	S2	G5	
Fishes	Platygobio gracilis	Flathead Chub	Resident	SOPC	S5	G5	
Fishes	Prosopium williamsoni	Mountain Whitefish	Resident	SOPC	S5	G5	
Fishes	Ptychocheilus lucius	Colorado Pikeminnow	Accidental	SOC	SX	G1	LE
Fishes	Rhinichthys osculus	Speckled Dace	Resident	SOC	S4	G5	
Fishes	Rhinichthys osculus thermalis	Kendall Warm Springs Dace	Resident	SOC	S1	G5T1	LE
Fishes	Sander canadensis	Sauger	Resident	SOPC	S3S4	G5	
Fishes	Scaphirhynchus platorynchus	Shovelnose Sturgeon	Resident	SOC	S1	G4	
Fishes	Thymallus arcticus - Upper Missouri River Fluvial	Upper Missouri River Fluvial Arctic Grayling	Resident	SOC	S1	G5T1Q	NW
Fishes	Xyrauchen texanus	Razorback Sucker	Accidental	SOC	SX	G1	LE
Insects	Allomyia chama	A Caddisfly	Resident	SOC	SH	G2G4	
Insects	Anthidium rodecki	A Mason Bee	Resident	SOC	S3	GNR	
Insects	Boloria alaskensis halli	Napaea Fritillary	Resident	SOC	SNR	G5T2T3	
Insects	Boloria eunomia ursadentis	Bog Fritillary	Resident	SOC	S3	G5T2	
Insects	Boloria improba harryi	Dingy Arctic Fritillary	Resident	SOC	SNR	G5T2	
Insects	Bombus occidentalis	Western Bumblebee	Resident		SNR	G2G3	UR
Insects	Bombus terricola	Yellow-banded Bumblebee	Resident		SNR	GU	UR
Insects	Boreus borean	Snow Scorpionfly	Resident	SOC	S4	GNR	
Insects	Cicindela fulgida pseudowillistoni	Crimson Saltflat Tiger Beetle	Resident	SOC	SNR	G5TNR	
Insects	Cicindela limbata	A Tiger Beetle	Resident	SOC	S3	G4	
Insects	Cicindela willistoni willistoni	Williston's Tiger Beetle	Resident	SOC	SNR	G4TU	
Insects	Danaus plexippus	Monarch Butterfly	Resident	SOC	SNA	G5	
Insects	Danaus plexippus plexippus	Monarch Butterfly	Resident	SOC	SNA	G5T3T4	UR
Insects	Euphilotes rita coloradensis	A Rita Dotted-Blue subspecies	Resident	SOC	S3	G4T2T3	
Insects	Glacicavicola bathyscioides	Blind Cave Leiodid Beetle	Resident	SOC	SNR	G1G3	
Insects	Hesperia dacotae	Dakota Skipper	Accidental		SU	G2	LT
Insects	Hesperia ottoe	Ottoe Skipper	Resident	SOC	S3	G3G4	
Insects	Hydroptila pullata	A Caddisfly	Resident	SOC	SH	GU	
Insects	Hygrotus diversipes	Narrow-foot Hygrotus Diving Beetle	Resident	SOC	S1S2	G1G2	UR
Insects	Lednia tumana	Mist Forestfly	Accidental		SU	G1G2	WPT

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Insects	Leucrocuta petersi	A Mayfly	Potential Occupier	SOC	SNR	G2G3	
Insects	Lycaena cupreus cupreus	Lustrous Copper	Resident	SOC	SH	G5TU	
Insects	Micrasema alexanderi	A Caddisfly	Resident	SOC	S3	G1G3	
Insects	Micrasema etra	A Caddisfly	Resident	SOC	S3	G1G3	
Insects	Osmia claremontensis	A Mason Bee	Resident	SOC	S3	GNR	
Insects	Osmia tanneri	A Mason Bee	Resident	SOC	SH	G3G5	
Insects	Paraleptophlebia packii	A Mayfly	Potential Occupier	SOC	SNR	G2G3	
Insects	Parameletus columbiae	A Mayfly	Potential Occupier	SOC	SNR	G2	
Insects	Perdita aff. knowltoni n. sp.	A Bee	Resident	SOC	S3	GNR	
Insects	Phyciodes batesii	Tawny Crescent	Resident	SOC	SNR	G4	
Insects	Rhyacophila oreia	A Caddisfly	Resident	SOC	SH	G1G3	
Insects	Somatochlora hudsonica	Hudsonian Emerald	Resident	SOC	S3	G5	
Insects	Speyeria idalia	Regal Fritillary	Resident	SOC	S3	G3	UR
Insects	Speyeria nokomis nokomis	Great Basin Silverspot	Accidental		SNA	G3	UR
Insects	Zapada glacier	Glacier Forestfly	Resident		SNR	G1	WPT
Mammals	Alces americanus	Moose	Resident		S4	G5	
Mammals	Antrozous pallidus	Pallid Bat	Resident	SOC	S2S3	G5	
Mammals	Bassariscus astutus	Ringtail	Resident	SOPC	S1S2	G5	
Mammals	Bos bison	American Bison	Resident	SOC	S1	G4	
Mammals	Bos bison bison	Plains Bison	Resident	SOC	S1	G4TU	UR
Mammals	Brachylagus idahoensis	Pygmy Rabbit	Resident	SOC	S2	G4	NW
Mammals	Canis lupus	Gray Wolf	Resident	SOC	S1	G4G5	DM
Mammals	Chaetodipus hispidus	Hispid Pocket Mouse	Resident		S1S3	G5	
Mammals	Corynorhinus townsendii	Townsend's Big-eared Bat	Resident	SOC	S2BS1N	G3G4	
Mammals	Cynomys leucurus	White-tailed Prairie Dog	Resident	SOC	S2S3	G4	NW
Mammals	Cynomys ludovicianus	Black-tailed Prairie Dog	Resident	SOC	S2S3	G4	NW
Mammals	Euderma maculatum	Spotted Bat	Resident	SOC	S1S2	G4	
Mammals	Geomys lutescens	Sand Hills Pocket Gopher	Resident		S1S3	G5	
Mammals	Glaucomys sabrinus	Northern Flying Squirrel	Resident		S3S4	G5	
Mammals	Glaucomys sabrinus - Black Hills	Black Hills Flying Squirrel	Resident		S1	G5TNRQ	
Mammals	Gulo gulo	Wolverine	Resident		S1S2	G4	
Mammals	Gulo gulo luscus	North American Wolverine	Resident		S1S2	G4T4	WPT
Mammals	Ictidomys tridecemlineatus	Thirteen-lined Ground Squirrel	Resident	SOC	S5	G5	
Mammals	Lasionycteris noctivagans	Silver-haired Bat	Resident	SOPC	S3B	G5	
Mammals	Lasiurus borealis	Eastern Red Bat	Resident		S3	G5	
Mammals	Lasiurus cinereus	Hoary Bat	Resident	SOPC	S4	G5	
Mammals	Lemmiscus curtatus	Sagebrush Vole	Resident		S4	G5	
Mammals	Lepus americanus seclusus	Bighorn Mountains Snowshoe Hare	Resident	SOC	S1	G5TNR	
Mammals	Lontra canadensis	Northern River Otter	Resident	SOC	S3S4	G5	NW
Mammals	Lynx canadensis	Canada Lynx	Resident	SOC	S1	G5	LT
Mammals	Lynx rufus	Bobcat	Resident		S5	G5	NW

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Mammals	Marmota flaviventris dacota	Black Hills Yellow-bellied Marmot	Resident	SOC	S3?	G5TNR	
Mammals	Martes caurina	Pacific Marten	Resident	SOPC	S3	G4G5	NW
Mammals	Martes caurina - Bighorn Mountains	Bighorn Mountains Marten	Resident	SOC	S1	G4G5TNRQ	NW
Mammals	Microtus richardsoni	Water Vole	Resident	SOC	S1	G5	
Mammals	Microtus richardsoni - Bighorn Mountains	Bighorn Mountains Water Vole	Resident	SOC	S1	G5TNRQ	
Mammals	Mustela nigripes	Black-footed Ferret	Resident	SOC	S1	G1	LEXN
Mammals	Mustela nivalis	Least Weasel	Resident	SOPC	S1S2	G5	
Mammals	Myodes gapperi - Bighorn Mountains	Bighorn Mountains Red-backed Vole	Resident	SOPC	S3	G5TNRQ	
Mammals	Myodes gapperi brevicaudus	Black Hills Red-backed Vole	Resident	SOPC	S2	G5T3	
Mammals	Myotis ciliolabrum	Western Small-footed Myotis	Resident	SOPC	S4	G5	
Mammals	Myotis evotis	Long-eared Myotis	Resident	SOPC	S4S5	G5	
Mammals	Myotis lucifugus	Little Brown Myotis	Resident	SOPC	S5	G3	UR
Mammals	Myotis septentrionalis	Northern Long-eared Myotis	Resident	SOC	S1	G2G3	LT
Mammals	Myotis thysanodes	Fringed Myotis	Resident	SOC	S2S3	G4	
Mammals	Myotis volans	Long-legged Myotis	Resident	SOPC	S5	G5	
Mammals	Myotis yumanensis	Yuma Myotis	Resident	SOC	S1	G5	
Mammals	Ochotona princeps	American Pika	Resident	SOC	S2	G5	NW
Mammals	Ochotona princeps princeps	Northern Rocky Mountain Pika	Resident	SOC	S2	G5TNR	NW
Mammals	Ochotona princeps princeps - Bighorn Mountains	Bighorn Mountains Pika	Resident	SOC	S1	G5T2	NW
Mammals	Ochotona princeps princeps - Medicine Bow Mountains	Medicine Bow Mountains Pika	Resident	SOC	S1	G5T5Q	NW
Mammals	Ochotona princeps princeps - Sierra Madre	Sierra Madre Pika	Resident	SOC	S1	G5T4T5Q	NW
Mammals	Ochotona princeps princeps - Yellowstone	Yellowstone Pika	Resident	SOC	S2	G5T5Q	NW
Mammals	Ochotona princeps uinta	Uinta Pika	Resident	SOC	S1	G5TNR	NW
Mammals	Ovis canadensis	Bighorn Sheep	Resident	SOPC	S2S3	G4	
Mammals	Pekania pennanti	Fisher	Accidental	SOC	SNA	G5	NW
Mammals	Perimyotis subflavus	American Perimyotis	Resident		S1	G3	UR
Mammals	Perognathus fasciatus	Olive-backed Pocket Mouse	Resident	SOPC	S3S5	G5	
Mammals	Perognathus flavescens	Plains Pocket Mouse	Resident		S2S3	G5	
Mammals	Perognathus flavus	Silky Pocket Mouse	Resident		S2S4	G5	
Mammals	Perognathus mollipilosus	Great Basin Pocket Mouse	Resident		S3S4	G5	
Mammals	Peromyscus crinitus	Canyon Deermouse	Resident	SOC	S1	G5	
Mammals	Peromyscus leucopus	White-footed Deermouse	Resident	SOPC	S3	G5	
Mammals	Peromyscus truei	Pinon Deermouse	Resident	SOC	S1	G5	

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Mammals	Reithrodontomys montanus	Plains Harvest Mouse	Resident		S3S5	G5	
Mammals	Scalopus aquaticus	Eastern Mole	Resident	SOPC	S2	G5	
Mammals	Sciurus aberti	Abert's Squirrel	Resident	SOPC	S1	G5	
Mammals	Sorex haydeni	Hayden's Shrew	Resident	SOC	S2S3	G4	
Mammals	Sorex hoyi	American Pygmy Shrew	Resident		S1	G5	
Mammals	Sorex hoyi montanus	Southern Rocky Mountain Pygmy Shrew	Resident	SOC	S1	G5T2T3	
Mammals	Sorex nanus	Dwarf Shrew	Resident	SOPC	S4S5	G4	
Mammals	Sorex preblei	Preble's Shrew	Resident	SOC	S2S3	G4	
Mammals	Spilogale gracilis	Western Spotted Skunk	Resident		S3S4	G5	
Mammals	Spilogale putorius	Eastern Spotted Skunk	Resident	SOPC	S3S4	G4	
Mammals	Spilogale putorius interrupta	Plains Spotted Skunk	Resident	SOPC	S3S4	G4T4	UR
Mammals	Sylvilagus floridanus	Eastern Cottontail	Resident	SOPC	S3	G5	
Mammals	Tamias amoenus	Yellow-pine Chipmunk	Resident		S3S4	G5	
Mammals	Tamiasciurus hudsonicus - Bighorn Mountains	Bighorn Mountains Red Squirrel	Resident	SOPC	S3	G5TNRQ	
Mammals	Tamiasciurus hudsonicus dakotensis	Black Hills Red Squirrel	Resident	SOC	S2	G5TNR	
Mammals	Tamias dorsalis	Cliff Chipmunk	Resident	SOC	S1	G5	
Mammals	Tamias dorsalis utahensis	Utah Cliff Chipmunk	Resident	SOC	S1	G5T5	
Mammals	Tamias umbrinus	Uinta Chipmunk	Resident	SOPC	S2S5	G5	
Mammals	Tamias umbrinus fremonti	Fremont's Uinta Chipmunk	Resident	SOPC	S2S5	G5TNR	
Mammals	Tamias umbrinus montanus	Southern Rocky Mountain Uinta Chipmunk	Resident	SOPC	S2S5	G5TNR	
Mammals	Tamias umbrinus umbrinus	Utah Uinta Chipmunk	Resident	SOPC	S2S5	G5TNR	
Mammals	Thomomys clusius	Wyoming Pocket Gopher	Resident	SOC	S1	G2	NW
Mammals	Thomomys idahoensis	Idaho Pocket Gopher	Resident	SOC	S1S2	G4	
Mammals	Urocitellus armatus	Uinta Ground Squirrel	Resident	SOPC	S3S4	G5	
Mammals	Urocitellus elegans	Wyoming Ground Squirrel	Resident	SOPC	S3S4	G5	
Mammals	Urocyon cinereoargenteus	Common Gray Fox	Accidental	SOPC	SNA	G5	
Mammals	Urocyon cinereoargenteus ocythous	Prairie Gray Fox	Accidental	SOPC	SNA	G5TNR	UR
Mammals	Ursus arctos	Grizzly Bear	Resident	SOC	S1	G4	LE
Mammals	Vulpes velox	Swift Fox	Resident	SOC	S2	G3	NW
Mammals	Xerospermophilus spilosoma	Spotted Ground Squirrel	Resident		S2S5	G5	
Mammals	Zapus hudsonius	Meadow Jumping Mouse	Resident	SOC	S3	G5	
Mammals	Zapus hudsonius campestris	Bear Lodge Meadow Jumping Mouse	Resident	SOC	S1	G5T3	
Mammals	Zapus hudsonius preblei	Preble's Meadow Jumping Mouse	Resident	SOC	S1	G5T2	LT
Mussels and Clams	Anodonta californiensis	California Floater	Resident	SOC	S2	G3Q	
Mussels and Clams	Anodontoides ferussacianus	Cylindrical Papershell	Resident	SOC	S3	G5	
Mussels and Clams	Lampsilis cardium	Plain Pocketbook	Resident	SOC	S3	G5	

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Mussels and Clams	Lampsilis siliquoidea	Fatmucket	Resident	SOC	S3	G5	
Mussels and Clams	Lasmigona complanata	White Heelsplitter	Resident	SOC	S2	G5	
Mussels and Clams	Margaritifera falcata	Western Pearlshell	Resident	SOC	S3	G4G5	
Mussels and Clams	Pisidium adamsi	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Pisidium casertanum	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Pisidium compressum	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Pisidium ferrugineum	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Pisidium idahoense	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Pisidium insigne	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Pisidium milium	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Pisidium variabile	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Pisidium ventricosum	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Pyganodon grandis	Giant Floater	Resident	SOC	S3	G5	
Mussels and Clams	Sphaerium lacustre	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Sphaerium occidentale	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Sphaerium simile	A Pill Clam	Resident		SNR	G5	
Mussels and Clams	Sphaerium striatinum	A Pill Clam	Resident		SNR	G5	
Reptiles	Apalone spinifera	Spiny Softshell	Resident	SOPC	S4	G5	
Reptiles	Apalone spinifera spinifera	Eastern Spiny Softshell	Resident	SOPC	S4	G5T5	
Reptiles	Aspidoscelis sexlineata	Six-lined Racerunner	Resident	SOC	S2	G5	
Reptiles	Aspidoscelis sexlineata viridis	Prairie Racerunner	Resident	SOC	S2	G5T5	
Reptiles	Charina bottae	Northern Rubber Boa	Resident	SOC	S2	G5	
Reptiles	Chrysemys picta bellii	Western Painted Turtle	Resident		S4	G5T5	
Reptiles	Coluber constrictor flaviventris	Eastern Yellow-bellied Racer	Resident	SOPC	S4	G5T5	
Reptiles	Coluber taeniatus	Striped Whipsnake	Resident	SOC	S1	G5	
Reptiles	Coluber taeniatus taeniatus	Desert Striped Whipsnake	Resident	SOC	S1	G5TNR	
Reptiles	Crotalus oreganus	Western Rattlesnake	Resident	SOC	S1	G5	
Reptiles	Crotalus oreganus concolor	Midget Faded Rattlesnake	Resident	SOC	S1	G5T4	
Reptiles	Crotalus viridis	Prairie Rattlesnake	Resident		S5	G5	
Reptiles	Heterodon nasicus	Plains Hog-nosed Snake	Resident		S4	G5	
Reptiles	Holbrookia maculata	Common Lesser Earless Lizard	Resident	SOC	S2	G5	
Reptiles	Holbrookia maculata maculata	Great Plains Earless Lizard	Resident	SOC	S2	G5TNR	
Reptiles	Lampropeltis gentilis	Western Milksnake	Resident	SOPC	S3	G5	
Reptiles	Opheodrys vernalis	Smooth Greensnake	Resident	SOC	S2	G5	
Reptiles	Phrynosoma hernandesi	Greater Short-horned Lizard	Resident		S4	G5	

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Reptiles	Phrynosoma hernandesi bauri	Baur's Short-horned Lizard	Resident		SNR	G5TNR	
Reptiles	Phrynosoma hernandesi brevirostris	Plains Short-horned Lizard	Resident		SNR	G5TNR	
Reptiles	Pituophis catenifer	Gophersnake	Resident	SOPC	S4	G5	
Reptiles	Pituophis catenifer deserticola	Great Basin Gophersnake	Resident	SOPC	S3	G5T5	
Reptiles	Pituophis catenifer sayi	Bullsnake	Resident	SOPC	S4	G5T5	
Reptiles	Plestiodon multivirgatus	Many-lined Skink	Resident	SOC	S2	G5	
Reptiles	Plestiodon multivirgatus multivirgatus	Northern Many-lined Skink	Resident	SOC	S1	G5T5	
Reptiles	Plestiodon skiltonianus utahensis	Great Basin Skink	Resident		S1	G5T5	
Reptiles	Sceloporus consobrinus	Prairie Lizard	Resident	SOC	S1	G5	
Reptiles	Sceloporus tristichus	Plateau Fence Lizard	Resident	SOC	S1	G5	
Reptiles	Storeria occipitomaculata	Red-bellied Snake	Resident	SOC	S1	G5	
Reptiles	Terrapene ornata	Ornate Box Turtle	Resident	SOC	S1	G5	
Reptiles	Terrapene ornata ornata	Plains Box Turtle	Resident	SOC	S1	G5T5	
Reptiles	Thamnophis radix	Plains Gartersnake	Resident	SOPC	S5	G5	
Reptiles	Thamnophis sirtalis	Common Gartersnake	Resident	SOPC	S5	G5	
Reptiles	Thamnophis sirtalis fitchi	Valley Gartersnake	Resident	SOPC	S2	G5TNR	
Reptiles	Thamnophis sirtalis parietalis	Red-sided Gartersnake	Resident	SOPC	S5	G5T5TNR	
Reptiles	Urosaurus ornatus	Ornate Tree Lizard	Resident	SOC	S2	G5	
Reptiles	Urosaurus ornatus wrighti	Northern Tree Lizard	Resident	SOC	S2	G5TNR	
Shrimp	Artemia franciscana	San Francisco Brine Shrimp	Potential Occupier	SOC	SNR	G5	
Shrimp	Branchinecta coloradensis	Colorado Fairy Shrimp	Resident	SOC	SNR	G5	
Shrimp	Branchinecta constricta	Constricted Fairy Shrimp	Resident	SOC	S4	G2	
Shrimp	Branchinecta gigas	Giant Fairy Shrimp	Potential Occupier	SOC	SNR	G3G4	
Shrimp	Branchinecta lateralis	Pocket Pouch Fairy Shrimp	Resident	SOC	S5	G4	
Shrimp	Branchinecta lindahli	Versatile Fairy Shrimp	Resident	SOC	S4	G5	
Shrimp	Branchinecta packardi	Rock Pool Fairy Shrimp	Resident	SOC	SNR	G5	
Shrimp	Branchinecta paludosa	Circumpolar Fairy Shrimp	Resident	SOC	S4	G5	
Shrimp	Branchinecta readingi	Eastern Alkali Fairy Shrimp	Potential Occupier	SOC	SNR	G4	
Shrimp	Branchinecta serrata	A Fairy Shrimp	Resident	SOC	S4	G1	
Shrimp	Eubranchipus bundyi	Knobbedlip Fairy Shrimp	Potential Occupier	SOC	SNR	G5	
Shrimp	Eubranchipus serratus	Ethologist Fairy Shrimp	Potential Occupier	SOC	SNR	G5	
Shrimp	Eulimnadia diversa	Diversity Clam Shrimp	Resident	SOC	S5	GNR	
Shrimp	Lepidurus bilobatus	Great Basin Tadpole Shrimp	Resident	SOC	S4	G2G3	
Shrimp	Lepidurus couesii	Couse tadpole shrimp	Resident	SOC	S3	G4	

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Shrimp	Lepidurus lemmoni	Lynch Tadpole Shrimp	Resident	SOC	SH	G4	
Shrimp	Leptestheria compleximanus	Spineynose Clam Shrimp	Resident	SOC	SNR	G5	
Shrimp	Lynceus brachyurus	Holarctic Clam Shrimp	Resident	SOC	SNR	G5	
Shrimp	Lynceus brevifrons	Short Finger Clam Shrimp	Resident	SOC	SNR	GNR	
Shrimp	Streptocephalus dorothae	Desert Fairy Shrimp	Resident	SOC	SH	G5	
Shrimp	Streptocephalus mackini	Mackin Fairy Shrimp	Resident	SOC	SNR	G5	
Shrimp	Streptocephalus texanus	Greater Plains Fairy Shrimp	Resident	SOC	SNR	G5	
Shrimp	Thamnocephalus platyurus	Beavertail Fairy Shrimp	Resident	SOC	SNR	G5	
Shrimp	Triops longicaudatus	Longtail Tadpole Shrimp	Resident	SOC	S4	G5	
Snails and Slugs	Amnicola limosa	Mud Amnicola	Resident	SOC	S3	G5	
Snails and Slugs	Aplexa elongata	Lance Aplexa	Resident	SOC	S3	G5	
Snails and Slugs	Catinella gelida	Frigid Ambersnail	Potential Occupier	SOC	SU	G1Q	NW
Snails and Slugs	Catinella stretchiana	Sierra Ambersnail	Resident	SOC	S3	G3	
Snails and Slugs	Catinella wandae	Slope Ambersnail	Potential Occupier	SOC	SNR	G2	
Snails and Slugs	Colligyrus greggi	Rocky Mountain Duskysnail	Potential Occupier	SOC	SU	G4	
Snails and Slugs	Discus catskillensis	Angular Disc	Resident		SNR	G5	
Snails and Slugs	Discus shimekii	Striate Disc	Resident	SOC	S3	G5	
Snails and Slugs	Discus whitneyi	Forest Disc	Resident		SNR	G5	
Snails and Slugs	Ferrissia fragilis	Fragile Ancylid	Potential Occupier	SOC	SNR	G5Q	
Snails and Slugs	Ferrissia rivularis	Creeping Ancylid	Resident	SOC	S4	G5Q	
Snails and Slugs	Fluminicola coloradoensis	Green River Pebblesnail	Resident	SOC	S4	G2G3	
Snails and Slugs	Fluminicola fuscus	Ashy Pebblesnail	Resident	SOC	SNR	G2	
Snails and Slugs	Fossaria bulimoides	Prairie Fossaria	Resident		SNR	G5	
Snails and Slugs	Fossaria dalli	Dusky Fossaria	Resident	SOC	S4	G5	
Snails and Slugs	Fossaria modicella	Rock Fossaria	Resident	SOC	S3	G5	
Snails and Slugs	Fossaria obrussa	Golden Fossaria	Resident	SOC	S3	G5	
Snails and Slugs	Fossaria parva	Pygmy Fossaria	Resident	SOC	S3	G5	
Snails and Slugs	Gastrocopta pentodon	Comb Snaggletooth	Resident		SNR	G5	
Snails and Slugs	Gastrocopta procera	Wing Snaggletooth	Resident		SNR	G5	
Snails and Slugs	Gastrocopta similis	Great Lakes Snaggletooth	Resident		SNR	G5	
Snails and Slugs	Gyraulus circumstriatus	Disc Gyro	Resident	SOC	S3	G5	
Snails and Slugs	Gyraulus crista	Star Gyro	Resident	SOC	S3	G5	
Snails and Slugs	Gyraulus parvus	Ash Gyro	Resident	SOC	S4	G5	
Snails and Slugs	Hawaiia minuscula	Minute Gem	Resident		SNR	G5	
Snails and Slugs	Helisoma anceps	Two-ridge Rams-horn	Resident	SOC	S2	G5	
Snails and Slugs	Helisoma newberryi	Great Basin Rams-horn	Resident	SOC	S1	G1Q	NW

Class	Sciname	Comname	WY occur	SOC (http://www.uwyo.edu/wyndd/species-of-concern/)	S Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	G Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	USFWS (http://www.uwyo.edu/wyndd/codes-and-definitions/federal-status/#USFWS)
Snails and Slugs	Lymnaea stagnalis	Swamp Lymnaea	Resident	SOC	S3	G5	
Snails and Slugs	Microphysula ingersolli	Spruce Snail	Resident		SNR	G5	
Snails and Slugs	Oreohelix cannifera	Keeled Mountain Snail	Resident	SOC	SU	G1	NW
Snails and Slugs	Oreohelix jugalis	A Mountainsnail	Resident		SNA	G1G2	
Snails and Slugs	Oreohelix peripherica	A Mountainsnail	Resident	SOC	SNR	G2	
Snails and Slugs	Oreohelix pygmaea	Pygmy Mountainsnail	Resident	SOC	S1	G1	NW
Snails and Slugs	Oreohelix strigosa	Rocky Mountain Mountainsnail	Resident	SOC	S3	G5Q	
Snails and Slugs	Oreohelix strigosa berryi	Berry's Mountainsnail	Resident	SOC	SH	G5QT2	
Snails and Slugs	Oreohelix strigosa cooperi	Cooper's Rocky Mountain Mountainsnail	Resident	SOC	S1	G5QT2T4	NW
Snails and Slugs	Oreohelix strigosa depressa	A Mountainsnail	Resident	SOC	SNR	G5QT5	
Snails and Slugs	Oreohelix strigosa ssp. 1	Bear Lodge Mountainsnail	Resident	SOC	S2	G5QTU	
Snails and Slugs	Oreohelix subrudis	Subalpine Mountainsnail	Resident	SOC	SNR	G5	
Snails and Slugs	Oreohelix yavapai	Yavapai Mountainsnail	Resident	SOC	SNR	G5	
Snails and Slugs	Oreohelix yavapai extremitatis	A Mountainsnail	Resident	SOC	SNR	G5TNR	
Snails and Slugs	Oxyloma haydeni	Niobrara Ambersnail	Potential Occupier	SOC	SNR	G3	
Snails and Slugs	Physa acuta	Pewter Physa	Resident	SOC	S4	G5Q	
Snails and Slugs	Physa ancillaria	Pumpkin Physa	Potential Occupier	SOC	SU	G5Q	
Snails and Slugs	Physa gyrina	Tadpole Physa	Resident	SOC	S4	G5	
Snails and Slugs	Physa megalochlamys	Cloaked Physa	Resident	SOC	S3	G3G4	
Snails and Slugs	Physa skinneri	Glass Physa	Resident	SOC	S3	G5	
Snails and Slugs	Physa spelunca	Cave Physa	Resident	SOC	S1	G1	NW
Snails and Slugs	Physella columbiana	Rotund Physa	Resident	SOC	S3	G2	
Snails and Slugs	Physella cooperi	Olive Physa	Potential Occupier	SOC	SNR	G3	
Snails and Slugs	Physella propinqua	Rocky Mountain Physa	Potential Occupier	SOC	SNR	G5Q	
Snails and Slugs	Planorbella subcrenata	Rough Rams-horn	Resident	SOC	S3	G5	
Snails and Slugs	Planorbella trivolvis	Marsh Rams-horn	Resident	SOC	S4	G5	
Snails and Slugs	Planorbula campestris	Meadow Rams-horn	Potential Occupier	SOC	SU	G5	
Snails and Slugs	Potamopyrgus antipodarum	New Zealand Mudsnail	Resident		SNA	G5	
Snails and Slugs	Promenetus exacuous	Sharp Sprite	Resident	SOC	S3	G5	
Snails and Slugs	Promenetus umbilicatellus	Umbilicate Sprite	Resident	SOC	S2	G4	
Snails and Slugs	Pupilla hebes	Crestless Column	Resident		SNR	G5	
Snails and Slugs	Pupoides hordaceus	Ribbed Dagger	Potential Occupier	SOC	SNR	G4	
Snails and Slugs	Pyrgulopsis pilsbryana	Bear Lake Springsnail	Potential Occupier	SOC	SNR	G2	
Snails and Slugs	Pyrgulopsis robusta	Jackson Lake Springsnail	Resident	SOC	S2	G5	NW
Snails and Slugs	Stagnicola apicina	Abbreviate Pondsnail	Potential Occupier	SOC	SNR	G5	

Class	Sciname	Comname	WY occur	SOC (http://www.uwyo.edu/wyndd/species-of-concern/)	S Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	G Rank (http://www.uwyo.edu/wyndd/codes-and-definitions/heritage-rank/)	USFWS (http://www.uwyo.edu/wyndd/codes-and-definitions/federal-status/#USFWS)
Snails and Slugs	Stagnicola bonnevillensis	Fat-whorled Pondsnail	Historic	SOC	SH	G3	NW
Snails and Slugs	Stagnicola caperata	Wrinkled Marshsnail	Potential Occupier	SOC	SNR	G5	
Snails and Slugs	Stagnicola catascopium	Woodland Pondsnail	Resident	SOC	S3	G5	
Snails and Slugs	Stagnicola elodes	Marsh Pondsnail	Resident	SOC	S3	G5	
Snails and Slugs	Stagnicola hinkleyi	Rustic Pondsnail	Resident	SOC	S3	G2	
Snails and Slugs	Stagnicola montanensis	Mountain Marshsnail	Resident	SOC	S3	G3	
Snails and Slugs	Stagnicola traski	Widelip Pondsnail	Potential Occupier	SOC	SNR	G3	
Snails and Slugs	Vallonia albula	Indecisive Vallonia	Resident	SOC	SNR	G4Q	
Snails and Slugs	Vallonia gracilicosta	Multirib Vallonia	Resident		SNR	G5Q	
Snails and Slugs	Vallonia perspectiva	Thin-lip Vallonia	Resident		SNR	G4G5	
Snails and Slugs	Valvata humeralis	Glossy Valvata	Resident	SOC	S3	G5Q	
Snails and Slugs	Valvata sincera	Mossy Valvata	Resident	SOC	S3	G5	
Snails and Slugs	Vertigo arthuri	Callused Vertigo Snail	Resident	SOC	S3	G5	
Snails and Slugs	Vertigo binneyana	Cylindrical Vertigo	Resident		SNR	G1	
Snails and Slugs	Vertigo paradoxa	Mystery Vertigo	Resident	SOC	S3	G4G5Q	
Snails and Slugs	Vitrina pellucida	Western Glass-snail	Resident		SNR	G5	
Snails and Slugs	Zonitoides arboreus	Quick Gloss	Resident		SNR	G5	

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20. APPENDIX Q: UW WYOMING NATURAL DIVERSITY DATABASE PLANT SPECIES OF CONCERN

WYOMING PLANT SPECIES OF CONCERN
Wyoming Natural Diversity Database, University of Wyoming
www.uwyo.edu/wyndd/
March 7, 2018

The 2018 Wyoming Plant Species of Concern list contains the 423 vascular plant species/varieties considered to be of greatest conservation concern in the state. It is accompanied by the Species of *Potential* Concern list, containing those species of limited distribution that could become vulnerable in the future, and species recognized as sensitive by federal agencies that are no longer tracked. There are also reference lists compiled of species added since 2012, and species deleted since 2012.

Every species added to the list has bold font across the entire row. Bold font is also used to highlight changes within a single value that has changed for the species, including changes to scientific name, common name, global or state ranks, county, managed area, or the various attributes that provide state rank context (# of populations, abundance, vulnerability, recent trends, range context). All species added since the 2012 list are in bold font, with 21 additions. There were also 33 deletions from the prior list.

Name changes abound! Scientific names follow the Wyoming Flora Checklist prepared by the Rocky Mountain Herbarium (Nelson 2018). Common names follow the PLANTS database almost throughout. In cases of scientific name changes, the prior name is included among synonyms, in brackets []. Please bear with us as we work to update WYNDD postings on plant species to follow the 2018 conventions, and come up with ways to look up the synonyms used in past WYNDD reports linked to the new names.

