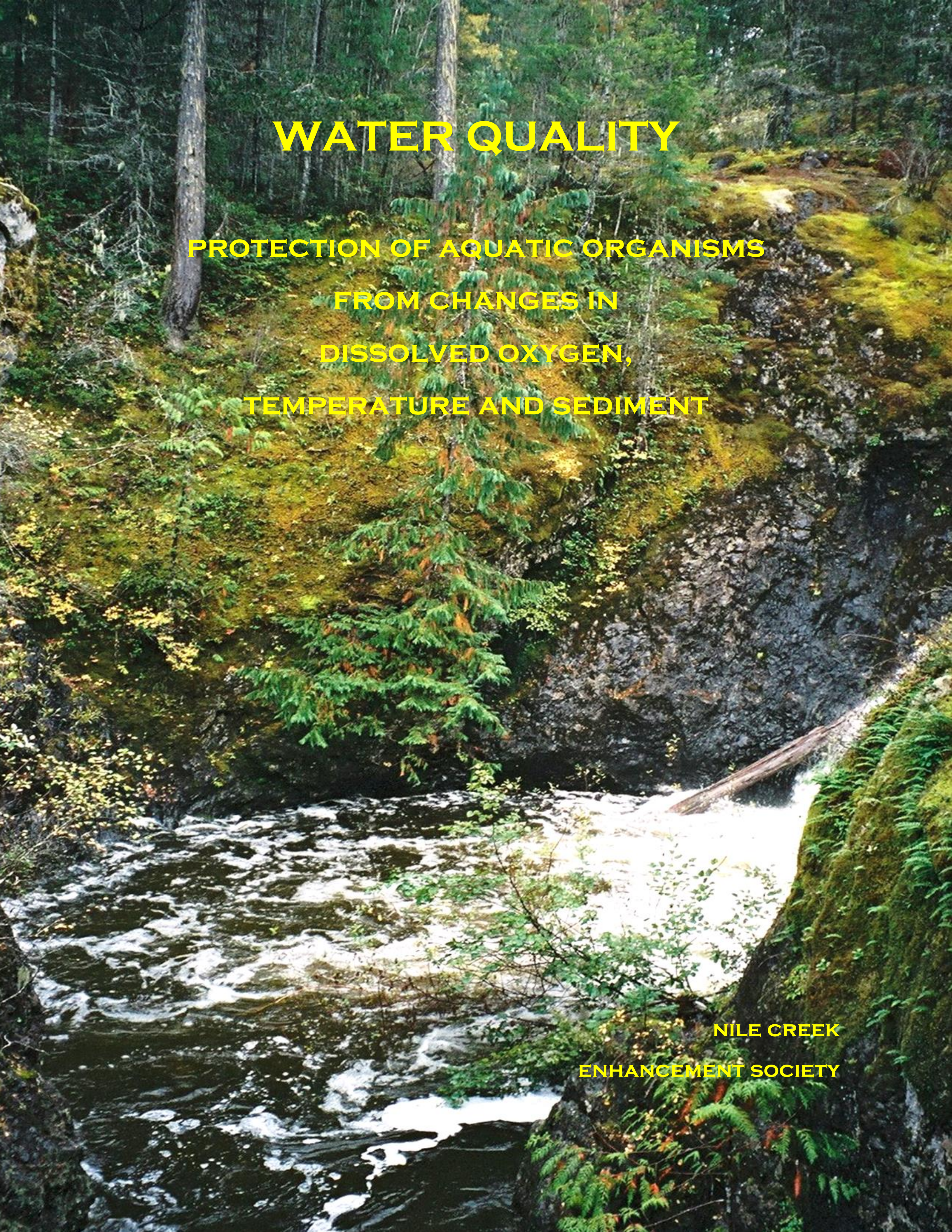


WATER QUALITY

PROTECTION OF AQUATIC ORGANISMS FROM CHANGES IN DISSOLVED OXYGEN, TEMPERATURE AND SEDIMENT

NILE CREEK
ENHANCEMENT SOCIETY

WATER QUALITY

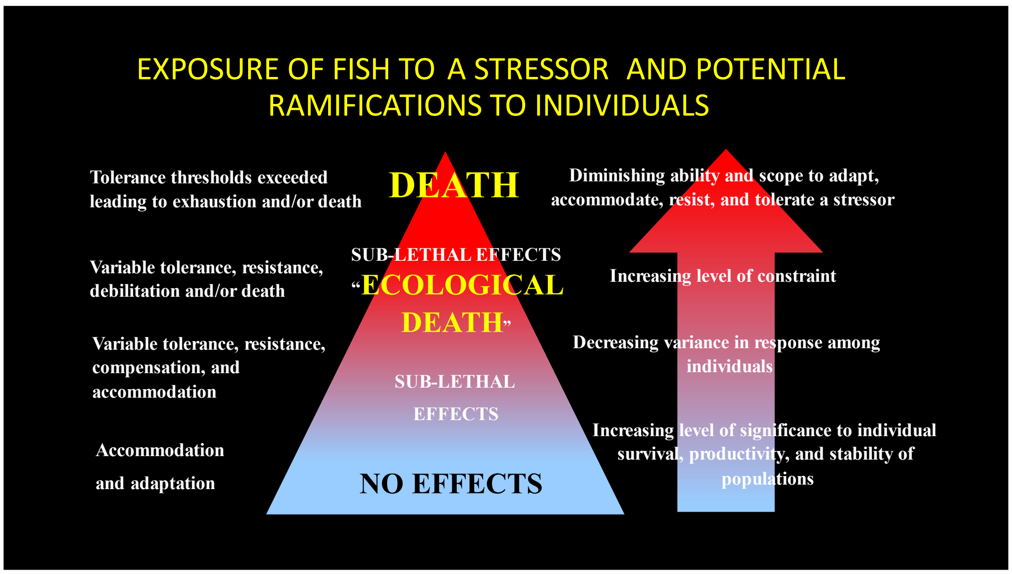
The effects on aquatic organisms of changes to their environment have been determined through many scientific studies, and criteria and guidelines developed for their protection. Exceedance of stipulated levels has been determined to be harmful. The following comments relate to dissolved oxygen, temperature, sediment and cloudy turbid waters.

The nature of harm relates to many factors, including the life stage of the organisms and susceptibility, the duration and nature of the change, and associated impacts on their necessary supporting habitat.

THE COMPETITIVE ENVIRONMENT

Fish in the wild live in a highly competitive environment. It is dynamic and with many challenges that, if met, will facilitate their survival.

Survival is related to the maintenance of health and performance. Completion of their life cycle requires that they must feed and grow, maintain health and fitness, avoid being eaten, and reproduce successfully. Stressful changes in water quality can interfere with these requirements.



Effects are in relation to the ability of individuals to accommodate or resist the stress at differing and increasing levels of intensity - from those that evoke no response, to those that result in death.

If the water quality change is accommodated there are unlikely to be effects. But, if the changes are greater, they could result in harmful sub-lethal effects, death and debilitation. (Death from these changes is an obvious event but corpses are not usually seen due to the actions of predators, scavengers and decomposers).

Changes in water quality can elicit changes in fish behaviour, such as habitat displacement, avoidance, disruption of territoriality, seeking or avoidance of cover, lethargy, altered food seeking, and swimming behaviour etc. Without knowledge of the importance of these changes to organism survival in the wild, it would be easy to overlook consequential indirect mortality or "ecological death".

DISSOLVED OXYGEN

The provision of an adequate supply of dissolved oxygen is important to sustain the health and functioning of aerobic organisms.

