

TECHNICAL MEMORANDUM

Results of Cyanobacteria and Microcystin Monitoring in the Vicinity of the Klamath Hydroelectric Project

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Date: September 23, 2016



Introduction

This technical memorandum summarizes the results for the 2016 public health monitoring for cyanobacteria species and an associated toxin, microcystin, within PacifiCorp's Klamath Hydroelectric Project (Project) from Upper Klamath Lake to the Klamath River below Iron Gate Dam. Microcystin results from 2016 baseline monitoring are also included in the results summaries below. This monitoring is particularly focused on *Microcystis aeruginosa* (MSAE), which is known to produce microcystin. This monitoring also assesses the presence of other potentially-toxigenic cyanobacteria, including *Dolichospermum* sp., and others. Monitoring is being conducted pursuant to Interim Measure 15, Water Quality Monitoring Activities, contained in the Klamath Hydroelectric Settlement Agreement (KHSAs) executed between the United States Department of Interior, the states of California and Oregon, PacifiCorp, and other parties.

Results from the baseline and public health sampling are used in coordination with the appropriate public health authority to determine if public health advisories are warranted^{1,2}. In addition to PacifiCorp's website (www.pacificorp.com/es/hydro/hl/kr.html#), these memos are also posted on the Klamath Basin Monitoring Program's (KBMP) website (www.kbmp.net) and inform the Blue Green Algae tracker on the KBMP website.

The data in Appendix 1 and Appendix 2 summarize results from all of the 2016 public health sampling events to date and microcystin results from the 2016 baseline sampling events.

¹ The California State Water Resources Control Board (SWRCB) provides guidelines for posting advisories in recreation water (California SWRCB 2016) for Project waters in California. SWRCB recommends posting advisories in recreation waters at three levels based on laboratory testing for microcystin. The posting levels are Caution, Warning, and Danger at microcystin concentrations of 0.8, 6, and 20 µg/L respectively. Toxin producing cells at concentrations of over 4,000 cells/ml or blooms, scums, or mats would result in posting at the Caution level.

² Postings of Project waters in Oregon are coordinated with the Oregon Health Authority (OHA; 2016). The health advisory guideline in Oregon waters is microcystin concentrations of 10 µg/L or more, over 100,000 cells/mL of all toxigenic species combined, or over 40,000 cells/mL of *Microcystis* spp. or *Planktothrix* spp.

Methods

PacifiCorp and the Oregon Department of Environmental Quality (ODEQ) are conducting public health sampling at ten sites (Table 1). Samples are collected and sent for laboratory analysis of potentially toxigenic cyanobacteria, notably MSAE and microcystin, from sites at:

- Three shoreline sites in Upper Klamath Lake, Oregon
- One shoreline site in Keno Reservoir, Oregon
- One shoreline site in J.C. Boyle Reservoir, Oregon
- Four shoreline sites in coves in Copco and Iron Gate reservoirs (i.e., two cove sites in each reservoir), California
- One Klamath River site below Iron Gate Dam near the hatchery bridge, California

Table 1. Sites of cyanobacteria and microcystin public health monitoring in Upper Klamath Lake, Keno Reservoir, J.C Boyle Reservoir, Copco Reservoir, Iron Gate Reservoir, and the Klamath River during 2016.			
Location	Approximate River Mile	Sampling Entity	Site ID
Upper Klamath Lake at Eagle Ridge County Park	N/A	ODEQ	UKEP
Upper Klamath Lake at Howard's Bay Park	N/A	ODEQ	UKHP
Upper Klamath Lake at Moore Park	N/A	ODEQ	UKMP
Keno Reservoir at Keno Park	234.0	ODEQ	KEKP
J.C. Boyle Reservoir at Topsy Campground	225.0	ODEQ	BRTC
Copco Reservoir at Mallard Cove	201.5	PacifiCorp	CRMC
Copco Reservoir at Copco Cove	200.0	PacifiCorp	CRCC
Iron Gate Reservoir at Camp Creek	192.8	PacifiCorp	IRCC
Iron Gate Reservoir at John Williams Campground	192.4	PacifiCorp	IRJW
Klamath River below Iron Gate dam near Hatchery Bridge	189.7	PacifiCorp	KRBI

Samples are planned to be taken at shoreline locations in the reservoirs once in May and twice per month in June, July, August, September, October, and November. Samples to be collected from the river site below Iron Gate Dam are scheduled to be collected according to the discretion of the sampling entity (PacifiCorp) based on river conditions.

In addition to public health sampling, monthly and bi-monthly baseline sampling for microcystin is conducted by PacifiCorp and the U.S. Bureau of Reclamation (BOR) from May through October at 14 locations extending from Link Dam to below Iron Gate Reservoir (Table 2).

