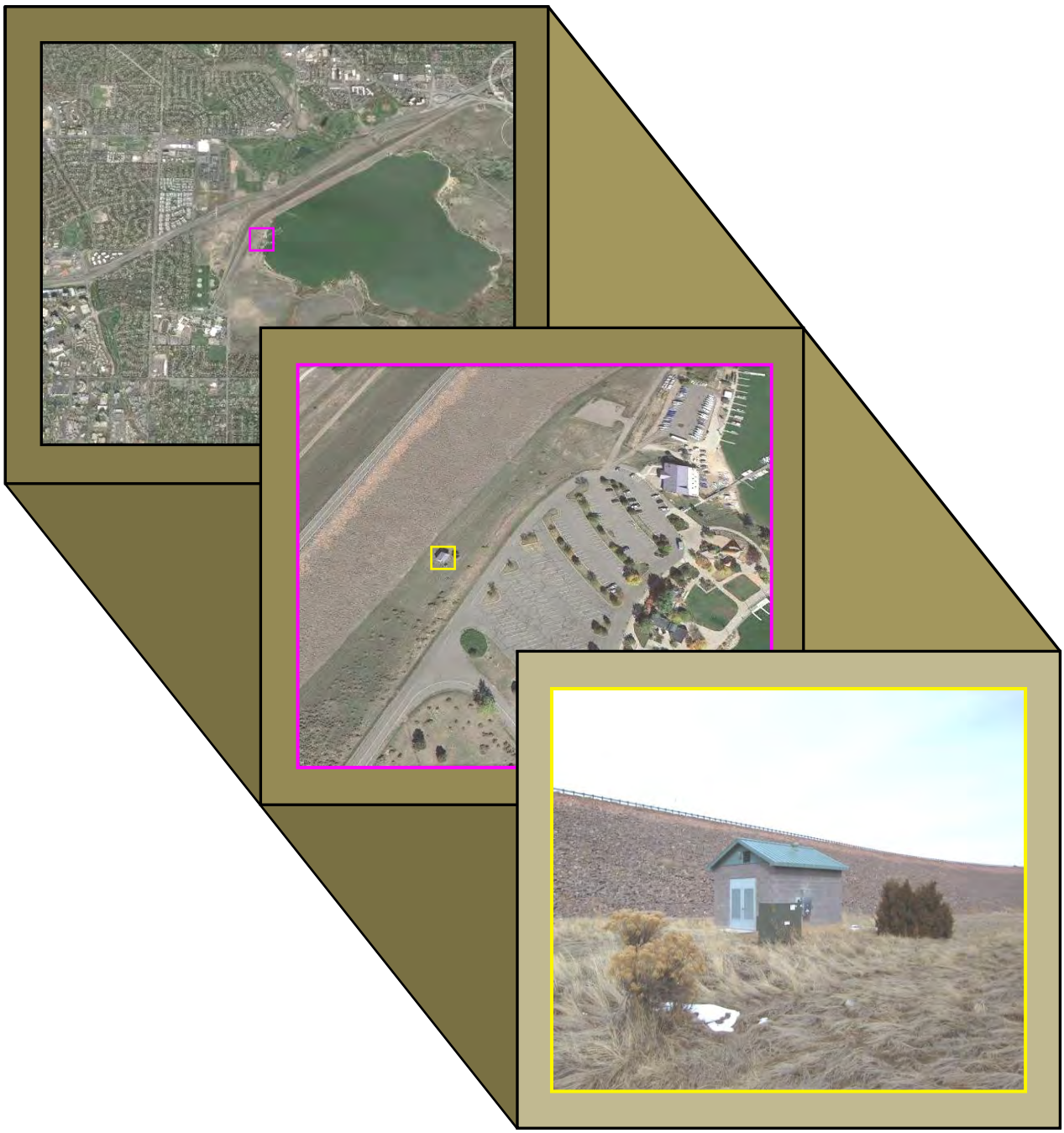
CHERRY CREEK RESERVOIR
DESTRATIFICATION FACILITIES

OPERATION AND MAINTENANCE
ANNUAL REPORT
2016



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CHERRY CREEK BASIN WATER QUALITY AUTHORITY

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INTRODUCTION:

JRS Engineering Consultant LLC was retained under the "Capital Projects Consultant" contract to operate, and coordinate maintenance of, the destratification system including the compressor and aeration system commonly referred to as the Cherry Creek Reservoir Destratification Facilities. This is the ninth consecutive year for operation of the facilities.