The plant species on the Wyoming plant species of concern list are not addressed by any state legislation but are routinely cited in policies and in development of sensitive species lists by federal land-managing agencies. Federal sensitive species status designations are represented on this list. Federal criteria are often more stringent and contingent on public lands distribution compared to the criteria for inclusion on the Wyoming species of concern list – check directly with the corresponding federal agency to confirm whether or not there have been any changes to federal sensitive species list contents.

Criteria for inclusion on the Wyoming plant species of concern list include a combination of state rank as indication of relative rarity, and Wyoming contribution as indicating the amount of a species' global distribution that is encompassed within Wyoming boundaries. A "conservation concern matrix" was posted with the 2012 list in which state rank ("relative rarity" scoring) diminishes as a screening criteria for species that have very high Wyoming contribution, i.e., extremely narrow distributions centered in Wyoming.

This document, supporting information, and staff contact information are available at: www.uwyo.edu/wyndd/ . Please contact WYNDD to convey comments, get printed copies of this list, get it in different electronic formats, or to get the supporting lists (species of potential concern, species additions, and species deletions). We can also be contacted at: Wyoming Natural Diversity Database, Dept. 3381, 1000 E. University Avenue, Laramie, WY 82071.

The citation for this list is:
Heidel, B. 2018. Wyoming plant species of concern, March 2018. Wyoming Natural Diversity Database, Laramie, WY. Accompanied by Wyoming plant species of potential concern, with tables of additions and deletions.

Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Abies concolor White fir	G5/S1		SWE, UIN	Rock Springs BLM Wasatch-Cache NF	Widespread/ Edge	Very Low	Rare	Low	Stable?	Low
Abronia ammophila Yellowstone sand verbena	G1/S1		PAR	Yellowstone NP	Local Endemic/ Core	Very Low	Rare	Moderate	Unknown	Very High
Achnatherum scribneri [*Stipa scribneri*] Scribner needlegrass	G4/S1		LAR		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Achnatherum swallenii [*Oryzopsis swallenii*] **Swallen's needlegrass**	G3G4/S2		LIN, SUB, SWE	Kemmerer BLM Pinedale BLM Rock Springs BLM	Regional Endemic/ Edge	Low	Uncommon	Moderate	Stable?	Medium
Adiantum aleuticum [*A. pedatum* var. *aleuticum*] Aleutian maidenhair	G5?/S1		TET	Grand Teton NP Targhee NF Yellowstone NP	Disjunct	Very Low	Rare	Low	Stable?	Medium
Agrostis oregonensis Oregon bentgrass	G4/S1		PAR, TET	Bridger-Teton NF Grand Teton NP? Shoshone NF Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Agrostis rossiae **Ross' bentgrass**	G1/S1		TET	Yellowstone NP	Local Endemic/ Core	Very Low	Rare	High	Stable	Very High
Aletes humilis Larimer aletes	G2G3/SH?	MBNF-SOLC	ALB?		Regional Endemic/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Amerorchis rotundifolia [*Orchis rotundifolia*] **Roundleaf orchid**	G5/S1	USFS R2 Sensitive	PAR	Shoshone NF	Disjunct	Very Low	Rare	High	Moderate Decline?	Medium
Ammannia robusta **Grand redstem**	G5/S1		WES		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Amphicarpaea bracteata **American hogpeanut**	G5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Anagallis minima [*Centunculus minimus*] Chaffweed	G5/S1		CRO, PLA	Black Hills NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Androsace chamaejasme var. *carinata* [*A. chamaejasme; A. c.* var. *lehmanniana*] **Sweetflower rockjasmine**	G5T4/S1S2	USFS R4 Sensitive	FRE, HOT, PAR, TET	**Cody BLM** Shoshone NF Targhee NF **Yellowstone NP**	Widespread/ Edge	Low	Uncommon	Moderate	Stable	Low
Anemone lyallii Lyall's wood anemone	**G4G5**/S1		TET	Targhee NF	Disjunct	Very Low	Unknown	Moderate	Unknown	Medium

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Anemone narcissiflora var. *zephyra* **Narcissus anemone**	G5T4/S1		BIG, JOH, SHE	Bighorn NF	Regional Endemic/ Edge	Very Low	Uncommon	Moderate	Stable	Medium
Antennaria flagellaris **Whip pussytoes**	**G5**/S2		PAR, TET	Shoshone NF Yellowstone NP	Disjunct	Low	Unknown	Low	Stable	Medium
Antennaria monocephala [*A. m.* ssp. *angustata*] **Pygmy pussytoes**	**G5**/S2	BGHRN NF-SOLC	FRE, JOH, PAR, SUB, TET	Bighorn NF Bridger-Teton NF Shoshone NF Targhee NF	Widespread/ Edge	Low	Rare	Moderate	Stable	Low
Aquilegia brevistyla Smallflower columbine	G5/S1		CRO, PAR?, WES	Black Hills NF Newcastle BLM Shoshone NF?	Disjunct	Very Low	Unknown	Low	Stable?	Medium
Aquilegia formosa* var. *formosa Crimson columbine	G5T5/S1		PAR, TET	Grand Teton NP JDR Parkway Shoshone NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Aquilegia laramiensis Laramie columbine	**G3/S3**	USFS R2 Sensitive WY BLM Sensitive	ALB, CON	Casper BLM Medicine Bow NF Rawlins BLM	Local Endemic/ Core	Moderate	Rare	Moderate	Stable?	Very High
Arceuthobium douglasii Douglas-fir dwarf mistletoe	G5/SH		LIN, TET	Bridger-Teton NF Targhee NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown
Arctous rubra [*Arctostaphylos rubra*] **Red fruit bearberry**	G5/S1		PAR	Shoshone NF	Disjunct	Very Low	Rare	Moderate	Stable?	Medium
Argyrochosma fendleri [*Notholaena fendleri*] Fendler's false cloak fern	G3/S1		LAR		Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Medium
Aristida curtissii [*A. basiramea* var. *curtissii*] **Curtis' threeawn**	G5/S1		CRO?, WES		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Aristida oligantha **Prairie threeawn**	G5/S1		WES	Thunder Basin NG	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Arnica angustifolia var. tomentosa [*A. alpina* var. *tomentosa*] Alpine arnica	G5T5/S1		FRE	Shoshone NF	Widespread/ Edge	Very Low	Rare	Moderate	Stable	Low
Artemisia biennis var. *diffusa* Mystery wormwood	G5T1Q/S1		SWE		Local Endemic/ Core?	Very Low	Rare	High	Large Decline	Very High

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Artemisia porteri **Porter's wormwood**	G2/S2	WY BLM Sensitive	FRE, JOH, NAT	Buffalo BLM Casper BLM Lander BLM	Local Endemic/ Core	Low	Uncommon	Moderate	Stable?	Very High
Artemisia simplex [*Sphaeromeria simplex*] **Laramie chickensage**	G2/S2	WY BLM Sensitive	ALB, CAR, CON, NAT	Casper BLM Rawlins BLM	Local Endemic/ Core	Low	Uncommon	Moderate	Stable	Very High
Asclepias arenaria Sand milkweed	G5?/S1		GOS	Casper BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Asclepias engelmanniana Engelmann's milkweed	G5/S1		GOS		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Asclepias hallii Hall's milkweed	G3/SH		ALB	Rawlins BLM?	Widespread/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Asclepias subverticillata **Horsetail milkweed**	G4G5/SH		CAR	Rawlins BLM?	Widespread/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Asclepias uncialis **Wheel milkweed**	G3G4/SH	USFS R2 Sensitive	SWE?	Rock Springs BLM? Seedskadee NWR?	Disjunct	Very Low	Unknown	Unknown	Unknown	Unknown
Aspidotis densa [*Cryptogramma densa*] **Indian's dream**	G5/S1		TET	Grand Teton NP	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Asplenium trichomanes* ssp. *trichomanes Maidenhair spleenwort	**G5T5**/S1		ALB, NAT	Medicine Bow NF	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Asplenium trichomanes-ramosum [*A. viride*] **Brightgreen spleenwort**	G4/**S2S3**		ALB, CAR, SHE, TET, WAS	Bighorn NF Bridger-Teton NF Grand Teton NP Medicine Bow NF Targhee NF	Disjunct	Low	Rare	Moderate	Stable?	Medium
Aster alpinus var. *vierhapperi* Alpine aster	G5T5/S1		PAR	Shoshone NF	Disjunct	Very low	Unknown	Moderate	Unknown	Medium
Astragalus bisulcatus var. *haydenianus* **Hayden's twogrooved milkvetch**	G5T5?/S1?		CAR, **FRE, LIN**, SWE, UIN	Lander BLM Kemmerer BLM Rawlins BLM Rock Springs BLM	Widespread/ Edge	Low?	Unknown	Moderate	Unknown	Low
Astragalus coltonii var. *moabensis* Moab milkvetch	G4T3?/S2		SWE, UIN	Kemmerer BLM Rock Springs BLM	Regional Endemic/ Edge	Low	Uncommon	Moderate	Stable?	Medium

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Astragalus diversifolius Meadow milkvetch	G2/**S1S2**	WY BLM Sensitive USFS R4 Sensitive	**FRE**, SWE	**Lander BLM** Rawlins BLM	Regional Endemic/ Core	Very Low	Rare	Moderate	Stable?	High
Astragalus gilviflorus var. *purpureus* [*Orophaca triphylla var. purpurea*] **Dubois plains milkvetch**	G5T2/S2	WY BLM Sensitive	BIG?, FRE, WAS, Wind River IR	Lander BLM Shoshone NF Worland BLM?	Local Endemic/ Core	Low	Uncommon	Moderate	Stable	Very High
***Astragalus hyalinus* var. *glabrata* Smooth summer milkvetch**	**G5T1/S1**		**PAR**	**Cody BLM Shoshone NF**	**Local Endemic/ Core**	**Very Low**	**Rare**	**Moderate**	**Unknown**	**Very High**
Astragalus jejunus var. *articulatus* **Hyattville starveling milkvetch**	G3T1/S1	WY BLM Sensitive	BIG	Worland BLM	Local Endemic/ Core	Very Low	Rare	Moderate	Moderate Decline?	Very High
Astragalus lentiginosus var. *salinus* **Salty loco milkvetch**	G5T5/S1		LIN, UIN	Fossil Butte NM Kemmerer BLM	Widespread/ Edge	Very Low	Unknown	Low	Unknown	Low
Astragalus leptaleus Park milkvetch	G4/**S1**	USFS R2 Sensitive Trgh NF-SOLC	CAR	Medicine Bow NF **Rawlins BLM**	Regional Endemic/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Astragalus paysonii Payson's milkvetch	G3/S2	USFS R4 Sensitive	LIN, SUB, TET	Bridger-Teton NF Targhee NF	Regional Endemic/ Core	Moderate	Uncommon	Moderate	Stable?	High
Astragalus platytropis **Broadkeel milkvetch**	G5/S1		PAR	Cody BLM	Disjunct	Very Low	Unknown	Moderate	Unknown	Medium
Astragalus proimanthus [*Orophaca proimantha*] Precocious milkvetch	G1/S1	WY BLM Sensitive	SWE	Rock Springs BLM	Local Endemic/ Core	Very Low	Rare	Moderate	Moderate Decline	Very High
Astragalus racemosus var. *treleasei* **Trelease's cream racemose milkvetch**	G5T2/S2	WY BLM Sensitive	LIN, SUB, UIN	Kemmerer BLM Pinedale BLM	Regional Endemic/ Core	Low	Rare	Moderate	Unknown	High
Astragalus terminalis Railhead milkvetch	G3/S2		TET	Bridger-Teton NF Grand Teton NP Natl Elk Refuge	Regional Endemic/ **Core**	Low	Uncommon	Moderate	Stable?	Medium
Atriplex wolfii* var. *tenuissima [*Atriplex tenuissima*] Wolf's orache	**G3G4TNR** /S1		CAR, SWE	Rawlins BLM Rock Springs BLM	Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	Medium

Species Scientific Common Name	Heritage Rank	Federal Status	County	Managed Area	Range Context	# Pops.	Abund.	Vulnerab.	Recent Trends	Wyoming Contrib.
Bacopa rotundifolia **Disk waterhyssop**	G5/S1		CRO, LAR	Black Hills NF	Widespread/ Edge	Very Low	Unknown	Moderate	Increase?	Low
Besseya alpina Alpine kittentails	G4/S1	MBNF-SOLC	ALB, CAR,	Medicine Bow NF	Regional Endemic/ Edge	Very Low	Uncommon	Moderate	Stable?	Medium
Besseya plantaginea **White River coraldrops**	GNR/S1	MBNF-SOLC	ALB	Medicine Bow NF	Regional Endemic/ Edge	Very Low	Uncommon	Moderate	Stable	Medium
Boechera crandallii [*Arabis crandallii*] Crandall's rockcress	**G2**/S1		CAR, SWE	Ashley NF [FGNRA] Rawlins BLM Rock Springs BLM	Regional Endemic/ Edge	Very Low	Rare	Moderate	Unknown	Medium
Boechera gracilenta [*B. selbyi ; Arabis selbyi; B. perennans* and *Arabis perennans;* misappl.] **Dainty rockcress**	**G4?Q/S1**		ALB, **LIN, NIO, SWE**	Ashley NF [FGNRA] Rawlins BLM Rock Springs BLM	Widespread/ Edge	Low	Unknown	Moderate	Unknown	Low
Boechera pusilla [*Arabis pusilla*] Small rockcress	G1/S1	WY BLM Sensitive	FRE	Rock Springs BLM	Local Endemic/ Core	Very Low	Rare	High	Moderate decline	Very High
Botrychium ascendens **Trianglelobe moonwort**	G2G3/S2	USFS R2 Sensitive , USFS R4 Sensitive	**BIG**, FRE, JOH, PAR, SHE	Bighorn NF Shoshone NF	Disjunct	Low	Rare	Moderate	Unknown	Medium
Botrychium campestre **Iowa moonwort**	G3G4/S1	USFS R2 Sensitive	CRO	Black Hills NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Medium
Botrychium crenulatum **Scalloped moonwort**	G3/S1	USFS R4 Sensitive	**BIG, SHE, SUB,** TET, **WAS**	Bighorn NF Targhee NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Botrychium hesperium Western moonwort	G4/S1		JOH, SHE	Bighorn NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Botrychium lanceolatum [*B. l. var. lanceolatum*] **Lanceleaf grapefern**	G5/S2	Bghrn NF-SOLC, MBNF-SOLC	BIG, CAR, FRE, JOH, PAR, SHE	Bighorn NF Shoshone NF Yellowstone NP	Widespread/ Edge	Low	Rare	Moderate	Unknown	Low
Botrychium lineare **Slender moonwort**	G2?/S1	USFWS Candidat e USFS R2 Sensitive	CRO	Black Hills NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium

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Species Scientific Common Name	Heritage Rank	Federal Status	County	Managed Area	Range Context	# Pops.	Abund.	Vulnerab.	Recent Trends	Wyoming Contrib.
Botrychium michiganense **Michigan moonwort**	**G3/S1**		**CRO, JOH**	**Bighorn NF Black Hills NF**	**Sparse/ Edge?**	**Very Low**	**Rare**	**Moderate**	**Unknown**	**Medium**
Botrychium pallidum Pale moonwort	G3/S1	USFS R2 Sensitive	CRO	Black Hills NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Botrychium paradoxum Puzzling moonwort	G2/**S2**	USFS R2 Sensitive	BIG, JOH, SHE, **SUB**	Bighorn NF	Sparse/ Core?	Very Low	Rare	Moderate	Unknown	**High**
Botrychium pinnatum **Northern moonwort**	**G5/S1**		BIG, JOH	Bighorn NF	**Widespread/Edge**	**Very Low**	**Rare**	**Moderate**	**Unknown**	**Low**
Botrychium yaaxudakeit **Yakutat moonwort**	**G3G4/S1**		**BIG**	**Bighorn NF**	**Sparse/ Disjunct**	**Very Low**	**Rare**	**Moderate**	**Unknown**	**Medium**
Bouteloua simplex Matted grama	G5/S1		LAR	FE Warren AFB	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Braya glabella* ssp. *glabella **Smooth northern-rockcress**	G5/S1	USFS R2 Sensitive	SUB, TET	Bridger-Teton NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Braya humilis* ssp. *humilis **Low northern-rockcress**	G5/S1		FRE	Shoshone NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Bromus pubescens **Hairy woodland brome**	G5/SH		CON		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown
Calochortus apiculatus **Pointedtip mariposa-lily**	G4/S1		CRO	Black Hills NF	Disjunct	Very Low	Very Rare	Moderate	Unknown	Medium
Campanula aparinoides Marsh bellflower	G5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Carex alopecoidea Foxtail sedge	G5/S2	USFS R2 Sensitive	CRO	Black Hills NF	Disjunct	Low	Rare	Moderate	Unknown	Medium
Carex aperta **Columbian sedge**	**G4/S1**		**PAR**	**Shoshone NF**	**Widespread/Edge**	**Very Low**	**Unknown**	**Moderate**	**Unknown**	**Low**
Carex arcta Northern clustered sedge	**G5/S1**		**CAR, PAR**	**Medicine Bow NF Shoshone NF**	**Widespread/Edge**	**Very Low**	**Unknown**	**Moderate**	**Unknown**	**Low**
Carex bella **Southwestern showy sedge**	**G5/SH**		**ALB**	**Medicine Bow NF**	**Widespread/Edge**	**Very Low**	**Unknown**	**Moderate**	**Unknown**	**Low**
Carex concinna **Low northern sedge**	G5/S1	MBNF-SOLC	CRO, PAR, SUB	Black Hills NF Bridger-Teton NF Shoshone NF Yellowstone NP	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Carex crawei Crawe's sedge	G5/S1		GOS, LAR	FE Warren AFB	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Carex diandra Lesser panicled sedge	G5/S2	USFS R2 Sensitive	ALB, CAR, PAR, SHE, TET	Bighorn NF Grand Teton NP Medicine Bow NF Shoshone NF Yellowstone NP	Disjunct	Low	Rare	Moderate	Stable	Medium

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Carex eburnea **Bristleleaf sedge**	G5/S1		CRO		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Carex egglestonii Eggleston's sedge	G4/S1		ALB, CAR	Medicine Bow NF	Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	Medium
Carex emoryi Emory's sedge	G5/**S2**		**CAR**, CRO, GOS, PLA	Camp Guernsey TA Casper BLM Devils Tower NM Fort Laramie NHS **Pathfinder NWR**	Widespread/ Edge	Very Low	Uncommon	Moderate	**Stable?**	Low
Carex flava Yellow sedge	G5/S1		PAR, TET	Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Carex foenea [*C. **aenea***] **Bronze sedge**	G5/S1		CRO	Black Hills NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Carex fuliginosa [*C. misandra* ; *C. f.* var. *misandra*] **Shortleaved sedge**	G5/S2	Bghrn NF-SOLC	FRE, JOH, PAR	Bighorn NF Shoshone NF	Disjunct	Low	Rare	Moderate	Unknown	Medium
Carex granularis [*C. g.* var. *haleana*] **Limestone meadow sedge**	G5T4/S2		CRO	Black Hills NF	Disjunct	Low	Unknown	Moderate	Unknown	Medium
Carex hallii [*C. parryana* var. *unica; C. parryana* ssp. *hallii*] **Deer sedge**	G4?Q/**S2**		ALB, CAR, LAR, PLA, **TET**	Medicine Bow NF Rawlins BLM **Yellowstone NP?**	Widespread/ Edge	Very Low	Uncommon	Moderate	Unknown	Low
Carex incurviformis [*C. i.* var. *danaensis; C. maritima*] **Coastal sand sedge**	G4G5T3/S2	USFS R4 Sensitive	FRE, PAR, SUB, TET	Bridger-Teton NF Grand Teton NP Shoshone NF	Disjunct	Low	Rare	Moderate	Stable?	Medium
Carex infirminervia [*C. bolanderi, C. deweyana* var. *bolanderi* - misapplied] **Weak-nerved sedge**	G5/S2		LIN, PAR, TET	Bridger-Teton NF Shoshone NF Targhee NF Yellowstone NP	Widespread/ Edge	Low	Unknown	Moderate	Unknown	Low
Carex intumescens **Greater bladder sedge**	G5/S1		CRO	Black Hills NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Carex laeviculmis **Smoothstem sedge**	G5/S1		TET	Grand Teton NP JDR Parkway Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Carex lenticularis var. *dolia* Enander's sedge	G5T3Q/S1		FRE	Shoshone NF	Disjunct	Very Low	Unknown	Moderate	Unknown	Medium

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Species Scientific Common Name	Heritage Rank	Federal Status	County	Managed Area	Range Context	# Pops.	Abund.	Vulnerab.	Recent Trends	Wyoming Contrib.
Carex luzulina var. *atropurpurea* **Black and purple woodrush sedge**	G5T3/S2	USFS R4 Sensitive	FRE, SUB, TET	Bridger-Teton NF Shoshone NF	Regional Endemic/ Core	Low	Uncommon	Moderate	Unknown	High
Carex microglochin* ssp. *microglochin **Fewseeded bog sedge**	G5?/S2		FRE, PAR, SUB	Bridger-Teton NF Pinedale BLM Shoshone NF Yellowstone NP	Disjunct	Low	Uncommon	Moderate	Unknown	Medium
Carex occidentalis Western sedge	G4/S1		ALB, CAR, PAR	Cody BLM Medicine Bow NF Rawlins BLM? Shoshone NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Carex oreocharis **Grassyslope sedge**	G3/S1		ALB, LAR	Medicine Bow NF Rawlins BLM	Regional Endemic/ Edge	Very Low	Uncommon	Moderate	Stable?	Medium
Carex proposita Smoky Mountain sedge	G4/S1		TET	Grand Teton NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Carex radiata [*C. rosea* misappl.] ***Eastern star sedge***	G5/**S2**		CRO	Black Hills NF	Disjunct	Low	Unknown	Moderate	Unknown	Medium
Carex scirpoides var. *scirpiformis* **Canadian single-spike sedge**	G5T4Q/S1		PAR, TET	Natl Elk Refuge Shoshone NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Carex scoparia* var. *scoparia Broom sedge	G5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Ceanothus herbaceus **Jersey tea**	G5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Ceanothus martinii **Martin's ceanothus**	G4/S1		LIN, SWE	Fossil Butte NM Rock Springs BLM	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Celtis occidentalis **Hackberry**	G5/S1		GOS, PLA, SHE	Bighorn NF Casper BLM?	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Centunculus – see *Anagallis*										
Cercocarpus ledifolius var. *intricatus* [*C. intricatus*] Dwarf mountain mahogany	G5T4/S1		SWE	Ashley NF (FGNRA) Rock Springs BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Chamaechaenactis scaposa [*C. s.* var. *parva*] Fullstem	G4/S1S2		SWE	Kemmerer BLM Rock Springs BLM	Regional Endemic/ Edge	Low	Rare	Moderate	Unknown	Medium

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Chenopodium incanum* var. *incanum Mealy goosefoot	G5T5/S1		GOS		Widespread/ Edge	Very Low	Uncommon	Low	Unknown	Low
Chenopodium watsonii Watson's goosefoot	G5/S1		GOS, LAR, WAS, WES	Thunder Basin NG Worland BLM	Widespread/ Edge	Very Low	Unknown	Low	Unknown	Low
Chionophila jamesii Rocky Mountain snowlover	G4?/S1		ALB, CAR	Medicine Bow NF	Regional Endemic/ Edge	Very Low	Uncommon	Moderate	Stable?	Medium
Chrysothamnus greenei **Greene's rabbitbrush**	G5/S1?		SWE	Rawlins BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Cicuta bulbifera **Bulbet-bearing water-hemlock**	G5/S1		TET	Targhee NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Circaea canadensis var. *canadensis* [*C. lutetiana* var. *canadensis*] **Broadleaf enchanter's nightshade**	G5T5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Cirsium barneby Barneby's thistle	G3G4/S1		CAR?, LIN	Kemmerer BLM	Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	Medium
Cirsium cymosum var. *canovirens* [*C. canovirens*] **Graygreen thistle**	G4G5/S1		PAR	Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Medium
Cirsium foliosum [*C. scariosum* - misappl.] **Elk thistle**	G5/S1	Bghrn NF-SOLC	PAR, SHE	Bighorn NF Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Cirsium ownbeyi Ownbey's thistle	G3/S2	WY BLM Sensitive	SWE	Ashley NF (FGNRA) Rock Springs BLM	Regional Endemic/ Edge	Low	Uncommon	Moderate	Stable?	Medium
Cirsium pulcherrimum* var. *aridum [*C. aridum*] Cedar Rim thistle	**G5T2**/S2	WY BLM Sensitive	CAR, FRE, SUB, SWE	Lander BLM Pinedale BLM Rawlins BLM Rock Springs BLM	Local Endemic/ Core	Low	Uncommon	Moderate	Moderate Decline?	Very High
Clarkia pulchella **Pinkfairies**	G5?/SH		TET	Bridger-Teton NF?	Widespread/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Cleome – see *Peritoma*										
Collomia grandiflora **Grand collomia**	G5/SH		LIN?		Widespread/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Crassula solieri [*C. aquatica, Tillaea aquatica* - misappl.] **Smooth-seed pygmyweed**	G4G5/S1		FRE, PAR	Shoshone NF Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Crocanthemum bicknellii [*Helianthemum bicknellii*] **Hoary frostweed**	G5/S1		CRO	Black Hills NF Devils Tower NM Newcastle BLM	Widespread/ Edge	Very Low	Rare	Moderate	Stable	Low
Cryptantha gracilis **Narrowstem cryptantha**	G5/S1		SWE	Ashley NF (FGNRA) Rock Springs BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Cryptantha rollinsii **Rollins' cryptantha**	G3/S1		**LIN**, SWE	Ashley NF? (FGNRA?) Rock Springs BLM Seedskadee NWR	Regional Endemic/ Edge	Very Low	Rare	Moderate	Unknown	Medium
Cryptantha subcapitata Owl Creek cryptantha	G2/S2	WY BLM Sensitive	FRE, Wind River IR	Lander BLM	Local Endemic/ Core	Low	Uncommon	Moderate	Stable?	Very High
Cryptogramma stelleri Fragile rockbrake	G5/S1	Bghrn NF-SOLC	FRE, PAR, SHE, TET	Bighorn NF Bridger-Teton NF Shoshone NF Targhee NF Yellowstone NP	Disjunct	Low	Rare	Moderate	Unknown	Medium
Cuscuta californica* var. *breviflora [*C. occidentalis*] **Chaparral dodder**	**G4G5TNR** /S1		LIN, SWE	Fossil Butte NM Kemmerer BLM Rock Springs BLM?	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Cuscuta indecora var. *neuropetala* **Bigseed dodder**	G5T5/S1		GOS, PLA, SHE	Casper BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Cuscuta megalocarpa [*C. umbrosa*] **Bigfruit dodder**	G5/S1		GOS, PLA		Widespread/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Cuscuta plattensis **Prairie dodder**	G1Q/S1	**USFS R2 Sensitive**	CON, GOS, PLA, WES	Casper BLM	Local Endemic/ Core?	Very Low	Unknown	Moderate	Unknown	Very High
Cymopterus alpinus [*Oreoxis alpina*] Alpine oreoxis	G4G5/S1		ALB	Medicine Bow NF Rawlins BLM?	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

Species Scientific Common Name	Heritage Rank	Federal Status	County	Managed Area	Range Context	# Pops.	Abund.	Vulnerab.	Recent Trends	Wyoming Contrib.
Cymopterus evertii **Evert's springparsley**	G2G3/S2S3	WY BLM Sensitive	HOT, PAR	Cody BLM Shoshone NF Worland BLM	Local Endemic/ Core	Low	Uncommon	Moderate	Stable?	Very High
Cymopterus sessiliflorus [*Aletes sessiliflorus*] **Sessileflower springparsley**	**G3/S1**		**FRE**	**Lander BLM**	**Disjunct**	**Unknown**	**Unknown**	**Moderate**	**Unknown**	**Medium**
Cymopterus williamsii **Williams' springparsley**	**G3/S3**	WY BLM Sensitive	BIG, JOH, NAT, WAS	**Bighorn NF** Buffalo BLM Casper BLM Worland BLM	Local Endemic/ Core	Low	Uncommon	Moderate	Stable?	Very High
Cyperus acuminatus **Tapertip flatsedge**	G5/S1		CAM, GOS	Fort Laramie NHS	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Cyperus bipartitus [*C. rivularis*] **Slender flatsedge**	G5/S1		GOS, PLA	Fort Laramie NHS	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Cyperus erythrorhizos **Redroot flatsedge**	G5/S1		CRO, PLA		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Cyperus odoratus [*C. engelmannii*] **Fragrant flatsedge**	G5/S1		PLA		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Cypripedium montanum Mountain lady's slipper	G4/S1	USFS R2 Sensitive	JOH, SHE, **WAS**	Bighorn NF Buffalo BLM	Widespread/ Edge	Low	Rare	Moderate	Moderate Decline	Low
Cypripedium parviflorum var. *pubescens* [*C. calceolus* var. *pubescens*;*C. pubescens*] **Greater yellow lady's slipper**	G5T5/S2	USFS R2 Sensitive	**ALB?**, BIG, CRO, FRE, JOH, SHE, WAS Wind River IR	Bighorn NF Black Hills NF **Medicine Bow NF?**	Disjunct	Low	Rare	Moderate	Moderate Decline	Medium
Dalea cylindriceps **Andean prairieclover**	G3G4/S2		GOS, PLA	Casper BLM Fort Laramie NHS?	Widespread/ Edge	Low	Unknown	Moderate	Unknown	Low
Dalea enneandra **Nineanther prairieclover**	G5/S1		CRO, WES	Newcastle BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Dalea villosa* var. *villosa **Silky prairieclover**	G5T5/S1		GOS, LAR	Casper BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Delphinium ramosum Mountain larkspur	G4/S1		LAR	FE Warren AFB	Regional Endemic/ Edge	Very Low	Rare	Moderate	Unknown	Medium
Deschampsia danthonioides Annual hairgrass	G5/S1		FRE, PAR, TET	Grand Teton NP Lander BLM Shoshone NF Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low

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Species Scientific Common Name	Heritage Rank	Federal Status	County	Managed Area	Range Context	# Pops.	Abund.	Vulnerab.	Recent Trends	Wyoming Contrib.
Descurainia incisa var. *paysonii* [*D. pinnata* var. *paysonii*] Payson's tansymustard	G5T3?/S2		CAR, SWE	Ashley NF (FGNRA)Rawlins BLMRock Springs BLM	Regional Endemic/ Edge	Low	Uncommon	Low	Unknown	Medium
Descurainia torulosa Wyoming tansymustard	G2/S2	USFS R2 Sensitive USFS R4 Sensitive WY BLM Sensitive	FRE, PAR, SWE, TET	Bridger-Teton NF Cody BLM? Rock Springs BLM Shoshone NF	Local Endemic/ Core	Low	Rare	Moderate	Unknown	Very High
Diaperia prolifera [*Filago prolifera, Evax prolifera*] **Bighead pygmycudweed**	G5/S1		CRO, **GOS**, NAT, PLA	Camp Guernsey TA? Casper BLM Devils Tower NM	Widespread/ Edge	Very Low	Rare	Low	Stable?	Low
Dichanthelium linearifolium [*Panicum linearifolium*] Slimleaf panicgrass	G5/S1	MBTB-SOLC	ALB, CRO, WES	Black Hills NF Medicine Bow NF	Disjunct	Very Low	Unknown	Moderate	Unknown	Medium
Dieteria bigelovii* var. *bigelovii [*Machaeranthera bigelovii* var. *bigelovii*] Bigelow's tansyaster	G4G5T3T4 /S2		ALB, CRO	Bamforth NWR? Black Hills NF Medicine Bow NF Mortenson Lake NWR?	Regional Endemic/ Edge	Low	Rare	Moderate	Unknown	Medium
Diphasiastrum complanatum [*Lycopodium complanatum*] Ground cedar	G5/S1	USFS R2 Sensitive	CRO	Black Hills NF	Disjunct	Very Low	Rare	Moderate	Stable?	Medium
Diplacus nanus [*Mimulus nanus* ssp. *nanus*] Dwarf purple monkeyflower	G5T4/S1		TET	Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Stable	Low
Dodecatheon – see *Primula*										
Downingia laeta **Great Basin calicoflower**	G5/S1		ALB, CAR, UIN	Kemmerer BLM? Rawlins BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Draba borealis Boreal draba	G4/S2	Bridger-Teton NF Forest Sensitive	LIN, PAR, SUB, TET	Bridger-Teton NF Grand Teton NP Natl Elk Refuge Shoshone NF Yellowstone NP	Disjunct	Low	Rare	Moderate	Stable?	Medium

Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Draba fladnizensis [*D. f.* var. *pattersonii*] **Austrian draba**	G4/S2	Bghrn NF-SOLC	FRE, JOH, LIN, PAR, TET	Bighorn NF Bridger-Teton NF Grand Teton NP Shoshone NF Targhee NF	Regional Endemic/ Edge	Low	Unknown	Moderate	Stable?	Medium
Draba novolympica [*D. paysonii* var. *treleasii*] Trelease's draba	G5T4T5/ S2		FRE, PAR	Shoshone NF Yellowstone NP	Widespread/ Edge	Low	Rare	Moderate	Unknown	Low
Draba paysonii [*D. paysonii* var. *paysonii*] Payson's draba	G5T3/S2		FRE, LIN, PAR, SUB	Bridger-Teton NF Shoshone NF Yellowstone NP	Regional Endemic/ Core?	Low	Rare	Moderate	Unknown	High
Draba pectinipila [*D. oligosperma* var. *pectinipila;* incl. *D. juniperina*] **Comb-hair draba**	**G2G3Q/S2**		**PAR, SWE, UIN**	**Ashley NF (FGNRA) Rock Springs BLM Shoshone NF**	**Regional Endemic/ Core**	**Low**	**Uncommon**	**Moderate**	**Stable**	**High**
Draba porsildii [Incl. vars. *brevicula* and *porsildii*] Porsild's draba	G3G4/S2		FRE, HOT, PAR, SUB	Bridger-Teton NF Shoshone NF	Widespread/ Edge	Low	Unknown	Moderate	Unknown	Low
Draba spectabilis [*D. spectabilis* var. *oxyloba*] Showy draba	G3G4/SH	MBNF-SOLC	CAR	Medicine Bow NF	Regional Endemic/ Edge	Very Low	Unknown	Unknown	Large Decline?	Unknown
Dryopteris carthusiana **Shield woodfern**	**G5/S1**		**CRO, WES**	**Black Hills NF**	**Widespread/ Edge**	**Very Low**	**Unknown**	**Moderate**	**Unknown**	**Low**
Dryopteris expansa [*D. assimilis;D. carthusiana* - misapplied] Spreading woodfern	G5/S1		PAR, TET	Grand Teton NP Shoshone NF Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Stable	Low
Dulichium arundinaceum* var. *arundinaceum Three-way sedge	G5/S1		TET	Yellowstone NP	Disjunct	Very Low	Rare	Moderate	Stable	Medium
Eleocharis bella **Beautiful spikerush**	G5/S1		TET	Grand Teton NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Eleocharis coloradoensis [*E. parvula; E. p.* var. *anachaeta*] **Dwarf spikerush**	G5/S1		GOS		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Eleocharis elliptica [*E. tenuis* var. *borealis*] **Boreal spikerush**	G5/S1S2	USFS R2 Sensitive	CRO, PLA, TET	Black Hills NF Medicine Bow NF Yellowstone NP	Widespread/ Edge	Low	Unknown	Moderate	Unknown	Low

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Eleocharis flavescens* var. *flavescens [Ours treated as var. *thermalis* by some authors] **Yellow spikerush**	G5T5/S2		PAR, TET	Grand Teton NP? JDR Parkway Yellowstone NP	Disjunct	Low	Rare	Moderate	Stable	Medium
Eleocharis ovata [*E. obtusa* var. *ovata*] **Ovate spikerush**	G5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Elymus simplex var. *luxurians* [*Leymus simplex* var. *luxurians*] Long-awned alkali wildrye	G4?QTNR/ S1S2	WY BLM Sensitive	SWE	Rock Springs BLM	Local Endemic/ Core	Very Low	Uncommon	Moderate	Stable	Very High
Elymus triticoides [*Leymus triticoides*] Creeping wildrye	G4G5/SH		ALB	Hutton Lake NWR	Widespread/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Elymus villosus Hairy wildrye	G5/S1S2		CRO	Black Hills NF Devils Tower NM Newcastle BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Ephedra cutleri [*E. viridis* var. *viscida*] Cutler's jointfir	G5/S1		SWE	Rock Springs BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Ephedra viridis [*E. v.* var. *viridis*] **Mormon tea**	G5/SH		SWE	Rock Springs BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Moderate Decline?	Unknown
Epipactis gigantea **Stream orchid**	G5/S1	USFS R2 Sensitive	BIG, TET	Grand Teton NP Yellowstone NP	Widespread/ Edge	Very Low	Rare	High	Stable	Low
Equisetum fluviatile Water horsetail	G5/S1		PAR, TET	**Grand Teton NP** Shoshone NF Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Equisetum scirpoides Dwarf scouring rush	G5/S1		CRO	Black Hills NF	Disjunct	Very Low	Rare	Moderate	Stable	Medium
Equisetum sylvaticum Woodland horsetail	G5/S2	Bgrhn NF-SOLC	CRO, JOH, SHE	Bighorn NF Black Hills NF	Disjunct	Low	Rare	Low	Unknown	Medium
Eragrostis hypnoides **Teal lovegrass**	G5/S1		GOS, PLA, SHE		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Ericameria linearis [*E. discoidea* var. *linearis; Haplopappus macronema* var. *linearis*] Narrowleaf goldenweed	**G4G5**/S2	USFS R4 Sensitive	FRE, LIN?, PAR, SUB, TET, Wind River IR	Bridger-Teton NF Kemmerer BLM? Shoshone NF Yellowstone NP	Regional Endemic/ Edge	Low	Uncommon?	Moderate	Stable?	Medium

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Species Scientific Common Name	Heritage Rank	Federal Status	County	Managed Area	Range Context	# Pops.	Abund.	Vulnerab.	Recent Trends	Wyoming Contrib.
Ericameria winwardii [*E. discoidea* var. *winwardii*] Winward's narrowleaf goldenweed	G4G5T1/ S1		LIN	Kemmerer BLM	Local endemic/ Core	Very Low	Rare	Moderate	Stable	Very High
Erigeron consimilis [*E. compactus* var. *consimilis*] **Foothill fleabane**	G4G5/S1		SWE	Rawlins BLM Rock Springs BLM	Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	Medium
Erigeron elatior Tall fleabane	G4/S2		ALB, CAR	Medicine Bow NF Rawlins BLM?	Regional Endemic/ Edge	Low	Uncommon	Moderate	Unknown	Medium
Erigeron humilis **Arctic alpine fleabane**	G5/S2	Bghrn NF-SOLC	BIG, FRE, PAR, SUB	Bighorn NF Bridger-Teton NF Shoshone NF	Widespread/ Edge	Low	Rare	Moderate	Unknown	Low
Erigeron lanatus Woolly fleabane	G3G4/S1	USFS R4 Sensitive	SUB, TET	Bridger-Teton NF Grand Teton NP	Disjunct	Very Low	Rare	Moderate	Stable?	Medium
Erigeron pinnatisectus **Featherleaf fleabane**	G4/S2		ALB, CAR	Medicine Bow NF	Regional Endemic/ Edge	Low	Uncommon	Moderate	Stable?	Medium
Eriogonum brevicaule var. *canum* [*E. lagopus*] Rabbit buckwheat	G3G4/S2		BIG, PAR, SHE	Bighorn Canyon NRA Cody BLM Worland BLM	Regional Endemic/ Edge	Low	Abundant	Moderate	Stable	High
Eriogonum corymbosum* var. *corymbosum **Crispleaf buckwheat**	G5T5/S1		SWE	Rock Springs BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Eriogonum divaricatum Divergent buckwheat	G4G5/S1		LIN, SUB, SWE, UIN	Kemmerer BLM Pinedale BLM Rock Springs BLM	Widespread/ Edge	Very Low	Uncommon	Moderate	Unknown	Low
Eriogonum exilifolium **Dropleaf buckwheat**	G3/S2	USFS R2 Sensitive	ALB, CAR	Medicine Bow NF Rawlins BLM	Regional Endemic/ Core	Low	Uncommon	Moderate	Unknown	High
Eriogonum hookeri **Hooker's buckwheat**	G5/S1		CAR, SWE	Rawlins BLM? Rock Springs BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Eriogonum mancum **Imperfect buckwheat**	G4/S1		BIG, PAR	Cody BLM	Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	Medium
Eriogonum umbellatum var. *cladophorum* **Yellowstone sulfur buckwheat**	G5T1/S1		TET	Yellowstone NP	Local Endemic/ Core	Very Low	Rare	Moderate	Stable	Very High
Eriophorum callitrix [*E. c.* var. *callitrix*] **Arctic cottongrass**	G5/S1		FRE, PAR	Shoshone NF	Disjunct	Very Low	Rare	Moderate	Stable?	Medium

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Species Scientific Common Name	Heritage Rank	Federal Status	County	Managed Area	Range Context	# Pops.	Abund.	Vulnerab.	Recent Trends	Wyoming Contrib.
Eriophorum scheuchzeri **White cottongrass**	G5/S2		FRE, PAR, SUB	Bridger-Teton NF Shoshone NF	Disjunct	Low	Rare	Moderate	Unknown	Medium
Eriophorum viridicarinatum **Thinleaf cottongrass**	G5/S2		PAR, TET	Grand Teton NP Natl Elk Refuge Shoshone NF Yellowstone NP	Disjunct	Low	Rare	Moderate	Stable	Medium
Eritrichium howardii **Howard's alpine forget-me-not**	G4/S2	Bghrn NF-SOLC	JOH, PAR, SHE	Bighorn NF Buffalo BLM Cody BLM Shoshone NF	Regional Endemic/ Edge	Low	Uncommon	Moderate	Unknown	Medium
Erythranthe rubella [*Mimulus rubellus*] **Little redstem monkeyflower**	G5/S1		CAR, NAT, PAR?	Casper BLM Rawlins BLM Yellowstone NP?	Widespread/ Edge	Very Low	Rare	Moderate	Stable	Low
Euphorbia exstipulata [*E. e.* var. *exstipulata*] **Squareseed spurge**	G5/SH		PLA	Casper BLM?	Disjunct	Very Low	Unknown	Unknown	Unknown	Unknown
Euphorbia geyeri* var. *geyeri [*Chamaesyce geyeri*] **Geyer's sandmat**	G5/S1		GOS	Casper BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Euphorbia hexagona **Sixangle spurge**	G5/S1		GOS, PLA	Camp Guernsey TA Casper BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Eustoma grandiflorum [*E. russellianum*] Showy prairie-gentian	G5/S1		GOS, NAT, PLA		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Euthamia graminifolia [*E. g.* var. *major; E. g.* var. *graminia, Solidago graminifolia* var. *major*] **Flat-top goldentop**	G5T5/S1	MBNF-SOLC	ALB, PLA	Camp Guernsey TA? Casper BLM Medicine Bow NF?	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Festuca hallii [*F. altaica* ssp. *hallii;* incl. in *F. scabrella* by some authors] **Plains rough fescue**	G4/S2	USFS R2 Sensitive	ALB, JOH?, PAR	Bighorn NF? Cody BLM Medicine Bow NF Shoshone NF	Widespread/ Edge	Low	Uncommon	Moderate	Unknown	Low
Festuca viviparoidea var. *krajinae* [*F. vivipara* - misappl.] Northern fescue	G4G5TNR/ S1		FRE, SUB	Bridger-Teton NF Shoshone NF	Disjunct	Very Low	Unknown	Moderate	Unknown	Medium
Filago – see *Diaperia*										

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Fimbristylis puberula var. *interior* Hairy fimbry	G5T5/S1		NIO		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Froelichia gracilis **Slender snakecotton**	G5/SH		WES		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown
Galium coloradoense [*G. multiflorum* var *coloradoense*] Colorado bedstraw	G4/S1		SWE	Rawlins BLM Rock Springs BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Galium mexicanum* var. *asperulum **Mexican bedstraw**	**G5T3T5/ S1**		**PAR**	**Shoshone NF**	**Widespread/ Edge**	**Very Low**	**Unknown**	**Moderate**	**Unknown**	**Low**
Gentiana bigelovii [*G. affinis* var. *bigelovii*] Bigelow's prairie gentian	G5/S1	MBTB-SOLC	ALB, LAR	Medicine Bow NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Gentianella propinqua* var. *propinqua [*Gentiana propinqua*] **Fourpart dwarf gentian**	**G5T5**/S1		PAR, TET	Shoshone NF Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Gentianopsis simplex [*Gentianella simplex*, *Gentiana simplex*] **Oneflower fringed gentian**	G5/S1		TET	Bridger-Teton NF JDR Parkway Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Glandularia bipinnatifida [*Verbena bipinnatifida*] Dakota mock vervain	G5/S1		CRO, FRE	Devils Tower NM	Widespread/ Edge	Very Low	Rare	Low	Stable	Low
Glossopetalon spinescens var. *meionandrum* [*Forsellesia meionandra*] **Spiny greasebush**	G5T3/S1		SWE	Ashley NF (FGNRA) Rock Springs BLM	Regional Endemic/ Edge	Very Low	Rare	Moderate	Stable	Medium
Gymnocarpium dryopteris [*incl. G. disjunctum & G. x brittonianum*] **Western oakfern**	G5/S2	MBNF-SOLC	CAR, CRO, TET	Black Hills NF Grand Teton NP Medicine Bow NF Yellowstone NP	Widespread/ Edge	Low	Rare	Low	Moderate Decline?	Low
Helianthemum – see *Crocanthemum*										
Helictotrichon mortonianum **Morton's alpine oatgrass**	G4/S1		FRE	Shoshone NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Hesperochiron californicus *California hesperochiron*	G4G5/S1		SUB, UIN	Pinedale BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

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Hesperostipa neomexicana [*Stipa neomexicana*] **New Mexico feathergrass**	G4G5/S1		PLA	Casper BLM Guernsey SP	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Heterocodon rariflorus Western pearl-flower	G5/SH		TET	Targhee NF	Widespread/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Heterotheca pumila [Incl. in *Chrysopsis villosa* by Cronquist] **Alpine false goldenaster**	G4/S1		ALB, CAR	Medicine Bow NF	Regional Endemic/ Edge	Very Low	Rare?	Moderate	Unknown	Medium
Huperzia haleakalae [*Lycopodium selago* var. *haleakalae, Huperzia selago* - misappl.] **Pacific clubmoss**	**G5**/S1		TET	Grand Teton NP	Disjunct	Very Low	Unknown	Moderate	Unknown	Medium
Hymenopappus tenuifolius **Chalkhill hymenopappus**	G5/SH		CRO	Black Hills NF?	Widespread/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Ionactis alpina [*Aster scopulorum*] Lava aster	G5/S1		PAR	Yellowstone NP	Widespread/ Edge	Very Low	Uncommon	Moderate	Stable	Low
Ipomopsis aggregata ssp. *weberi* [*I. a.* var. *weberi*] **Weber's ipomopsis**	G5T2/S1	USFS R2 Sensitive	CAR	Medicine Bow NF Rawlins BLM	Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	High
Ipomopsis longiflora* ssp. *longiflora [*Gilia longiflora*] **Flaxflowered ipomopsis**	G5/S1		GOS		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Ipomopsis polycladon [*Gilia polycladon*] **Manybranched ipomopsis**	G4/S1		SWE	Ashley NF (FGNRA)	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Ipomopsis spicata var. robruthii [*I. s.* var. *robruthiorum*] Kirkpatrick's ipomopsis	G5T2/S2		**FRE?**, HOT, PAR	Shoshone NF	Local Endemic/ Core	Low	Rare	Moderate	Stable?	Very High
Ipomopsis tenuituba* ssp. *tenuituba [*I. aggregata* var. *tenuituba, Gilia aggregata* var. *macrosiphon*] **Slendertube ipomopsis**	**G4G5TNR** /S1		ALB, CAR, **LIN, SUB**	Medicine Bow NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Isoetes echinospora **Spiny-spore quillwort**	**G5/S1**		**TET**	**Yellowstone NP**	**widespread/ Edge**	**Very Low**	**Unknown**	**Low**	**Unknown**	**Low**

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Isoetes occidentalis [*I. lacustris* var. *paupercula*] **Western quillwort**	G4G5/S1		**PAR**, TET	Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Juncus triglumis var. albescens [*J. albescens*] Northern white rush	G5T5/S2	MBNF-SOLC	ALB, FRE, PAR, SUB	Bridger-Teton NF Medicine Bow NF Shoshone NF	Disjunct	Low	Rare	Moderate	Stable?	Medium
Juncus triglumis var. triglumis Three-flower rush	G5T5/S1	Bghrn NF-SOLC	JOH, PAR	Bighorn NF Shoshone NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Juncus vaseyi Vasey's rush	**G5**/S1	MBNF-SOLC	ALB, FRE, SUB, TET	Bridger-Teton NF Medicine Bow NF Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Kobresia sibirica [*K. macrocarpa, K. schoenoides*] **Siberian bog sedge**	G5/S1		PAR	Shoshone NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Kobresia simpliciuscula **Simple bog sedge**	G5/S1	USFS R2 Sensitive	**FRE**, PAR, SUB	Pinedale BLM Shoshone NF	Disjunct	Very Low	Rare	Moderate	Stable?	Medium
Koenigia islandica Koenigia	G4/S1		FRE, PAR	Shoshone NF	Disjunct	Low	Rare	Moderate	Unknown	Medium
Lathyrus eucosmus **Bush vetchling**	G4G5/S1		FRE	Lander BLM	Disjunct	Very Low	Unknown	Moderate	Unknown	Medium
Lathyrus lanszwertii var. *lanszwertii* Nevada sweetpea	G4G5T4/ S1?		HOT?, UIN, WAS?	Kemmerer BLM Wasatch-Cache NF? Worland BLM?	Widespread/ Edge	Very Low?	Unknown	Moderate	Unknown	Low
Lechea intermedia **Largepod pinweed**	G5/S1		CRO	Black Hills NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Lemna gibba **Swollen duckweed**	**G4G5/S1**		**TET**	**Yellowstone NP**	**Disjunct**	**Very Low**	**Unknown**	**Moderate**	**Unknown**	**Medium**
Lemna valdiviana **Valdivia duckweed**	G5/S1		PAR, TET	Grand Teton NP Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Low	Unknown	Low
Lepidium integrifolium [*L. i.* var. *integrifolium*] **Thickleaf pepperweed**	G2G3/S1	WY BLM Sensitive	LIN, UIN	Cokeville NWR Fossil Butte NM Kemmerer BLM	Regional Endemic/ Core?	Very Low	Uncommon	Moderate	Unknown	High
Liatris lancifolia **Lanceleaf blazing star**	G4/S1		GOS		Widespread/ Edge	Very Low	Rare	Moderate	Moderate Decline	Low
Ligusticum tenuifolium **Idaho licorice-root**	G5/S1?	MBNF-SOLC	CAR	Medicine Bow NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

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Linanthus watsonii [*Leptodactylon watsonii*] Watson's prickly phlox	G3G5/S1	Bghrn NF-SOLC	FRE, HOT, SWE, WAS, Wind River IR	Ashley NF (FGNRA) Bighorn NF **Worland BLM**	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Lipocarpha aristulata [*L. drummondii; Hemicarpha drummondii*] **Awned halfchaff sedge**	G4G5/S1		ALB, GOS, PLA	Fort Laramie NHS	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Listera convallarioides Broad-leaved twayblade	G5/S1S2	Bghrn NF-SOLC, BlHll NF-SOLC, MBNF-SOLC	ALB, CON, **LIN**, SHE, TET	Bighorn NF Bridger-Teton NFGrand Teton NPMedicine Bow NFTarghee NF Yellowstone NP	Widespread/ Edge	Low	Rare	High	Unknown	Low
Lithospermum multiflorum Many-flowered gromwell	G4/SH		LAR		Disjunct	Very Low	Unknown	Unknown	Unknown	Unknown
Lobelia siphilitica* var. *ludovicana Great blue lobelia	G5/S1		GOS, LAR, NIO	Ft. Laramie NHS	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Loeflingia squarrosa [Incl. var. *artemisiarum* and var. *texanum*] **Spreading pygmyleaf**	G5/S1		CRO, SWE, WES	Newcastle BLM? Rock Springs BLM?	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Lomatium attenuatum **Tapertip desertparsley**	G3/S2		PAR	Cody BLM Shoshone NF	Regional Endemic/ Core	Moderate	Uncommon	Moderate	Stable?	High
Lomatium triternatum var. *anomalum* [Incl. var. *triternatum*] **Broad nineleaf biscuitroot**	G5T4T5/ S1		LIN	Fossil Butte NM Kemmerer BLM	Regional Endemic/ Edge?	Very Low	Rare	Moderate	Unknown	Medium
Lomatogonium rotatum Marsh felwort	G5/S2	MBNF-SOLC	ALB, CAR, LAR	Medicine Bow NF Mortenson Lake NWR	Disjunct	Low	Rare	Moderate	Unknown	Medium
Luzula hitchcockii [*L. glabrata* var. *hitchcockii*] **Hitchcock's woodrush**	**G5**/S2		PAR, TET	Bridger-Teton NF Grand Teton NP Shoshone NF Targhee NF Yellowstone NP	Widespread/ Edge	Low	Rare	Moderate	Unknown	Low
***Luzula subcapitata* Colorado woodrush**	**G3/S1**		**ALB, CAR**	**Medicine Bow NF**	**Regional Endemic/ Edge**	**Very Low**	**Rare**	**Unknown**	**Unknown**	**Medium**

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Lycopus uniflorus Northern bugleweed	G5/S1		CRO, TET	Black Hills NF **Targhee NF** Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Lysimachia thyrsiflora Tufted loosestrife	G5/S1		ALB, TET	Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Lythrum alatum* var. *alatum **Winged lythrum**	G5T5/S1		CRO, NIO, PLA	Casper BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Machaeranthera – see *Dieteria, Xanthisma*										
Marsilea oligospora [*M. vestita* var. *oligospora*] **Pacific waterclover**	G5/S1		SUB, TET	Bridger-Teton NF Grand Teton NP JDR Parkway	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Mentzelia rusbyi [*Nuttallia rusbyi*] **Rusby's blazingstar**	G4?/S1		ALB, CAR, **SWE**	Medicine Bow NF? Rawlins BLM? GET	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Mentzelia sinuata **Leechleaf blazingstar**	G3/S2		ALB, LAR	Rawlins BLM?	Regional Endemic/ Edge	Low	Unknown	Moderate	Unknown	High
Mentzelia speciosa [*Nuttallia speciosa*] Jeweled blazingstar	G3?/S1		LAR		Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	Medium
Mimulus – see *Diplacus, Erythranthe*										
Monarda pectinata **Pony beebalm**	G5/S1		GOS	Casper BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Monardella odoratissima var. *glauca* Mountain wild-mint	**G3G5TNR** /S1		LIN	Bridger-Teton NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Montia linearis [*Montiastrum lineare*] **Narrowleaf minerslettuce**	G5/S1		**PAR,** TET	Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Stable	Low
Muhlenbergia montana Mountain muhly	G5/S1		CAR, LAR		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Muhlenbergia torreyi Ring muhly	G4/S1		LAR		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Musineon vaginatum **Sheathed wildparsley**	G3G4/S2	Bghrn NF-SOLC	BIG, SHE	Bighorn NF Cody BLM	Regional Endemic/ Edge	Low	Rare	Moderate	Stable	Medium
Myosotis verna [*M. virginiana auct. non*] Spring forget-me-not	G5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

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Myriophyllum verticillatum Whorl-leaf watermilfoil	G5/**S2**		FRE, PAR, TET	Grand Teton NP Shoshone NF Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Najas flexilis **Nodding waternymph**	**G5/S1**		**TET**	**Yellowstone NP**	**Widespread/Edge**	**Very Low**	**Unknown**	**Low**	**Unknown**	**Low**
Najas guadalupensis **Slender waternymph**	G5/S1		**SHE, SUB?**, TET	Bighorn NF Bridger-Teton NF Grand Teton NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Nothocalais troximoides [*Microseris troximoides*] **Sagebrush false dandelion**	G5/S1		PAR, SHE	Cody BLM Grand Teton NP Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Oenothera canescens Spotted evening primrose	G4G5/S1		GOS		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Oenothera coloradensis [*Gaura neomexicana* ssp. *coloradensis, O. c.* ssp. *coloradensis*] Colorado butterfly plant	G3T2/S2	USFWS Threaten.	LAR, PLA	FE Warren AFB	Regional Endemic/ Core	Low	Uncommon	Moderate	Stable?	High
Oenothera howardii **Howard's evening primrose**	G3G4/S1		LAR		Regional Endemic/ Edge	Very Low	Rare	Moderate	Unknown	Medium
Oenothera laciniata **Cutleaf evening primrose**	G5/S1		CAM, CRO	Black Hills NF Devils Tower NM	Widespread/ Edge	very Low	Unknown	Moderate	Unknown	Low
Onoclea sensibilis Sensitive fern	G5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Ophioglossum pusillum [*O. vulgatum*] **Northern adderstongue**	G5/S1		TET	Yellowstone NP	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Orobanche corymbosa [*O. c.* var. *corymbosa; O. californica* var. *corymbosa*] Flat-top broomrape	**G4**/S1S2		PAR, SUB, TET	Bridger-Teton NF Grand Teton NP Shoshone NF Yellowstone NP	Widespread/ Edge	Low	Rare	Moderate	Moderate	Low
Oxytheca dendroidea* ssp. *dendroidea **Narrowleaf oxytheca**	G4/SH		FRE, HOT, SWE	Lander BLM? Rock Springs BLM? Worland BLM?	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown
Oxytropis besseyi var. *obnapiformis* [*O. obnapiformis*] Maybell locoweed	G5T2/S1		FRE, NAT, SWE, UIN	Lander BLM Kemmerer BLM	Regional Endemic/ Edge?	Very Low	Rare	Moderate	Unknown	High

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Packera crocata [*Senecio crocatus*] **Saffron ragwort**	G4/S1?	MBNF-SOLC	ALB, **CAR**, SWE	Medicine Bow NF Rock Springs BLM	Regional Endemic/ Edge	Very Low	Rare	Moderate	Unknown	Medium
Paeonia brownii Brown's peony	G5/S1		TET	Grand Teton NP Targhee NF Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Palafoxia rosea [*P. r.* var. *macrolepis*] **Rosy Palafox**	**G5**/S1	TBNG-SOLC	CON, GOS, **PLA**	Thunder Basin NG	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Papaver radicatum* ssp. *kluane [*P. kluanense; P. lapponicum* var. *occidentale*] Alpine poppy	**G5T4**/S2	Bghrn NF-SOLC	BIG, FRE, JOH?, PAR, SUB	Bighorn NF Bridger-Teton NF Cody BLM Shoshone NF	Disjunct	Low	Rare	Moderate	Stable?	Medium
Paronychia jamesii James' nailwort	G4/S1		ALB, GOS		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Paronychia pulvinata Rocky Mountain nailwort	G3?/S1		ALB, CAR	Medicine Bow NF Rawlins BLM	Regional Endemic/ Edge	Very Low	Rare	Moderate	Stable?	Medium
Parrya rydbergii [*P. nudicaulis*, misappl.] **Rydberg's parrya**	**GNR**/S2	USFS R4 Sensitive	FRE, PAR, SUB, TET	Bridger-Teton NF Shoshone NF	Disjunct	Low	Uncommon	Moderate	Stable	Medium
Pectis angustifolia* var. *angustifolia **Narrowleaf pectis**	G4G5TNR/ S1	TBNG-SOLC	CON, GOS, PLA	Casper BLM? Thunder Basin NG	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Pedicularis contorta var *ctenophora* Coil-beaked lousewort	G5T3/S2		BIG, JOH, SHE, WAS	Bighorn NF Buffalo BLM	Regional Endemic/ Edge	Low	Uncommon	Moderate	Unknown	Medium
Pedicularis oederi Oeder's lousewort	G5/**S2**		PAR	Shoshone NF	Disjunct	Very Low	Uncommon	Moderate	Stable?	Medium
Pedicularis parryi ssp. *mogollonica* *Mogollon lousewort*	G5T2T4Q/ S1		**BIG**, UIN	**Bighorn NF** Wasatch-Cache NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Pediomelum digitatum [*Psoralea digitata*] **Palmleaf Indian breadroot**	G5/S1		GOS	Casper BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Pediomelum linearifolium [*Psoralea linearifolia*] **Narrowleaf Indian breadroot**	G4?/S1		LAR		Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Pellaea glabella var. *simplex* [*P. suksdorfiana*] **Simple western dwarf cliffbrake**	G5T4?/S1		CRO, PLA, TET	Black Hills NF Targhee NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Penstemon absarokensis Absaroka beardtongue	G2/S2	USFS R2 Sensitive WY BLM Sensitive	FRE, PAR, Wind River IR?	Cody BLM Shoshone NF	Local Endemic/ Core	Moderate	Uncommon	Moderate	Stable?	Very High
Penstemon acaulis [*P. acaulis* var. *acaulis*] Stemless beardtongue	G2/S1	USFS R4 Sensitive WY BLM Sensitive	SWE	Ashley NF (FGNRA) Rock Springs BLM	Local Endemic/ Core	Very Low	Uncommon	Moderate	Moderate Decline	Very High
Penstemon angustifolius var. *caudatus* **Narrowleaf broadbeard beardtongue**	G5T4?/S1		GOS	Casper BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Penstemon cyathophorus **Sagebrush beardtongue**	G3/S2	MBNF-SOLC	CAR	Medicine Bow NF Rawlins BLM	Regional Endemic/ Edge	Low	Rare	Moderate	Stable?	Medium
Penstemon gibbensii Gibbens' beardtongue	G1G2/S1	WY BLM Sensitive	CAR, SWE	Rawlins BLM	Regional Endemic/ Core	Very Low	Rare	Moderate	Moderate Decline?	High
Penstemon haydenii **Blowout beardtongue**	G1G2/S1	USFWS Endanger	CAR	Rawlins BLM	Regional Endemic/ Edge	Very Low	Rare	Moderate	Stable?	Medium
Penstemon scariosus var. *garrettii* Garrett's beardtongue	G4T3/S1		SWE, UIN	Rock Springs BLM	Regional Endemic/ Edge	Very Low	Rare	Unknown	Unknown	Medium
Penstemon watsonii Watson's beardtongue	G5/SH		UIN	Kemmerer BLM?	Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown
Penstemon yampaensis [*P. acaulis* var. *yampaensis*] Yampa beardtongue	**G2**/S1		SWE	Rock Springs BLM	Regional Endemic/ Edge	Very Low	Very Rare	Moderate	Unknown	Medium
Peritoma multicaulis [*Cleome multicaulis*] **Slender spiderflower**	G2G3/S1	WY BLM Sensitive	**FRE**, NAT	Casper BLM **Lander BLM** Pathfinder NWR	Disjunct	Very Low	Uncommon	Moderate	Stable?	Medium
Phacelia alba [*P. neomexicana* var. *alba*] **White phacelia**	G4G5/S1	MBNF-SOLC	ALB, LAR	Medicine Bow NF Rawlins BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Phacelia demissa* var. *demissa [Incl. var. *knightii*] Intermountain phacelia	G5T3?Q /S1		SWE	Rock Springs BLM	Regional Endemic/ Edge	Very Low	Rare	Moderate	Unknown	Medium
Phacelia demissa* var. *minor **Small intermountain phacelia**	**G5T3?Q/ S1**		**FRE**	**Rock Springs BLM**	**Regional Endemic/ Edge**	**Very Low**	**Very Rare**	**Unknown**	**Unknown**	**Medium**
Phacelia denticulata Rocky Mountain phacelia	G3?/S2	MBNF-SOLC	ALB, LAR	Medicine Bow NF Rawlins BLM	Regional Endemic/ Edge	Low	Rare	Moderate	Moderate Decline?	Medium
Phacelia glandulosa var. *deserta* Desert glandular phacelia	G4T2Q/S2		CAR, LIN, SUB, SWE	Ashley NF (FGNRA) Kemmerer BLM Pinedale BLM Rawlins BLM Rock Springs BLM	Local Endemic/ Core	Low	Rare	Moderate	Unknown	Very High
Phacelia incana **Hoary phacelia**	G3G4/S1		CAR, SWE	Ashley NF (FGNRA) Rawlins BLM? Rock Springs BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Phacelia salina **Bitter Creek phacelia**	G3?Q/S2		CAR, LIN, SUB, SWE, UIN	Pinedale BLM Rawlins BLM Rock Springs BLM	Widespread/ Edge	Low	Rare	Moderate	Unknown	Low
Phacelia tetramera **Fourpart phacelia**	G4/S1		FRE, SWE	Rawlins BLM Rock Springs BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Philadelphus microphyllus var. *occidentalis* **Littleleaf mockorange**	G5?T3T4/ S1		SWE	Ashley NF (FGNRA) Rock Springs BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Phippsia algida **Icegrass**	G5/S1		FRE, PAR, SUB	Bridger-Teton NF Shoshone NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Phlox albomarginata **Whitemargin phlox**	G4/S1		LIN	Kemmerer BLM	Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	Medium
Phlox diffusa ssp. *scleranthifolia* [Incl. in *Phlox hoodii* by some authors] Spreading phlox	G5TNR/S1		PAR	Shoshone NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Phryma leptostachya **American lopseed**	G5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Physalis virginiana [*P. v.* var. *virginiana*] **Virginia groundcherry**	G5/S1		CRO, WES	Black Hills NF Newcastle BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Physaria arenosa* ssp. *argillosa [*Lesquerella arenosa* var. *argillosa*] Sidesaddle bladderpod	G5T4/S1	WY BLM Sensitive	NIO	Newcastle BLM	Regional Endemic/ Edge	Very Low	Uncommon	Moderate	Stable	Medium
Physaria carinata* ssp. *carinata [*Lesquerella carinata* var. *carinata*] Keeled bladderpod	G3G4T3T4 /S2		FRE?, TET	Bridger-Teton NF Grand Teton NP Natl Elk Refuge Targhee NF	Regional Endemic/ Edge	Low	Uncommon	Moderate	Stable	Medium
Physaria dornii Dorn's twinpod	G1/S1	WY BLM Sensitive	LIN, UIN	Kemmerer BLM	Local Endemic/ Core	Very Low	Uncommon	Moderate	Stable	Very High
Physaria fremontii [*Lesquerella fremontii*] Fremont's bladderpod	G2/S2	USFS R2 Sensitive WY BLM Sensitive	FRE	Lander BLM Shoshone NF	Local Endemic/ Core	Low	Uncommon	Moderate	Stable	Very High
Physaria didymocarpa* var. *lanata [*P. lanata*] Woolly twinpod	G5T2/S2	USFS R2 Sensitive	BIG, CAM, JOH, SHE	Bighorn NF Buffalo BLM	Regional Endemic/ Core	Low	Uncommon	Moderate	Stable	Very High
Physaria macrocarpa [*Lesquerella macrocarpa*] Large-fruited bladderpod	G2/S2	WY BLM Sensitive	FRE, LIN, SUB, SWE	Kemmerer BLM Pinedale BLM Rock Springs BLM	Local Endemic/ Core	Low	Uncommon	Moderate	Moderate Decline?	Very High
Physaria multiceps [*Lesquerella multiceps*] Western bladderpod	G3/S1		LIN	Targhee NF	Regional Endemic/ Edge	Very Low	Rare	Moderate	Stable	Medium
***Physaria pachyphylla* Thickleaf bladderpod**	**G2G3/S1**		**BIG**	**Bighorn Canyon NRA**	**Local Endemic/Edge**	**Very Low**	**Rare**	**Moderate**	**Unknown**	**High**
Physaria parvula [*Lesquerella parvula, L. alpina* var. *parvula*] **Pygmy bladderpod**	G3?Q/S2		CAR, SWE, UIN	Kemmerer BLM Medicine Bow NF? Rock Springs BLM Wasatch-Cache NF	Regional Endemic/ Edge	Low	Rare	Moderate	Stable?	Medium
Physaria prostrata [*Lesquerella prostrata*] Prostrate bladderpod	G2G3/S2	WY BLM Sensitive	LIN, UIN	Kemmerer BLM	Regional Endemic/ Core	Low	Uncommon	Moderate	Stable?	High

