Subject Matter Expert Report: TOTAL SUSPENDED SOLIDS. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population

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EXECUTIVE SUMMARY

Abundances of both juvenile and adult life stages of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*; WCT) in the upper Fording River (UFR) were substantively lower in 2019 than 2017, indicating a large decline during that two-year period (the Westslope Cutthroat Trout Population Decline Window, also referred to as the Decline Window). Teck Coal Limited (Teck Coal) initiated the "Evaluation of Cause" (EoC) to determine whether and to what extent various stressors and conditions played a role in the decline. One of several potential stressors identified is exposure to total suspended solids (TSS) in watercourses, which can be caused by sediment-laden runoff and may have deleterious effects on fish. This report investigates if, and to what extent, TSS in the UFR and nearby tributaries caused or contributed to the WCT decline.

The impact hypothesis evaluated was:

- Did exposure to TSS (from any source) in the UFR and its tributaries cause or contribute to the observed WCT population decline?

TSS data were provided by Teck Coal from water quality monitoring within the UFR, its tributaries and direct inputs from mine-influenced releases between January 2012 and December 2019. These data were collected during routine water quality monitoring and event-based water quality monitoring (i.e., in response to road runoff or other events related to mine-influenced releases). To evaluate potential harm to various life stages of WCT, the severity of ill effects (SEV) impact assessment model developed by Newcombe and Jensen (1996) was used. This model describes absolute harm to fish (e.g., mortality rates), and thus is better suited to assessing a population decline than BC water quality guidelines, which provide a threshold for increase over background and thus do not relate TSS concentrations to specific biological effects, nor evaluate potential harm from natural (background) conditions. SEV scores can range from 0 to 14, which for the purposes of this assessment were further categorized from negligible (e.g., SEV <1) to very high (e.g., SEV 12 – 14) based on published categories of effect, where high scores correspond to potential mortality rates of 0-40%, and very high scores correspond to potential mortality of >40%. SEV modelling was done 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 only for event-based monitoring data.

The SEV results were evaluated for the Decline Window and in comparison to the preceding years (2012 to 2016; hereafter the historical period). Where SEV results were high or very high, these results were compared to additional circumstances that would need to be met ("requisite conditions") for TSS exposure in the UFR and tributaries to cause or contribute to the WCT population decline. These requisite conditions consider the spatial and temporal extent of the TSS event in relation to WCT life stage, habitat use and periodicity. A requisite condition to cause was identified if TSS concentrations had the potential for high or very high magnitude effects during the Decline Window relative to the historical period that were widespread (i.e., spatio-temporally overlapping with the majority of fish). A requisite condition to contribute was identified if TSS concentrations had the potential for localized high or very high magnitude effects and/or widespread moderate magnitude effects during the

Decline Window relative to the historical period. To determine whether differences existed between the historical period and the Decline Window, the SEV results were determined for each station individually, and weighted by the habitat area of each station to determine an area-weighted SEV across sites for each year, and for the entire historical and Decline Window periods.

The area-weighted SEV modelling results for chronic TSS exposure indicate that conditions for all life stages of WCT during the Decline Window were equal to or better than the historical period. Chronic SEV effects to adults and juveniles were moderate throughout the Decline Window, while chronic SEV effects to eggs and larvae were high or very high, but equal to or lower than the historical period. Acute SEV results for routine monitoring during the Decline Window were also equal or better than the historical period, with low or moderate effects to adults and juveniles, and moderate or high effects to eggs and larvae. Finally, acute SEV results for event-based monitoring found that TSS conditions during most events were moderate or high, which is a similar magnitude to the chronic effects these habitat areas regularly experience. One event (July 4, 2019) was associated with very high effects to several life stages of WCT and thus was flagged for further analysis, which found that the spatio-temporal extent of this event was limited and not coincident with a substantial portion of the WCT population.

Overall, no effects from TSS were identified that satisfied the requisite conditions to cause the WCT population decline, as the chronic and acute results for routine monitoring during the Decline Window were consistent with the historical period, while event-based monitoring contained no acute events of sufficient magnitude and spatio-temporal overlap with WCT to be the cause. The requisite conditions to contribute to the WCT population decline were satisfied, even though TSS did not show a relative increase during the Decline Window, because of the potential for high TSS to exacerbate other stressors. In many cases TSS was not higher than the historical period but was high enough to be harmful, such as: (1) chronic effects during the Decline Window had the potential to cause moderate magnitude effects (adults, juveniles) or high to very high effects (eggs and larvae), (2) acute results for routine monitoring during the Decline Window showed that TSS had the potential to cause moderate magnitude effects (adults, juveniles) or moderate to high effects (eggs and larvae), and (3) acute results for event-based monitoring during the Decline Window showed numerous events of moderate to high magnitude and one event with high to very high effects for all life stages but limited in overlap with WCT.

Confidence in these conclusions is limited by several uncertainties. Most notably, relatively large temporal gaps exist in the dataset because routine sampling has generally been conducted weekly or monthly, such that high magnitude and widespread acute events may have gone unsampled. There are also spatial gaps in the existing dataset, where the extent of TSS events is difficult to determine and some events could have been mischaracterized or were undetected. However, the potential effects of this are low since any such event would necessarily have been localized. Additionally, the ability of the SEV models to accurately describe effects to WCT from TSS is uncertain as the SEV models apply more widely (typically to all salmonids) and thus effects to WCT may be less or greater than the models state. Last, there is uncertainty as to how TSS interacts with other stressors. TSS concentrations may be harmful to WCT, but the consequences of this stress may be more or less depending on other stressors. For these last two areas of uncertainty (SEV model accuracy and TSS interactions), there is low risk of missing substantial TSS-based effects to WCT because neither of these areas of uncertainty affect the relative comparison between the historical period and Decline Window — there was no increase in TSS and SEV during the Decline Window. Thus, aside from the potential scenario of an unsampled acute event, the data provide good support for a conclusion that TSS was not the primary cause of the decline but may have been a contributing factor.

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SIGNATORY PAGE

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ACRONYMNS AND ABBREVIATIONS

EoC – Evaluation of Cause

FRO – Fording River Operations

SME – Subject Matter Expert

SEV – Severity of Ill Effects

TSS – Total Suspended Solids

UFR – Upper Fording River

WCT – Westslope Cutthroat Trout

READER'S NOTE

What is the Evaluation of Cause and what is its purpose?

The Evaluation of Cause is the process used to investigate, evaluate and report on the reasons the Westslope Cutthroat Trout population declined in the upper Fording River between fall 2017 and fall 2019.

Background

The Elk Valley is located in the southeast corner of British Columbia (BC), Canada. It contains the main stem of the Elk River (220 km long) and many tributaries, including the Fording River (70 km long). This report focuses on the upper Fording River, which starts 20 km upstream from its confluence with the Elk River at Josephine Falls. The Ktunaxa First Nation has occupied lands in the region for more than 10,000 years. Rivers and streams of the region provide culturally important sources of fish and plants.

The upper Fording River watershed is at a high elevation and is occupied by only one fish species, a genetically pure population of Westslope Cutthroat Trout *(Oncorhynchus clarkii lewisi)* — an iconic fish species that is highly valued in the area. This population is physically isolated because Josephine Falls is a natural barrier to fish movement. The species is protected under the federal Fisheries Act and the Species at Risk Act. In BC, the Conservation Data Center categorized Westslope Cutthroat Trout as "*imperiled or of special concern, vulnerable to extirpation or extinction.*" Finally, it has been identified as a priority sport fish species by the Province of BC.

The upper Fording River watershed is influenced by various human-caused disturbances including roads, a railway, a natural gas pipeline, forest harvesting and coal mining. Teck Coal Limited (Teck Coal) operates the three surface coal mines within the upper Fording River

Evaluation of Cause

Following identification of the decline in the Westslope Cutthroat Trout population, Teck Coal initiated an Evaluation of Cause process. The overall results of this process are reported in a separate document (Evaluation of Cause Team, 2021) and are supported by a series of Subject Matter Expert reports.

The report that follows this Reader's Note is one of those Subject Matter Expert Reports.

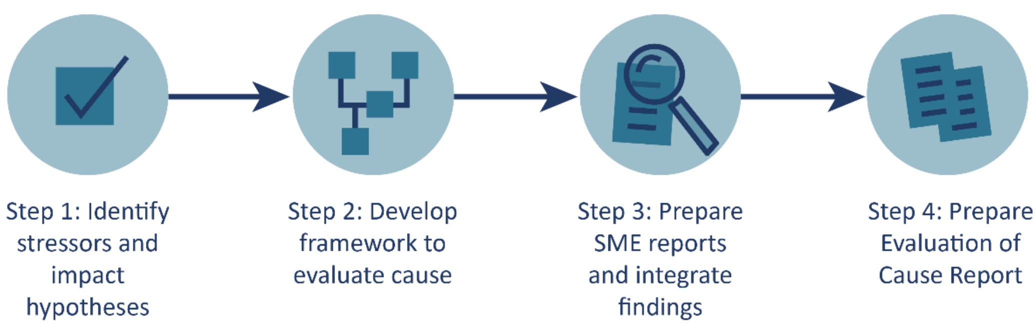
watershed, upstream of Josephine Falls: Fording River Operations, Greenhills Operations and Line Creek Operations.

Monitoring conducted for Teck Coal in the fall of 2019 found that the abundance of Westslope Cutthroat Trout adults and sub-adults in the upper Fording River had declined significantly since previous sampling in fall 2017. In addition, there was evidence that juvenile fish density had decreased. Teck Coal initiated an *Evaluation of Cause* process. The overall results of this process are reported separately (Evaluation of Cause Team, 2021) and are supported by a series of Subject Matter Expert reports such as this one. The full list of SME reports follows at the end of this Reader's Note.

Building on and in addition to the Evaluation of Cause, there are ongoing efforts to support fish population recovery and implement environmental improvements in the upper Fording River.

How the Evaluation of Cause was approached

When the fish decline was identified, Teck Coal established an *Evaluation of Cause Team* (the Team), composed of *Subject Matter Experts* and coordinated by an Evaluation of Cause *Team Lead.* Further details about the Team are provided in the Evaluation of Cause report. The Team developed a systematic and objective approach (see figure below) that included developing a Framework for Subject Matter Experts to apply in their specific work. All work was subjected to rigorous peer review.



Conceptual approach to the Evaluation of Cause for the decline in the upper Fording River Westslope Cutthroat Trout population.

With input from representatives of various regulatory agencies and the Ktunaxa Nation Council, the Team initially identified potential stressors and impact hypotheses that might explain the cause(s) of the population decline. Two overarching hypotheses (essentially, questions for the Team to evaluate) were used:

- Overarching Hypothesis #1: The significant decline in the upper Fording River Westslope Cutthroat Trout population was a result of a single acute stressor[1] or a single chronic stressor[2].
- Overarching Hypothesis #2: The significant decline in the upper Fording River Westslope Cutthroat Trout population was a result of a combination of acute and/or chronic stressors, which individually may not account for reduced fish numbers, but cumulatively caused the decline.

The Evaluation of Cause examined numerous stressors in the UFR to determine if and to what extent those stressors and various conditions played a role in the Westslope Cutthroat Trout's decline. Given that the purpose was to evaluate the cause of the decline in abundance from 2017 to 2019[3], it was important to identify stressors or conditions that changed or were different during that period. It was equally important to identify the potential stressors or conditions that did not change during the decline window but may, nevertheless, have been important constraints on the population with respect to their ability to respond to or recover from the stressors. Finally, interactions between stressors and conditions had to be considered in an integrated fashion. Where an *impact hypothesis* depended on or may have been exacerbated by interactions among stressors or conditions, the interaction mechanisms were also considered.

The Evaluation of Cause process produced two types of deliverables:

1. **Individual Subject Matter Expert (SME) reports** (such as the one that follows this Note): These reports mostly focus on impact hypotheses under Overarching Hypothesis #1 (see list, following). A Framework was used to align SME work for all the potential stressors, and, for consistency, most SME reports have the same overall format. The format covers: (1) rationale for impact hypotheses, (2) methods, (3) analysis and (4) findings, particularly

[1] Implies September 2017 to September 2019.

[2] Implies a chronic, slow change in the stressor (using 2012–2019 timeframe, data dependent).

[3] Abundance estimates for adults/sub-adults are based on surveys in September of each year, while estimates for juveniles are based on surveys in August.

whether the requisite conditions4 were met for the stressor(s) to be the sole cause of the fish population decline, or a contributor to it. In addition to the report, each SME provided a summary table of findings, generated according to the Framework. These summaries were used to integrate information for the Evaluation of Cause report. Note that some SME reports did not investigate specific stressors; instead, they evaluated other information considered potentially useful for supporting SME reports and the overall Evaluation of Cause, or added context (such as in the SME report that describes climate (Wright et al., 2021).

2. **The Evaluation of Cause report** (prepared by a subset of the Team, with input from SMEs): This overall report summarizes the findings of the SME reports and further considers interactions between stressors (Overarching Hypothesis #2). It describes the reasons that most likely account for the decline in the Westslope Cutthroat Trout population in the upper Fording River.

Participation, Engagement & Transparency

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

Ktunaxa Nation Council

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

BC Ministry Environment & Climate Change Strategy

Ministry of Energy, Mines and Low Carbon Innovation

Environmental Assessment Office

[4] These are the conditions that would need to have occurred for the impact hypothesis to have resulted in the observed decline of Westslope Cutthroat Trout population in the upper Fording River.

Citation for the Evaluation of Cause Report

When citing the Evaluation of Cause Report use:

Evaluation of Cause Team, (2021). *Evaluation of Cause — Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Evaluation of Cause Team.

Citations for Subject Matter Expert Reports

Focus	Citation for Subject Matter Expert Reports
Climate, temperature, and streamflow	Wright, N., Greenacre, D., & Hatfield, T. (2021). *Subject Matter Expert Report: Climate, Water Temperature, Streamflow and Water Use Trends. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Ice	Hatfield, T., & Whelan, C. (2021). *Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. Report Prepared by Ecofish Research Ltd.
Habitat availability (instream flow)	Healey, K., Little, P., & Hatfield, T. (2021). *Subject Matter Expert Report: Habitat availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd.
Stranding – ramping	Faulkner, S., Carter, J., Sparling, M., Hatfield, T., & Nicholl, S. (2021). *Subject Matter Expert Report: Ramping and stranding. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd.

Focus	Citation for Subject Matter Expert Reports
Stranding – channel dewatering	Hatfield, T., Ammerlaan, J., Regehr, H., Carter, J., & Faulkner, S. (2021). *Subject Matter Expert Report: Channel dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd.
Stranding – mainstem dewatering	Hocking M., Ammerlaan, J., Healey, K., Akaoka, K., & Hatfield T. (2021). *Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd. Zathey, N., & Robinson, M.D. (2021). *Summary of ephemeral conditions in the upper Fording River Watershed. In Hocking et al. (2021). Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd.
Calcite	Hocking, M., Tamminga, A., Arnett, T., Robinson M., Larratt, H., & Hatfield, T. (2021). *Subject Matter Expert Report: Calcite. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd., Lotic Environmental Ltd., and Larratt Aquatic Consulting Ltd.
Total suspended solids	Durston, D., Greenacre, D., Ganshorn, K & Hatfield, T. (2021). *Subject Matter Expert Report: Total suspended solids. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.
Fish passage (habitat connectivity)	Harwood, A., Suzanne, C., Whelan, C., & Hatfield, T. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. Akaoka, K., & Hatfield, T. (2021). Telemetry Movement Analysis. In Harwood et al. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper*

Focus	Citation for Subject Matter Expert Reports
	Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Cyanobacteria Algae / macrophytes	Larratt, H., & Self, J. (2021). *Subject Matter Expert Report: Cyanobacteria, periphyton and aquatic macrophytes. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Larratt Aquatic Consulting Ltd.
Water quality (all parameters except water temperature and TSS [Ecofish])	Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. Healey, K., & Hatfield, T. (2021). *Calculator to assess Potential for cryoconcentration in upper Fording River.* In Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.
Industrial chemicals, spills and unauthorized releases	Van Geest, J., Hart, V., Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. Branton, M., & Power, B. (2021). *Stressor Evaluation – Sewage.* In Van Geest et al. (2021). *Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.
Wildlife predators	Dean, D. (2021). *Subject Matter Expert Report: Wildlife predation. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc.
Poaching	Dean, D. (2021). *Subject Matter Expert Report: Poaching. Evaluation of Cause – Decline in upper Fording River*

Focus	Citation for Subject Matter Expert Reports
	Westslope Cutthroat Trout population. Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc.
Food availability	Orr, P., & Ings, J. (2021). *Subject Matter Expert Report: Food availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc.
Fish handling	Cope, S. (2020). *Subject Matter Expert Report: Fish handling. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Westslope Fisheries Ltd.
	Korman, J., & Branton, M. (2021). *Effects of capture and handling on Westslope Cutthroat Trout in the upper Fording River: A brief review of Cope (2020) and additional calculations.* Report prepared for Teck Coal Limited. Prepared by Ecometric Research and Azimuth Consulting Group.
Infectious disease	Bollinger, T. (2021). *Subject Matter Expert Report: Infectious disease. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd.
Pathophysiology	Bollinger, T. (2021). *Subject Matter Expert Report: Pathophysiology of stressors on fish. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd.
Coal dust and sediment quality	DiMauro, M., Branton, M., & Franz, E. (2021). *Subject Matter Expert Report: Coal dust and sediment quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Azimuth Consulting Group Inc.
Groundwater quality and quantity	Henry, C., & Humphries, S. (2021). *Subject Matter Expert Report: Hydrogeological stressors. Evaluation of Cause - Decline in upper Fording River Westslope Cutthroat Trout population.* Report Prepared for Teck Coal Limited. Prepared by SNC-Lavalin Inc.

