Subject Matter Expert Report: TOTAL SUSPENDED SOLIDS. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population

Prepared for:

Teck Coal Limited
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Sparwood, BC, V0B 2G0

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Prepared by:

Ecofish Research Ltd.

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For inquiries contact: Technical Lead documentcontrol@ecofishresearch.com 250-334-3042

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Senior Reviewer:

Todd Hatfield, Ph.D., R.P.Bio. No. 927

Senior Environmental Scientist/Project Director

Technical Lead:

Dan Durston, M.Sc.

Environmental Biologist

EXECUTIVE SUMMARY

Abundance of age-1 Westslope Cutthroat Trout (WCT) was lower in 2018, 2019, and 2020 (spawning cohorts 2017, 2018, and 2019) in the Harmer Creek WCT population in comparison to previous years and in comparison to the adjacent Grave Creek population. Teck Coal Ltd. (Teck Coal) initiated an "Evaluation of Cause" to assess potential stressors responsible for the Reduced Recruitment in the Harmer Creek population. This report investigates if, and to what extent, TSS in Harmer Creek and its tributaries caused or contributed to the WCT Reduced Recruitment.

TSS data were provided by Teck Coal from water quality monitoring within Harmer Creek, Grave Creek, and tributaries thereof between May 1981 and December 2020. These data were collected during routine and opportunistic water quality monitoring. To evaluate potential effects to various life stages of WCT, the severity of ill effects (SEV) impact assessment model developed by Newcombe, and Jensen (1996) was applied. SEV scores can range from 0 to 14, which for the purposes of this assessment were further categorized as negligible (e.g., SEV <1) to very high (e.g., SEV 12 – 14) based on published categories of effect. High SEV scores corresponded to potential mortality rates of 0-40%, and very high scores corresponded to potential mortality of >40%. SEV modelling was completed for all life stages of WCT (adults, juveniles, eggs and larvae) in relation to potential chronic (30-day) and acute (96-hour) exposures for routine monitoring data, or acute exposures only for the opportunistic monitoring data.

SEV results were evaluated for the available data record and compared over that time period with a focus on recent years (primarily 2018-2019 but also considering 2016 to 2020). SEV scores that were moderate or greater were compared to additional criteria that would need to be met for TSS exposure in the study area to have caused or contributed to Reduced Recruitment. Explanatory factors considered the spatial and temporal extent of the TSS event in relation to WCT life stage, habitat use, and periodicity. TSS conditions were identified as causal if concentrations in the Harmer Creek population area had the potential for high or very high magnitude effects that were widespread (i.e., spatiotemporally overlapping with the majority of fish) and higher in 2018 - 2019 relative to long term trends. TSS conditions were identified as contributory if concentrations in the Harmer Creek population area had the potential for localized high or very high magnitude effects and/or widespread moderate magnitude effects during the period of Reduced Recruitment, irrespective of whether TSS was higher in 2018 - 2019 relative to long term trends. To determine whether differences in TSS concentrations occurred in recent years, mean SEV and maximum SEV were compared using statistical modelling for one site (EV_HC1) with the most complete long-term record available.

Routine monitoring results for chronic and acute SEV indicated that TSS conditions for adult and juvenile life stages in Harmer Creek were always moderate or better, generally similar to or better from 2016 to present compared to older records, and consistent with Grave Creek TSS conditions. The routine monitoring results for eggs and larvae showed that chronic and acute SEV was often high but similar to or improved in recent years and consistent with results in Grave Creek. An

anomalous result of very high chronic SEV for eggs and larvae in Dry Creek in 2018 was identified for further investigation, but this observation is considered unreliable as it contradicted turbidity measurements from that date. The opportunistic monitoring data were limited but showed moderate SEV for adults and juveniles and often high SEV for eggs and larvae during the period of 2016 to 2020. These results were consistent with the routine monitoring and thus not flagged for further analysis.

Overall, no effects from TSS were identified that met the criteria for concluding cause of the Reduced Recruitment because high chronic and acute SEV for eggs and larvae in Harmer Creek were generally better in recent years and similar to Grave Creek; the anomalous result from Dry Creek for eggs and larvae was determined to be unreliable, not a widespread condition, and similar to other results from Grave Creek and the older Harmer Creek data.

The criteria needed to conclude contribution to the Reduced Recruitment were satisfied in several cases. Moderate magnitude effects to adults and juveniles were a widespread condition, high magnitude effects to eggs and larvae were a common condition, and anomalous very high magnitude effects to eggs and larvae did occur or may have occurred to a spatially limited extent.

Confidence in these conclusions is limited by several uncertainties. Temporal gaps for weeks, months, or years were common in the dataset such that anomalous chronic and acute TSS events may have gone unsampled. Spatial gaps between the monitoring stations also created uncertainty about the occurrence of possible localized events that may have been partially or entirely attenuated at the available stations. Additionally, the accuracy of the SEV models in describing effects of TSS on WCT is uncertain, as the SEV models apply more broadly (typically to all salmonids); thus, effects to WCT may be less or greater than the models indicated. Last, there is uncertainty as to how TSS interacts with other stressors. TSS concentrations may have had effects to WCT that depended on interactions with other stressors.

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ACRONYMS AND ABBREVIATIONS

EoC – Evaluation of Cause

SME – Subject Matter Expert

SEV – Severity of Ill Effects

TSS – Total Suspended Solids

WCT – Westslope Cutthroat Trout

READER'S NOTE

Background

The Elk Valley (Qukin ʔamaʔkis) is located in the southeast corner of British Columbia (BC), Canada. "Ktunaxa people have occupied Qukin ʔamaʔkis for over 10,000 years. . . . The value and significance of ʔa·kxamis ʼqapi qapsin (All Living Things) to the Ktunaxa Nation and in Qukin ʔamaʔkis must not be understated" (text provided by the Ktunaxa Nation Council [KNC]).

The Elk Valley contains the main stem of the Elk River, and one of the tributaries to the Elk River is Grave Creek. Grave Creek has tributaries of its own, including Harmer Creek. Harmer and Grave Creeks are upstream of a waterfall on Grave Creek, and they are home to isolated, genetically pure Westslope Cutthroat Trout (WCT; *Oncorhynchus clarkii lewisi*). This fish species is iconic, highly valued in the area and of special concern under federal and provincial legislation and policy.

In the Grave Creek watershed[1], the disturbance from logging, roads and other development is limited. The mine property belonging to Teck Coal Limited's Elkview Operations includes an area in the southwest of the Harmer Creek subwatershed. These operations influence Harmer Creek through its tributary Dry Creek, and they influence Grave Creek below its confluence with Harmer Creek (Harmer Creek Evaluation of Cause, 2023)[2]. Westslope Cutthroat Trout populations in both Harmer and Grave Creeks are part of Teck Coal's monitoring program.

[1] Including Grave and Harmer Creeks and their tributaries.

[2] Harmer Creek Evaluation of Cause Team. (2023*). Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited.

The Evaluation of Cause Process

The Process Was Initiated

Teck Coal undertakes aquatic monitoring programs in the Elk Valley, including fish population monitoring. Using data collected as part of Teck Coal's monitoring program, Cope & Cope (2020) reported low abundance of juvenile WCT in 2019, which appeared to be due to recruitment failure in Harmer Creek. Teck Coal initiated an Evaluation of Cause — a process to evaluate and report on what may have contributed to the apparent recruitment failure. Data were analyzed from annual monitoring programs in the Harmer and Grave Creek population areas[3] from 2017 to 2021 (Thorley et al. 2022; Chapter 4, Evaluation of Cause), and several patterns related to recruitment[4] were identified:

- *Reduced Recruitment*[5] occurred during the 2017, 2018 and 2019 spawn years[6] in the Harmer Creek population and in the 2018 spawn year in the Grave Creek population.
- The magnitude of Reduced Recruitment in the Harmer Creek population in the 2018 spawn year was significant enough to constitute *Recruitment Failure*[7].
- Recruitment was *Above Replacement*[8] for the 2020 spawn year in both the Harmer and Grave Creek populations.

[3] Grave Creek population area" includes Grave Creek upstream of the waterfall at river kilometer (rkm) 2.1 and Harmer Creek below Harmer Sedimentation Pond. "Harmer Creek population area" includes Harmer Creek and its tributaries (including Dry Creek) from Harmer Sedimentation Pond and upstream.

[4] Recruitment refers to the addition of new individuals to a population through reproduction.

[5] For the purposes of the Evaluation of Cause, Reduced Recruitment is defined as a probability of > 50% that annual recruitment is <100% of that required for population replacement (See Chapter 4, Evaluation of Cause, Harmer Creek Evaluation of Cause Team 2023).

[6] The spawn year is the year a fish egg was deposited, and fry emerged.

[7] For the purposes of the Evaluation of Cause, Recruitment Failure is defined as a probability of > 50% that annual recruitment is <10% of that required for population replacement (See Chapter 4, Evaluation of Cause, Harmer Creek Evaluation of Cause Team 2023).

[8] For the purposes of the Evaluation of Cause, Above Replacement is defined as a probability of > 50% that annual recruitment is >100% of that required for population replacement (See Chapter 4, Evaluation of Cause, Harmer Creek Evaluation of Cause Team 2023).

The recruitment patterns from 2017, 2018 and 2019 in Harmer Creek are collectively referred to as Reduced Recruitment in this report. To the extent that there are specific nuances within 2017-2019 recruitment patterns that correlate with individual years, such as the 2018 Recruitment Failure, these are referenced as appropriate.

How the Evaluation of Cause Was Approached

When the Evaluation of Cause was initiated, an *Evaluation of Cause Team* (the Team) was established. It was composed of *Subject Matter Experts* (SMEs) who evaluated stressors with the potential to impact the WCT population. Further details about the Team are provided in the Evaluation of Cause report (Harmer Creek Evaluation of Cause Team, 2023).

During the Evaluation of Cause process, the Team had regularly scheduled meetings with representatives of the KNC and various agencies (the participants). These meetings included discussions about the overarching question that would be evaluated and about technical issues, such as identifying potential stressors, natural and anthropogenic, which had the potential to impact recruitment in the Harmer Creek WCT population. This was an iterative process driven largely by the Team's evolving understanding of key parameters of the WCT population, such as abundance, density, size, condition and patterns of recruitment over time. Once the approach was finalized and the data were compiled, SMEs presented methods and draft results for informal input from participants. Subject Matter Experts then revised their work to address feedback and, subsequently, participants reviewed and commented on the reports. Finally, results of the analysis of the population monitoring data and potential stressor assessments were integrated to determine the relative contribution of each potential stressor to the Reduced Recruitment in the Harmer Creek population.

The Overarching Question the Team Investigated

The Team investigated the overarching question identified for the Evaluation of Cause, which was:

> **What potential stressors can explain changes in the Harmer Creek Westslope Cutthroat Trout population over time, specifically with respect to Reduced Recruitment?**

The Team developed a systematic and objective approach to investigate the potential stressors that could have contributed to the Reduced Recruitment in the Harmer Creek population. This approach is illustrated in the figure that follows the list of deliverables, below. The approach included evaluating patterns and trends, over time, in data from fish monitoring and potential stressors within the Harmer Creek population area and comparing them with patterns and trends in the nearby Grave Creek population area, which was used as a reference. The SMEs used currently available data to investigate causal effect pathways for the stressors and to determine if the stressors were present at a magnitude and for a duration sufficient to have adversely impacted the WCT. The results of this investigation are provided in two types of deliverables:

1. Individual Subject Matter Expert reports (such as the one that follows this Note). Potential stressors were evaluated by SMEs and their co-authors using the available data. These evaluations were documented in a series of reports that describe spatial and temporal patterns associated with the potential stressors, and they focus on the period of Reduced Recruitment, including the Recruitment Failure of the 2018 spawn year where appropriate. The reports describe if and to what extent potential stressors may explain the Reduced Recruitment.

   The full list of Subject Matter Expert reports follows at the end of this Reader's Note.

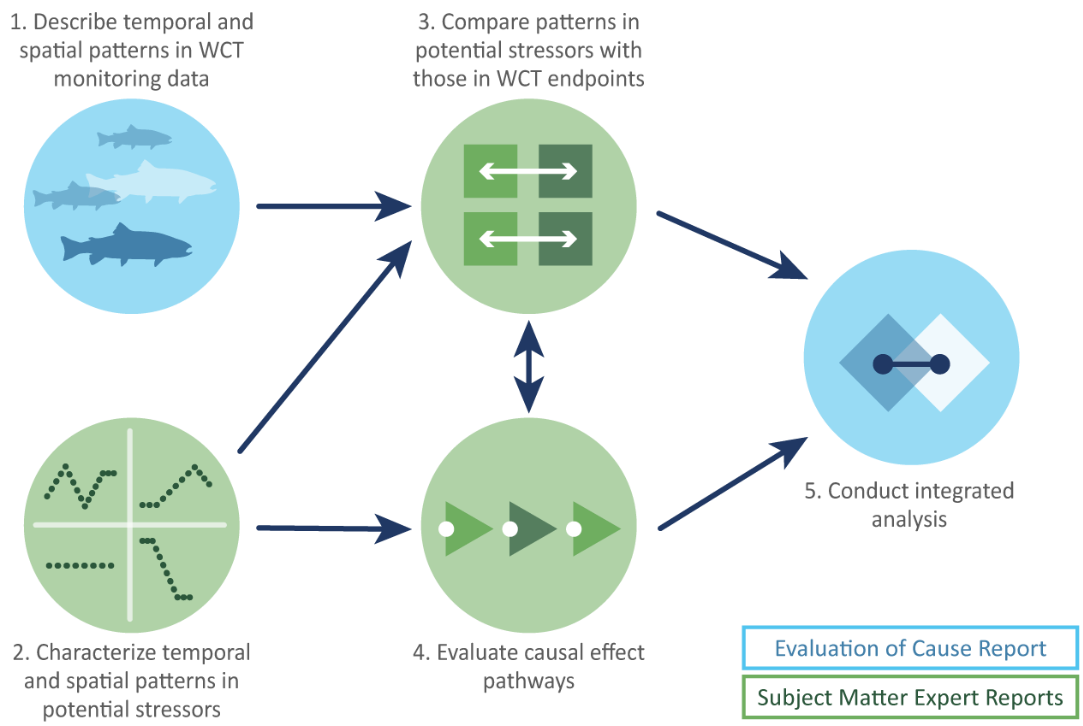
2. The Evaluation of Cause report. The SME reports provided the foundation for the Evaluation of Cause report, which was prepared by a subset of the Team and included input from SMEs.

   The Evaluation of Cause report:

   a. Provides readers with context for the SME reports and describes Harmer and Grave Creeks, the Grave Creek watershed, the history of development in the area and the natural history of WCT in these creeks

b. Presents fish monitoring data, which characterize the Harmer Creek and Grave Creek populations over time

c. Uses an integrated approach to assess the role of each potential stressor in contributing to Reduced Recruitment in the Harmer Creek population area.



Conceptual approach to the Evaluation of Cause for the Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout population.

Participation, Engagement & Transparency

To support transparency, the Team engaged frequently with participants throughout the Evaluation of Cause process. Participants in the Evaluation of Cause process, through various committees, included:

- Ktunaxa Nation Council
- BC Ministry of Forests,
- BC Ministry of Land, Water and Resource Stewardship

- BC Ministry Environment & Climate Change Strategy
- Ministry of Energy, Mines and Low Carbon Innovation
- Environmental Assessment Office

Citations for Evaluation of Cause Team Reports

Focus	Citation
Harmer Creek Evaluation of Cause report	Harmer Creek Evaluation of Cause Team. (2023). *Evaluation of Cause - Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited.
Calcite	Hocking, M. A., Cloutier, R. N., Braga, J., & Hatfield, T. (2022). *Subject Matter Expert Report: Calcite. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Dissolved oxygen	Abell, J., Yu, X., Braga, J., & Hatfield, T. (2022). *Subject Matter Expert Report: Dissolved Oxygen. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Energetic Status	Thorley, J.L. & Branton, M.A. (2023) *Subject Matter Expert Report: Energetic Status at the Onset of Winter Based on Fork Length and Wet Weight. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population*. Report prepared for Teck Coal Limited. Prepared by Poisson Consulting Ltd and Branton Environmental Consulting.
Food availability	Wiebe, A., Orr, P., & Ings, J. (2022). *Subject Matter Expert Report: Food Availability. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc.

Focus	Citation
Groundwater	Canham, E., & Humphries, S. (2022). *Evaluation of Groundwater as a Potential Stressor to Westslope Cutthroat Trout in the Harmer and Grave Creek Watersheds.* Memo prepared for Teck Coal Limited. Prepared by SNC-Lavalin Inc.
Habitat availability (instream flow)	Wright, N., Little, P., & Hatfield, T. (2022). *Subject Matter Expert Report: Streamflow and Inferred Habitat Availability. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Sediment quality	Wiebe, A., Orr, P., & Ings, J. (2022). Subject Matter Expert Report: Sediment Quality. *Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population*. Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc.
Selenium	de Bruyn, A., Bollinger, T., & Luoma, S. (2022). *Subject Matter Expert Report: Selenium. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by ADEPT Environmental Sciences Ltd, TKB Ecosystem Health Services, and SNL PhD, LLC.
Small population size	Thorley, J. L., Hussein, N., Amish, S. J. (2022). *Subject Matter Expert Report: Small Population Size. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Poisson Consulting and Conservation Genomics Consulting, LLC.
Telemetry analysis	Akaoka, K., & Hatfield, T. (2022). *Harmer and Grave Creeks Telemetry Movement Analysis.* Memo prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Total suspended solids	Durston, D., & Hatfield, T. (2022). *Subject Matter Expert Report: Total Suspended Solids. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.

Focus	Citation
Water quality	Warner, K., & Lancaster, S. (2022). *Subject Matter Expert Report: Surface Water Quality. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by WSP-Golder.
Water temperature and ice	Hocking, M., Whelan, C. & Hatfield, T. (2022). *Subject Matter Expert Report: Water Temperature and Ice. Evaluation of Cause – Reduced Recruitment in the Harmer Creek Westslope Cutthroat Trout Population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.

1. INTRODUCTION

Teck Coal undertakes aquatic monitoring programs in the Elk Valley, including fish population monitoring. Using data collected from 2017 to 2019 in Harmer and Grave Creeks, Cope and Cope (2020) reported low abundance of juvenile Westslope Cutthroat Trout (WCT; *Oncorhynchus clarkii lewisi*), which indicated apparent recruitment failure in Harmer Creek. Teck Coal initiated an Evaluation of Cause — a process to evaluate and report on what may have contributed to the apparent recruitment failure. Data were analyzed from annual monitoring programs in the Harmer and Grave Creek population areas[9] from 2017 to 2021 (Thorley et al. 2022; Chapter 4, Evaluation of Cause), and several patterns related to recruitment[10] were identified:

- *Reduced Recruitment*[11] occurred during the 2017, 2018 and 2019 spawn years[12] in the Harmer Creek population and in the 2018 spawn year in the Grave Creek population.
- The magnitude of Reduced Recruitment in the Harmer Creek population in the 2018 spawn year was significant enough to constitute *Recruitment Failure*[13].
- Recruitment was *Above Replacement*[14] for the 2020 spawn year in both the Harmer and Grave Creek populations.

