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GAHCHO KUÉ PROJECT
2012 ENVIRONMENTAL IMPACT STATEMENT SUPPLEMENTAL INFORMATION SUBMISSION

Modelling of Sediment Resuspension in Area 2 and Areas 3 and 5 of Kennady Lake Following Dewatering

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De Beers Canada Inc.

REPORT

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Executive Summary

During the dewatering phase of the Gahcho Kué Project, Kennady Lake is proposed to be drawn down to the maximum extent possible to safely access and mine the kimberlite ore bodies that are located beneath Kennady Lake. This study evaluated potential changes in total suspended solids (TSS) concentrations that may result from the change in water surface elevation during the drawdown period.

Three linked systems were used to predict the TSS concentrations in Area 2 and Areas 3 and 5 of Kennady Lake at a water surface elevation of 420.7 metres (m) and after a three metre drawdown to an elevation of 417.7 m. The first system predicted wave geometry for single wind storms on the lake by applying the classic forecasting equations for waves in shallow water, as presented in U.S. Army Corps of Engineers (1984). Second, the modelling used equations developed by Sheng and Lick (1979) to predict wave-induced resuspension of bed sediment. Finally, the modelling employed the Generalized Environmental Modelling System for Surfacewaters (GEMSS®) to simulate hydrodynamic dispersion and settling of TSS in the lake.

Model simulations were completed for the following parameters:

- water surface elevations of 420.7 and 417.7 m;
- a 6-hour (h) duration storm event;
- wind speeds of 6, 8 and 10 metres per second (m/s);
- wind directions from the southwest and northeast;
- sediment settling velocities of 1.0, 0.10 and 0.01 metres per day (m/d); and
- a single storm event during the open-water season and just before the ice-covered season.

In general, the mass of sediment resuspended into the water column was predicted to increase as the magnitude of the wind speed increased from 6 to 10 m/s and the TSS concentration in Kennady Lake was predicted to be greater over time as the settling velocity decreased from 1.0 to 0.01 m/d. The model results predicted that a 6-h duration storm event with wind speeds of 6, 8 and 10 m/s would have little effect on TSS concentrations in Kennady Lake at a water surface elevation of 420.7 m. TSS concentrations in most areas of the lake were predicted to remain within the observed background TSS range. At a water surface elevation of 417.7 m, the model results predicted that localized areas of high TSS would occur in shallow areas along the downwind shorelines with maximum concentrations ranging from 35 to 3,100 milligrams per litre (mg/L) within 24 hours of a storm event. Wind-induced mixing would cause elevated levels of TSS throughout most of the basin for longer periods of time.

On average, 16 storms with wind speed conditions evaluated in this study occur during the open-water season each year. If multiple storm events are considered, the potential is for greater long-term TSS concentrations in Area 2 and Areas 3 and 5 of Kennady Lake after the lake has been drawn down to 417.7 m.

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

During the dewatering phase of the Gahcho Kué Project (Project), Kennady Lake is proposed to be drawn down to the maximum extent possible to safely access and mine the kimberlite ore bodies that are located beneath Kennady Lake. This technical memorandum describes the sediment resuspension model developed to predict the concentration of total suspended solids (TSS) in Area 2 and Areas 3 and 5 of Kennady Lake at an elevation of 420.7 metres (m) and after a three metre drawdown to an elevation of 417.7 m. Drawdown of Area 2 and Areas 3 and 5 has the potential to entrain suspended sediment into the water column and cause deterioration of fish habitat. The modelling assessment has been developed using all available data for TSS and lake bed sediments relevant to this study.

The model setup is described in Section 2. TSS predictions for Area 2 and Areas 3 and 5 are presented in Section 3. Data gaps and model uncertainty are discussed in Section 4, and recommendations for future monitoring and modelling are provided in Section 5.