1. INTRODUCTION

Abundances of adult and juvenile life stages of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) (WCT) in the upper Fording River (UFR) have been estimated since 2012 through high-effort snorkel and electrofishing surveys, supported by radio-telemetry and redd surveys (Cope *et al*. 2016). Annual snorkel and electrofishing surveys were conducted in the autumns of 2012-2014, 2017, and 2019. Abundances of both juvenile and adult life stages were substantively lower in 2019 than 2017, indicating a large decline during the two-year period between September 2017 to September 2019 (Westslope Cutthroat Trout Population Decline Window; hereafter referred to as Decline Window; Cope 2020). The magnitude of the decline as well as refinements in the timing of decline are reviewed in detail by Cope (2020) and the Evaluation of Cause Team (2021).

Teck Coal Limited (Teck Coal) initiated the "Evaluation of Cause" (EoC) to assess factors that could be responsible for the population decline. The EoC evaluates multiple impact hypotheses to determine whether and to what extent various stressors and conditions played a role in the decline of WCT. Given that the primary objective is to evaluate the cause of the sudden decline over a short time period (from 2017 to 2019), it is important to identify stressors or conditions that changed or were different from normal during the Decline Window. However, it is equally important to identify all potential stressors or conditions that did not change during the Decline Window but nevertheless may be important constraints on the population. Finally, interactions among stressors are also considered in the EoC. Where an impact hypothesis depends on interactions among stressors or conditions, or where the impact may be exacerbated by particular interactions, the mechanisms of interaction are considered as part of the evaluation of specific impact hypotheses.

A project team is evaluating the cause of WCT decline in abundance and is investigating two "overarching" hypotheses:

- Overarching Hypothesis #1: The significant decline in the UFR WCT population was a result of a single acute stressor[5] or a single chronic stressor[6].
- Overarching Hypothesis #2: The significant decline in the UFR WCT population was a result of a combination of acute and/or chronic stressors, which individually may not account for reduced WCT numbers, but cumulatively caused the decline.

Ecofish Research Ltd. (Ecofish) was asked to provide support as Subject Matter Expert (SME) for an evaluation of total suspended solids (TSS) as a stressor. This report investigates concentrations of TSS in the UFR, its tributaries, and locations that directly input mine-influenced releases. Exposure to TSS can have deleterious effects on fish and fish habitat, thus there is the potential that TSS exposure may have caused or contributed to the observed WCT decline.

[5] Implies the single acute stressor acted between September 2017 and September 2019.

[6] Implies a chronic slow change in the stressor (using 2011-2019 timeframe, data dependent).

1.1. Background

1.1.1. Overall Background

This document is one of a series of SME reports that supports the overall EoC of the UFR WCT population decline (Evaluation of Cause Team 2021). For general information, see the preceding Reader's Note.

1.1.2. Report-Specific Background

Short duration or prolonged exposures to elevated 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). Potential physiological effects can be lethal or sublethal to fish; the severity of effects 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 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)). All these potential effects depend not only on the magnitude and duration of TSS exposure, but also on related factors (e.g., sediment chemistry, sediment particle size distribution, and substrate embeddedness). Where those factors have been identified as potential causes of the population decline (e.g., sediment chemistry), separate stressor reports have been developed (see Evaluation of Cause Team 2021).

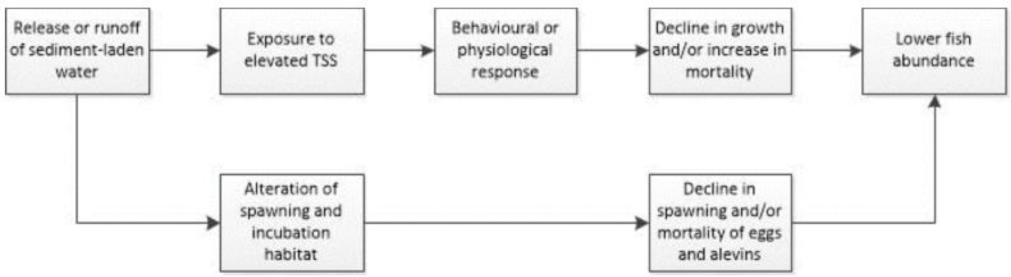
Riverine TSS concentrations fluctuate widely based on a range of factors including local and seasonal hydrologic regimes, geology/geomorphology, and human influences. Collectively, these factors determine the magnitude, duration, and frequency of river sediment inputs and transport (Bash *et al.* 2001), where the duration and frequency of exposure to TSS are important along with the magnitude to the health of aquatic organisms (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 UFR watershed 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 response to specific events or conditions ("event-based monitoring") such as releases of mine-influenced water. To date, TSS concentrations have been monitored primarily through spot samples (i.e., a bottle of water collected at a single moment and place that is submitted for laboratory quantification of TSS). TSS data for the

January 2012 and December 2019 period were provided to Ecofish for an analysis of TSS in relation to the observed UFR WCT population decline.

Figure 1 provides a pathway of effect conceptual model for the cause-effect linkages between TSS exposure and fish abundance.

Figure 1. Potential pathways of effect relevant to effects to fish and fish habitat due to mining activities.



1.1.3. 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 developed management plans and guidelines for industry and government related to many different development types. Todd is currently in his third 4-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 part of 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 data for the mainstem UFR and nearby tributaries from January 2012 to December 2019 to assess potential effects to WCT abundance from TSS exposure. Potential impacts to fish can occur from short duration (acute) and prolonged (chronic) exposures to elevated TSS concentrations that directly or indirectly affect the health and survival of WCT. Thus, exposure to TSS could lead to population decline if a large proportion of the population is impacted.

The specific impact hypothesis evaluated was:

- Did exposure to TSS in the UFR and its tributaries cause or contribute to the observed WCT population decline?

1.3. Approach

TSS data from the UFR, its tributaries, and direct input locations were provided by Teck Coal for routine and event-based monitoring conducted during the January 2012 to December 2019 period (Map 1). Routine water quality monitoring has been conducted in the mainstem of the UFR, tributaries and at additional release locations of mine-influenced water (licensed releases of effluent from settling pond decants (point sources) in accordance with regulatory permit conditions). Event-based monitoring has been conducted for releases of mine-influenced water where TSS exceeded the concentration specified by license permits and for un-licensed discharges not associated with a licence or permit (e.g., road runoff from a heavy rain that enters the UFR or tributaries directly rather than via a settling pond). Although road runoff is directed toward settling ponds specified in effluent permits, water from road runoff occasionally discharges into the UFR or tributaries river without going to a settling pond, and a measurement is only taken if the runoff is noticed (e.g., inspection after or during a heavy rain); therefore, these events were assessed separately from routine monitoring data. These data were parsed into either the Decline Window (September 2017 to September 2019) or prior to that (i.e., January 2012 to August 2017; hereafter "historical period").

All data were analyzed to determine trends or anomalies in TSS for WCT life history periods that may have caused or contributed to the observed WCT population decline. Potential effects to WCT from TSS were quantified using a severity of ill effects (SEV) impact assessment model (Newcombe and Jensen 1996; Section 2.2). This SEV model uses both the duration and magnitude of exposure to TSS to calculate a SEV index score that can be related to potential effects to fish. A more 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 threshold for increase over background), whereas the SEV model predicts effects in relation to absolute TSS criteria (not as a proportion to background) and thus 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 population decline), the SEV model is a more appropriate approach.

For the 2012 – 2019 dataset, SEV index scores were calculated assuming acute (96-hour) and chronic (30-day) durations at the routine monitoring stations, and an acute duration only for event-based monitoring. The 30-day duration for chronic SEV was selected because chronic guidelines are commonly based on 30-day exposure and in most cases sufficient TSS data exist to have a reasonable estimate of average TSS for this period. The 96-hour duration for acute SEV was selected because (1) the actual durations of high TSS events are unknown, and 96-hours provides a more conservative assumption than a 24-hour duration, and (2) the available TSS data are relatively low resolution (e.g., often weekly) and thus are unlikely to capture peak TSS for an event; assuming a longer duration helps to compensate for observations that are lower than the real peak TSS for that event. If TSS data were collected at an event peak and for an event that did persisted for less than 96 hours, these assumptions would overstate SEV.

SEV index scores were used to categorize the probability and type (e.g., behavioural effects, sublethal effects, and lethal/paralethal effects) of potential effects to fish, and were compared against a threshold corresponding to requisite TSS conditions to cause a population decline of the magnitude documented for WCT in the UFR (Section 2.3). Index scores were compared between two time periods, the Decline Window (2017-2019) and the historical period (2012-2016), to determine if the requisite threshold was met during the Decline Window but not in the historical period, such that TSS exposure during the Decline Window could be responsible for the WCT population decline.

2. METHODS

2.1. Data Collection

A bulk transfer of TSS data was received by Ecofish from Teck Coal comprising approximately 6,700 sample results from 340 locations in the Elk Valley during the January 2012 to December 2019 period. These data did not include information on sediment particle size, sediment chemistry, nor visual observations (e.g., sediment residue). TSS data were provided from both routine water quality monitoring stations and event-based sampling associated with Teck Coal Operations. To avoid inclusion of unrelated sampling locations (e.g., isolated sumps, tailings ponds, etc. that are not connected to the UFR) the data analyses were restricted to sites located in the UFR and its fish accessible tributaries (hereafter referred to as "the receiving environment"), or directly connected input sources (hereafter referred to as "mine-influenced releases"). These sites were identified with the assistance of staff from Teck Coal and Golder Associates Ltd. to ensure suitability of the locations for characterizing TSS in the receiving environment and from associated inputs. Teck Coal and Golder Associates Ltd. also provided pairings between these monitoring site and the fish habitat area and stream segments (Table 1). Fish habitat areas were developed by Teck Coal based on the average area of non-fragmented fish-bearing habitat under high and low flow conditions represented by each station, while the stream segments were developed by Cope *et al.* 2016 in relation to fish usage.

The analysis included 3691 data points collected between 2012 to 2019 from 29 stations in the UFR mainstem, tributaries, and associated input locations (Table 1) and 41 TSS data points collected during 27 events in the Decline Window (event-based monitoring; Table 2). The event-based data were collected in response to road runoff or other events related to mine-influenced releases (e.g., when TSS concentrations were higher than license permitted concentrations) and were assessed for acute TSS effects assuming a 96-hour exposure (Map 1, Table 2). Consistent with the methods by which other water quality parameters are being evaluated (Costa and de Bruyn, 2021), samples where TSS could not be detected were treated as having a concentration equal to the minimum detection limit (3 mg/L prior to October 2013, and 1 mg/L thereafter; laboratory procedures changed in 2013 resulting in lower detection limits).

Table 1. Routine water quality monitoring stations included in the UFR watershed TSS effects assessment.

Description	WQ Station Code	Biological Area Code	Fish Habitat[1] (ha)	Stream Segment[2]	Number of TSS Samples Collected 2012	2013	2014	2015	2016	2017	2018	2019	Total
Mainstem Fording River													
u/s Henretta Cr. and FRO	FR_UFR1	FO26	7.40	10, 11	25	29	27	41	35	38	34	37	266
d/s Henretta Cr.	FR_FR1	FODHE	2.88	9	18	49	19	31	21	24	18	24	204
d/s North Greenhills Diversion	FR_FRABEC1	FODNGD	0.56	8	15	52	0	1	6	1	0	0	75
Multiplate Culvert	FR_MULTIPLATE	MP1	0.89	8	15	43	2	1	17	3	10	4	95
u/s Kilmarnock Cr.	FR_FR2	FOUKI	0.92	8	27	88	27	33	28	38	26	30	297
d/s Swift Cr., u/s Cataract Cr.	FR_FR4	FOBSC	0.68	7	24	43	25	23	12	8	9	3	147
d/s Cataract, u/s Porter	FR_FRCP1	FOBCP	1.38	7	0	0	0	44	38	36	37	40	195
u/s Porter	FR_FRRD	FRUPO	2.22	6	0	0	1	28	13	17	13	11	83
d/s Porter Cr., u/s Chauncey Cr.	GH_PC2	FODPO	1.86	6	0	0	0	0	0	0	2	2	4
u/s Chauncey Creek	FR_FRABCH	FO22	1.94	6	0	1	0	13	10	13	29	35	101
d/s Chauncey Cr., u/s Ewin Cr.	FR_FR5	FOUEW	11.33	4,5	16	14	10	16	12	11	11	3	93
Tributaries													
Henretta Creek	FR_HC3	HENUP	1.74	9	21	10	3	18	26	33	25	25	161
Chauncey Creek	RG_CH1	CHCK	0.40	6	0	0	0	0	26	32	33	31	122
Henretta Creek	FR_HC1	HENFO	2.99	9	25	60	26	28	28	28	25	26	246
Fish Pond Creek	FR_FC1	FR_FC1	0.29	9	6	10	4	1	3	6	1	0	31
Clode Creek (Settling Pond Decant)	FR_CC1	CLODE	0.30	9	26	49	45	34	26	28	27	26	261
Kilmarnock Creek (D/S of Rock Drain)	FR_KC1	KICK	0.08	7	37	28	26	26	27	28	26	26	224
Swift Creek (Sediment Pond Decant/Bypass)	GH_SC1-2	SWCK	0.06	7	0	0	0	0	26	32	33	31	122
Porter Creek	GH_PC1	POCK	0.15	6	0	0	0	0	0	5	25	25	55
LCO Dry Creek	LC_DC1	LC_DC1	0.20	3	0	0	0	0	1	0	0	0	1
Additional Release Locations													
Eagle Settling Pond Decant	FR_EC1	N/A	N/A	N/A	37	39	32	23	21	20	18	0	190
Lake Mountain Sediment Pond Decant	FR_LMP1	N/A	N/A	N/A	0	0	0	0	2	73	49	27	151
Liverpool Sed. Pond Decant	FR_LP1	N/A	N/A	N/A	0	0	0	0	12	36	25	30	103
North Loop Settling Pond Decant to the Fording River	FR_NL1	N/A	N/A	N/A	2	1	4	0	0	5	15	3	30
Post Sed. Pond Decant	FR_PP1	N/A	N/A	N/A	0	0	0	0	0	0	1	47	48
South Kilmarnock Settling Pond Decant - Phase 1	FR_SKP1	N/A	N/A	N/A	5	12	18	7	0	0	15	2	59
South Kilmarnock Settling Pond Decant- Phase 2	FR_SKP2	N/A	N/A	N/A	6	9	8	3	0	4	2	0	32
Smith Ponds Decant	FR_SP1	N/A	N/A	N/A	25	14	12	21	27	28	25	25	177
Cataract Creek (Sediment Pond Decant)	GH_CC1	FR_CATCK	N/A	N/A	0	0	0	0	31	37	25	25	118

[1] Average between non-fragmented fish accessible habitat area at low-flow and high-flow (bankful) conditions

[2] as per Cope et al. 2016

Table 2. Monitoring stations and sample counts for event-based monitoring during 2017 to 2019.

Description	Site Name	# TSS Samples			
		2017	2018	2019	Total Samples[1]
WQ Exceedances[2]					
Lake Mountain Sediment Pond Decant	FR_LMP1	-	8	-	8
Liverpool Sed. Pond Decant	FR_LP1	1	-	6	7
North Loop Settling Pond Decant to the Fording River	FR_NL1	-	1	-	1
Post Sed. Pond Decant	FR_PP1	-	-	18	18
Waste Water Cells North Pond Decant	FR_WWC1	-	-	1	1
Swift Creek	GH_SC1	-	1	-	1
Road Runoff					
u/s Henretta Cr. and FRO (reference)	FR_UFR1	-	-	1	1
Confluence of UFR and Swift Creek	Swift Bridge	-	-	2	2
Below multiplate culvert into Fording River	N/A	-	-	1	1
Discharge to Swift Creek	N/A	-	-	1	1
Fording River upstream of FR_LP1	N/A	-	-	N/A[3]	-
Number of Days		1	3	13	16

[1] Unless multiple replicates were specified, data records were assumed to have been derived from a single sample.

[2] Defined as any sample where measured TSS was greater than the permit limit (50 mg/L)

[3] A runoff event was observed in 2019, however sample data were not available

2.2. 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 (e.g., Singleton 2001, McCoy 2013). Consistent with the assessment of other water quality constituents (Costa and de Bruyn 2021), 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). These models were developed for different types of aquatic biota including 1) freshwater and anadromous adult salmonids, 2) freshwater and anadromous juvenile salmonids, and 3) eggs and larvae of salmonids and non-salmonids including freshwater, anadromous, and estuarine fish (Table 3). 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 the different SEV models are provided in Table 3. SEV index scores and associated categories are provided in Table 4.

Table 3. 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 spatio-temporal discontinuities in the dataset and other limitations, the application of the SEV model to the available data required several key assumptions:

1. Individual TSS observations at stations in the receiving environment are representative of conditions at that location (e.g., the waters are fully mixed) and representative of that river/stream segment (e.g., nearby conditions are not substantially different as a result of further inputs or settling, dilution, and resuspension processes);
2. Average TSS from discrete samples collected over the chronic (30 days) and acute (96 hour) durations are representative of actual average conditions (e.g., events did not occur between sampling that would have substantially lowered or raised the average);
3. TSS observations measured during event-based monitoring are representative of that event; and

4. TSS particle sizes are within the applicable particle size range for the SEV models (provided in Table 3).

These assumptions apply to the historical period and Decline Window. In all cases, the actual effects to fish from TSS could be greater or less depending on the actual conditions relative to the assumptions. Although the validity of these assumptions adds uncertainty to the SEV results, SEV modelling remains a useful tool to assess biological effects of TSS and for identifying trends and anomalies that may be related to the WCT population decline.