START-UP PROCEDURE AND OPERATING POLICY HISTORY/UPDATE:

Prior to the beginning of the 2014 operating season, the Authority reviewed the prior year's Reservoir Destratification System operating policies and procedures in light of reservoir data collected from system operations for the years from 2008 through 2013. Data collected during this time period (2008 through 2013) indicates that the destratification system provides two primary benefits. One is the reduction in the dominance of blue-green algae as part of the whole algal assemblage and the second is the reduction in the periods when the reservoir is thermally stratified during the summer.[1]

The data further suggested that operating the aeration system in early spring did not significantly affect blue-green algae (i.e.: cyanobacteria) growth, since the primary cyanobacteria growth period is from June through September when water temperatures are warmer[2]. The aeration system additionally provides destratification of the reservoir reducing the tendency for the reservoir to "turn over" bringing up anoxic water and higher concentrations of nutrients from the reservoir floor. The data from 2008 through 2013 suggested that the reservoir begins to stratify in late-April to mid-May.

After review of the data, it was concluded that operation of the destratification system, beginning in 2014, shall be modified as follows:

a. System start-up shall occur between the dates of May 1st and May 10th.
b. System shut-down shall occur between the dates of November 1st and November 15th.

Additionally, operation of the destratification system shall be limited to those times when ice is not present on the reservoir, except under specific scenarios. The "Operation Policy Regarding Ice" policy adopted by the Authority's Board on February 20, 2014 is included in Appendix A. The "Destratification System Compressor Start-up Procedure" approved by the Authority's Technical Advisory Committee on April 3, 2014 is included in Appendix B.

[1] CCBWQA January 28, 2013. *Compressor Design Basis - Daily Operation,* William P. Ruzzo, P.E., Craig Wolf, GEI.
[2] GEI, Consultants, Inc. January 2014. *Cherry Creek Reservoir 2013 Water Year Aquatic Biological Nutrient Monitoring Study and Cottonwood Creek Pollutant Reduction Facilities Monitoring.*

2016 START-UP:

As noted in the 2013 Reservoir Destratification System Operation and Maintenance Annual Report, the compressor shut down unexpectedly on October 22, 2013. The compressor motor had seized up and required replacement. Prior to the anticipated system start-up date, installation of a new electric motor for the compressor was completed on April 17, 2014.

Prior to the start of the 2014 operation of the destratification season, a question surfaced regarding whether, or not, the system should be started to allow for reservoir data to be collected with the destratification system in non-operational mode. This would provide additional water quality data to be collected for the in-progress reservoir modeling effort currently underway. The Authority's Technical Advisory Committee took this question under advisement and at their May 1, 2014 meeting recommended to the Authority's Board that the system not operate during the 2014 season. The Authority's Board, at their May 15, 2014 meeting, approved a change in the Destratification Operating Policy such that the system not be placed into operation for the entire 2014 season.

The Authority's Technical Advisory Committee (TAC) took the question of whether the destratification system should operate in 2015 under advisement at their February 5, 2015 meeting and recommended to the Authority's Board that the system not operate during the 2015 season. The Authority's Board, at their February 19, 2015 meeting, approved TAC's recommendation to not operate the destratification system for the entire 2015 season.

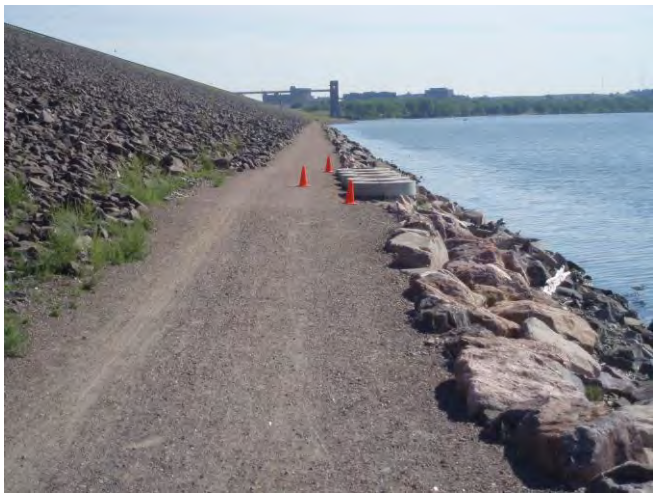
The Authority's Technical Advisory Committee (TAC) took the question of whether the destratification system should operate in 2016 under advisement at their April 7, 2016 meeting and recommended to the Authority's Board that the system not operate during the 2016 season. The Authority's Board, at their April 21, 2016 meeting, approved TAC's recommendation to not operate the destratification system for the entire 2016 season.