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Species Scientific Common Name	Heritage Rank	Federal Status	County	Managed Area	Range Context	# Pops.	Abund.	Vulnerab.	Recent Trends	Wyoming Contrib.
Physaria pycnantha [*Lesquerella alpina* var. *condensata*] **Mountain-view bladderpod**	**GNR/S1**		**PAR**	**Shoshone NF**	**Regional Endemic/ Edge**	**Very Low**	**Unknown**	**Moderate**	**Unknown**	**Medium**
Physaria subumbellata **Parasol bladderpod**	**G3/S2**		**CAR, NAT, SWE**	**Casper BLM Rawlins BLM Rock Springs BLM**	**Regional Endemic/ Core?**	**Low**	**Unknown**	**Moderate**	**Unknown**	**High**
Physocarpus alternans Dwarf ninebark	G4/S1		SWE	Rock Springs BLM	Widespread/ Edge	Very Low	Unknown	High	Unknown	Low
Platanthera orbiculata [*Habenaria orbiculata*] **Lesser roundleaved orchid**	G5/S1	USFS R2 Sensitive	CRO	Black Hills NF	Disjunct	Very Low	Rare	Unknown	Unknown	Medium
Polemonium micranthum Annual polemonium	G5/SH		PAR	Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown
Polygala verticillata [*P. verticillata* var. *isocycla*] Whorled milkwort	G5/S1		CAM, CRO	Black Hills NF Newcastle BLM Thunder Basin NG	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Polygonatum biflorum [*P. biflorum* var. *commutatum*] **Solomon's-seal**	G5/S1		CRO	Black Hills NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Polygonum spergulariiforme [*P. douglasii* var. *spergulariiforme*] **Fall knotweed**	**G5**/S1		JOH?, PAR, SHE, WAS	Worland BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Polypodium saximontanum [*P. vulgare* var. *columbianum*] Rocky Mountain polypody	G3?/S1		ALB, CAR, CON	Medicine Bow NF	Regional Endemic/ Edge	Very Low	Rare	Unknown	Stable?	Medium
Polystichum scopulinum **Mountain hollyfern**	G5/SH		TET	Targhee NF Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown
Populus deltoides var. *wislizeni* [*P. fremontii* var. *wislizeni*] Fremont cottonwood	G5T4T5/ S1		CAR, SWE	Rawlins BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low

Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Porterella carnosula **Little hogweed**	G4/S1		TET, UIN	Grand Teton NP Wasatch-Cache NF Yellowstone NP	Widespread/ Edge	Very Low	Uncommon	Moderate	Stable	Low
Potamogeton amplifolius **Largeleaf pondweed**	G5/**S1S2**	Bghrn NF-SOLC	CAR, FRE, JOH, PAR, SUB, **TET**	Bighorn NF Bridger-Teton NF Medicine Bow NF Shoshone NF **Yellowstone NP**	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Potamogeton diversifolius **Waterthread pondweed**	G5/S1		CAM, CRO	Black Hills NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Potamogeton illinoensis Illinois pondweed	G5/S1		ALB, NAT, PAR, SUB	Bridger-Teton NFLander BLM? Shoshone NF Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Potamogeton nodosus Longleaf pondweed	G5/S1		CAR, FRE, PLA, TET, Wind River IR	Rawlins BLM? Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Potamogeton obtusifolius **Bluntleaf pondweed**	G5/S1		**PAR**, TET	Grand Teton NP JDR Parkway Yellowstone NP	Disjunct	Very Low	Unknown	Moderate	Unknown	Medium
Potamogeton strictifolius **Narrowleaf pondweed**	G5/S1		ALB, PAR, SUB, TET	Bridger-Teton NF Rawlins BLM Yellowstone NP	Disjunct	Very Low	Unknown	Unknown	Moderate Decline?	Medium
Potamogeton zosteriformis Flatstem pondweed	G5/**S1S2**		**PAR**, TET	Grand Teton NP Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Moderate Decline?	Low
***Potentilla* sp. nov.** [P. *"subjuga"*] **Undesc. cinquefoil**	**GNR**/S2		FRE, HOT, PAR	Cody BLM Shoshone NF Worland BLM	Regional Endemic/ Edge	Low	Rare	Low	Unknown	Medium
Potentilla ambigens **Silkyleaf cinquefoil**	G3/SH		ALB	Rawlins BLM?	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown
Potentilla hyparctica [*P. nana*] Arctic cinquefoil	**G5**/S1		FRE, SUB	Bridger-Teton NF Shoshone NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Potentilla multisecta [*P. diversifolia* var. *multisecta*] **Featherleaf cinquefoil**	**GNR**/S1		SWE, UIN	Kemmerer BLM Rock Springs BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Potentilla subgorodkovii [*P. uniflora*] One-flower cinquefoil	G5/S2		FRE, PAR, SUB, TET	Bridger-Teton NF Shoshone NF	Widespread/ Edge	More common than previously known	Rare	Moderate	Unknown	Low
Primula egaliksensis Greenland primrose	G4/S1	USFS R2 Sensitive **USFS R4 Sensitive**	PAR, SUB	Bridger-Teton NF Shoshone NF	Disjunct	Very Low	Rare	Moderate	Stable?	Medium
Primula jeffreyi [*Dodecatheon jeffreyi* ssp. *jeffreyi*] **Jeffrey's shootingstar**	G5T3T5/ S1		TET	Grand Teton NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Prosartes hookeri **Hooker's fairy bell**	G5/S2		CRO	Black Hills NF	Disjunct	Low	Rare	Moderate	Unknown	Medium
Pseudognaphalium microcephalum var. *thermale* [*P. thermale; Gnaphalium microcephalum* var. *thermale*] **Hotsprings cudweed**	G5T4Q/S1		PAR, TET	Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Stable	Low
Pyrrocoma carthamoides var. *subsquarrosa* [*Haplopappus carthamoides* var. *subsquarrosus*] **Absaroka largeflower goldenweed**	**G4G5 T3T4**/S2	USFS R2 Sensitive	PAR	Cody BLM Shoshone NF	Regional Endemic/ Core	Low	Uncommon	Moderate	Stable?	Medium
Pyrrocoma crocea* var. *crocea [*Haplopappus croceus*] **Curlyhead goldenweed**	G4?T4?/S2	MBNF-SOLC	CAR	Medicine Bow NF Rawlins BLM	Widespread/ Edge	Low	Uncommon	Moderate	Unknown	Low
Pyrrocoma integrifolia [*Haplopappus integrifolius*] **Manystemmed goldenweed**	**G3G4**/S1	USFS R2 Sensitive	FRE, **JOH**, TET, WAS	Shoshone NF Worland BLM? Yellowstone NP	Regional Endemic/ Edge	Very Low	Unknown	Moderate	Unknown	Medium
Ranunculus aquatilis var. *aquatilis* [*R. aquatilis s.s.*; *R. a.* var. *hispidulus*] **White water crowfoot**	G5/S1		PAR	Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Unknown	Unknown	Unknown
Ranunculus flabellaris **Yellow water crowfoot**	G5/SH		UIN	Kemmerer BLM?	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown

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Ranunculus gelidus [*R. verecundus, R. karelinii*] Timberline buttercup	G5/S1	USFS R2 Sensitive	FRE, PAR, TET	Bridger-Teton NF Shoshone NF	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Rubus arcticus* ssp. *acaulis [*R. acaulis*] **Dwarf raspberry**	G5/S2	USFS R2 Sensitive	ALB?, CAR, JOH, PAR, TET	Bighorn NF Medicine Bow NF? Yellowstone NP	Disjunct	Low	Rare	Moderate	Stable?	Medium
Sabulina macrantha [*Arenaria filiorum; A. rubella* var. *filiorum, Incl. in Minuartia macrantha*] **Thread-branch stitchwort**	**G3**/S1		SUB, TET	Bridger-Teton NF Grand Teton NP	Regional Endemic/ Edge	Very Low	Rare	Moderate	Unknown	Medium
Sagittaria latifolia [*S. l.* var. *latifolia*] Broadleaf arrowhead	G5/S1		GOS		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Salix barrattiana Barratt's willow	G5/S1	USFS R2 Sensitive	PAR	Shoshone NF	Disjunct	Very Low	Rare	Moderate	Stable	Medium
Salix candida **Sageleaf willow**	G5/**S2S3**	USFS R2 Sensitive	ALB, FRE, PAR, SUB, TET	Bridger-Teton NF Medicine Bow NF Natl Elk Refuge Pinedale BLM Shoshone NF Yellowstone NP	Widespread/ Edge	Low	Rare	Moderate	Stable?	Low
Salix myrtillifolia* var. *myrtillifolia [*S. myrtillifolia*] **Blueberry willow**	G5/S1	USFS R2 Sensitive	PAR	Shoshone NF	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Salix serissima Autumn willow	**G5**/S1	USFS R2 Sensitive	ALB	Medicine Bow NF	Disjunct	Very Low	Rare	Moderate	Stable	Medium
Sambucus nigra* ssp. *cerulea [*S. cerulea* var. *cerulea*] Blue elderberry	G5T5/S1?		#NAME?	Bighorn NF? Rock Springs BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Saussurea weberi [Incl. in *S. densa* by some authors] Weber's saw-wort	G2G3/S2	USFS R4 Sensitive	FRE, SUB, TET	Bridger-Teton NF Shoshone NF	Regional Endemic/ Edge	Low	Uncommon	Moderate	Stable?	Medium

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Saxifraga chrysantha [*S. serpyllifolia* var. *chrysantha*, *Hirculus serpyllifolius* ssp. *chrysanthus*] **Goldenbloom saxifrage**	G4/S2		ALB, CAR, FRE, PAR, SUB	Bridger-Teton NF Medicine Bow NF Shoshone NF	Widespread/ Edge	Low	Uncommon	Moderate	Unknown	Low
Scheuchzeria palustris **Rannoch-rush**	G5/S1		TET	Targhee NF Yellowstone NP	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Schoenoplectus heterochaetus [*Scirpus heterochaetus*] Slender bulrush	G5/S1		CAM, CRO, SHE		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Schoenoplectus saximontanus [*Scirpus saximontanus*] Rocky Mountain bulrush	G5/S1		GOS	Casper BLM?	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Schoenoplectus subterminalis [*Scirpus subterminalis*] **Swaying bulrush**	G4G5/S1		TET	Yellowstone NP	Disjunct	Very Low	Rare	Moderate	Stable?	Medium
Scirpus pendulus Rufous bulrush	G5/S1		CON		Widespread/ Edge	Very Low	Very Rare	Moderate	Stable	Low
Scolochloa festucacea **Rivergrass**	G5/S1		**JOH,** PAR	Buffalo BLM Yellowstone NP	Disjunct	Very Low	Rare	Moderate	Moderate Decline?	Medium
Selaginella mutica var. *mutica* **Bluntleaf spikemoss**	G4G5/S1		CAR, LAR, SWE	Ashley NF (FGNRA) Medicine Bow NF	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Selaginella rupestris **Northern spikemoss**	G5/S1		CRO, WES	Black Hills NF	Disjunct	Very Low	Rare	Moderate	Stable?	Medium
Selaginella selaginoides **Club spikemoss**	G5/S1	USFS R2 Sensitive	PAR, SUB, TET	Bridger-Teton NF Pinedale BLM Targhee NF Yellowstone NP	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Selaginella watsonii **Watson's spikemoss**	G4/S1		PAR	Shoshone NF	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Senecio hydrophiloides [*S. foetidus* var. *hydrophiloides*] **Tall groundsel**	**G5**/S1		TET	Grand Teton NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Sesuvium verrucosum **Verrucose seapurslane**	G5/S1?		CAM	Thunder Basin NG?	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Shoshonea pulvinata Shoshonea	**G3**/S2	USFS R2 Sensitive WY BLM Sensitive	FRE, HOT, PAR, Wind River IR	Cody BLM Shoshone NF Worland BLM	Regional Endemic/ Core	Low	Uncommon	Moderate	Stable?	High
Silene douglasii Douglas' campion	G4/S1		LIN	Kemmerer BLM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Silene kingii [Incl. undesc. variety] King's campion	G2G4Q/S2		FRE, HOT, PAR	Cody BLM Shoshone NF	Disjunct	Low	Rare	Moderate	Unknown	Medium
Silene repens [*S. r.* var. *australe*] **Pink campion**	G5/S1		SUB, TET	Bridger-Teton NF	Regional Endemic/ Edge	Very Low	Rare	Moderate	Unknown	Medium
***Silene uralensis* ssp. *uralensis* Nodding catchfly**	**G5TNR/S1**		**SUB, TET**	**Bridger-Teton NF**	**Disjunct**	**Very Low**	**Unknown**	**Moderate**	**Unknown**	**Medium**
Silphium integrifolium var. *laeve* **Wholeleaf rosinweed**	G5T4?/S1		LAR	FE Warren AFB	Disjunct	Very Low	Very Rare	Moderate	Moderate Decline?	Medium
Sisyrinchium idahoense var. *idahoense* Idaho blue-eyed grass	G5T4/S1		TET	Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Sparganium eurycarpum **Broadfruit bur-reed**	G5/S1		CRO, NIO, SHE	Black Hills NF	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Sphaeromeria – see *Artemisia*										
Spiranthes diluvialis **Ute lady's tresses**	G2G3/ S1S2	USFWS Threaten.	CON, GOS, LAR, NIO	Casper BLM	Sparse/ Core?	Low	Rare	Moderate	Moderate Decline?	High
Sporobolus heterolepis Northern dropseed	G5/S1		CRO, WES		Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Stephanomeria fluminea **Teton wirelettuce**	G2/S2		PAR, SUB, TET	Bridger-Teton NF Grand Teton NP Shoshone NF	Local Endemic/ Core	Low	Uncommon	Moderate	Unknown	Very High
Stephanomeria pauciflora **Brownplume wirelettuce**	G5/S1		**LAR**, PLA	Casper BLM	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Symphyotrichum porteri [*Aster porteri*] **Smooth white aster**	G3G4/S1	MBNF-SOLC	ALB, LAR	Medicine Bow NF	Regional Endemic/ Edge	Very Low	Rare	Moderate	Stable?	Medium

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Thelesperma caespitosum [*T. pubescens* var. *caespitosum*, *T. subnudum* var. *caespitosum*, incl. in *T. pubescens* by some authors] **Low greenthread**	G2?/S1	USFS R4 Sensitive WY BLM Sensitive	SWE	Ashley NF (FGNRA) Rock Springs BLM	Regional Endemic/ Core	Very Low	Uncommon	Moderate	Moderate Decline?	Very High
Thelesperma pubescens **Hairy greenthread**	G2/S1	USFS R4 Sensitive WY BLM Sensitive	SWE, UIN	Rock Springs BLM Wasatch-Cache NF	Local Endemic/ Core	Very Low	Uncommon	Moderate	Stable?	Very High
Tonestus pygmaeus [*Haplopappus pygmaeus*] Pygmy goldenweed	G4/S1		ALB, CAR	Medicine Bow NF	Widespread/ Edge	Very Low	Rare	Moderate	Stable?	Low
Torreyochloa pallida var. *fernaldii* [*Puccinellia fernaldii*] Fernald's false mannagrass	G5T4Q/S1		TET	Grand Teton NP	Disjunct	Very Low	Rare	Unknown	Unknown	Medium
Townsendia florifera [*T. florifer*] Showy Townsend daisy	G5/SH		TET	Bridger-Teton NF? Grand Teton NP?	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Unknown
Townsendia microcephala **Smallheaded Townsend daisy**	G1/S1	WY BLM Sensitive	SWE, UIN	Rock Springs BLM	Local Endemic/ Core	Very Low	Rare	Moderate	Stable?	Very High
Tradescantia bracteata Longbract spiderwort	G5/S1		CRO	Black Hills NF?	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Trautvetteria caroliniensis **Western bugbane**	G5/S1		TET	Yellowstone NP	Disjunct	Very Low	Rare	Moderate	Unknown	Medium
Trichophorum pumilum [*Scirpus rollandii*, *S. pumilus*] **Rolland's bulrush**	G5/S1	MBTB-SOLC	ALB, PAR, SUB, TET	Bridger-Teton NF Medicine Bow NF Natl Elk Refuge Pinedale BLM Shoshone NF	Disjunct	Very Low	Rare	High	Stable?	Medium
Trifolium barnebyi [*T. haydenii* var. *barnebyi*] Barneby's clover	G1/S1	WY BLM Sensitive	FRE	Lander BLM	Local Endemic/ Core	Very Low	Uncommon	Moderate	Stable?	Very High
Trillium ovatum* var. *ovatum **Pacific trillium**	G5T5/S2	MBNF-SOLC	CAR	Medicine Bow NF Rawlins BLM?	Disjunct	Low	Rare	Moderate	Unknown	Medium
Triodanis holzingeri **Holzinger's Venus' looking-glass**	G4/S1		GOS, PLA	Casper BLM?	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low

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Species Scientific Common Name	**Heritage Rank**	**Federal Status**	**County**	**Managed Area**	**Range Context**	**# Pops.**	**Abund.**	**Vulnerab.**	**Recent Trends**	**Wyoming Contrib.**
Triodanis leptocarpa **Slimpod Venus' looking-glass**	G5?/S1		CAM, CRO, JOH, SHE	Bighorn NF? Black Hills NF	Widespread/ Edge	Low	Unknown	Moderate	Unknown	Low
Trisetum canescens Tall trisetum	G5/S1		TET	Yellowstone NP	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Triteleia grandiflora [*Brodiaea douglasii*] **Largeflower triteleia**	G4G5/S2	USFS R2 Sensitive	ALB?, LIN, TET	Bridger-Teton NF? Caribou-Targhee NF Grand Teton NP Medicine Bow NF? Yellowstone NP	Widespread/ Edge	Low	Rare	Moderate	Moderate Decline?	Low
Utricularia intermedia **Flatleaf bladderwort**	G5/S1		TET	Bridger-Teton NF Natl Elk Refuge **Yellowstone NP**	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Utricularia ochroleuca **Northern bladderwort**	**G4G5/S2**		**PAR, SUB, TET**	**Pinedale BLM Yellowstone NP**	**Disjunct**	**Low**	**Unknown**	**Moderate**	**Unknown**	**Medium**
Vaccinium myrtillus [*V. myrtillus* var. *oreophilum]* **Whortleberry**	G5T4T5/ S1		ALB, CAR, TET	Medicine Bow NF Yellowstone NP?	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Viola pedatifida Prairie violet	G5/S1		CRO	Black Hills NF Devils Tower NM	Widespread/ Edge	Very Low	Rare	Moderate	Unknown	Low
Viola renifolia [*V. renifolia* var. *brainerdii*] **White violet**	G5T5/S1		CRO, TET	Black Hills NF Bridger-Teton NF Grand Teton NP Targhee NF	Disjunct	Very Low	Unknown	Moderate	Unknown	Medium
Xanthisma coloradense [*Machaeranthera coloradoensis; Haplopappus coloradoensis*] **Colorado tansyaster**	G3/S2	USFS R2 Sensitive	ALB, CAR	Medicine Bow NF Rawlins BLM	Regional Endemic/ Core	Low	Rare	Moderate	Unknown	High
Xerophyllum tenax **Beargrass**	G5/S1		TET	Grand Teton NP JDR Parkway Targhee NF Yellowstone NP	Widespread/ Edge	Very Low	Unknown	Moderate	Unknown	Low
Yermo xanthocephalus Desert yellowhead	G1/S1	USFWS Threaten.	FRE	Lander BLM	Local Endemic/ Core	Very Low	Rare	Moderate	Stable?	Very High

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Background

The first Wyoming plant species of concern list was prepared in 1982, based in large part on the information compiled in Dorn (1977). Since that time, over 700 vascular plant species are or have been tracked as species of concern in Wyoming, reflecting discoveries in the state as represented by floristic surveys of the Rocky Mountain Herbarium, species-specific surveys, taxonomic research, and other changes reflected in revisions to the state flora (Dorn 1988, 1992, 2001, Nelson 2018). Over the years, these updates have been evaluated and incorporated into the Wyoming plant species of concern lists by Robert Lichvar, Hollis Marriott, Walter Fertig and Bonnie Heidel. The 700 species represent over 20% of the current state flora, and most of the species that are no longer tracked were found to be more common than previously known. In turn, the continual compilation and periodic updating has funneled attention on the *de facto* rarest species.

Acknowledgements

Much of the original data for this document comes from specimens deposited at the Rocky Mountain Herbarium. Additional information and suggestions were provided over time by David Anderson, Larry Apple, Melanie Arnett, Darcie Bacon, Frank Blomquist, Bernie Bornong, Janet Britt, Greg Brown, Sabine Mellmann-Brown, Beth Burkhart, Jeff Carroll, Susan Corey, Reed Crook, Jean Daly, Charmaine Delmatier, Robert and Jane Dorn, Katy Duffy, Brian Elliott, Erwin Evert, Donald Farrar, Walt Fertig, Erin Foley, Ben Franklin, Emma Freeland, Jim Glennon, Wendy Haas, Joy Handley, Jill Handwerk, Ron Hartman, Katie Haynes, Don Hazlett, Pat and Noel Holmgren, Kent Houston, Kelly Hughes, Ann Humphrey, George Jones, Marcel Jouseau, Greg Karow, John Kartesz, Dave Scott Kesonie, Andrew King, C. Lynn Kinter, Grace Kostel, Andy Kratz, Clay Kyte, Steve Laster, Ben Legler, Rose Lehman, Claire Leon, Michael Mancuso, Stuart Markow, Hollis Marriott, Rob Massatti, Jerry Mastel, Cheryl Mayer, Daryl Mergen, Scott Mincemoyer, Chelsea Monks, Bob Moseley, Mary Neighbours, B. E. Nelson, Dave Ode, Kevin O'Dea, Jim Ozenberger, Barb Packer, Adrienne Pilmanis, Teresa Prendusi, John Proctor, Deanna Reyher, Kathy Roche, Richard and Bev Scott, Phil Shephard, Carolyn Sieg, Susan Spackman-Punjabi, Mathew Spann, Gerry Steinauer, Amy and Kevin Taylor, Klara Varga, Chelsea Vollmer, Jill Wellborn, Laura Welp, Jennifer Whipple, and Katharine Zacharkevics.

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21. APPENDIX R: U.S. CENSUS BUREAU ALBANY COUNTY, WY QUICKFACTS

U.S. Department of Commerce | Blc

QuickFacts
Albany County, Wyoming

QuickFacts provides statistics for all states and counties, and for cities and towns with a ***population of 5,000 or more***

Table

ALL TOPICS	Albany County, Wyoming
Population estimates, July 1, 2018, (V2018)	**NA**
PEOPLE	
Population	
Population estimates, July 1, 2018, (V2018)	**NA**
Population estimates, July 1, 2017, (V2017)	38,332
Population estimates base, April 1, 2010, (V2018)	NA
Population estimates base, April 1, 2010, (V2017)	36,299
Population, percent change - April 1, 2010 (estimates base) to July 1, 2018, (V2018)	NA
Population, percent change - April 1, 2010 (estimates base) to July 1, 2017, (V2017)	5.6%
Population, Census, April 1, 2010	36,299
Age and Sex	
Persons under 5 years, percent	▲ 4.8%
Persons under 18 years, percent	▲ 16.5%
Persons 65 years and over, percent	▲ 11.2%
Female persons, percent	▲ 47.7%
Race and Hispanic Origin	
White alone, percent	▲ 90.9%
Black or African American alone, percent (a)	▲ 1.9%
American Indian and Alaska Native alone, percent (a)	▲ 1.2%
Asian alone, percent (a)	▲ 3.4%
Native Hawaiian and Other Pacific Islander alone, percent (a)	▲ 0.1%
Two or More Races, percent	▲ 2.5%
Hispanic or Latino, percent (b)	▲ 9.6%
White alone, not Hispanic or Latino, percent	▲ 82.6%
Population Characteristics	
Veterans, 2013-2017	2,231
Foreign born persons, percent, 2013-2017	6.8%
Housing	
Housing units, July 1, 2017, (V2017)	19,304
Owner-occupied housing unit rate, 2013-2017	49.6%
Median value of owner-occupied housing units, 2013-2017	$223,000
Median selected monthly owner costs -with a mortgage, 2013-2017	$1,473
Median selected monthly owner costs -without a mortgage, 2013-2017	$442
Median gross rent, 2013-2017	$748
Building permits, 2017	125
Families & Living Arrangements	
Households, 2013-2017	16,009
Persons per household, 2013-2017	2.23
Living in same house 1 year ago, percent of persons age 1 year+, 2013-2017	89.6%
Language other than English spoken at home, percent of persons age 5 years+, 2013-2017	10.8%
Computer and Internet Use	
Households with a computer, percent, 2013-2017	94.5%
Households with a broadband Internet subscription, percent, 2013-2017	81.0%
Education	
High school graduate or higher, percent of persons age 25 years+, 2013-2017	96.2%
Bachelor's degree or higher, percent of persons age 25 years+, 2013-2017	49.8%
Health	
With a disability, under age 65 years, percent, 2013-2017	7.0%
Persons without health insurance, under age 65 years, percent	▲ 11.7%

https://www.census.gov/quickfacts/fact/table/albanycountywyoming/PST045218 3/21/2019

Economy	
In civilian labor force, total, percent of population age 16 years+, 2013-2017	68.7%
In civilian labor force, female, percent of population age 16 years+, 2013-2017	67.8%
Total accommodation and food services sales, 2012 ($1,000) (c)	79,553
Total health care and social assistance receipts/revenue, 2012 ($1,000) (c)	178,231
Total manufacturers shipments, 2012 ($1,000) (c)	D
Total merchant wholesaler sales, 2012 ($1,000) (c)	132,765
Total retail sales, 2012 ($1,000) (c)	479,554
Total retail sales per capita, 2012 (c)	$12,865
Transportation	
Mean travel time to work (minutes), workers age 16 years+, 2013-2017	12.7
Income & Poverty	
Median household income (in 2017 dollars), 2013-2017	$45,816
Per capita income in past 12 months (in 2017 dollars), 2013-2017	$26,034
Persons in poverty, percent	▲ 19.5%

BUSINESSES

Businesses	
Total employer establishments, 2016	1,041
Total employment, 2016	9,743
Total annual payroll, 2016 ($1,000)	326,707
Total employment, percent change, 2015-2016	-1.5%
Total nonemployer establishments, 2016	2,613
All firms, 2012	3,396
Men-owned firms, 2012	1,465
Women-owned firms, 2012	1,250
Minority-owned firms, 2012	280
Nonminority-owned firms, 2012	2,870
Veteran-owned firms, 2012	229
Nonveteran-owned firms, 2012	2,811

GEOGRAPHY

Geography	
Population per square mile, 2010	8.5
Land area in square miles, 2010	4,273.84
FIPS Code	56001

About datasets used in this table

Value Notes

Estimates are not comparable to other geographic levels due to methodology differences that may exist between different data sources.

Some estimates presented here come from sample data, and thus have sampling errors that may render some apparent differences between geographies statistically indistinguishable. Click the Q left of each row in TABLE view to learn about sampling error.

The vintage year (e.g., V2018) refers to the final year of the series (2010 thru 2018). *Different vintage years of estimates are not comparable.*

Fact Notes

- **(a)** Includes persons reporting only one race
- **(b)** Hispanics may be of any race, so also are included in applicable race categories
- **(c)** Economic Census - Puerto Rico data are not comparable to U.S. Economic Census data

Value Flags

- **-** Either no or too few sample observations were available to compute an estimate, or a ratio of medians cannot be calculated because one or both of the median estimates falls in the interval of an open ended distribution.
- **D** Suppressed to avoid disclosure of confidential information
- **F** Fewer than 25 firms
- **FN** Footnote on this item in place of data
- **NA** Not available
- **S** Suppressed; does not meet publication standards
- **X** Not applicable
- **Z** Value greater than zero but less than half unit of measure shown

QuickFacts data are derived from: Population Estimates, American Community Survey, Census of Population and Housing, Current Population Survey, Small Area Health Insurance Estimates, Sm Poverty Estimates, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits.

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22. APPENDIX S: CEP 2018 TITLE V PERMIT

AIR QUALITY DIVISION
CHAPTER 6, SECTION 3
OPERATING PERMIT

WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION
200 West 17th Street
Cheyenne, Wyoming 82002

DEPARTMENT OF ENVIRONMENTAL QUALITY
WYOMING

PERMIT NO. P0022349

Issue Date: **April 3, 2018**
Effective Date: **April 3, 2018**
Replaces Permit No: **3-3-156-1**

Permit Basis Date: **January 9, 2018**
Expiration Date: **April 3, 2023**

In accordance with the provisions of W.S. §35-11-203 through W.S. §35-11-212 and Chapter 6, Section 3 of the Wyoming Air Quality Standards and Regulations,

University of Wyoming
Heat Plant
Section 34, Township 16 North, Range 73 West
Albany County, Wyoming

is authorized to operate a stationary source of air contaminants consisting of emission units described in this permit. The units described are subject to the terms and conditions specified in this permit. All terms and conditions of the permit are enforceable by the State of Wyoming. All terms and conditions of the permit, except those designated as not federally enforceable, are enforceable by EPA and citizens under the Act. A copy of this permit shall be kept on-site at the above named facility.

Nancy E. Vehr, Administrator
Air Quality Division

Date April 3, 2018

Alan Edwards

Todd Parfitt, Director
Department of Environmental Quality

Date April 3, 2018

WAQSR CHAPTER 6, SECTION 3 OPERATING PERMIT

WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION

TABLE OF CONTENTS

GENERAL INFORMATION

Company Name: University of Wyoming

Facility Name: Heat Plant

IMPACT Facility ID: F000832

Facility Location: Section 34, Township 16 North, Range 73 West, Albany County, Wyoming
(654 North 19th Street, Laramie)

Facility Contact: Forrest Selmer Phone: (307) 766-2077

Mailing Address: 1000 East University Ave., Department 3227

City: Laramie State: WY Zip: 82701

DEQ Air Quality Contact: District 1 Engineer
200 W. 17th Street
Cheyenne, WY 80002
Phone: (307) 777-7391

SIC Code: 4961 NAICS Code: 221330

Description of Process: The facility produces steam, chilled water, and compressed air for heating and cooling the university campus buildings.

Permit Description: Fourth renewal

Permit No. P0022349 Permit Basis Date: 2018.01.09 Page 3

FACILITY SUMMARY

This table may not include any or all insignificant activities at this facility.

COMPANY ID	IMPACT ID	TYPE	DESCRIPTION	CH 6, SEC 2 PERMITS
1	BOL001	EU	E. Keeler D.S. oil/gas boiler (37.5 MMBtu/hr)	MD-150
2	BOL002	EU	IBW VSG-60 coal/oil/gas boiler (73.17 MMBtu/hr)	MD-150
	BAG001	CE	Baghouse	
3	BOL003	EU	IBW VSG-60 coal/oil/gas boiler (73.17 MMBtu/hr)	MD-150
	BAG001	CE	Baghouse	
4	BOL004	EU	IBW VSG-60 coal/oil/gas boiler (73.17 MMBtu/hr)	MD-150
	BAG001	CE	Baghouse	
5	TNK001	EU	Fly Ash Silo (10 ton/hr)	OP-137
	BAG002	CE	Baghouse	
6	LUD001	EU	Fly Ash Silo Loadout	None
7	FUG001	EU	Coal Unloading	None
ENG002	ENG002	EU	Cummins QSK50-G5 NR2 back-up generator engine (2,200 hp)	P0021967
ENG003	ENG003	EU	Cummins QSK50-G5 NR2 back-up generator engine (2,200 hp)	P0021967

The IMPACT ID's in the above table reflect those in the IMPACT Facility Inventory on January 9, 2018.

TOTAL FACILITY ESTIMATED EMISSIONS

For informational purposes only. These emissions are not to be assumed as permit limits.

POLLUTANT	EMISSIONS (TPY)
CRITERIA POLLUTANT EMISSIONS	
Particulate Matter	20
PM_{10} Particulate Matter	20
$PM_{2.5}$ Particulate Matter	20
Sulfur Dioxide (SO_2)	441
Nitrogen Oxides (NO_X)	212
Carbon Monoxide (CO)	90
Volatile Organic Compounds (VOCs)	2
HAZARDOUS AIR POLLUTANT (HAP) EMISSIONS	5.4
GREENHOUSE GAS EMISSIONS (CO_2e)	141,574

Emission estimates are from information provided in the operating permit application.