Acute and chronic SEV were calculated for 96-hour and 30-day durations respectively, based on the rationale provided in Section 1.3. To account for temporal discontinuities including gaps and variation in the frequency of collection, chronic TSS concentrations were determined by averaging TSS by date for each site (to avoid weighting days more heavily when multiple samples were collected on a day) and then daily means were averaged into mean for that calendar month, for which a chronic SEV score was calculated using an assumed 30-day duration. Applying a 30-day duration to all months rather than assigning slightly longer or shorter durations to different calendar months equalizes the effect of the assumed duration. The peak monthly chronic SEV score was then selected at each site for each year. Acute SEV scores were calculated by selecting the maximum daily average TSS concentration observed in each year at each site.

To account for spatial discontinuities, SEV results for each station were assumed to apply to the entire habitat area represented by each water quality monitoring station (Table 1). To calculate SEV across these habitat areas (i.e., for the UFR and its tributaries) a weighted-average SEV was calculated for each year, with weight assigned by relative habitat area. Habitat areas without TSS data were excluded from this area-weighted average, rather than assuming SEV from nearby areas. This habitat area weighted SEV provides a metric for comparing SEV across years, but could obscure localized effects where they are averaged out, which is why individual site SEV results are also compared against absolute thresholds.

2.2.1. 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 4 (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, slight impairment, significant impairment, and severe impairment) (Table 4). The duration of these effects will vary widely based on the specific effect, where some would cease in conjunction with a return to clear waters (e.g., visual feeding) while other conditions may persist (embedded sediments) or take time to reverse (e.g., reductions in growth rates). The SEV models provide predictions for the occurrence of these effects, but we do not consider how effects persist or interact over longer time scales because the long-term effects of TSS on population dynamics have not been well studied (Kjelland *et al.* 2015).

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 4).

These categories use the same divisions as the impairment categories from Newcombe (2003) except the highest category (SEV 9 – 14 or "severe impairment") has been subdivided into two categories ("high" and "very high") in recognition that this category is otherwise overly broad in the context of causing population declines (i.e., it equates to effects ranging widely from reduced growth to 100% mortality; Table 4). SEV 12 was selected as the threshold to divide the high and very high magnitude categories because SEV 12 is associated with 40-60% mortality (Newcombe and Jensen 1996) and thus approximately corresponds to an LD50 event, which is consistent with the approach used for other water quality constituents in setting a threshold capable of causing the observed decline (Costa and de Bruyn 2021). A summary of the TSS concentrations required to reach various SEV results for each SEV model are provided in Table 5 for acute and chronic durations.

Table 4. 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 Jensen 1996

[2]Newcombe 2003

[3] Unique categorization system developed for the evaluation of requisite conditions.

[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 5. Summary of TSS concentrations required to reach SEV scores corresponding to acute (96-hr) and chronic (30-day) exposure durations.

Exposure Duration	SEV Model[1]	TSS Concentration (mg/L)													
	SEV Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Acute: 96 hours	Adult Salmonids	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	0.02	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	0.09	2.28	56.5	1,397	34,540	854,400	21,130,000
Chronic: 30 days	Adult Salmonids	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	0.01	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	0.05	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 6. Periodicity of Westslope Cutthroat Trout in the upper Fording River watershed.

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
Adult												
Juvenile												
Eggs and Larvae (Incubation)												

2.3. Evaluation of Requisite Conditions

Requisite conditions are defined as the circumstances that would need to be met for TSS exposure in the UFR and tributaries to cause or contribute to the WCT population decline (Table 7). The requisite conditions can be used to judge whether TSS conditions resulted in stress for fish and whether such events could have caused or contributed to the population decline.

Table 7. The requisite conditions for TSS to cause or contribute to the WCT population decline.

Intensity	TSS exposure was of sufficient concentration to cause or contribute to fish mortality
Duration	TSS exposure was of sufficient duration to cause or contribute to fish mortality.
Spatial extent	TSS exposure occurred over a large enough portion of the UFR and tributary habitat that it could have caused or contributed to WCT mortality
Location	TSS exposure was spatially coincident with WCT usage of the UFR and tributary habitat to the extent that it could have caused or contributed to WCT mortality
Timing	TSS exposure occurred during the Decline Window and when WCT were present (adults are present throughout the year, fry are present from August through October; Table 6)

Two of these conditions (intensity and duration) are combined by the SEV model into a magnitude score for TSS (Table 4). As such, further evaluation of the requisite conditions relies on this combined magnitude condition rather than intensity and duration individually.

Information on the life history of WCT including life stages and their spatio-temporal distribution (e.g., habitat use and periodicity) is required to determine the outcome of exposure to TSS events. To account for differences in susceptibility among life stages, SEV index scores were calculated separately for three WCT life stages (adults, juveniles, eggs, and larvae). Matrices illustrating how the SEV index varies with different combinations of TSS concentration 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.

The life stage periodicity of WCT results in early life stages (eggs and larvae) present from mid-May to August, while juveniles and adults are present throughout the year (Table 6). Habitat use in the UFR by adult life stages was assessed by Cope *et al.* (2016) and is summarized in Evaluation of Cause Team (2021) and Table 8. This distribution and timing information is used to relate SEV scores for different monitoring stations to expected fish use of the nearby habitats during the overwintering, rearing, and spawning periods. The spatial extent of potential effects was evaluated for individual sites by linking SEV results with fish use at that site (in instances where SEV exceeded identified thresholds), and for all sites collectively by weighting the SEV scores by the proportion of affected fish habitat area.

Table 8. Relative fish use of UFR stream segments based on WCT telemetry data and corresponding WQ monitoring stations

Stream Segment[1]	WQ Stations	Relative Fish Use			
		Overwintering	Rearing	Spawning[2]	Average
10, 11	FR_UFR1	1.89%	3.37%	2.33%	2.53%
9	FR_FR1, HENUP, FR_HC1, FR_CLODE, FR_FC1	15.15%	18.47%	14.44%	16.02%
8	FR_FRABAC1, FR_MULTIPLATE, FR_FR2	15.91%	10.37%	4.21%	10.16%
7	FR_FR4, FR_FRCP1, FR_KC1, GH_SC1-2	1.52%	5.26%	0.72%	2.50%
6	FR_FRRD, GH_PC2, FR_FRABCH, GH_PC1	36.74%	15.37%	31.97%	28.02%
4, 5	FR_FR5	4.92%	17.79%	7.57%	10.09%
3	LC_DC1	0.00%	0.00%	2.92%	0.97%

[1]Identified in Cope *et al.,* 2020

[2]Average of usage from tagged WCT and redd surveys

The results of the requisite conditions analysis are intended to support evaluation of Hypothesis 1 (requisite condition to cause) and Hypothesis 2 (requisite condition to contribute) for the TSS stressor. A **requisite condition to cause** was identified when TSS concentrations had the potential for high or very high magnitude effects during the Decline Window relative to the historical period and occurred over a wide area where fish were present. This may 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 a population-level effect consistent with the observed WCT population decline.

A **requisite condition to contribute** was identified when SEV data had the potential for (1) localized high or very high magnitude effects, (2) widespread moderate magnitude effects during the Decline Window relative to the historical period, and/or (3) was at high enough levels to be harmful to WCT (moderate or greater effects) during the Decline Window irrespective of the historical conditions. High but localized effects could result in mortality but at a limited spatial scale that is insufficient to explain the mortality levels associated with the WCT decline; whereas, widespread moderate magnitude effects do not directly cause mortality but are associated with reductions in feeding and increased stress, which can negatively affect fish populations if the effects are increased relative to the historical period and/or act in combination with other stressors.

SEV results that did not meet the above requisite conditions were said to have not caused or contributed to the decline, although the possibility remains that low SEV scores may have contributed to the decline in a minor way.

3. RESULTS

3.1. Routine Monitoring

3.1.1. TSS Overview

TSS concentrations were obtained for discrete samples collected at 29 water quality stations in the receiving environment (i.e., UFR, tributaries, and directly connected inputs) between January 2012 to December 2019 (Table 1; Figure 2). The frequency distributions of the available TSS data for different years and seasonal periods (as identified by Cope *et al.* 2016) are provided in Figure 3 and show a similar pattern for all years; results are typically <10 mg/L and few results are above this value. Maximum TSS at the routine monitoring stations during the Decline Window were 104 mg/L, 151 mg/L, and 376 mg/L in 2017, 2018, and 2019, respectively, which is within the range observed during the historical period (56 – 8,080 mg/L or 56 – 2,000 mg/L excluding the extreme flood event in 2013). Daily average TSS concentrations during the Decline Window were similar to those during the historical period. The average annual TSS concentration in 2017, 2018 and 2019 ranged from 5.6 mg/L to 7.0 mg/L compared to 2.6 to 6.1 mg/L from 2012 to 2016, except in 2013 when average TSS was 9.9 mg/L due to an extreme event in October 2013, wherein the highest recorded TSS concentration among all records (8,080 mg/L) was observed. TSS concentrations during the Decline Window generally followed annual discharge patterns with the highest TSS occurring during spring freshet (usually May and June).

Figure 2. TSS concentrations (mg/L) in routine monitoring samples from 2012 to 2019.

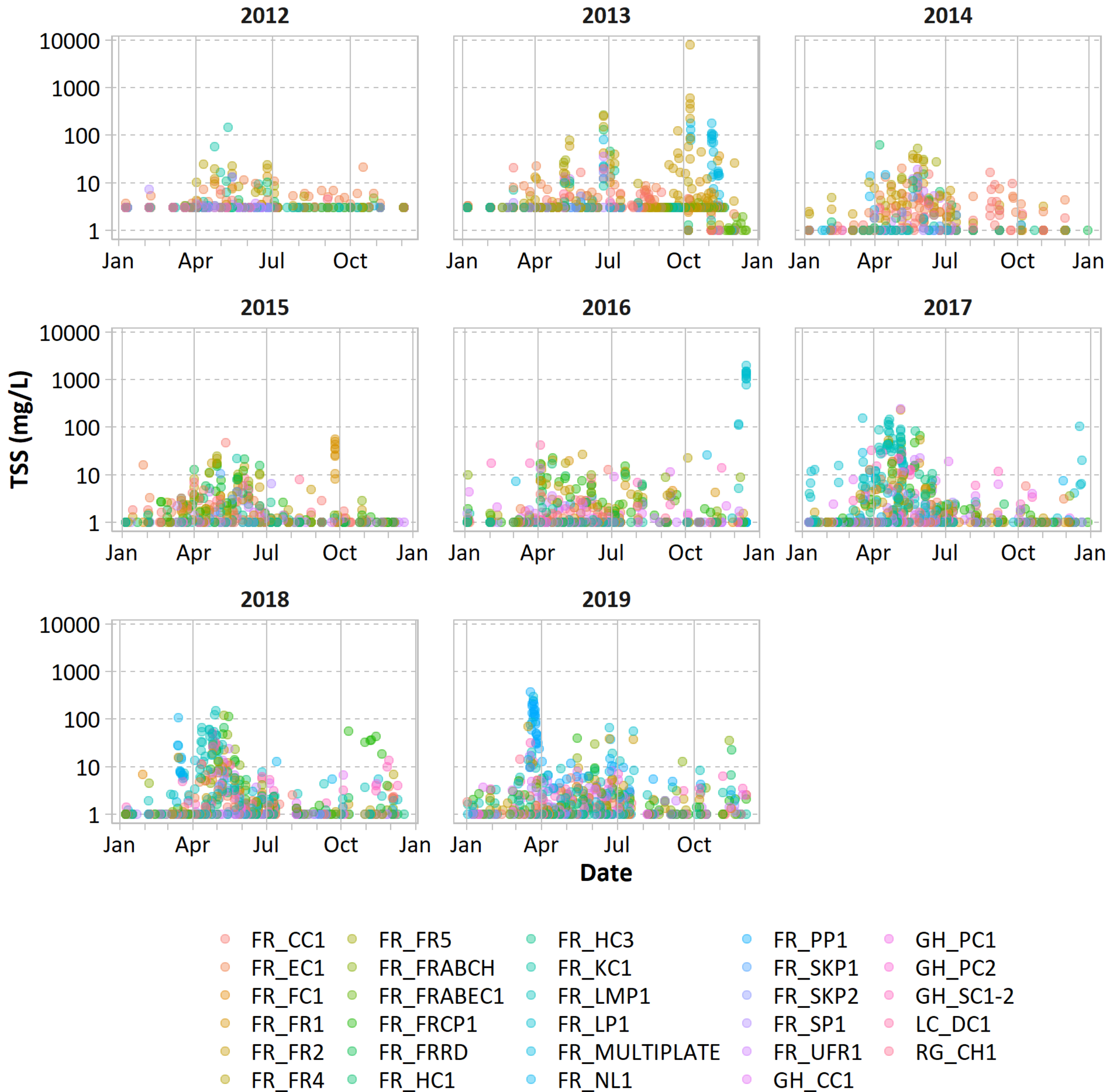
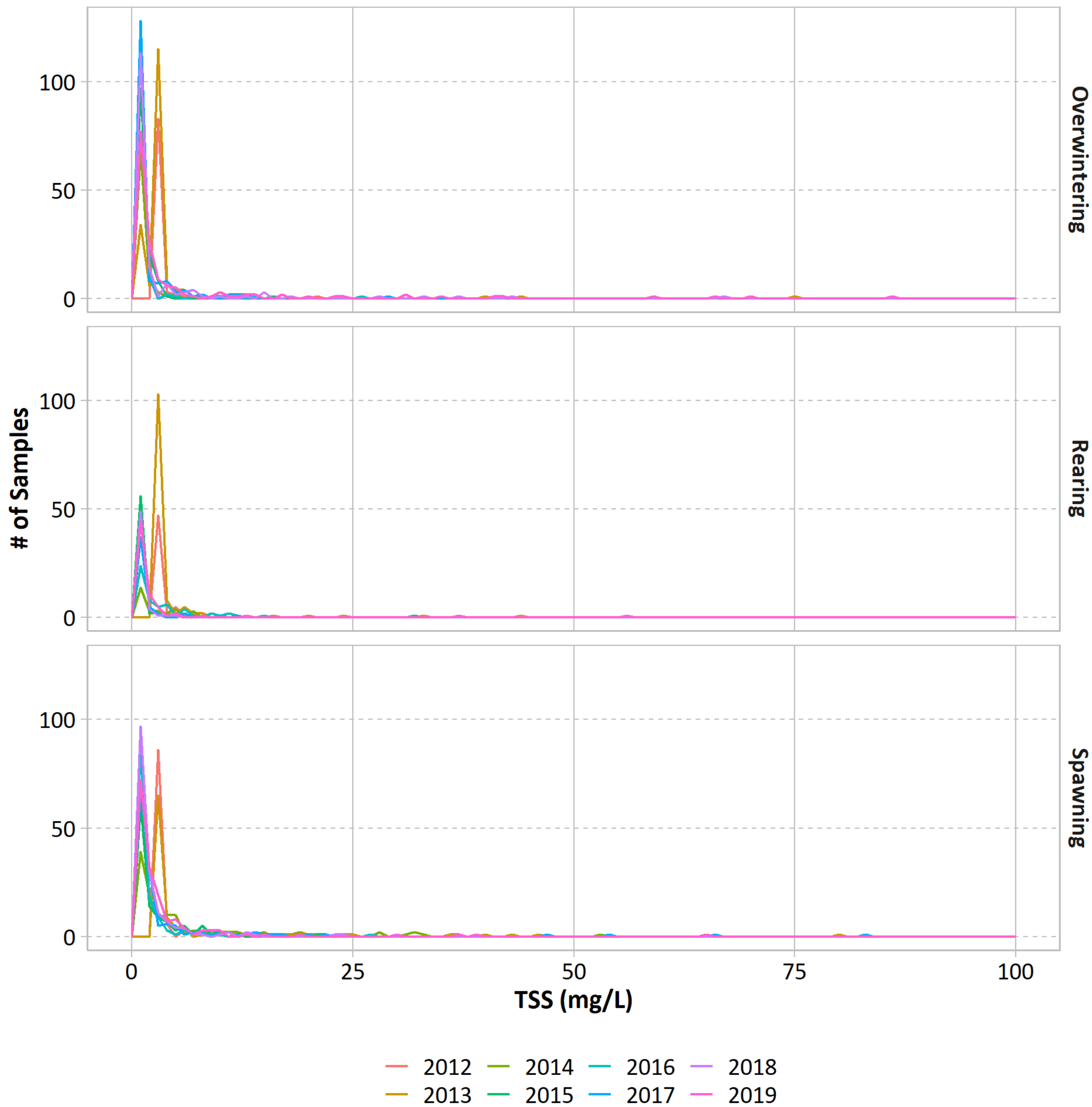


Figure 3. Frequency distribution of TSS sampled from routine water quality monitoring stations in the receiving environment and at direct input location from 2012 to 2019 during WCT annual life stage periods (per Cope *et al.* 2016) [7]



[7] Note, a small number of TSS samples had concentrations >100 mg/L. These are described in section 3.1.1. but excluded here to improve visualization of the more numerous, lower-concentration measurements.

3.1.2. Chronic SEV

Chronic TSS exposure for adult and juvenile salmonids was less than the threshold score of SEV 12 (potential to cause >40-60% mortality) throughout the period of record (Figure 4, Figure 5), while chronic TSS exposure for eggs and larvae was occasionally greater than SEV 12 in both the historical period and Decline Window (Figure 6). All SEV results during the Decline Window for adults and juveniles were classified as moderate (Table 9, Table 10). Note that the floor observed in SEV results for adult and juvenile salmonids between SEV 5-6 reflects a 30-day exposure to TSS at the minimum detection limit of 1 mg/L. This floor shifts downward in late 2013 due to a change in the minimum detection limit for TSS from 3 mg/L to 1 mg/L. A similar floor exists for eggs and larvae at SEV 11.3 (2012 – 2013) and SEV 10.9 (2014 onward).