The recruitment patterns from 2017, 2018 and 2019 in Harmer Creek are collectively referred to as Reduced Recruitment in this report. To the extent that there are specific nuances within 2017-2019 recruitment patterns that correlate with individual years, such as the 2018 Recruitment Failure, these are referenced where appropriate.

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[9] "Grave Creek population area" includes Grave Creek upstream of the waterfall and Harmer Creek below Harmer Sedimentation Pond. "Harmer Creek population area" includes Harmer Creek and its tributaries (including Dry Creek) from Harmer Sedimentation Pond and upstream.

[10] Recruitment refers to the addition of new individuals to a population through reproduction. For the EoC, recruitment is defined as the estimated number of age-1 fish in the fall (i.e., late-September/early October) following the first full overwintering period.

[11] For the purposes of the Evaluation of Cause, Reduced Recruitment is defined as a probability of >50% that annual recruitment was <100% of that required for population replacement (See Chapter 4, Evaluation of Cause, Harmer Creek Evaluation of Cause Team, 2022).

[12] The spawn year is the year a fish egg was deposited, and fry emerged.

[13] For the purposes of the Evaluation of Cause, Recruitment Failure is defined as a probability of >50% that annual recruitment is <10% of that required for population replacement (See Chapter 4 Evaluation of Cause, Harmer Creek Evaluation of Cause Team, 2022).

[14] For the purposes of the Evaluation of Cause, recruitment Above Replacement is defined as a probability of >50% that annual recruitment is >100% of that required for population replacement (See Chapter 4 Evaluation of Cause, Harmer Creek Evaluation of Cause Team, 2022).

The Evaluation of Cause Project Team investigated one overarching question: **What potential stressors can explain changes in the Harmer Creek Westslope Cutthroat Trout population over time, specifically with respect to patterns of Reduced Recruitment?** To investigate this question, the Team evaluated trends in WCT population parameters, including size, condition, and recruitment, and in the potential stressors[15] that could impact these parameters. They evaluated the trends in WCT population parameters based on monitoring data collected from 2017 to 2021 (reported in Thorley et al., 2022 and Chapter 4, Harmer Creek Evaluation of Cause Team, 2022). The Grave Creek population area was used as a reference area for this evaluation.

The approach for analyzing potential stressors for the Evaluation of Cause was to: (1) characterize trends in each stressor for the Harmer and Grave Creek populations, (2) compare the trends between the two population areas, (3) identify any changes in Harmer Creek during the period of Reduced Recruitment, including the Recruitment Failure of the 2018 spawn year where appropriate, and (4) evaluate how each stressor trended relative to the fish population parameters. The Team then identified mechanisms by which the potential stressors could impact WCT and determined if the stressors were present at a sufficient magnitude and duration to have an adverse effect on WCT during the period of Reduced Recruitment. Together, these analyses were used in the Evaluation of Cause report to support conclusions about the relative contribution of each potential stressor to the Reduced Recruitment observed in the Harmer Creek population area.

Ecofish Research Ltd. (Ecofish) was asked to act as a Subject Matter Expert (SME) for an evaluation of total suspended solids (TSS) as one potential stressor. This document is one of a series of SME reports that support the overall Harmer Creek Westslope Cutthroat Trout Evaluation of Cause (Harmer Creek Evaluation of Cause Team, 2022). For additional information, see the preceding Reader's Note.

1.1. Background

1.1.1. Report-Specific Background

Short duration or prolonged exposures to TSS concentrations can directly or indirectly result in a range of effects to fish and their habitats. Effects to salmonids, which prefer clear water conditions, can broadly be grouped into three categories: physiological effects, behavioural effects, and habitat effects (Bash *et al.* 2001). Potential physiological effects to fish include direct damage to tissues (e.g., gill abrasion or clogging), changes to blood chemistry (e.g., increased stress hormones), interrupted osmoregulation, and retarded growth and development (reviewed by Kemp *et al.* 2011).

[15] The Evaluation of Cause process was initiated early in 2021 with currently available data. Although the process continued through mid-2022, data collected in 2021 were not included in the Evaluation of Cause because most stressor reports were already complete. Exceptions were made for the 2021 fish monitoring data and (1) selenium data because the selenium report was not complete and substantive new datasets were available and (2) water temperature data for 2021 in the temperature report because a new sampling location was added in upper Grave Creek that contributed to our understanding of the Grave Creek population area.

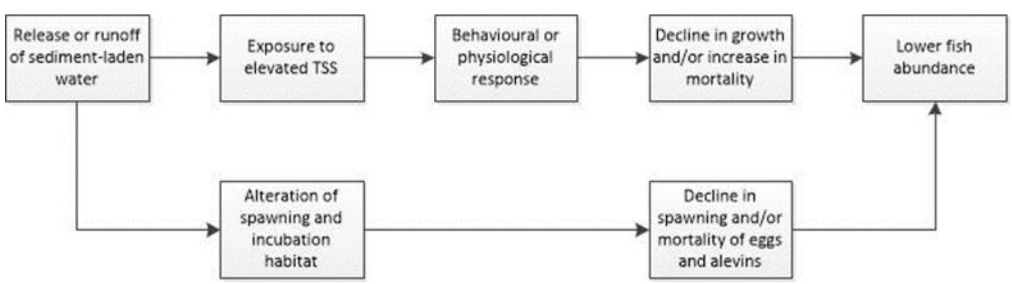
These physiological effects can be lethal or sublethal to fish; the severity of effect increases in proportion to TSS concentration and exposure duration, with sensitivity dependent on fish species and life stage (Newcombe and Jensen 1996). Potential behavioural effects include avoidance of suspended sediment (e.g., seeking refuge or moving to unimpacted reaches), altered territoriality (e.g., because fish cannot see other individuals), disrupted feeding, and impaired homing and migration (e.g., reviewed in Bash *et al.* 2001 and Kemp *et al.* 2011). Increased TSS concentrations can also result in harmful alteration of fish spawning and incubation habitats through sediment deposition (e.g., sediment deposition can entomb eggs, block egg micropores, and decrease interstitial flow (Kemp *et al.* 2011)).

Riverine TSS concentrations fluctuate widely based on a range of factors including local and seasonal hydrologic regimes, geology/geomorphology, and human influences. Collectively, these factors determine the magnitude, duration, and frequency of river sediment inputs and transport (Bash *et al.* 2001) and thereby the magnitude, duration, and frequency of exposure to TSS for the aquatic organisms under assessment (Newcombe and Jensen 1996). Effects to aquatic life from TSS can occur as acute effects (e.g., high magnitude, short duration) and/or chronic effects (e.g., lower magnitude, longer duration).

TSS sampling in the Grave Creek and Harmer Creek population areas has been conducted as part of past and ongoing surface water quality monitoring for Teck Coal's operations (Map 1). Sampling is conducted at regular intervals in accordance with monitoring requirements ("routine monitoring") and in conjunction with specific events, conditions, or other monitoring work ("opportunistic monitoring"). To date, TSS concentrations have been monitored through spot samples rather than derived from a continuous turbidity series. TSS data from May 1981 to December 2020 were provided to Ecofish for an analysis of TSS in relation to the observed Reduced Recruitment.

Figure 1 provides a pathway of effect conceptual model for the cause-effect linkages between TSS exposure and fish abundance. The figure is general and does not distinguish between fish age classes, although our analysis does assess effects separately for eggs and alevins, juveniles, and adults.

Figure 1. Causal effect pathway diagram showing the linkages between TSS and fish.



1.1.2. Author Qualifications

Todd Hatfield, Ph.D., R.P.Bio.

This project is being led by Todd Hatfield, Ph.D., a registered Professional Biologist and Principal at Ecofish Research Ltd. Todd has been a practising biological consultant since 1996 and he has focused his professional career on three core areas: environmental impact assessment of aquatic resources, environmental assessment of flow regime changes in regulated rivers, and conservation biology of freshwater fishes. Since 2012, Todd has provided expertise to a wide array of projects for Teck Coal: third party review of reports and studies, instream flow studies, environmental flow needs assessments, aquatic technical input to structured decision making processes and other decision support, environmental impact assessments, water licensing support, fish community baseline studies, calcite effects studies, habitat offsetting review and prioritizations, aquatic habitat management plans, streamflow ramping assessments, development of effectiveness and biological response monitoring programs, population modelling, and environmental incident investigations.

Todd has facilitated technical committees as part of multi-stakeholder structured decision making processes for water allocation in the Lower Athabasca, Campbell, Quinsam, Salmon, Peace, Capilano, Seymour, and Fording rivers. He has been involved in detailed studies and evaluation of environmental flows needs and effects of river regulation for Lois River, China Creek, Tamihi Creek, Fording River, Duck Creek, Chemainus River, Sooke River, Nicola valley streams, Okanagan valley streams, and Dry Creek. Todd was the lead author or co-author on guidelines related to water diversion and allocation for the BC provincial government and industry, particularly as related to the determination of instream flow for the protection of valued ecosystem components in BC. He has worked on numerous projects related to water management, fisheries conservation, and impact assessments, and he has developed management plans and guidelines for industry and government related to many different development types. Todd recently completed his third four-year term with COSEWIC (Committee on the Status of Endangered Wildlife in Canada) on the Freshwater Fishes Subcommittee.

Dan Durston, M.Sc., Biologist

Dan Durston is a freshwater aquatic biologist who obtained his Master of Science in Ecosystem Ecology at the University of Victoria. He has 7 years of experience working in freshwater environments with an emphasis on sediments, nutrients, fish habitat, and aquatic food webs. During that time, he has authored a wide range of scientific papers relating to water quality and fish. Since 2018, Dan has worked at Ecofish where he has designed and analysed studies on the effects to freshwater fish from suspended sediments and a wide range of other water quality parameters.

Dan has provided expertise to Teck Coal in relation to potential effects to fish from suspended sediments as the technical lead for TSS UFR Evaluation of Cause for TSS as a potential stressor, and for the Corbin Dam Spillway upgrade project. He also has experience working with TSS and turbidity dose-response models throughout BC including for the Peace River, Kitimat River, Iskut River, Ramona Creek, and Upper Lillooet River. For these and other projects he has managed inputs of sediment to waterbodies in real-time for construction related activities and assessed the potential effects of exposure to sediment on clear water fish.

1.2. Objective

The objective of this report is to evaluate TSS conditions in the Grave Creek watershed using data collected from May 1981 to December 2020 to assess potential effects to WCT in recent years (2016 - 2019) from TSS exposure. Potential impacts could have occurred from short duration (acute) and/or prolonged (chronic) exposures to elevated TSS concentrations that directly or indirectly affected the health and survival of WCT. Thus, exposure to TSS could have led to Reduced Recruitment if a large proportion of the population was sufficiently affected. TSS data from 2016 – 2019 were used to evaluate Reduced Recruitment in the 2017 to 2019 spawning-year cohorts. The analysis evaluated effects from TSS that may have been direct (e.g., mortality of embryos or fry) or indirect (e.g., stress to reproductively mature fish prior to spawning).

The specific question evaluated was:

1. Did exposure to TSS cause or contribute to the observed Reduced Recruitment in Harmer Creek in the 2017, 2018, and 2019 spawn years?

1.3. Approach

TSS data from sites in Grave Creek, Harmer Creek, tributaries thereof, and direct input locations were provided by Teck Coal for all monitoring conducted during the May 1981 to December 2020 period (Teck 2021). TSS data consisted of 1221 samples collected across 27 sites (Map 1; Table 1). Individual TSS results that were below the minimum detection limit (MDL) were assigned the MDL value for the purpose of TSS reporting and severity of ill effects (SEV) calculations (Newcombe and Jensen 1996; and see description in Section 2.1), even though the MDL may be higher than the actual value. Of note, the MDL was raised in 2014 from 0.1 mg/L to 1 mg/L, which affected comparisons before and after this date for values below this threshold and where means or other summary statistics were calculated.

The majority of the TSS data were from one site at the outlet of Harmer Creek Sedimentation Pond (EV_HC1, 822 samples), for which a relatively complete long-term dataset exists from 1981 to 2020. These data primarily informed conditions within the 600 m reach downstream of the Harmer Dam to the confluence with Grave Creek, since water quality at the outlet was decoupled from upstream conditions in Harmer Creek due to settling processes and turnover time within the sedimentation pond. However, a review of the available data indicated that EV_HC1 data were correlated with data at the sedimentation pond inlet and thus could reflect upstream conditions, although with attenuation (Appendix B). EV_HC1 samples were typically collected weekly from March to June and monthly at other times of the year.

There was also a relatively complete, long-term dataset at Dry Creek at Sedimentation Pond outlet (EV_DC1, 139 samples) with samples collected in 1994 and then regularly from 2004 to 2020. These data primarily informed conditions in the 150 m reach from the pond outlet to the Dry Creek confluence with Harmer Creek. Like the EV_HC1 samples, data from EV_DC1 were decoupled from upstream conditions due to settling of TSS within the pond. Furthermore, conditions below the Dry-Harmer confluence could have been substantially different due to Harmer Creek inputs.

Substantial monitoring was also conducted at a third site above the Harmer Creek Sedimentation Pond on Harmer Creek (EV_HC1A) (117 samples), but those samples were almost entirely collected during 1983 – 1985 and 1998 – 2002, such that very few data were available for recent years (only 2 samples since 2002). Where these data were available, they reflected conditions in Harmer Creek upstream of the sedimentation pond (the majority of its reach). Monitoring also occurred at four other sites for at least a few months during the historical record (EV_GV1, 39 samples; EV_GV3, 34 samples; EV_HC3, 18 samples; EV_HC6, 15 samples), although none of these sites has been sampled since 2016.

Collectively, the data from the seven sites where on-going monitoring has been conducted are referred to as the "routine" monitoring data. Gaps in these data series have not been infilled based on correlations with other stations because changes in land use and/or anomalous events could have produced conditions that depart from historical correlations.

In addition, limited TSS data (37 samples) were available for a further 21 sites (1 – 6 samples per site; Table 1). These data were collected during specific events, conditions, or other monitoring work and are referred to as the "opportunistic monitoring" data. These data are from the 2017 – 2020 period and usually cover one or two dates per site.

Table 1. Water quality monitoring stations included in the Grave Creek watershed TSS effects assessment.

Frequency	Station ID	Station Name	Period of Record		# of Samples	TSS (mg/L)	
			Start	End		Minimum	Maximum
Routine	EV_DC1	Dry Creek at pond outlet	1994-04-27	2020-11-17	139	0.2	28.1
	EV_GV1	Grave Creek near the mouth	2008-03-18	2016-09-12	39	0.7	209.0
	EV_GV3	Grave Creek upstream of Harmer Creek	2013-10-01	2016-09-12	34	1.0	240.0
	EV_HC1	Harmer Creek at Harmer Dam outlet	1981-05-07	2020-12-01	822	0.1	256.0
	EV_HC1A	Harmer Creek above Harmer Dam reservoir	1983-01-12	2019-10-08	117	0.1	521.0
	EV_HC3	Harmer Creek downstream of Dry Creek	1983-02-01	1983-12-06	18	0.3	5.7
	EV_HC6	Harmer Creek upstream of Dry Creek	2014-02-25	2016-09-12	15	1.0	8.6
Opportunistic	EV_DC2		2019-10-09	2019-10-09	1	3.6	3.6
	EV_DC3		2019-10-09	2019-10-09	1	11.8	11.8
	EV_DC-EF1		2019-10-09	2019-10-09	1	8.4	8.4
	EV_DC-EF2		2019-10-09	2019-10-09	1	1.8	1.8
	EV_HC4		2019-07-02	2020-06-03	6	1.0	3.0
	EV_HCUSDC		2019-10-09	2020-06-03	4	1.0	2.9
	RG_FLA_GV1		2020-05-11	2020-05-11	1	1.9	1.9
	RG_FLA_GV2		2020-05-11	2020-05-11	1	2.5	2.5
	RG_FLA_GV3		2020-05-11	2020-05-11	1	2.3	2.3
	RG_FLA_GV4		2020-05-11	2020-05-11	1	3.1	3.1
	RG_FLA_GV5		2020-05-12	2020-10-06	2	1.0	2.4
	RG_FLA_GV6		2020-05-12	2020-10-06	2	1.6	3.0
	RG_FLA_GV7		2020-05-12	2020-10-06	2	1.7	3.1
	RG_FLA_GV8		2020-05-12	2020-05-12	1	4.3	4.3
	RG_FLA_GV9		2020-05-13	2020-05-13	1	2.7	2.7
	RG_FLA_HM2		2020-05-13	2020-10-07	2	1.1	2.1
	RG_FLA_HM3		2020-05-13	2020-10-07	2	1.2	2.2
	RG_GRDS		2018-09-12	2019-09-04	2	1.2	2.8
	RG_HACKDS		2017-09-16	2020-09-16	4	1.2	2.4
	RG_HARM5		2020-09-21	2020-09-21	1	2.1	2.1

Potential effects to WCT from TSS were investigated initially through a review of the available TSS data and then quantified using the SEV impact assessment model (Newcombe and Jensen 1996). This SEV model used both the duration and magnitude of exposure to TSS to calculate a SEV index score that could be related to potential effects to fish. A common approach for evaluating TSS data is to compare the monitoring results to BC water quality guidelines (WQGs; BC MOE 2019). The SEV model was used in the development of the BC WQG for TSS and thus both approaches consider the magnitude and duration of TSS exposure (Caux *et al.* 1997). However, the BC WQG for TSS was designed as a relative criterion (e.g., it provides a specified increase over background), whereas the SEV model predicts effects in relation to absolute TSS criteria (not as a proportion to background), and therefore only the SEV model can relate TSS concentrations to specific effects (e.g., mortality rates). Since the objective of this report is to evaluate the potential for TSS concentrations to cause a specific effect (i.e., WCT reduced recruitment), the SEV model was selected as the appropriate approach.

The available TSS data were analyzed for long-term trends or anomalous events in 2016 – 2019 (the period of interest). Anomalous events were defined as SEV results occurring in the period of interest in which the mean and/or maximum SEV was near or above the upper end of the historical range observed at that site. This approach relied on intra-site comparisons over time because: (1) temporally matched data were often lacking for inter-site comparisons, (2) a widespread event would have affected many or all sites such that inter-site comparisons for that period of time would fail to detect widespread anomalies, (3) inter-site comparisons were confounded by other factors (e.g., TSS at many sites routinely seemed high compared the sedimentation pond outlet sites), and (4) high TSS at a site that normally had low TSS was considered anomalous and potentially harmful to fish there regardless of TSS concentrations elsewhere.