2.0 METHODS

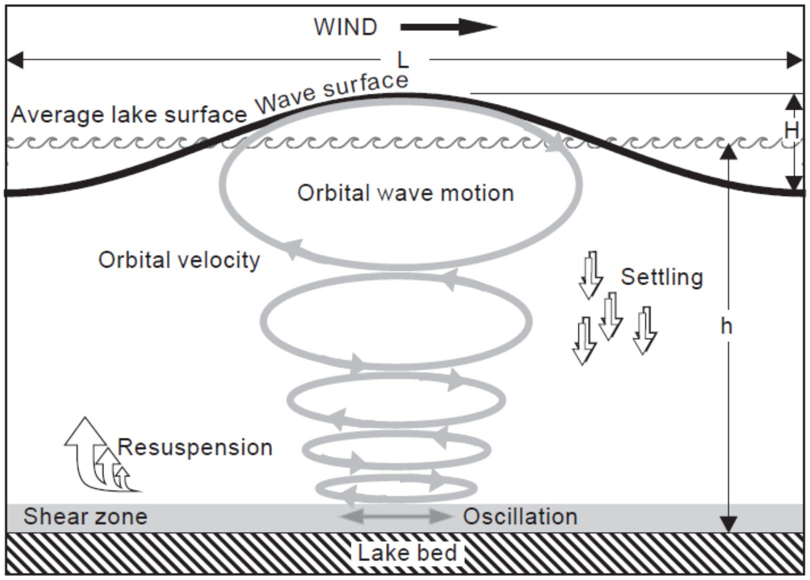
2.1 BACKGROUND

In shallow, wind-exposed lakes, wind-induced resuspension of bed sediment into the water column increases as the lake elevation becomes lower (Laenen and LeTourneau 1996). The development of waves in shallow lakes is affected by:

- wind speed;
- fetch (unobstructed distance along a water surface for wave development by wind); and
- water depth (Laenen and LeTourneau 1996).

When wind-shear forces create waves, water particles are set into elliptical orbits that are more highly elongated in shallow water (Figure 1). If the wave height (H) is sufficiently large when the water depth (h) is shallow, the orbit of moving water particles creates a shear force on the lake bottom great enough to move the bed sediment. The magnitude of the stress that causes resuspension in the shear zone along the bottom is a function of wave length, wave height and water depth, and is generally sufficient to begin resuspension when water depth is less than one-half the wave length (L) (Laenen and LeTourneau 1996).

Figure 1 Forces Induced by Wind that Cause Resuspension of Bed Sediment (Laenen and LeTourneau 1996)



L = wave length; H = wave height; h = water depth.

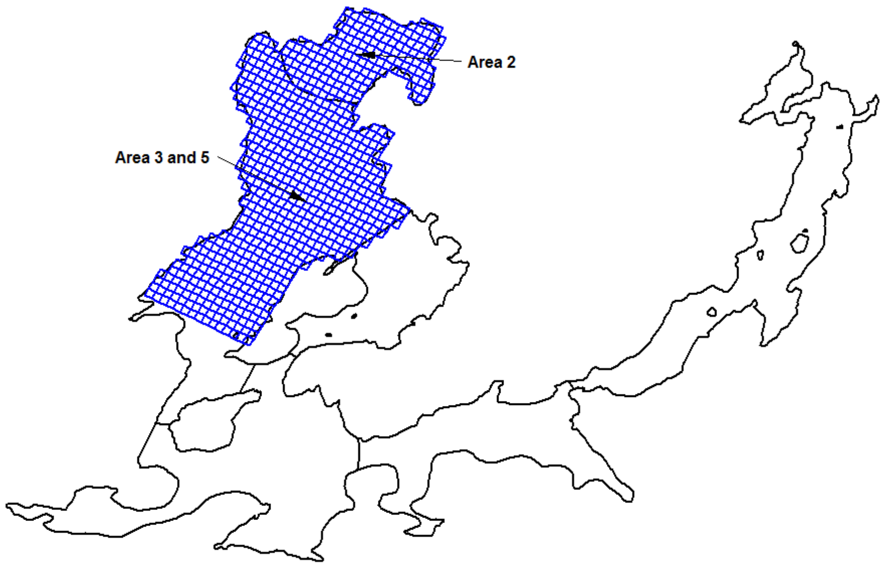
2.2 MODEL PLATFORM

In this study, the classic forecasting equations for waves in shallow water as presented in U.S. Army Corps of Engineers (1984) were used to predict wave geometry. The forecasting equations for waves in shallow water are applicable for water depths less than 90 m (U.S. Army Corps of Engineers 1984). Coupled to the wave geometry, equations developed by Sheng and Lick (1979) were used to predict wind-induced resuspension of bed sediment for shallow water areas in Lake Erie. These equations have also been applied by Laenen and LeTourneau (1996) in Upper Klamath Lake, Oregon. Bed sediment consisting of fine-grained silt and clay was used to calculate bottom shear stress and estimate rates of sediment resuspension. To account for dispersion and settling of suspended bed sediment throughout Area 2 and Areas 3 and 5 of Kennady Lake, the predicted TSS concentrations were input as initial conditions in the Generalized Environmental Modelling System for Surfacewaters (GEMSS®). GEMSS® was recently used to develop a three-dimensional (3-D) hydrodynamic and water quality model for Kennady Lake (see Appendix 8.V in the 2012 EIS Supplement [De Beers 2012]). The hydrodynamic calibration from the 3-D Kennady Lake model was applied to Area 2 and Areas 3 and 5 to predict dispersion of TSS.