Depressions (causing "hypoxia") beyond those accommodated are of concern to organism wellbeing. Effects of a reduction in dissolved oxygen are indiscriminate and can potentially adversely affect all exposed organisms reliant upon an adequate supply. As oxygen declines so does metabolic rate and the abilities to perform various activities which in turn have significant ramifications for growth, recruitment, and survival. Migrating adult salmon will use hypoxic staging zones to avoid low flow and high temperature but is detrimental to their health and survival. Juveniles will quickly feed in waters where prolonged occupancy would be lethal.

Dissolved oxygen can be measured as a concentration (mg/L) and the % relative to that when the water is fully mixed with air (100% of air saturation). The concentration varies in relation to temperature, less being present in warmer than in cooler water. The percentage saturation is independent of temperature. Both factors are important in fish respiration.

GUIDELINES

A. Canadian Council of Minsters for the Environment

<u>Early life stages</u> 9.5 mg/L; **<u>other life stages</u> 6.5 mg/L**
"The lowest acceptable dissolved oxygen concentration for the protection of aquatic life":

B. Summary criteria (mg/L and % of air saturation) that afford different levels of protection:

Free-swimming stages of salmonids

Criterion	Effects
Level A **7.75 mg/L** **(76-93%)**	"**<u>Represents more or less ideal conditions</u>** (i.e., little or no foreseeable harm) and permits little depression of oxygen from full saturation. It represents a level that assures a high degree of safeguard for many important stocks in prime areas."
Level B **6 mg/L** **(57-72 %)**	"**<u>Some degree of risk</u>** (i.e., possibility of moderate harm) to a portion of a fish population exists **<u>if the oxygen minimum is prolonged beyond a few hours</u>**." This level represents "the oxygen value where the average member of a species in a fish community starts to exhibit symptoms of oxygen distress."
Level C **4.25 mg/L** **(38-51 %)**	"**<u>A large portion of a given fish population or fish community may be affected by low oxygen</u>**. This deleterious effect may be severe (i.e., possibility of severe harm), especially if oxygen minimum prolonged beyond a few hours."