For the 1981 – 2020 dataset, SEV index scores were calculated with two exposure duration assumptions: acute (96-hour) and chronic (30-day) durations for the routine and opportunistic monitoring data. The 30-day duration for chronic SEV was selected because chronic guidelines are commonly based on 30-day exposure, while the 96-hour duration for acute SEV was selected because (1) the actual durations of high TSS events were unknown, and 96 hours provided a more conservative assumption than a 24-hour duration (i.e., assumed the event lasted longer than it likely did), and (2) the available TSS data were relatively low resolution (e.g., often weekly) and thus were unlikely to capture peak event TSS, so assuming a longer duration helps to compensate for results that were likely to be lower than peak TSS for that event. If TSS data were collected at an event peak and for an event that lasted less than 96 hours, these assumptions would overstate SEV. Similarly, chronic SEV could be over- or understated if the available data did not accurately reflect mean TSS for a given 30-day period.

SEV index scores were used to categorize the probability and type (e.g., behavioural effects, sublethal effects, lethal effects) of potential effects to fish. SEV index scores were evaluated and compared for the entire 1981 – 2020 period to determine whether long-term trends (e.g., increasing SEV) or anomalous events may have been responsible for the Reduced Recruitment. Where long-term data records existed (i.e., at EV_HC1), a generalized additive model (GAM) was applied to the SEV data to identify the moving average and 95% confidence interval. In cases where increasing SEV trends, anomalous SEV results, or sufficiently high SEV were identified, the SEV results were compared to explanatory factors (Section 2.2) that could have caused or contributed to the Reduced Recruitment of the Harmer Creek population, including the intensity, duration, timing, location, and spatial extent of TSS exposure. SEV scores were calculated separately for WCT adults, juveniles, and eggs and larvae due to differences in sensitivity to TSS for different life history stages.

2. METHODS

2.1. Severity of Ill Effects Modelling

TSS data were analyzed using SEV models developed by Newcombe and Jensen (1996). Index scores derived from the models are a method of quantifying effects to aquatic life that is generally accepted by regulators in British Columbia (e.g., Singleton 2001, McCoy 2013). Consistent with the assessment of other water quality constituents (Warner *& Lancaster,* 2022), the SEV analysis was used to assess both acute (96-hour) and chronic (30-day) TSS conditions to provide a means of identifying potential effects to WCT.

The SEV models were developed from studies that relate biological responses to the magnitude and duration of exposure to suspended sediments (Newcombe and Jensen 1996; Caux *et al.* 1997). The models apply to different types of aquatic biota including freshwater and anadromous adult salmonids (Group 2), freshwater and anadromous juvenile salmonids (Group 3), and eggs and larvae of salmonids and non-salmonids including freshwater, anadromous, and estuarine fish (Group 4; Table 2). For the calculation of SEV for eggs and larvae, the data are restricted to the period where these life stages are present. In all cases, the equation to calculate the SEV index score has the form:

$$\mathbf{z = a + b(\log_e x) + c(\log_e y)}$$

Where:

z = SEV index score;

x =duration of exposure (hours);

y =concentration of total suspended solids (mg/L);

a =intercept (specific to different groups of biota);

b =slope coefficient for duration of exposure (specific to different groups of biota); and

c =slope coefficient for concentration of exposure (specific to different groups of biota).

The constants used and their sources for different life history stages are provided in Table 2. SEV index scores and associated categories are provided in Table 3.

Table 2. SEV model parameters developed by Newcombe and Jensen (1996).

SEV Model	Sediment Particle Size[1]	n[2]	SEV Model Parameters			Source of Model Parameter Values
			a	b	c	
Adult Salmonids; Freshwater and Anadromous	0.5 µm to 250 µm	63	1.6814	0.4769	0.7565	Group 2 in Newcombe and Jensen (1996)
Juvenile Salmonids; Freshwater and Anadromous	0.5 µm to 75 µm	108	0.7262	0.7034	0.7144	Group 3 in Newcombe and Jensen (1996)
Eggs and Larvae of Salmonids and Non-Salmonids; Freshwater, Anadromous, and Estuarine	0.5 µm to 75 µm	43	3.7466	1.0946	0.3117	Group 4 in Newcombe and Jensen (1996)

[1] Fine particles <75 µm are small enough to pass through gill membranes into the interlamellar spaces of gill tissue and include clay, silt, and very fine sand particles. Coarse particles >75 µm are large enough to cause mechanical abrasion of gills, and include very fine to fine sand particles.

[2] Sample size for model development (Newcombe and Jensen 1996).

As a result of spatiotemporal discontinuities and other limitations in the Grave Creek watershed TSS dataset, the application of the SEV model to the available data required several key assumptions:

1. Individual TSS observations at sites in the receiving environment were assumed to be representative of conditions at that location (e.g., the waters were assumed to be fully mixed) and representative of that river/stream segment (i.e., nearby conditions were assumed to be not substantially different as a result of further inputs or settling, dilution, and resuspension processes). The extent to which sample sites were representative of more distant conditions is largely unknown.
2. Average TSS from discrete samples collected over the chronic (30-day) and acute (96-hour) durations were assumed to be representative of actual average conditions (e.g., events did not occur between sampling that would have substantially lowered or raised the average). Since the data were low resolution (i.e., one sample for each 96-hour period and typically 1 – 4 samples for each 30-day period), dissimilar conditions could have existed within that period.
3. TSS particle sizes were assumed to be within the applicable particle size range for the SEV models (provided in Table 2). Particle sizes for the study dataset were unknown, but the SEV models were informed by and apply to a wide range of particle size conditions (Newcombe and Jensen 1996).
4. The SEV models were assumed to accurately predict effects to WCT. Predictions of effects from TSS were based on general SEV models that are not specific to WCT such that the actual

effects could have been less or greater. The SEV models for adults and juveniles have been developed to apply to all salmonids (both freshwater and anadromous), while the SEV model for eggs and larvae is broader as it applies to both salmonids and non-salmonids.

The actual effects to fish from TSS could have been greater or less depending on the actual conditions in comparison to these assumptions. Despite this uncertainty, SEV modelling remains a useful tool to assess biological effects of observed TSS and for identifying trends and anomalies that may have been related to Reduced Recruitment. For periods with no TSS data (e.g., between sampling or in unsampled areas), effects to fish are unknown.

The acute and chronic SEV scores were calculated using 96-hour and 30-day durations respectively, based on the rationale provided in Section 1.3. The 96-hour acute SEV was calculated for each TSS data point individually on the assumption that the acute event may have lasted for 96 hours. Chronic SEV was calculated using a mean of TSS observations within each calendar month using an assumed 30-day duration. We applied a 30-day duration to all months rather than adjusting for slight differences in length of each month (i.e., 28-day, 30-day and 31-day months were treated as equivalent periods).

Matrices illustrating how the SEV index varies with different combinations of TSS concentration (intensity) and exposure duration are provided in Appendix A for 1) adult salmonids, 2) juvenile salmonids, and 3) eggs and larvae of salmonids and non-salmonids.

2.1.1. Categorization of Effects

SEV index scores occur on a scale of 0 to 14, where each index score is associated with a description of biological effects (e.g., alarm reactions, physiological effects, lethal effects), as provided in Table 3 (Caux *et al.* 1997; Newcombe and Jensen 1996). Newcombe (2003) further grouped the SEV index scores into four categories that describe degree of impairment (i.e., ideal conditions, slight impairment, significant impairment, and severe impairment) (Table 3).

To aid the current evaluation of cause and to simplify the discussion of SEV results, we developed an additional "magnitude" category with five divisions ranging from negligible to very high (Table 3). These divisions mirror the impairment categories from Newcombe (2003), except the highest impairment category (SEV 9 – 14 or "severe impairment") has been subdivided into "high" and "very high" magnitudes, in recognition that the "severe impairment" category is otherwise overly broad in the context of evaluating recruitment (i.e., it equates to effects ranging widely from reduced growth to 100% mortality; Table 3). SEV 12 was selected as the threshold for division into high and very high magnitude because SEV 12 is associated with 40-60% mortality (Newcombe and Jensen 1996) and thus approximately corresponds to an LD50 event (i.e., the dose at which 50% of exposed individuals die). A summary of the TSS concentrations that correspond to various SEV index scores for each WCT life stage is provided in Table 4 for acute and chronic durations.

Table 3. SEV index score descriptions for fish (adapted from Newcombe and Jensen 1996 and Newcombe 2003).

SEV Index	Biological Effect[1]	Degree of Impairment[2]	Magnitude[3]
0	No behavioural effects	*Ideal.* Best for adult fishes that must live in a clear water environment most of the time.	Negligible
1	Alarm reaction	*Slightly Impaired.* Minor effect, feeding and other behaviours begin to change.	Low
2	Abandonment of cover		
3	Avoidance response		
4	Short-term reduction in feeding rates or feeding success	*Significantly Impaired.* Minor to Moderate Sublethal Effects. Marked increase in water cloudiness could reduce fish growth rate, habitat size, or both.	Moderate
5	Minor physiological stress; increased coughing; increased respiration rate		
6	Moderate physiological stress		
7	Moderate habitat degradation; impaired homing		
8	Indications of major physiological stress; long-term reduction in feeding rate or success; poor condition		
9	Reduced growth rate; delayed hatching; reduced fish density	*Severely Impaired.* Lethal and Paralethal[4] Effects. Profound increases in water cloudiness could cause poor "condition" or habitat alienation.	High
10	0-20% mortality; increased predation; moderate to severe habitat degradation		
11	>20-40 % mortality		
12	>40-60% mortality		Very high
13	>60-80% mortality		
14	>80-100% mortality		

[1] Newcombe and Jenson 1996

[2] Newcombe 2003

[3] Unique categorization system developed for the Grave-Harmer Evaluation of Cause

[4] Paralethal effects include reduced growth, reduced fish density, habitat damage such as reduced porosity of spawning gravel, delayed hatching, and reduction in population size. Paralethal effects can result in reduced rates of survival from one life stage to the next.

Table 4. Summary of TSS concentrations that correspond to various SEV index scores for acute (96-hour) and chronic (30-day) exposure durations.

Exposure Duration	SEV Model[1] / SEV Score	TSS Concentration (mg/L) 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Acute: 96 hours	Adult Salmonids	0.01	0.02	0.09	0.32	1.21	4.52	17.0	63.6	239	895	3,357	12,590	47,220	177,100	664,200
	Juvenile Salmonids	0.00	0.02	0.07	0.27	1.09	4.43	18.0	72.8	295	1,197	4,852	19,670	79,760	323,400	1,311,000
	Fish Eggs and Larvae[2]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	2.28	56.5	1,397	34,540	854,400	21,130,000
Chronic: 30 days	Adult Salmonids	0.00	0.01	0.02	0.09	0.34	1.27	4.76	17.9	67	251	943	3,535	13,260	49,720	186,500
	Juvenile Salmonids	0.00	0.00	0.01	0.04	0.15	0.61	2.47	10.0	41	165	667	2,706	10,970	44,470	180,300
	Fish Eggs and Larvae[2]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	1.18	29.2	722	17,870

[1]Equations are provided in Section 2.2 and Table 3.

[2]Model includes both salmonids and non-salmonids

Table 5. Periodicity of Westslope Cutthroat Trout in the Grave Creek watershed. Shaded periods indicate presence of each life stage.

Life Stage	Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Adults	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Juveniles	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Eggs and Larvae																						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■								

2.2. Evaluation of Explanatory Factors

Five explanatory factors were used to assess effects of TSS exposure on WCT recruitment: exposure intensity, duration, spatial extent, location, and timing. Criteria for each of these factors (Table 6) were used to determine whether TSS caused or contributed to the Reduced Recruitment. Intensity and duration are components of the SEV model and therefore were assessed through evaluation of SEV results.

Table 6. Criteria for TSS explanatory factors that were used to determine whether TSS was a cause of or contributor to Reduced Recruitment.

Intensity	TSS exposure was of sufficient concentration to cause or contribute to Reduced Recruitment.
Duration	TSS exposure was of sufficient duration to cause or contribute to Reduced Recruitment.
Spatial extent	TSS exposure occurred over a large enough portion of Harmer Creek habitat to have caused or contributed to Reduced Recruitment.
Location	TSS exposure was spatially coincident with WCT use of the habitat to the extent that it could have caused or contributed to Reduced Recruitment.
Timing	TSS exposure occurred in recent years and when WCT were present. (Adults and juveniles are present throughout the year, fry are present from August through October; see Table 6.)

To account for differences in sensitivity among life stages, SEV index scores were calculated separately for three WCT life stages (adults, juveniles, and eggs and larvae) using information on the life history of WCT (e.g., habitat use and periodicity). Most likely, TSS would have disproportionately affected early life stages if TSS were to explain Reduced Recruitment. Effects to adults and juveniles were also evaluated for completeness and to provide a comparison among life stages. It is also possible that TSS effects were somewhat indirect, by stressing adults and thereby causing lower reproductive investment (e.g., displacement or disruption during spawning).

Life stage periodicity for the Grave Creek and Harmer Creek populations of WCT indicated that eggs and larvae occur from mid-June to late October; whereas juveniles and adults are present throughout the year (Table 5; Cope and Cope 2020). Periodicity information was used to apply SEV models to appropriate times of the year when each life stage is expected to be present.

In terms of location, although a fish barrier exists at the Harmer Dam, WCT are known to occur throughout Grave and Harmer Creeks and some tributaries thereof, including Dry Creek (Thorley et al. 2022). Adult abundance was generally lower in Harmer Creek (which includes Dry

Creek) compared to Grave Creek but relatively stable, whereas abundance of the youngest age classes in Harmer Creek was particularly low compared to Grave Creek and to older assessments of Harmer and Dry creeks (Thorley et al. 2022).

Assessment of the explanatory factors and life stage SEV effects was intended to support evaluation of the study question for the TSS stressor (Section 1.2).

Cause of the Reduced Recruitment would be indicated if the SEV index was consistent with effects to eggs and larvae that were of high or very high magnitude, increased during the 2016 – 2019 period relative to the prior period, and widespread (spatiotemporally coincident with a large portion of the fish distribution). This level of effect could occur through multiple high magnitude events (0 – 20% mortality) or as few as one very high magnitude event (40 – 100% mortality). Meeting these conditions could result in Reduced Recruitment consistent with the observed trends.

Contribution to the Reduced Recruitment would be indicated if the SEV index was consistently high or very high magnitude localized effects and/or widespread moderate magnitude effects to any life stage of WCT during 2016 – 2019. Localized high or very high effects could have resulted in mortality and/or reduced reproductive investment at a spatial scale that was insufficient to fully explain the Reduced Recruitment. Widespread moderate magnitude effects do not directly cause mortality but are associated with reductions in feeding and increased stress, which could have reduced fish health and resulted in mortality in combination with other effects and/or reduced investment in reproduction. A determination that TSS contributed the Reduced Recruitment did not require an increase in effect in 2016 – 2019 relative to prior conditions because harm from TSS may have been a pre-existing condition that exacerbated the effects of other stressors occurring during the period of Reduced Recruitment.

SEV results that did not meet the above criteria were said to have not caused or contributed to the Reduced Recruitment, although there is a possibility that lower SEV scores could still have contributed in a minor way.

3. RESULTS

3.1. Routine Monitoring

3.1.1. TSS Overview

TSS concentrations were assessed for 1,184 routine TSS samples collected from seven water quality sites in Harmer Creek and Grave Creek from May 1981 to December 2020 (Figure 2). Of note, the MDL for TSS was raised in 2014 to 1 mg/L (from 0.1 mg/L), which affected mean TSS calculations and created the visible floor in TSS results in Figure 2, since values below the MDL were treated as being equal to the MDL.

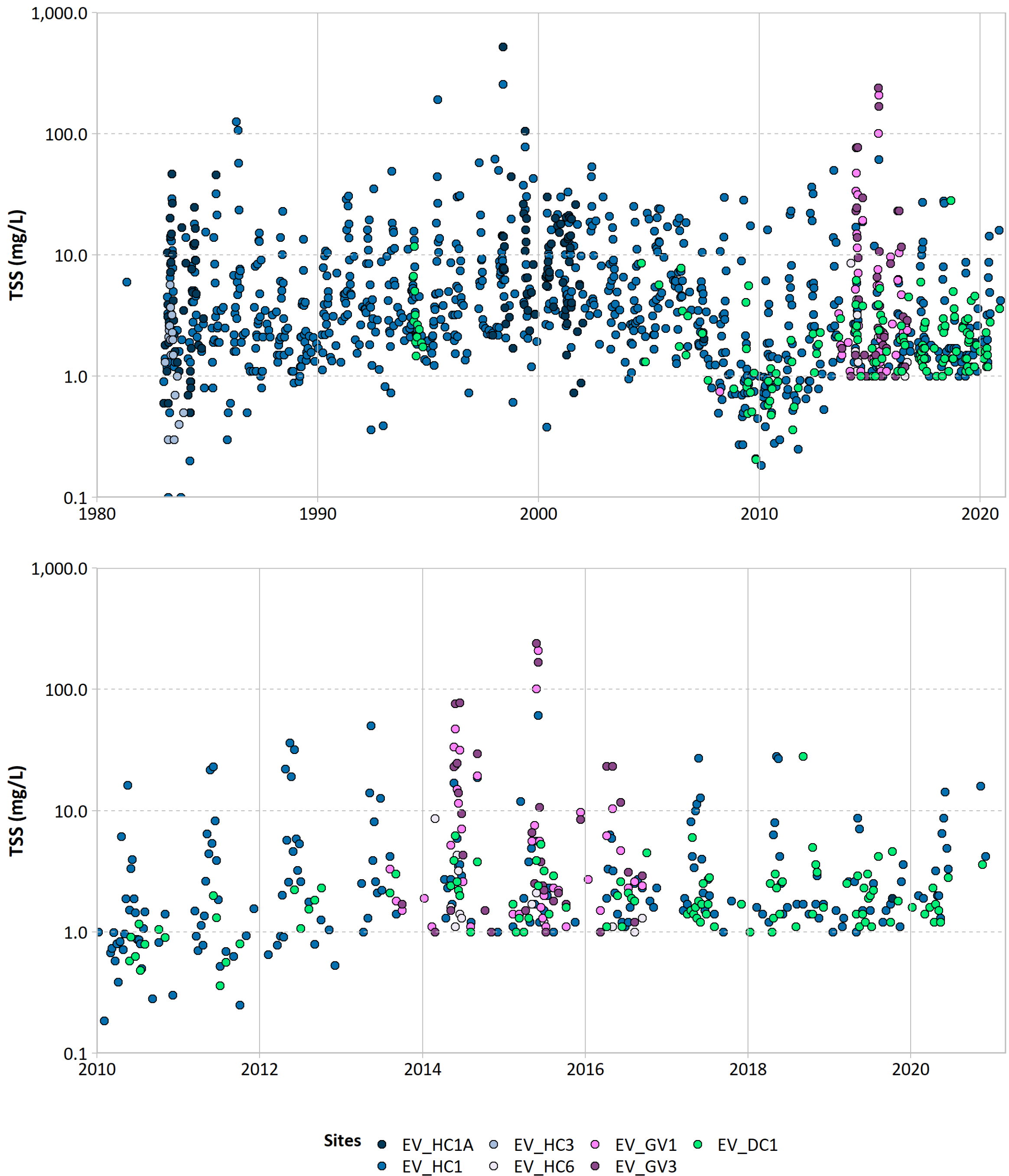
The routine monitoring dataset for the Harmer Creek population area (including Dry Creek) contained 1,111 samples from five sites (EV_HC1, EV_HC1A, EV_HC3, EV_HC6, and EV_DC1), with a mean TSS of 7.2 mg/L. The dataset included 972 samples from Harmer Creek (mean of 7.8 mg/L) and 139 samples from Dry Creek (mean of 2.5 mg/L). The highest TSS value recorded for Harmer Creek was 521 mg/L (HC1A on May 27, 1998), which was corroborated by a lab turbidity result of 148 NTU. During the period of interest (2016 – 2019), mean TSS within the Harmer Creek population area was 3.3 mg/L, including data from Harmer Creek (mean of 3.8 mg/L) and Dry Creek (mean of 2.6 mg/L). The maximum TSS during the period of interest was 28.1 mg/L at Dry Creek (EV_DC1 on September 4, 2018), although this result is considered unreliable because concurrent measurements of field turbidity (0.7 NTU) and lab turbidity (0.44 NTU) showed clearer waters. Contamination or misidentification of the sample may have occurred.