Table 2. Sites of microcystin baseline monitoring in J.C. Boyle, Copco, and Iron Gate reservoirs and the Klamath River during 2016.				
Site Description	Approximate River Mile	Depth (m)	Sampling Entity	Site ID
Link Dam	254.4	0.5	BOR	KR254.4
Keno Reservoir at Miller Island	246.0	0.5	BOR	KR246.0
Klamath River below Keno Dam near a USGS Gage	231.8	0.5	BOR	KBK
Klamath River above JC Boyle Reservoir	228.2	0.5	PacifiCorp	KR22822
JC Boyle Reservoir at Log Boom (surface)	224.8	0.5	PacifiCorp	KR22478
Klamath River below JC Boyle Reservoir	224.6	0.5	PacifiCorp	KR22460
Klamath River at USGS Gage	219.5	0.5	PacifiCorp	KR21950
Klamath River above Shovel Creek	206.4	0.5	PacifiCorp	KR20642
Copco Reservoir at Buoy Line (surface)	198.7	0.5	PacifiCorp	KR19874
Copco Reservoir at Buoy Line (integrated)	198.7	0-8	PacifiCorp	KR19874
Klamath River below Copco 2 Reservoir	196.5	0.5	PacifiCorp	KR19645
Iron Gate Reservoir at Log Boom (surface)	190.2	0.5	PacifiCorp	KR19019
Iron Gate Reservoir at Log Boom (integrated)	190.2	0-8	PacifiCorp	KR19019
Klamath River below Hatchery Bridge	189.7	0.5	PacifiCorp	KR18973

Public health samples are taken as grab samples offshore according to the standard operating procedure (SOP) developed by the Klamath Blue Green Algae Working Group (www.kbmp.net/collaboration/klamath-hydroelectric-settlement-agreement-monitoring). Samples collected for potentially toxic phytoplankton are preserved in Lugol's solution and sent to Aquatic Analysts in Friday Harbor, Washington for analysis. The samples are labeled "Rush" for timely analysis and only potentially toxic cyanobacteria are identified and enumerated. However, once a reservoir or river reach is posted with health advisories signs, the samples are collected but not rushed until it visually appears that the algae bloom conditions have waned. Results for cyanobacteria species are reported as individual cells per milliliter.

Samples for determination of microcystin toxin are placed in a cooler on ice and shipped to the U.S. Environmental Protection Agency (EPA) Region 9 Laboratory in Richmond, California. The samples are analyzed using the competitive Enzyme-Linked ImmunoSorbent Assay (ELISA) method based on the EnviroLogix QuantiPlate Kit for microcystins through June 22, 2016 and the Abraxis Kit thereafter. For samples analyzed through June 22, 2016 the detection limit for microcystin using this method was 0.15 µg/L or parts per billion (ppb) while the quantitation limit was 0.18 µg/L or ppb. For samples analyzed after June 22, 2016, the detection limit was to 0.10 µg/L and the quantification limit was 0.15 µg/L. This test method does not distinguish between the specific microcystin congeners, but detects their presence to differing degrees. That is, ELISA test results yield one value as the sum of measurable microcystin variants.

Results

All public health samples (Table 3) were collected as planned. One baseline microcystin sample (KR16155) was collected on 9/21/16 because the site was not accessible on 9/5/2016. All other baseline

microcystin samples were collected as planned (Tables 4 and 5). Appendix 3 includes the raw phytoplankton results for the samples reported in Table 3.

Table 3. Summary of available public health laboratory algal identification and enumeration and microcystin results from sampling August 8, 2016 through September 13, 2016.

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth	MSAE ⁽¹⁾	AFA ⁽²⁾	DKFA ⁽³⁾	Other ^{(4),(5),(6),(7),(8),(9),(10), or (11)}	Microcystin (µg/L)
08/08/16	11:15	UKEP	N/A	ODEQ	UKEP16005	SG	0	168,251	0	0	4.9
08/08/16	11:38	UKHP	N/A	ODEQ	UKHP16005	SG	*	*	*	*	170
08/08/16	11:56	UKMP	N/A	ODEQ	UKMP16005	SG	0	277,381	0	0	3.4
08/08/16	10:22	KEKP	234.0	ODEQ	KEKP16005	SG	0	16,955	0	0	0.28
08/08/16	10:03	BRTC	225.0	ODEQ	BRTC16005	SG	0	1,115	0	0	0.21
08/10/16	16:20	CRMC	201.5	PacifiCorp	KR16825	SG	*	*	*	*	5000
08/11/16	9:00	CRCC	200.0	PacifiCorp	KR16826	SG	*	*	*	*	3400
08/10/16	13:10	IRCC	192.8	PacifiCorp	KR16827	SG	*	*	*	*	790
08/10/16	12:45	IRJW	192.4	PacifiCorp	KR16828	SG	*	*	*	*	2500
08/10/16	17:00	KRBI	189.7	PacifiCorp	KR16829	SG	6,792	0	0	0	ND
08/22/16	8:00	CRMC	201.5	PacifiCorp	KR16830	SG	*	*	*	*	430
08/22/16	9:00	CRCC	200.0	PacifiCorp	KR16831	SG	*	*	*	*	7600
08/22/16	9:40	IRCC	192.8	PacifiCorp	KR16832	SG	*	*	*	*	30
08/22/16	10:00	IRJW	192.4	PacifiCorp	KR16833	SG	*	*	*	*	72
08/22/16	10:15	KRBI	189.7	PacifiCorp	KR16834	SG	*	*	*	*	0.38
08/30/16	12:13	UKEP	N/A	ODEQ	UKEP16006	SG	0	0	0	0	0.33
08/30/16	12:33	UKHP	N/A	ODEQ	UKHP16006	SG	*	*	*	*	1.2
08/30/16	12:52	UKMP	N/A	ODEQ	UKMP16006	SG	0	0	0	0	0.17
08/30/16	11:28	KEKP	234.0	ODEQ	KEKP16006	SG	64,845	2,708	0	0	10
08/30/16	11:07	BRTC	225.0	ODEQ	BRTC16006	SG	3,391	0	0	0	2.9
09/06/16	19:50	CRMC	201.5	PacifiCorp	KR16835	SG	*	*	*	*	86
09/06/16	19:20	CRCC	200.0	PacifiCorp	KR16836	SG	*	*	*	*	5.6
09/06/16	18:35	IRCC	192.8	PacifiCorp	KR16837	SG	*	*	*	*	780
09/06/16	18:00	IRJW	192.4	PacifiCorp	KR16838	SG	*	*	*	*	420
09/07/16	12:10	KRBI	189.7	PacifiCorp	KR16839	SG	*	*	*	*	4.9
09/13/16	11:45	UKEP	N/A	ODEQ	UKEP16007	SG	976	976	0	0	0.67
09/13/16	11:58	UKHP	N/A	ODEQ	UKHP16007	SG	*	*	*	*	1.4
09/13/16	12:20	UKMP	N/A	ODEQ	UKMP16007	SG	430	0	0	0	0.31
09/13/16	10:56	KEKP	234.0	ODEQ	KEKP16007	SG	1,203	0	0	0	5.8
09/13/16	10:38	BRTC	225.0	ODEQ	BRTC16007	SG	573	0	0	107 ^d	0.92