It was recommended by Power Service Inc., the compressor maintenance contractor, that the new motor and compressor operate periodically during the operating season to maintain it in a "ready state" condition incase operation was required. During operation of the compressor, air was blown-off to the atmosphere at the five aeration manholes, located on the north shore of the reservoir.

OPERATION PERIOD / INSPECTIONS:

The compressor exercise (periodic system operations) was conducted during the summer and fall of 2016, for varying lengths of time and at various "Unload" and "Load" air pressure settings.

Prior to each compressor exercise operation an email was sent to Authority representatives, Cherry Creek State Park representatives and the Marina operator, notifying them that the compressor would be exercised that day and air would be blown off to the atmosphere. Since this "blow off" is noisy and located adjacent to the dam trail (now open across the face of the dam for Park users) three orange cones were placed adjacent to the manholes directing trail users to the dam side of the trail. See photo.



The orange cones were set up each time the system was operated. The valves in the

manholes were adjusted prior to each operation so that each was exercised regularly and all compressed air was discharged through a selected aeration zone manhole blow-off. The orange cones were picked up following each system exercise.

The initial compressor exercise was performed on Thursday, June 2, 2016 at 12:00 PM. The table in Appendix C - 2016 Aeration Equipment Data Log summarizes the operating data recorded each time the system was operated during the destratification system exercise program.

Prior to the equipment start-up, the electrical voltage was checked at the compressor. The amperage draw was checked during the compressor operation as well. This information is recorded on the table in Appendix D - 2016 Compressor Electrical Monitoring Log.

EQUIPMENT REPAIRS AND MAINTENANCE:

ROUTINE SERVICE:

Since the compressor was exercised once a week for a short duration of time during the 2016 destratification system exercise program, regular maintenance to the compressor was deferred to 2017. Aerator inspection, cleaning and maintenance of the in-lake system was performed in 2015. The summary is included in Appendix E - 2016 Aeration System Maintenance Summary.

ELECTRICAL USAGE / RATE SCHEDULE:

During the 2016 destratification system operation season, the Xcel electrical rate schedule continued through the destratification system exercise program under Schedule SGL.

Schedule SG (Secondary General Service) includes higher monthly demand charges and lower kilowatt usage rates. Operation under this billing rate schedule is more economical when operating the destratification system continuously.

Schedule SGL (Secondary General Low-load Factor) includes lower monthly demand charges and higher kilowatt usage rates. Operation under this billing rate schedule is more economical when operating the destratification system in the exercise mode.

The customer service representative from Xcel stated that since the Authority operates the system seasonally, there isn't an issue with changing from one rate schedule to the other during the year to "best fit" the system's seasonal operation. A paragraph will be added to the Destratification System Compressor Start-up Procedure, during its next update, to outline the procedure to establish the Authority's billing rate schedule to the optimum rate schedule for the system's operational status.

RECOMMENDATIONS:

The following recommendations are provided for consideration to improve system operation:

- Determine if the destratification system should operate in 2017 and if so what that operation procedure should be.
- Perform routine service to the compressor in spring of 2017.

APPENDIX A - OPERATION POLICY REGARDING ICE

Cherry Creek Basin Water Quality Authority

Cherry Creek Reservoir Destratification System
Operation Policy Regarding Ice
Board Adopted Version

February 20, 2014

Operation of the Cherry Creek Reservoir Destratification System shall be limited to those times when ice is not present on the Reservoir, except under the following scenario:

- System Start-up before ice is off the Reservoir if either:
  1. The Authority has determined that doing so is in the best interest of the Authority to assist in protection of the constructed Pollutant Reduction Facilities (PRF's)[1].
  2. The Park Manager has determined that doing so is in the best interest of the Park to assist in protecting the Park facilities such as the marina, constructed PRF's, other Park improvements or the unprotected shoreline. Or, has determined that doing so would alleviate a dangerous condition/situation for Park users[2].

All start-up and shut-down notifications, decisions, procedures, detail, dates and conditions shall be documented in the Destratification Facilities - Operation and Maintenance Annual Report.

Start-up of the destratification system each year shall be performed in accordance with the "Compressor Start-up Procedures".