For adult salmonids, chronic SEV at the receiving environment sites was commonly moderate throughout the historical period aside from one instance of a high result (SEV 9.0 at FR_FRABCH; Table 9). Aside from this high result, SEV during the historical period ranged from 5.1 to 8.4 compared with 4.8 – 7.6 during the Decline Window (Table 9). All Decline Window results were moderate and area-weighted SEV was equal for both periods at 6.3. At the additional release locations, all results were moderate for the historical period and Decline Window, aside from one high result in the historical period (SEV 9.8 at FR_LP1 in 2016).

Juvenile SEV results were higher, but otherwise similar to the adult results as both rely on the same data but with slightly different SEV coefficients. Receiving environment results were SEV 5.4 – 8.8 (historical period) versus SEV 5.4 – 8.1 (Decline Window), excluding one result of SEV 9.3 in 2013 (Figure 5, Table 10). Area-weighted average SEV was identical for both periods at 6.8. SEV results at the additional release locations were also similar for both periods and ranged from SEV 5.7 – 7.6 (historical period) or SEV 5.5 – 8.6 (Decline Window) except for one higher SEV result of 10.1 during the historical period (December 2016).

Results for eggs and larvae are provided for the incubation period (May 15 to September 1 in the UFR). The model developed for eggs and larvae often yields higher SEV index scores because it applies to life stages that are particularly sensitive to the effects of TSS. For eggs and larvae in the receiving environment, SEV was 10.9 – 12.3 in the historical period versus 10.9 – 12.1 in the Decline Window, with a slightly lower area-weighted average SEV during the Decline Window (SEV 11.4 vs. 11.6; Figure 6). Very high SEV (>12) was observed in the receiving environment in 2013 (six sites), 2014 (three sites), 2017 (two sites), and 2018 (one site; Table 11). The only very high result during the Decline Window occurred at FR_FRCP1 (segment S7) where SEV 12.1 was observed. The same result was also observed at this site during the previous year within the historical period. Very high ratings in the receiving environment were most prevalent during 2013 and 2014; 58% of area-weighted assessed habitat in each year indicated potential for very high magnitude effects. In all other years only 0-9% of assessed habitat had a very high magnitude rating (Table 11). At the additional release locations, all SEV results were high for the entire period of record and had the same range of SEV 10.9 – 11.9 for both the historical period and Decline Window. Results do not show an increase in SEV for eggs and larvae during the Decline Window, but do show high SEV continuing throughout both periods, which poses an on-going risk of mortality to eggs and larvae. Effects to eggs and larvae have poorly understood effects on population dynamics (Kjelland *et al.,* 2015).

Overall, area weighted average SEV index scores (Table 9, Table 10, Table 11) determined by taking an area weighted average of the peak SEV at each site per year show that across all life stages, chronic SEV was equal or better during the Decline Window than the historical period. At individual sites, for adults and juveniles there were 7 sites with higher-than-average SEV during the Decline Window than the historical period, whereas 8 sites were lower during the Decline Window than the historical period. A further 5 sites were equal or had incomplete data to make this comparison. For eggs and larvae, only 1 site (FR_FRCP1) representing 1.38 ha of fish habitat had higher average SEV during the Decline Window, whereas 11 sites representing 24.09 ha of fish habitat had lower SEV. A further 8 sites were equal or had incomplete data to make this comparison.

Chronic SEV results were also compared based on the distribution of SEV results (across all sites) for each year rather than as averages (Figure 7). All of the results for adults and juveniles during the Decline Window were below the threshold for a high magnitude effect (SEV 9) and the upper limit of the interquartile range was consistently <6 (adults) or near 6 (juveniles) for both the Decline Window and most of the historical years. Overall, there is no indication of a widespread increase in moderate SEV conditions (SEV 4-9) during the Decline Window for adult and juveniles. For eggs and larvae, the Decline Window results are limited to the 2018 and 2019 years. The frequency data shown in Figure 7 indicate that 2018 was the lowest or near-lowest for a wide range of metrics (e.g., median, upper limit of the interquartile range). SEV was higher in 2019 but with an interquartile range similar to several historical years (e.g., 2014, 2016).

Overall, no notable trends or anomalies (high TSS events) potentially related to the WCT population decline were detected during the Decline Window. Peak SEV was not higher during the Decline Window, high or very high magnitude conditions were not more common during the Decline Window than historical period, and moderate magnitude conditions occurred at a relatively similar frequency.

Figure 4. SEV for adult salmonids throughout 2012 to 2019 assuming a chronic (30-day) exposure duration. Red horizontal line indicates a threshold score of 12 (potential to cause >40-60% mortality).

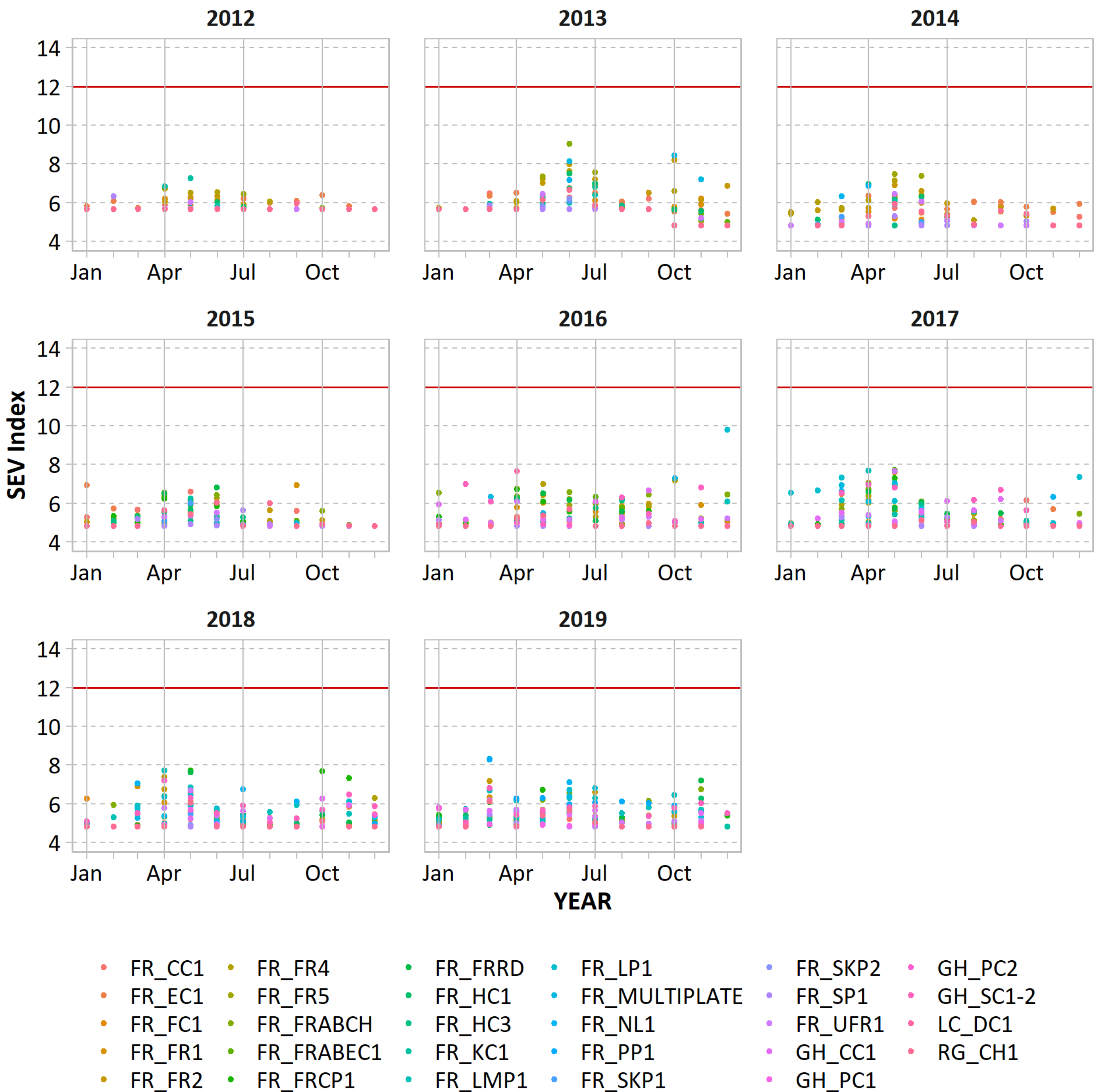


Figure 5. SEV for juvenile salmonids throughout 2012 to 2019 assuming a chronic (30-day) exposure duration. Red horizontal line indicates a threshold score of 12 (potential to cause >40-60% mortality).

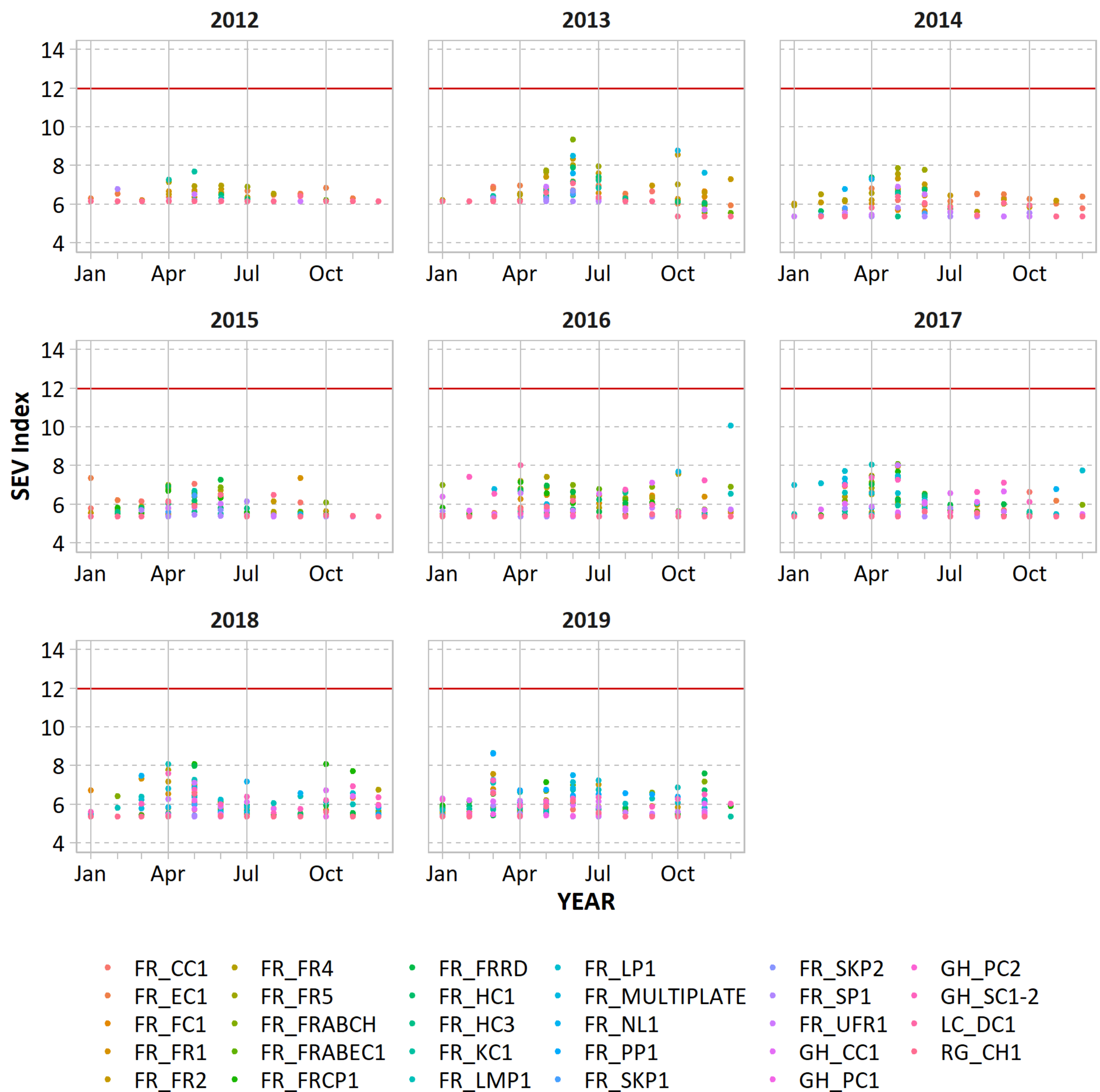


Figure 6. SEV for eggs and larvae during the incubation period (May 15 – September 1) throughout 2012 to 2019 assuming a chronic (30-day) exposure duration. Red horizontal line indicates a threshold score of 12 (potential to cause >40-60% mortality).

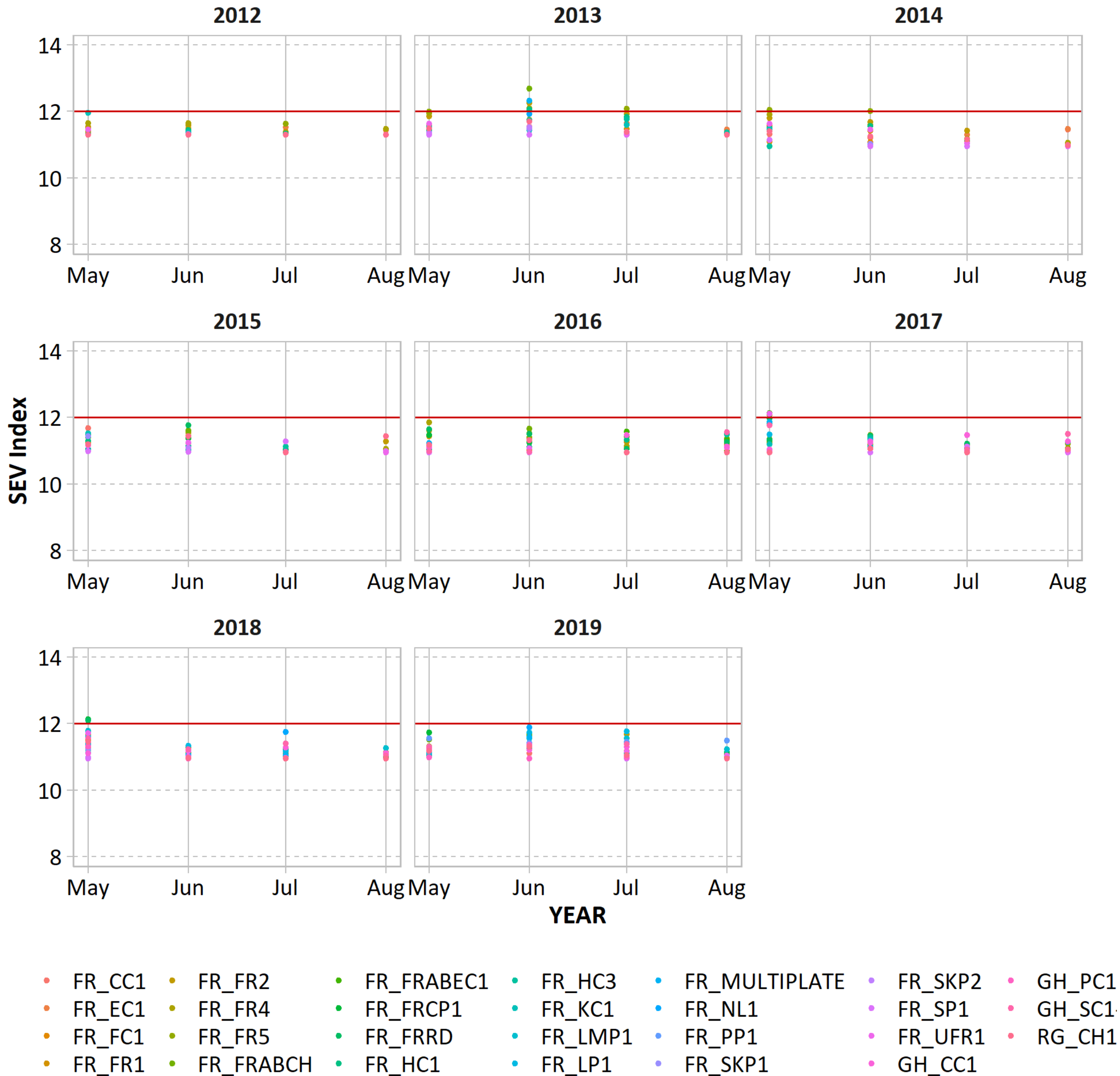


Figure 7. **Boxplot showing the frequency of chronic SEV results each year for all sites combined. Results are divided into panels for each SEV life stage. Note that results in 2012 and 2013 are skewed higher by the higher MDL for TSS in those years.**