¹MSAE = *Microcystis aeruginosa* (cells/mL)

²AFA = *Aphanizomenon flos-aquae* (cells/mL)

³DKFA = *Dolichospermum flos-aquae*

Other = Cells/mL of either ⁴*Planktothrix (Oscillatoria)* sp., ⁵*Gloeotrichia echinulata*, ⁶*Dolichospermum* sp., ⁷*Lyngbya* sp.,

⁸*Dolichospermum circinalis*, ⁹*Dolichospermum planctonica*, ¹⁰*Planktothrix (Oscillatoria) limosa*, or ¹¹*Pseudanabaena* spp.

"ND" value indicates a result less than the laboratory analytical detection limit (0.1 µg/L)

"0" value indicates non-detect by analytical laboratory

"**" value indicates no result available

Table 4. Summary of August and September 2016 baseline laboratory microcystin results for samples collected in Oregon.

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
08/09/16	8:00	KR254.4	254.4	BOR	2016KHSA-51	0.5	0.38
08/09/16	9:40	KR246.0	246.0	BOR	2016KHSA-54	0.5	0.19
08/09/16	7:15	KBK	231.8	BOR	2016KHSA-55	0.5	0.15
08/09/16	10:40	KR22822	228.2	PacifiCorp	KR16130	0.5	0.11 ¹
08/09/16	13:20	KR22478	224.8	PacifiCorp	KR16132	0.5	0.10 ¹
08/09/16	12:55	KR22460	224.6	PacifiCorp	KR16129	0.5	0.14 ¹
08/09/16	12:50	KR22460	224.6	PacifiCorp	KR16135	0.5	0.11 ¹
08/09/16	12:00	KR21950	219.5	PacifiCorp	KR16131	0.5	ND
08/23/16	8:30	KR254.4	254.4	BOR	2016KHSA-57	0.5	0.10
09/05/16	11:00	KR22822	228.2	PacifiCorp	KR16153	0.5	1.1
09/05/16	13:00	KR22460	224.6	PacifiCorp	KR16152	0.5	0.56
09/05/16	13:20	KR22460	224.6	PacifiCorp	KR16158	0.5	0.71
09/05/16	12:30	KR21950	219.5	PacifiCorp	KR16154	0.5	0.43
09/13/16	8:30	KR254.4	254.4	BOR	2016KHSA-62	0.5	0.14
09/13/16	9:45	KR246.0	246.0	BOR	2016KHSA-65	0.5	0.22
09/13/16	7:45	KBK	231.8	BOR	2016KHSA-66	0.5	0.40
09/21/16	15:45	KR22478	224.8	PacifiCorp	KR16155	0.5	*

¹The reported result for this analyte should be considered an estimated value because although the result was above the laboratory detection limit (0.1 µg/L) it was below the laboratory quantitation limit (0.15 µg/L).

“ND” value indicates a result less than the laboratory analytical detection limit (0.1 µg/L)

“*” value indicates no result available

Table 5. Summary of August and September 2016 baseline laboratory microcystin results for samples collected in California.

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
08/10/16	15:50	KR20642	206.4	PacifiCorp	KR16146	0.5	ND
08/11/16	9:30	KR19874	198.7	PacifiCorp	KR16142	0.5	22
08/11/16	9:50	KR19874	198.7	PacifiCorp	KR16143	0-8	3.6
08/10/16	14:30	KR19645	196.5	PacifiCorp	KR16141	0.5	3.6
08/10/16	10:30	KR19019	190.2	PacifiCorp	KR16137	0.5	15
08/10/16	10:40	KR19019	190.2	PacifiCorp	KR16138	0-8	3.7
08/10/16	16:55	KR18973	189.7	PacifiCorp	KR16136	0.5	2.3
08/10/16	17:20	KR18973	189.7	PacifiCorp	KR16149	0.5	1.4
08/22/16	10:10	KR18973	189.7	PacifiCorp	KR16151	0.5	0.42
09/06/16	20:05	KR20642	206.4	PacifiCorp	KR16169	0.5	0.53
09/07/16	10:00	KR19874	198.7	PacifiCorp	KR16165	0.5	0.99
09/07/16	10:10	KR19874	198.7	PacifiCorp	KR16166	0-8	0.44
09/06/16	19:00	KR19645	196.5	PacifiCorp	KR16164	0.5	0.44
09/06/16	12:20	KR19019	190.2	PacifiCorp	KR16160	0.5	6.4
09/06/16	12:30	KR19019	190.2	PacifiCorp	KR16161	0-8	3
09/07/16	12:00	KR18973	189.7	PacifiCorp	KR16159	0.5	2.7
09/07/16	12:25	KR18973	189.7	PacifiCorp	KR16172	0.5	2.1