The Authority, at its sole discretion, may shut the destratification system down at any time during the aeration season if, or when, there is no water quality benefit to continued operation.

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[1] *If floating ice is observed on the Reservoir and it is believed that constructed PRF's will be damaged by the ice, the Authority, authorizes the Authority Manager after consultation with the Authority's engineering, water quality and legal consultant, and the TAC chair, to make the determination on start-up. Prior to start-up of the destratification system, the notification procedures outlined in the "Compressor Start-up Procedure" shall be completed and documented in writing (by email, letter or fax). All start-up decisions, detail and notifications shall be documented and included in the annual report. Board and TAC members shall be notified by email if the system is started under this condition.*

[2] *If the Park Manager notifies the Authority, in writing (by email, letter or fax), that starting the system while ice is on the Reservoir is in the best interest of the Park, the Authority Manager, with assistance of the Authority engineering and water quality consultants, will confirm that water quality conditions are satisfactory prior to start-up. The Park Manager shall then perform the notification procedures outlined in the "Compressor Start-up Procedure" and provide copies of the written notifications to the Authority Manager. All written notifications shall state the Reservoir conditions and concern prompting the request. Parks shall assist the Authority to confirm no persons are on the ice when the system is started. Once the ice condition is no longer an issue as determined by the Park Manager, the Authority, at its sole discretion, may elect to shut the destratification system down.*

APPENDIX B - DESTRATIFICATION SYSTEM COMPRESSOR START-UP PROCEDURE

CHERRY CREEK BASIN WATER QUALITY AUTHORITY

CHERRY CREEK RESERVOIR DESTRATIFICATION SYSTEM

COMPRESSOR START-UP PROCEDURE

March 25, 2014

Start-up Criteria:

Operation of the Cherry Creek Reservoir Destratification System shall be in accordance with the terms, conditions and policy set forth in the Destratification System - Operation Policy Regarding Ice; adopted by the Authority's Board on February 20, 2014. This policy requires that operation of the system be limited to those times when ice is not present on the Reservoir, except when early start-up is determined necessary as outlined in the operation policy.

An on-site inspection shall be conducted by the Authority's System Operator to verify that ice is not present on the Reservoir prior to start-up. In the event that early start-up is required while ice is on the reservoir, the Authority's System Operator shall confirm that all notifications, responses and other details are completed in accordance with the Destratification System - Operation Policy Regarding Ice. The Authority's System Operator shall then log the detail of the start-up procedure in the Cherry Creek Reservoir Destratification Facilities Operation and Maintenance Annual Report.

Start-up Procedure:

The system shall be started, following the pre-start system check outlined in the Operation and Maintenance Manual, utilizing the soft-start procedure as follows:

> *Starting the system shall be accomplished by opening up one aeration zone at a time with some interval (i.e.: 2 to 4-hours) before opening the next zone. A soft start also includes a lower than normal unload / load pressure for start-up of the initial zone (typically 45.0 psi / 39.0 psi) and then increasing the pressure when each additional zone is brought on-line, over the start-up period as necessary to cause bubbles to rise to the surface, until the unload / load pressure reaches 52.0 psi / 48.0 psi with all five zones operating.*

Start-up / Shut-down Schedule:

System start-up shall occur between the dates of May 1st and May 10th to provide the system operator flexibility in scheduling the start-up, unless early start-up is required.

System shut-down shall occur between the dates of November 1st and November 15th.

Start-up Conditions with Ice on the Reservoir:

When it becomes necessary to operate the system before ice is off the Reservoir then three conditions need to be considered during start up:

1. The rising bubbles may bring anoxic water from the bottom to the surface *under the ice*, trapping the fish in an unsafe habitat. Past experience has shown that by using the “soft start” approach, which starts the aeration lines one at a time under or near open water areas, then a hazardous fish environment was not created. Dissolved Oxygen profile information will be provided and analyzed as a part of the start-up procedure.
2. Starting the system prior to March 1 potentially creates problems for CCSP. The aquatic nuisance control program (i.e.: zebra and quagga mussel inspection) requires that all boats be inspected, which begins on March 1st.
3. Starting the system while ice is present on the Reservoir requires written notification to the following parties and written confirmation of their concurrence to start the system while ice is on the Reservoir. All written notifications and confirmations shall be in the form of email, fax or letter.
   - *Cherry Creek State Park (CCSP) Park Manager.*
   - *Colorado Parks and Wildlife (CPW) Sr. Aquatic Biologist; Platte Basin.*
   - *Marina Operator.*
   - *Cherry Creek Basin Water Quality Authority Manager.*