FACILITY-SPECIFIC PERMIT CONDITIONS

Facility-Wide Permit Conditions

(F1) SULFUR DIOXIDE EMISSIONS INVENTORY [WAQSR Ch 14, Sec 3]
The permittee shall comply with the requirements of WAQSR Ch 14, Sec 3, including estimating SO_2 emissions in accordance with Ch 14 Sec 3(b), and adjusting estimates in accordance with Ch 14 Sec 3(c), if necessary.

Source-Specific Permit Conditions

(F2) VISIBLE EMISSIONS [WAQSR Ch 3, Sec 2]
(a) Visible emissions of particulate matter from each boiler (BOL001-BOL004) shall not exceed 20 percent opacity, except that 40 percity opacity shall be allowed for not more than two minutes in any hour.
(b) Visible emissions from each back-up generator engine (ENG002 and ENG003) shall not exceed 30 percent opacity except for periods not exceeding ten consecutive seconds.
(c) Visible emissions of any contaminant discharged into the atmosphere from any other single emission source shall not exhibit greater than 20 percent opacity except for one period or periods aggregating not more than six minutes in any one hour of not more than 40 percent opacity.

(F3) COAL AND FUEL OIL REQUIREMENTS [WAQSR Ch 6, Sec 2 Permit MD-150]
(a) Coal consumption for the IBW boilers (BOL002-BOL004) shall not exceed 36,000 tons per year. The coal sulfur content shall not exceed 0.7 percent.
(b) Fuel oil consumption for all four boilers (BOL001-BOL004) shall not exceed 50,000 gallons per year. Fuel oil sulfur content shall not exceed 0.45 percent.

(F4) BOILER EMISSION LIMITATIONS [WAQSR Ch 6, Sec 2 Permit MD-150]
(a) The permittee may not operate more than three of the boilers (BOL001-BOL004) simultaneously.
(b) During the operation of any combination of the boilers, emission rates shall not exceed the emission rates in Table I.

Table I: Particulate, SO_2, NO_X, and CO Emission Limits

Pollutant	lb/MMBtu	lb/hr	TPY
Particulate (filterable)	0.05	11.0	18.9
SO_2		322.4	441.0
NO_X	0.7	153.7	210.2
CO		65.8	90.0

(F5) FLY ASH SILO EMISSION LIMITATION [WAQSR Ch 6, Sec 2 Permit OP-137]
Particulate emissions from the fly ash silo (TNK001) shall not exceed 0.2 lb/hr.

(F6) ENGINE REQUIREMENTS [WAQSR Ch 6, Sec 2 Waiver P0021967; Ch 6, Sec 3(h)(i)(I)]
Each back-up generator engine (ENG002 and ENG003) shall be:
(a) U.S. EPA Tier 2 certified;
(b) Limited to 100 hours of annual non-emergency operation. The permittee shall operate and maintain a non-resettable hour meter on each engine to demonstrate compliance with this limit; and
(c) Maintained according to manufacturer's or supplier's recommended maintenance.

(F7) ENGINE REPLACEMENT [WAQSR Ch 6, Sec 2; Ch 6, Sec 3(h)(i)(I)]
(a) Permanent replacement of an engine must be evaluated by the Division under WAQSR Ch 6, Sec 2 prior to such replacement to determine the appropriate permitting action and evaluate the need for additional requirements resulting from the permanent replacement.

(b) Should an engine break down or require an overhaul, the permittee may bring on site and operate a temporary replacement engine until repairs are made. The temporary replacement unit shall be identical or similar to the unit replaced, with emission levels at or below those of the unit replaced. The permittee shall notify the Division in writing of such temporary replacement within five working days and include the following:

(i) The startup date of the temporary replacement unit; and

(ii) A statement regarding the applicability of any New Source Performance Standards (NSPS) in 40 CFR 60; any National Emission Standards for Hazardous Air Pollutants (NESHAPS) in 40 CFR 63; and Compliance Assurance Monitoring (CAM) in WAQSR Ch 7, Sec 3 for the temporary replacement unit.

Testing and Monitoring Requirements

(F8) EMISSIONS TESTING [W.S. 35-11-110]

(a) The Division reserves the right to require additional testing as provided under condition G1 of this permit. The Division shall specify the necessary test method(s) and procedure(s) prior to the test, which may include the following test methods found at 40 CFR 60, Appendix A:

(i) For visible emissions, Method 9.

(ii) For particulate emissions, Methods 1-4 and 5.

(iii) For NO_X emissions, Methods 1-4 and 7 or 7E.

(iv) For CO emissions, Methods 1-4 and 10.

(v) For SO_2 emissions, Methods 1-4 and 6 or 6C.

(vi) For alternative test methods, or methods used for other pollutants, the approval of the Administrator must be obtained prior to using the test method to measure emissions.

(b) Unless otherwise specified, testing shall be conducted in accordance with WAQSR Ch 5, Sec 2(h).

(F9) BOILER EMISSIONS TESTING [WAQSR Ch 6, Sec 3(h)(i)(C)(I)]

The permittee shall measure emissions from the boilers (BOL001-BOL004) once every five years for comparison to the emission limits specified in condition F4.

(a) For the IBW boilers (BOL002-BOL004), the permittee shall conduct particulate, SO_2, NO_X, and CO emissions testing. Testing shall occur during operation of at least two of the IBW boilers, or during the anticipated peak seasonal load period. If a boiler was not tested in the previous test, it shall be included in the next test. The IBW boilers shall consume coal for the duration of the test.

(b) For the E. Keeler boiler (BOL001), the permittee shall conduct testing based on the following:

(i) The boiler shall be one of the boilers tested in the first performance test conducted following the issuance of this permit, and shall be tested while operating at full load.

(ii) If the boiler consumed fuel oil for over 14 days (336 hours) during any year from the previous emissions test, the permittee shall conduct particulate, SO_2, NO_X, and CO emissions testing with the boiler consuming fuel oil for the test. If the boiler did not burn fuel oil for over 14 days (336 hours), the permittee shall conduct NO_X and CO emissions testing with the boiler consuming natural gas for the test.

(c) Testing required by paragraphs (a) and (b) of this condition shall be done in within seven days of eachother and under similar load conditions unless an extension is granted by the Division.

(d) Emissions shall be measured using the EPA reference methods described in condition F8.

(F10) BOILER CAM [WAQSR Ch 6, Sec 3(h)(i)(C)(I)]

For particulate emissions from the baghouse controlled boilers (BOL002-BOL004), the permittee shall adhere to the compliance assurance monitoring (CAM) plan, attached as Appendix A of this permit, and shall conduct monitoring as follows during active operation of each emission source:

(a) The permittee shall conduct, at minimum once daily, Method 22-like visual observations of each unit listed above, in accordance with the CAM plan, to determine the presence of visible emissions. The visual observations shall be conducted by a person who is educated on the general procedures for determining the presence of visible emissions but not necessarily certified to perform Method 9 observations.

(b) The baghouse shall be maintained as described in the CAM plan.

(c) An excursion, which is considered observation of any visible emissions from any of these units, shall prompt immediate inspection and, if appropriate, corrective action as described in the CAM plan.

(d) The permittee shall follow all other applicable requirements under conditions CAM-1 through CAM-4 of this permit.

(F11) COAL AND FUEL OIL MONITORING [WAQSR Ch 6, Sec 3(h)(i)(C)(I)]

(a) The permittee shall monitor the monthly consumption of coal and fuel oil for comparison with the consumption limits in condition F3.

(b) The permittee shall acquire at least one coal analysis per week to determine sulfur content of the coal for comparison with the sulfur content limit in condition F3(a).

(c) The permittee shall acquire analyses of all fuel oil delivered to the facility to determine the sulfur content of the fuel oil for comparison with the sulfur content limit in condition F3(b).

(F12) ADDITIONAL VISIBLE MONITORING [WAQSR Ch 6, Sec 3(h)(i)(C)(I)]

(a) For visible emissions from the E. Keeler boiler (BOL001), the permittee shall monitor the fuel being sonsumed and either:

(i) Ensure natural gas is the sole fuel source for this unit; or

(ii) Perform daily Method 9 observations in the event fuel oil is burned for more than seven days (168 hours) during any operating period when natural gas is not consumed in the boiler.

(A) The Method 9 observations shall begin no later than the first day of the seven days (168 hours) time period has been exceeded, and shall occur every day during the operating period that the boiler is using fuel oil.

(B) The observations shall be performed by a qualified observer certified in accordance with Section 3.1 of Method 9 and shall follow the requirements and procedures of Method 9.

(b) For visible emissions from the fly ash silo (TNK001), the permittee shall conduct, at minimum, weekly Method 22-like visual observations to determine maintenance needs and/or corrective action.

(c) The permittee shall conduct observations of visible emissions from the back-up generator engines (ENG002 and ENG003) during periodic availability assurance tests of these sources, at least semi-annually, to identify maintenance needs.

(d) The visual observations conducted in paragraphs (b) and (c) of this condition shall be conducted by a person who is educated on the general procedures for determining the presence of visible emissions but not necessarily certified to perform Method 9 observations.

(e) Observation of excess visible emissions from any source listed above shall prompt immediate inspection and, if necessary, corrective action.

(F13) OPERATING HOURS MONITORING [WAQSR Ch 6, Sec 3(h)(i)(C)(I)]

The permittee shall monitor the operating hours of each back-up generator engine (ENG002 and ENG003) on at least a monthly basis for comparison with the operating hours limit in condition F6.

Recordkeeping Requirements

(F14) SULFUR DIOXIDE EMISSIONS INVENTORY RECORDS [WAQSR Ch 14, Sec 3(b)]

(a) The permittee shall maintain all records used in the calculation of SO_2 emissions for the inventory required by condition F1, including but not limited to the following:

(i) Amount of fuel consumed;

(ii) Percent sulfur content of fuel and how the content was determined;

(iii) Quantity of product produced;

(iv) Emissions monitoring data;

(v) Operating data; and

(vi) How the emissions are calculated, including monitoring/estimation methodology with a demonstration that the selected methodology is acceptable under Ch 14, Sec 3.

(b) The permittee shall maintain records of any physical changes to facility operations or equipment, or any other changes (e.g. raw material or feed) that may affect emissions projections of SO_2.

(c) The permittee shall retain all records and support information for compliance with this condition and with the reporting requirements of condition F17 at the facility, for a period of at least ten (10) years from the date of establishment, or if the record was the basis for an adjustment to the milestone, five years after the date of an implementation plan revision, whichever is longer.

(F15) TESTING AND MONITORING RECORDS
[WAQSR Ch 6, Sec 3(h)(i)(C)(II); Ch 7, Sec 3(i)(ii); Ch 6, Sec 2 Permit MD-150 and Waiver P0021967]

(a) For any testing or monitoring performed under conditions F8, F9, and F12(b) and (c), other than Method 9, the permittee shall record, as applicable, the following:
   (i) The date, place, and time of sampling, measurements, or observations;
   (ii) The date(s) analyses were performed;
   (iii) The company or entity that performed the analyses or observations;
   (iv) The analytical techniques or methods used;
   (v) The results of such analyses or observations; and
   (vi) The operating conditions and parameters as they existed at the time of testing, monitoring, or observation.

(b) For any Method 9 observations required by the Division under condition F8 or F12(a), the permittee shall keep field records in accordance with Section 2.2 of Method 9.

(c) The permittee shall maintain records of the date(s) and duration of time that the E. Keeler boiler (BOL001) consumed fuel oil.

(d) For the CAM monitoring required under condition F10 the permittee shall:
   (i) Maintain records of monitoring data, monitor performance data, any written quality improvement plan required pursuant to WAQSR Ch 7, Sec 3(h), any activities undertaken to implement a QIP, and other supporting information required to be maintained under WAQSR Ch 7, Sec 3 and as specified in the CAM plan attached as Appendix A of this permit.
   (ii) Record the date, time, and duration of any excursions as well as the CAM indicator value(s) during each excursion.
   (iii) Maintain records of the indicator evaluation required under condition F10(c).

(e) For the monitoring required by condition F11, the permittee shall maintain records of the coal and fuel oil sulfur content analyses, and the monthly and calendar year-to-date totals of coal and fuel oil consumption.

(f) For the monitoring required by condition F13, the permittee shall record the operating hours of each back-up generator engine.

(g) The permittee shall retain these records on-site at the facility for a period of at least five years from the date the records are generated.

(F16) MAINTENANCE AND CERTIFICATION RECORDS
[WAQSR Ch 6, Sec 3(h)(i)(C)(II); Ch 6, Sec 2 Waiver P0021967]

(a) The permittee shall maintain records of all maintenance activities for the boiler baghouse (BAG001) and the generators (ENG002 and ENG003), which shall include:
   (i) The maintenance activity performed;
   (ii) The date and place the activity was performed;
   (iii) The company and individual(s) that performed the activity;
   (iv) The purpose of the activity; and
   (v) An explanation for any deviation from the manufacturer's or supplier's recommended maintenance or the CAM plan, as applicable.
   (vi) The permittee shall retain these records on-site at the facility, for a period of at least five years from the date the records are generated.

(b) A record demonstrating that each back-up generator engine (ENG002 and ENG003) is EPA Tier 2 certified shall be maintained for the life of the engine.

Reporting Requirements

(F17) SULFUR DIOXIDE EMISSIONS INVENTORY REPORTS [WAQSR Ch 14, Sec 3(b) and (c)]

(a) The permittee shall report calendar year SO_2 emissions by April 15th of the following year. The inventory shall be submitted in the format specified by the Division.

(b) Emissions from startup, shutdown, and upset conditions shall be included in the inventory.

(c) If the permittee uses a different emission monitoring or calculation method than was used to report SO_2 emissions in 2006, the permittee shall adjust reported SO_2 emissions to be comparable to the emission monitoring or calculation method that was used in 2006. The calculations that are used to make this adjustment shall be included with the annual emission report.

(d) The annual reports shall reference this permit condition (F17) and shall be submitted in accordance with condition G4 of this permit.

(F18) NOTIFICATION REQUIREMENTS [WAQSR Ch 6, Sec 3(h)(i)(C)(III)]

(a) Notification of the test date for the testing required by condition F9 shall be provided to the Division at least 15 days prior to testing.

(b) Upon shutdown and removal of an engine from the facility, written notification is required within 15 days of removal. Such notification shall be submitted on a complete Engine Installation/Removal form. The form can be downloaded from the Air Quality Division website http://deq.wyoming.gov/aqd/new-source-review/ or obtained from the Air Quality Division.

(c) Notifications may be provided electronically through the Division's IMPACT system (https://airimpact.wyo.gov), or in writing to the DEQ Air Quality Contact listed on page 3 of this permit.

(F19) TEST REPORTS [WAQSR Ch 6, Sec 3(h)(i)(C)(III)]

(a) The permittee shall report the results of any emissions tests performed under conditions F8 and F9, within 45 days of completing the tests. The reports shall include the information indicated in condition F15(a).

(b) The reports shall reference this permit condition (F19) and be submitted to the Division in accordance with condition G4.

(F20) MONITORING REPORTS [WAQSR Ch 6, Sec 3(h)(i)(C)(III)]

(a) The following shall be reported to the Division for each semiannual reporting period from January 1 through June 30, and from July 1 through December 31, within 31 days of the end of each period (by July 31 and January 31, respectively, each year):

(i) The calendar year-to-date operating hours for each back-up generator engine (ENG002 and ENG003).

(ii) Summary results of the of the coal and fuel oil consumption and sulfur content monitoring required under condition F11, including the calendar year-to-date totals of coal and fuel oil consumption.

(iii) Summary results of the visible emissions monitoring required under condition F12. If the E. Keeler boiler (BOL001) fired only natural gas for the duration of the reporting period, this shall be stated in the report.

(iv) Results of the CAM monitoring required under condition F10 for the IBW boilers (BOL002-BOL004), which shall include the following:

(A) Summary information on the number, duration, and cause of excursions, as applicable, and the corrective actions taken. If no excursions occurred during the reporting period, this shall be noted in the report; and

(B) A description of the action taken to implement a QIP (if required) during the reporting period as specified in Ch 7, Sec 3 (h). Upon completion of a QIP, the permittee shall include in the next summary report documentation that the implementation of the plan has reduced the likelihood of similar excursions.

(b) All instances of deviations from the conditions of this permit must be clearly identified in each report.

(c) The reports shall reference this permit condition (F20), and be submitted to the Division in accordance with condition G4.

(F21) GREENHOUSE GAS REPORTS [W.S. 35-11-110]

The permittee shall submit to the Division a summary of any report(s) required to be submitted to the EPA under 40 CFR 98.

(a) The reports shall be submitted to the Division within 60 days of submission to EPA, in a format as specified by the Division.

(b) The reports shall be submitted in accordance with condition G4(a) of this permit, to the attention of the Division's Emission Inventory Program.

(F22) REPORTING EXCESS EMISSIONS & DEVIATIONS FROM PERMIT REQUIREMENTS
[WAQSR Ch 6, Sec 3(h)(i)(C)(III)]

(a) General reporting requirements are described under the General Conditions of this permit. The Division reserves the right to require reports as provided under condition G1 of this permit.

(b) Emissions which exceed the limits specified in this permit and which are not reported under a different condition of this permit shall be reported annually with the emission inventory unless specifically superseded by condition G17, condition G19, or other condition(s) of this permit. The probable cause of such exceedance, the duration of the exceedance, the magnitude of the exceedance, and any corrective actions or preventative measures taken shall be included in this annual report. For sources and pollutants which are not continuously monitored, if at any time emissions exceed the limits specified in this permit by 100 percent, or if a single episode of emission limit exceedance spans a period of 24 hours or more, such exceedance shall be reported to the Division within one working day of the exceedance. (Excess emissions due to an emergency shall be reported as specified in condition G17. Excess emissions due to unavoidable equipment malfunction shall be reported as specified in condition G19.)

(c) Any other deviation from the conditions of this permit shall be reported to the Division in writing or electronically through the Division's IMPACT system (https://airimpact.wyo.gov), within 30 days of the deviation or discovery of the deviation.

WAQSR CHAPTER 5, SECTION 2 NEW SOURCE PERFORMANCE STANDARDS (NSPS)

40 CFR 60 SUBPART IIII REQUIREMENTS
FOR STATIONARY COMPRESSION IGINITION INTERNAL COMBUSTION ENGINES

SUBPART IIII REQUIREMENTS

[40 CFR 60 Subparts A and IIII; WAQSR Ch 5, Sec 2 and Ch 6, Sec 2 Waiver P0021967]
The permittee shall meet all applicable requirements of 40 CFR 60 Subparts A and IIII and WAQSR Ch 5, Sec 2, as, they apply to stationary compression ignition (CI) internal combustion engines. (As required by condition F7(b), if an engine is replaced or reconstructed, subpart applicability will need to be reevaluated and a statement regarding applicability submitted to the Division.) For the purposes of this subpart, the date that construction commences is the date the engine is ordered by the owner or operator. An affected facility is defined at §60.4200.

The back-up generator engines (ENG002 and ENG003), must met the requirements of Subpart ZZZZ by meeting the requirements of 40 CFR 60, subpart IIII.

The subparts are available from the Division upon request, or in the most recent Code of Federal Regulations at http://www.gpo.gov/fdsys/search/home.action, with updates in the Federal Register available at the same webpage.

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WAQSR CHAPTER 5, SECTION 3 NATIONAL EMISSIONS STANDARDS FOR HAZARDOUS AIR POLLUTANTS (NESHAPS)

40 CFR 63 SUBPART ZZZZ REQUIREMENTS
FOR STATIONARY RECIPROCATING INTERNAL COMBUSTION ENGINES

SUBPART ZZZZ REQUIREMENTS
[40 CFR 63 Subparts A and ZZZZ; WAQSR Ch 5, Sec 3; Ch 6, Sec 2 Waiver P0021967]

The permittee shall meet all requirements of 40 CFR 63 Subparts A and ZZZZ and WAQSR Ch 5, Sec 3, as they apply to each affected source as indicated in §63.6590(a). An affected source is any existing, new, or reconstructed stationary RICE located at a major or area source of HAP emissions, excluding stationary RICE being tested at a stationary RICE test cell/stand. (As required by condition F7(b), if an engine is replaced or reconstructed, subpart applicability will need to be re-evaluated and a statement regarding applicability submitted to the Division.) This facility is currently identified as an area source of HAP emissions. Affected sources at this facility include the back-up generator engines (ENG002 and ENG003).

40 CFR 63 SUBPART JJJJJJ REQUIREMENTS
FOR INDUSTRIAL, COMMERCIAL, AND INSTITUTIONAL BOILERS AREA SOURCES

SUBPART JJJJJJ REQUIREMENTS [40 CFR 63 Subparts A and JJJJJJ; and WAQSR Ch 5, Sec 3]

The permittee shall meet all requirements of 40 CFR 63 Subparts A and JJJJJJ and WAQSR Chapter 5, Section 3 as they apply to any existing, new, or reconstructed industrial, commercial, and institutional boiler as identified in §63.11194 (with the exceptions defined in §63.11195), within a subcategory (coal, biomass, oil), as listed in §63.11200 and defined in §63.11237, located at an area source. Affected sources at this facility include the E. Keeler boiler (BOL001) and the three IBW boilers (BOL002 – BOL004).

The subparts are available from the Division upon request, or in the most recent Code of Federal Regulations at http://www.gpo.gov/fdsys/search/home.action, with updates in the Federal Register available at the same webpage.

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WAQSR CHAPTER 7, SECTION 3

COMPLIANCE ASSURANCE MONITORING (CAM) REQUIREMENTS

WAQSR Ch 7, Sec 3 is available at http://soswy.state.wy.us/Rules/ or from the Division upon request.

(CAM-1) COMPLIANCE ASSURANCE MONITORING REQUIREMENTS [WAQSR Ch 7, Sec 3(b) and (c)]

The permittee shall follow the CAM plan attached as Appendix A of this permit and meet all CAM requirements of WAQSR Ch 7, Sec 3 as they apply to the units identified in condition F10. All CAM requirements in this permit apply upon permit issuance. Compliance with the source specific monitoring, recordkeeping, and reporting requirements of this permit meets the monitoring, recordkeeping, and reporting requirements of WAQSR Ch 7, Sec 3, except for additional requirements specified under conditions CAM-2 through CAM-4.

(CAM-2) OPERATION OF APPROVED MONITORING [WAQSR Ch 7, Sec 3(g)]

(a) At all times, the permittee shall maintain the monitoring under this section, including but not limited to, maintaining necessary parts for routine repairs of the monitoring equipment.

(b) Except for monitoring malfunctions, associated repairs, and required quality assurance or control activities, the permittee shall conduct all monitoring in continuous operation (or at all required intervals) at all times that the pollutant specific emissions unit is operating.

(c) Upon detecting an excursion, the permittee shall restore operation of the pollutant-specific emission unit to its normal or usual manner of operation as expeditiously as practicable in accordance with good air pollution control practices. The response shall include minimizing the period of any start-up, shutdown or malfunction and taking any corrective actions to restore normal operation and prevent the likely recurrence of the cause of an excursion.

(d) If the permittee identifies a failure to achieve compliance with an emission limit for which the monitoring did not provide an indication of an excursion while providing valid data, or the results of compliance or performance testing documents a need to modify the existing indicator ranges, the permittee shall promptly notify the Division and, if necessary, submit a proposed modification to this permit to address the necessary monitoring changes.

(CAM-3) QUALITY IMPROVEMENT PLAN (QIP) REQUIREMENTS [WAQSR Ch 7, Sec 3(h)]

(a) If the Division or the EPA Administrator determines, based on available information, that the permittee has used unacceptable procedures in response to an excursion or exceedance, the permittee may be required to develop and implement a Quality Improvement Plan (QIP).

(b) If required, the permittee shall maintain a written Quality Improvement Plan (QIP) and have it available for inspection.

(c) The plan shall include procedures for conducting one or more of the following:

(i) Improved preventative maintenance practices.
(ii) Process operation changes.
(iii) Appropriate improvements to control methods.
(iv) Other steps appropriate to correct control.
(v) More frequent or improved monitoring (in conjunction with (i) - (iv) above).

(d) If a QIP is required, the permittee shall develop and implement a QIP as expeditiously as practicable and shall notify the Division if the period for completing the QIP exceeds 180 days from the date on which the need to implement the QIP was determined.

(e) Following implementation of a QIP, upon any subsequent determination under paragraph (a) above, the Division may require the permittee to make reasonable changes to the QIP if the QIP failed to address the cause of control device problems, or failed to provide adequate procedures for correcting control device problems as expeditiously as practicable.

(f) Implementation of a QIP shall not excuse the permittee from compliance with any existing emission limit(s) or any existing monitoring, testing, reporting, or recordkeeping requirements that may be applicable to the facility.

(CAM-4) SAVINGS PROVISIONS [WAQSR Ch 7, Sec 3(j)]

Nothing in the CAM regulations shall excuse the permittee from compliance with any existing emission limit or standard, or any existing monitoring, testing, reporting or recordkeeping requirement that may be applicable to the facility.

COMPLIANCE CERTIFICATION AND SCHEDULE

Compliance Certification [WAQSR Ch 6, Sec 3(h)(iii)(E)]

(C1) (a) The permittee shall submit by January 31 each year a certification addressing compliance with the requirements of this permit. The certification shall be submitted as a stand-alone document separate from any monitoring reports required under this permit.

(b) (i) For the sulfur dioxide emissions inventory, the permittee shall assess compliance with condition F1 by reviewing records kept in accordance with condition F14 and verifying reports were submitted in accordance with condition F17.

(ii) For visible emissions from the boilers (BOL001-BOL004), the permittee shall assess compliance with condition F2(a) by conducting the monitoring required by conditions F10(a) and F12(a).

(iii) For visible emissions from the fly ash silo (TNK001) and the back-up generator engines (ENG002 and ENG003), the permittee shall assess compliance with conditions F2(b) and F2(c) by conducting the monitoring required by condition F12(b) and (c).

(iv) For the coal and fuel oil requriements, the permittee shall assess compliance with condition F3 by conducting the monitoring required by condition F11.

(v) For PM, NO_X, CO, and SO_2 emissions from the boilers (BOL001-BOL004), the permittee shall assess compliance with condition F4(b) by conducting the testing and monitoring required by conditions F9 and F10. The permittee shall also certify that the boilers were operated in accordance with condition F4(a).

(vi) For engine certification and operational requirements, the permittee shall assess compliance with conditions F6(a) and (c) by reviewing records kept in accordance with condition F16.

(vii) For engine operational hour restrictions, the permittee shall assess compliance with condition F6(b) by conducting the monitoring required by condition F13.

(viii) For greenhouse gas reporting, the permittee shall assess compliance with condition F21 by verifying that reports were submitted in accordance with condition F21(a) and (b).

(ix) For any engine subject to 40 CFR 60 Subpart IIII, the permittee shall assess compliance with Subpart IIII by conducting any applicable testing and monitoring required by §§60.4209, 60.4211, 60.4212, and 60.4213, and by reviewing the records required by §§60.4211 and 60.4214.

(x) For the reciprocating internal combustion engines, the permittee shall assess compliance with 40 CFR 63 Subpart ZZZZ by conducting any applicable testing and monitoring required by §§63.6610 through 63.6640 and by reviewing the records required by §§63.6655 and 63.6665.

(xi) The permittee shall assess compliance with 40 CFR 63 Subpart JJJJJJ by conducting any applicable compliance demonstrations and monitoring required by §§63.11201 through 63.11224, and by reviewing the records required by §63.11225.

(c) The compliance certification shall include:

(i) The permit condition or applicable requirement that is the basis of the certification;
(ii) The current compliance status;
(iii) Whether compliance was continuous or intermittent; and
(iv) The methods used for determining compliance.

(d) For any permit conditions or applicable requirements for which the source is not in compliance, the permittee shall submit with the compliance certification a proposed compliance plan and schedule for Division approval.

(e) The compliance certification shall be submitted to the Division in accordance with condition G4 of this permit and to the Assistant Regional Administrator, Office of Enforcement, Compliance, and Environmental Justice (8ENF-T), U.S. EPA - Region VIII, 1595 Wynkoop Street, Denver, CO 80202-1129.

(f) Determinations of compliance or violations of this permit are not restricted to the monitoring requirements listed in paragraph (b) of this condition; other credible evidence may be used.

Compliance Schedule [WAQSR Ch 6, Sec 3(h)(iii)(C) and (D)]

(C2) The permittee shall continue to comply with the applicable requirements with which the permittee has certified that it is already in compliance.

(C3) The permittee shall comply in a timely manner with applicable requirements that become effective during the term of this permit.

GENERAL PERMIT CONDITIONS

Powers of the Administrator: [W.S. 35-11-110]

(G1) (a) The Administrator may require the owner or operator of any point source to complete plans and specifications for any application for a permit required by the Wyoming Environmental Quality Act or regulations made pursuant thereto and require the submission of such reports regarding actual or potential violations of the Wyoming Environmental Quality Act or regulations thereunder.

(b) The Administrator may require the owner or operator of any point source to establish and maintain records; make reports; install, use and maintain monitoring equipment or methods; sample emissions, or provide such other information as may be reasonably required and specified.

Permit Renewal and Expiration: [WAQSR Ch 6, Sec 3(c)(i)(C), (d)(ii), (d)(iv)(B), and (h)(i)(B)] [W.S. 35-11-206(f)]

(G2) This permit is issued for a fixed term of five years. Permit expiration terminates the permittee's right to operate unless a timely and complete renewal application is submitted at least six months prior to the date of permit expiration. If the permittee submits a timely and complete application for renewal, the permittee's failure to have an operating permit is not a violation of WAQSR Chapter 6, Section 3 until the Division takes final action on the renewal application. This protection shall cease to apply after a completeness determination if the applicant fails to submit by the deadline specified in writing by the Division any additional information identified as being needed to process the application.

Duty to Supplement: [WAQSR Ch 6, Sec 3(c)(iii)]

(G3) The permittee, upon becoming aware that any relevant facts were omitted or incorrect information was submitted in the permit application, shall promptly submit such supplementary facts or corrected information. The permittee shall also provide additional information as necessary to address any requirements that become applicable to the facility after this permit is issued.

Submissions: [WAQSR Ch 6, Sec 3(c)(iv)] [W.S. 35-11-206(c)]

(G4) Any application form, report, or certification submitted shall be certified as being true, accurate, and complete by a responsible official.

(a) Submissions to the Division including reports, certifications, and emission inventories required under this permit shall be submitted either:

(i) Electronically through the Division's IMPACT system (https://airimpact.wyo.gov); or

(ii) As separate, stand-alone documents sent to:

Administrator, Air Quality Division
Department of Environmental Quality
200 West 17th Street
Cheyenne, Wyoming 82002

(b) Submissions to EPA:

(i) Each certification required under condition C1 of this permit shall also be sent to:

Assistant Regional Administrator
Office of Enforcement, Compliance, and Environmental Justice (8ENF-T)
U.S. EPA - Region VIII
1595 Wynkoop Street
Denver, CO 80202-1129.

(ii) All other required submissions to EPA shall be sent to:

Office of Partnerships and Regulatory Assistance
Air and Radiation Program (8P-AR)
U.S. EPA - Region VIII
1595 Wynkoop Street
Denver, CO 80202-1129

Changes for Which No Permit Revision Is Required: [WAQSR Ch 6, Sec 3(d)(iii)]

(G5) The permittee may change operations without a permit revision provided that:

- (a) The change is not a modification under any provision of Title I of the Clean Air Act;
- (b) The change has met the requirements of Chapter 6, Section 2 of the WAQSR and is not a modification under Chapter 5, Section 2 or Chapter 6, Section 4 of the WAQSR and the changes do not exceed the emissions allowed under the permit (whether expressed therein as a rate of emissions or in terms of total emissions); and
- (c) The permittee provides EPA and the Division with written notification at least 14 days in advance of the proposed change. The permittee, EPA, and the Division shall attach such notice to their copy of the relevant permit. For each such change, the written notification required shall include a brief description of the change within the permitted facility, the date on which the change will occur, any change in emissions, and any permit term or condition that is no longer applicable as a result of the change. The permit shield, if one exists for this permit, shall not apply to any such change made.

Transfer of Ownership or Operation: [WAQSR Ch 6, Sec 3(d)(v)(A)(IV)]

(G6) A change in ownership or operational control of this facility is treated as an administrative permit amendment if no other change in this permit is necessary and provided that a written agreement containing a specific date for transfer of permit responsibility, coverage, and liability between the current and new permittee has been submitted to the Division.

Reopening for Cause: [WAQSR Ch 6, Sec 3(d)(vii)] [W.S. 35-11-206(f)(ii) and (iv)]

(G7) The Division will reopen and revise this permit as necessary to remedy deficiencies in the following circumstances:

- (a) Additional applicable requirements under the Clean Air Act or the WAQSR that become applicable to this source if the remaining permit term is three or more years. Such reopening shall be completed not later than 18 months after promulgation of the applicable requirement. No reopening is required if the effective date of the requirement is later than the date on which the permit is due to expire, unless the original permit or any of its terms and conditions have been extended.
- (b) Additional requirements (including excess emissions requirements) become applicable to an affected source under the acid rain program. Upon approval by EPA, excess emissions offset plans shall be deemed to be incorporated into the permit.
- (c) The Division or EPA determines that the permit contains a material mistake or that inaccurate statements were made in establishing the emissions standards or other terms or conditions of the permit.
- (d) The Division or EPA determines that the permit must be revised or revoked to assure compliance with applicable requirements.