“ND” value indicates a result less than the laboratory analytical detection limit (0.1 µg/L)

References

California SWRCB 2016. Draft Statewide Voluntary Guidance on CyanoHABs in Recreational Waters. Available online at:

http://www.mywaterquality.ca.gov/monitoring_council/cyanoHab_network/docs/triggers.pdf

Oregon Health Authority. 2016. Oregon Harmful Algal Bloom Surveillance (HABS) Program – Public Health Advisory Guidelines, Harmful Algae Blooms in Freshwater Bodies. 27 pp.

https://public.health.oregon.gov/HealthyEnvironments/Recreation/HarmfulAlgaeBlooms/Pages/resources_for_samplers.aspx

Appendix 1 Cyanobacteria Species and Microcystin Data for 2016 Public Health Samples

Table A1. Summary of 2016 public health laboratory algal identification and enumeration microcystin results.											
Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth	MSAE ⁽¹⁾	AFA ⁽²⁾	DKFA ⁽³⁾	Other ^{(4),(5), (6), (7), (8), (9), (10), or (11)}	Microcystin (µg/L)
05/23/16	14:05	CRMC	201.5	PacifiCorp	KR16800	SG	0	0	0	0	ND
05/23/16	13:15	CRCC	200.0	PacifiCorp	KR16801	SG	0	0	0	0	ND
05/23/16	12:45	IRCC	192.8	PacifiCorp	KR16802	SG	0	0	0	0	ND
05/23/16	12:25	IRJW	192.4	PacifiCorp	KR16803	SG	0	0	0	0	ND
05/23/16	11:55	KRBI	189.7	PacifiCorp	KR16804	SG	0	0	0	0	ND
06/14/16	11:47	UKEP	N/A	ODEQ	UKEP16001	SG	0	349,320	0	0	0.76
06/14/16	11:24	UKHP	N/A	ODEQ	UKHP16001	SG	100,686	296,927	0	0	14
06/14/16	11:10	UKMP	N/A	ODEQ	UKMP16001	SG	0	302,081	0	55,817 ⁽⁵⁾	0.56
06/14/16	10:38	KEKP	234.0	ODEQ	KEKP16001	SG	0	0	46,979	587 ⁽⁶⁾	0.23
06/14/16	10:09	BRTC	225.0	ODEQ	BRTC16001	SG	0	0	0	0	ND
06/08/16	16:15	CRMC	201.5	PacifiCorp	KR16805	SG	0	0	0	0	ND
06/08/16	13:10	CRCC	200.0	PacifiCorp	KR16806	SG	0	0	503	0	3.7
06/08/16	11:40	IRCC	192.8	PacifiCorp	KR16807	SG	0	0	0	0	ND
06/08/16	11:20	IRJW	192.4	PacifiCorp	KR16808	SG	0	0	0	0	ND
06/08/16	17:00	KRBI	189.7	PacifiCorp	KR16809	SG	0	0	0	0	ND
06/28/16	11:17	UKEP	N/A	ODEQ	UKEP16002	SG	163,293	10,103,761	0	0	56
06/28/16	11:34	UKHP	N/A	ODEQ	UKHP16002	SG	*	*	*	*	130
06/28/16	11:50	UKMP	N/A	ODEQ	UKMP16002	SG	1,485,481	3,157,000	0	0	32
06/28/16	10:35	KEKP	234.0	ODEQ	KEKP16002	SG	18,090	279,025	0	0	3.2
06/28/16	10:07	BRTC	225.0	ODEQ	BRTC16002	SG	490	456,392	0	0	0.53
06/20/16	16:40	CRMC	201.5	PacifiCorp	KR16810	SG	68,407	0	807	0	25
06/20/16	15:20	CRCC	200.0	PacifiCorp	KR16811	SG	496,424	0	17,034	0	61
06/20/16	14:40	IRCC	192.8	PacifiCorp	KR16812	SG	12,272	0	0	0	14
06/20/16	14:25	IRJW	192.4	PacifiCorp	KR16813	SG	4,940	0	859	658 ⁽⁶⁾ , 403 ⁽⁹⁾	1
06/20/16	13:50	KRBI	189.7	PacifiCorp	KR16814	SG	0	0	16	0	ND
07/12/16	11:58	UKEP	N/A	ODEQ	UKEP16003	SG	*	*	*	*	0.51
07/12/16	12:32	UKHP	N/A	ODEQ	UKHP16003	SG	*	*	*	*	79
07/12/16	12:46	UKMP	N/A	ODEQ	UKMP16003	SG	*	*	*	*	3.4
07/12/16	10:59	KEKP	234.0	ODEQ	KEKP16003	SG	0	20,528	0	78 ⁽⁶⁾	0.55
07/12/16	10:42	BRTC	225.0	ODEQ	BRTC16003	SG	0	775	0	0	0.31
07/12/16	16:55	CRMC	201.5	PacifiCorp	KR16815	SG	*	*	*	*	9.1
07/12/16	15:00	CRCC	200.0	PacifiCorp	KR16816	SG	*	*	*	*	21
07/12/16	12:40	IRCC	192.8	PacifiCorp	KR16817	SG	*	*	*	*	6.4
07/12/16	12:30	IRJW	192.4	PacifiCorp	KR16818	SG	*	*	*	*	2.5
07/12/16	18:00	KRBI	189.7	PacifiCorp	KR16819	SG	0	0	0	0	0.15
07/26/16	12:34	UKEP	N/A	ODEQ	UKEP16004	SG	*	*	*	*	1.9
07/26/16	12:08	UKHP	N/A	ODEQ	UKHP16004	SG	*	*	*	*	37
07/26/16	13:14	UKMP	N/A	ODEQ	UKMP16004	SG	*	*	*	*	0.54
07/26/16	11:37	KEKP	234.0	ODEQ	KEKP16004	SG	0	30,067	0	0	0.29
07/26/16	11:17	BRTC	225.0	ODEQ	BRTC16004	SG	0	0	0	0	0.20
07/26/16	11:15	CRMC	201.5	PacifiCorp	KR16820	SG	*	*	*	*	870