The routine monitoring dataset for Grave Creek contained 73 samples from two sites (EV_GV1 and EV_GV3) with a mean TSS of 18.6 mg/L and a maximum TSS of 240 mg/L (EV_GV3 on May 26, 2015). During the period of interest (2016 – 2019), data from Grave Creek were only available for one year (2016); the mean TSS was 6.6 mg/L and the maximum was 23.2 mg/L (observed at EV_GV3 on April 6, 2016).

A comparison of TSS data from the Harmer Creek and Grave Creek population areas showed higher mean TSS in Grave Creek for both the entire dataset (18.6 mg/L vs 7.2 mg/L) and for the 2016 - 2019 period (6.6 mg/L vs 3.3 mg/L). However, the Harmer Creek population area data were primarily collected at sedimentation pond outlets, unlike in Grave Greek. The limited data collected at the Harmer Creek Sedimentation Pond inlet (EV_HC1A) showed higher TSS (14.5 mg/L) compared with the outlet (7.1 mg/L), which suggests that the Harmer Creek population area results would have been higher and more similar to Grave Creek if the data had been collected at sedimentation pond inlet sites rather than outlets.

In general, TSS data indicated lower TSS in recent years, with mean TSS in Harmer Creek during 2016-2019 lower than in previous years for both the Harmer Creek and Grave Creek population areas.

Figure 2. **TSS concentrations (mg/L) in all routine monitoring samples from 1981 to 2020 (top panel) and 2010 to 2020 (bottom panel). Relationships between TSS and SEV are provided in Table 4.**



3.1.2. Acute SEV

Acute TSS exposure (measured as 96-hour SEV) was consistent with low to moderate effects for adult and juvenile salmonids for the entire period of record (Figure 3). For adult salmonids, acute SEV ranged from 2.0 to 8.6 across all dates and sites (Table 7), with no results above the high (SEV 9) threshold. SEV values for juvenile salmonids were similar, with an observed SEV range of 2.2 to 8.4 (Table 8). Most of these results were in the range of moderate effects (SEV 3 – 9), with occasional low magnitude results (SEV 1-3) observed in 1983 – 1984 and 2009 – 2011. An increase in the MDL to 1 mg/L for 2014 precluded further detection of low magnitude effects (since 1 mg/L equates to a 96-hour SEV of 3.9; Table 4).

Acute SEV results for eggs and larvae ranged from 8.0 – 10.1 (Table 9), which corresponds to moderate to high effects (Table 3). These results are based on the same TSS observations as those used to evaluate effects on other life stages, except the data were limited to those from the time periods when egg and larvae life stages occur. The eggs and larvae SEV model returned higher SEV scores due to the greater sensitivity of early life stages to suspended sediments.

Long-term trends in SEV are indicated in Table 7, Table 8, and Table 9, and allow comparison of mean SEV within and across sites for the available data record. The two sites with the most complete data (EV_DC1 and EV_HC1) showed similar results when the period of interest (2016 -2019) was compared to the historical record. At EV_DC1, mean egg and larvae SEV ranged from 8.9 to 9.2 during 2016 – 2019 compared with 8.6 – 9.4 for the prior years (1994, 2004 – 2015). In the pre-2016 period (34 years) at the EV_HC1 site, acute SEV for eggs and larvae ranged from 8.7 to 9.4, while in the most recent five years acute SEV for these life stages ranged from 8.9 to 9.1 (Table 9). For juveniles and adults, acute SEV was also similar between the period of interest and the historical record, but with lower SEV scores than for eggs and larvae due to the reduced sensitivity of the older life stages (Table 7, Table 8).

Long-term trends in acute SEV are indicated using a generalized additive model (GAM) applied to the long-term dataset at the EV_HC1 site (Figure 4). The GAM provided a modelled mean acute SEV and 95% confidence interval for the 1981-2020 period for each life stage. Similar to the chronic SEV results, this modelling showed relatively stable acute SEV for adults and juveniles over the 40-year period, with the past five years similar to or lower than most of the historical record. For eggs and larvae, the modelled relationship was limited to data from the period when these life stages were present and also showed no increase in SEV in recent years.

For each site, the maximum SEV during the 2016 – 2019 period was within or less than the pre-2016 range, with the exception of a higher maximum SEV at EV_DC1 in 2018, which exceeded the maximums for all other years at this site. This anomalous result was moderate in magnitude for adults (SEV 6.4) and juveniles (SEV 6.3) but high for eggs and larvae (SEV 9.8). While this outlier was the highest acute SEV result for eggs and larvae in the data record at Dry Creek and was higher than Harmer Creek records since 2001, it was derived from a single TSS observation of 28.1 mg/L, which is considered unreliable (as explained in Section 3.1.1).

Also notable were some acute SEV results at two Grave Creek sites (EV_GV1 and EV_GV3) in 2014-2015. For adults, acute SEV at these sites showed maxima of up to SEV 7.9 (still a moderate level), which was higher than other years within Grave Creek (maxima in the range of SEV 4.3-6.2) and higher than results during the 2014 – 2015 years within Dry Creek and Harmer Creek (maximum adult acute SEV of 6.9). Only the 2014 TSS observations were within the period when eggs and larvae were present; for these life stages acute SEV was as high as 10.1. Historical norms at these sites are largely unknown due to the limited coverage of the dataset (2008, 2013 – 2016), but the 2014 results for eggs and larvae (up to SEV 10.1) were the highest acute SEV in the full dataset.

Figure 3. **Acute SEV at all routine monitoring sites. SEV is shown for adult salmonids (top panel), juvenile salmonids (middle panel), and eggs and larvae (bottom panel) for 1981 – 2020. Horizontal lines indicate the thresholds between SEV magnitude groupings (described in Table 3).**

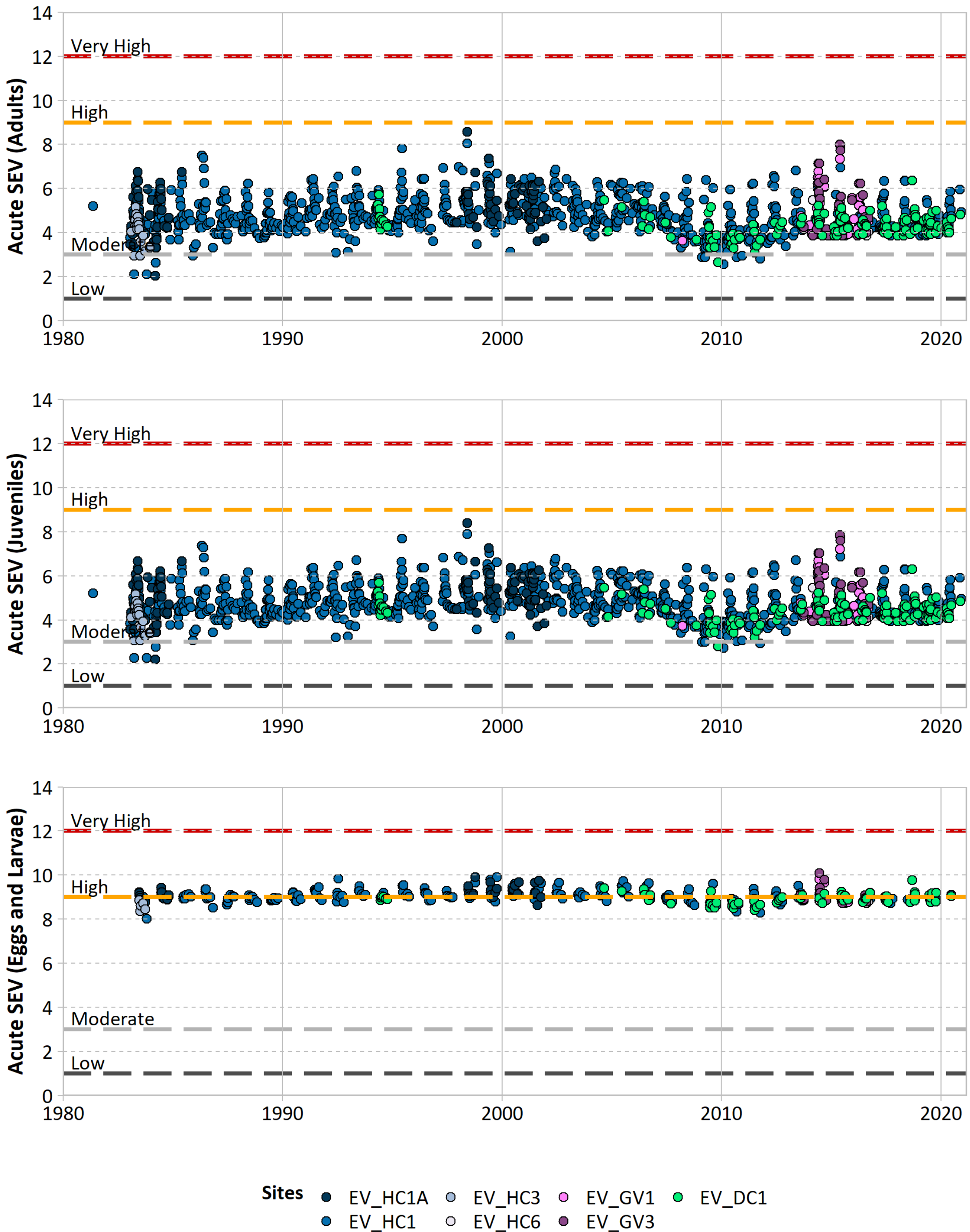


Figure 4. **Acute SEV at the HC1 monitoring site only with a GAM smoothing function (black solid line) to show long term trends. SEV is shown for adult salmonids (top panel), juvenile salmonids (middle panel), and eggs and larvae (bottom panel) for 1981 – 2020. Horizontal lines indicate the thresholds between SEV magnitude groupings (described in Table 3).**

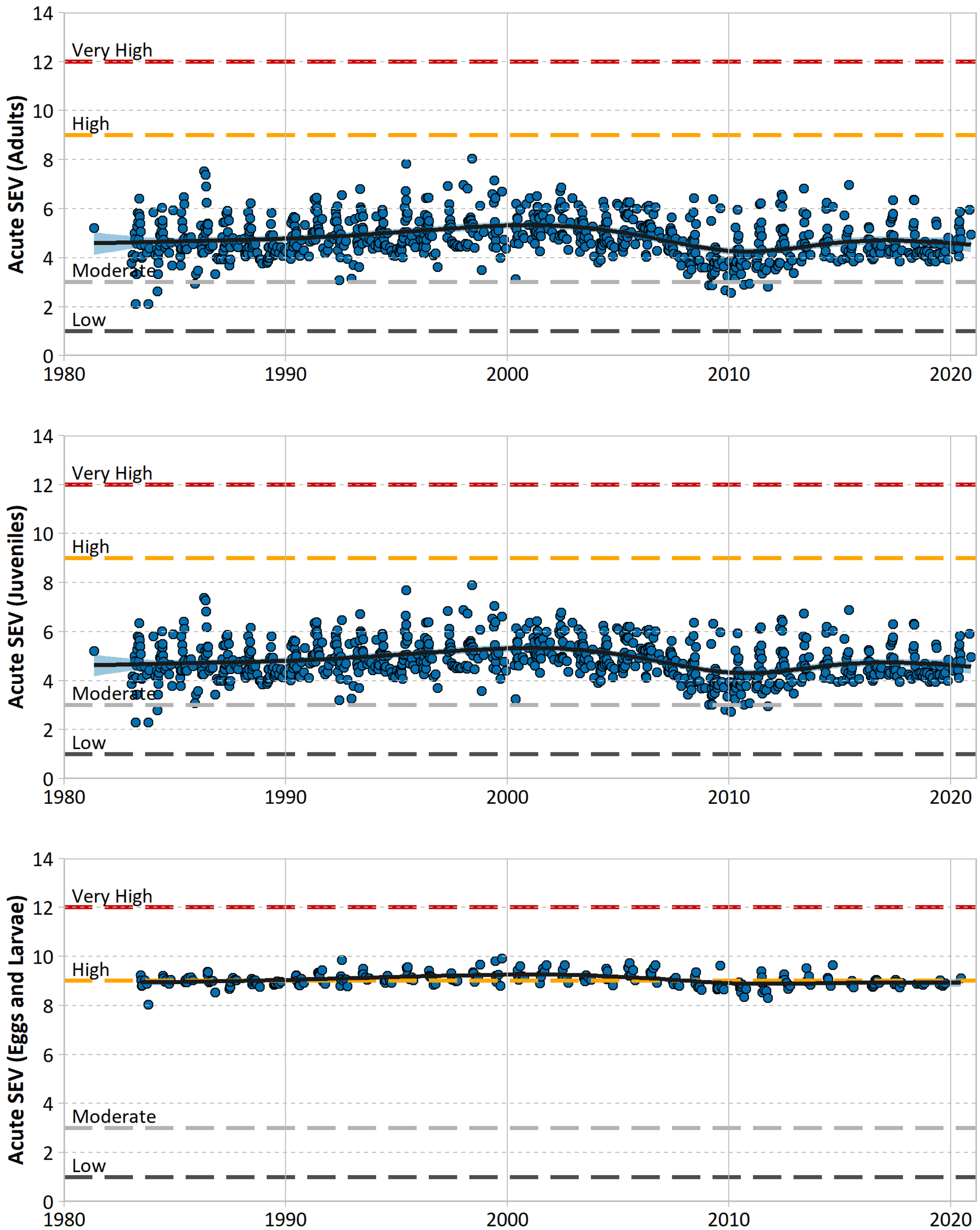


Table 7. Acute SEV results for adult salmonids at the routine monitoring sites.

Year	Site: EV_GV1 Mean	EV_GV1 Max	EV_GV3 Mean	EV_GV3 Max	EV_HC1 Mean	EV_HC1 Max	EV_HC1A Mean	EV_HC1A Max	EV_HC3 Mean	EV_HC3 Max	EV_HC6 Mean	EV_HC6 Max	EV_DC1 Mean	EV_DC1 Max
1981					5.2	5.2								
1982														
1983					4.5	6.4	5.0	6.8	4.1	5.2				
1984					4.6	6.0	4.7	6.3						
1985					4.7	6.5	6.8	6.8						
1986					5.0	7.5								
1987					4.7	5.9								
1988					4.6	6.2								
1989					4.4	5.8								
1990					4.8	5.7								
1991					5.2	6.4								
1992					4.9	6.6								
1993					5.0	6.8								
1994					4.8	5.9							4.7	5.7
1995					5.1	7.8								
1996					5.0	6.5								
1997					5.2	6.9	4.4	4.4						
1998					5.4	8.1	5.7	8.6						
1999					5.4	7.2	5.5	7.4						
2000					5.1	6.2	5.6	6.4						
2001					5.4	6.5	5.3	6.3						
2002					5.5	6.9	4.6	4.6						
2003					5.1	6.2								
2004					4.9	6.3							4.8	5.5
2005					5.3	6.3							5.2	5.2
2006					5.2	6.1							4.7	5.4
2007					4.6	5.6	4.4	4.4					4.1	4.5
2008	3.6	3.6			4.4	6.4							3.7	3.7
2009					3.9	6.4							3.9	5.2
2010					3.9	6.0							3.7	4.0
2011					4.4	6.2							3.7	4.4
2012					4.7	6.6							4.3	4.5
2013	4.4	4.8	4.3	4.3	4.9	6.8							4.6	4.7
2014	5.4	6.8	5.5	7.2	4.8	6.2					4.5	5.5	4.6	5.2
2015	4.9	7.9	5.1	8.0	4.6	7.0					4.2	4.4	4.4	5.1
2016	4.8	5.6	5.1	6.2	4.4	5.3					3.9	4.1	4.4	5.0
2017					4.8	6.4							4.3	5.2
2018					4.6	6.4							4.5	6.4
2019					4.4	5.5	4.3	4.3					4.4	5.0
2020					4.9	6.0							4.3	4.8

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

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Table 8. Acute SEV results for juvenile salmonids at the routine monitoring sites.

Year	Site: EV_GV1		EV_GV3		EV_HC1		EV_HC1A		EV_HC3		EV_HC6		EV_DC1	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
1981					5.2	5.2								
1982														
1983					4.6	6.3	5.0	6.7	4.2	5.2				
1984					4.7	6.0	4.7	6.2						
1985					4.7	6.4	6.7	6.7						
1986					5.0	7.4								
1987					4.7	5.9								
1988					4.7	6.2								
1989					4.5	5.8								
1990					4.8	5.6								
1991					5.2	6.4								
1992					4.9	6.5								
1993					5.0	6.7								
1994					4.9	5.9							4.7	5.7
1995					5.1	7.7								
1996					5.0	6.4								
1997					5.2	6.8	4.5	4.5						
1998					5.4	7.9	5.6	8.4						
1999					5.3	7.0	5.5	7.3						
2000					5.1	6.1	5.5	6.4						
2001					5.4	6.4	5.3	6.3						
2002					5.5	6.8	4.7	4.7						
2003					5.1	6.1								
2004					4.9	6.2							4.8	5.5
2005					5.3	6.2							5.2	5.2
2006					5.2	6.1							4.7	5.4
2007					4.6	5.6	4.4	4.4					4.2	4.5
2008	3.7	3.7			4.5	6.4							3.8	3.8
2009					4.0	6.3							3.9	5.2
2010					4.0	5.9							3.8	4.0
2011					4.4	6.2							3.8	4.4
2012					4.7	6.5							4.3	4.5
2013	4.5	4.8	4.3	4.3	4.9	6.7							4.6	4.7
2014	5.4	6.7	5.5	7.0	4.9	6.2					4.5	5.5	4.6	5.2
2015	5.0	7.8	5.1	7.9	4.7	6.9					4.3	4.5	4.4	5.1
2016	4.8	5.6	5.1	6.2	4.5	5.3					4.0	4.1	4.4	5.0
2017					4.8	6.3							4.3	5.2
2018					4.7	6.3							4.5	6.3
2019					4.4	5.5	4.4	4.4					4.4	5.0
2020					4.9	5.9							4.3	4.9

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

Table 9. Acute SEV results for eggs and larvae at the routine monitoring sites. Data were limited to the period during which the egg and larvae life stages were present.