Annual Fee Payment: [WAQSR Ch 6, Sec 3(f)(i), (ii), and (vi)] [W.S. 35-11-211]

(G8) The permittee shall, as a condition of continued operations, submit an annual fee to the Division as established in Chapter 6, Section 3 (f) of the WAQSR. The Division shall give written notice of the amount of fee to be assessed and the basis for such fee assessment annually. The assessed fee is due on receipt of the notice unless the fee assessment is appealed pursuant to W.S. 35-11-211(d). If any part of the fee assessment is not appealed it shall be paid to the Division on receipt of the written notice. Any remaining fee which may be due after completion of the appeal is immediately due and payable upon issuance of the Council's decision. Failure to pay fees owed the Division is a violation of Chapter 6, Section 3 (f) and W.S. 35-11-203 and may be cause for the revocation of this permit.

Annual Emissions Inventories: [WAQSR Ch 6, Sec 3(f)(v)(G)]

(G9) The permittee shall submit an annual emission inventory for this facility to the Division for fee assessment and compliance determinations within 60 days following the end of the calendar year. The emissions inventory shall be in a format specified by the Division and be submitted in accordance with condition G4(a) of this permit.

Severability Clause: [WAQSR Ch 6, Sec 3(h)(i)(E)]

(G10) The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

Compliance: [WAQSR Ch 6, Sec 3(h)(i)(F)(I) and (II)] [W.S. 35-11-203(b)]

(G11) The permittee must comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Clean Air Act, Article 2 of the Wyoming Environmental Quality Act, and the WAQSR and is grounds for enforcement action; for permit termination, revocation and reissuance, or modification; or for denial of a permit renewal application. It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

Permit Actions: [WAQSR Ch 6, Sec 3(h)(i)(F)(III)] [W.S. 35-11-206(f)]

(G12) This permit may be modified, revoked, reopened, and reissued, or terminated for cause. The filing of a request by the permittee for a permit modification, revocation and reissuance, or termination, or of a notification of planned changes or anticipated noncompliance does not stay any permit condition.

Property Rights: [WAQSR Ch 6, Sec 3(h)(i)(F)(IV)]

(G13) This permit does not convey any property rights of any sort, or any exclusive privilege.

Duty to Provide Information: [WAQSR Ch 6, Sec 3(h)(i)(F)(V)]

(G14) The permittee shall furnish to the Division, within a reasonable time, any information that the Division may request in writing to determine whether cause exists for modifying, revoking and reissuing, or terminating the permit or to determine compliance with the permit. Upon request, the permittee shall also furnish to the Division copies of records required to be kept by the permit, including information claimed and shown to be confidential under W.S. 35-11-1101 (a) of the Wyoming Environmental Quality Act. Upon request by the Division, the permittee shall also furnish confidential information directly to EPA along with a claim of confidentiality.

Emissions Trading: [WAQSR Ch 6, Sec 3(h)(i)(H)]

(G15) No permit revision is required, under any approved economic incentives, marketable permits, emissions trading and other similar programs or processes for changes that are provided for in this permit.

Inspection and Entry: [WAQSR Ch 6, Sec 3(h)(iii)(B)] [W.S. 35-11-206(c)]

(G16) Authorized representatives of the Division, upon presentation of credentials and other documents as may be required by law, shall be given permission to:

(a) enter upon the permittee's premises where a source is located or emissions related activity is conducted, or where records must be kept under the conditions of this permit;
(b) have access to and copy at reasonable times any records that must be kept under the conditions of this permit;
(c) inspect at reasonable times any facilities, equipment (including monitoring and air pollution control equipment), practices, or operations regulated or required under this permit;
(d) sample or monitor any substances or parameters at any location, during operating hours, for the purpose of assuring compliance with this permit or applicable requirements.

Excess Emissions Due to an Emergency: [WAQSR Ch 6, Sec 3(l)]

(G17) The permittee may seek to establish that noncompliance with a technology-based emission limitation under this permit was due to an emergency, as defined in Ch 6, Sec 3(l)(i) of the WAQSR. To do so, the permittee shall demonstrate the affirmative defense of emergency through properly signed, contemporaneous operating logs, or other relevant evidence that:

(a) an emergency occurred and that the permittee can identify the cause(s) of the emergency;
(b) the permitted facility was, at the time, being properly operated;

(c) during the period of the emergency the permittee took all reasonable steps to minimize levels of emissions that exceeded the emissions standards, or other requirements in this permit;

(d) The permittee submitted notice of the emergency to the Division within one working day of the time when emission limitations were exceeded due to the emergency. This notice must contain a description of the emergency, any steps taken to mitigate emissions, and corrective actions taken.

Diluting and Concealing Emissions: [WAQSR Ch 1, Sec 4]

(G18) No person shall cause or permit the installation or use of any device, contrivance, or operational schedule which, without resulting in reduction of the total amount of air contaminant released to the atmosphere, shall dilute or conceal an emission from a source. This condition shall not apply to the control of odors.

Unavoidable Equipment Malfunction: [WAQSR Ch 1, Sec 5]

(G19) (a) Any source believing that any emissions in excess of established regulation limits or standards resulted from an unavoidable equipment malfunction, shall notify the Division within 24 hours of the incident via telephone, electronic mail, fax, or other similar method.

(b) A detailed description of the circumstances of the incident as described in paragraph 5(a)(i)(A) Chapter 1, including a corrective program directed at preventing future such incidents, must be submitted within 14 days of the onset of the incident either through the Division's IMPACT system (https://airimpact.wyo.gov) or in writing to the DEQ Air Quality Contact listed on page 3 of this permit. The Administrator may extend this 14-day time period for cause.

(c) The burden of proof is on the owner or operator of the source to provide sufficient information to demonstrate that an unavoidable equipment malfunction occurred.

Fugitive Dust: [WAQSR Ch 3, Sec 2(f)]

(G20) The permittee shall minimize fugitive dust in compliance with standards in Ch 3, Sec 2(f) of WAQSR for construction/demolition activities, handling and transportation of materials, and agricultural practices.

Carbon Monoxide: [WAQSR Ch 3, Sec 5]

(G21) The emission of carbon monoxide in stack gases from any stationary source shall be limited as may be necessary to prevent ambient standards from being exceeded.

Asbestos: [WAQSR Ch 3, Sec 8]

(G22) The permittee shall comply with emission standards for asbestos during abatement, demolition, renovation, manufacturing, spraying and fabricating activities.

(a) No owner or operator shall build, erect, install, or use any article, machine, equipment, process, or method, the use of which conceals an emission which would otherwise constitute a violation of an applicable standard. Such concealment includes, but is not limited to, the use of gaseous dilutants to achieve compliance with a visible emissions standard, and the piecemeal carrying out of an operation to avoid coverage by a standard that applies only to operations larger than a specified size.

(b) All owners and operators conducting an asbestos abatement project, including an abatement project on a residential building, shall be responsible for complying with Federal requirements and State standards for packaging, transportation, and delivery to an approved waste disposal facility as provided in paragraph (m) of Ch 3, Sec 8.

(c) The permittee shall follow State and Federal standards for any demolition and renovation activities conducted at this facility, including:

(i) A thorough inspection of the affected facility or part of the facility where the demolition or renovation activity will occur shall be conducted to determine the presence of asbestos, including Category I and Category II non-friable asbestos containing material. The results of the inspection will determine which notification and asbestos abatement procedures are applicable to the activity.

(ii) The owner or operator shall follow the appropriate notification requirements of Ch 3, Sec 8(i)(ii).

(iii) The owner or operator shall follow the appropriate procedures for asbestos emissions control, as specified in Chapter 3, Section 8(i)(iii).

(d) No owner or operator of a facility may install or reinstall on a facility component any insulating materials that contain commercial asbestos if the materials are either molded and friable or wet-applied and friable after drying. The provisions of this paragraph do not apply to spray-applied insulating materials regulated under paragraph (j) of Ch 3, Sec 8.

(e) The permittee shall comply with all other requirements of WAQSR Ch 3, Sec 8.

Construction Permit Application Commitments: [WAQSR Ch 6, Sec 2, 4]

(G23) All substantive commitments and descriptions set forth in applications for WAQSR Chapter 6 Section 2 and 4 permits and waivers referenced in this operating permit, unless superseded by a specific condition of this operating permit or by subsequent actions under Chapter 6 or W.S. 35-11-110, are enforceable as conditions of this permit.

Open Burning Restrictions: [WAQSR Ch 10, Sec 2]

(G24) The permittee conducting an open burn shall comply with all rules and regulations of the Wyoming Department of Environmental Quality, Division of Air Quality, and with the Wyoming Environmental Quality Act.

(a) No person shall burn prohibited materials using an open burning method, except as may be authorized by permit. ***"Prohibited materials"*** means substances including, but not limited to; natural or synthetic rubber products, including tires; waste petroleum products, such as oil or used oil filters; insulated wire; plastic products, including polyvinyl chloride ("PVC") pipe, tubing and connectors; tar, asphalt, asphalt shingles, or tar paper; railroad ties; wood, wood waste, or lumber that is painted or chemically treated; explosives or ammunition; batteries; hazardous waste products; asbestos or asbestos containing materials; or materials which cause dense smoke discharges, excluding refuse and flaring associated with oil and gas well testing, completions and well workovers.

(b) No person or organization shall conduct or cause or permit open burning for the disposal of trade wastes, for a salvage operation, for the destruction of fire hazards if so designated by a jurisdictional fire authority, or for firefighting training, except when it can be shown by a person or organization that such open burning is absolutely necessary and in the public interest. Any person or organization intending to engage in such open burning shall file a request to do so with the Division.

Sulfur Dioxide Emission Trading and Inventory Program [WAQSR Ch 14]

(G25) Any BART (Best Available Retrofit Technology) eligible facility, or facility which has actual emissions of SO_2 greater than 100 TPY in calendar year 2000 or any subsequent year, shall comply with the applicable requirements of WAQSR Ch 14, Sections 1 through 3, with the exceptions described in sections 2(c) and 3(a).

Stratospheric Ozone Protection Requirements: [40 CFR 82]

(G26) The permittee shall comply with all applicable Stratospheric Ozone Protection Requirements, including but not limited to:

(a) *Standards for Appliances* [40 CFR 82, Subpart F]
The permittee shall comply with the standards for recycling and emission reduction pursuant to 40 CFR 82, Subpart F - Recycling and Emissions Reduction, except as provided for motor vehicle air conditioners (MVACs) in Subpart B:

(i) Persons opening appliances for maintenance, service, repair, or disposal must comply with the required practices pursuant to §82.156.

(ii) Equipment used during the maintenance, service, repair, or disposal of appliances must comply with the standards for recycling and recovery equipment pursuant to §82.158.

(iii) Persons performing maintenance, service, repair, or disposal of appliances must be certified by an approved technician certification program pursuant to §82.161.

(iv) Persons disposing of small appliances, MVACs, and MVAC-like appliances must comply with record keeping requirements pursuant to §82.166. ("MVAC-like appliance" is defined at §82.152).

(v) Persons owning commercial or industrial process refrigeration equipment must comply with the leak repair requirements pursuant to §82.166.

(vi) Owners/operators of appliances normally containing 50 or more pounds of refrigerant must keep records of refrigerant purchased and added to such appliances pursuant to §82.166.

(vii) The permittee shall comply with all other requirements of Subpart F.

(b) *Standards for Motor Vehicle Air Conditioners* [40 CFR 82, Subpart B]

If the permittee performs service on motor (fleet) vehicles when this service involves ozone-depleting substance refrigerant in the MVAC, the permittee is subject to all applicable requirements as specified in 40 CFR 82, Subpart B, Servicing of Motor Vehicle Air Conditioners. The term "motor vehicle" as used in Subpart B does not include a vehicle in which final assembly of the vehicle has not been completed. The term "MVAC" as used in Subpart B does not include the air-tight sealed refrigeration system used as refrigerated cargo, or the system used on passenger buses using HCFC-22 refrigerant.

STATE ONLY PERMIT CONDITIONS

The conditions listed in this section are State only requirements and are not federally enforceable.

Ambient Standards

(S1) The permittee shall operate the emission units described in this permit such that the following ambient standards are not exceeded:

POLLUTANT	STANDARD*	CONDITION	WAQSR CH. 2, SEC.
PM_{10} particulate matter	50 micrograms per cubic meter	annual arithmetic mean	2 (a)
	150 micrograms per cubic meter	24-hr average concentration with not more than one exceedance per year	
$PM_{2.5}$ particulate matter	12.0 micrograms per cubic meter	annual arithmetic mean	2 (b) & (c)
	15 micrograms per cubic meter	annual arithmetic mean	
	35 micrograms per cubic meter	98th percentile 24-hr average concentration	
Nitrogen dioxide	53 parts per billion	annual average concentration	3
	100 parts per billion	three-year average of the annual 98th percentile of the daily maximum 1-hr average concentration	
	0.053 parts per million	annual arithmetic mean	
Sulfur dioxide	75 parts per billion	three-year average of the annual (99th percentile) of the daily max 1-hr average	4
	0.5 parts per million	3-hr blocks not to be exceeded more than once per calendar year	
Carbon monoxide	10 milligrams per cubic meter	max 8-hr concentration with not more than one exceedance per year	5
	40 milligrams per cubic meter	max 1-hr concentration with not more than one exceedance per year	
Ozone	0.070 parts per million	three-year average of the annual fourth-highest daily maximum 8-hr average concentration	6
Hydrogen sulfide	70 micrograms per cubic meter	½ hour average not to be exceeded more than two times per year	7
	40 micrograms per cubic meter	½ hour average not to be exceeded more than two times in any five consecutive days	
Suspended sulfate	0.25 milligrams SO_3 per 100 square centimeters per day	maximum annual average	8
	0.50 milligrams SO_3 per 100 square centimeters per day	maximum 30-day value	
Lead and its compounds	0.15 micrograms per cubic meter	maximum arithmetic 3-month mean concentration for a 3-year period	10

*Exceedances of these standards shall be determined using the procedures in 40 CFR 50.

Hydrogen Sulfide: [WAQSR Ch 3, Sec 7]

(S2) Any exit process gas stream containing hydrogen sulfide which is discharged to the atmosphere from any source shall be vented, incinerated, flared or otherwise disposed of in such a manner that ambient sulfur dioxide and hydrogen sulfide standards are not exceeded.

Odors: [WAQSR Ch 2, Sec 11]

(S3) (a) The ambient air standard for odors from any source shall be limited to an odor emission at the property line which is undetectable at seven dilutions with odor free air as determined by a scentometer as manufactured by the Barnebey-Cheney Company or any other instrument, device, or technique designated by the Division as producing equivalent results. The occurrence of odors shall be measured so that at least two measurements can be made within a period of one hour, these determinations being separated by at least 15 minutes.

(b) Odor producing materials shall be stored, transported, and handled in a manner that odors produced from such materials are confined and that accumulation of such materials resulting from spillage or other escape is prevented.

SUMMARY OF SOURCE EMISSION LIMITS AND REQUIREMENTS

Source ID#: BOL001 Source Description: E. Keeler Boiler

Pollutant	Emissions Limit/Work Practice Standard	Corresponding Regulation(s)	Testing and Monitoring Requirements	Recordkeeping Requirements	Reporting Requirements
All Regulated Pollutants	Combined (BOL001-BOL004) coal use not to exceed 36,000 TPY [F3] Combined (BOL001-BOL004) fuel oil use not to exceed 50,000 gallons per year [F3] Three of four boilers (BOL001-BOL004) can operate at any time [F4]	WAQSR Ch 6, Sec 2 Permit MD-150	Additional testing if required [F8] Monitor fuel use [F11]	Record any testing and results [F15] Record monthly fuel oil usage [F15]	If additional testing is required, submit reports within 45 days [F18] Semiannual: report coal and fuel oil usage [F20] Report excess emissions and permit deviations [F22]
Particulate	20 percent opacity [F2] 0.05 lb/MMBtu, 11.0 lb/hr, 18.9 TPY combined limit (BOL001-BOL004) [F4]	WAQSR Ch 3, Sec 2; WAQSR Ch 6, Sec 2 Permit MD-150	Test once every five years if using fuel oil [F9] Monitor emissions daily [F12]	Record test results [F15] Recording visible emissions monitoring [F15] Record Baghouse maintenance [F16]	Test notification [F18] Submit test reports within 45 days [F19] Semiannual: visible emission monitoring [F20]
SO_2	Coal sulfur content not to exceed 0.7% [F3] Fuel oil sulfur content not to exceed 0.45% [F3] 322.4 lb/hr, 441.0 TPY combined limit (BOL001-BOL004) [F4]	WAQSR Ch 6, Sec 2 Permit MD-150	Test once every five years if using fuel oil [F9] Monitor fuel sulfur content [F11]	Record test results [F15] Record coal and fuel oil sulfur content [F15]	Test notification [F18] Submit test reports within 45 days [F19] Semiannual: report fuel sulfur content [F20]
NO_X	0.7 lb/MMBtu, 153.7 lb/hr, 210.2 TPY combined limit (BOL001-BOL004) [F4]	WAQSR Ch 6, Sec 2 Permit MD-150	Test at least once every five years [F9]	Record testing and results [F15]	Test notification [F18] Submit test reports within 45 days [F19]
CO	65.8 lb/hr, 90.0 TPY combined limit (BOL001-BOL004) [F4]	WAQSR Ch 6, Sec 2 Permit MD-150	Test at least once every five years [F9]	Record testing and results [F15]	Test notification [F18] Submit test reports within 45 days [F19]
HAPS	WAQSR Ch 5, Sec 3 and 40 CFR 63 Subparts A & JJJJJJ				

These tables are intended only to highlight and summarize applicable requirements for each source. The corresponding permit conditions, listed in brackets, contain detailed descriptions of the compliance requirements. Compliance with the summary conditions in these tables may not be sufficient to meet permit requirements. These tables may not reflect all emission sources at this facility.

Source ID#: BOL002-BOL004 Source Description: IBW Boilers

Pollutant	Emissions Limit/Work Practice Standard	Corresponding Regulation(s)	Testing and Monitoring Requirements	Recordkeeping Requirements	Reporting Requirements
All Regulated Pollutants	Combined (BOL001-BOL004) coal use not to exceed 36,000 TPY [F3] Combined (BOL001-BOL004) fuel oil use not to exceed 50,000 gallons per year [F3] Three of four boilers (BOL001-BOL004) can operate at any time [F4]	WAQSR Ch 6, Sec 2 Permit MD-150	Additional testing if required [F8] Monitor fuel use [F11]	Record any testing and results [F15] Record monthly coal and fuel oil usage [F15]	If additional testing is required, submit reports within 45 days [F18] Semiannual: report coal and fuel oil usage [F20] Report excess emissions and permit deviations [F22]
Particulate	20 percent opacity [F2] 0.05 lb/MMBtu, 11.0 lb/hr, 18.9 TPY combined limit (BOL001-BOL004) [F4]	WAQSR Ch 3, Sec 2; WAQSR Ch 6, Sec 2 Permit MD-150	Test at least once every five years [F9] Monitor visible emissions daily [F10, CAM-1 through 4]	Record test results [F15] Record CAM results [F15] Recording visible emissions monitoring [F15] Record Baghouse maintenance [F16]	Test notification [F18] Submit test reports within 45 days [F19] Semiannual: report CAM results [F20] Semiannual: visible emission monitoring [F20]
SO_2	Coal sulfur content not to exceed 0.7% [F3] Fuel oil sulfur content not to exceed 0.45% [F3] 322.4 lb/hr, 441.0 TPY combined limit (BOL001-BOL004) [F4]	WAQSR Ch 6, Sec 2 Permit MD-150	Test at least once every five years [F9] Monitor fuel sulfur content [F11]	Record test results [F15] Record coal and fuel oil sulfur content [F15]	Test notification [F18] Submit test reports within 45 days [F19] Semiannual: report fuel sulfur content [F20]
NO_X	0.7 lb/MMBtu, 153.7 lb/hr, 210.2 TPY combined limit (BOL001-BOL004) [F4]	WAQSR Ch 6, Sec 2 Permit MD-150	Test at least once every five years [F9]	Record testing and results [F15]	Test notification [F18] Submit test reports within 45 days [F19]
CO	65.8 lb/hr, 90.0 TPY combined limit (BOL001-BOL004) [F4]	WAQSR Ch 6, Sec 2 Permit MD-150	Test at least once every five years [F9]	Record testing and results [F15]	Test notification [F18] Submit test reports within 45 days [F19]
HAPS	WAQSR Ch 5, Sec 3 and 40 CFR 63 Subparts A & JJJJJJ				

These tables are intended only to highlight and summarize applicable requirements for each source. The corresponding permit conditions, listed in brackets, contain detailed descriptions of the compliance requirements. Compliance with the summary conditions in these tables may not be sufficient to meet permit requirements. These tables may not reflect all emission sources at this facility.

Source ID#: TNK001 Source Description: Fly Ash Silo

Pollutant	Emissions Limit/Work Practice Standard	Corresponding Regulation(s)	Testing and Monitoring Requirements	Recordkeeping Requirements	Reporting Requirements
Particulate	20 percent opacity [F2] 0.2 lb/hr [F5]	WAQSR Ch 3, Sec 2 Ch 6, Sec 2 Permit OP-137	Testing if required [F8] Weekly visible monitoring [F12]	Record results of visible emission monitoring and any testing [F15]	Submit test reports within 45 days [F19] Semiannual: visible emission monitoring [F20] Report excess emissions and permit deviations [F22]

Source ID#: ENG002 and ENG003 Source Description: Cummins QSK50-G5 NR2 Back-up Generator Engines

Pollutant	Emissions Limit/Work Practice Standard	Corresponding Regulation(s)	Testing and Monitoring Requirements	Recordkeeping Requirements	Reporting Requirements
Particulate	30 percent opacity [F2] 100 hour annual non-emergency operation limit; Tier 2 certified; follow manufacturer's or supplier's recommended maintenance [F6] Engine replacement [F7]	WAQSR Ch 3, Sec 2; WAQSR Ch 6, Sec 2 Waiver P0021967; WAQSR Ch 6, Sec 3(h)(i)(I)	Testing if required [F8] Semiannual visible emissions monitoring during availability [F12] Operating hours monitoring [F13]	Record results of visible emission monitoring and any testing [F15] Record engine certification [F16] Record maintenance [F16]	Engine shutdown and removal notification [F18] Submit any test reports within 45 days [F19] Semiannual: visible emission monitoring [F20] Semiannual: report operating hours [F20] Report excess emissions and permit deviations [F22]
Additional NO_X, CO, and VOC	WAQSR Ch 5, Sec 2 and 40 CFR 60 Subparts A & IIII [1]				
HAPS	WAQSR Ch 5, Sec 3 and 40 CFR 63 Subparts A & ZZZZ				

[1] On January 9, 2018 engines ENG002 and ENG003 were subject to Subpart IIII according to information submitted to the Division by the permittee.

These tables are intended only to highlight and summarize applicable requirements for each source. The corresponding permit conditions, listed in brackets, contain detailed descriptions of the compliance requirements. Compliance with the summary conditions in these tables may not be sufficient to meet permit requirements. These tables may not reflect all emission sources at this facility.

ABBREVIATIONS

ACFM	Actual cubic feet per minute
AFRC	Air-fuel ratio controls
AQD	Air Quality Division
BACT	Best available control technology (see Definitions)
bbl(s)	Barrel(s)
Btu	British thermal unit
CAA	Clean Air Act
CAM	Compliance Assurance Monitoring
CE	Control Equipment
CFR	Code of Federal Regulations
CO	Carbon monoxide
CO_2e	Carbon dioxide equivalent
DEQ	Wyoming Department of Environmental Quality
EPA	United States Environmental Protection Agency (see Definitions)
ESP	Electrostatic Precipitator
EU	Emission Unit
g/hp-hr	Gram(s) per horsepower hour
gal	Gallon(s)
gr	Grain(s)
H_2S	Hydrogen sulfide
HAP(S)	Hazardous air pollutant(s)
hp	Horsepower
hr	Hour(s)
lb	Pound(s)
M	Thousand
MACT	Maximum available control technology (see Definitions)
mfr	Manufacturer
mg	Milligram(s)
MM	Million
MVACs	Motor vehicle air conditioners
NAICS	North American Industry Classification System
NMHC(s)	Non-methane hydrocarbon(s)
NO_X	Oxides of nitrogen
NSCR	Non-selective catalytic reduction
O_2	Oxygen
PM	Particulate matter
PM_{10}	Particulate matter less than or equal to a nominal diameter of 10 micrometers
$PM_{2.5}$	Particulate matter less than or equal to a nominal diameter of 2.5 micrometers
ppmv	Parts per million (by volume)
ppmw	Parts per million (by weight)
QIP	Quality Improvement Plan
RICE	Reciprocating internal combustion engine
SCF	Standard cubic foot (feet)
SCFD	Standard cubic foot (feet) per day
SCM	Standard cubic meter(s)
SIC	Standard Industrial Classification
SO_2	Sulfur dioxide
SO_X	Oxides of sulfur
S/W/B	Standing/Working/Breathing
TBD	To be determined
TPD	Ton(s) per day (1 ton = 2000 pounds, unless otherwise specified)
TPH	Ton(s) per hour (1 ton = 2000 pounds, unless otherwise specified)
TPY	Tons per year (1 ton = 2000 pounds, unless otherwise specified)
U.S.C.	United States Code
μg	Microgram(s)
VOC(s)	Volatile organic compound(s)
W.S.	Wyoming Statute
WAQSR	Wyoming Air Quality Standards & Regulations (see Definitions)
2SLB	2-stroke lean burn
4SLB	4-stroke lean burn
4SRB	4-stroke rich burn

DEFINITIONS

"Act" means the Clean Air Act, as amended, 42 U.S.C. 7401, *et seq*.

"Administrator" means Administrator of the Air Quality Division, Wyoming Department of Environmental Quality.

"Applicable requirement" means all of the following as they apply to emissions units at a source subject to Chapter 6, Section 3 of the WAQSR (including requirements with future effective compliance dates that have been promulgated or approved by the EPA or the State through rulemaking at the time of issuance of the operating permit):

(a) Any standard or other requirement provided for in the Wyoming implementation plan approved or promulgated by EPA under Title I of the Act that implements the relevant requirements of the Act, including any revisions to the plan promulgated in 40 CFR 52;

(b) Any standards or requirements in the WAQSR which are not a part of the approved Wyoming implementation plan and are not federally enforceable;

(c) Any term or condition of any preconstruction permits issued pursuant to regulations approved or promulgated through rulemaking under Title I, including parts C or D of the Act and including Chapter 5, Section 2 and Chapter 6, Sections 2 and 4 of the WAQSR;

(d) Any standard or other requirement promulgated under Section 111 of the Act, including Section 111(d) and Chapter 5, Section 2 of the WAQSR;

(e) Any standard or other requirement under Section 112 of the Act, including any requirement concerning accident prevention under Section 112(r)(7) of the Act and including any regulations promulgated by EPA and the State pursuant to Section 112 of the Act;

(f) Any standard or other requirement of the acid rain program under Title IV of the Act or the regulations promulgated thereunder;

(g) Any requirements established pursuant to Section 504(b) or Section 114(a)(3) of the Act concerning enhanced monitoring and compliance certifications;

(h) Any standard or other requirement governing solid waste incineration, under Section 129 of the Act;

(i) Any standard or other requirement for consumer and commercial products, under Section 183(e) of the Act (having to do with the release of volatile organic compounds under ozone control requirements);

(j) Any standard or other requirement of the regulations promulgated to protect stratospheric ozone under Title VI of the Act, unless the EPA has determined that such requirements need not be contained in a Title V permit;

(k) Any national ambient air quality standard or increment or visibility requirement under part C of Title I of the Act, but only as it would apply to temporary sources permitted pursuant to Section 504(e) of the Act; and

(l) Any state ambient air quality standard or increment or visibility requirement of the WAQSR.

(m) Nothing under paragraphs (A) through (L) above shall be construed as affecting the allowance program and Phase II compliance schedule under the acid rain provision of Title IV of the Act.

"BACT" or "Best available control technology" means an emission limitation (including a visible emission standard) based on the maximum degree of reduction of each pollutant subject to regulation under the WAQSR or regulation under the Federal Clean Air Act, which would be emitted from or which results for any proposed major emitting facility or major modification which the Administrator, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such source or modification through application or production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of such pollutant. If the Administrator determines that technological or economic limitations on the application of measurement methodology to a particular class of sources would make the imposition of an emission standard infeasible, he may instead prescribe a design, equipment, work practice or operational standard or combination thereof to satisfy the requirement of Best Available Control Technology. Such standard shall, to the degree possible, set forth the emission reduction achievable by implementation of such design, equipment, work practice, or operation and shall provide for compliance by means which achieve equivalent results. Application of BACT shall not result in emissions in excess of those allowed under Chapter 5, Section 2 of the WAQSR and any other new source performance standard or national emission standards for hazardous air pollutants promulgated by EPA but not yet adopted by the state.

"Department" means the Wyoming Department of Environmental Quality or its Director.

"Director" means the Director of the Wyoming Department of Environmental Quality.

"Division" means the Air Quality Division of the Wyoming Department of Environmental Quality or its Administrator.

"Emergency" means any situation arising from sudden and reasonably unforeseeable events beyond the control of the source, including acts of God, which situation requires immediate corrective action to restore normal operation, and that causes the source to exceed a technology-based emission limitation under the permit, due to unavoidable increases in emissions attributable to the emergency. An emergency shall not include noncompliance to the extent caused by improperly designed equipment, lack of preventative maintenance, careless or improper operation, or operator error.

"EPA" means the Administrator of the U.S. Environmental Protection Agency or the Administrator's designee.

"Fuel-burning equipment" means any furnace, boiler apparatus, stack, or appurtenances thereto used in the process of burning fuel or other combustible material for the purpose of producing heat or power by indirect heat transfer.

"Fugitive emissions" means those emissions which could not reasonably pass through a stack chimney, vent, or other functionally equivalent opening.

"Insignificant activities" means those activities which are incidental to the facility's primary business activity and which result in emissions of less than one ton per year of a regulated pollutant not included in the Section 112 (b) list of hazardous air pollutants or emissions less than 1000 pounds per year of a pollutant regulated pursuant to listing under Section 112 (b) of the Act provided, however, such emission levels of hazardous air pollutants do not exceed exemptions based on insignificant emission levels established by EPA through rulemaking for modification under Section 112 (g) of the Act.

"MACT" or "Maximum achievable control technology" means the maximum degree of reduction in emissions that is deemed achievable for new sources in a category or subcategory that shall not be less stringent than the emission control that is achieved in practice by the best controlled similar source, as determined by the Administrator. Emission standards promulgated for existing sources in a category or subcategory may be less stringent than standards for new sources in the same category or subcategory but shall not be less stringent, and may be more stringent than:

(a) the average emission limitation achieved by the best performing 12 percent of the existing sources (for which the Administrator has emission information), excluding those sources that have, within 18 months before the emission standard is proposed or within 30 months before such standard is promulgated, whichever is later, first achieved a level of emission rate or emission reduction which complies, or would comply if the source is not subject to such standard, with the lowest achievable emission rate applicable to the source category and prevailing at the time, in the category or subcategory for categories and subcategories with 30 or more sources, or

(b) the average emission limitation achieved by the best performing five sources (for which the Administrator has or could reasonably obtain emissions information) in the category or subcategory for categories or subcategories with fewer than 30 sources.

"Modification" means any physical change in, or change in the method of operation of, an affected facility which increases the amount of any air pollutant (to which any state standards applies) emitted by such facility or which results in the emission of any such air pollutant not previously emitted.

"Permit Basis Date" means the date representing a delineation between what is evaluated and included in a Chapter 6, Section 3 operating permit and what will be addressed in a subsequent operating permit modification, reopening, or renewal. All emission sources installed as of the Permit Basis Date, as well as those sources authorized for construction by a Chapter 6 Section 2 (New Source Review) permit but not yet started up by the Permit Basis Date, will be included in the operating permit. The operating permit will also include all requirements that apply on the Permit Basis Date, as well as those requirements that have been identified as of the Permit Basis Date that will become effective during the operating permit term.

"Permittee" means the person or entity to whom a Chapter 6, Section 3 permit is issued.

"Potential to emit" means the maximum capacity of a stationary source to emit any air pollutant under its physical and operational design. Any physical or operational limitation on the capacity of a source to emit an air pollutant, including air pollution control equipment and restrictions on hours of operation or on the type or amount of material combusted, stored or processed, shall be treated as part of its design if the limitation is enforceable by EPA and the Division. This term does not alter or affect the use of this term for any other purposes under the Act, or the term "capacity factor" as used in Title IV of the Act or the regulations promulgated thereunder.

"Regulated air pollutant" means the following:

(a) Nitrogen oxides (NO_X) or any volatile organic compound;
(b) Any pollutant for which a national ambient air quality standard has been promulgated;
(c) Any pollutant that is subject to any standard established in Chapter 5, Section 2 of the WAQSR or Section 111 of the Act;
(d) Any Class I or II substance subject to a standard promulgated under or established by Title VI of the Act; or
(e) Any pollutant subject to a standard promulgated under Section 112 or other requirements established under Section 112 of the Act, including Sections 112(g), (j), and (r) of the Act, including the following:
    (i) Any pollutant subject to requirements under Section 112(j) of the Act. If EPA fails to promulgate a standard by the date established pursuant to Section 112(e) of the Act, any pollutant for which a subject source would be major shall be considered to be regulated on the date 18 months after the applicable date established pursuant to Section 112(e) of the Act; and
    (ii) Any pollutant for which the requirements of Section 112(g)(2) of the Act have been met, but only with respect to the individual source subject to Section 112(g)(2) requirement.
(f) Pollutants regulated solely under Section 112(r) of the Act are to be regulated only with respect to the requirements of Section 112(r) for permits issued under this Chapter 6, Section 3 of the WAQSR.

"Renewal" means the process by which a permit is reissued at the end of its term.