2.3 MODEL SEGMENTATION

For the sediment resuspension simulations, a 2-D grid (Figure 2) was developed that covers Area 2 and Areas 3 and 5 of Kennady Lake. The horizontal grid spacing was 62.5 m comprising a total of 741 active cells. Wind-induced resuspension of bed sediment was calculated for each of the active cells, and the predicted TSS concentrations were input as initial concentrations in GEMSS®.

Figure 2 Sediment Resuspension Model Grid for Area 2 and Areas 3 and 5



2.4 RESUSPENSION EQUATIONS

Resuspension within each grid cell was calculated by applying the equations described in this section. Fetch was computed by estimating the distance from the shore downwind to the centre of each grid cell. Using bathymetric data, a bottom shear stress was calculated for the corresponding combinations of fetch and depth at each grid cell. The calculation of bottom shear stress required the computation of wave period, T (Equation 1), wave length in shallow water, L_0 (Equation 2), wave height, H (Equation 3) (U.S. Army Corps of Engineers 1984) and maximum bottom boundary velocity, U_m (Equation 4) (Sheng and Lick 1979). Finally, the bottom shear stress, τ, was calculated using Equation 5 (Sheng and Lick 1979). Equations 1 to 5 are:

$$T = 7.54\left(\frac{U_A}{g}\right)\tanh\left(0.833\left(\frac{gh}{{U_A}^2}\right)^{0.375}\right)\tanh\left(\frac{0.0379\left(\frac{gF}{{U_A}^2}\right)^{0.333}}{\tanh\left(0.833\left(\frac{gh}{{U_A}^2}\right)^{0.375}\right)}\right) \quad (1)$$

Where: T = wave period (seconds [s]); U_A = wind speed (metres per second [m/s]); g = gravitational acceleration (metres per square second [m/s^2]); h = water depth (m); F = fetch (m).

$$L_o = \left(\frac{gT^2}{2\pi}\right)\tanh\left(\frac{2\pi h}{\frac{gT^2}{2\pi}}\right) \quad (2)$$

Where: L_o = wave length in shallow water (m).

$$H = 0.283\left(\frac{U_A{}^2}{g}\right)\tanh\left(0.530\left(\frac{gh}{U_A{}^2}\right)^{0.750}\right)\tanh\left(\frac{0.00565\left(\frac{gF}{U_A{}^2}\right)^{0.500}}{\tanh\left(0.530\left(\frac{gh}{U_A{}^2}\right)^{0.750}\right)}\right) \tag{3}$$

$$u_m = \frac{\pi H}{T\sinh\left(\frac{2\pi h}{L_o}\right)} \tag{4}$$

Where: u_m = maximum bottom boundary velocity (m/s).

$$\tau = \rho f u_m{}^2 \tag{5}$$

Where: τ = bottom shear stress (dynes per square centimetre [dynes/cm^2]); ρ = density of water (gram per cubic centimetre [g/cm^3]); f = dimensionless skin friction coefficient (= 0.04); u_m = maximum bottom boundary velocity (centimetre per second [cm/s]).

For the fine-grained bed sediment, Equation 6 was used to calculate rates of sediment resuspension for a bottom shear stress less than two dynes/cm^2, and Equation 7 was used to calculate rates of sediment resuspension for a bottom shear stress greater than two dynes/cm^2 (Sheng and Lick 1979). Finally, Equation 8 (Laenen and LeTourneau 1996) was used to calculate the predicted TSS concentration in each grid cell.

$$E = 1.33 \times 10^{-6}(\tau - 0.5) \tag{6}$$

Where: E = rate of sediment resuspension (gram per square centimetre second [g/cm^2·s]); τ = bottom shear stress (dynes/cm^2).

$$E = 4.12 \times 10^{-6}(\tau - 1.515) \tag{7}$$

$$TSS = \frac{Et}{h} \times 10{,}000 \tag{8}$$

Where: TSS = total suspended solids concentration (mg/L); t = duration of storm (s).