Year	Site													
	EV_GV1		EV_GV3		EV_HC1		EV_HC1A		EV_HC3		EV_HC6		EV_DC1	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
1981														
1982														
1983					8.8	9.2	9.0	9.2	8.6	8.9				
1984					9.0	9.2	9.1	9.4						
1985					9.0	9.2								
1986					9.1	9.4								
1987					8.9	9.1								
1988					8.9	9.1								
1989					8.9	9.0								
1990					9.0	9.2								
1991					9.2	9.5								
1992					9.1	9.9								
1993					9.2	9.5								
1994					9.0	9.2							9.0	9.0
1995					9.3	9.6								
1996					9.2	9.4								
1997					9.1	9.3								
1998					9.3	9.7	9.3	9.9						
1999					9.3	9.9	9.3	9.7						
2000					9.3	9.6	9.4	9.7						
2001					9.3	9.6	9.3	9.8						
2002					9.2	9.7								
2003					9.1	9.2								
2004					9.1	9.5							9.4	9.4
2005					9.4	9.7							9.3	9.3
2006					9.3	9.7							9.1	9.4
2007					9.0	9.2	9.0	9.0					8.7	8.7
2008					8.9	9.4								
2009					8.8	9.6							8.7	9.3
2010					8.7	8.9							8.7	8.8
2011					8.8	9.4							8.6	8.8
2012					9.0	9.3							8.9	9.0
2013	9.0	9.1	8.9	8.9	9.1	9.5							9.0	9.1
2014	9.3	9.8	9.5	10.1	9.2	9.7					8.8	8.8	9.0	9.2
2015	8.9	9.0	9.0	9.2	8.9	9.0					8.8	8.8	9.0	9.3
2016	9.0	9.0	9.0	9.1	8.9	9.1					8.8	8.8	9.0	9.2
2017					8.9	9.1							8.9	9.1
2018					8.9	8.9							9.2	9.8
2019					8.9	9.0	8.9	8.9					9.0	9.2
2020					9.1	9.1							9.1	9.1

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

3.1.3. Chronic SEV

Chronic TSS exposure (measured as SEV) for both adult and juvenile salmonids was less than the high threshold of SEV 9 for the entire period of record (Figure 5). All chronic SEV results for adults and juveniles were moderate with an observed range of SEV 3.1 – 8.6 (adults; Table 10) or SEV 3.7 - 8.9 (juveniles; Table 11). The floor observed in SEV results from 2014 onward reflects an increase in the MDL for TSS from 0.1 mg/L to 1 mg/L (Figure 5).

Chronic SEV for eggs and larvae was higher than for adults and juveniles due to the greater sensitivity of these life stages (Figure 5). Chronic SEV for eggs and larvae was commonly high and occasionally very high with a range of SEV 10.2 – 12.1 (Table 12), including four results above SEV 12. Three of the very high results were collected in Harmer Creek (EV_HC1, EV_HC1A) in the 1990s, while one result was collected within Grave Creek (EV_GV3) in September 2014 (Table 12). Since 2014 there have been no results of very high SEV for eggs and larvae.

Table 10, Table 11, and Table 12 indicate long-term trends and/or anomalies in chronic SEV by comparing annual mean and maximum SEV for sites with available data. Mean SEV during the 2016-2019 period was always within or less than the historical range at each site, while maximum SEV was also always within or less than the historical range at each site, except for one result at EV_DC1 in 2018 where maximum SEV was above the historical range at the site but within the historical range across sites. This 2018 maximum SEV (at EV_DC1) was moderate for adults (SEV 7.3) and juveniles (SEV 7.7) and very high for eggs and larvae (SEV 12.0; Table 12). Notably, this 2018 anomaly was based on only one TSS observation for that month, of 28.1 mg/L, and is considered unreliable as explained in Section 3.1.1.

Prior to the 2016 – 2019 period, some 2014 - 2015 SEV results in Grave Creek (EV_GV1, EV_GV3) were among the highest historical results across all sites. These included SEV of up to 8.2 for adults and 8.5 for juveniles. Only the 2014 TSS observations occurred during the egg and larvae period, where high or very high results (SEV 11.9 – 12.0) were observed at both Grave Creek sites. The 2015-2016 data at these sites had a lower mean and maximum SEV, while data from 2017 to 2020 data were unavailable for those locations. Since data from Grave Creek were only available for five years (2008, 2013 – 2016), it is unknown to what extent the 2014 - 2015 results were anomalous relative to historical conditions.

Long-term trends at the EV_HC1 site are shown in Figure 6 because this site had the most complete long-term TSS record. Long-term trends were explored using a GAM to show the modelled mean and 95% confidence interval over the 1981 – 2020 period. For all life stages, GAM results showed relatively stable chronic SEV over the entire period, with the past five years similar to or lower than most of the historical record.

Overall, long-term trends in the available data showed that chronic SEV in recent years (e.g., 2016 - 2019) was similar to or lower than most historical conditions for all life stages, and that no general increase in SEV had occurred. There were, however, some anomalous results with maximum SEV at EV_DC1 reaching a historical high in 2018 of SEV 12.0 for eggs and larvae (although based on an unreliable TSS result), and historically high results in 2014 – 2015 at the two Grave Creek sites (although only the 2014 results were applicable to eggs and larvae due to the timing of the TSS observations). The 2014 data for Grave Creek indicated high (EV_GC1) or very high (EV_GV3) effects to eggs and larvae (Table 12).

Figure 5. Chronic SEV at all routine monitoring sites (based on 30-day average TSS). SEV is shown for adult salmonids (top panel), juvenile salmonids (middle panel) and eggs and larvae (bottom panel) for 1981 - -2020. Horizontal lines indicate the thresholds between SEV magnitude groupings (described in Table 3).

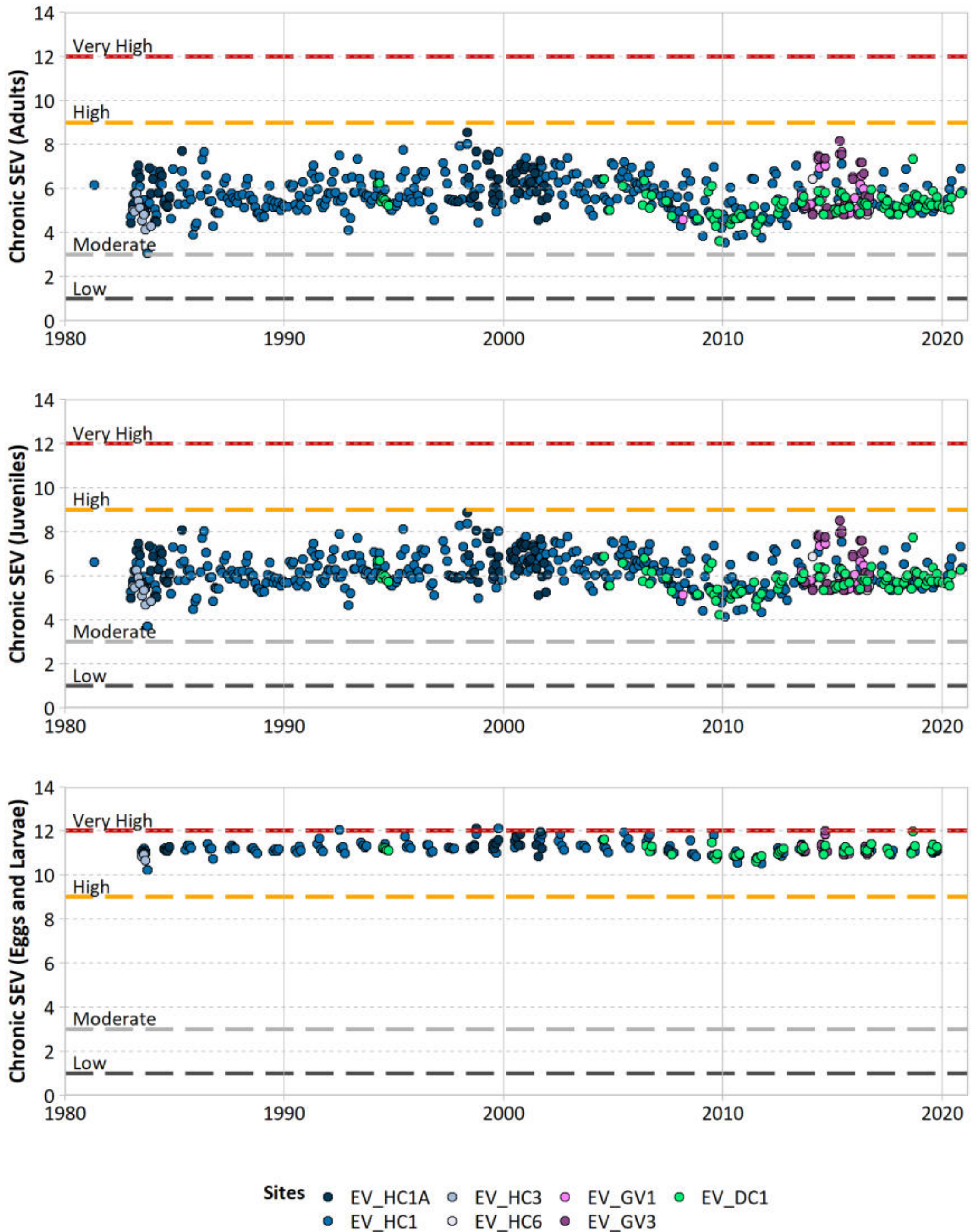

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Figure 6. Chronic SEV at the HC1 monitoring site only, with a GAM smoothing function (black solid line) to show long term trends. SEV is shown for adult salmonids (top panel), juvenile salmonids (middle panel), and eggs and larvae (bottom panel) for 1981 – 2020. Horizontal lines indicate the thresholds between SEV magnitude groupings (described in Table 3).

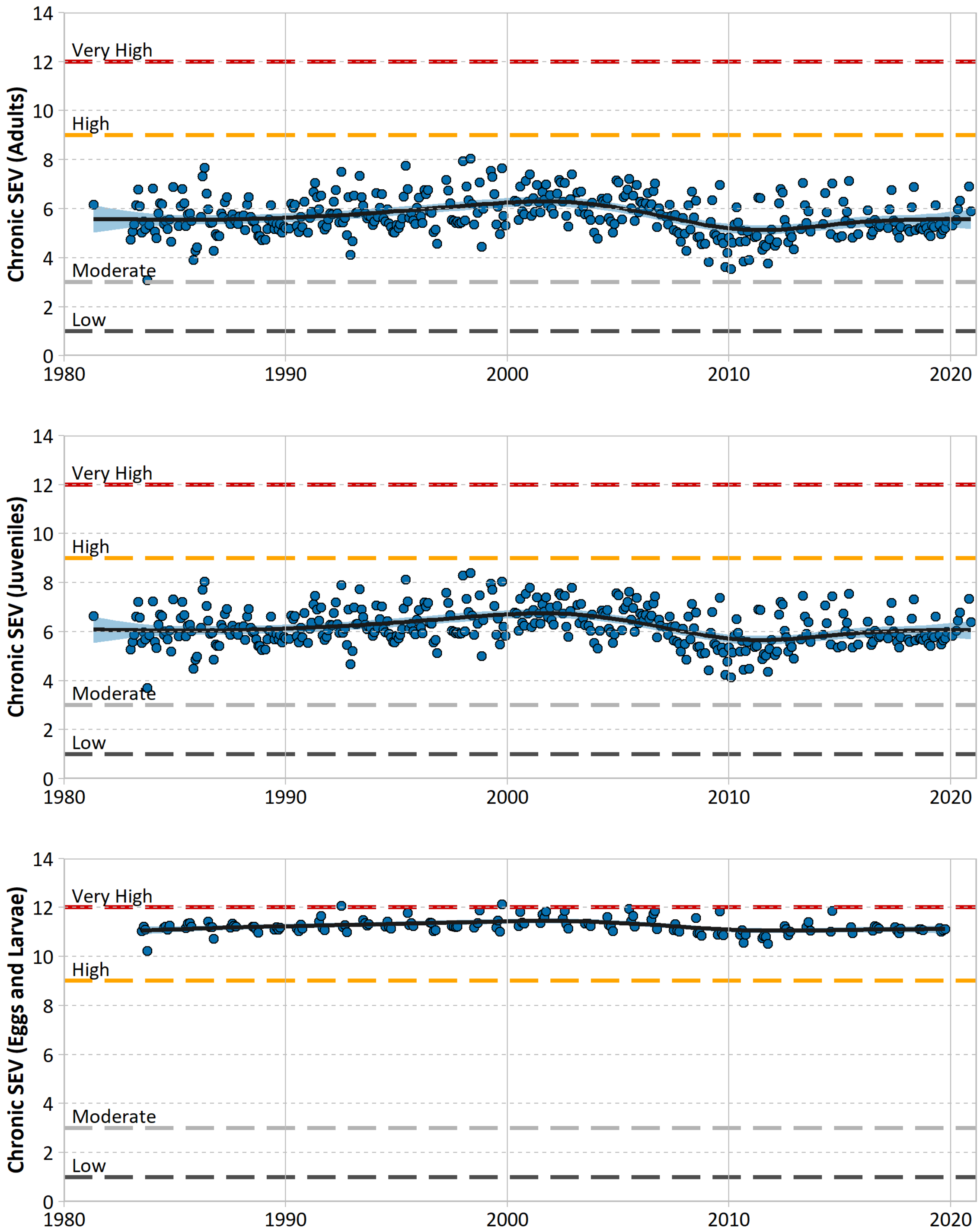

Table 10. Chronic SEV results for adult salmonids at the routine monitoring sites.

Year	Site													
	EV_GV1		EV_GV3		EV_HC1		EV_HC1A		EV_HC3		EV_HC6		EV_DC1	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
1981					6.2	6.2								
1982														
1983					5.3	6.8	5.8	7.1	4.9	5.8				
1984					5.7	6.9	5.7	6.8						
1985					5.5	6.8	7.7	7.7						
1986					5.7	7.7								
1987					5.7	6.5								
1988					5.4	6.5								
1989					5.3	6.1								
1990					5.6	6.3								
1991					5.9	7.1								
1992					5.8	7.5								
1993					5.9	7.3								
1994					5.7	6.6							5.6	6.2
1995					5.9	7.8								
1996					5.8	6.8								
1997					5.9	7.2	5.4	5.4						
1998					6.3	8.0	6.5	8.6						
1999					6.3	7.7	6.4	7.5						
2000					6.3	7.1	6.6	7.1						
2001					6.4	7.4	6.1	7.3						
2002					6.4	7.4	5.6	5.6						
2003					6.0	6.7								
2004					5.9	7.2							5.7	6.4
2005					6.4	7.2							6.1	6.1
2006					6.2	7.0							5.6	6.4
2007					5.4	6.2	5.4	5.4					5.1	5.4
2008	4.6	4.6			5.3	6.7							4.6	4.6
2009					5.0	7.0							4.9	6.1
2010					4.8	6.1							4.7	4.9
2011					5.0	6.5							4.6	5.2
2012					5.3	6.8							5.2	5.4
2013	5.4	5.7	5.2	5.2	5.8	7.0							5.5	5.7
2014	6.0	7.4	6.1	7.5	5.8	7.0					5.7	6.4	5.5	5.9
2015	5.8	7.7	6.0	8.2	5.6	7.1					5.1	5.3	5.3	5.8
2016	5.7	6.6	6.0	7.2	5.4	5.9					4.9	5.0	5.3	6.0
2017					5.5	6.8							5.3	5.6
2018					5.5	6.9							5.5	7.3
2019					5.3	6.1	5.3	5.3					5.4	5.9
2020					6.0	6.9							5.3	5.8

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

Table 11. Chronic SEV results for juvenile salmonids at the routine monitoring sites.

Year	Site: EV_GV1 Mean	EV_GV1 Max	EV_GV3 Mean	EV_GV3 Max	EV_HC1 Mean	EV_HC1 Max	EV_HC1A Mean	EV_HC1A Max	EV_HC3 Mean	EV_HC3 Max	EV_HC6 Mean	EV_HC6 Max	EV_DC1 Mean	EV_DC1 Max
1981					6.6	6.6								
1982														
1983					5.8	7.2	6.3	7.5	5.4	6.3				
1984					6.2	7.3	6.1	7.2						
1985					6.0	7.2	8.1	8.1						
1986					6.2	8.1								
1987					6.1	6.9								
1988					5.9	6.9								
1989					5.8	6.6								
1990					6.1	6.8								
1991					6.4	7.5								
1992					6.3	7.9								
1993					6.4	7.7								
1994					6.2	7.1							6.1	6.7
1995					6.4	8.1								
1996					6.3	7.2								
1997					6.4	7.6	5.9	5.9						
1998					6.8	8.4	7.0	8.9						
1999					6.7	8.0	6.8	7.9						
2000					6.7	7.5	7.0	7.5						
2001					6.9	7.8	6.6	7.7						
2002					6.9	7.8	6.1	6.1						
2003					6.4	7.1								
2004					6.3	7.6							6.2	6.9
2005					6.9	7.6							6.6	6.6
2006					6.7	7.4							6.1	6.8
2007					5.9	6.6	5.9	5.9					5.6	5.9
2008	5.1	5.1			5.8	7.1							5.2	5.2
2009					5.5	7.4							5.4	6.6
2010					5.3	6.5							5.2	5.4
2011					5.5	6.9							5.1	5.7
2012					5.8	7.2							5.7	5.9
2013	5.9	6.2	5.7	5.7	6.3	7.5							6.0	6.1
2014	6.5	7.8	6.6	7.9	6.3	7.4					6.2	6.9	6.0	6.4
2015	6.3	8.1	6.5	8.5	6.1	7.5					5.6	5.8	5.8	6.3
2016	6.2	7.0	6.5	7.6	5.9	6.4					5.4	5.5	5.9	6.4
2017					6.0	7.2							5.8	6.1
2018					6.0	7.3							6.0	7.7
2019					5.8	6.6	5.8	5.8					5.9	6.4
2020					6.5	7.3							5.8	6.3

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

Table 12. Chronic SEV results for eggs and larvae at the routine monitoring sites. Data were limited to the period during which the egg and larvae life stages were present.