<u>Salmonid larvae and mature eggs of salmon</u> (0-25°C)

Level A: **9.75 mg/L (98-100% air saturation)**

Level B: 8.0 mg/L (76-95% air saturation)

Level C: 6.5 mg/L (54-78% air saturation)

TEMPERATURE

Temperature is the most important environmental factor governing the life of aquatic organisms. It acts as a controlling, limiting and directive factor with effects on physiological, ecological, and behavioural aspects of life history.

Conditions that exceed optimum temperatures have serious implications on growth, development, disease resistance, reproduction and species interactions.

The fundamental thermal requirement of fishes is an external environmental temperature most suitable to their internal tissues.

Temperature sets lethal limits to life; it conditions the animal through acclimation to meet levels of temperature that would otherwise be intolerable; it governs the rate of development; it sets the limits of metabolic rate within which the animal is free to perform; and it acts as a directive factor resulting in the congregation of fish within given thermal ranges, or movements to new environmental conditions.

The effects of temperature on the survival, resistance, tolerance, and metabolism of juvenile salmon have been comprehensively examined. For example, "no growth occurred at approximately 23°C, despite the presence of excess food, and a temperature range from 5°C to 17°C was deduced as the most favourable for young salmon: a general physiological optimum occurs in the vicinity of 15°C - which governs the success of an organism in nature". Fish will, however, temporarily feed in waters above the optimal temperature and which would be injurious with prolonged residency.

GUIDELINES

The guideline for the protection of aquatic organisms from thermal change approved for application in BC. The BC guideline stipulates ± 1°C change beyond optimum temperature range shown in the table below for each life history phase of the most sensitive salmonid species present.

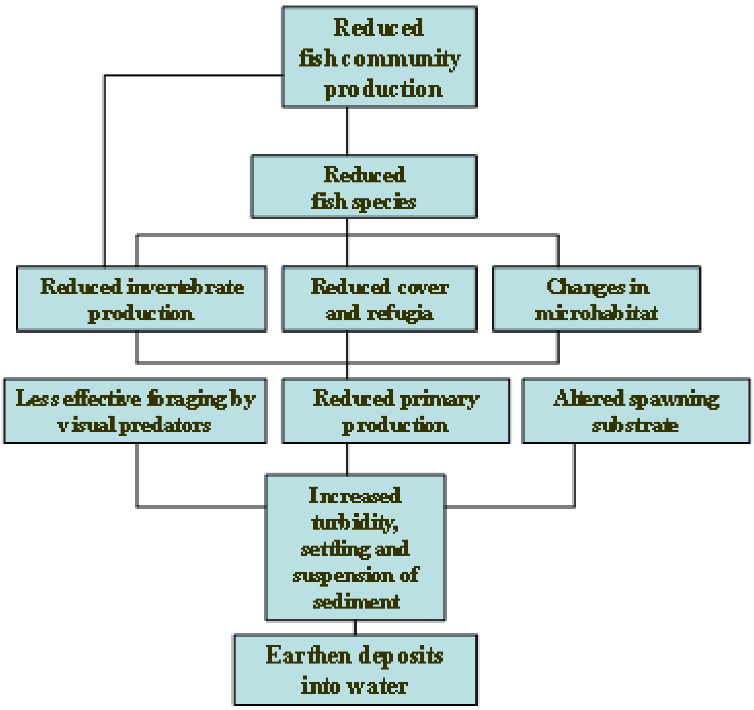
<u>Optimum</u> temperature ranges (°C) of specific life history stages of salmonids for guideline application.

SPECIES	INCUBATION	REARING	MIGRATION	SPAWNING
Coho salmon	4-13	9-16	7.2-15.6	4.4-12.8
Pink salmon	4-13	9.3-15.5	7.2-15.6	7.2-12.8
Chum salmon	4-13	12-14	7.2-15.6	7.2-12.8
Chinook salmon	5-14	10-15.5	3.3-19	5.6-13.9
Cutthroat trout	9-12	7-16		9-12
Rainbow trout	10-12	16-18		10-15.5

An upper threshold for the 7-day maximum temperature of 16.5 ºC was deduced to be appropriate for Coho salmon, and 20.5 ºC appropriate for steelhead (Rainbow trout lowest salmonid thermal sensitivity): 22-24°C represents the thermal limit to salmonid distribution.

SEDIMENT AND TURBIDITY

Sediment is a component in aquatic habitats that varies naturally; it provides substrates for various organisms and is integral to their perpetuation. The input of excessive amounts of sediment and turbid waters is viewed as a significant global, primarily human-induced, problem for aquatic organisms as they can indiscriminately affect all levels of biological organisation.