2.5 MODEL INPUTS

2.5.1 Wind Conditions

Hourly wind speed and wind direction data were available from the meteorological station at Snap Lake, NWT. A summary of the data for the open-water season from 2000 to 2011 is presented in Table 1. Prevailing wind directions in the open-water season were assumed to originate from the northeast and southwest along the major axis of Area 2 and Areas 3 and 5. These wind directions were selected to demonstrate potential wind effects along the maximum fetch of the lake.

Table 1 Average Number of Storms per Year during the Open-water Season from 2000 to 2011

Wind Speed [m/s]	Storm Duration [h]	Average Number of Storms per Year
6	6	11
8	6	4
10	6	1

m/s = metres per second; h = hour.

2.5.2 Sediment Characteristics

Samples of Kennady Lake basin sediments collected between 1995 and 2011 were mainly composed of sand (approximately 70%) followed by silt (approximately 28%) and clay (2%). The sediment was composed of 7% to 15% total organic carbon (De Beers 2010).

2.5.2.1 Clastic Sediment Size

Particle size distribution curves were available for two fine clastic sediment samples from Kennady Lake, which were screened to remove sand-sized, and larger, particles from the sediment sample. The data from both samples showed that 95% of the sample was composed of silt-sized material (Figure 3). As discussed in Section 2.2, equations for bed sediment consisting of fine-grained silt and clay were used to calculate bottom shear stress and estimate rates of sediment resuspension.

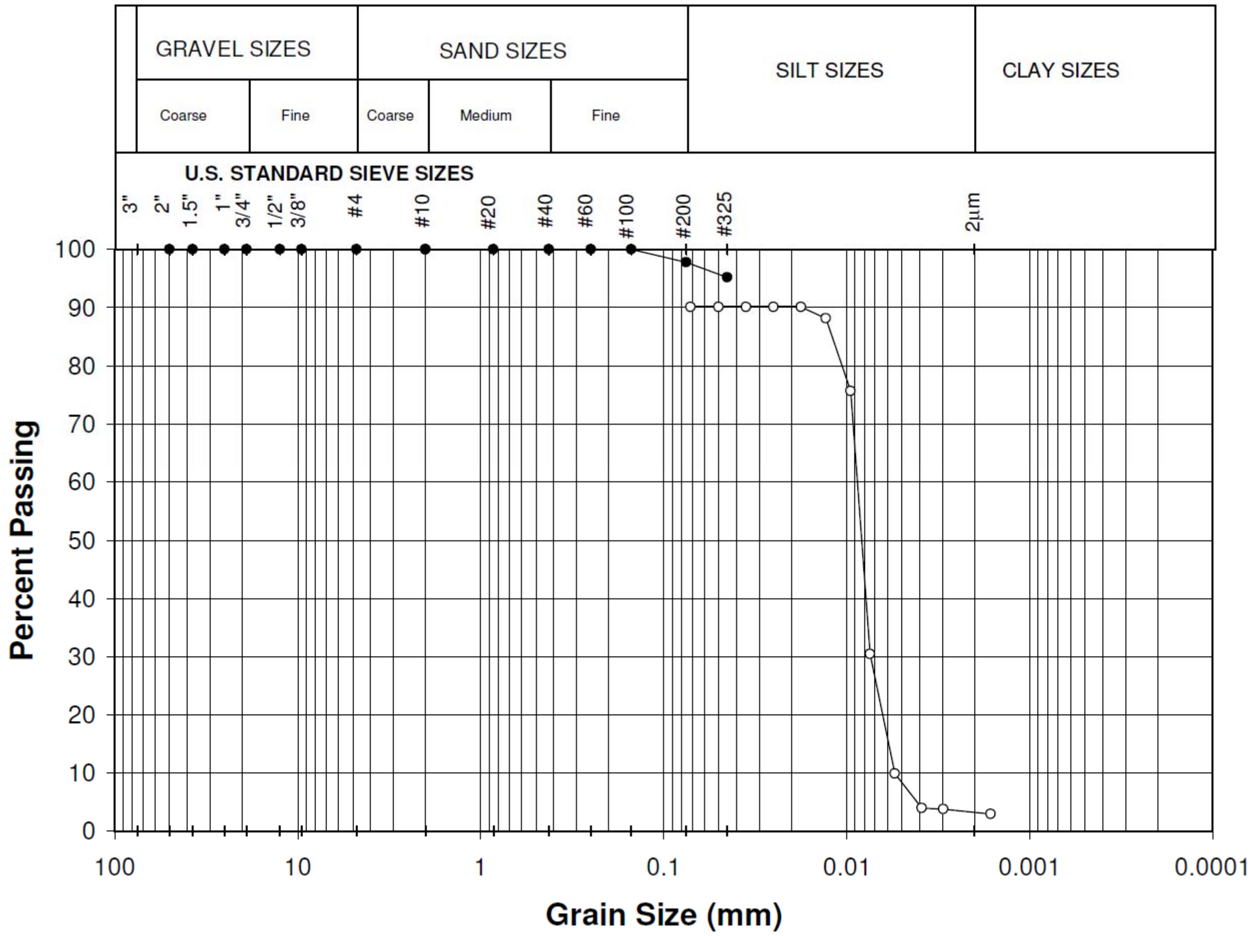
2.5.2.2 Total Suspended Solids Concentrations