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Table A1 (cont.)

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth	MSAE ⁽¹⁾	AFA ⁽²⁾	DKFA ⁽³⁾	Other ^{(4),(5), (6), (7), (8), (9), (10), or (11)}	Microcystin (µg/L)
07/26/16	12:15	CRCC	200.0	PacifiCorp	KR16821	SG	*	*	*	*	34000
07/26/16	12:45	IRCC	192.8	PacifiCorp	KR16822	SG	*	*	*	*	73
07/26/16	13:10	IRJW	192.4	PacifiCorp	KR16823	SG	*	*	*	*	380
07/26/16	13:40	KRBI	189.7	PacifiCorp	KR16824	SG	241	0	0	62 ⁽⁵⁾	0.38
08/08/16	11:15	UKEP	N/A	ODEQ	UKEP16005	SG	0	168,251	0	0	4.9
08/08/16	11:38	UKHP	N/A	ODEQ	UKHP16005	SG	*	*	*	*	170
08/08/16	11:56	UKMP	N/A	ODEQ	UKMP16005	SG	0	277,381	0	0	3.4
08/08/16	10:22	KEKP	234.0	ODEQ	KEKP16005	SG	0	16,955	0	0	0.28
08/08/16	10:03	BRTC	225.0	ODEQ	BRTC16005	SG	0	1,115	0	0	0.21
08/10/16	16:20	CRMC	201.5	PacifiCorp	KR16825	SG	*	*	*	*	5000
08/11/16	9:00	CRCC	200.0	PacifiCorp	KR16826	SG	*	*	*	*	3400
08/10/16	13:10	IRCC	192.8	PacifiCorp	KR16827	SG	*	*	*	*	790
08/10/16	12:45	IRJW	192.4	PacifiCorp	KR16828	SG	*	*	*	*	2500
08/10/16	17:00	KRBI	189.7	PacifiCorp	KR16829	SG	6,792	0	0	0	ND
08/22/16	8:00	CRMC	201.5	PacifiCorp	KR16830	SG	*	*	*	*	430
08/22/16	9:00	CRCC	200.0	PacifiCorp	KR16831	SG	*	*	*	*	7600
08/22/16	9:40	IRCC	192.8	PacifiCorp	KR16832	SG	*	*	*	*	30
08/22/16	10:00	IRJW	192.4	PacifiCorp	KR16833	SG	*	*	*	*	72
08/22/16	10:15	KRBI	189.7	PacifiCorp	KR16834	SG	*	*	*	*	0.38
08/30/16	12:13	UKEP	N/A	ODEQ	UKEP16006	SG	0	0	0	0	0.33
08/30/16	12:33	UKHP	N/A	ODEQ	UKHP16006	SG	*	*	*	*	1.2
08/30/16	12:52	UKMP	N/A	ODEQ	UKMP16006	SG	0	0	0	0	0.17
08/30/16	11:28	KEKP	234.0	ODEQ	KEKP16006	SG	64,845	2,708	0	0	10
08/30/16	11:07	BRTC	225.0	ODEQ	BRTC16006	SG	3,391	0	0	0	2.9
09/06/16	19:50	CRMC	201.5	PacifiCorp	KR16835	SG	*	*	*	*	86
09/06/16	19:20	CRCC	200.0	PacifiCorp	KR16836	SG	*	*	*	*	5.6
09/06/16	18:35	IRCC	192.8	PacifiCorp	KR16837	SG	*	*	*	*	780
09/06/16	18:00	IRJW	192.4	PacifiCorp	KR16838	SG	*	*	*	*	420
09/07/16	12:10	KRBI	189.7	PacifiCorp	KR16839	SG	*	*	*	*	4.9
09/13/16	11:45	UKEP	N/A	ODEQ	UKEP16007	SG	976	976	0	0	0.67
09/13/16	11:58	UKHP	N/A	ODEQ	UKHP16007	SG	*	*	*	*	1.4
09/13/16	12:20	UKMP	N/A	ODEQ	UKMP16007	SG	430	0	0	0	0.31
09/13/16	10:56	KEKP	234.0	ODEQ	KEKP16007	SG	1,203	0	0	0	5.8
09/13/16	10:38	BRTC	225.0	ODEQ	BRTC16007	SG	573	0	0	107 ⁴	0.92