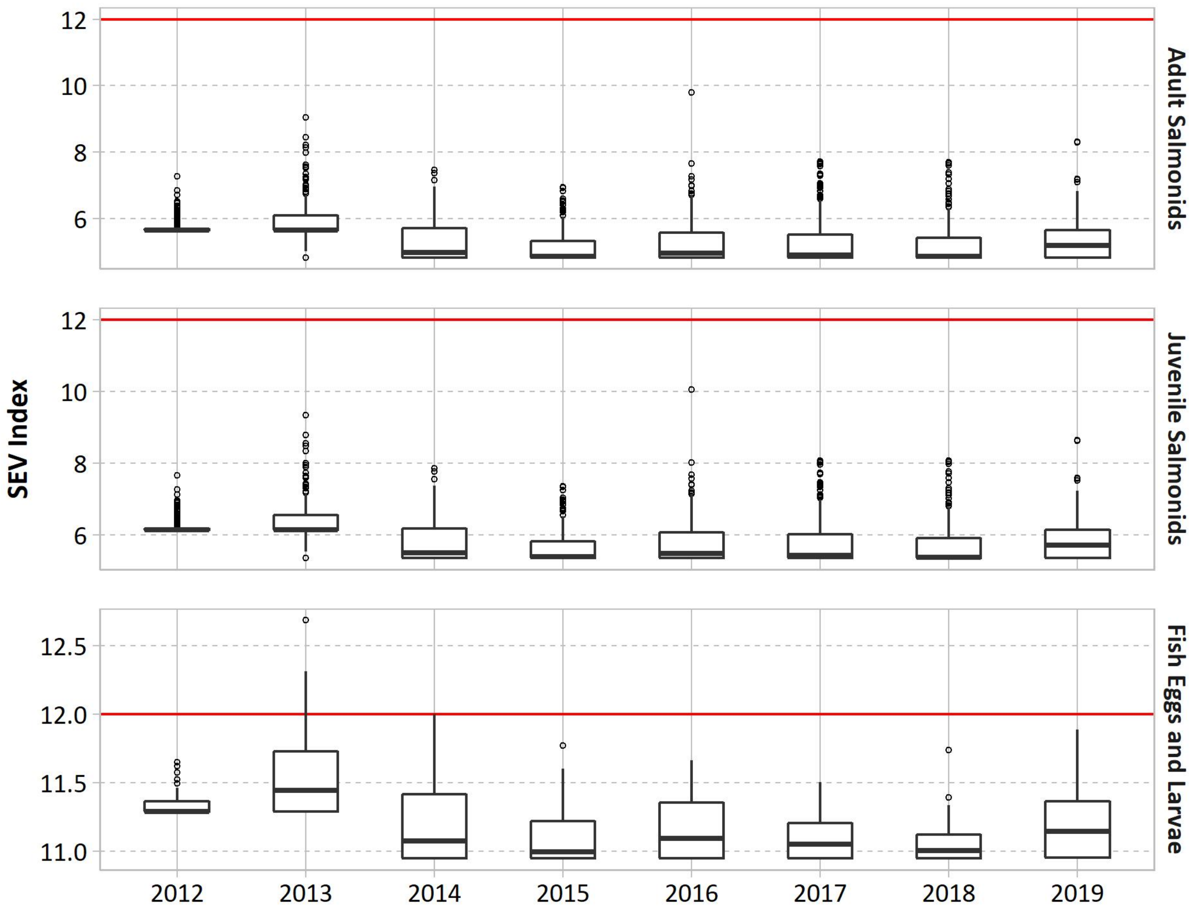


Table 9. Maximum chronic SEV model results for adult salmonids based on 30-day exposure duration.

Description	WQ Station Code	Biological Area Code	Fish Habitat (ha)	Stream Segment[1]	Peak Monthly Average SEV Score[2] 2012	2013	2014	2015	2016	2017	2018	2019	Average Score Historical Period	Decline Window
Mainstem Fording River														
u/s Henretta Cr. and FRO	FR_UFR1	FO26	7.40	10, 11	6.0	6.6	6.4	5.5	6.1	7.6	6.7	6.2	6.1	6.8
d/s Henretta Cr.	FR_FR1	FODHE	2.88	9	6.2	6.8	6.3	6.9	6.1	7.6	6.9	6.3	6.5	6.9
d/s North Greenhills Diversion	FR_FRABEC1	FODNGD	0.56	8	5.7	5.7	-	5.1	6.3	7.7	-	-	5.7	7.7
Multiplate Culvert	FR_MULTIPLATE	MP1	0.89	8	5.7	8.4	4.8	5.0	7.3	7.0	6.4	6.8	6.2	6.7
u/s Kilmarnock Cr.	FR_FR2	FOUKI	0.92	8	6.3	8.2	6.9	6.5	6.7	7.0	6.7	7.2	6.9	7.0
d/s Swift Cr., u/s Cataract Cr.	FR_FR4	FOBSC	0.68	7	6.7	7.6	7.1	6.4	7.2	6.1	7.4	5.0	7.0	6.1
d/s Cataract, u/s Porter	FR_FRCP1	FOBCP	1.38	7	-	-	-	6.2	6.7	7.3	7.7	6.7	6.5	7.2
u/s Porter	FR_FRRD	FRUPO	2.22	6	-	-	4.8	6.8	6.5	6.6	7.6	7.2	6.1	7.1
d/s Porter Cr., u/s Chauncey Cr.	GH_PC2	FODPO	1.86	6	-	-	-	-	-	-	5.4	5.7	-	5.6
u/s Chauncey Creek	FR_FRABCH	FO22	1.94	6	-	9.0	-	6.4	6.6	6.7	7.7	6.7	7.3	7.0
d/s Chauncey Cr., u/s Ewin Cr.	FR_FR5	FOUEW	11.33	4,5	6.5	7.6	7.5	6.5	6.3	6.4	6.7	4.8	6.9	6.0
Tributaries														
Henretta Creek	FR_HC3	HENUP	1.74	9	6.0	6.8	4.8	5.3	6.1	7.1	5.4	5.6	5.8	6.0
Chauncey Creek	RG_CH1	CHCK	0.40	6	6.0	6.6	5.9	6.0	5.7	5.1	6.1	6.1	6.0	5.8
Henretta Creek	FR_HC1	HENFO	2.99	9	6.0	7.5	7.0	5.7	6.2	6.9	6.0	6.3	6.5	6.4
Fish Pond Creek	FR_FC1	FR_FC1	0.29	9	5.7	6.2	5.2	4.8	6.0	4.8	6.3	-	5.6	5.5
Clode Creek (Settling Pond Decant)	FR_CC1	CLODE	0.30	9	5.9	6.5	6.1	6.6	5.9	6.1	5.4	5.5	6.2	5.7
Kilmarnock Creek (D/S of Rock Drain)	FR_KC1	KICK	0.08	7	7.3	6.4	6.1	6.2	5.1	5.4	5.2	5.6	6.2	5.4
Swift Creek (Sediment Pond Decant/Bypass)	GH_SC1-2	SWCK	0.06	7	-	-	-	-	7.0	7.0	7.2	6.8	7.0	7.0
Porter Creek	GH_PC1	POCK	0.15	6	-	-	-	-	-	4.8	5.7	5.0	-	5.2
LCO Dry Creek	LC_DC1	LC_DC1	0.20	3	-	-	-	-	7.6	-	-	-	7.6	-
Area-weighted Average SEV score					**6.1**	**7.1**	**6.1**	**6.0**	**6.4**	**6.5**	**6.5**	**6.1**	**6.4**	**6.4**
Area-weighted Summary			% Neglible Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			% Low Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			% Moderate Rating		100	94.0	100	100	100	100	100	100	98.8	100
			% High Rating		0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0
			% Very High Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Additional Release Locations														
Eagle Settling Pond Decant	FR_EC1	N/A	N/A	N/A	6.4	6.5	6.3	6.9	5.4	6.5	6.1	-	6.3	6.3
Lake Mountain Sediment Pond Decant	FR_LMP1	N/A	N/A	N/A	-	-	-	-	6.1	7.7	7.7	6.7	6.1	7.3
Liverpool Sed. Pond Decant	FR_LP1	N/A	N/A	N/A	-	-	-	-	9.8	7.3	6.3	8.3	9.8	7.3
North Loop Settling Pond Decant to the Fording River	FR_NL1	N/A	N/A	N/A	5.7	7.2	6.9	-	-	6.6	7.1	7.1	6.6	6.9
Post Sed. Pond Decant	FR_PP1	N/A	N/A	N/A	-	-	-	-	-	-	5.0	8.3	-	6.6
South Kilmarnock Settling Pond Decant - Phase 1	FR_SKP1	N/A	N/A	N/A	5.7	6.1	5.9	6.0	-	-	5.5	4.9	5.9	5.2
South Kilmarnock Settling Pond Decant - Phase 2	FR_SKP2	N/A	N/A	N/A	5.7	6.2	6.5	5.2	-	5.0	4.9	-	5.9	4.9
Smith Ponds Decant	FR_SP1	N/A	N/A	N/A	6.3	5.8	5.3	5.6	5.1	5.3	4.8	5.4	5.6	5.2
Cataract Creek (Sediment Pond Decant)	GH_CC1	FR_CATCK	N/A	N/A	-	-	-	-	6.7	6.2	6.3	5.8	6.7	6.1

[1] Identified in Cope *et al*., 2020

[2] Colours correspond to effects ratings based on SEV index scores as follows: Neglible (<1); Low (1-4); Moderate (4-9); High (9-12); Very High (≥12)

"-" denotes no data available

Shaded years denotes years belonging to the Decline Window

Table 10. Maximum chronic SEV model results for juvenile salmonids based on a 30-day exposure duration.

Description	WQ Station Code	Biological Area Code	Fish Habitat (ha)	Stream Segment[1]	Peak Monthly Average SEV Score[2]								Average Score	
					2012	2013	2014	2015	2016	2017	2018	2019	Historical Period	Decline Window
Mainstem Fording River														
u/s Henretta Cr. and FRO	FR_UFR1	FO26	7.40	10, 11	6.5	7.1	6.9	6.0	6.6	8.0	7.1	6.6	6.6	7.2
d/s Henretta Cr.	FR_FR1	FODHE	2.88	9	6.7	7.2	6.8	7.4	6.6	8.0	7.3	6.8	6.9	7.3
d/s North Greenhills Diversion	FR_FRABEC1	FODNGD	0.56	8	6.2	6.2	-	5.6	6.8	8.1	-	-	6.2	8.1
Multiplate Culvert	FR_MULTIPLATE	MP1	0.89	8	6.2	8.8	5.4	5.5	7.7	7.4	6.9	7.2	6.7	7.2
u/s Kilmarnock Cr.	FR_FR2	FOUKI	0.92	8	6.8	8.6	7.3	7.0	7.1	7.5	7.2	7.6	7.4	7.4
d/s Swift Cr., u/s Cataract Cr.	FR_FR4	FOBSC	0.68	7	7.1	8.0	7.5	6.8	7.6	6.5	7.8	5.5	7.4	6.6
d/s Cataract, u/s Porter	FR_FRCP1	FOBCP	1.38	7	-	-	-	6.7	7.1	7.7	8.1	7.1	6.9	7.6
u/s Porter	FR_FRRD	FRUPO	2.22	6	-	-	5.4	7.2	7.0	7.0	8.0	7.6	6.5	7.5
d/s Porter Cr., u/s Chauncey Cr.	GH_PC2	FODPO	1.86	6	-	-	-	-	-	-	5.9	6.2	-	6.1
u/s Chauncey Creek	FR_FRABCH	FO22	1.94	6	-	9.3	-	6.9	7.0	7.1	8.0	7.2	7.7	7.4
d/s Chauncey Cr., u/s Ewin Cr.	FR_FR5	FOUEW	11.33	4,5	6.9	7.9	7.8	7.0	6.8	6.8	7.2	5.4	7.3	6.4
Tributaries														
Henretta Creek	FR_HC3	HENUP	1.74	9	6.5	7.2	5.4	5.8	6.6	7.5	5.9	6.1	6.3	6.5
Chauncey Creek	RG_CH1	CHCK	0.40	6	6.4	7.1	6.4	6.5	6.2	5.6	6.5	6.6	6.5	6.2
Henretta Creek	FR_HC1	HENFO	2.99	9	6.5	7.9	7.4	6.2	6.7	7.3	6.5	6.7	6.9	6.8
Fish Pond Creek	FR_FC1	FR_FC1	0.29	9	6.1	6.7	5.7	5.4	6.4	5.4	6.7	-	6.1	6.0
Clode Creek (Settling Pond Decant)	FR_CC1	CLODE	0.30	9	6.3	6.9	6.5	7.0	6.3	6.6	5.9	6.0	6.6	6.2
Kilmarnock Creek (D/S of Rock Drain)	FR_KC1	KICK	0.08	7	7.7	6.8	6.5	6.7	5.6	5.9	5.7	6.1	6.7	5.9
Swift Creek (Sediment Pond Decant/Bypass)	GH_SC1-2	SWCK	0.06	7	-	-	-	-	7.4	7.4	7.6	7.2	7.4	7.4
Porter Creek	GH_PC1	POCK	0.15	6	-	-	-	-	-	5.4	6.2	5.5	-	5.7
LCO Dry Creek	LC_DC1	LC_DC1	0.20	3	-	-	-	-	8.0	-	-	-	8.0	-
Area-weighted Average SEV score					**6.6**	**7.5**	**6.5**	**6.5**	**6.9**	**7.0**	**6.9**	**6.6**	**6.8**	**6.8**
Area-weighted Summary				% Neglible Rating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				% Low Rating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				% Moderate Rating	100	94.0	100	100	100	100	100	100	99.0	100
				% High Rating	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
				% Very High Rating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Additional Release Locations														
Eagle Settling Pond Decant	FR_EC1	N/A	N/A	N/A	6.8	6.9	6.8	7.3	5.9	6.9	6.5	-	6.8	6.7
Lake Mountain Sediment Pond Decant	FR_LMP1	N/A	N/A	N/A	-	-	-	-	6.5	8.0	8.1	7.1	6.5	7.7
Liverpool Sed. Pond Decant	FR_LP1	N/A	N/A	N/A	-	-	-	-	10.1	7.7	6.8	8.6	10.1	7.7
North Loop Settling Pond Decant to the Fording River	FR_NL1	N/A	N/A	N/A	6.2	7.6	7.3	-	-	7.1	7.5	7.5	7.0	7.3
Post Sed. Pond Decant	FR_PP1	N/A	N/A	N/A	-	-	-	-	-	-	5.5	8.6	-	7.1
South Kilmarnock Settling Pond Decant - Phase 1	FR_SKP1	N/A	N/A	N/A	6.1	6.5	6.4	6.5	-	-	6.0	5.4	6.4	5.7
South Kilmarnock Settling Pond Decant - Phase 2	FR_SKP2	N/A	N/A	N/A	6.1	6.7	6.9	5.7	-	5.5	5.4	-	6.4	5.5
Smith Ponds Decant	FR_SP1	N/A	N/A	N/A	6.8	6.3	5.8	6.1	5.6	5.8	5.4	5.9	6.1	5.7
Cataract Creek (Sediment Pond Decant)	GH_CC1	FR_CATCK	N/A	N/A	-	-	-	-	7.1	6.7	6.7	6.3	7.1	6.6

[1] Identified in Cope *et al*., 2020

[2] Colours correspond to effects ratings based on SEV index scores as follows: Neglible (<1); Low (1-4); Moderate (4-9); High (9-12); Very High (≥12)

"-" denotes no data available

Shaded years denotes years belonging to the Decline Window

Table 11. Maximum chronic SEV model results for eggs and larvae of salmonids and non-salmonids based on 30-day exposure duration during the incubation period only (May 15 to September 1).

