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TECHNICAL MEMORANDUM

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To: Brandi Lubliner, Washington Department of Ecology

Copy to: Jessica Atlakson, City of Redmond
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From: John Lenth, Herrera Environmental Consultants

Subject: Redmond Paired Watershed Study – Hydrologic Indicator Reporting Errata

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Reporting Errata

Reporting for the Redmond Paired Watershed Study (RPWS) involves the preparation of data summary reports on an annual basis to summarize compiled monitoring data collected through each of the major components of the RPWS. These reports also document any quality assurance issues associated with these data and resultant limitations (if any) on their use or interpretation. Finally, these reports document all rehabilitation efforts that have been implemented by the City of Redmond (City) or King County (County) over the previous year. Each annual data summary report documents this information based on monitoring that was conducted over the previous water year (i.e., October through September). Data summary reports (Herrera 2017, 2018, 2019, 2020a, 2021) were prepared previously for data collected over water years (WY) 2016, 2017, 2018, 2019 and 2020, respectively.

In years 4, 8, and 10 of the RPWS's implementation, trend analyses reports will also be prepared as companion documents to the data summary reports described above. These reports will summarize the results of statistical analyses that will be performed on the compiled data from all previous years of monitoring to detect potential relationships between rehabilitation efforts and improved receiving water conditions. Each report will also present major conclusions from these analyses. A trend analysis report (Herrera 2020b) was prepared following year 4 of the RPWS's implementation.

Annual data summary reports prepared for WY2016 through WY2019 summarized values for the following nine indicators for evaluating hydrologic impacts that are computed from continuous flow monitoring data collected at 14 monitoring stations:

- High Pulse Count
- High Pulse Duration
- High Pulse Range
- Low Pulse Count
- Low Pulse Duration

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- Low Pulse Range
- Flow Reversal
- Richard-Baker Flashiness Index
- TQ Mean

This technical memorandum corrects errors that have been identified in the data for these indicators in the reporting described above. Specifically, all of the indicators are calculated using average daily flows at each station that are derived from the continuous flow monitoring data. The continuous flow monitoring data are managed using the Aquarius software package. This software package has built-in data processing and analysis functionality that was used to compute average daily flows at each station from the continuous flow monitoring data. However, due to a defect in an earlier version of the Aquarius software package, maximum daily flows at each station from WY2016 and WY2017 were inadvertently used to calculate the indicator values that were summarized in the data summary reports that were prepared for WY2016 through WY2019. Hence, the indicator values presented in these reports are inaccurate. Corrected indicator values that were computed using average daily flows over all four water years are summarized in Table 1 (all tables are located at the end of this memorandum).

The inaccurate indicator values were also used in analyses that were performed for the trend analysis report (Herrera 2020b) that was prepared following year 4 of the RPWS's implementation. These analyses involved using the Kendall's tau and Pearson's r tests to detect statistically significant correlations between the indicators and time. Statistical significance of the correlations was evaluated based on an α-level of 0.05 for a one-tailed test and the following null and alternative hypotheses related to hydrologic impacts:

- Ho: Hydrologic conditions remain unchanged or have deteriorated over time.
- Ha: Hydrologic conditions have improved over time.

Tables 2 and 3 present updated results from these analyses based on the corrected values for each of these tests, respectively. These updated results did not change any of the major conclusions from the trend analysis report.

For consistency, all the indicator values presented herein were computed based on continuous flow monitoring data that were collected through the end of WY2019. Values for all nine indicators will be updated again for the trend analysis report that will be prepared following year 8 of the RPWS's implementation based on continuous flow monitoring data that were collected through the end of WY2023.

It should be noted that King County (County) implements the flow monitoring for the RPWS; data obtained from this monitoring can be accessed via the County's Hydrologic Information Center. To calculate the indicator values, Herrera obtains the continuous flow monitoring data from the County and performs reviews to identify any significant gaps. Because the indicator values cannot be computed if

gaps are present over the period of interest, Herrera fills any identified data gaps using tools that are available through the Aquarius software package. Hence, the data used to calculate the indicator values may not directly align with the data that are accessible via the Hydrologic Information Center.