The equations described in Section 2.4 were used to predict TSS concentrations in individual locations of Area 2 and Areas 3 and 5. As discussed in Section 2.2, to account for dispersion and settling of suspended sediment throughout Area 2 and Areas 3 and 5 of Kennady Lake, the predicted TSS concentrations were input as initial conditions in GEMSS®.

2.5.2.3 Suspended Sediment Settling Velocity

The in-situ settling velocity of suspended sediments for Kennady Lake has not been measured. Therefore, Equations 9 to 13 derived by Wu and Wang (2006) were used to calculate the settling velocity for a range of sediment sizes (Table 2). These equations were used because they consider the effect of particle shape on sediment settling velocity. Many experiments have shown that the settling velocity of fine sediment particles deviates from Stokes' Law, which is applicable for spherical particles (Wu and Wang 2006). In GEMSS®, the following three settling velocities (one velocity per simulation) were applied to the suspended sediment: 1.0 metres per day (m/d), 0.10 m/d and 0.01 m/d.

Figure 3 Particle Size Distribution Curve for Kennady Lake Sediment



µm = micron; mm = millimetres.

$$w_s = \frac{Mv}{Nd}\left[\sqrt{\frac{1}{4} + \left(\frac{4N}{3M^2}D^3\right)^{1/n}} - \frac{1}{2}\right]^n \qquad (9)$$

Where: w_s = settling velocity (m/s); v = kinematic viscosity (square metre per second [m^2/s]); d = nominal diameter of sediment particles (m); M (Equation 10), N (Equation 11) and n (Equation 12) = coefficients; D = Equation 13.

$$M = 53.3e^{-0.65S_f} \qquad (10)$$

Where: S_f = Corey shape factor = 0.7 for natural sediment

$$N = 5.65e^{-2.5S_f} \quad (11)$$

$$n = 0.7 + 0.9S_f \quad (12)$$

$$D = d\left[\frac{\left(\frac{\rho_s}{\rho - 1}\right)g}{v^2}\right]^{1/3} \quad (13)$$

Where: ρ_s = sediment density (kilograms per cubic metre [kg/m^3]); ρ = water density (kg/m^3); g = gravitational acceleration (metres per square second [m/s^2]).

Table 2 Suspended Sediment Settling Velocities

	Sand	Silt	Clay	Organic Material
Diameter (µm)[a]	62.5-2,000	4-62.5	<4	0.2-200
Density (kg/m^3)	2,650	2,650	2,650	1,200
Settling Velocity at 10°C (m/d)[b]	162-16000	0.7-162	<0.7	0.0002-196

[a] The diameter range of sand, silt and clay is based on the Wentworth scale and the diameter range of organic material is based on phytoplankton diameters (Wetzel 2001)

[b] The settling velocity at 10°C is calculated from Wu and Wang (2006)

µm = micron; kg/m^3 = kilogram per cubic metre; °C = degree Celsius; m/d = metre per day; < = less than.

2.6 MODEL SCENARIOS

The model was run for the wind scenarios presented in Table 3. For each scenario, the model was used to predict TSS concentrations at a water surface elevation of 420.7 and 417.7 m for two different seasons, as follows:

- July 1, 2012 to September 30, 2012; a 6-hour (h) duration storm was simulated using Equations 1 – 8 and GEMSS® was then run from July 1, 2012 to September 30, 2012 to predict the effect of dispersion and settling on TSS concentrations throughout Area 2 and Areas 3 and 5 during the open-water season.
- October 7, 2012 to July 1, 2013; a 6-h duration storm was simulated using Equations 1 – 8 and GEMSS® was then run from October 7, 2012 to July 1, 2013 to predict the effect of dispersion and settling on TSS concentrations throughout Area 2 and Areas 3 and 5 during the ice-covered season.