Description	WQ Station Code	Biological Area Code	Fish Habitat (ha)	Stream Segment[1]	Peak Monthly Average SEV Score[2] 2012	2013	2014	2015	2016	2017	2018	2019	Average Score Historical Period	Average Score Decline Window
Mainstem Fording River														
u/s Henretta Cr. and FRO	FR_UFR1	FO26	7.40	10, 11	11.5	11.7	11.8	11.2	11.1	11.8	11.7	11.4	11.5	11.5
d/s Henretta Cr.	FR_FR1	FODHE	2.88	9	11.5	11.7	11.7	11.3	11.5	11.7	11.4	11.3	11.6	11.3
d/s North Greenhills Diversion	FR_FRABEC1	FODNGD	0.56	8	11.3	11.3	-	-	11.6	-	-	-	11.4	-
Multiplate Culvert	FR_MULTIPLATE	MP1	0.89	8	11.3	12.3	-	-	-	-	11.1	11.6	11.8	11.3
u/s Kilmarnock Cr.	FR_FR2	FOUKI	0.92	8	11.6	12.2	12.0	11.5	11.7	11.9	11.4	11.7	11.8	11.5
d/s Swift Cr., u/s Cataract Cr.	FR_FR4	FOBSC	0.68	7	11.7	12.1	12.1	11.5	11.5	11.5	11.1	-	11.7	11.1
d/s Cataract, u/s Porter	FR_FRCP1	FOBCP	1.38	7	-	-	-	11.5	11.5	12.1	12.1	11.4	11.7	11.8
u/s Porter	FR_FRRD	FRUPO	2.22	6	-	-	-	11.8	11.5	11.4	11.7	11.3	11.6	11.5
d/s Porter Cr., u/s Chauncey Cr.	GH_PC2	FODPO	1.86	6	-	-	-	-	-	-	-	-	-	-
u/s Chauncey Creek	FR_FRABCH	FO22	1.94	6	-	12.7	-	11.6	11.7	11.0	11.8	11.7	11.7	11.7
d/s Chauncey Cr., u/s Ewin Cr.	FR_FR5	FOUEW	11.33	4,5	11.6	12.1	12.2	11.7	11.4	11.2	11.1	-	11.7	11.1
Tributaries														
Henretta Creek	FR_HC3	HENUP	1.74	9	11.4	11.8	-	11.1	11.5	12.0	11.2	11.3	11.6	11.2
Chauncey Creek	RG_CH1	CHCK	0.40	6	11.3	11.7	11.5	11.4	11.3	11.1	11.5	11.3	11.4	11.4
Henretta Creek	FR_HC1	HENFO	2.99	9	11.4	12.1	11.7	11.4	11.5	11.6	11.4	11.3	11.6	11.4
Fish Pond Creek	FR_FC1	FR_FC1	0.29	9	11.3	11.3	11.1	-	10.9	10.9	-	-	11.1	-
Clode Creek (Settling Pond Decant)	FR_CC1	CLODE	0.30	9	11.3	11.7	11.5	11.2	11.4	11.1	11.2	11.2	11.3	11.2
Kilmarnock Creek (D/S of Rock Drain)	FR_KC1	KICK	0.08	7	11.5	11.6	11.7	11.7	10.9	11.1	11.0	11.1	11.4	11.0
Swift Creek (Sediment Pond Decant/Bypass)	GH_SC1-2	SWCK	0.06	7	-	-	-	-	11.6	11.6	11.4	11.4	11.6	11.4
Porter Creek	GH_PC1	POCK	0.15	6	-	-	-	-	-	-	11.1	11.0	-	11.1
LCO Dry Creek	LC_DC1	LC_DC1	0.20	3	-	-	-	-	-	-	-	-	-	-
Area-weighted Average SEV score					**11.4**	**11.9**	**11.7**	**11.5**	**11.4**	**11.5**	**11.4**	**11.3**	**11.6**	**11.4**
Area-weighted Summary			% Neglible Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			% Low Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			% Moderate Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			% High Rating		100	42.1	41.6	100	100	91.0	96.3	100	79.1	98.2
			% Very High Rating		0.0	57.9	58.4	0.0	0.0	9.0	3.7	0.0	20.9	1.8
Additional Release Locations														
Eagle Settling Pond Decant	FR_EC1	N/A	N/A	N/A	11.6	11.6	11.5	11.1	11.2	11.1	11.2	-	11.4	11.2
Lake Mountain Sediment Pond Decant	FR_LMP1	N/A	N/A	N/A	-	-	-	-	-	11.5	11.3	11.6	11.5	11.4
Liverpool Sed. Pond Decant	FR_LP1	N/A	N/A	N/A	-	-	-	-	-	11.3	11.3	11.8	11.3	11.6
North Loop Settling Pond Decant to the Fording River	FR_NL1	N/A	N/A	N/A	-	11.9	-	-	-	-	11.7	11.9	11.9	11.8
Post Sed. Pond Decant	FR_PP1	N/A	N/A	N/A	-	-	-	-	-	-	-	11.5	-	11.5
South Kilmarnock Settling Pond Decant - Phase 1	FR_SKP1	N/A	N/A	N/A	11.3	11.5	11.6	11.4	-	-	11.0	-	11.4	11.0
South Kilmarnock Settling Pond Decant - Phase 2	FR_SKP2	N/A	N/A	N/A	11.3	11.5	11.6	11.1	-	11.0	11.0	-	11.3	11.0
Smith Ponds Decant	FR_SP1	N/A	N/A	N/A	11.3	11.3	10.9	11.3	10.9	11.1	10.9	11.0	11.2	11.0
Cataract Creek (Sediment Pond Decant)	GH_CC1	FR_CATCK	N/A	N/A	-	-	-	-	11.5	11.5	11.3	11.3	11.5	11.3

[1] Identified in Cope *et al*., 2020

[2] Colours correspond to effects ratings based on SEV index scores as follows: Neglible (<1); Low (1-4); Moderate (4-9); High (9-12); Very High (≥12)

"-" denotes no data available

Shaded years denotes years belonging to the Decline Window

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3.1.3. Acute SEV

Acute TSS exposure for all life stages of WCT was less than the threshold of SEV 12 throughout the period of record for receiving environment sites and additional release locations (Figure 8, Figure 9, Figure 10). During the Decline Window, SEV was classed as low or moderate for adults and juveniles, while SEV for eggs and larvae was commonly high with some moderate results. As with the assessment for chronic TSS exposure, the floor observed in SEV index scores for each life stage corresponds to a 96-hour exposure to TSS at the minimum detection limit.

For adult salmonids, SEV at the receiving environment sites was commonly moderate during the historical period with occasional low results, and one instance of a high result (SEV 9.3 at FR_FR2 in 2013; Table 12). Aside from this high result, SEV during the historical period ranged from 3.9 to 8.1. Results for the receiving environment during the Decline Window were similar with low or moderate results and an overall range of SEV 3.9 – 8.0 (Table 12). Area-weighted SEV was also equal for both periods at 5.8. All additional release location results were moderate for both the historical period and Decline Window, aside from one high result in the historical period (SEV 9.3 at FR_LP1 in 2016) and two low results during the Decline Window.

SEV model results for juvenile salmonids are provided in Table 13. These results are near identical to the adult results as they rely on the same data and the juvenile coefficients give equal or slightly lower results at the acute (96-hour) duration. SEV in both the historical period and Decline Window had the same result of SEV 5.8, with all Decline Window SEV results within the range observed for the historical period. For both juvenile and adults, all SEV results in the Decline Window were low (1 – 30% per annum) or moderate (70 – 99% per annum).

Eggs and larvae are more sensitive to suspended sediments and thus showed higher SEV scores than for other life stages. Results were similar in the historical period and Decline Window. All receiving environment results were moderate (0 – 2%) or high (98 – 100%) based on area-weighted averages for the historical period. Results were also moderate (1 – 37%) or high (63 – 99%) during the Decline Window period. The area-weighted average for the receiving environment during the Decline Window was slightly lower (SEV 9.3) than for the historical period (SEV 9.5) based on ranges of 8.7 – 10.5 (historical period) and 8.8 – 10.2 (Decline Window). The additional release locations showed similar results, with the range of SEV observed during the Decline Window (SEV 8.8 – 10.0) similar to the historical period (8.7 – 9.7).

Overall, area weighted average SEV index scores show that acute TSS conditions were similar or slightly better during the Decline Window compared to the historical period. No notable trends or anomalies during the Decline Window were found.

Figure 8. SEV index for adult salmonids, 2012 to 2019 assuming a 96-hour exposure. Red horizontal line indicates a threshold score of 12 (potential to cause >40-60% mortality).

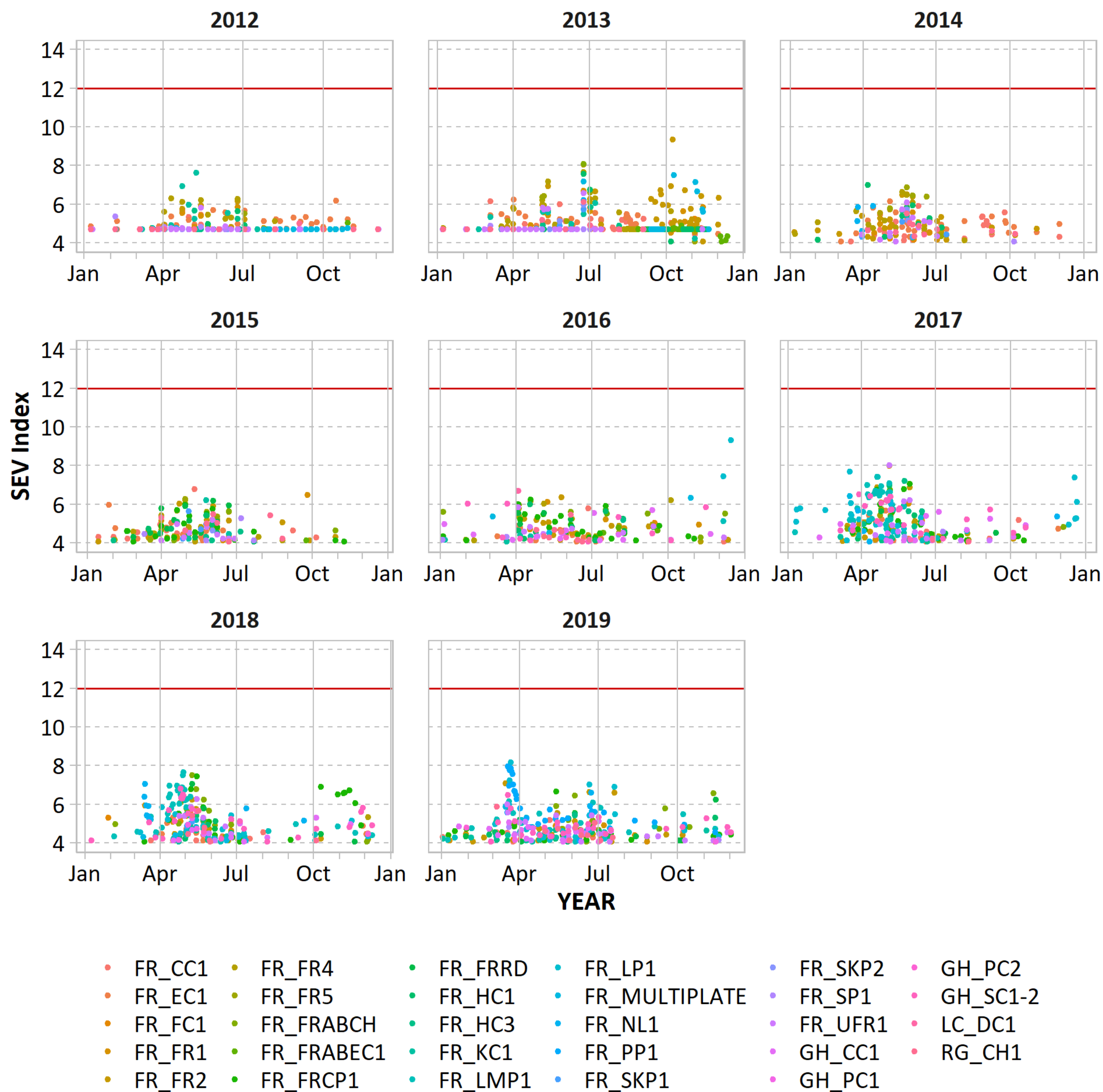


Figure 9. SEV index for juvenile salmonids, 2012 to 2019 assuming a 96-hour exposure duration. Red horizontal line indicates a threshold score of 12 (potential to cause >40-60% mortality).

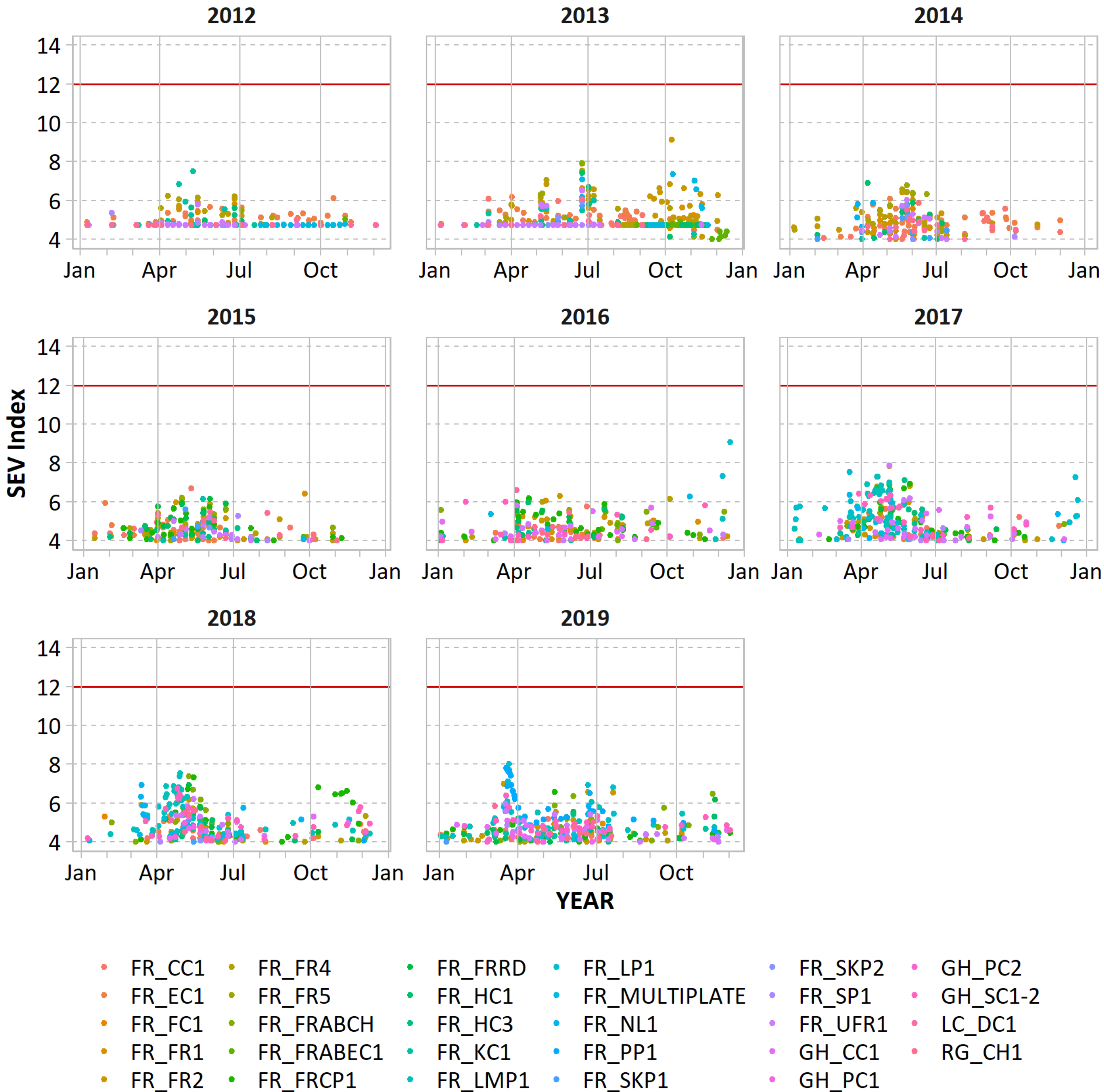


Figure 10. SEV index for eggs and larvae for the incubation period (May 15 - September 1), 2012 to 2019 assuming a 96-hour exposure duration. Red horizontal line indicates a threshold score of 12 (potential to cause >40-60% mortality).

Table 12. Peak daily average SEV model results for adult salmonids based on acute 96-hour exposure duration.

Description	WQ Station Code	Biological Area Code	Fish Habitat (ha)	Stream Segment[1]	Peak Daily Average SEV Score[2] 2012	2013	2014	2015	2016	2017	2018	2019	Average Score Historical Period	Average Score Decline Window
Mainstem Fording River														
u/s Henretta Cr. and FRO	FR_UFR1	FO26	7.40	10, 11	5.8	6.6	6.1	5.2	5.8	8.0	6.3	6.0	5.9	6.8
d/s Henretta Cr.	FR_FR1	FODHE	2.88	9	5.8	6.7	5.8	6.5	6.1	8.0	5.9	5.8	6.2	6.6
d/s North Greenhills Diversion	FR_FRABEC1	FODNGD	0.56	8	5.0	4.9	-	4.1	5.7	6.7	-	-	4.9	6.7
Multiplate Culvert	FR_MULTIPLATE	MP1	0.89	8	4.8	7.5	3.9	4.0	6.3	6.4	5.5	5.9	5.3	5.9
u/s Kilmarnock Cr.	FR_FR2	FOUKI	0.92	8	6.1	9.3	6.5	6.2	6.4	6.9	6.4	7.1	6.9	6.8
d/s Swift Cr., u/s Cataract Cr.	FR_FR4	FOBSC	0.68	7	6.3	7.7	6.6	6.0	6.2	5.1	6.4	4.0	6.6	5.2
d/s Cataract, u/s Porter	FR_FRCP1	FOBCP	1.38	7	-	-	-	6.0	6.2	7.0	7.4	6.6	6.1	7.0
u/s Porter	FR_FRRD	FRUPO	2.22	6	-	-	3.9	6.2	5.6	5.6	7.0	6.2	5.2	6.3
d/s Porter Cr., u/s Chauncey Cr.	GH_PC2	FODPO	1.86	6	-	-	-	-	-	-	4.5	4.8	-	4.6
u/s Chauncey Creek	FR_FRABCH	FO22	1.94	6	-	8.1	-	6.0	5.6	5.7	7.5	6.6	6.6	6.6
d/s Chauncey Cr., u/s Ewin Cr.	FR_FR5	FOUEW	11.33	4,5	5.5	6.6	6.9	6.3	5.4	5.4	5.8	3.9	6.1	5.0
Tributaries														
Henretta Creek	FR_HC3	HENUP	1.74	9	5.7	6.2	3.9	4.6	5.2	7.2	4.7	5.4	5.1	5.8
Chauncey Creek	RG_CH1	CHCK	0.40	6	5.0	6.1	5.5	5.5	5.5	4.2	5.7	5.9	5.5	5.2
Henretta Creek	FR_HC1	HENFO	2.99	9	5.6	7.5	7.0	5.4	6.0	7.0	5.4	5.5	6.3	6.0
Fish Pond Creek	FR_FC1	FR_FC1	0.29	9	4.7	5.3	4.2	3.9	5.0	3.9	5.3	-	4.6	4.6
Clode Creek (Settling Pond Decant)	FR_CC1	CLODE	0.30	9	5.3	6.1	5.9	6.8	5.8	5.2	5.2	5.2	6.0	5.2
Kilmarnock Creek (D/S of Rock Drain)	FR_KC1	KICK	0.08	7	7.6	6.0	5.7	6.2	4.4	5.2	4.8	4.6	6.0	4.9
Swift Creek (Sediment Pond Decant/Bypass)	GH_SC1-2	SWCK	0.06	7	-	-	-	-	6.0	6.5	6.8	6.5	6.0	6.6
Porter Creek	GH_PC1	POCK	0.15	6	-	-	-	-	-	3.9	5.3	4.2	-	4.4
LCO Dry Creek	LC_DC1	LC_DC1	0.20	3	-	-	-	-	6.7	-	-	-	6.7	-
Area-weighted Average SEV score					**5.6**	**6.8**	**5.5**	**5.5**	**5.8**	**6.0**	**5.9**	**5.5**	**5.8**	**5.8**
Area-weighted Summary			% Neglible Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			% Low Rating		0.0	0.0	15.1	0.8	0.0	1.2	0.0	30.4	3.2	10.5
			% Moderate Rating		100	97.2	84.9	99.2	100	98.8	100	69.6	96.2	89.5
			% High Rating		0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			% Very High Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Additional Release Locations														
Eagle Settling Pond Decant	FR_EC1	N/A	N/A	N/A	6.2	6.2	6.1	6.0	4.8	5.8	5.3	-	5.9	5.6
Lake Mountain Sediment Pond Decant	FR_LMP1	N/A	N/A	N/A	-	-	-	-	5.1	7.4	7.7	6.1	5.1	7.1
Liverpool Sed. Pond Decant	FR_LP1	N/A	N/A	N/A	-	-	-	-	9.3	7.7	5.8	8.2	9.3	7.2
North Loop Settling Pond Decant to the Fording River	FR_NL1	N/A	N/A	N/A	4.8	6.2	5.9	-	-	5.7	7.0	6.6	5.6	6.4
Post Sed. Pond Decant	FR_PP1	N/A	N/A	N/A	-	-	-	-	-	-	4.0	8.0	-	6.0
South Kilmarnock Settling Pond Decant - Phase 1	FR_SKP1	N/A	N/A	N/A	4.7	5.7	5.6	5.6	-	-	5.1	3.9	5.4	4.5
South Kilmarnock Settling Pond Decant - Phase 2	FR_SKP2	N/A	N/A	N/A	4.7	6.0	5.7	4.6	-	4.0	4.0	-	5.3	4.0
Smith Ponds Decant	FR_SP1	N/A	N/A	N/A	5.4	4.9	4.3	5.3	4.3	4.9	3.9	4.8	4.8	4.6
Cataract Creek (Sediment Pond Decant)	GH_CC1	FR_CATCK	N/A	N/A	-	-	-	-	5.7	5.6	5.3	5.1	5.7	5.3