References

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Table 1. Computed Indicator Values for Evaluating Hydrologic Impacts.

Station	Water Year or Calendar Year	High Pulse Count (count)	High Pulse Duration (days)	High Pulse Range (days)	Low Pulse Count (count)	Low Pulse Duration (days)	Low Pulse Range (days)	Flow Reversal (count)	Richard-Baker Flashiness Index	TQ Mean (fraction of the year)
COLM	2016	9	3.2	90	7	31.1	248	116	0.43	0.22
COLM	2017	17	5.7	208	4	42.8	293	80	0.31	0.39
COLM	2018	8	9.3	150	6	32.2	282	74	0.30	0.27
COLM	2019	7	3.0	75	4	51.3	254	88	0.20	0.40
COUMI	2016	16	1.9	149	15	10.7	348	124	0.32	0.33
COUMI	2017	15	2.6	215	8	15.6	177	110	0.36	0.30
COUMI	2018	17	2.8	164	14	8.3	195	120	0.37	0.30
COUMI	2019	5	2.2	135	26	5.0	288	121	0.19	0.34
COUMO	2016	21	1.9	169	16	6.4	130	162	0.39	0.29
COUMO	2017	25	2.6	245	17	5.9	200	133	0.43	0.34
COUMO	2018	21	2.2	181	19	10.4	284	136	0.50	0.28
COUMO	2019	14	1.8	136	36	6.2	349	137	0.48	0.26
EVALSS	2016	7	2.4	90	1	3.0	2	121	0.18	0.26
EVALSS	2017	14	2.1	203	0	0	0	108	0.22	0.38
EVALSS	2018	13	1.5	162	2	2.0	4	138	0.16	0.39
EVALSS	2019	7	1.1	135	3	3.0	75	123	0.14	0.39
EVAMS	2016	7	2.3	93	3	10.3	34	145	0.18	0.30
EVAMS	2017	21	1.5	203	5	6.0	56	129	0.24	0.44
EVAMS	2018	17	1.8	221	4	1.8	183	154	0.20	0.33
EVAMS	2019	6	1.5	135	17	4.2	211	149	0.17	0.38
MONMN	2016	13	4.9	148	13	15.3	351	110	0.39	0.28
MONMN	2017	24	3.5	216	15	12.3	346	110	0.51	0.34
MONMN	2018	12	5.7	179	14	14.6	306	113	0.40	0.29
MONMN	2019	13	2.4	316	22	10.9	330	100	0.47	0.30
MONM	2016	15	4.3	148	12	14.4	344	142	0.33	0.31
MONM	2017	24	2.8	214	16	10.6	343	130	0.42	0.37
MONM	2018	14	4.9	238	11	16.1	218	134	0.35	0.32
MONM	2019	11	2.0	317	24	8.3	322	113	0.36	0.31
MONMS	2016	17	4.5	169	20	8.4	263	126	0.32	0.34
MONMS	2017	26	1.9	215	17	8.4	303	126	0.52	0.32
MONMS	2018	20	2.5	221	12	10.9	188	115	0.37	0.34
MONMS	2019	13	1.6	316	18	11.1	260	106	0.37	0.37
SEIMN	2016	7	8.4	117	6	27.7	184	124	0.21	0.36
SEIMN	2017	24	2.9	209	5	27.4	149	107	0.28	0.42
SEIMN	2018	11	5.9	149	5	28.8	172	103	0.21	0.39
SEIMN	2019	4	1.5	106	10	16.0	255	100	0.14	0.42
SEIMS	2016	9	2.6	104	10	7.1	129	140	0.21	0.35
SEIMS	2017	14	1.9	214	3	4.0	31	125	0.24	0.37
SEIMS	2018	13	2.7	148	2	1.0	3	128	0.20	0.33
SEIMS	2019	2	1.0	73	16	6.2	140	135	0.15	0.41
TOSMI	2016	25	1.7	225	21	6.8	259	162	0.57	0.28
TOSMI	2017	29	1.8	346	12	12.3	318	139	0.62	0.28
TOSMI	2018	21	1.9	179	16	8.6	220	148	0.52	0.27
TOSMI	2019	15	1.4	164	31	5.7	317	147	0.38	0.33
TOSMO	2016	15	1.8	222	8	11.3	101	144	0.38	0.28
TOSMO	2017	29	1.6	245	9	14.0	141	137	0.55	0.27
TOSMO	2018	20	1.7	180	11	8.9	129	150	0.43	0.28
TOSMO	2019	18	1.3	317	17	2.7	208	135	0.34	0.29
TYLMI	2016	15	2.2	152	16	13.4	356	119	0.50	0.24
TYLMI	2017	24	2.5	219	15	13.3	358	99	0.58	0.29
TYLMI	2018	24	2.6	330	27	8.0	339	122	0.60	0.26
TYLMI	2019	17	3.1	336	30	8.0	350	107	0.61	0.25
TYLMO	2016	21	2.4	329	30	6.1	355	148	0.56	0.27
TYLMO	2017	27	2.4	346	18	9.8	345	137	0.58	0.32
TYLMO	2018	27	2.2	244	22	9.7	299	132	0.57	0.30
TYLMO	2019	16	1.7	317	32	7.4	351	121	0.57	0.30