Table 3 Sediment Resuspension Model Scenarios

Scenario	Wind Direction	Wind Speed [m/s]	Settling Velocity [m/d]	Simulation Period
1	Southwest	6	1.0	July 1, 2012 – September 30, 2012
2	Southwest	6	0.10	July 1, 2012 – September 30, 2012
3	Southwest	6	0.01	July 1, 2012 – September 30, 2012
4	Southwest	8	1.0	July 1, 2012 – September 30, 2012
5	Southwest	8	0.10	July 1, 2012 – September 30, 2012
6	Southwest	8	0.01	July 1, 2012 – September 30, 2012
7	Southwest	10	1.0	July 1, 2012 – September 30, 2012
8	Southwest	10	0.10	July 1, 2012 – September 30, 2012
9	Southwest	10	0.01	July 1, 2012 – September 30, 2012
10	Southwest	6	1.0	October 7, 2012 – July 1, 2013
11	Southwest	6	0.10	October 7, 2012 – July 1, 2013
12	Southwest	6	0.01	October 7, 2012 – July 1, 2013
13	Southwest	8	1.0	October 7, 2012 – July 1, 2013
14	Southwest	8	0.10	October 7, 2012 – July 1, 2013
15	Southwest	8	0.01	October 7, 2012 – July 1, 2013
16	Southwest	10	1.0	October 7, 2012 – July 1, 2013
17	Southwest	10	0.10	October 7, 2012 – July 1, 2013
18	Southwest	10	0.01	October 7, 2012 – July 1, 2013
19	Northeast	6	1.0	July 1, 2012 – September 30, 2012
20	Northeast	6	0.10	July 1, 2012 – September 30, 2012
21	Northeast	6	0.01	July 1, 2012 – September 30, 2012
22	Northeast	8	1.0	July 1, 2012 – September 30, 2012
23	Northeast	8	0.10	July 1, 2012 – September 30, 2012
24	Northeast	8	0.01	July 1, 2012 – September 30, 2012
25	Northeast	10	1.0	July 1, 2012 – September 30, 2012
26	Northeast	10	0.10	July 1, 2012 – September 30, 2012
27	Northeast	10	0.01	July 1, 2012 – September 30, 2012
28	Northeast	6	1.0	October 7, 2012 – July 1, 2013
29	Northeast	6	0.10	October 7, 2012 – July 1, 2013
30	Northeast	6	0.01	October 7, 2012 – July 1, 2013
31	Northeast	8	1.0	October 7, 2012 – July 1, 2013
32	Northeast	8	0.10	October 7, 2012 – July 1, 2013
33	Northeast	8	0.01	October 7, 2012 – July 1, 2013
34	Northeast	10	1.0	October 7, 2012 – July 1, 2013
35	Northeast	10	0.10	October 7, 2012 – July 1, 2013
36	Northeast	10	0.01	October 7, 2012 – July 1, 2013

m/s = metres per second; m/d = metres per day.

2.7 TOTAL SUSPENDED SOLIDS WATER QUALITY GUIDELINES

For the purposes of the modelling assessment, predicted TSS concentrations in Area 2 and Areas 3 and 5 of Kennady Lake were compared to the following guidelines for the protection of aquatic life:

- acute guideline: a maximum increase of 25 mg/L of suspended sediment from background levels for any short-term exposure (24-h period) (CCME 1999); and
- chronic guideline: a maximum average increase of 5 mg/L of suspended sediment from background levels for longer term exposures (inputs lasting between 24 hours and 30 days) (CCME 1999).