Memorandum

To: CCBWQA Technical Advisory Committee and Destratification Sub-committee
From: James R. Swanson, PE- JRS Engineering Consultant, LLC, William P. Ruzzo, PE, LLC
Date: March 18, 2014
Subject: Destratification System Compressor Start-up Procedure

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Presented in the memorandum is a summary of the Authority's destratification system compressor start-up procedure, discussion of prior years practice, review and discussion of the water quality data from prior year's operation and resulting start-up procedure modifications to optimize water quality conditions and system operating efficiency.

Background:
The destratification system consists of a rotary screw air compressor, piping and 116 air diffusers placed at the floor of the deepest part of the reservoir. The system works by pumping air into the bottom of the reservoir providing mixing and oxygenation of the water. The Authority began operation of the destratification system on April 4, 2008. Prior to initial start-up in 2008, it was determined the aeration system would be operated for as long of a season as practical, typically from approximately March 1st through the end of November[1]. In doing so, continued water quality data monitoring developed a consistent baseline from which to evaluate, and predict, the benefits of operating the aeration system and to manage various water quality parameters within the reservoir. Specific start-up and shut-down dates were previously determined annually based on the Reservoir water quality data, weather patterns, ice cover and other factors.

It was found the destratification system needed to operate for approximately two weeks to attain full development of the water column circulation pattern, thereby reducing thermal stratification.

Data collected during this time period (2008 through 2013) indicates that the destratification system provides two primary benefits. One is the reduction in the dominance of blue-green algae as part of the whole algal assemblage and the second is the reduction in the periods when the reservoir is thermally stratified during the summer.[2]

Data Results and Trends:
Water quality data collected from 2008 through 2013 suggests that operating the aeration system in early spring does not significantly affect blue-green algae (i.e.: cyanobacteria) growth, since the primary cyanobacteria growth period is from June through September when water temperatures are warmer[3]. A summary of this data is attached. Cyanobacteria are generally most active at temperature ranges above 15° C, which makes them most active in the summer months. This trend is supported by comparing chlorophyll a concentrations for pre and post-aeration system conditions, as shown in the attached data. Also, the daily maximum ambient temperatures near the reservoir are generally below 15° C from October through April (see attached data) providing further support for a later season system start date.

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[1] March 1 is the start of the boating season. Allowing boater access to the Reservoir before March 1 required Parks to have their safety and ANS (Aquatic Nuisance Species, such as Quagga and Zebra mussels) inspection personnel in place sooner, which potentially created an administrative problem. Starting the system before March 1 could clear the ice cover on the Reservoir and allow boaters to launch before Parks was ready.

[2] CCBWQA January 28, 2013. *Compressor Design Basis - Daily Operation,* William P. Ruzzo, P.E., Craig Wolf, GEI.

[3] GEI, Consultants, Inc. January 2014. *Cherry Creek Reservoir 2013 Water Year Aquatic Biological Nutrient Monitoring Study and Cottonwood Creek Pollutant Reduction Facilities Monitoring.*

The aeration system additionally provides destratification of the reservoir reducing the tendency for the reservoir to "turn over" bringing up anoxic water and higher concentrations of nutrients from the reservoir floor. The data from 2008 through 2013 suggests that the reservoir begins to stratify in late-April to mid-May. This varies from year-to-year, typically caused by an influx of snowmelt in the early spring and/or cold rainfall in the warm summer months causing temperature stratifications. It is noted that the aeration system is effective in minimizing stratification within the reservoir.

Conclusions:

1. The aeration system should be operational on, or about, May 15th to minimize the dominance of the blue-green algae (cyanobacteria) growth in the reservoir.

2. The aeration system should be started on, or about, May 1st to provide a fully developed water column circulation pattern by mid-May.

3. Operation of the destratification system beyond mid-November isn't supported by ambient temperature or algal population data for cyanobacteria or diatoms.

In summary, operation of the destratification system shall be modified as follows:

a. System start-up shall occur between the dates of May 1st and May 10th.
b. System shut-down shall occur between the dates of November 1st and November 15th.