"Responsible official" means one of the following:

(a) For a corporation:
    (i) A president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person who performs similar policy or decision-making functions for the corporation; or
    (ii) A duly authorized representative of such person if the representative is responsible for the overall operation of one or more manufacturing, production, or operating facilities applying for or subject to a permit and either:
        (A) the facilities employ more than 250 persons or have gross annual sales or expenditures exceeding $25 million (in second quarter 1980 dollars); or
        (B) the delegation of authority to such representative is approved in advance by the Division;
(b) For a partnership or sole proprietorship: a general partner or the proprietor, respectively;
(c) For a municipality, State, Federal, or other public agency: Either a principal executive officer or ranking elected official. For the purposes of this part, a principal executive officer of a federal agency includes the chief executive officer having responsibility for the overall operations of a principal geographic unit of the agency; or
(d) For affected sources:
    (i) The designated representative or alternate designated representative in so far as actions, standards, requirements, or prohibitions under Title IV of the Act or the regulations promulgated thereunder are concerned; and
    (ii) The designated representative, alternate designated representative, or responsible official under Chapter 6, Section 3 (b)(xxvi) of the WAQSR for all other purposes under this section.

"WAQSR" means the Wyoming Air Quality Standards and Regulations promulgated under the Wyoming Environmental Quality Act, W.S. §35-11-101, *et seq.*

APPENDIX A

COMPLIANCE ASSURANCE MONITORING PLAN

Permit No. P0022349 Permit Basis Date: 2018.01.09

COMPLIANCE ASSURANCE MONITORING PLAN:
FABRIC FILTER FOR PM CONTROL – 1

I. Background

A. Emissions Unit

Description:	Steam Heating Plant
Identification:	IBW VSG-60 Boilers: Units BOL002-BOL004 (2-4)
Facility:	University of Wyoming, Central Energy Plant Laramie, USA

B. Applicable Regulation, Emission Limit, and Pre-CAM Monitoring Requirements

Regulation:	Permit MD-150
CAM Emission limits:	Particulate matter: 0.05 lb/MMBtu, 11.0 lb/hr, 18.9 TPY
Pre-CAM monitoring requirements:	Visible emissions, periodic monitoring (Method 22)

C. Control Technology, Capture System, Bypass, PTE

Controls:	Reverse-air baghouse operated under negative pressure.
Capture System:	Closed-duct system
Bypass:	Bypass is closed when burning coal. Open when burning natural gas, during start-up on coal, and when switching from coal to gas
PTE before controls:	3,780 TPY (Based on 99.5% control efficiency of the baghouse)
PTE after controls:	18.9 TPY (Based on max coal consumption of 36,000 tons per year)

II. Monitoring Approach

A. Indicators

Visible emissions will be used as an indicator. Normal process operations will not produce conditions that adversely affect the baghouse, so no process operational parameters will be monitored.

B. Measurement Approach

Visible emissions from the baghouse exhaust will be monitored daily using EPA Reference Method 22-like procedures. A 6-minute observation will be performed and recorded in a log book by the observer.

C. Indicator Range

An excursion is defined as the presence of visible emissions.

D. Performance Criteria

Data Representativeness:	Measurements are being made at the emission point (baghouse exhaust).
QA/QC Practices and Criteria:	The observer will be familiar with Reference Method 22 and follow Method 22-like procedures.

III. Response to Excursion

A. Upon noting visible emissions, the observer will immediately notify maintenance to inspect the baghouse, and operations to slow down production as feasible. Upon receiving notification, maintenance personnel will inspect the baghouse and make needed repairs as soon as practicable. Operations will return to normal upon completed corrective action.

JAN 9 2018 12/15/17

Permit No. P0022349 Permit Basis Date: 2018.01.09

JUSTIFICATION

I. Background

The University of Wyoming Central Energy Plant consists of three 73.17 MMBtu/hr coal/oil/gas fired boilers and one 37.5 MMBtu/hr gas/oil fired boiler. The boilers were constructed to meet the steam requirements for the university. The monitoring approach outlined here applies to the three 73.17 MMBtu/hr coal boilers baghouse cells 1-7. They are Zurn reverse-air baghouses with 1,155 bags which filter flue gas from any of the three boilers. The induced draft fans maintain airflow through the baghouse.

The baghouse bypass is closed when burning coal. The bypass is open when burning natural gas, during start-up on coal, and when switching fuels. During start-up and switching fuels, the flue gas temperature is not high enough to prevent moisture from collecting in the bags, causing caking and plugging of the bags.

II. Rationale for Selection of Performance Indicators

Visible emissions was selected as the performance indicator because it is indicative of good operation and maintenance of the baghouse. When the baghouse is operating properly, there will not be any visible emissions from the exhaust. Any increase in visible emissions indicates reduced performance of a particulate control device, therefore, the presence of visible emissions is used as a performance indicator.

Annually, each cell of the baghouse is inspected to verify that the bags and equipment are operating properly. Other items on the baghouse inspection report include: the bags replaced, tension adjustments, loose bags, and any bag supports which were repaired. A Report of Maintenance and Repairs is also filled out for any maintenance done in the baghouse.

Additionally, a baghouse log sheet provides documentation that the baghouse is in good repair and operating properly. Once per day, at a minimum, the baghouse is cleaned and pressure drop checked to verify that the bags and equipment are operating properly. Proper operation of the cleaning cycle facilitates gas flow through the baghouse and the removal of particulate, and also helps prevent blinding of the filter bags. Other items on the baghouse log sheet include the inlet pressure, cleaning cycle operation time, differential pressure, vacuum pressure after ash removal, and differential pressure before and after cleaning.

III. Rationale for Selection of Indicator Ranges

The selected indicator range is no visible emissions. When an excursion occurs, corrective action will be initiated, beginning with an evaluation of the occurrence to determine the action required to correct the situation. All excursions will be documented and reported. An indicator range of no visible emissions was selected because: (1) an increase in visible emissions is indicative of an increase in particulate emissions; and (2) a monitoring technique which does not require a Method 9 certified observer is desired. Although RM 22 applies to fugitive sources, the visible/no visible emissions observation technique of RM-22 can be applied to ducted emissions; i.e., Method 22-like observations.

JAN 9 2018 12/15/17

Permit No. P0022349 Permit Basis Date: 2018.01.09

23. APPENDIX T: CEP PLANT SAFETY DATA SHEETS

SAFETY DATA SHEET

FCT Companies

Date Printed: 11/30/2018
Date Issued: 12/3/2015
Date Revised: 1/20/2016
Revision No: 2

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT CODE: BWT913
PRODUCT TRADE NAME: BWT913
COMMON NAMES/SYNONYMS: BWT913
CATEGORY: BT
RECOMMENDED USE: BOILER TREATMENT, For industrial use only, refer to label and technical data sheet or call number below

MANUFACTURER
FCT
1309 North 17th Ave., Greeley, CO 80631, Phone 970-346-8002

24 HR. EMERGENCY TELEPHONE NUMBERS
800-535-5053

Emergency Contact: INFO TRAC
E-Mail: customerservice@floridacirtech.com
Emergency Phone: 800-535-5053
Alternate Emergency Phone: 800-686-6504

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

PHYSICAL APPEARANCE: Amber
IMMEDIATE CONCERNS: Skin Corrosion/Irritation

POTENTIAL HEALTH EFFECTS

EYES: Causes severe irritation (tears, blurred vision and redness) May result in permanent eye damage.
SKIN: Causes severe skin irritation and tissue damage.
INGESTION: Causes damage to mouth, throat and stomach.
INHALATION: May cause physical discomfort to the respiratory tract.

UNCLASSIFIED HAZARDS: Use good industrial practices when handling. Avoid eye, skin, and clothing contact.
SIGNAL WORD: Danger
Potential Carcinogens as listed by OSHA, IARC, or NTP: NONE
OSHA HCS Status This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).
GHS Pictogram:

Hazard Statement(s)

Code	Statement	GHS Chapter	Category
H290	May be corrosive to metals	Corrosive to metals (chapter 2.16)	1
H302	Harmful if swallowed	Acute toxicity, oral (chapter 3.1)	4
H314	Causes severe skin burns and eye damage	Skin corrosion/irritation (chapter 3.2)	1A, 1B, 1C
H318	Causes serious eye damage	Serious eye damage/eye irritation (chapter 3.3)	1
H333	May be harmful if inhaled	Acute toxicity, inhalation (chapter 3.1)	5

H373	May cause damage to organs through prolonged or repeated exposure	Specific target organ toxicity, repeated exposure (chapter 3.9)	2
H402	Harmful to aquatic life	Hazardous to the aquatic environment, acute toxicity (chapter 4.1)	3

Precautionary Statement(s)

P234	Keep only in original container.
P260	Do not breathe dust/fume/gas/mist/vapours/spray.
P264	Wash skin thoroughly after handling
P270	Do not eat, drink or smoke when using this product.
P273	Avoid release to the environment.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P301+ P310	IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.
P301+ P312	IF SWALLOWED: Call a POISON CENTER or doctor/physician if you feel unwell.
P301+P330 + P331	IF SWALLOWED: rinse mouth. Do NOT induce vomiting.
P303+ P361 + P353	IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304+ P340	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P305+ P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P363	Wash contaminated clothing before reuse.
P390	Absorb spillage to prevent material damage.
P405	Store locked up.
P406	Store in corrosive resistant/... container with a resistant inner liner.
P501	Dispose of contents/ container to an approved waste disposal plant.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	Common Names	CAS	Weight %age
Polycarboxylate, sodium salt	Polycarboxylate, sodium salt	Not Hazardous	1.00 % - 6.00 %
Phosphino carboxylic acid	Phosphino carboxylic acid	71050-62-9	1.00 % - 5.00 %
Sodium Hydroxide	Sodium Hydroxide	1310-73-2	0.00 % - 12.00 %

4. FIRST AID MEASURES

COMMON SYMPTOMS OF OVEREXPOSURE: No Applicable data available

EYES: Immediately flush with water for at least 15 minutes or until the chemical is removed. Get medical attention!

SKIN: Wash off immediately with large amounts of water. Get medical attention if irritation develops. If clothing is contaminated, remove and launder before reuse.

INGESTION: If conscious, rinse mouth with water. Seek medical advice on whether to induce vomiting. Never give anything by mouth to an unconscious person. Get medical attention.

INHALATION: Move to fresh air. Remove any contaminated clothing. If breathing is difficult, administer oxygen. Get medical attention.

NOTES TO PHYSICIAN: Follow usual and customary procedures

ADDITIONAL INFORMATION: No Applicable data available

COMMENTS: No Applicable data available

5. FIRE FIGHTING MEASURES

FLASH POINT AND METHOD: No applicable data available

FLAMMABLE LIMITS: LEL : No applicable data available UEL: No applicable data available

GENERAL HAZARD: As with any chemical fire, combustion products of unknown toxicity are always possible.

EXTINGUISHING MEDIA: Carbon dioxide, dry chemical, foam or water spray.

FIRE FIGHTING EQUIPMENT: Vapors and fumes may be irritating and toxic. Firefighters should wear self contained breathing apparatus and full firefighting turnout gear.

SENSITIVE TO STATIC DISCHARGE: No applicable data available

COMMENTS: Standard procedure for chemical fires.

6. ACCIDENTAL RELEASE MEASURES

SMALL SPILL: Neutralize spilled material. Pump spilled liquid into disposal container.

LARGE SPILL: No data available

EMERGENCY PROCEDURES: For hazardous waste regulations call 800-424-9346, the RCRA Hotline. Personal precautions, protective equipment and emergency procedures: Evacuate area. Keep upwind of spill. Refer to section 7, Handling, for additional precautionary measures. Only trained and properly protected personnel must be involved in clean-up operations. Ventilate area of leak or spill. Use appropriate safety equipment. For additional information, refer to Section 8, Exposure Controls and personal protection.

GENERAL PROCEDURES: No data available

RELEASE NOTES: Collect as much as possible in a clean container for reuse (if not contaminated) or disposal (if contamintated). Prevent from entering into soil, ditches, sewers, waterways and/or ground water. See section 12 Ecological information.

SPECIAL PROTECTIVE EQUIPMENT: Isolate area. Use appropriate safety equipment. For additional information, refer to section 8, Exposure Controls and Personal Protection.

COMMENTS: See also section 13 for disposal information.

7. HANDLING AND STORAGE

HANDLING: Avoid contact with skin and eyes. Avoid formation of dust and aerosols.Further processing of solid materials may result in the formation of combustible dusts. The potential for combustible dust formation should be taken into consideration before additional processing occurs.

Provide appropriate exhaust ventilation at places where dust is formed.

For precautions see section 2.2.

STORAGE: Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

Storage class (TRGS 510): Non-combustible, corrosive hazardous materials

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Chemical Name	OSHA PEL	OSHA STEL	ACGIH TWA	ACGIH STEL
Polycarboxylate, sodium salt	NE	NE	NE	NE
Phosphino carboxylic acid	NE	NE	NE	NE
Sodium Hydroxide	2mg/m3	2mg/m3	2mg/m3	2mg/m3

ENGINEERING CONTROLS: Work in well ventilated areas. Do not breathe vapors or mist. Ensure that existing ventilation is sufficient to prevent the circulation and/or accumulation of vapors in the air.

PERSONAL PROTECTIVE EQUIPMENT:

EYES AND FACE: Eye protection such as chemical splash goggles and/or face shield must be worn when possibility exists for eye contact due to splashing or spraying liquid, airborne particles, or vapor.

SKIN: Wear nitrile or latex gloves. Wear protective clothing.

RESPIRATORY: Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multipurpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

WORK HYGIENIC PRACTICES: Discard contaminated gloves after use. Have eye-wash facilities in the immediate vicinity. Work in adequately ventilated area. Do not breathe vapors or mist. Minimize any contact with any chemical.

COMMENTS: Eye wash station and safety shower should be available in immediate work area. To identify additional Personal Protective Equipment (PPE) requirements, it is recommended that a hazard assessment, in accordance with the OSHA PPE Standard (29 CFR 1910.132), be conducted before using this product.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance Form: Liquid
Appearance Color: Amber
Odor: None
Odor Threshold: Not Determined
pH-value @ 68 °F: >12.5
Melting point: Not Determined
Boiling Point: >300 F
Flash Point: Non Flammable
Flammability: no data available
Ignition temperature: no data available
Auto Igniting: no data available
Danger of explosion: no data available
Explosion Lower Limit: NE
Explosion Upper Limit: NE
Vapor pressure @ 68 °F: N/A
Relative Density: 1.10
Vapor Density: N/A
Evaporation Rate: N/A
Solubility in Water: Complete
Partition coefficient: no data available
Dynamic viscosity: no data available
Kinematic viscosity: no data available
Organic Content %age: no data available
Water %age: no data available
Solids Content %age: no data available
Other Informartion: no data available

10. STABILITY AND REACTIVITY

STABILITY: Stable
REACTIVITY: See sub-sections below.
POLYMERIZATION: Hazardous polymerization is not expected to occur under normal temperatures and pressures.
CONDITIONS TO AVOID: Elevated temperatures
POSSIBILITY OF HAZARDOUS REACTIONS: None expected.
INCOMPATIBLE MATERIALS: Water, Light metals, Alkali metals, Metals, Organic materials, Copper, reacts violently with:, vigorous reaction with:,
Halogens, Nitro compounds, Magnesium, Azides, Contact with aluminum, tin and zinc liberates hydrogen gas. Contact with nitromethane and other similar nitro compounds causes formation of shock-sensitive salts.

HAZARDOUS DECOMPOSITION MATERIALS: Other decomposition products - No data available
In the event of fire: see section 5 "

11. TOXICOLOGICAL INFORMATION

SKIN: Skin Corrosion/Irritation: Severely irritating., Skin Acute Toxicity: LD50(rabbit > 2000 mg/Kg
EYES: Severely irritating.
INHALATION: Not Determined
INGESTION: LD50(rat) > 5000 mg/Kg
CARCINOGENICITY
IARC: None of the components of this product are listed as a carcinogen by IARC, NTP, OSHA, or ACGIH.
NTP: None of the components of this product are listed as a carcinogen by IARC, NTP, OSHA, or ACGIH.
OSHA: None of the components of this product are listed as a carcinogen by IARC, NTP, OSHA, or ACGIH.
DERMAL TOXICITY: LD50(rabbit > 2000 mg/Kg
MUTAGENICITY: Not Determined
SENSITIZATION: Not Determined
TERATOGENICITY: Not Determined
REPRODUCTIVE EFFECTS: Not Determined
TARGET ORGAN EFFECTS: Not Determined
ADDITIONAL INFORMATION: no additional information

12. ENVIRONMENTAL INFORMATION

PRODUCT	TEST	DURATION	ORGANISM TYPE	TEST RESULTS
same as sds name	Fish- Acute Toxicity	96 hrs.	Rainbow Trout	>1100 mg/L
same as sds name	Invertebrates- Acute Toxicity	48 hrs.	Daphnia Magna	LC50: >1040 mg/L, EC50: no applicable data available
same as sds name	Plants- Acute Toxicity	96 hrs.	Marine algae	>50 MG/l

ECOTOXICITY: no applicable data available
BIOACCUMULATION: Not determined
PERSISTENCE DEGRADABILITY: Degradation is expected under aerobic and anaerobic conditions.
MOBILITY: Not determined
ENVIRONMENTAL DATA: no applicable data available

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: Dispose of in accordance with national, state and local regulations. It is the waste generator's responsibility to determine if a particular waste is hazardous under RCRA.
EMPTY CONTAINER: Empty Container Warning (Where applicable). Empty Containers may contain residue and can be dangerous. Do not attempt to refill or clean containers without proper instructions. Empty containers should be taken for recycling, recovery or disposal through suitably qualified or licensed contractor and in accordance with governmental regulations.
DISPOSAL INSTRUCTIONS: The generation of waste should be avoided or minimized wherever possible and should at all times comply with the requirements of evironmental protection and waste disposal legislation and any regional local authority requirements.
WASTE FROM RESIDUES / UNUSED PRODUCTS: For hazardous waste regulations call 800-424-9346, the RCRA Hotline.

CONTAMINATED PACKAGING: For hazardous waste regulations call 800-424-9346, the RCRA Hotline.

14. TRANSPORT INFORMATION

DOT (DEPARTMENT OF TRANSPORTATION)

PROPER SHIPPING NAME: SODIUM HYDROXIDE, SOLUTION,

TECHNICAL NAME: no applicable data available

PRIMARY HAZARD CLASS/DIVISION: 8,

UN/NA NUMBER: UN1824,

PACKING GROUP: PG II

NAERG: 154

LABEL: 8,

EMS NO: F-A, S-B

ADDITIONAL INFO: none

15. REGULATORY INFORMATION

UNITED STATES

TSCA (TOXIC SUBSTANCE CONTROL ACT)

TSCA STATUS: On the inventory, or in compliance with the inventory

US federal regulations

TSCA Section 12(b) Export Notification (40 CFR 707, Subpt. D)

US. OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050) no applicable data available

CERCLA Hazardous Substance List (40 CFR 302.4): NO

Superfund amendments and reauthorization act of 1986 (SARA)

SARA 302 Extremely hazardous substance NO

SARA 304 Emergency release notification no applicable data available

SARA 311/312 Hazardous chemical no applicable data available

SARA 313 (TRI reporting) NO

Clean Water Act Section 311 Hazardous Substances (40 CFR 117.3) no applicable data available

Clean Air Act (CAA) Section 112(r) Accidental Release Prevention (40 CFR 68.130):no applicable data available

US state regulations

US. California Proposition 65: NO

US. New Jersey Worker and Community Right-to-Know Act: no applicable data available

US. Massachusetts RTK - Substance List: no applicable data available

US. Pennsylvania RTK - Hazardous Substances: no applicable data available

US. Rhode Island RTK: no applicable data available

Inventory Status:

Europe REACH: On the inventory, or in compliance with the inventory

USA TSCA: On the inventory, or in compliance with the inventory

Canada DSL: On the inventory, or in compliance with the inventory

Australia AICS: On the inventory, or in compliance with the inventory

New Zealand NZIOC: On the inventory, or in compliance with the inventory

Japan ENCS: On the inventory, or in compliance with the inventory

Korea KECI: On the inventory, or in compliance with the inventory

Philippines PICCS: On the inventory, or in compliance with the inventory

China IECSC: On the inventory, or in compliance with the inventory

16. OTHER INFORMATION

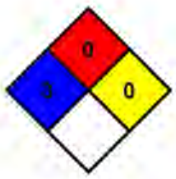
TITLE: EHS Management

PREPARED BY: FCT EHS and Compliance Dept.

HEALTH: 3

FIRE: 0

REACTIVITY: 0



MANUFACTURER SUPPLEMENTAL NOTES: no applicable data available

MANUFACTURER DISCLAIMER: The information contained herein is based on data believed to be accurate and is offered at no charge. No warranty is expressed or implied regarding the accuracy of this data. Liability is expressly disclaimed for loss or injury arising out of use of this information or the use of any materials designated. It is the user's responsibility for determining whether the product is suitable for its intended conditions of use.

Key or legend to abbreviations and acronyms used in the safety data sheet			
ACGIH	American Conference of Government Industrial Hygienists	LD50	Lethal Dose 50%
AICS	Australia, Inventory of Chemical Substances	LOAEL	Lowest Observed Adverse Effect Level
DSL	Canada, Domestic Substances List	NFPA	National Fire Protection Agency
NDSL	Canada, Non-Domestic Substances List	NIOSH	National Institute for Occupational Safety & Health
CNS	Central Nervous System	NTP	National Toxicology Program
CAS	Chemical Abstract Service	NZIoC	New Zealand Inventory of Chemicals
EC50	Effective Concentration	NOAEL	No Observable Adverse Effect
EC	Effective Concentration	NOAEL	No Observable Adverse Effect Level
EC50	Effective Concentration 50%	NOEC	No Observed Effect Concentration
EGEST	EOSCA Generic Exposure Scenario Tool	OSHA	Occupational Safety & Health Administration
EOSCA	European Oilfield Specialty Chemicals Association	PEL	Permissible Exposure Limit
EINECS	European Inventory of Existing Chemical Substances	PICCS	Philippines Inventory of Commercial Chemical Substances
MAK	Germany Maximum Concentration Values	PRNT	Presumed Not Toxic
GHS	Globally Harmonized System	RCRA	Resource Conservation Recovery Act
>=	Greater Than or Equal To	STEL	Short-term Exposure Limit
IC50	Inhibition Concentration 50%	SARA	Superfund Amendments and Reauthorization Act.
IARC	International Agency for Research on Cancer	TLV	Threshold Limit Value
IECSC	Inventory of Existing Chemical Substances in China	TWA	Time Weighted Average
ENCS	Japan, Inventory of Existing and New Chemical Substances	TSCA	Toxic Substance Control Ac
KECI	Korea, Existing Chemical Inventory	UVCB	Unknown or Variable Composition,Complex Reaction Products, and Biological Materials
<=	Less Than or Equal To	WHMIS	Workplace Hazardous Materials Information System
LC50	Lethal Concentration 50%		

SAFETY DATA SHEET

FCT Companies

Date Printed: 11/30/2018
Date Issued: 5/22/2015
Date Revised: 5/22/2015
Revision No: 1

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT CODE: BWT1300
PRODUCT TRADE NAME: BWT1300
COMMON NAMES/SYNONYMS: BWT1300 BOILER TREATMENT
CATEGORY: BT
RECOMMENDED USE: BOILER WATER TREATMENT, For industrial use only, refer to label and technical data sheet or call number below

MANUFACTURER	**24 HR. EMERGENCY TELEPHONE NUMBERS**
FCT 1309 North 17th Ave., Greeley, CO 80631, Phone 970-346-8002	800-535-5053

Emergency Contact: INFO TRAC
E-Mail: customerservice@floridacirtech.com
Emergency Phone: 800-535-5053
Alternate Emergency Phone: 800-686-6504

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

PHYSICAL APPEARANCE: Water white liquid
IMMEDIATE CONCERNS: Skin Corrosion/Irritation

POTENTIAL HEALTH EFFECTS

EYES: May cause eye irritation.
SKIN: Prolonged contact may cause mild skin irritation.
INGESTION: May cause nausea and vomitting. May cause irritation to the mouth, throat and stomach.
INHALATION: May cause physical discomfort to the respiratory tract.

UNCLASSIFIED HAZARDS: Use good industrial practices when handling. Avoid eye, skin, and clothing contact.
SIGNAL WORD: Warning
Potential Carcinogens as listed by OSHA, IARC, or NTP: NONE
OSHA HCS Status This material is NOT considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).
GHS Pictogram:

Hazard Statement(s)

Code	**Statement**	**GHS Chapter**	**Category**

Precautionary Statement(s)

P264	Wash skin thoroughly after handling.
P301+ P310	IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.
P330	Rinse mouth.
P501	Dispose of contents/ container to an approved waste disposal plant.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	Common Names	CAS	Weight %age
Sodium Bisulfite	Sodium Bisulfite	7631-90-5	20.00 % - 40.00 %

4. FIRST AID MEASURES

COMMON SYMPTOMS OF OVEREXPOSURE: No Applicable data available

EYES: Immediately flush with water for at least 15 minutes or until the chemical is removed. Get medical attention!

SKIN: Wash off immediately with soap and water. If clothing is contaminated, remove and launder before reuse.

INGESTION: If conscious, rinse mouth with water. Seek medical advice on whether to induce vomiting. Never give anything by mouth to an unconscious person. Get medical attention.

INHALATION: Move to fresh air. Get medical attention if symptoms occur.

NOTES TO PHYSICIAN: Follow usual and customary procedures

ADDITIONAL INFORMATION: No Applicable data available

COMMENTS: No Applicable data available

5. FIRE FIGHTING MEASURES

FLASH POINT AND METHOD: No applicable data available

FLAMMABLE LIMITS: LEL : No applicable data available UEL: No applicable data available

GENERAL HAZARD: As with any chemical fire, combustion products of unknown toxicity are always possible.

EXTINGUISHING MEDIA: Carbon dioxide, dry chemical, foam or water spray

FIRE FIGHTING EQUIPMENT: Vapors and fumes may be irritating and toxic. Firefighters should wear selfNo applicable data availablecontained breathing apparatus and full fireNo applicable data availablefighting turnout gear.

SENSITIVE TO STATIC DISCHARGE: No applicable data available

COMMENTS: Standard procedure for chemical fires.

6. ACCIDENTAL RELEASE MEASURES

SMALL SPILL: Absorb spilled liquid in a suitable material. Sweep or vacuum material into disposal containers.

LARGE SPILL: No data available

EMERGENCY PROCEDURES: For hazardous waste regulations call 800-424-9346, the RCRA Hotline. Personal precautions, protective equipment and emergency procedures: Evacuate area. Keep upwind of spill. Refer to section 7, Handling, for additional precautionary measures. Only trained and properly protected personnel must be involved in clean-up operations. Ventilate area of leak or spill. Use appropriate safety equipment. For additional information, refer to Section 8, Exposure Controls and personal protection.

GENERAL PROCEDURES: No data available

RELEASE NOTES: Collect as much as possible in a clean container for reuse (if not contaminated) or disposal (if contamintated). Prevent from entering into soil, ditches, sewers, waterways and/or ground water. See section 12 Ecological information.

SPECIAL PROTECTIVE EQUIPMENT: Isolate area. Use appropriate safety equipment. For additional information, refer to section 8, Exposure Controls and Personal Protection.

COMMENTS: See also section 13 for disposal information.

7. HANDLING AND STORAGE

HANDLING: Use good industrial practices when handling. Avoid eye, skin, and clothing contact. Do not inhale mist or vapors. Do not taste or swallow. Use only with adequate ventilation.

STORAGE: Keep container closed when not in use. Avoid elevated and freezing temperatures.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Chemical Name	OSHA PEL	OSHA STEL	ACGIH TWA	ACGIH STEL
Sodium Bisulfite	5 mg/m3	NE	5 mg/m3	NE

ENGINEERING CONTROLS: Work in well ventilated areas. Do not breathe vapors or mist. Ensure that existing ventilation is sufficient to prevent the circulation and/or accumulation of vapors in the air.

PERSONAL PROTECTIVE EQUIPMENT:

EYES AND FACE: Eye protection such as chemical splash goggles and/or face shield must be worn when possibility exists for eye contact due to splashing or spraying liquid, airborne particles, or vapor.

SKIN: Wear nitrile or latex gloves. Wear protective clothing.

RESPIRATORY: Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multipurpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

WORK HYGIENIC PRACTICES: Discard contaminated gloves after use. Have eye-wash facilities in the immediate vicinity. Work in adequately ventilated area. Do not breathe vapors or mist. Minimize any contact with any chemical.

COMMENTS: Eye wash station and safety shower should be available in immediate work area. To identify additional Personal Protective Equipment (PPE) requirements, it is recommended that a hazard assessment, in accordance with the OSHA PPE Standard (29 CFR 1910.132), be conducted before using this product.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance Form: Liquid
Appearance Color: Light yellow
Odor: Pungent
Odor Threshold: Not Determined
pH-value @ 68 °F: 4-6
Melting point: Not Determined
Boiling Point: >200 F
Flash Point: Non Flammable
Flammability: no data available
Ignition temperature: no data available
Auto Igniting: no data available
Danger of explosion: no data available
Explosion Lower Limit: NE
Explosion Upper Limit: NE
Vapor pressure @ 68 °F: 77 mg Hg at 20 C
Relative Density: 1.27
Vapor Density: >1
Evaporation Rate: Not Determined
Solubility in Water: Complete
Partition coefficient: no data available
Dynamic viscosity: no data available

Kinematic viscosity: no data available
Organic Content %age: no data available
Water %age: no data available
Solids Content %age: no data available
Other Informartion: no data available

10. STABILITY AND REACTIVITY

STABILITY: Stable
REACTIVITY: See sub-sections below
POLYMERIZATION: Hazardous polymerization is not expected to occur under normal temperatures and pressures.
CONDITIONS TO AVOID: Elevated temperatures
POSSIBILITY OF HAZARDOUS REACTIONS: None expected.
INCOMPATIBLE MATERIALS: Strong alkalis, strong oxidizing and reducing agents
HAZARDOUS DECOMPOSITION MATERIALS: Carbon Dioxide, Carbon Monoxide and HCl gas

11. TOXICOLOGICAL INFORMATION

SKIN: Skin Corrosion/Irritation: Mildly irritating., Skin Acute Toxicity: Not Determined
EYES: Severely irritating.
INHALATION: Not Determined
INGESTION: LD50(rat) = 2000 mg/Kg
CARCINOGENICITY
IARC: None of the components of this product are listed as a carcinogen by IARC, NTP, OSHA, or ACGIH.
NTP: None of the components of this product are listed as a carcinogen by IARC, NTP, OSHA, or ACGIH.
OSHA: None of the components of this product are listed as a carcinogen by IARC, NTP, OSHA, or ACGIH.
DERMAL TOXICITY: Not Determined
MUTAGENICITY: One of the components of this product is considered a mutagen.
SENSITIZATION: Not a skin sensitizer. Lung sensitizer
TERATOGENICITY: None
REPRODUCTIVE EFFECTS: None
TARGET ORGAN EFFECTS: Not Determined
ADDITIONAL INFORMATION: no additional information.

12. ENVIRONMENTAL INFORMATION

PRODUCT	TEST	DURATION	ORGANISM TYPE	TEST RESULTS
same as sds name	Fish- Acute Toxicity	96 hrs.	Mosquito Fish	240 ppm

ECOTOXICITY: no applicable data available
BIOACCUMULATION: No appreciable bioaccumulation is expected.
PERSISTENCE DEGRADABILITY: Degradation is expected under aerobic and anaerobic conditions.
MOBILITY: Not determined
ENVIRONMENTAL DATA: no applicable data available

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: Dispose of in accordance with national, state and local regulations. It is the waste generator's responsibility to determine if a particular waste is hazardous under RCRA.

EMPTY CONTAINER: Empty Container Warning (Where applicable). Empty Containers may contain residue and can be dangerous. Do not attempt to refill or clean containers without proper instructions. Empty containers should be taken for recycling, recovery or disposal through suitably qualified or licensed contractor and in accordance with governmental regulations.

DISPOSAL INSTRUCTIONS: The generation of waste should be avoided or minimized wherever possible and should at all times comply with the requirements of evironmental protection and waste disposal legislation and any regional local authority requirements.

WASTE FROM RESIDUES / UNUSED PRODUCTS: For hazardous waste regulations call 800-424-9346, the RCRA Hotline.

CONTAMINATED PACKAGING: For hazardous waste regulations call 800-424-9346, the RCRA Hotline.