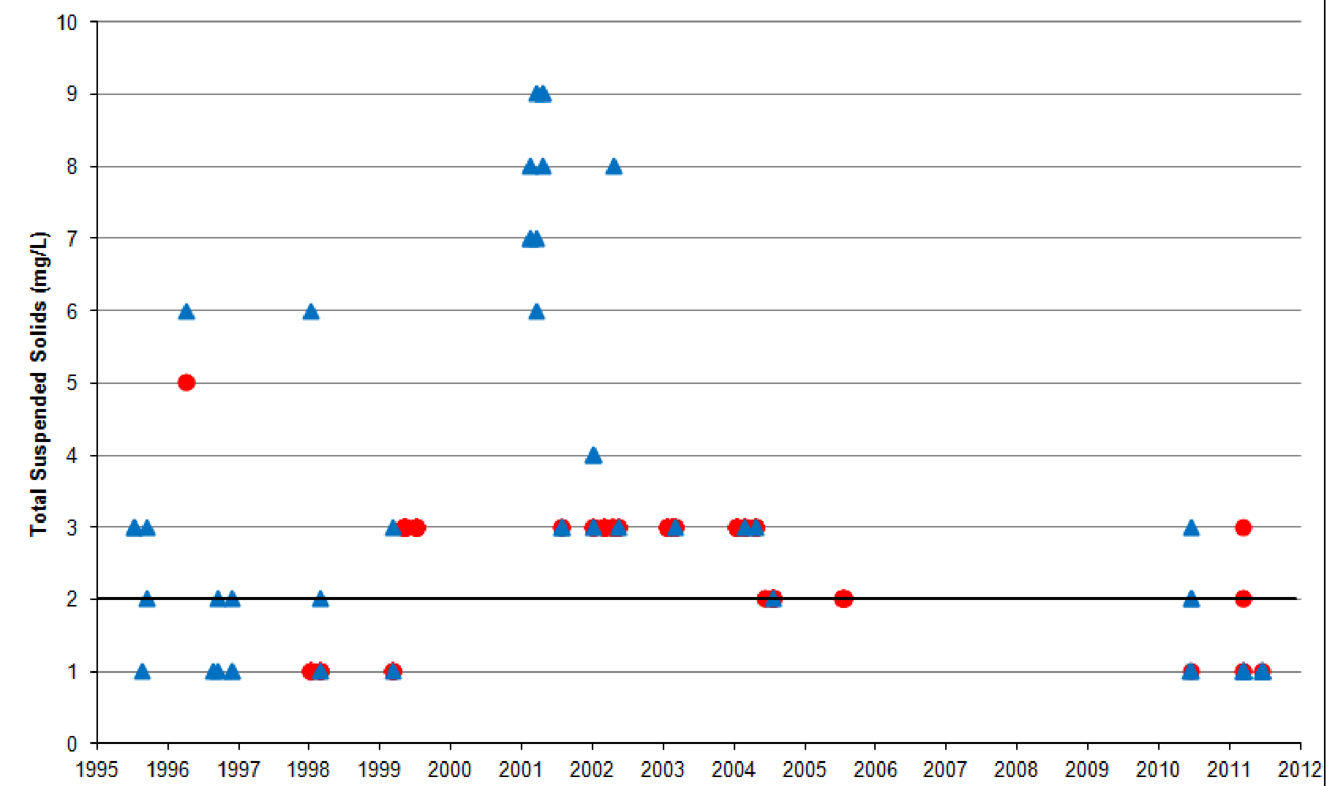
Because observed TSS measurements in Kennady Lake are frequently below the typical method detection limit (the average background TSS concentration in Area 2 and Areas 3 and 5 is below 3 mg/L [Figure 4]), the acute and chronic guidelines were set at 25 and 5 mg/L, respectively.

2.8 ASSUMPTIONS

The model results are based on the following assumptions:

- The background TSS concentration in Area 2 and Areas 3 and 5 of Kennady Lake is below detection, but for the purposes of this modelling was assumed to be zero. This condition is expected to be representative of Kennady Lake under quiescent conditions, as observed TSS measurements in Kennady Lake are frequently below the method detection limit (Figure 4).
- Each storm was modelled as an isolated event. This condition is expected to under-predict TSS concentrations in Kennady Lake, because overlapping storm events would lead to higher TSS than what would be predicted in isolation. As shown in Table 1, an average of 16 storms occur per year during the open-water season, based on meteorological data collected at Snap Lake, located approximately 80 kilometres (km) northwest of the Project site.
- Kennady Lake substrate was assumed to be uniformly composed of fine-grained silt and clay with unlimited erodible depth throughout the resuspension zone. This condition may over-predict TSS concentrations in Kennady Lake after drawdown. However, as discussed in Section 3, the mass of sediment resuspended in individual grid cells accounted for less than 10 millimetres (mm) of the sediment bed in the near shore areas of the lake. Therefore, this assumption is realistically acceptable.
- A water withdrawal was included to account for ice formation each winter from October to January, and a discharge was returned back to the lake each spring from March to June to simulate melting. Melting dates and volumes were derived from observed ice measurements at Snap Lake, NWT (Golder 2011). The water withdrawn and returned following ice formation and melting was assumed to have no associated constituents, meaning that TSS were rejected from the ice and remained within Kennady Lake.
- TSS inputs through inflows associated with spring thaw and freshet flows in the watershed of Area 2 and Areas 3 and 5 were not considered in the model. Whilst it is understood that there will be TSS in catchment runoff during the freshet to the dewatered Area 2 and Areas 3 and 5, the TSS associated with these inflows would be small relative to the TSS generated from the lake bed.