Table 2. Kendall's Tau Correlation Coefficients for Hydrologic Indicators Versus Time (WY2016 through WY2019).

	High Pulse Count[a]		High Pulse Duration[b]		High Pulse Range[a]		Low Pulse Count[a]		Low Pulse Duration[b]		Low Pulse Range[b]		Flow Reversal[a]		Richard-Baker Flashiness Index[a]		TQ Mean[b]	
Station	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
EVALSS	-0.18	0.36	-1.00	1.00	0.00	0.50	0.67	0.17	0.18	0.36	0.67	0.17	0.33	0.38	-0.67	0.17	0.91	1.00
EVAMS	-0.33	0.38	-0.55	0.14	0.33	0.38	0.67	0.17	-0.67	0.17	1.00	**0.04**	0.33	0.38	-0.33	0.38	0.33	0.38
MONMN	-0.18	0.36	-0.33	0.38	0.67	0.17	0.67	0.17	-0.67	0.17	-0.67	0.17	-0.18	0.36	0.33	0.38	0.33	0.38
MONMS	-0.33	0.38	-0.67	0.17	1.00	1.00	-0.33	0.38	0.91	**0.04**	-0.33	0.38	-0.91	**0.04**	0.18	0.36	0.55	0.14
MONM	-0.67	0.17	-0.33	0.38	1.00	1.00	0.33	0.38	-0.33	0.38	-0.67	0.17	-0.67	0.17	0.33	0.38	-0.18	0.36
TOSMO	0.00	0.50	-0.67	0.17	0.33	0.38	1.00	1.00	-0.67	0.17	0.67	0.17	-0.33	0.38	-0.33	0.38	0.55	0.14
TOSMI	-0.67	0.17	0.00	0.50	-0.67	0.17	0.33	0.38	-0.33	0.38	0.00	0.50	-0.33	0.38	-0.67	0.17	0.18	0.36
COLM	-0.67	0.17	0.00	0.50	-0.33	0.38	-0.55	0.14	0.67	0.17	0.00	0.50	-0.33	0.38	-1.00	**0.04**	0.67	0.17
SEIMN	-0.33	0.38	-0.67	0.17	-0.33	0.38	0.18	0.36	-0.33	0.38	0.33	0.38	-1.00	**0.04**	-0.55	0.14	0.55	0.14
SEIMS	-0.33	0.38	-0.33	0.38	-0.33	0.38	0.00	0.50	-0.33	0.38	0.00	0.50	0.00	0.50	-0.67	0.17	0.33	0.38
COUMO	-0.55	0.14	-0.33	0.38	-0.33	0.38	1.00	1.00	0.00	0.50	1.00	**0.04**	0.00	0.50	0.67	0.17	-0.67	0.17
COUMI	-0.33	0.38	0.33	0.38	-0.33	0.38	0.33	0.38	-0.67	0.17	0.00	0.50	0.00	0.50	0.00	0.50	0.18	0.36
TYLMO	-0.18	0.36	-0.91	1.00	-0.33	0.38	0.33	0.38	0.00	0.50	-0.33	0.38	-1.00	**0.04**	0.18	0.36	0.18	0.36
TYLMI	0.18	0.36	1.00	**0.04**	1.00	1.00	0.67	0.17	-0.91	1.00	-0.33	0.38	0.00	0.50	1.00	1.00	0.00	0.50

[a] Indicator is expected to increase in response to urbanization (DeGasperi et al. 2009).