¹MSAE = *Microcystis aeruginosa* (cells/mL)

²AFA = *Aphanizomenon flos-aquae* (cells/mL)

³DKFA = *Dolichospermum flos-aquae*

Other = Cells/mL of either ⁴*Planktothrix (Oscillatoria)* sp., ⁵*Gloeotrichia echinulata*, ⁶*Dolichospermum* sp., ⁷*Lyngbya* sp.,

⁸*Dolichospermum circinalis*, ⁹*Dolichospermum planctonica*, ¹⁰*Planktothrix (Oscillatoria) limosa*, or ¹¹*Pseudanabaena* spp.

"ND" value indicates a result less than the laboratory analytical detection limit, which was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016

"0" value indicates non-detect by analytical laboratory

"**" value indicates no result available

Appendix 2

Microcystin Data for 2016 Baseline Samples

Table A2-1. Summary of 2016 baseline laboratory microcystin results for samples collected in Oregon.							
Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
05/10/16	10:00	KR246.0	246.0	BOR	2016-KHSA-22	0.5	0.15
05/10/16	7:45	KBK	231.8	BOR	2016-KHSA-23	0.5	0.19
05/10/16	9:50	KR22822	228.2	PacifiCorp	KR16062	0.5	0.16 ¹
05/10/16	12:35	KR22478	224.8	PacifiCorp	KR16064	0.5	ND
05/10/16	13:15	KR22460	224.6	PacifiCorp	KR16061	0.5	0.16 ¹
05/10/16	11:20	KR21950	219.5	PacifiCorp	KR16063	0.5	0.16 ¹
06/07/16	10:15	KR246.0	246.0	BOR	2016KHSA-32	0.5	ND
06/07/16	8:00	KBK	231.8	BOR	2016KHSA-33	0.5	ND
06/07/16	11:00	KR22822	228.2	PacifiCorp	KR16084	0.5	0.15 ¹
06/07/16	14:10	KR22478	224.8	PacifiCorp	KR16086	0.5	ND
06/07/16	14:30	KR22460	224.6	PacifiCorp	KR16083	0.5	0.15 ¹
06/07/16	15:00	KR22460	224.6	PacifiCorp	KR16089	0.5	ND
06/07/16	13:10	KR21950	219.5	PacifiCorp	KR16085	0.5	ND
07/12/16	8:30	KR254.4	254.4	BOR	2016KHSA-40	0.5	0.74
07/12/16	10:30	KR246.0	246.0	BOR	2016KHSA-43	0.5	0.13
07/12/16	7:40	KBK	231.8	BOR	2016KHSA-44	0.5	SL
07/11/16	9:40	KR22822	228.2	PacifiCorp	KR16107	0.5	0.2
07/11/16	12:35	KR22478	224.8	PacifiCorp	KR16109	0.5	0.12
07/11/16	11:50	KR22460	224.6	PacifiCorp	KR16106	0.5	0.13
07/11/16	12:00	KR22460	224.6	PacifiCorp	KR16112	0.5	0.1
07/11/16	11:10	KR21950	219.5	PacifiCorp	KR16108	0.5	ND
07/26/16	9:00	KR254.4	254.4	BOR	2016KHSA-46	0.5	0.34
08/09/16	8:00	KR254.4	254.4	BOR	2016KHSA-51	0.5	0.38
08/09/16	9:40	KR246.0	246.0	BOR	2016KHSA-54	0.5	0.19
08/09/16	7:15	KBK	231.8	BOR	2016KHSA-55	0.5	0.15
08/09/16	10:40	KR22822	228.2	PacifiCorp	KR16130	0.5	0.11 ¹
08/09/16	13:20	KR22478	224.8	PacifiCorp	KR16132	0.5	0.1 ¹
08/09/16	12:55	KR22460	224.6	PacifiCorp	KR16129	0.5	0.14 ¹
08/09/16	12:50	KR22460	224.6	PacifiCorp	KR16135	0.5	0.11 ¹
08/09/16	12:00	KR21950	219.5	PacifiCorp	KR16131	0.5	ND
08/23/16	8:30	KR254.4	254.4	BOR	2016KHSA-57	0.5	0.10
09/05/16	11:00	KR22822	228.2	PacifiCorp	KR16153	0.5	1.1
09/05/16	13:00	KR22460	224.6	PacifiCorp	KR16152	0.5	0.56
09/05/16	13:20	KR22460	224.6	PacifiCorp	KR16158	0.5	0.71
09/05/16	12:30	KR21950	219.5	PacifiCorp	KR16154	0.5	0.43

Table A2-1. (Cont.)							
Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
09/13/16	8:30	KR254.4	254.4	BOR	2016KHSA-62	0.5	0.14
09/13/16	9:45	KR246.0	246.0	BOR	2016KHSA-65	0.5	0.22
09/13/16	7:45	KBK	231.8	BOR	2016KHSA-66	0.5	0.40
09/21/16	15:45	KR22478	224.8	PacifiCorp	KR16155	0.5	*

¹The reported result for this analyte should be considered an estimated value because although the result was above the laboratory detection limit it was below the laboratory quantitation limit. The laboratory detection limit was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016. The laboratory quantitation limit for was originally 0.18 µg/L and was changed to 0.15 µg/L as of June 23, 2016.