APPENDIX C - 2016 AERATION EQUIPMENT OPERATING DATA LOG

APPENDIX C - 2016 AERATION EQUIPMENT OPERATING DATA LOG

DATE	DAY OF WEEK	TIME OF DAY	DAILY RUNTIME[1]	ELECTRIC METER KWHRS		UNIT HOURS				LOAD RELAY COUNTS (X1000)		UNIT STARTS	TEMPERATURE; DEGREES FAHRENHEIT (°F)					OUTLET PRESSURE	
			MINUTES	READING	USAGE	RUNNING	ELAPSED	LOADED	ELAPSED	TOTAL	ELAPSED		OUTSIDE	AMBIENT	OUTLET	ELEMENT	OIL	UNLOAD	LOAD
2-Jun	Thursday	12:00 PM	57	47626		35196		15332		4992		557	76	75	101	450	149		45.0
15-Jun	Wednesday	7:00 AM	100	47628	2	35198	2	15333	1	4992	0	559	66	79	93	450	142	48.0	45.0
27-Jun	Monday	7:15 AM	76	47631	3	35200	2	15334	1	4993	1	560	74	79	97	490	149	48.0	46.0
12-Jul	Tuesday	7:30 AM	122	47635	4	35202	2	15335	1	4993	0	561	78	84	101	484	157	50.0	46.0
26-Jul	Tuesday	10:45 AM	67	47640	5	35203	1	15336	1	4993	0	562	88	96	103	458	154	50.0	46.0
12-Aug	Friday	7:00 AM	270	47642	2	35207	4	15338	2	4993	0	563	80	81	102	489	152	50.0	46.0
26-Aug	Friday	7:30 AM	172	47650	8	35210	3	15340	2	4994	1	564	69	96	92	482	147	50.0	46.0
2-Sep	Friday	7:10 AM	238	47655	5	35214	4	15342	2	4994	0	565	74	79	97	490	157	50.0	46.0
14-Sep	Wednesday	9:40 AM	78	47662	7	35215	1	15343	1	4994	0	566	62	68	84	462	136	50.0	46.0
26-Sep	Monday	8:00 AM	215	47665	3	35219	4	15345	2	4995	1	567	72	78	97	479	154	50.0	46.0
3-Oct	Monday	7:30 AM	176	47672	7	35222	3	15346	1	4995	0	568	75	81	97	480	152	50.0	46.0
17-Oct	Monday	7:45 AM	163	47677	5	35224	2	15347	1	4995	0	569	50	72	85	479	142	51.0	46.0

Footnote 1 - Daily Runtime recoreded by Mission Controller.

APPENDIX D - 2016 ELECTRICAL MONITORING LOG

APPENDIX D - 2016 COMPRESSOR ELECTRICAL MONITORING LOG

DATE	DAY OF WEEK	MOTOR VOLTAGE						MOTOR AMPERAGE						OUTLET PRESSURE	
								LOADING			UNLOADING				
		L_1 - G	L_2 - G	L_3 - G	L_1 - L_2	L_1 - L_3	L_2 - L_3	L1	L2	L3	L1	L2	L3	UNLOAD	LOAD
2-Jun	Thursday	289	289	289	499	500	500	117	109	114	69	64	66	48.0	45.0
15-Jun	Wednesday	286	285	286	495	495	499	116	111	115	69	65	66	48.0	45.0
27-Jun	Monday	285	284	286	494	495	494	118	112	116	70	64	65	50.0	46.0
12-Jul	Tuesday	285	286	287	497	496	494	120	115	120	70	65	68	50.0	46.0
26-Jul	Tuesday	288	287	289	498	498	497	116	115	117	70	67	67	50.0	46.0
12-Aug	Friday	285	284	285	493	492	492	121	115	104	65	66	57	50.0	46.0
26-Aug	Friday	287	286	287	496	495	494	123	117	121	71	67	68	50.0	46.0
2-Sep	Friday	286	285	286	494	495	494	121	117	119	71	67	66	50.0	46.0
14-Sep	Wednesday	287	285	287	496	497	495	122	117	121	71	66	68	50.0	46.0
26-Sep	Monday	288	287	289	498	498	497	123	117	122	72	67	69	50.0	46.0
3-Oct	Monday	288	287	286	497	498	496	118	115	116	71	68	66	50.0	46.0
17-Oct	Monday	287	287	287	496	495	496	119	117	120	70	67	68	50.0	46.0

APPENDIX E - 2016 AERATION SYSTEM MAINTENANCE SUMMARY

[No maintenance was performed in 2016]