Year	Site: EV_GV1 Mean	EV_GV1 Max	EV_GV3 Mean	EV_GV3 Max	EV_HC1 Mean	EV_HC1 Max	EV_HC1A Mean	EV_HC1A Max	EV_HC3 Mean	EV_HC3 Max	EV_HC6 Mean	EV_HC6 Max	EV_DC1 Mean	EV_DC1 Max
1981														
1982														
1983														
1984					11.2	11.3	11.2	11.3						
1985					11.3	11.4								
1986					11.1	11.4								
1987					11.2	11.3								
1988					11.1	11.2								
1989					11.1	11.2								
1990					11.2	11.3								
1991					11.3	11.7								
1992					11.4	12.1								
1993					11.4	11.5								
1994					11.2	11.4							11.2	11.3
1995					11.4	11.8								
1996					11.2	11.4								
1997					11.2	11.2								
1998					11.5	11.9	11.6	12.1						
1999					11.4	12.1	11.4	11.6						
2000					11.4	11.8	11.6	11.9						
2001					11.6	11.8	11.4	12.0						
2002					11.5	11.9								
2003					11.3	11.3								
2004					11.3	11.6							11.6	11.6
2005					11.6	11.9								
2006					11.6	11.9							11.2	11.3
2007					11.1	11.3	11.2	11.2					10.9	10.9
2008					11.1	11.6								
2009					11.1	11.8							11.0	11.5
2010					10.8	11.1							10.9	11.0
2011					10.7	10.8							10.8	10.9
2012					11.1	11.2							11.1	11.2
2013	11.2	11.3	11.1	11.1	11.2	11.4							11.2	11.3
2014	11.4	11.9	11.5	12.0	11.4	11.9							11.2	11.4
2015	11.1	11.2	11.1	11.2	11.1	11.2							11.1	11.3
2016	11.2	11.2	11.2	11.3	11.2	11.2					11.0	11.0	11.2	11.4
2017					11.1	11.2							11.1	11.2
2018					11.1	11.1							11.4	12.0
2019					11.1	11.2	11.1	11.1					11.3	11.4
2020														

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

3.2. Opportunistic Monitoring

TSS data collected during opportunistic monitoring were evaluated for potential acute effects (measured as 96-hour SEV). Opportunistic monitoring data consisted of 37 observations collected primarily in 2019 (11 samples) and 2020 (23 samples), with some observations during 2017 and 2018 (1 – 3 samples per year). The opportunistic TSS samples ranged from 1.0 to 11.8 mg/L, with 35 observations of less than 5 mg/L. When these samples were limited to the period when egg and larvae life stages were present, there were 19 observations, ranging from 1.0 to 11.8 mg/L.

The mean and maximum acute SEV from the samples are provided annually for each site for adult salmonids (Table 13), juvenile salmonids (Table 14), and eggs and larvae (Table 15). These results are also presented visually in Figure 7 along with the results from the routine monitoring for context.

Acute SEV in the opportunistic monitoring was consistent with the results of the routine monitoring (Figure 7). Adult acute SEV was always moderate in magnitude, with a range of SEV 3.9 – 5.7, which is within the range observed during routine monitoring (SEV 2.2 – 8.4) and below the annual maxima recorded during routine monitoring. Results for juvenile SEV were similar (Table 14) with the same SEV 3.9 – 5.7 range, while results for the more sensitive egg and larvae life stages were higher (SEV 8.7 – 9.5) but based on only a few observations and again within the observed range from routine monitoring (SEV 8.0 – 10.7).

Results for chronic SEV using the opportunistic monitoring data were also consistent with the chronic SEV results from routine monitoring. Adult chronic SEV was moderate, in the range of SEV 5.0 - 6.7 (compared with SEV 3.1 – 8.6 in routine monitoring), juvenile chronic SEV was moderate, in the range of SEV 5.5 –7.1 (compared with SEV 3.7 – 8.9 in routine monitoring), and chronic SEV for eggs and larvae was consistently high and in the range of SEV 10.9 – 11.7 (compared with SEV 10.2 - 12.1 in routine monitoring). The chronic SEV results for opportunistic monitoring were higher than the acute SEV results since they assumed a longer duration for the same observations (30 days instead of 96 hours).

Opportunistic monitoring data were limited in quantity and temporal coverage (dating back to only 2017) and thus were not assessed for long-term trends. The data were screened for anomalies but showed no outliers that could be linked with anomalous effects to WCT (e.g., the highest results for eggs and larvae of SEV 9.5 at EV_DC3 were consistent with many observations for acute SEV from routine monitoring in the Grave Creek watershed).

Figure 7. **Acute SEV at all opportunistic monitoring sites (2017 – 2020) along with the long-term routine monitoring record for context (translucent grey points). SEV is shown for adult salmonids (top panel), juvenile salmonids (middle panel), and eggs and larvae (bottom panel). Horizontal lines indicate the thresholds between SEV magnitude groupings (described in Table 3).**

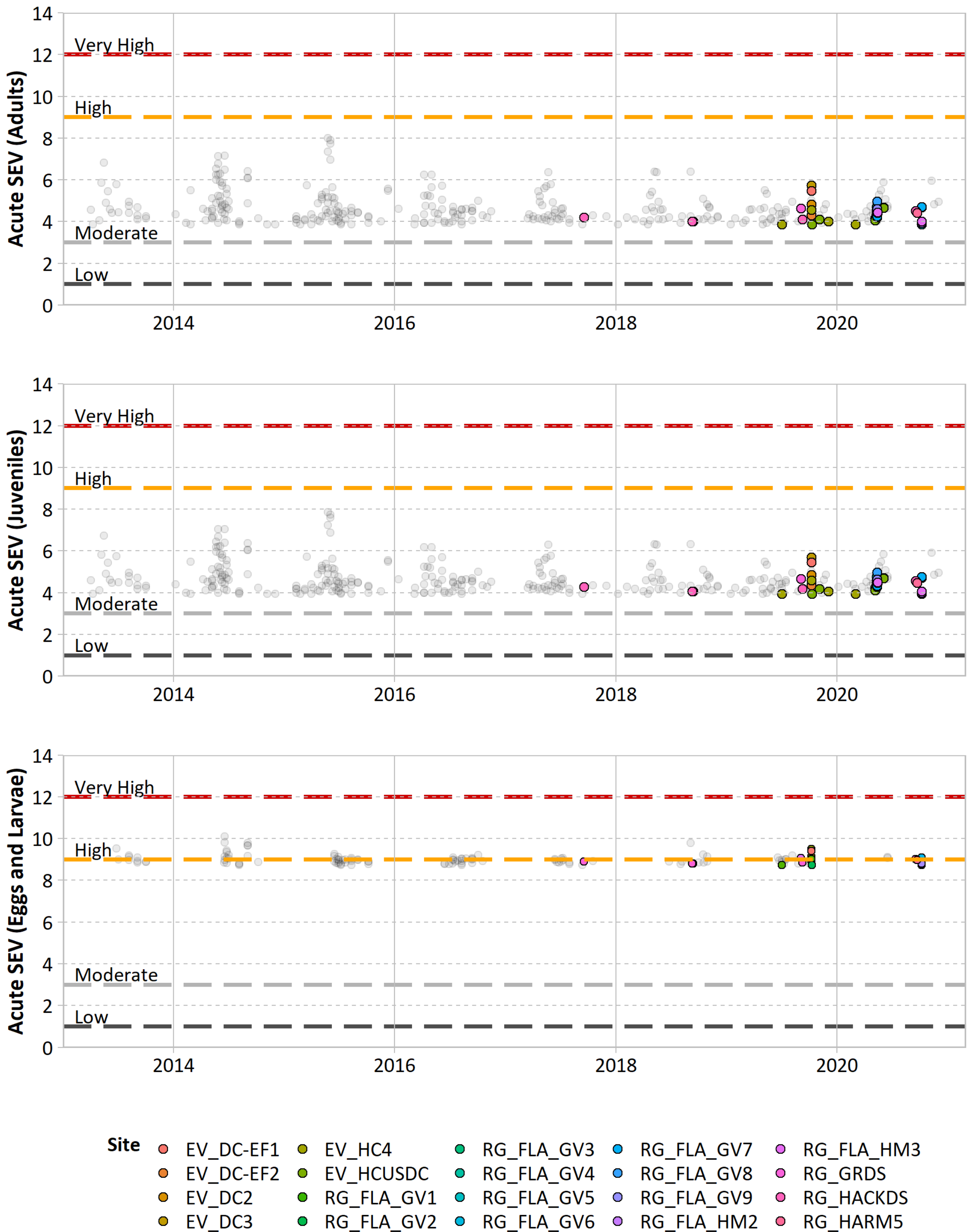

Table 13. Acute SEV results for adult salmonids at the opportunistic monitoring sites.

Site	Year							
	2017		2018		2019		2020	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
RG_FLA_GV1							4.3	4.3
RG_GRDS			4.0	4.0	4.6	4.6		
RG_FLA_GV2							4.6	4.6
RG_FLA_GV3							4.5	4.5
RG_FLA_GV4							4.7	4.7
RG_FLA_GV5							4.2	4.5
RG_FLA_GV6							4.5	4.7
RG_FLA_GV7							4.5	4.7
RG_FLA_GV8							5.0	5.0
RG_FLA_GV9							4.6	4.6
RG_HACKDS	4.2	4.2	4.0	4.0	4.1	4.1	4.5	4.5
RG_FLA_HM2							4.2	4.4
RG_FLA_HM3							4.2	4.5
RG_HARM5							4.4	4.4
EV_HC4					4.1	4.6	4.2	4.7
EV_HCUSDC					4.0	4.1	4.4	4.7
EV_DC2					4.8	4.8		
EV_DC3					5.7	5.7		
EV_DC-EF1					5.5	5.5		
EV_DC-EF2					4.3	4.3		

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

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Table 14. Acute SEV results for juvenile salmonids at the opportunistic monitoring sites.

Site	Year							
	2017		2018		2019		2020	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
RG_FLA_GV1							4.4	4.4
RG_GRDS			4.1	4.1	4.7	4.7		
RG_FLA_GV2							4.6	4.6
RG_FLA_GV3							4.5	4.5
RG_FLA_GV4							4.7	4.7
RG_FLA_GV5							4.2	4.6
RG_FLA_GV6							4.5	4.7
RG_FLA_GV7							4.5	4.7
RG_FLA_GV8							5.0	5.0
RG_FLA_GV9							4.6	4.6
RG_HACKDS	4.3	4.3	4.1	4.1	4.2	4.2	4.6	4.6
RG_FLA_HM2							4.2	4.5
RG_FLA_HM3							4.3	4.5
RG_HARM5							4.5	4.5
EV_HC4					4.2	4.6	4.3	4.7
EV_HCUSDC					4.1	4.2	4.4	4.7
EV_DC2					4.9	4.9		
EV_DC3					5.7	5.7		
EV_DC-EF1					5.5	5.5		
EV_DC-EF2					4.4	4.4		

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

Table 15. Acute SEV results for eggs and larvae at the opportunistic monitoring sites. Data were limited to the period during which the egg and larvae life stages were present.

Site	Year							
	2017		2018		2019		2020	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
RG_GRDS			8.8	8.8	9.1	9.1		
RG_FLA_GV5							8.7	8.7
RG_FLA_GV6							9.1	9.1
RG_FLA_GV7							9.1	9.1
RG_HACKDS	8.9	8.9	8.8	8.8	8.8	8.8	9.0	9.0
RG_FLA_HM2							8.8	8.8
RG_FLA_HM3							8.8	8.8
RG_HARM5							9.0	9.0
EV_HC4					8.9	9.0		
EV_HCUSDC					8.7	8.7		
EV_DC2					9.1	9.1		
EV_DC3					9.5	9.5		
EV_DC-EF1					9.4	9.4		
EV_DC-EF2					8.9	8.9		

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

Figure 8. **Chronic SEV at all opportunistic monitoring sites (2017 – 2020) along with the long-term routine monitoring record for context (translucent grey points). SEV is shown for adult salmonids (top panel), juvenile salmonids (middle panel), and eggs and larvae (bottom panel). Horizontal lines indicate the thresholds between SEV magnitude groupings (described in Table 3).**

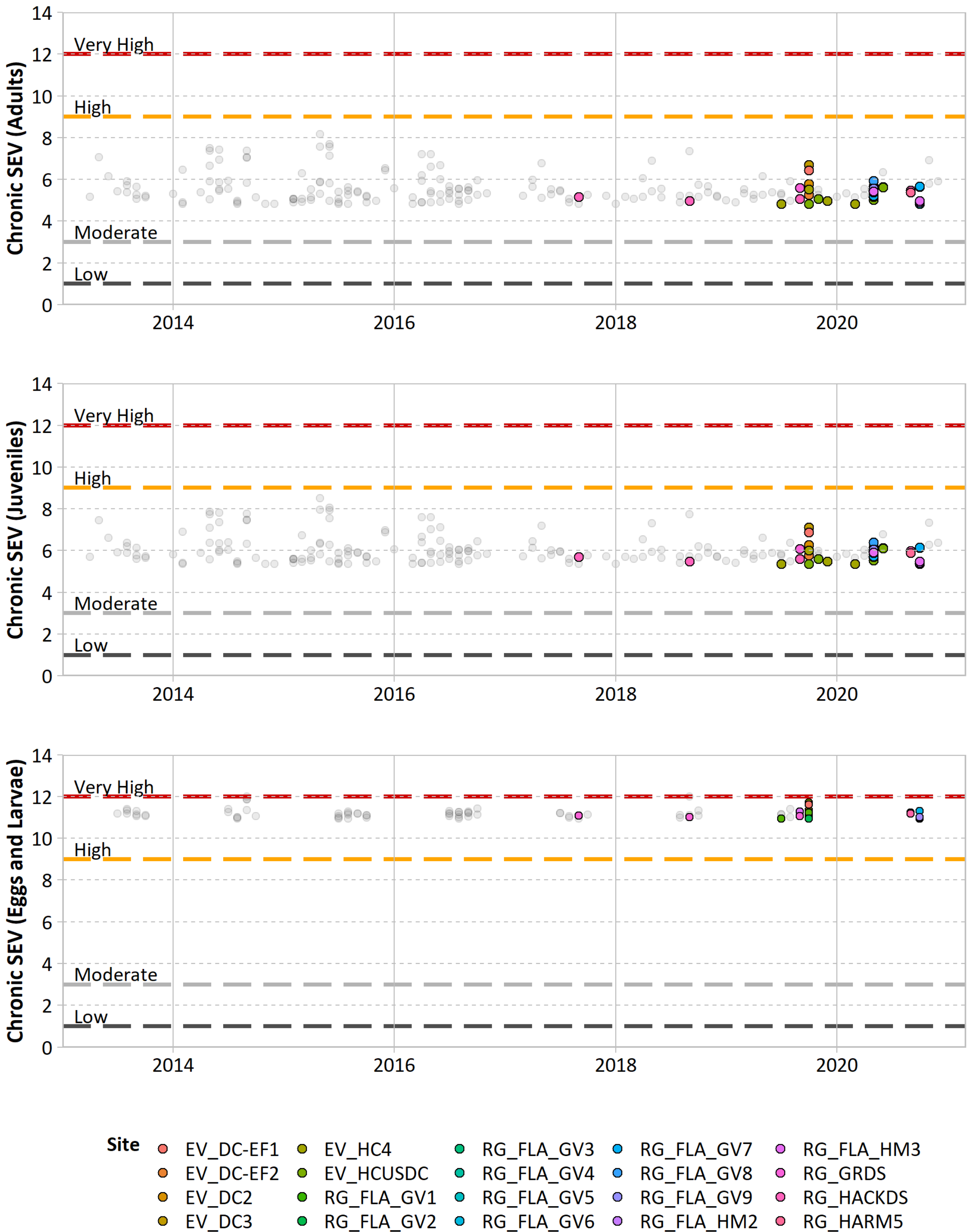

Table 16. Chronic SEV results for adult salmonids at the opportunistic monitoring sites.

Site	2017		2018		2019		2020	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
RG_FLA_GV1							5.3	5.3
RG_GRDS			5.0	5.0	5.6	5.6		
RG_FLA_GV2							5.5	5.5
RG_FLA_GV3							5.4	5.4
RG_FLA_GV4							5.7	5.7
RG_FLA_GV5							5.2	5.5
RG_FLA_GV6							5.4	5.7
RG_FLA_GV7							5.4	5.7
RG_FLA_GV8							5.9	5.9
RG_FLA_GV9							5.6	5.6
RG_HACKDS	5.2	5.2	5.0	5.0	5.1	5.1	5.5	5.5
RG_FLA_HM2							5.1	5.4
RG_FLA_HM3							5.2	5.4
RG_HARM5							5.4	5.4
EV_HC4					5.1	5.5	5.2	5.7
EV_HCUSDC					4.9	5.1	5.3	5.6
EV_DC2					5.8	5.8		
EV_DC3					6.7	6.7		
EV_DC-EF1					6.4	6.4		
EV_DC-EF2					5.3	5.3		

(Year spans 2017–2020 columns.)

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

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Table 17. Chronic SEV results for juvenile salmonids at the opportunistic monitoring sites.

Site	Year							
	2017		2018		2019		2020	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
RG_FLA_GV1							5.8	5.8
RG_GRDS			5.5	5.5	6.1	6.1		
RG_FLA_GV2							6.0	6.0
RG_FLA_GV3							5.9	5.9
RG_FLA_GV4							6.2	6.2
RG_FLA_GV5							5.7	6.0
RG_FLA_GV6							5.9	6.1
RG_FLA_GV7							5.9	6.2
RG_FLA_GV8							6.4	6.4
RG_FLA_GV9							6.1	6.1
RG_HACKDS	5.7	5.7	5.5	5.5	5.6	5.6	6.0	6.0
RG_FLA_HM2							5.7	5.9
RG_FLA_HM3							5.7	5.9
RG_HARM5							5.9	5.9
EV_HC4					5.6	6.0	5.7	6.1
EV_HCUSDC					5.5	5.6	5.8	6.1
EV_DC2					6.3	6.3		
EV_DC3					7.1	7.1		
EV_DC-EF1					6.9	6.9		
EV_DC-EF2					5.8	5.8		

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

Table 18. Chronic SEV results for eggs and larvae at the opportunistic monitoring sites. Data were limited to the period during which the egg and larvae life stages were present.

Site	Year							
	2017		2018		2019		2020	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
RG_GRDS			11.0	11.0	11.3	11.3		
RG_FLA_GV5							10.9	10.9
RG_FLA_GV6							11.3	11.3
RG_FLA_GV7							11.3	11.3
RG_HACKDS	11.1	11.1	11.0	11.0	11.1	11.1	11.2	11.2
RG_FLA_HM2							11.0	11.0
RG_FLA_HM3							11.0	11.0
RG_HARM5							11.2	11.2
EV_HC4					11.1	11.2		
EV_HCUSDC					10.9	10.9		
EV_DC2					11.3	11.3		
EV_DC3					11.7	11.7		
EV_DC-EF1					11.6	11.6		
EV_DC-EF2					11.1	11.1		

Low (SEV < 4)
Moderate (SEV 4 - 9)
High (SEV 9 - 12)
Very High (SEV > 12)

3.3. Effects of TSS on the WCT Population

Linkages between TSS conditions and potential population-level effects to WCT were assessed relative to the five explanatory factors described in Section 2.2. These factors included the intensity (i.e., magnitude) and duration of TSS exposure (expressed as SEV) to determine whether TSS as a stressor had the ability to cause or contribute to Reduced Recruitment. If intensity and duration conditions were met, the spatiotemporal overlap with WCT was evaluated (based on WCT habitat use and the location, extent, and timing of the TSS event) to assess effects to the WCT population.

SEV for eggs and larvae that is high or very high in magnitude and increased in recent years has the potential to be the cause of the Reduced Recruitment, while SEV for any life stage that is of moderate magnitude or greater – irrespective of temporal increase – has the potential to contribute to Reduced

Recruitment if those conditions spatially and temporally overlap with the WCT population (Section 2.2). Based on these criteria, the following events or conditions were identified and investigated further for their spatiotemporal overlap with WCT.