"ND" value indicates a result less than the laboratory analytical detection limit, which was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016

"SL" indicates sample loss

Table A2-2. Summary of 2016 baseline laboratory microcystin results for samples collected in California.

Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
05/11/16	15:10	KR20642	206.4	PacifiCorp	KR16078	0.5	ND
05/11/16	12:50	KR19874	198.7	PacifiCorp	KR16074	0.5	0.15 ¹
05/11/16	13:00	KR19874	198.7	PacifiCorp	KR16075	0-8	ND
05/11/16	12:05	KR19645	196.5	PacifiCorp	KR16073	0.5	0.17 ¹
05/11/16	9:45	KR19019	190.2	PacifiCorp	KR16069	0.5	ND
05/11/16	9:55	KR19019	190.2	PacifiCorp	KR16070	0-8	ND
05/11/16	16:35	KR18973	189.7	PacifiCorp	KR16068	0.5	ND
05/23/16	11:50	KR18973	189.7	PacifiCorp	KR16082	0.5	ND
06/08/16	15:25	KR20642	206.4	PacifiCorp	KR16100	0.5	ND
06/08/16	13:30	KR19874	198.7	PacifiCorp	KR16096	0.5	ND
06/08/16	13:40	KR19874	198.7	PacifiCorp	KR16097	0-8	ND
06/08/16	12:20	KR19645	196.5	PacifiCorp	KR16095	0.5	ND
06/08/16	9:10	KR19019	190.2	PacifiCorp	KR16091	0.5	ND
06/08/16	9:20	KR19019	190.2	PacifiCorp	KR16092	0-8	ND
06/08/16	16:50	KR18973	189.7	PacifiCorp	KR16090	0.5	ND
06/08/16	17:20	KR18973	189.7	PacifiCorp	KR16103	0.5	ND
06/20/16	13:40	KR18973	189.7	PacifiCorp	KR16105	0.5	ND
07/12/16	16:40	KR20642	206.4	PacifiCorp	KR16123	0.5	0.1
07/12/16	14:20	KR19874	198.7	PacifiCorp	KR16119	0.5	6.2
07/12/16	14:30	KR19874	198.7	PacifiCorp	KR16120	0-8	3.2
07/12/16	13:40	KR19645	196.5	PacifiCorp	KR16118	0.5	0.89
07/12/16	10:30	KR19019	190.2	PacifiCorp	KR16114	0.5	0.2
07/12/16	10:50	KR19019	190.2	PacifiCorp	KR16115	0-8	0.36
07/12/16	17:20	KR18973	189.7	PacifiCorp	KR16113	0.5	0.13
07/12/16	17:40	KR18973	189.7	PacifiCorp	KR16126	0.5	0.18
07/12/16	13:30	KR18973	189.7	PacifiCorp	KR16128	0.5	0.3
08/10/16	15:50	KR20642	206.4	PacifiCorp	KR16146	0.5	ND
08/11/16	9:30	KR19874	198.7	PacifiCorp	KR16142	0.5	22
08/11/16	9:50	KR19874	198.7	PacifiCorp	KR16143	0-8	3.6
08/10/16	14:30	KR19645	196.5	PacifiCorp	KR16141	0.5	3.6
08/10/16	10:30	KR19019	190.2	PacifiCorp	KR16137	0.5	15
08/10/16	10:40	KR19019	190.2	PacifiCorp	KR16138	0-8	3.7
08/10/16	16:55	KR18973	189.7	PacifiCorp	KR16136	0.5	2.3
08/10/16	17:20	KR18973	189.7	PacifiCorp	KR16149	0.5	1.4
08/22/16	10:10	KR18973	189.7	PacifiCorp	KR16151	0.5	0.42
09/06/16	20:05	KR20642	206.4	PacifiCorp	KR16169	0.5	0.53
09/07/16	10:00	KR19874	198.7	PacifiCorp	KR16165	0.5	0.99
09/07/16	10:10	KR19874	198.7	PacifiCorp	KR16166	0-8	0.44

Table A2-2. (Cont.)							
Date	Time	Site ID	RM	Sampling Entity	Sample ID	Depth (m)	Microcystin (µg/L)
09/06/16	19:00	KR19645	196.5	PacifiCorp	KR16164	0.5	0.44
09/06/16	12:20	KR19019	190.2	PacifiCorp	KR16160	0.5	6.4
09/06/16	12:30	KR19019	190.2	PacifiCorp	KR16161	0-8	3
09/07/16	12:00	KR18973	189.7	PacifiCorp	KR16159	0.5	2.7
09/07/16	12:25	KR18973	189.7	PacifiCorp	KR16172	0.5	2.1

¹ The reported result for this analyte should be considered an estimated value because although the result was above the laboratory detection limit it was below the laboratory quantitation limit. The laboratory detection limit was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016. The laboratory quantitation limit was originally 0.18 µg/L and was changed to 0.15 µg/L as of June 23, 2016.