[b] Indicator is expected to decrease in response to urbanization (DeGasperi et al. 2009).

Bold values indicate there was significant improvement in hydrologic condition over time at the indicated station.

Table 3. Pearson's r Correlation Coefficients for Hydrologic Indicators Versus Time (WY2016 through WY2019).

	High Pulse Count[a]		High Pulse Duration[b]		High Pulse Range[a]		Low Pulse Count[a]		Low Pulse Duration[b]		Low Pulse Range[b]		Flow Reversal[a]		Richard-Baker Flashiness Index[a]		TQ Mean[b]	
Station	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**	**Coefficient**	**p-value**
EVALSS	-0.18	0.49	-1.00	1.00	0.00	0.37	0.67	0.10	0.18	0.41	0.67	0.11	0.33	0.31	-0.67	0.16	0.91	0.10
EVAMS	-0.33	0.44	-0.55	0.14	0.33	0.35	0.67	0.10	-0.67	0.10	1.00	**0.03**	0.33	0.28	-0.33	0.36	0.33	0.37
MONMN	-0.18	0.37	-0.33	0.27	0.67	0.09	0.67	0.09	-0.67	0.16	-0.67	0.17	-0.18	0.20	0.33	0.36	0.33	0.48
MONMS	-0.33	0.29	-0.67	0.10	1.00	1.00	-0.33	0.29	0.91	1.00	-0.33	0.34	-0.91	**0.03**	0.18	0.50	0.55	0.16
MONM	-0.67	0.25	-0.33	0.27	1.00	1.00	0.33	0.16	-0.33	0.27	-0.67	0.30	-0.67	0.06	0.33	0.47	-0.18	0.39
TOSMO	0.00	0.50	-0.67	0.08	0.33	0.25	1.00	1.00	-0.67	0.09	0.67	0.06	-0.33	0.37	-0.33	0.33	0.55	0.19
TOSMI	-0.67	0.09	0.00	0.26	-0.67	0.23	0.33	0.24	-0.33	0.35	0.00	0.40	-0.33	0.26	-0.67	0.08	0.18	0.17
COLM	-0.67	0.29	0.00	0.44	-0.33	0.39	-0.55	0.20	0.67	0.16	0.00	0.48	-0.33	0.19	-1.00	**0.02**	0.67	0.20
SEIMN	-0.33	0.34	-0.67	0.13	-0.33	0.37	0.18	0.18	-0.33	0.14	0.33	0.17	-1.00	**0.05**	-0.55	0.19	0.55	0.17
SEIMS	-0.33	0.24	-0.33	0.17	-0.33	0.33	0.00	0.33	-0.33	0.37	0.00	0.50	0.00	0.39	-0.67	0.12	0.33	0.24
COUMO	-0.55	0.15	-0.33	0.38	-0.33	0.27	1.00	0.08	0.00	0.38	1.00	**<0.01**	0.00	0.16	0.67	0.06	-0.67	0.22
COUMI	-0.33	0.14	0.33	0.33	-0.33	0.33	0.33	0.17	-0.67	0.15	0.00	0.37	0.00	0.49	0.00	0.21	0.18	0.41
TYLMO	-0.18	0.32	-0.91	0.05	-0.33	0.30	0.33	0.40	0.00	0.37	-0.33	0.36	-1.00	**0.01**	0.18	0.34	0.18	0.28
TYLMI	0.18	0.42	1.00	**0.02**	1.00	1.00	0.67	1.00	-0.91	0.05	-0.33	0.22	0.00	0.42	1.00	1.00	0.00	0.50

[a] Indicator is expected to increase in response to urbanization (DeGasperi et al. 2009).

[b] Indicator is expected to decrease in response to urbanization (DeGasperi et al. 2009).

Bold values indicate there was significant improvement in hydrologic condition over time at the indicated station.