[1] Identified in Cope *et al*., 2020

[2] Colours correspond to effects ratings based on SEV index scores as follows: Neglible (<1); Low (1-4); Moderate (4-9); High (9-12); Very High (≥12)

"-" denotes no data available

Shaded years denotes years belonging to the Decline Window

Table 13. Peak daily average SEV model results for juvenile salmonids based on acute 96-hour exposure.

Description	WQ Station Code	Biological Area Code	Fish Habitat (ha)	Stream Segment[1]	Peak Daily Average SEV Score[2] 2012	2013	2014	2015	2016	2017	2018	2019	Average Score Historical Period	Average Score Decline Window
Mainstem Fording River														
u/s Henretta Cr. and FRO	FR_UFR1	FO26	7.40	10, 11	5.8	6.5	6.0	5.2	5.8	7.9	6.2	6.0	5.9	6.7
d/s Henretta Cr.	FR_FR1	FODHE	2.88	9	5.8	6.6	5.8	6.4	6.1	7.8	5.9	5.8	6.1	6.5
d/s North Greenhills Diversion	FR_FRABEC1	FODNGD	0.56	8	5.0	4.9	-	4.2	5.7	6.7	-	-	4.9	6.7
Multiplate Culvert	FR_MULTIPLATE	MP1	0.89	8	4.8	7.4	3.9	4.1	6.3	6.3	5.5	5.8	5.3	5.9
u/s Kilmarnock Cr.	FR_FR2	FOUKI	0.92	8	6.1	9.1	6.4	6.1	6.3	6.8	6.4	7.0	6.8	6.7
d/s Swift Cr., u/s Cataract Cr.	FR_FR4	FOBSC	0.68	7	6.2	7.5	6.6	6.0	6.2	5.1	6.3	4.1	6.5	5.2
d/s Cataract, u/s Porter	FR_FRCP1	FOBCP	1.38	7	-	-	-	5.9	6.2	6.9	7.3	6.6	6.1	6.9
u/s Porter	FR_FRRD	FRUPO	2.22	6	-	-	3.9	6.1	5.5	5.6	6.9	6.2	5.2	6.2
d/s Porter Cr., u/s Chauncey Cr.	GH_PC2	FODPO	1.86	6	-	-	-	-	-	-	4.5	4.8	-	4.7
u/s Chauncey Creek	FR_FRABCH	FO22	1.94	6	-	7.9	-	6.0	5.6	5.7	7.4	6.5	6.5	6.5
d/s Chauncey Cr., u/s Ewin Cr.	FR_FR5	FOUEW	11.33	4,5	5.5	6.5	6.8	6.2	5.4	5.4	5.7	3.9	6.1	5.0
Tributaries														
Henretta Creek	FR_HC3	HENUP	1.74	9	5.6	6.1	3.9	4.6	5.2	7.1	4.8	5.4	5.1	5.8
Chauncey Creek	RG_CH1	CHCK	0.40	6	5.0	6.1	5.5	5.5	5.4	4.2	5.6	5.8	5.5	5.2
Henretta Creek	FR_HC1	HENFO	2.99	9	5.6	7.4	6.9	5.4	6.0	6.9	5.4	5.5	6.3	5.9
Fish Pond Creek	FR_FC1	FR_FC1	0.29	9	4.7	5.3	4.3	3.9	5.0	3.9	5.3	-	4.6	4.6
Clode Creek (Settling Pond Decant)	FR_CC1	CLODE	0.30	9	5.3	6.1	5.9	6.7	5.8	5.2	5.2	5.2	6.0	5.2
Kilmarnock Creek (D/S of Rock Drain)	FR_KC1	KICK	0.08	7	7.5	6.0	5.7	6.1	4.4	5.2	4.8	4.7	5.9	4.9
Swift Creek (Sediment Pond Decant/Bypass)	GH_SC1-2	SWCK	0.06	7	-	-	-	-	6.0	6.4	6.7	6.4	6.0	6.5
Porter Creek	GH_PC1	POCK	0.15	6	-	-	-	-	-	3.9	5.3	4.2	-	4.5
LCO Dry Creek	LC_DC1	LC_DC1	0.20	3	-	-	-	-	6.6	-	-	-	6.6	-
Area-weighted Average SEV score					**5.6**	**6.7**	**5.5**	**5.5**	**5.7**	**6.0**	**5.8**	**5.5**	**5.8**	**5.8**
Area-weighted Summary			% Neglible Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			% Low Rating		0.0	0.0	15.1	0.8	0.0	1.2	0.0	30.4	3.2	10.5
			% Moderate Rating		100	97.2	84.9	99.2	100	98.8	100	69.6	96.2	89.5
			% High Rating		0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			% Very High Rating		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Additional Release Locations														
Eagle Settling Pond Decant	FR_EC1	N/A	N/A	N/A	6.1	6.2	6.1	5.9	4.8	5.8	5.3	-	5.8	5.5
Lake Mountain Sediment Pond Decant	FR_LMP1	N/A	N/A	N/A	-	-	-	-	5.1	7.3	7.5	6.1	5.1	7.0
Liverpool Sed. Pond Decant	FR_LP1	N/A	N/A	N/A	-	-	-	-	9.1	7.5	5.8	8.0	9.1	7.1
North Loop Settling Pond Decant to the Fording River	FR_NL1	N/A	N/A	N/A	4.8	6.2	5.9	-	-	5.6	6.9	6.5	5.6	6.4
Post Sed. Pond Decant	FR_PP1	N/A	N/A	N/A	-	-	-	-	-	-	4.1	7.8	-	5.9
South Kilmarnock Settling Pond Decant - Phase 1	FR_SKP1	N/A	N/A	N/A	4.7	5.7	5.6	5.6	-	-	5.1	4.0	5.4	4.6
South Kilmarnock Settling Pond Decant - Phase 2	FR_SKP2	N/A	N/A	N/A	4.7	5.9	5.7	4.7	-	4.1	4.1	-	5.3	4.1
Smith Ponds Decant	FR_SP1	N/A	N/A	N/A	5.4	4.9	4.4	5.3	4.4	4.9	4.0	4.9	4.9	4.6
Cataract Creek (Sediment Pond Decant)	GH_CC1	FR_CATCK	N/A	N/A	-	-	-	-	5.7	5.6	5.3	5.1	5.7	5.3

[1] Identified in Cope *et al*., 2020

[2] Colours correspond to effects ratings based on SEV index scores as follows: Neglible (<1); Low (1-4); Moderate (4-9); High (9-12); Very High (≥12)

"-" denotes no data available

Shaded years denotes years belonging to the Decline Window

Table 14. Peak daily average SEV model results for eggs and larvae of salmonids and non-salmonids based on acute 96-hour exposure duration.

Description	WQ Station Code	Biological Area Code	Fish Habitat (ha)	Stream Segment[1]	Peak Daily Average SEV Score[2] 2012	2013	2014	2015	2016	2017	2018	2019	Average Score Historical Period	Average Score Decline Window
Mainstem Fording River														
u/s Henretta Cr. and FRO	FR_UFR1	FO26	7.40	10, 11	9.5	9.9	9.7	9.3	9.1	9.7	9.7	9.4	9.5	9.6
d/s Henretta Cr.	FR_FR1	FODHE	2.88	9	9.6	9.9	9.6	9.2	9.3	9.6	9.3	9.3	9.5	9.3
d/s North Greenhills Diversion	FR_FRABEC1	FODNGD	0.56	8	9.1	9.1	-	-	9.5	-	-	-	9.2	-
Multiplate Culvert	FR_MULTIPLATE	MP1	0.89	8	9.1	10.1	-	-	-	-	8.8	9.4	9.6	9.1
u/s Kilmarnock Cr.	FR_FR2	FOUKI	0.92	8	9.7	10.5	9.8	9.6	9.8	10.0	9.3	9.9	9.9	9.6
d/s Swift Cr., u/s Cataract Cr.	FR_FR4	FOBSC	0.68	7	9.7	10.3	9.9	9.5	9.3	9.3	8.8	-	9.7	8.8
d/s Cataract, u/s Porter	FR_FRCP1	FOBCP	1.38	7	-	-	-	9.5	9.6	10.0	10.2	9.4	9.7	9.8
u/s Porter	FR_FRRD	FRUPO	2.22	6	-	-	-	9.7	9.3	9.2	9.5	9.1	9.4	9.3
d/s Porter Cr., u/s Chauncey Cr.	GH_PC2	FODPO	1.86	6	-	-	-	-	-	-	-	-	-	-
u/s Chauncey Creek	FR_FRABCH	FO22	1.94	6	-	10.5	-	9.5	9.5	8.8	9.7	9.8	9.5	9.8
d/s Chauncey Cr., u/s Ewin Cr.	FR_FR5	FOUEW	11.33	4,5	9.4	9.9	10.0	9.5	9.2	9.0	8.9	-	9.5	8.9
Tributaries														
Henretta Creek	FR_HC3	HENUP	1.74	9	9.3	9.7	-	9.0	9.3	10.1	9.1	9.4	9.5	9.2
Chauncey Creek	RG_CH1	CHCK	0.40	6	9.1	9.7	9.4	9.4	9.4	8.9	9.5	9.2	9.3	9.4
Henretta Creek	FR_HC1	HENFO	2.99	9	9.5	10.3	9.6	9.4	9.5	9.6	9.3	9.4	9.6	9.4
Fish Pond Creek	FR_FC1	FR_FC1	0.29	9	9.1	9.1	8.9	-	8.7	8.7	-	-	8.9	-
Clode Creek (Settling Pond Decant)	FR_CC1	CLODE	0.30	9	9.2	9.7	9.6	9.3	9.5	9.0	9.3	9.0	9.4	9.1
Kilmarnock Creek (D/S of Rock Drain)	FR_KC1	KICK	0.08	7	9.5	9.6	9.5	9.7	8.7	9.0	8.8	9.0	9.4	8.9
Swift Creek (Sediment Pond Decant/Bypass)	GH_SC1-2	SWCK	0.06	7	-	-	-	-	9.3	9.5	9.5	9.3	9.4	9.4
Porter Creek	GH_PC1	POCK	0.15	6	-	-	-	-	-	-	9.1	8.8	-	9.0
LCO Dry Creek	LC_DC1	LC_DC1	0.20	3	-	-	-	-	-	-	-	-	-	-
Area-weighted Average SEV score					**9.4**	**9.9**	**9.6**	**9.4**	**9.3**	**9.4**	**9.3**	**9.3**	**9.5**	**9.3**
Area-weighted Summary				% Neglible Rating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				% Low Rating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				% Moderate Rating	0.0	0.0	1.1	0.0	1.1	2.0	36.7	0.7	0.7	18.7
				% High Rating	100	100	98.9	100.0	98.9	98.0	63.3	99.3	99.3	81.3
				% Very High Rating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Additional Release Locations														
Eagle Settling Pond Decant	FR_EC1	N/A	N/A	N/A	9.5	9.5	9.3	9.1	9.1	9.0	9.0	-	9.2	9.0
Lake Mountain Sediment Pond Decant	FR_LMP1	N/A	N/A	N/A	-	-	-	-	-	9.6	9.1	9.7	9.6	9.4
Liverpool Sed. Pond Decant	FR_LP1	N/A	N/A	N/A	-	-	-	-	-	9.3	9.4	10.0	9.3	9.7
North Loop Settling Pond Decant to the Fording River	FR_NL1	N/A	N/A	N/A	-	9.7	-	-	-	-	9.5	9.9	9.7	9.7
Post Sed. Pond Decant	FR_PP1	N/A	N/A	N/A	-	-	-	-	-	-	-	9.5	-	9.5
South Kilmarnock Settling Pond Decant - Phase 1	FR_SKP1	N/A	N/A	N/A	9.1	9.5	9.5	9.2	-	-	8.8	-	9.3	8.8
South Kilmarnock Settling Pond Decant - Phase 2	FR_SKP2	N/A	N/A	N/A	9.1	9.6	9.5	9.1	-	8.8	8.8	-	9.2	8.8
Smith Ponds Decant	FR_SP1	N/A	N/A	N/A	9.1	9.1	8.7	9.3	8.7	9.0	8.7	8.9	9.0	8.8
Cataract Creek (Sediment Pond Decant)	GH_CC1	FR_CATCK	N/A	N/A	-	-	-	-	9.4	9.5	9.2	9.3	9.4	9.2

[1] Identified in Cope *et al*., 2019

[2] Colours correspond to effects ratings based on SEV index scores as follows: Neglible (<1); Low (1-4); Moderate (4-9); High (9-12); Very High (≥12)

"-" denotes no data available

Shaded years denotes years belonging to the Decline Window

3.2. Event-Based Monitoring

Potential acute (96-hour exposure) effects were evaluated for spot TSS measurements collected by event-based monitoring in relation to 27 mine-influenced releases during the Decline Window (Table 2). These TSS observations have been collected in either the receiving environment or discharge waters and represent either single samples or averages of duplicate or triplicate samples on an individual date. Records on separate dates were evaluated separately although in some cases there are records on consecutive days at the same location to represent multi-day events. Among these records, TSS concentrations ranged from 50.5 mg/L to 46,200 mg/L, with 22 of 27 records falling below 500 mg/L, and of the remaining five, only one being above 3,500 mg/L. Mean SEV index scores across all records were 8.0, 7.8, and 10.3, for adult salmonids, juvenile salmonids, and eggs and larvae, respectively although in many cases these life stages were not exposed to these conditions as the SEV scores are often based on samples from discharges rather than diluted conditions in the receiving environment.

Only one event (July 4, 2019) had TSS concentrations sufficient for SEV index scores to exceed a threshold score of 12 (potential to cause >40-60% mortality). This July 4, 2019 event occurred at the Swift Bridge, which crosses the mainstem of the Fording River adjacent to its confluence with Swift Creek. There, the TSS concentration of uncontained road runoff entering the UFR was measured at 46,200 mg/L, corresponding to acute SEV index scores that ranged from 11.6 to 12.1 across all life stages (Table 15). However, these results are based on TSS in the discharge water and are not representative of the diluted conditions in the UFR. To better characterize the effects of this event in the UFR, TSS samples were also collected approximately 150-200 m downstream of the Swift Bridge (FR_DSSWFTCRB). TSS concentrations at this downstream site were measured at 4 mg/L during the event, suggesting a substantial dilution of TSS within a short distance downstream (assuming full mixing) and thus a limited spatial extent.

The other mine-influenced releases during the Decline Window had potential acute effects to adult and juvenile salmonids of high magnitude in 2 cases (juveniles) or 4 other cases (adults, Table 15). For all but one of these events, contemporaneous downstream sampling demonstrated moderate SEV and thus a highly limited spatial extent. For one high magnitude event (March 18, 2019) follow up sampling data are unavailable such that the spatial extent is unknown.

Aside from the July 4, 2019 event, six other events with potential acute effects to eggs and larvae from mine-influenced TSS releases were observed during the Decline Window and incubation season. These events were all of high magnitude (SEV 10.0 – 10.9) but that is similar to conditions in the UFR observed in routine monitoring (see Table 14). Follow up sampling results are available for all but one event and found consistently lower but still high magnitude results (SEV 9.2 – 9.9; Table 15).

Table 15. Mine-influenced releases of TSS during the Decline Window and corresponding SEV index scores (acute 96-hour exposure) for adult salmonids, juvenile salmonids, and eggs and larvae of salmonids and non-salmonids.