"ND" value indicates a result less than the laboratory analytical detection limit, which was originally 0.15 µg/L and was changed to 0.1 µg/L as of June 23, 2016

Appendix 3 Laboratory Phytoplankton Results

Note: To reflect current taxonomic decisions, the genus for *Anabaena* was changed to *Dolichospermum* in the summary data presented in the body of this memo but not in the actual lab results presented in this appendix.

Phytoplankton Sample Analysis

Sample: Klamath Basin
 Sample Site: UKEP
 Sample Depth:
 Sample Date: 8-Aug-16 1115

Total Density (#/mL): 7,648
 Total Biovolume (um³/mL): 10,599,811
 Trophic State Index: 66.9

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	7,648	100.0	10,599,811	100.0

Aphanizomenon flos-aquae cells/mL = 168,251

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
 Sample Site: UKMP
 Sample Depth:
 Sample Date: 8-Aug-16 1156

Total Density (#/mL): 13,209
 Total Biovolume (um³/mL): 17,475,024
 Trophic State Index: 70.5

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	13,209	100.0	17,475,024	100.0

Aphanizomenon flos-aquae cells/mL = 277,381

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: KEKP
Sample Depth:
Sample Date: 8-Aug-16 1022

Total Density (#/mL): 706
Total Biovolume (um³/mL): 1,068,158
Trophic State Index: 50.3

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	706	100.0	1,068,158	100.0

Aphanizomenon flos-aquae cells/mL = 16,955

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
 Sample Site: BRTC
 Sample Depth:
 Sample Date: 8-Aug-16 1003

Total Density (#/mL): 51
 Total Biovolume (um³/mL): 70,266
 Trophic State Index: 30.8

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	51	100.0	70,266	100.0

Aphanizomenon flos-aquae cells/mL = 1,115

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample ID: KR16829
Sample Depth:
Sample Date: 10-Aug-16 1700

Total Density (#/mL): 679
Total Biovolume (um³/mL): 54,333
Trophic State Index: 29.0

Species	Density #/mL	Density Percent	Biovolume um³/mL	Biovolume Percent
-	-	-	-	-
1 Microcystis aeruginosa	679	100.0	54,333	100.0

Microcystis aeruginosa cells/mL = 6,792

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: KEKP
Sample Depth:
Sample Date: 30-Aug-16 1128

Total Density (#/mL): 1,803
Total Biovolume (um³/mL): 689,378
Trophic State Index: 47.2

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Microcystis aeruginosa	1,706	94.6	518,761	75.3
2 Aphanizomenon flos-aquae	97	5.4	170,617	24.7

Microcystis aeruginosa cells/mL = 64,845

Aphanizomenon flos-aquae cells/mL = 2,708

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: UKEP
Sample Depth:
Sample Date: 13-Sep-16 1145

Total Density (#/mL): 33
Total Biovolume (um³/mL): 69,310
Trophic State Index: 30.7

Species	Density #/mL	Density Percent	Biovolume um ³ /mL	Biovolume Percent
1 Aphanizomenon flos-aquae	24	75.0	61,500	88.7
2 Microcystis aeruginosa	8	25.0	7,810	11.3

Aphanizomenon flos-aquae cells/mL = 976

Microcystis aeruginosa cells/mL = 976

Note: Toxic Algae Only

Phytoplankton Sample

Analysis

Sample: Klamath Basin
Sample Site: UKMP
Sample Depth:
Sample Date: 13-Sep-16 1220

Total Density (#/mL): 6
Total Biovolume (um³/mL): 3,436
Trophic State Index: 10.7

Species	Density #/mL	Density Percent	Biovolume um³/mL	Biovolume Percent
1 Microcystis aeruginosa	6	100.0	3,436	100.0

Microcystis aeruginosa cells/mL = 430

Note: Toxic Algae Only

Phytoplankton Sample

Analysis

Sample: Klamath Basin
Sample Site: KEKP
Sample Depth:
Sample Date: 13-Sep-16 1056

Total Density (#/mL): 100
Total Biovolume (um³/mL): 9,621
Trophic State Index: 17.0

Species	Density #/mL	Density Percent	Biovolume um³/mL	Biovolume Percent
1 Microcystis aeruginosa	100	100.0	9,621	100.0

Microcystis aeruginosa cells/mL = 1,203

Note: Toxic Algae Only

Phytoplankton Sample

Analysis

Sample: Klamath Basin
Sample Site: BRTC
Sample Depth:
Sample Date: 13-Sep-16 1038

Total Density (#/mL): 7
Total Biovolume (um³/mL): 11,239
Trophic State Index: 18.1

Species	Density #/mL	Density Percent	Biovolume um³/mL	Biovolume Percent
-	-	-	-	-
1 Oscillatoria sp.	4	50.0	6,658	59.2
2 Microcystis aeruginosa	4	50.0	4,582	40.8

Oscillatoria sp. cells/mL = 107

Microcystis aeruginosa cells/mL = 573

Note: Toxic Algae Only

Phytoplankton Sample Analysis

Sample: Klamath Basin
Sample Site: BRTC
Sample Depth:
Sample Date: 30-Aug-16 1107

Total Density (#/mL): 339
Total Biovolume (um³/mL): 27,128
Trophic State Index: 24.1

Species	Density #/mL	Density Percent	Biovolume um³/mL	Biovolume Percent
-	-	-	-	-
1 Microcystis aeruginosa	339	100.0	27,128	100.0

Microcystis aeruginosa cells/mL = 3,391