Potential to cause the Reduced Recruitment:

There was no evidence of a general increase in SEV in the Harmer Creek population area in recent years, but one result during the period of interest (2016-2019) was identified as being high or very high in magnitude and anomalous relative to typical conditions. This observation was:

- TSS on September 4, 2018 was 28.1 mg/L at the EV_DC1 site in Dry Creek, which corresponds to high magnitude acute effects (up to SEV 9.8) and very high magnitude chronic effects (up to SEV 12.0) for eggs and larvae.

This 2018 observation occurred at only one site and is considered unreliable because the high TSS result (28.1 mg/L) contrasts with turbidity measurements in the field (0.7 NTU) and lab (0.44 NTU). Nevertheless, it is possible that the TSS result is real while the turbidity measurements were in error, so we have evaluated the potential effects of this result.

Data were limited to inform the extent of these conditions, since the only other data point on or within a few days of this date was the same-day result from EV_HC1 (Harmer Creek at the Harmer Dam Outlet). That TSS observation was much lower (1.7 mg/L) and the acute SEV (8.9) and chronic SEV (11.1) were also lower. However, since TSS at EV_HC1 was largely decoupled from upstream conditions by settling processes in the sedimentation pond, it is possible that high TSS was present from Dry Creek down to the Harmer Pond. Thus, the spatial extent of high TSS is unknown but may have been sufficiently widespread to affect the majority of the eggs and larvae present in Harmer Creek at that time.

The high TSS observation occurred during the late incubation period. Incubation can end as early as August 12; fry emergence peaks soon thereafter, followed by a long-tailed distribution of emergence to October 31. The chronic SEV 12.0 result translates to 40-60% mortality for eggs and larvae present at that time, yet a large portion of the eggs would have finished incubation prior to September 4. Thus, at most this TSS exposure would have affected a small portion of the egg cohort in a single year. Therefore, it is not considered sufficient to have caused the Reduced Recruitment.

Potential to contribute to the Reduced Recruitment:

TSS in the Harmer Creek population area was not higher relative to previous years nor relative to the Grave Creek population area. However, TSS was still high enough to be harmful and thus could have contributed to Reduced Recruitment through low levels of mortality, sublethal effects to fish (e.g., reduced growth and reproductive investment), and/or interactions with other stressors. Support for a conclusion that TSS contributed to the Reduced Recruitment includes:

- Most chronic and acute SEV results for adults in Harmer Creek were moderate in magnitude;

- Most chronic and acute SEV results for juveniles in Harmer Creek were moderate in magnitude; and
- Chronic SEV for eggs and larvae in Harmer Creek was commonly high in magnitude, with one possible anomalous result in Dry Creek that was very high and may have affected Harmer Creek; acute SEV for eggs and larvae in Harmer Creek was commonly high.

Moderate magnitude effects for adults and juveniles and high magnitude effects for eggs and larvae were common across all sites, seasons, and years in Harmer Creek and thus were considered a widespread condition (affecting the majority of adults, juveniles, and eggs and larvae) for the Harmer Creek WCT population. The effects of the very high magnitude result for eggs and larvae within Dry Creek and possibly Harmer Creek have been previously discussed. This result was not identified as a widespread condition, but may have contributed to localized effects.

4. DISCUSSION

4.1. Evaluation of Explanatory Factors

Explanatory factors provide criteria that would need to be met for TSS exposure in Harmer Creek to have caused or contributed to the Reduced Recruitment (see descriptions in Section 2.2). A summary of whether the conditions were met is as follows:

- Cause of the Reduced Recruitment was not met because:
  - For adult and juvenile life stages in Harmer Creek, all chronic and acute SEV results were moderate or low in magnitude for all routine and opportunistic monitoring, consistent with data prior to the period of interest (pre-2016) in the Harmer Creek population area;
  - For adult and juvenile life stages in Harmer Creek, chronic and acute SEV results were not elevated relative to the Grave Creek population area, where Reduced Recruitment did not occur;
  - For the egg and larvae life stages in the Harmer Creek population area, high magnitude results for chronic and acute SEV were common in routine and opportunistic monitoring between 2016 and 2019, but these results were similar to or lower than Harmer Creek SEV in the historical period (based on mean SEV, maximum SEV, and modelled trends at the EV_HC1 site) and similar to historical conditions for egg and larvae life stages in the Grave Creek population area where Reduced Recruitment did not occur, and
  - For the egg and larvae life stages in the Harmer Creek population area, one anomalous and very high magnitude result was identified in the routine monitoring data for the Dry Creek tributary, but it is considered unreliable, and the timing of this event did not overlap with most of the egg incubation period nor did it occur in multiple years. Thus, this event was not a widespread condition affecting a large proportion of the WCT population during

the period of interest. This event was also similar in severity to events in the Grave Creek population area where Reduced Recruitment did not occur.

- Although TSS conditions were not notably different during the period of interest, we conclude that the conditions for contribution to the Reduced Recruitment were met because:
  - Moderate magnitude effects to adults and juveniles in the Harmer Creek population area were a widespread condition both spatially and temporally;
  - High magnitude effects to eggs and larvae in the Harmer Creek population area were a widespread condition both spatially and temporally; and
  - An anomalous, very high magnitude effect to eggs and larvae may have occurred in Dry Creek during 2018, which could have affected eggs present in Harmer Creek during that time, although if this occurred it would only have affected the minority of the egg cohort in one year.

4.2. Key Uncertainties

Key uncertainties that limit confidence in the conclusions of this assessment are:

- Temporal gaps at the monitoring sites occurred for weeks, months, and years. Most sites were only monitored for relatively minor portions of the 1981 – 2020 period. For example, the EV_HC1A long-term dataset was almost entirely collected during 1983 – 1985 and 1998-2002, such that recent data were largely unavailable. This analysis cannot capture effects that may have occurred during periods of no data. Where long-term monitoring data did exist, these data were obtained from spot samples taken at weekly or monthly intervals where anomalous conditions could have occurred between samples. SEV is more commonly calculated using high-frequency continuous monitoring (e.g., 5-minute to 1-hour resolution).
- Spatial gaps existed among monitoring locations. Substantial recent data were available at only two sites: (1) EV_DC1, which is far upstream in Dry Creek and does not capture conditions within the mainstem of Harmer Creek nor within Grave Creek, and (2) EV_HC1, which is at the Harmer Creek Sedimentation Pond outlet just upstream of the confluence with Grave Creek and neither captures conditions in Grave Creek (especially upper Grave Creek) nor accurately reflects upstream conditions in Harmer Creek, due to the buffering effect of the sedimentation pond. Accordingly, a review of paired data for HC1 (sedimentation pond outlet) and HC1A (sedimentation pond inlet) was conducted to determine the correlation between these sites and the potential for high SEV above the pond (see Appendix B). These results showed a correlation between these sites of R^2 = 0.65 – 0.92, such that it is unlikely that high TSS conditions above the pond went undetected. The relationships indicated that TSS above the pond was 50-100% higher than downstream of the pond, which corresponds to an increase in SEV of up to 0.5 – 0.6 (adults) or 0.2 (eggs and larvae) over the HC1 results. However, the SEV results at the HC1 site during the period of Reduced Recruitment did not

contain anomalously high observations and were not higher than historical norms at this site, indicating that higher SEV at the inlet site would not have substantively affected conclusions.

- Predictions of harm from TSS are based on general SEV models that are not specific to WCT and are derived from limited data, such that the actual effects could be less or greater. The SEV models for adults and juveniles have been developed to apply to all salmonids (both freshwater and anadromous), while the SEV model for eggs and larvae is broader yet as it applies to both salmonids and non-salmonids. Further, these models are created from a limited set of studies on TSS and none more recent than 1995. As such, there is uncertainty regarding how well the effects indicated by the SEV models corresponded to actual harm to WCT.

5. CONCLUSION

This assessment evaluated the potential for TSS exposure to have caused or contributed to the Reduced Recruitment in Harmer Creek. Potential effects from TSS on WCT were evaluated at 27 water quality monitoring sites located in Grave Creek, Harmer Creek, tributaries thereof, and direct input locations.

Data from each site were assessed for potential effects on WCT using SEV models to evaluate chronic and acute TSS conditions. SEV results were compared throughout the available data record at each site, between all sites in each creek, and between creeks to identify trends and/or anomalies in recent years. Results for Harmer Creek and Dry Creek were assessed against the explanatory factors described in Section 2.2 to determine whether TSS events caused or contributed to the Reduced Recruitment.

Criteria for cause of the Reduced Recruitment were not met. SEV conditions in the Harmer Creek population area during the period of interest (2016 – 2019) were similar to or better than the preceding period and were consistent with or better than the results in the Grave Creek population area where Reduced Recruitment did not occur. An anomalous result with potential for very high effects to eggs and larvae in 2018 was based on an unreliable data point and was limited in its spatiotemporal overlap with the egg and larval fish life stages, such that even if it is a real result, it is insufficient to explain the Reduced Recruitment. Uncertainties were identified (Section 4.2) that limit confidence in this conclusion. In particular, TSS conditions during the Reduced Recruitment are largely unknown due to the combination of spatial and temporal gaps in the dataset.

Criteria for contribution to the Reduced Recruitment were met. Available data indicated that TSS conditions during the period of interest were sufficient to act as a stressor that could have interacted with other stressors, even though TSS and SEV data did not indicate an increase relative to the historical data (pre-2016) nor relative to Grave Creek.

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PROJECT MAPS

SME Report: TSS. Water Quality Monitoring Stations

Legend

Water Quality Monitoring Stations

- Routine Sampling
- Opportunistic Sampling
- Reach Break Start
- Study Area
- Streams
- Water Management Polygons

MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES

0 1 2 km

Scale: 1:70,000

NO.	DATE	REVISION	BY
1	2022-01-05	1229_SME_StressorTSS_4258_20220105	EEC
2			
3			
4			
5			

Date Saved: 2022-01-05
Coordinate System: NAD 1983 UTM Zone 11N

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Map 1

Path: M:\Projects-Active\1229_EVWQP\MXD\Overview\1229_SME_StressorTSS_4258_20220105.mxd

APPENDICES

Appendix A. Matrices of total suspended solids (TSS) concentrations by duration and corresponding severity of ill effect (SEV) index scores by life stage

LIST OF TABLES

1. MATRICES OF TSS CONCENTRATIONS

Table 1. Matrix of TSS concentration by exposure duration and corresponding SEV index scores for adult salmonids (from Newcombe and Jensen 1996).

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30
Hours	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	720
TSS (mg/L)																					
60,000	11.5	11.9	12.0	12.2	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.7	12.7	12.8	12.8	12.8	12.9	12.9	12.9	12.9	13.1
40,000	11.2	11.5	11.7	11.9	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.4	12.5	12.5	12.5	12.6	12.6	12.6	12.6	12.8
20,000	10.7	11.0	11.2	11.4	11.5	11.5	11.6	11.7	11.7	11.8	11.8	11.9	11.9	11.9	12.0	12.0	12.0	12.1	12.1	12.1	12.3
10,000	10.2	10.5	10.7	10.8	10.9	11.0	11.1	11.2	11.2	11.3	11.3	11.3	11.4	11.4	11.5	11.5	11.5	11.5	11.6	11.6	11.8
8,000	10.0	10.3	10.5	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.3	11.3	11.4	11.4	11.4	11.6
7,000	9.9	10.2	10.4	10.6	10.7	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.2	11.2	11.3	11.3	11.3	11.5
6,000	9.8	10.1	10.3	10.4	10.5	10.6	10.7	10.8	10.8	10.9	10.9	11.0	11.0	11.0	11.1	11.1	11.1	11.2	11.2	11.2	11.4
5,000	9.6	10.0	10.2	10.3	10.4	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	10.9	11.0	11.0	11.0	11.0	11.1	11.3
3,500	9.4	9.7	9.9	10.0	10.1	10.2	10.3	10.4	10.4	10.5	10.5	10.6	10.6	10.6	10.7	10.7	10.7	10.7	10.8	10.8	11.0
2,500	9.1	9.4	9.6	9.8	9.9	10.0	10.0	10.1	10.2	10.2	10.3	10.3	10.3	10.4	10.4	10.4	10.5	10.5	10.5	10.5	10.7
2,000	8.9	9.3	9.5	9.6	9.7	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.2	10.3	10.3	10.3	10.4	10.4	10.6
1,750	8.8	9.2	9.4	9.5	9.6	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.1	10.2	10.2	10.2	10.3	10.3	10.5
1,500	8.7	9.1	9.3	9.4	9.5	9.6	9.7	9.7	9.8	9.8	9.9	9.9	10.0	10.0	10.0	10.1	10.1	10.1	10.1	10.2	10.4
1,250	8.6	8.9	9.1	9.3	9.4	9.4	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	9.9	9.9	10.0	10.0	10.0	10.2
1,000	8.4	8.8	8.9	9.1	9.2	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.6	9.7	9.7	9.7	9.8	9.8	9.8	9.9	10.0
900	8.3	8.7	8.9	9.0	9.1	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.6	9.7	9.7	9.7	9.7	9.8	10.0
800	8.3	8.6	8.8	8.9	9.0	9.1	9.2	9.2	9.3	9.4	9.4	9.4	9.5	9.5	9.5	9.6	9.6	9.6	9.7	9.7	9.9
700	8.2	8.5	8.7	8.8	8.9	9.0	9.1	9.1	9.2	9.3	9.3	9.3	9.4	9.4	9.4	9.5	9.5	9.5	9.6	9.6	9.8
600	8.0	8.4	8.6	8.7	8.8	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.3	9.4	9.4	9.4	9.4	9.5	9.7
500	7.9	8.2	8.4	8.6	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.2	9.2	9.3	9.3	9.3	9.5
400	7.7	8.1	8.3	8.4	8.5	8.6	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.0	9.1	9.1	9.1	9.1	9.2	9.4
300	7.5	7.8	8.0	8.2	8.3	8.4	8.4	8.5	8.6	8.6	8.7	8.7	8.7	8.8	8.8	8.8	8.9	8.9	8.9	8.9	9.1
200	7.2	7.5	7.7	7.9	8.0	8.1	8.1	8.2	8.3	8.3	8.3	8.4	8.4	8.5	8.5	8.5	8.6	8.6	8.6	8.6	8.8
150	7.0	7.3	7.5	7.6	7.8	7.8	7.9	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.3	8.4	8.4	8.4	8.6
125	6.8	7.2	7.4	7.5	7.6	7.7	7.8	7.8	7.9	7.9	8.0	8.0	8.1	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.5
100	6.7	7.0	7.2	7.3	7.4	7.5	7.6	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.1	8.3
90	6.6	6.9	7.1	7.3	7.4	7.5	7.5	7.6	7.6	7.7	7.7	7.8	7.8	7.9	7.9	7.9	8.0	8.0	8.0	8.0	8.2
75	6.5	6.8	7.0	7.1	7.2	7.3	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8	7.8	7.8	7.9	7.9	8.1
60	6.3	6.6	6.8	7.0	7.1	7.1	7.2	7.3	7.3	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.6	7.7	7.7	7.7	7.9
50	6.2	6.5	6.7	6.8	6.9	7.0	7.1	7.1	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.8
40	6.0	6.3	6.5	6.6	6.8	6.8	6.9	7.0	7.0	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.4	7.4	7.4	7.6
35	5.9	6.2	6.4	6.5	6.7	6.7	6.8	6.9	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.2	7.3	7.3	7.3	7.5
30	5.8	6.1	6.3	6.4	6.5	6.6	6.7	6.8	6.8	6.9	6.9	7.0	7.0	7.0	7.1	7.1	7.1	7.1	7.2	7.2	7.4
25	5.6	6.0	6.2	6.3	6.4	6.5	6.6	6.6	6.7	6.7	6.8	6.8	6.9	6.9	6.9	7.0	7.0	7.0	7.0	7.1	7.3
20	5.5	5.8	6.0	6.1	6.2	6.3	6.4	6.5	6.5	6.6	6.6	6.6	6.7	6.7	6.8	6.8	6.8	6.8	6.9	6.9	7.1
15	5.2	5.6	5.8	5.9	6.0	6.1	6.2	6.2	6.3	6.3	6.4	6.4	6.5	6.5	6.5	6.6	6.6	6.6	6.6	6.7	6.9
10	4.9	5.3	5.5	5.6	5.7	5.8	5.9	5.9	6.0	6.0	6.1	6.1	6.2	6.2	6.2	6.3	6.3	6.3	6.3	6.4	6.6
5	4.4	4.7	4.9	5.1	5.2	5.3	5.3	5.4	5.5	5.5	5.6	5.6	5.6	5.7	5.7	5.7	5.8	5.8	5.8	5.8	6.0
1	3.2	3.5	3.7	3.9	4.0	4.1	4.1	4.2	4.2	4.3	4.3	4.4	4.4	4.5	4.5	4.5	4.5	4.6	4.6	4.6	4.8

Colours correspond to SEV impact categories, where light green are negligible effects (<1); blue are limited or low effects (1-4); yellow is moderate potential for sublethal effects (5-8); pink is high potential for lethal or paralethal effects (9-11.9); and bright red is very high potential for severe lethal effects (<12) sufficient to cause mortality of 40% or more.