Adverse effects can be complex because sediment is an indiscriminating stressor potentially impacting all exposed organisms and the habitat they rely on for the completion of their life cycle. Food chains can be indirectly or directly affected and reduce overall biological productivity (see figure).

The general effects of exposure of individuals to suspended sediments can, for example, kill fish directly or indirectly, reduce their feeding, growth rate, resistance to disease, clog and abrade gills etc.; prevent successful development of eggs and larvae through the blanketing of spawning gravels; disabling and impairing proper egg and fry development and rearing; modifying natural survival behaviours, reducing the abundance of food available and impairing its' capture etc..

Specific relevance to the incubation and rearing of pink salmon at the NCES Hatchery

Settled sediment may not only reduce emergence of alevins due to a physical barrier, but it is also of significance during the incubation period when even <1 mm of clay-sized particles may impede gas exchange between the surface of developing eggs and their incubation environment, this aside from any impact that may occur to block the prior fertilisation process.

Very fine coatings of sediment can reduce oxygen availability within the incubation environment and its' supply is a limiting factor. Developmental rate is very sensitive to low dissolved oxygen levels (hypoxic conditions) which tend to reduce the rate of development, delays hatching as well as reduce the size of the embryos. Hypoxia can also result in retarded development, reduced growth, premature hatch, and emergence. A consequence of such adverse effects on developing salmonid embryos and larvae has led to selective predation upon them in the wild.

GUIDELINES

Levels of suspended sediment, its' creation of "cloudy" turbid water, and stipulations regarding settled particles have been formulated to help protect aquatic systems and the organisms they support. Water cloudiness/turbidity is measured by NTU (Nephelometric Turbidity Units) - the lower the value the clearer the water). The concentration of suspended sediment is recorded as mg/L; settled sediment primarily through substrate particle size composition.

Canadian national and British Columbia provincial criteria for the protection of aquatic organisms from elevated levels of sediment and turbid water

Suspended sediments

<u>In clear water or during clear flows</u>:

An increase of 25 mg/L from background levels *at any one time* for a duration of 24 h.
An increase of 5 mg/L from background levels *at any one time* for a duration of 30 d.

<u>In turbid water or during high flows</u>:

An increase of 10 mg/L from background levels *at any time* when background levels are between 25 and 100 mg/L.
An increase of 10 % from background levels *at any time* when background is >100 mg/L.

Turbidity

<u>In clear water or during clear flows</u>:

An increase of 8 NTU from background levels *at any one time* for a duration of 24 h.
An increase of 2 NTU from background levels *at any one time* for a duration of 30 d.

<u>In turbid water or during high flows</u>:

An increase of 5 NTU from background levels *at any time* when background levels are between 8 and 50 NTU.
An increase from background of 10% *at any time* when background level is >50 NTU.

(The recommended transition value (25 mg/L TSS or 8 NTU; respective ratio 1: 0.32) between clear and turbid flows was selected after examining streams in British Columbia).

Streambed substrate (spawning sites)

The percentage of fine sediments in streambed substrates:
should not exceed 10% <2 mm; 19% <3 mm; and 28% <6.35 mm.
Geometric mean diameter: should not exceed 12 mm.
Fredle number: should not exceed 5 mm.

Turbidity levels and responses that may lead to adverse effects on *aquatic life in flowing waters*.

TURBIDITY (NTU)	**SELECTED ORGANISM RESPONSE**
<3 – 25	Primary productivity: dependent on water depth/colour/nutrients.0.5 m water depth, (shallower water: less effect; deeper water: more effect)
<4	Invertebrate densities, dependent on primary production and allochthonous inputs
≤10	Fish reactive distance (visible range is decreased by approximately one-half, with potential change to active feeding strategy)
10 – 20	Fish foraging and feeding strategy.
<22	Salmonid growth rate (significant decrease at 22 NTU, the lowest level tested above the control at ≈0 NTU)

Predicted risk of harm upon exposure of *clear water fish* to turbid waters.

Duration	**Turbidity Levels *above* which Adverse Effects occur to Clear Water Fish (NTU)**		
	Slight impairment (behavioural effects, feeding)	**Significant impairment** (growth rate, habitat)	**Severe impairment** (poor condition, habitat alienation)
1 hour	35	150	
3 hours	20	95	
7 hours	12	55	702
1 day	7	35	400
2 days	5	20	270
6 days	3	12	150
2 weeks	2	7	95
7 weeks	1	5	55
4 months	<1	3	35
11 months	<1	2	20
30 months	<1	<1	

Effects of turbidity levels on *clear water fish* with respect to duration of exposure.

Risk of significant impairment	**Receiving water turbidity (NTU)**	**Duration**
none	Ambient - <3	
low	>3-<8	>3 weeks to <10 months
moderate	9-20	5 d to 3 weeks
significant	21-100	3 h to 5 days
unacceptable	>100	<3h

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