Mine-Influenced Releases							Follow Up Sampling						
Year	Date	Location	TSS (mg/L)[1]	SEV Score			Description	Date	Location	TSS (mg/L)[1]	SEV Score		
				Adult	Juvenile	Eggs and Larvae[2]					Adult	Juvenile	Eggs and Larvae[2]
2017	18-Dec	FR_LP1	104	7.4	7.3	-	Day After	19-Dec	FR_LP1	6	5.2	5.2	-
2018	14-Mar	FR_NL1	106	7.4	7.3	-	Downstream Dilution	14-Mar	FR_NL1.5	98	7.3	7.2	-
	12-Apr	FR_LMP1	60	7.0	6.9	-	Day After	13-Apr	FR_LMP1	33	6.5	6.4	-
	21-Apr		60	7.0	6.9	-	Day After	22-Apr	FR_LMP1	44	6.7	6.6	-
	25-Apr		72	7.1	7.0	-	Downstream Dilution	25-Apr	FR_FR2	19	6.1	6.0	-
	27-Apr		54	6.9	6.8	-	Downstream Dilution	29-Apr	FR_FR2	28	6.4	6.3	-
	28-Apr		122	7.5	7.4	-	Downstream Dilution	29-Apr	FR_FR2	28	6.4	6.3	-
	29-Apr		151	7.7	7.5	-	Downstream Dilution	29-Apr	FR_FR2	28	6.4	6.3	-
	25-Apr	GH_SC1	51	6.8	6.7	-	Downstream Dilution	25-Apr	FR_FRCP1SW	32	6.5	6.4	-
2019	16-Mar	Fording River U/S of FR_LP1	-	-	-	-	Downstream Dilution	18-Mar	FR_UFR1DS50M	100	7.3	7.2	-
		FR_LP1	95	7.3	7.2	-	Downstream Dilution	16-Mar	FR_FR2	14	5.9	5.8	-
	18-Mar	FR_UFR1	3,430	10.0	9.8	-	-	-	-	-	-	-	-
	19-Mar	FR_PP1	227	8.0	7.8	-	Downstream Dilution	21-Mar	FR_FR2	12	5.7	5.7	-
	20-Mar		59	6.9	6.9	-	Downstream Dilution	21-Mar	FR_FR2	12	5.7	5.7	-
	21-Mar	FR_LP1	86	7.2	7.1	-	Downstream Dilution	21-Mar	FR_FR2	12	5.7	5.7	-
		FR_PP1	179	7.8	7.6	-	Downstream Dilution	21-Mar	FR_FR2	12	5.7	5.7	-
	22-Mar	FR_LP1	294	8.2	8.0	-	-	-	-	-	-	-	-
		FR_PP1	197	7.9	7.7	-	-	-	-	-	-	-	-
	23-Mar	FR_PP1	159	7.7	7.6	-	-	-	-	-	-	-	-
	24-Mar	FR_PP1	134	7.6	7.4	-	-	-	-	-	-	-	-
	25-Mar	FR_PP1	83	7.2	7.1	-	-	-	-	-	-	-	-
	29-May	FR_WWC1	148	7.6	7.5	10.3	-	-	-	-	-	-	-
	21-Jun	FR_LP1	66	7.0	6.9	10.0	Downstream Dilution	21-Jun	FR_FR2	39	6.6	6.6	9.9
		FR_LP1	857	9.0	8.8	10.8	Downstream Dilution	21-Jun	FR_FR2	39	6.6	6.6	9.9
		Swift Bridge	1,050	9.1	8.9	10.9	Downstream Dilution	21-Jun	FR_DSSWFTCRB	12	5.7	5.7	9.5
	04-Jul	Swift Bridge	46,200	12.0	11.6	12.1	Downstream Dilution	04-Jul	FR_DSSWFTCRB	4	4.9	4.9	9.2
	20-Jul	Below multiplate culvert into Fording River	265	8.1	7.9	10.5	Downstream Dilution	20-Jul	FR_30MBLP1	6	5.2	5.2	9.3
		Discharge to Swift Creek	1,100	9.2	8.9	10.9	Downstream Dilution	20-Jul	FR_DSSWFTCRB	26	6.3	6.3	9.8

[1]Mean TSS concentration is presented here for cases where multiple samples were collected for a given site and date

[2]During incubation period only (May 15 - September 1)

Red shading indicates a SEV score ≥ 12 which is sufficient to cause >40-60% mortality

"-" denotes no data available

ECOFISH RESEARCH

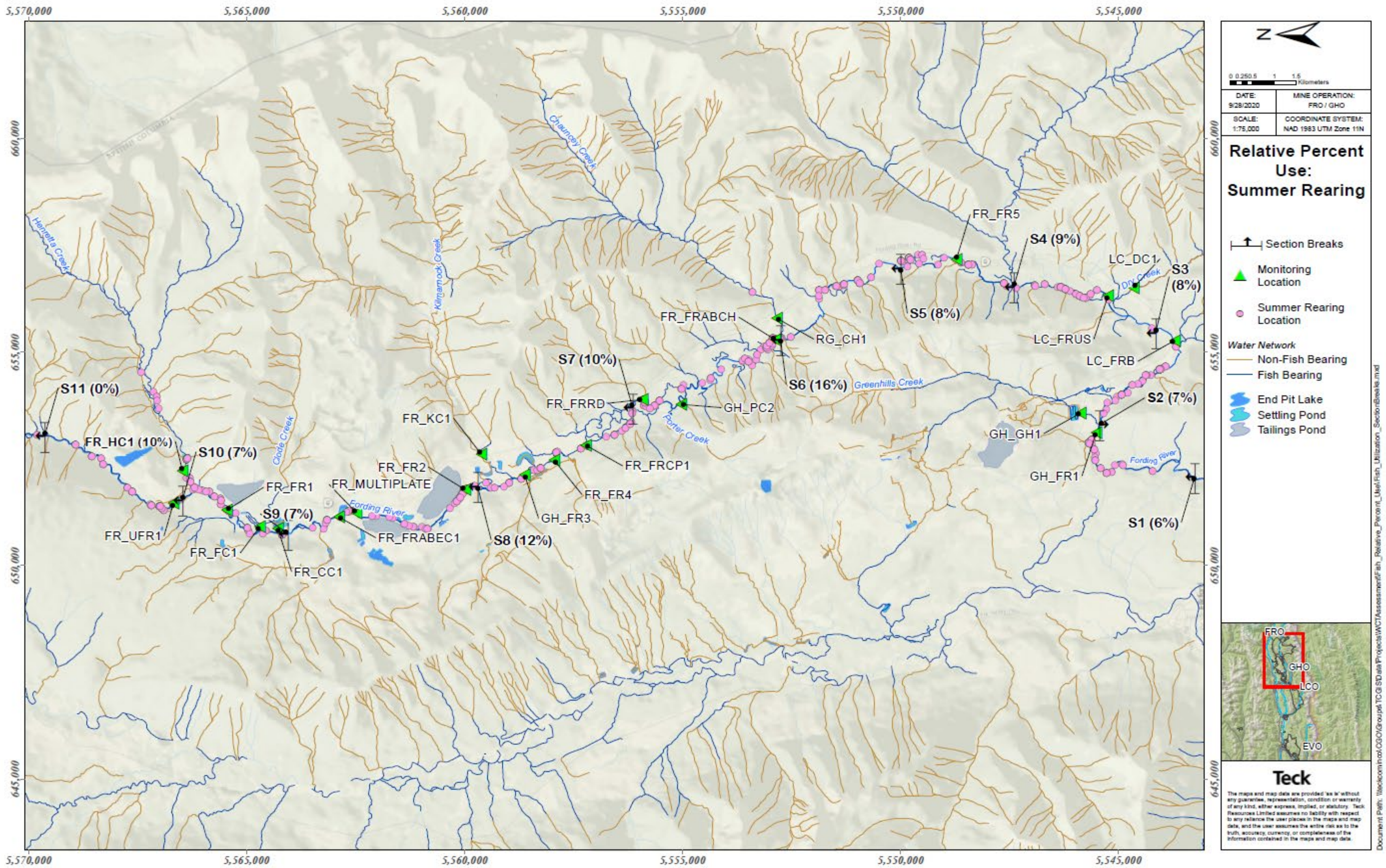
3.3. Effects of TSS on the WCT Population

Linkages between TSS conditions in the receiving environment and potential population level effects to WCT were assessed in accordance with the requisite conditions provided in Table 7. The requisite conditions include the magnitude and duration of TSS (expressed as SEV) to determine whether TSS as a potential stressor had the ability to cause effects, and the spatio-temporal distribution of WCT (e.g., the location, extent, and timing of the event) and the possibility that a large proportion of the population was exposed to TSS.

Chronic and acute events were investigated further when the results were high or very high magnitude for adults or juveniles (since lesser magnitude events are common across all sites for both the historical period and Decline Window), or very high magnitude for eggs and larvae (since lesser magnitude results for eggs and larvae are ubiquitous across sites in the historical period and Decline Window). This further analysis identified no events for adults or juveniles, and one event for eggs and larvae where SEV was 12.1 in May 2018 at FR_FRCP1 (Table 11). This site is located in stream segment 7, which contains ~10% of fish use during the season (Figure 11; Cope *et al.* 2020) such that any effects from these conditions are only relevant to a small portion of the population.

No mine-influenced releases were investigated further in the context of fish habitat use because the follow up monitoring has already demonstrated a limited spatio-temporal extent for events, as described in Section 3.2.

Figure 11. Relative WCT fish use of the UFR during the summer rearing period (data from Cope *et al.* 2016).



4. DISCUSSION

4.1. Evaluation of Requisite Conditions

Requisite conditions are defined as the circumstances that would need to be met for TSS exposure in the UFR and tributaries to cause or contribute to the WCT population decline. The components of the requisite conditions are described in Section 2.3. A summary of whether the requisite conditions have been met by chronic and/or acute TSS condition is as follows:

- A requisite condition to cause the WCT population decline was not met because:
    - For all life stages, chronic SEV (as area-weighted peak monthly average results) during the Decline Window (September 2017 to September 2019) were either similar to or better than during the historical period (January 2012 to September 2017);
    - For all life stages, acute SEV (as peak monthly average SEV model results) during the Decline Window (September 2017 to September 2019) were similar or improved from peak monthly average SEV model results prior to the Decline Window; and
    - For all life stages, SEV associated with mine-influenced releases during the Decline Window had limited spatial and temporal effects and therefore the exposure was limited to a small proportion of the population.
- A requisite condition to contribute to the WCT population decline was met because:
    - Chronic SEV (as area-weighted peak monthly average results) showed that TSS concentrations during the Decline Window had the potential to cause:
        - Moderate magnitude chronic effects to adult and juvenile salmonids; and
        - High or very high magnitude chronic effects to eggs and larvae.
    - Acute SEV model results showed TSS concentrations during the Decline Window had the potential to cause:
        - Moderate magnitude acute effects to adult and juvenile salmonids; and
        - Moderate or high magnitude acute effects to eggs and larvae.
    - SEV associated with mine-influenced releases during the Decline Window had the potential to cause:
        - Moderate to very high magnitude acute effects to adults;
        - Moderate to high magnitude acute effects to juveniles; and
        - High or very high magnitude acute effects to eggs and larvae.

4.2. Key Uncertainties

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

- All TSS data were obtained from spot samples, which were generally taken at weekly or monthly intervals meaning that substantial gaps exist in the available data wherein potential effects may have occurred. TSS data or visual observations are not currently available to inform whether anomalous events occurred during these data gaps. Should site photos or other imagery become available for these periods this uncertainty could be reduced. The temporal assumptions made when analyzing the data (i.e., spot measurements are representative for the entire 96-hour or 30-day period) may not be valid, so greater or lesser acute or chronic effects may have occurred. SEV is more commonly calculated using high-frequency continuous monitoring (e.g., 5-minute to 1-hour resolution) where temporal uncertainty is much reduced.

- Results from the sampling locations are spatially representative of the surrounding reach of the UFR. Samples are assumed to be representative of the average TSS conditions for the corresponding habitat area. This is deemed to be a reasonable assumption but the influence of the assumption is likely to vary depending on the characteristics of localized sediment sources upstream or downstream of the sample location. This assumption means that events occurring at a smaller spatial scale may have gone undetected or been mischaracterized, but the potential consequences of this are low since any such as event would necessarily be localized (e.g., widespread events would be detected and characterized by the sampling).

- Predictions of harm from TSS are based on general SEV models that are not specific to WCT and 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 these SEV models correspond to actual harm to WCT. Nonetheless, the consequences of this uncertainty are low because error in the model predictions would not affect the relative comparison between the historical period and the Decline Window — there was no increase in TSS and SEV during the Decline Window.

5. CONCLUSION

This assessment evaluated the potential for TSS exposure to have caused or contributed to the observed WCT decline. Potential effects from TSS on WCT were evaluated at 29 water quality monitoring stations located in the UFR, its tributaries, and direct input locations using TSS sample data collected at these stations during the Decline Window and preceding historical period.

Data from each location were assessed for potential effects on WCT using SEV models to assess chronic and acute TSS conditions as a means of comparing effects during the historical period and the Decline Window. Thus, this approach allowed requisite conditions to be evaluated to determine whether TSS events caused or contributed to reduced WCT abundance.

The requisite condition to cause the decline was not met because TSS conditions were determined to be similar between the Decline Window and the historical period across all assessed locations and corresponding habitat areas. Uncertainties were identified (Section 4.3) that limit confidence in this conclusion. In particular, high TSS events may have gone undetected in between the spot measurements.

A requisite condition to contribute to the decline was identified because available data suggest that TSS conditions during the Decline Window, although similar to conditions during the historical period, may have been sufficient to act as a moderate stressor that interacted with other stressors.

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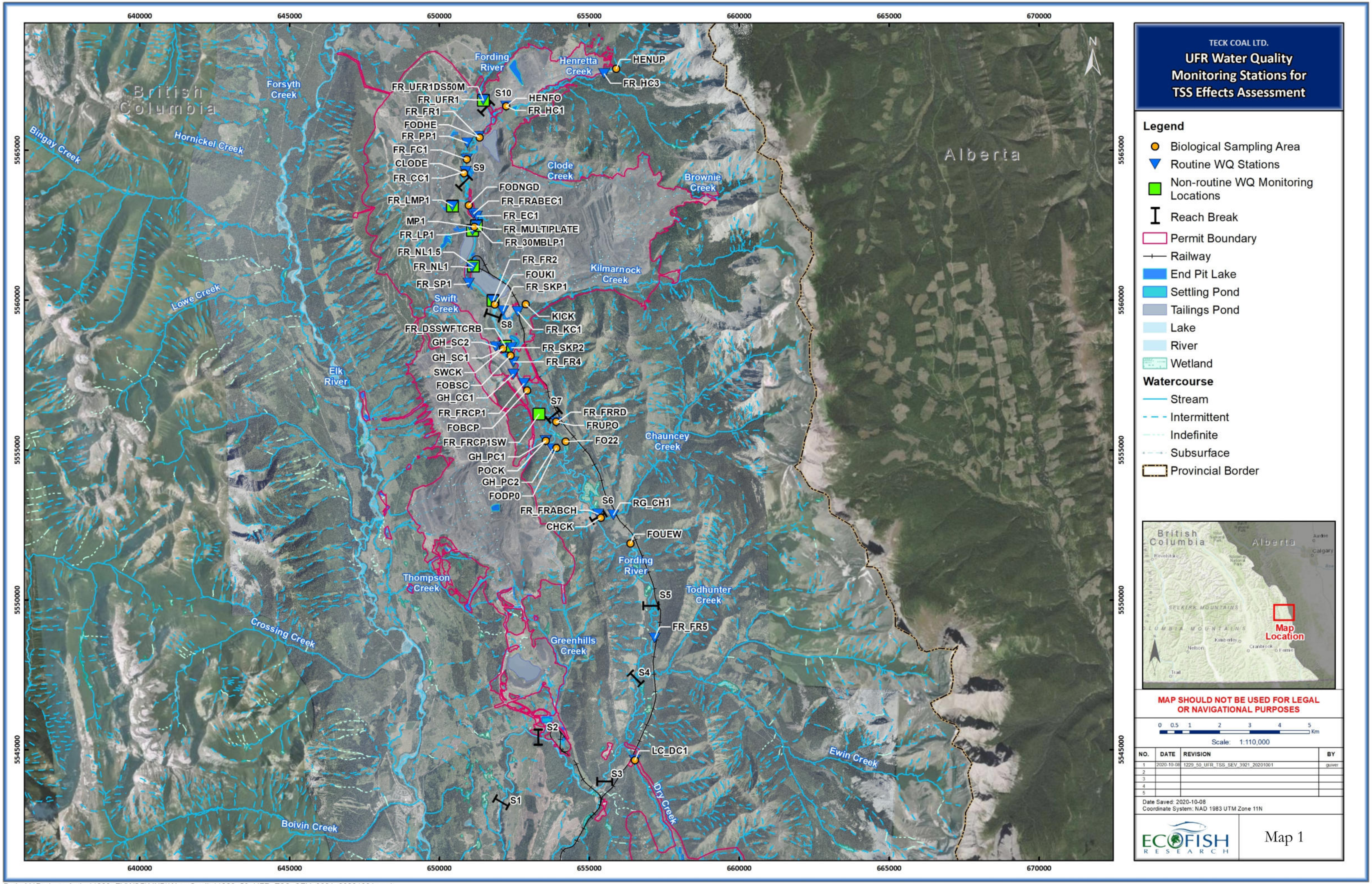
PROJECT MAPS



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APPENDICES

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

LIST OF TABLES

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

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

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). 3

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.

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

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