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Table 2. **Matrix of TSS concentration by exposure duration and corresponding SEV index scores for juvenile salmonids (from Newcombe and Jensen 1996).**

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30
Hours	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	720
TSS (mg/L)																					
80,000	11.0	11.5	11.8	12.0	12.2	12.3	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	12.9	13.0	13.0	13.1	13.1	13.1	13.4
60,000	10.8	11.3	11.6	11.8	12.0	12.1	12.2	12.3	12.4	12.4	12.5	12.6	12.6	12.7	12.7	12.8	12.8	12.9	12.9	12.9	13.2
40,000	10.5	11.0	11.3	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.2	12.3	12.3	12.4	12.4	12.5	12.5	12.6	12.6	12.6	12.9
20,000	10.0	10.5	10.8	11.0	11.2	11.3	11.4	11.5	11.6	11.7	11.7	11.8	11.8	11.9	11.9	12.0	12.0	12.1	12.1	12.1	12.4
10,000	9.5	10.0	10.3	10.5	10.7	10.8	10.9	11.0	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.5	11.6	11.6	11.6	11.9
8,000	9.4	9.9	10.2	10.4	10.5	10.6	10.8	10.8	10.9	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.5	11.5	11.8
7,000	9.3	9.8	10.1	10.3	10.4	10.5	10.7	10.7	10.8	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.3	11.3	11.4	11.4	11.7
6,000	9.2	9.7	9.9	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	10.9	11.0	11.0	11.1	11.1	11.2	11.2	11.2	11.3	11.6
5,000	9.0	9.5	9.8	10.0	10.2	10.3	10.4	10.5	10.6	10.7	10.7	10.8	10.9	10.9	11.0	11.0	11.0	11.1	11.1	11.2	11.4
3,500	8.8	9.3	9.6	9.8	9.9	10.1	10.2	10.3	10.3	10.4	10.5	10.5	10.6	10.6	10.7	10.7	10.8	10.8	10.9	10.9	11.2
2,500	8.6	9.0	9.3	9.5	9.7	9.8	9.9	10.0	10.1	10.2	10.2	10.3	10.4	10.4	10.5	10.5	10.5	10.6	10.6	10.7	10.9
2,000	8.4	8.9	9.2	9.4	9.5	9.7	9.8	9.9	9.9	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.4	10.4	10.5	10.5	10.8
1,750	8.3	8.8	9.1	9.3	9.4	9.6	9.7	9.8	9.8	9.9	10.0	10.0	10.1	10.2	10.2	10.2	10.3	10.3	10.4	10.4	10.7
1,500	8.2	8.7	9.0	9.2	9.3	9.4	9.6	9.6	9.7	9.8	9.9	9.9	10.0	10.0	10.1	10.1	10.2	10.2	10.3	10.3	10.6
1,250	8.1	8.5	8.8	9.0	9.2	9.3	9.4	9.5	9.6	9.7	9.7	9.8	9.9	9.9	10.0	10.0	10.0	10.1	10.1	10.2	10.4
1,000	7.9	8.4	8.7	8.9	9.0	9.2	9.3	9.4	9.4	9.5	9.6	9.6	9.7	9.8	9.8	9.8	9.9	9.9	10.0	10.0	10.3
900	7.8	8.3	8.6	8.8	9.0	9.1	9.2	9.3	9.4	9.4	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.9	9.9	9.9	10.2
800	7.7	8.2	8.5	8.7	8.9	9.0	9.1	9.2	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.8	9.8	10.1
700	7.6	8.1	8.4	8.6	8.8	8.9	9.0	9.1	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7	9.7	9.7	10.0
600	7.5	8.0	8.3	8.5	8.7	8.8	8.9	9.0	9.1	9.2	9.2	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.6	9.9
500	7.4	7.9	8.2	8.4	8.5	8.7	8.8	8.9	8.9	9.0	9.1	9.1	9.2	9.3	9.3	9.4	9.4	9.4	9.5	9.5	9.8
400	7.2	7.7	8.0	8.2	8.4	8.5	8.6	8.7	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.2	9.2	9.3	9.3	9.3	9.6
300	7.0	7.5	7.8	8.0	8.2	8.3	8.4	8.5	8.6	8.7	8.7	8.8	8.8	8.9	8.9	9.0	9.0	9.1	9.1	9.1	9.4
200	6.7	7.2	7.5	7.7	7.9	8.0	8.1	8.2	8.3	8.4	8.4	8.5	8.6	8.6	8.7	8.7	8.7	8.8	8.8	8.9	9.1
150	6.5	7.0	7.3	7.5	7.7	7.8	7.9	8.0	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.6	8.6	8.9
125	6.4	6.9	7.2	7.4	7.5	7.7	7.8	7.9	8.0	8.0	8.1	8.2	8.2	8.3	8.3	8.4	8.4	8.4	8.5	8.5	8.8
100	6.3	6.7	7.0	7.2	7.4	7.5	7.6	7.7	7.8	7.9	7.9	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.3	8.4	8.6
90	6.2	6.7	6.9	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	7.9	8.0	8.0	8.1	8.1	8.2	8.2	8.2	8.3	8.6
75	6.0	6.5	6.8	7.0	7.2	7.3	7.4	7.5	7.6	7.7	7.7	7.8	7.9	7.9	8.0	8.0	8.0	8.1	8.1	8.2	8.4
60	5.9	6.4	6.7	6.9	7.0	7.1	7.3	7.3	7.4	7.5	7.6	7.6	7.7	7.7	7.8	7.8	7.9	7.9	8.0	8.0	8.3
50	5.8	6.2	6.5	6.7	6.9	7.0	7.1	7.2	7.3	7.4	7.4	7.5	7.6	7.6	7.7	7.7	7.7	7.8	7.8	7.9	8.1
40	5.6	6.1	6.4	6.6	6.7	6.9	7.0	7.1	7.1	7.2	7.3	7.3	7.4	7.5	7.5	7.5	7.6	7.6	7.7	7.7	8.0
35	5.5	6.0	6.3	6.5	6.6	6.8	6.9	7.0	7.0	7.1	7.2	7.2	7.3	7.4	7.4	7.5	7.5	7.5	7.6	7.6	7.9
30	5.4	5.9	6.2	6.4	6.5	6.7	6.8	6.9	6.9	7.0	7.1	7.1	7.2	7.2	7.3	7.3	7.4	7.4	7.5	7.5	7.8
25	5.3	5.7	6.0	6.2	6.4	6.5	6.6	6.7	6.8	6.9	6.9	7.0	7.1	7.1	7.2	7.2	7.3	7.3	7.3	7.4	7.7
20	5.1	5.6	5.9	6.1	6.2	6.4	6.5	6.6	6.6	6.7	6.8	6.8	6.9	7.0	7.0	7.1	7.1	7.1	7.2	7.2	7.5
15	4.9	5.4	5.7	5.9	6.0	6.2	6.3	6.4	6.4	6.5	6.6	6.6	6.7	6.8	6.8	6.8	6.9	6.9	7.0	7.0	7.3
10	4.6	5.1	5.4	5.6	5.7	5.9	6.0	6.1	6.2	6.2	6.3	6.4	6.4	6.5	6.5	6.6	6.6	6.6	6.7	6.7	7.0
5	4.1	4.6	4.9	5.1	5.2	5.4	5.5	5.6	5.7	5.7	5.8	5.9	5.9	6.0	6.0	6.1	6.1	6.1	6.2	6.2	6.5
1	3.0	3.4	3.7	3.9	4.1	4.2	4.3	4.4	4.5	4.6	4.6	4.7	4.8	4.8	4.9	4.9	5.0	5.0	5.0	5.1	5.4

Colours correspond to SEV impact categories, where light green are negligible effects (<1); blue are limited or low effects (1-4); yellow is moderate potential for sublethal effects (5-8); pink is high potential for lethal or paralethal effects (9-11.9); and bright red is very high potential for severe lethal effects (<12) sufficient to cause mortality of 40% or more.

Table 3. Matrix of TSS concentration by exposure duration and corresponding SEV index scores for eggs and larvae of salmonids and non-salmonids (from Newcombe and Jensen 1996).

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30
Hours	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	720
TSS (mg/L)																					
60,000	10.7	11.4	11.9	12.2	12.4	12.6	12.8	12.9	13.1	13.2	13.3	13.4	13.5	13.5	13.6	13.7	13.8	13.8	13.9	13.9	14.4
40,000	10.5	11.3	11.7	12.0	12.3	12.5	12.7	12.8	12.9	13.0	13.2	13.2	13.3	13.4	13.5	13.6	13.6	13.7	13.8	13.8	14.3
20,000	10.3	11.1	11.5	11.8	12.1	12.3	12.4	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.3	13.4	13.5	13.5	13.6	14.0
10,000	10.1	10.9	11.3	11.6	11.9	12.1	12.2	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.1	13.2	13.3	13.3	13.4	13.8
8,000	10.0	10.8	11.2	11.5	11.8	12.0	12.2	12.3	12.4	12.5	12.7	12.7	12.8	12.9	13.0	13.1	13.1	13.2	13.2	13.3	13.7
7,000	10.0	10.7	11.2	11.5	11.7	11.9	12.1	12.3	12.4	12.5	12.6	12.7	12.8	12.9	12.9	13.0	13.1	13.1	13.2	13.3	13.7
6,000	9.9	10.7	11.1	11.5	11.7	11.9	12.1	12.2	12.3	12.5	12.6	12.7	12.7	12.8	12.9	13.0	13.0	13.1	13.2	13.2	13.7
5,000	9.9	10.6	11.1	11.4	11.6	11.8	12.0	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.2	13.6
3,500	9.8	10.5	11.0	11.3	11.5	11.7	11.9	12.0	12.2	12.3	12.4	12.5	12.6	12.7	12.7	12.8	12.9	12.9	13.0	13.0	13.5
2,500	9.7	10.4	10.9	11.2	11.4	11.6	11.8	11.9	12.1	12.2	12.3	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	12.9	13.4
2,000	9.6	10.4	10.8	11.1	11.4	11.6	11.7	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.6	12.7	12.8	12.8	12.9	13.3
1,750	9.6	10.3	10.8	11.1	11.3	11.5	11.7	11.8	12.0	12.1	12.2	12.3	12.4	12.4	12.5	12.6	12.7	12.7	12.8	12.8	13.3
1,500	9.5	10.3	10.7	11.0	11.3	11.5	11.6	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.5	12.6	12.7	12.7	12.8	13.2
1,250	9.4	10.2	10.7	11.0	11.2	11.4	11.6	11.7	11.9	12.0	12.1	12.2	12.3	12.3	12.4	12.5	12.5	12.6	12.7	12.7	13.2
1,000	9.4	10.1	10.6	10.9	11.1	11.3	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.3	12.4	12.5	12.5	12.6	12.7	13.1
900	9.3	10.1	10.5	10.9	11.1	11.3	11.5	11.6	11.8	11.9	12.0	12.1	12.2	12.2	12.3	12.4	12.4	12.5	12.6	12.6	13.1
800	9.3	10.1	10.5	10.8	11.1	11.3	11.4	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.3	12.4	12.5	12.5	12.6	13.0
700	9.3	10.0	10.5	10.8	11.0	11.2	11.4	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.2	12.3	12.4	12.4	12.5	12.5	13.0
600	9.2	10.0	10.4	10.7	11.0	11.2	11.3	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.3	12.4	12.4	12.5	12.9
500	9.2	9.9	10.4	10.7	10.9	11.1	11.3	11.4	11.6	11.7	11.8	11.9	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.4	12.9
400	9.1	9.9	10.3	10.6	10.9	11.1	11.2	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.1	12.1	12.2	12.3	12.3	12.4	12.8
300	9.0	9.8	10.2	10.5	10.8	11.0	11.1	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0	12.0	12.1	12.2	12.2	12.3	12.7
200	8.9	9.6	10.1	10.4	10.6	10.8	11.0	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.2	12.6
150	8.8	9.5	10.0	10.3	10.5	10.7	10.9	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.8	11.9	12.0	12.0	12.1	12.5
125	8.7	9.5	9.9	10.2	10.5	10.7	10.9	11.0	11.1	11.3	11.4	11.5	11.5	11.6	11.7	11.8	11.8	11.9	12.0	12.0	12.5
100	8.7	9.4	9.9	10.2	10.4	10.6	10.8	10.9	11.1	11.2	11.3	11.4	11.5	11.5	11.6	11.7	11.8	11.8	11.9	11.9	12.4
90	8.6	9.4	9.8	10.1	10.4	10.6	10.8	10.9	11.0	11.1	11.3	11.3	11.4	11.5	11.6	11.7	11.7	11.8	11.9	11.9	12.4
75	8.6	9.3	9.8	10.1	10.3	10.5	10.7	10.8	11.0	11.1	11.2	11.3	11.4	11.5	11.5	11.6	11.7	11.7	11.8	11.9	12.3
60	8.5	9.3	9.7	10.0	10.3	10.5	10.6	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.5	11.6	11.7	11.7	11.8	12.2
50	8.4	9.2	9.6	10.0	10.2	10.4	10.6	10.7	10.8	11.0	11.1	11.2	11.3	11.3	11.4	11.5	11.5	11.6	11.7	11.7	12.2
40	8.4	9.1	9.6	9.9	10.1	10.3	10.5	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.3	11.4	11.5	11.5	11.6	11.7	12.1
35	8.3	9.1	9.5	9.9	10.1	10.3	10.5	10.6	10.7	10.9	11.0	11.1	11.1	11.2	11.3	11.4	11.4	11.5	11.6	11.6	12.1
30	8.3	9.0	9.5	9.8	10.0	10.2	10.4	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.2	11.3	11.4	11.4	11.5	11.6	12.0
25	8.2	9.0	9.4	9.7	10.0	10.2	10.4	10.5	10.6	10.7	10.9	10.9	11.0	11.1	11.2	11.3	11.3	11.4	11.5	11.5	12.0
20	8.2	8.9	9.4	9.7	9.9	10.1	10.3	10.4	10.6	10.7	10.8	10.9	11.0	11.0	11.1	11.2	11.3	11.3	11.4	11.4	11.9
15	8.1	8.8	9.3	9.6	9.8	10.0	10.2	10.3	10.5	10.6	10.7	10.8	10.9	11.0	11.0	11.1	11.2	11.2	11.3	11.3	11.8
10	7.9	8.7	9.1	9.5	9.7	9.9	10.1	10.2	10.3	10.5	10.6	10.7	10.8	10.8	10.9	11.0	11.0	11.1	11.2	11.2	11.7
5	7.7	8.5	8.9	9.2	9.5	9.7	9.9	10.0	10.1	10.2	10.4	10.4	10.5	10.6	10.7	10.8	10.8	10.9	10.9	11.0	11.4
1	7.2	8.0	8.4	8.7	9.0	9.2	9.4	9.5	9.6	9.7	9.9	9.9	10.0	10.1	10.2	10.3	10.3	10.4	10.4	10.5	10.9

Colours correspond to SEV impact categories, where light green are negligible effects (<1); blue are limited or low effects (1-4); yellow is moderate potential for sublethal effects (5-8); pink is high potential for lethal or paralethal effects (9-11.9); and bright red is very high potential for severe lethal effects (<12) sufficient to cause mortality of 40% or more.

REFERENCES

Newcombe, C.P. and J.O. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management, 16: 693–727.

Appendix B. Harmer Creek Sedimentation Pond - Comparison of TSS at Pond Inlet (HC1A) and outlet (HC1) sites

LIST OF FIGURES

Figure 1. Correlation of all available paired TSS data from the pond inlet (HC1A) and pond outlet (HC1) for the Harmer Creek sedimentation pond.

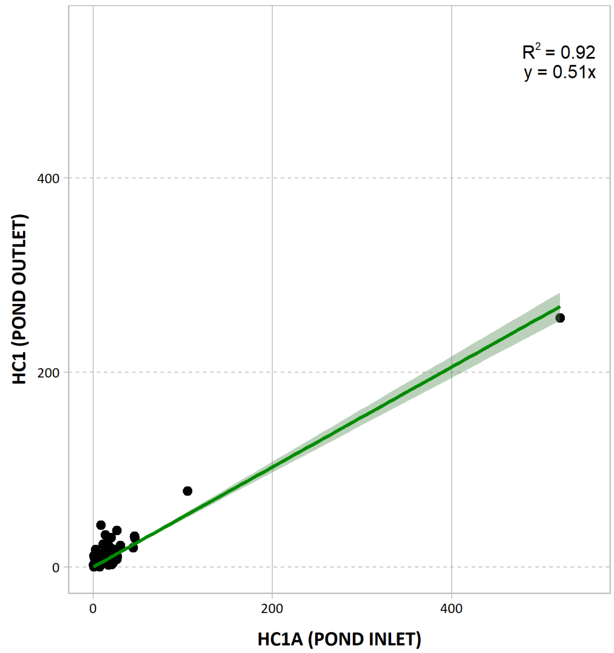

Figure 2. Correlation of all the paired TSS data from the pond inlet (HC1A) and pond outlet (HC1) for the Harmer Creek sedimentation pond, excluding two high (>50 mg/L) outlying values.

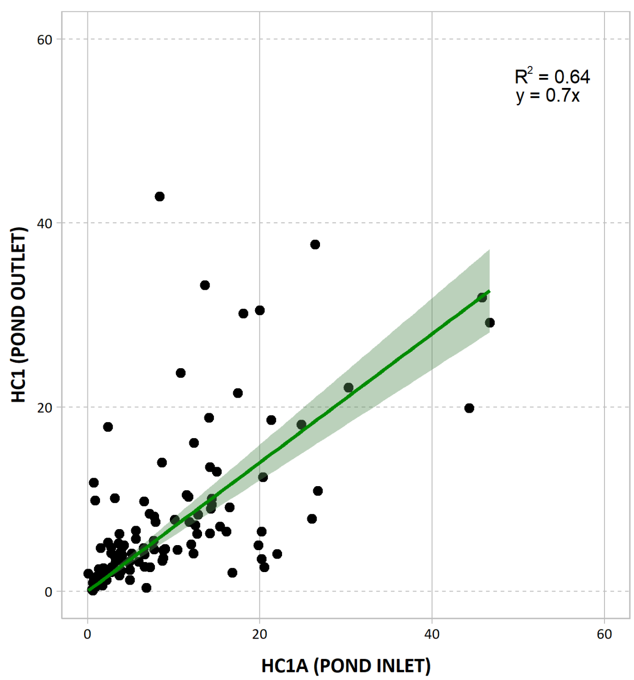

Figure 3. TSS at the Harmer sedimentation pond outlet (HC1 site) in comparison to acute SEV at this site and predicted acute SEV at the pond inlet (HC1A site) using the 0.51:1 relationship

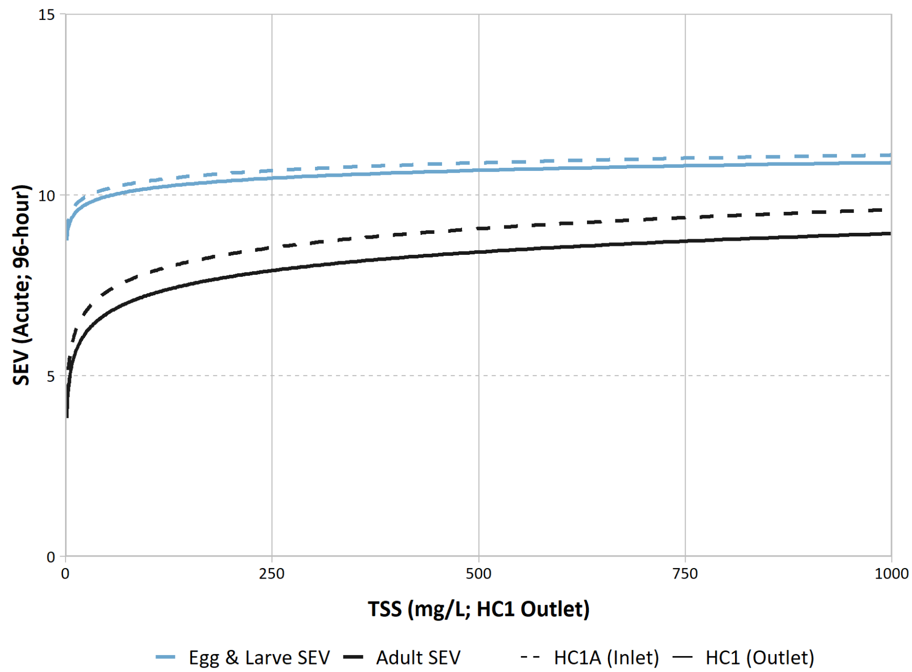

Figure 4. TSS at the Harmer sedimentation pond outlet (HC1 site) in comparison to chronic SEV at this site and predicted chronic SEV at the pond inlet (HC1A site) using the 0.51:1 relationship