14. TRANSPORT INFORMATION

DOT (DEPARTMENT OF TRANSPORTATION)

PROPER SHIPPING NAME: BISULFITES, AQUEOUS SOLUTIONS, N.O.S. (SODIUM BISULFITE),

TECHNICAL NAME: no applicable data available

PRIMARY HAZARD CLASS/DIVISION: 8,

UN/NA NUMBER: UN2693,

PACKING GROUP: PGIII

NAERG: 154

LABEL: 8,

EMS NO: F-A,S-B

ADDITIONAL INFO: none

15. REGULATORY INFORMATION

UNITED STATES

TSCA (TOXIC SUBSTANCE CONTROL ACT)

TSCA STATUS: On the inventory, or in compliance with the inventory

US federal regulations

TSCA Section 12(b) Export Notification (40 CFR 707, Subpt. D)

US. OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050) no applicable data available

CERCLA Hazardous Substance List (40 CFR 302.4): YES RQ=5000

Superfund amendments and reauthorization act of 1986 (SARA)

SARA 302 Extremely hazardous substance NO

SARA 304 Emergency release notification no applicable data available

SARA 311/312 Hazardous chemical no applicable data available

SARA 313 (TRI reporting) NO

Clean Water Act Section 311 Hazardous Substances (40 CFR 117.3) no applicable data available

Clean Air Act (CAA) Section 112(r) Accidental Release Prevention (40 CFR 68.130):no applicable data available

US state regulations

US. California Proposition 65: NO

US. New Jersey Worker and Community Right-to-Know Act: no applicable data available

US. Massachusetts RTK - Substance List: no applicable data available

US. Pennsylvania RTK - Hazardous Substances: no applicable data available

US. Rhode Island RTK: no applicable data available

Inventory Status:

Europe REACH: On the inventory, or in compliance with the inventory

USA TSCA: On the inventory, or in compliance with the inventory

Canada DSL: On the inventory, or in compliance with the inventory

Australia AICS: On the inventory, or in compliance with the inventory

New Zealand NZIOC: On the inventory, or in compliance with the inventory

Japan ENCS: On the inventory, or in compliance with the inventory

Korea KECI: On the inventory, or in compliance with the inventory

Philippines PICCS: On the inventory, or in compliance with the inventory

China IECSC: On the inventory, or in compliance with the inventory

16. OTHER INFORMATION

TITLE: EHS Management

PREPARED BY: FCT EHS and Compliance Dept

HEALTH: 2

FIRE: 0

REACTIVITY: 0

MANUFACTURER SUPPLEMENTAL NOTES: no applicable data available

MANUFACTURER DISCLAIMER: The information contained herein is based on data believed to be accurate and is offered at no charge. No warranty is expressed or implied regarding the accuracy of this data. Liability is expressly disclaimed for loss or injury arising out of use of this information or the use of any materials designated. It is the user's responsibility for determining whether the product is suitable for its intended conditions of use.

Key or legend to abbreviations and acronyms used in the safety data sheet			
ACGIH	American Conference of Government Industrial Hygienists	LD50	Lethal Dose 50%
AICS	Australia, Inventory of Chemical Substances	LOAEL	Lowest Observed Adverse Effect Level
DSL	Canada, Domestic Substances List	NFPA	National Fire Protection Agency
NDSL	Canada, Non-Domestic Substances List	NIOSH	National Institute for Occupational Safety & Health
CNS	Central Nervous System	NTP	National Toxicology Program
CAS	Chemical Abstract Service	NZIoC	New Zealand Inventory of Chemicals
EC50	Effective Concentration	NOAEL	No Observable Adverse Effect
EC	Effective Concentration	NOAEL	No Observable Adverse Effect Level
EC50	Effective Concentration 50%	NOEC	No Observed Effect Concentration
EGEST	EOSCA Generic Exposure Scenario Tool	OSHA	Occupational Safety & Health Administration
EOSCA	European Oilfield Specialty Chemicals Association	PEL	Permissible Exposure Limit
EINECS	European Inventory of Existing Chemical Substances	PICCS	Philippines Inventory of Commercial Chemical Substances
MAK	Germany Maximum Concentration Values	PRNT	Presumed Not Toxic
GHS	Globally Harmonized System	RCRA	Resource Conservation Recovery Act
>=	Greater Than or Equal To	STEL	Short-term Exposure Limit
IC50	Inhibition Concentration 50%	SARA	Superfund Amendments and Reauthorization Act.

IARC	International Agency for Research on Cancer	TLV	Threshold Limit Value
IECSC	Inventory of Existing Chemical Substances in China	TWA	Time Weighted Average
ENCS	Japan, Inventory of Existing and New Chemical Substances	TSCA	Toxic Substance Control Ac
KECI	Korea, Existing Chemical Inventory	UVCB	Unknown or Variable Composition,Complex Reaction Products, and Biological Materials
<=	Less Than or Equal To	WHMIS	Workplace Hazardous Materials Information System
LC50	Lethal Concentration 50%		

SAFETY DATA SHEET

FCT Companies

Date Printed: 11/30/2018
Date Issued: 1/17/2018
Date Revised: 1/17/2018
Revision No: 1

1. PRODUCT AND COMPANY IDENTIFICATION

PRODUCT CODE: BWT3340
PRODUCT TRADE NAME: BWT3340
COMMON NAMES/SYNONYMS: BWT3340
CATEGORY: BWT
RECOMMENDED USE: Neutralizing Amine, For industrial use only, refer to label and technical data sheet or call number below

MANUFACTURER
FCT
1309 North 17th Ave., Greeley, CO 80631, Phone 970-346-8002

24 HR. EMERGENCY TELEPHONE NUMBERS
800-535-5053

Emergency Contact: INFO TRAC
E-Mail: customerservice@floridacirtech.com
Emergency Phone: 800-535-5053
Alternate Emergency Phone: 800-686-6504

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

PHYSICAL APPEARANCE: Clear liquid

IMMEDIATE CONCERNS: Skin Corrosion/Irritation

POTENTIAL HEALTH EFFECTS

EYES: Causes severe irritation (tears, blurred vision and redness) May result in permanent eye damage.

SKIN: Causes severe skin irritation and tissue damage.

INGESTION: Causes damage to mouth, throat and stomach.

INHALATION: May cause physical discomfort to the respiratory tract.

UNCLASSIFIED HAZARDS: Use good industrial practices when handling. Avoid eye, skin, and clothing contact.

SIGNAL WORD: Danger

Potential Carcinogens as listed by OSHA, IARC, or NTP: NONE

OSHA HCS Status This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

GHS Pictogram:

Hazard Statement(s)

Code	Statement	GHS Chapter	Category
H301	Toxic if swallowed	Acute toxicity, oral (chapter 3.1)	3
H311	Toxic in contact with skin	Acute toxicity, dermal (chapter 3.1)	3
H314	Causes severe skin burns and eye damage	Skin corrosion/irritation (chapter 3.2)	1A, 1B, 1C
H318	Causes serious eye damage	Serious eye damage/eye irritation (chapter 3.3)	1

H361	Suspected of damaging fertility or the unborn child	Reproductive toxicity (chapter 3.7)	2
H402	Harmful to aquatic life	Hazardous to the aquatic environment, acute toxicity (chapter 4.1)	3

Precautionary Statement(s)

P201	Obtain special instructions before use.
P202	Do not handle until all safety precautions have been read and understood.
P233	Keep container tightly closed.
P261	Avoid breathing dust/fume/gas/mist/vapours/spray.
P264	Wash skin thoroughly after handling.
P270	Do not eat, drink or smoke when using this product.
P273	Avoid release to the environment.
P280	Wear protective gloves/protective clothing/eye protection/face protection
P281	Use personal protective equipment as required.
P301+ P310	IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.
P301+P330 + P331	IF SWALLOWED: rinse mouth. Do NOT induce vomiting.
P303+ P361 + P353	IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304+ P340	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P305+ P351 + P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P308+ P313	IF exposed or concerned: Get medical advice/attention.
P403+ P235	Store in a well-ventilated place. Keep cool.
P405	Store locked up.
P501	Dispose of contents/ container to an approved waste disposal plant.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Chemical Name	Common Names	CAS	Weight %age
Morpholine	Morpholine	110-91-8	5.00 % - 20.00 %
Cyclohexylamine	Cyclohexylamine	108-91-8	5.00 % - 20.00 %
Diethylaminoethanol	Diethylaminoethanol	100-37-8	5.00 % - 20.00 %

4. FIRST AID MEASURES

COMMON SYMPTOMS OF OVEREXPOSURE: No Applicable data available

EYES: Immediately flush with water for at least 15 minutes or until the chemical is removed.

SKIN: Wash off immediately with large amounts of water. Get medical attention if irritation develops. If clothing is contaminated, remove and launder before reuse.

INGESTION: Do not induce vomiting. Never give anything by mouth to an unconscious person. Get immediate medical attention.

INHALATION: Move to fresh air. Remove any contaminated clothing. If breathing is difficult, administer oxygen. Get medical attention.

NOTES TO PHYSICIAN: Follow usual and customary procedures

ADDITIONAL INFORMATION: No Applicable data available

COMMENTS: No Applicable data available

5. FIRE FIGHTING MEASURES

FLASH POINT AND METHOD: No applicable data available

FLAMMABLE LIMITS: LEL : No applicable data available UEL: No applicable data available

GENERAL HAZARD: As with any chemical fire, combustion products of unknown toxicity are always possible.

EXTINGUISHING MEDIA: Carbon dioxide, dry chemical, foam or water spray.

FIRE FIGHTING EQUIPMENT: Vapors and fumes may be irritating and toxic. Firefighters should wear self contained breathing apparatus and full firefighting turnout gear.

SENSITIVE TO STATIC DISCHARGE: No applicable data available

COMMENTS: Standard procedure for chemical fires.

6. ACCIDENTAL RELEASE MEASURES

SMALL SPILL: Neutralize spilled material. Pump spilled liquid into disposal container.

LARGE SPILL: No data available

EMERGENCY PROCEDURES: For hazardous waste regulations call 800-424-9346, the RCRA Hotline. Personal precautions, protective equipment and emergency procedures: Evacuate area. Keep upwind of spill. Refer to section 7, Handling, for additional precautionary measures. Only trained and properly protected personnel must be involved in clean-up operations. Ventilate area of leak or spill. Use appropriate safety equipment. For additional information, refer to Section 8, Exposure Controls and personal protection.

GENERAL PROCEDURES: No data available

RELEASE NOTES: Collect as much as possible in a clean container for reuse (if not contaminated) or disposal (if contamintated). Prevent from entering into soil, ditches, sewers, waterways and/or ground water. See section 12 Ecological information.

SPECIAL PROTECTIVE EQUIPMENT: Isolate area. Use appropriate safety equipment. For additional information, refer to section 8, Exposure Controls and Personal Protection.

COMMENTS: See also section 13 for disposal information.

7. HANDLING AND STORAGE

HANDLING: Use good industrial practices when handling. Avoid eye, skin, and clothing contact. Do not inhale mist or vapors. Do not taste or swallow. Use only with adequate ventilation.

STORAGE: Keep container closed when not in use. Avoid elevated and freezing temperatures.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Chemical Name	OSHA PEL	OSHA STEL	ACGIH TWA	ACGIH STEL
Morpholine	20 ppm	30 ppm	20 ppm	NE
Cyclohexylamine	10 ppm	NE	10 ppm	NE
Diethylaminoethanol	10 ppm	NE	2 ppm	NE

ENGINEERING CONTROLS: Work in well ventilated areas. Do not breathe vapors or mist. Ensure that existing ventilation is sufficient to prevent the circulation and/or accumulation of vapors in the air.

PERSONAL PROTECTIVE EQUIPMENT:

EYES AND FACE: Eye protection such as chemical splash goggles and/or face shield must be worn when possibility exists for eye contact due to splashing or spraying liquid, airborne particles, or vapor.

SKIN: Wear nitrile or latex gloves. Wear protective clothing.

RESPIRATORY: Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multipurpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

WORK HYGIENIC PRACTICES: Discard contaminated gloves after use. Have eye-wash facilities in the immediate vicinity. Work in adequately ventilated area. Do not breathe vapors or mist. Minimize any contact with any chemical.

COMMENTS: Eye wash station and safety shower should be available in immediate work area. To identify additional

Personal Protective Equipment (PPE) requirements, it is recommended that a hazard assessment, in accordance with the OSHA PPE Standard (29 CFR 1910.132), be conducted before using this product.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance Form: Liquid
Appearance Color: clear to yellow
Odor: Amine
Odor Threshold: Not Established
pH-value @ 68 °F: >12
Melting point: Not Determined
Boiling Point: Not Determined
Flash Point: no data available
Flammability: no data available
Ignition temperature: no data available
Auto Igniting: no data available
Danger of explosion: no data available
Explosion Lower Limit: NE
Explosion Upper Limit: NE
Vapor pressure @ 68 °F: no data available
Relative Density: .99
Vapor Density: no data available
Evaporation Rate: Not Determined
Solubility in Water: Complete
Partition coefficient: no data available
Dynamic viscosity: no data available
Kinematic viscosity: no data available
Organic Content %age: no data available
Water %age: no data available
Solids Content %age: no data available
Other Informartion: no data available

10. STABILITY AND REACTIVITY

STABILITY: Stable
REACTIVITY: See sub-sections below.
POLYMERIZATION: Hazardous polymerization is not expected to occur under normal temperatures and pressures.
CONDITIONS TO AVOID: Heat, sparks, open flames
POSSIBILITY OF HAZARDOUS REACTIONS: None expected.
INCOMPATIBLE MATERIALS: Strong oxidizing agents, Strong acids, Copper, Zinc, Iron, Do not store near acids
HAZARDOUS DECOMPOSITION MATERIALS: Thermal decomposition may generate toxic and corrosive fumes of carbon oxides"

11. TOXICOLOGICAL INFORMATION

SKIN: Skin Corrosion/Irritation: Severely irritating., Skin Acute Toxicity: Not Determined
EYES: Severely irritating.
INHALATION: Not Determined

INGESTION: Not Determined

CARCINOGENICITY

IARC: None of the components of this product are listed as a carcinogen by IARC, NTP, OSHA, or ACGIH.

NTP: None of the components of this product are listed as a carcinogen by IARC, NTP, OSHA, or ACGIH.

OSHA: None of the components of this product are listed as a carcinogen by IARC, NTP, OSHA, or ACGIH.

DERMAL TOXICITY: Not Determined

MUTAGENICITY: Not Determined

SENSITIZATION: Not Determined

TERATOGENICITY: Not Determined

REPRODUCTIVE EFFECTS: Not Determined

TARGET ORGAN EFFECTS: Not Determined

ADDITIONAL INFORMATION: no additional information

12. ENVIRONMENTAL INFORMATION

PRODUCT	TEST	DURATION	ORGANISM TYPE	TEST RESULTS

ECOTOXICITY: no applicable data available

BIOACCUMULATION: No appreciable bioaccumulation is expected.

PERSISTENCE DEGRADABILITY: Degradation is expected under aerobic and anaerobic conditions.

MOBILITY: Appreciable volitilization is expected from water to air.

ENVIRONMENTAL DATA: no applicable data available

13. DISPOSAL CONSIDERATIONS

DISPOSAL METHOD: Dispose of in accordance with national, state and local regulations. It is the waste generator's responsibility to determine if a particular waste is hazardous under RCRA.

EMPTY CONTAINER: Empty Container Warning (Where applicable). Empty Containers may contain residue and can be dangerous. Do not attempt to refill or clean containers without proper instructions. Empty containers should be taken for recycling, recovery or disposal through suitably qualified or licensed contractor and in accordance with governmental regulations.

DISPOSAL INSTRUCTIONS: The generation of waste should be avoided or minimized wherever possible and should at all times comply with the requirements of evironmental protection and waste disposal legislation and any regional local authority requirements.

WASTE FROM RESIDUES / UNUSED PRODUCTS: For hazardous waste regulations call 800-424-9346, the RCRA Hotline.

CONTAMINATED PACKAGING: For hazardous waste regulations call 800-424-9346, the RCRA Hotline.

14. TRANSPORT INFORMATION

DOT (DEPARTMENT OF TRANSPORTATION)

PROPER SHIPPING NAME: Amines, liquid, corrosive, n.o.s. (Cyclohexylamine, Diethylaminoethanol),

TECHNICAL NAME: no applicable data available

PRIMARY HAZARD CLASS/DIVISION: 8,

UN/NA NUMBER: UN2735,

PACKING GROUP: PGII

NAERG: 153

LABEL: 8,

EMS NO: F-A, S-B

ADDITIONAL INFO: none

15. REGULATORY INFORMATION

UNITED STATES

TSCA (TOXIC SUBSTANCE CONTROL ACT)

TSCA STATUS: On the inventory, or in compliance with the inventory

US federal regulations

TSCA Section 12(b) Export Notification (40 CFR 707, Subpt. D)

US. OSHA Specifically Regulated Substances (29 CFR 1910.1001-1050) no applicable data available

CERCLA Hazardous Substance List (40 CFR 302.4): NO

Superfund amendments and reauthorization act of 1986 (SARA)

SARA 302 Extremely hazardous substance YES RQ=10000, Cyclohexylamine

SARA 304 Emergency release notification no applicable data available

SARA 311/312 Hazardous chemical no applicable data available

SARA 313 (TRI reporting) NO

Clean Water Act Section 311 Hazardous Substances (40 CFR 117.3) no applicable data available

Clean Air Act (CAA) Section 112(r) Accidental Release Prevention (40 CFR 68.130):no applicable data available

US state regulations

US. California Proposition 65: NO

US. New Jersey Worker and Community Right-to-Know Act: no applicable data available

US. Massachusetts RTK - Substance List: no applicable data available

US. Pennsylvania RTK - Hazardous Substances: no applicable data available

US. Rhode Island RTK: no applicable data available

Inventory Status:

Europe REACH: On the inventory, or in compliance with the inventory

USA TSCA: On the inventory, or in compliance with the inventory

Canada DSL: On the inventory, or in compliance with the inventory

Australia AICS: On the inventory, or in compliance with the inventory

New Zealand NZIOC: On the inventory, or in compliance with the inventory

Japan ENCS: On the inventory, or in compliance with the inventory

Korea KECI: On the inventory, or in compliance with the inventory

Philippines PICCS: On the inventory, or in compliance with the inventory

China IECSC: On the inventory, or in compliance with the inventory

16. OTHER INFORMATION

TITLE: EHS Management

PREPARED BY: FCT EHS and Compliance Dept.

HEALTH: 3

FIRE: 1

REACTIVITY: 0

MANUFACTURER SUPPLEMENTAL NOTES: no applicable data available

MANUFACTURER DISCLAIMER: The information contained herein is based on data believed to be accurate and is offered at no charge. No warranty is expressed or implied regarding the accuracy of this data. Liability is expressly disclaimed for loss or injury arising out of use of this information or the use of any materials designated. It is the user's responsibility for determining whether the product is suitable for its intended conditions of use.

Key or legend to abbreviations and acronyms used in the safety data sheet			
ACGIH	American Conference of Government Industrial Hygienists	LD50	Lethal Dose 50%
AICS	Australia, Inventory of Chemical Substances	LOAEL	Lowest Observed Adverse Effect Level
DSL	Canada, Domestic Substances List	NFPA	National Fire Protection Agency
NDSL	Canada, Non-Domestic Substances List	NIOSH	National Institute for Occupational Safety & Health
CNS	Central Nervous System	NTP	National Toxicology Program
CAS	Chemical Abstract Service	NZIoC	New Zealand Inventory of Chemicals
EC50	Effective Concentration	NOAEL	No Observable Adverse Effect
EC	Effective Concentration	NOAEL	No Observable Adverse Effect Level
EC50	Effective Concentration 50%	NOEC	No Observed Effect Concentration
EGEST	EOSCA Generic Exposure Scenario Tool	OSHA	Occupational Safety & Health Administration
EOSCA	European Oilfield Specialty Chemicals Association	PEL	Permissible Exposure Limit
EINECS	European Inventory of Existing Chemical Substances	PICCS	Philippines Inventory of Commercial Chemical Substances
MAK	Germany Maximum Concentration Values	PRNT	Presumed Not Toxic
GHS	Globally Harmonized System	RCRA	Resource Conservation Recovery Act
>=	Greater Than or Equal To	STEL	Short-term Exposure Limit
IC50	Inhibition Concentration 50%	SARA	Superfund Amendments and Reauthorization Act
IARC	International Agency for Research on Cancer	TLV	Threshold Limit Value
IECSC	Inventory of Existing Chemical Substances in China	TWA	Time Weighted Average
ENCS	Japan, Inventory of Existing and New Chemical Substances	TSCA	Toxic Substance Control Ac
KECI	Korea, Existing Chemical Inventory	UVCB	Unknown or Variable Composition,Complex Reaction Products, and Biological Materials
<=	Less Than or Equal To	WHMIS	Workplace Hazardous Materials Information System
LC50	Lethal Concentration 50%		

24. APPENDIX U: CEP LANDFILL DISPOSAL AGREEMENT

Office of General Counsel Use Only
Approved for signature: ☐Procurement Services ☑Division of Administration ☐Other ____________
Employee/Independent Contractor Determination Checklist needed? ☑Yes ☐No

Paula Whaley 7-11-17
Signature Date

AGREEMENT FOR SERVICES
BETWEEN
THE UNIVERSITY OF WYOMING
AND
TDS COLLECTION SERVICES INC.

1. Parties. This Agreement is made and entered into by and between the University of Wyoming (hereinafter "University") and TDS Collection Services Inc., a corporation, institution of higher education] (hereinafter "Contractor"), whose address is 1122 S. Main, Torrington, WY 82240.

2. Purpose. The University, in the exercise of its lawful duties, has determined that the services of Contractor are necessary to the performance of its duties as the State of Wyoming's educational institution. The University has concluded that either its personnel are not available to perform said function, or it would not be feasible to utilize its personnel to perform said function.

3. Term. This Agreement shall commence upon July 1, 2017, and shall remain in full force and effect until June 30, 2018. The University may, under the provisions of this Agreement, grant up to two (2), one (1) year annual extensions of time for a maximum period of no longer than three (3) years which shall be set forth as a written Amendment to this Agreement.

4. Termination.

A. The University can terminate this Agreement without cause, upon ten (10) days prior written notice.

B. Termination of this Agreement shall not relieve a party from its obligations incurred prior to the termination date. Upon early termination of this Agreement by the University, except in the case of a material breach by Contractor, the University shall pay all costs accrued by the Contractor as of the date of termination. In the event of termination, all work product prepared by the Contractor shall be immediately surrendered to the University.

5. Payment. The University of Wyoming agrees to pay the unit prices listed in Exhibit A for the services described herein. The total payment under this Agreement shall not exceed $25,000. Payment shall be made monthly, upon invoice, or whatever is appropriate]. Payment shall be made from the 1100 budget/account.

6. Reporting. Contractor shall report to and keep Richard Allen informed of the progress of his/her work on a monthly basis.

7. Services. Contractor will perform the services described in the attached Exhibit A, which is incorporated herein.

8. General Provisions

A. **Amendments.** Either party may request changes in this Agreement. Any changes, modifications, revisions or amendments to this Agreement which are mutually agreed upon shall be incorporated by written instrument, executed and signed by all parties to this Agreement.

B. **Applicable Laws.** Both parties shall fully adhere to all applicable local, state and federal law, including equal employment opportunity and including but not limited to compliance with Title VI of the Civil Rights Act of 1964, Title IX of the Education Amendments of 1972, Section 504 of the Rehabilitation Act of 1973, the Age Discrimination Act of 1975 and the Americans with Disabilities Act of 1990. The University's policy has been, and will continue to be, one of nondiscrimination, offering equal opportunity to all employees and applicants for employment on the basis of their demonstrated ability and competence without regard to such matters as race, gender, color, religion, national origin, disability, age, veteran status, sexual orientation, genetic information, political belief, or other status protected by state and federal statutes or University Regulations.

C. **Assignment.** Without prior written consent of the other party, neither party may assign this Agreement. This Agreement shall inure to the benefit of, and be binding upon, permitted successors and assigns of the parties.

D. **Availability of Funds.** Payment by the University is conditioned upon the availability of government funds which are appropriated or allocated for the payment of this obligation. The University will pay for services rendered before giving the other party notice of the unavailability of funds. If funds are not allocated and available for the continuance of the services, the Agreement may be terminated by the University at the end of the period for which the funds are available. The University shall notify the other party at the earliest possible time of the services which will or may be affected by a shortage of funds. No penalty shall accrue to the University in the event this provision is exercised, and the University shall not be obligated or liable for any future payments due or for any damages as a result of termination under this section. This provision shall not be construed to permit the University to terminate this Agreement to acquire similar services from another party.

E. **Entirety of Agreement.** This Agreement represents the entire and integrated agreement between the parties and supersedes all prior negotiations, representations and agreements, whether written or oral.

F. **Governmental Claims.** Any actions or claims against the University under this Agreement must be in accordance with and are controlled by the Wyoming Governmental Claims Act, W.S. 1-39-101 et seq. (1977) as amended.

G. **Indemnification.** Contractor agrees to defend, indemnify and hold harmless the University and its public employees from any and all claims arising from the services performed under this Agreement or related to this Agreement.

H. **Independent Contractor.** Contractor is acting as an independent contractor. This Agreement does not commit the University to the traditional role of employer. The University is not responsible for the payment of withholding taxes, unemployment insurance, workers' compensation insurance, social security, pensions, retirement fees, licenses or other fees. Such costs are the responsibility of the Contractor.

I. **Insurance.** Contractor shall carry liability insurance including coverage for property damage, personal injury, contractual liability, completed and on-going operations, and bodily injury with no exclusion for pollution or environmental impairment liability and with minimum limits of not less than $1,000,000 occurrence and $2,000,000 aggregate. If Contractor will use automobiles in performance of the Agreement, Contractor must carry automobile liability insurance covering all owned, non-owned and hired autos with minimum limits of $500,000 $1,000,000 combined single limit and no exclusion for pollution or environmental impairment liability. Contractor must carry any workers' compensation coverage and employer's stop gap liability coverage required by law. Insurance shall be placed with insurers licensed to do business in Wyoming. Policies other than workers' compensation and employer's liability must name the University, its trustees, officers, and employees as additional insureds. Certificates must be on file with University Risk Management prior to any work and must be kept current throughout the term of the Agreement.

J. **Interpretation.** The construction, interpretation and enforcement of this Agreement shall be governed by the laws of the State of Wyoming. The courts of the State of Wyoming shall have jurisdiction over any action arising out of this Agreement and over the parties, and the venue shall be the Second Judicial District, Albany County, Wyoming.

K. **Notices.** All notices and other correspondence related to this Agreement shall be in writing and shall be effective when delivered by: (i) certified mail with return receipt, (ii) hand delivery with signature or delivery receipt provided by a third party courier service (such as FedEx, UPS, etc.), (iii) fax transmission if verification of receipt is obtained, or (iv) email with return receipt, to the designated representative of the party as indicated below. A party may change its designated representative for notice purposes at any time by written notice to the other party. The initial representatives of the parties are as follows:

To University:
Richard Allen
University of Wyoming
1000 E. University Ave, Dept. 3227
Laramie, WY 82071

To Contractor:
Tammy Exley
TDS Collection Services Inc.
1122 South Main
Torrington, WY 82240

A copy of any notice concerning a breach, alleged breach, or dispute arising under this Agreement shall also be sent to:
Office of the General Counsel
Department 3434
1000 E. University Avenue
Laramie, Wyoming 82071-2000

L. **Prior Approval.** This Agreement shall not be binding upon either party unless this Agreement has been reduced to writing before performance begins as described under the terms of this Agreement, and unless this Agreement is approved as to form by the Office of General Counsel.

M. **Severability.** Should any portion of this Agreement be judicially determined to be illegal or unenforceable, the remainder of the Agreement shall continue in full force and effect.

N. **Sovereign Immunity.** The University does not waive its sovereign or governmental immunity by entering into this Agreement, and fully retains all immunities and defenses provided by law with respect to any action based on or occurring as a result of this Agreement.

O. **Third Party Beneficiary Rights.** The parties do not intend to create in any other individual or entity the status of third party beneficiary, and this Agreement shall not be construed so as to create such status. The rights, duties and obligations contained in this Agreement shall operate only between the parties to this Agreement, and shall inure solely to the benefit of the parties to this Agreement. The provisions of this Agreement are intended only to assist the parties in determining and performing their obligations under this Agreement. The parties to this Agreement intend and expressly agree that only parties signatory to this Agreement shall have any legal or equitable right to seek to enforce this Agreement, to seek any remedy arising out of a party's performance or failure to perform any term or condition of this Agreement, or to bring an action for the breach of this Agreement.

P. **Legal Authority**. Each party to this Agreement warrants that it possesses the legal authority to enter into this Agreement and that it has taken all actions required by its regulations, procedures, bylaws, and/or applicable law to exercise that authority, and to lawfully authorize its undersigned signatory to execute this Agreement and to bind it to its terms. The person(s) executing this Agreement on behalf of a party warrant(s) that such person(s) have full authorization to execute this Agreement.

9. Signatures. In witness whereof, the parties to this Agreement through their duly authorized representatives have executed this Agreement on the days and dates set out below, and certify that they have read, understood, and agreed to the terms and conditions of this Agreement as set forth herein.

APPROVED BY:

University of Wyoming	**Contractor**
William Mai 7/11/17	07/17/17
Signature Date	Signature Date
William Mai	Kurt Sittner
Name	Name
Vice President for Administration	Operations Manager
Title	Title

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Updated January 28, 2014

Exhibit A

1. Contractor shall be responsible for performing the following duties:

   Ash Disposal: Contractor shall accept and dispose of coal combustion residue (ash and clinkers) from University property at TDS's land farm facility near Torrington, WY. The University will arrange for delivery of the ash to TDS's facility near Torrington, WY. TDS shall accept, dispose and/or land farm ash in accordance with applicable state and federal regulations.

   Ash Hauling (Optional): Contractor may also, with the University's prior authorization, transport coal combustion residue from the University of Wyoming's Central Energy Plant and deliver it to TDS's land farm facility near Torrington, WY for disposal. The Contractor shall coordinate and schedule ash haulage with the plant manager. Normal hours for haulage will be between the hours of 7:00 A.M. and 3:00 P.M. with exceptions only by prior arrangements. The Contractor shall provide proper haul vehicles to prevent dust loss in transit. Ash is contained in a 78-ton live storage silo fitted with a dustless rotary ash unloader and bin fluidizer sized for 30 tons per hour. Trailers shall be covered with a tarp, without holes or gaps, except for 3 flaps for ash placement. University staff and equipment will be used to load haul trucks.

   The Contractor shall take ownership of the ash when it is loaded into his vehicles. The Contractor shall attend to all details of the disposal of ash and hold the Owner free from all liability in connection with ash transportation and disposal. Ash shall be transported and land farmed in accordance with applicable state and federal regulations.

2. Contractor shall be entitled to reimbursement in accordance with UW Regulation 3-177 and applicable Wyoming law for the following expenses incurred as a result of the performance of the above-described duties. This reimbursement, if any, is in addition to the payment described under section 5 unless otherwise agreed to in the Agreement. If expenses will not be reimbursed, state so below.

   Payment for ash disposal shall be per the following unit prices:
   - Disposal @ $15.00 per ton,
   - Scale charge @ $9 per truck.

   Keys will be provided for weekend delivery and there will be no cost difference for weekend delivery.

   Optional ash hauling shall be paid for per the following unit prices:
   - Trucks = $95.00 per hour, including truck, driver, and fuel,
   - Fuel surcharge will be based on Current Market Price, attached fuel surcharge chart, and roundtrip mileage,
   - Drivers after 8 hours = $84.00 per hour.

AMENDMENT NUMBER 1 TO AGREEMENT FOR SERVICES BETWEEN UNIVERSITY AND CONTRACTOR TDS COLLECTION SERVICES INC.

Amendment Number 1 to the Agreement for Services between University and Contractor ("Amendment No. 1") is dated effective as of the later of **May 9, 2018,** or date fully executed by both parties ("Effective Date"), and is entered into by and between The University of Wyoming ("University"), an agency and institution of higher education organized under the laws of the State of Wyoming, and TDS Collection Services, ("Contractor").

University and Contractor entered into that certain Agreement for Services dated effective July 17, 2017 ("Agreement").

University and Contractor now desire to amend the terms of the Agreement as more particularly set forth below:

1. Article 3 - Term
   "3.a. – The term of this agreement shall remain in full force and effect until June 30, 2019. The University may, under the provisions of this Agreement, grant up to one (1), one (1) year annual extension of time for a maximum period of no longer than three (3) years which shall be set forth as a written Amendment to this Agreement."

2. Article 5- Payment
   "5.a. – The University of Wyoming agrees to pay the unit prices listed in Exhibit A for the services described herein. The total payment under this Agreement for FY 2019 (July 1, 2018 - June 30, 2019) shall not exceed $30,000.00. Payment shall be made monthly upon receipt of an approved invoice."

3. Article 8- General Provisions
   "8.K. – Designated Representative for University shall be as follows:
   Forrest Selmer, fselmer@uwyo.edu
   University of Wyoming
   1000 E University Avenue, Dept 3227
   Laramie, WY 82071."

4. Exhibit A
   Section 2, Paragraph 2, shall be amended and hereafter read as follows:
   "Payment for ash disposal shall be per the following unit prices for FY 2019 (July 1, 2018 – June 30, 2019):
   - Disposal @ $20.00/TON
   - Scale Charge @ $9.00/truck."

5. Except as provided in this Amendment No. 1, all terms used in this Amendment that are not otherwise defined shall have the respective meanings ascribed to such terms in the Agreement.

6. This Amendment No. 1 embodies the entire agreement between University and Contractor with respect to the amendment of the Agreement. In the event of any conflict or inconsistency between the provisions of the Agreement and this Amendment No. 1, the provisions of this Amendment No. 1 shall control and govern.

7. Except as specifically modified and amended herein, all of the terms, provisions, requirements and specifications contained in the Agreement remain in full force and effect. Except as otherwise expressly provided herein, the parties do not intend to, and the execution of this Amendment shall not, in any manner impair the Agreement, the purpose of this Amendment No. 1 being simply to amend and ratify the Agreement, as hereby amended and ratified, and to confirm and carry forward the Agreement, as hereby amended, in full force and effect.

8. This Amendment No. 1 shall be governed by the laws of the State of Wyoming.

IN WITNESS WHEREOF, University and Contractor have executed and delivered this Amendment effective as of the Effective Date.

TRUSTEES OF THE UNIVERSITY OF WYOMING	**TDS COLLECTION SERVICES INC.**
DocuSigned by: William Mai 89242AE0198C483	, Oper. Mgr.
Vice President for Administration Deputy Treasurer Board of Trustees	Signature/Title
5/11/2018	05/10/18
Date	Date