Figure 4 Background Open-water and Under-ice Total Suspended Solids Concentrations in Kennady Lake



Note: Triangles (blue) represent measured data; dots (red) represent measured data that were reported as below detection; dots are shown at the detection limit; line (black) represents the average TSS concentration. The average concentration was calculated using data reported as below detection at one-half the detection limit.

Data Source: De Beers (2010, 2011)

mg/L = milligrams per litre.

3.0 RESULTS

The predicted total mass of sediment resuspended from the lake bed for each of the modelled storm events is presented in Table 4. The mass of sediment resuspended in individual grid cells accounted for less than a 10 mm thickness of the bottom sediment in the near shore areas of the lake.

As discussed in Section 2.1, the development of waves capable of causing sediment resuspension in shallow water is dependent on a number of factors including wind speed, fetch and water depth. The maximum depth of the disturbance by a water wave sufficient to cause suspension of sediment is identified as the resuspension zone. Modelling shows that this depth in Kennady Lake is approximately 2.2 m (Table 5).

Table 4 Total Mass of Sediment Resuspended in Area 2 and Areas 3 and 5 of Kennady Lake

Water Surface Elevation [m]	Wind Speed [m/s]	Storm Duration [h]	Wind Direction	Sediment Mass [tonnes]
420.7	6	6	Northeast	0
	8	6	Northeast	1
	10	6	Northeast	9
	6	6	Southwest	0
	8	6	Southwest	8
	10	6	Southwest	70
417.7	6	6	Northeast	187
	8	6	Northeast	403
	10	6	Northeast	712
	6	6	Southwest	464
	8	6	Southwest	1,076
	10	6	Southwest	1,968

m = metre; m/s = metres per second; h = hour.

Table 5 Water Depth Below Which Resuspension Occurred in Area 2 and Areas 3 and 5 of Kennady Lake

Wind Speed [m/s]	Storm Duration [h]	Fetch[a] [m]	Water Depth [m]
6	6	<100	0.1
8	6		0.1
10	6		0.1
6	6	<1,000	0.3
8	6		0.3
10	6		0.3
6	6	<2,000	0.9
8	6		1.6
10	6		1.7
6	6	>2,000	1.4
8	6		1.7
10	6		2.2

[a] The maximum fetch in Kennady Lake is about 3,000 m.

m/s = metres per second; m = metre; h = hour; < = less than; > = greater than.

3.1 RESULTS BEFORE DRAWDOWN

It is assumed that over the years, Kennady Lake has achieved a roughly steady-state condition between the near shore sediments and TSS in the water column, whereby fine material along beach areas has been winnowed from the near shore sediment assemblages, resulting in typically low TSS concentrations in the lake (Figure 4). To replicate this condition in the model, the near shore area with depths of less than 1.4 m were assumed to be free of fine sediments. The depth of 1.4 m corresponds to the depth of the resuspension zone for a 6-h duration storm with wind speeds of 6 m/s and a fetch of greater than 2 km (Table 5). Since an average of 11 of these storms occurs each year, it was assumed that virtually all of the fines would be winnowed from this zone in wind prone areas. This premise is substantiated by long-term GEMSS® modelling of the sediment movement on the lake bottom, as shown in Figure 5.

The results of the modelling of Area 2 and Areas 3 and 5 of Kennady Lake before drawdown suggest that a 6-h duration storm event with wind speeds of 8 and 10 m/s would have limited effects on TSS concentrations in the lake. In general, TSS concentrations in most areas of the lake were predicted to remain within the observed background TSS range as displayed in Figures 6 and 7 for a storm event with wind speeds of 8 and 10 m/s and with a sediment settling velocity of 0.01 m/d.

3.2 RESULTS AFTER DRAWDOWN

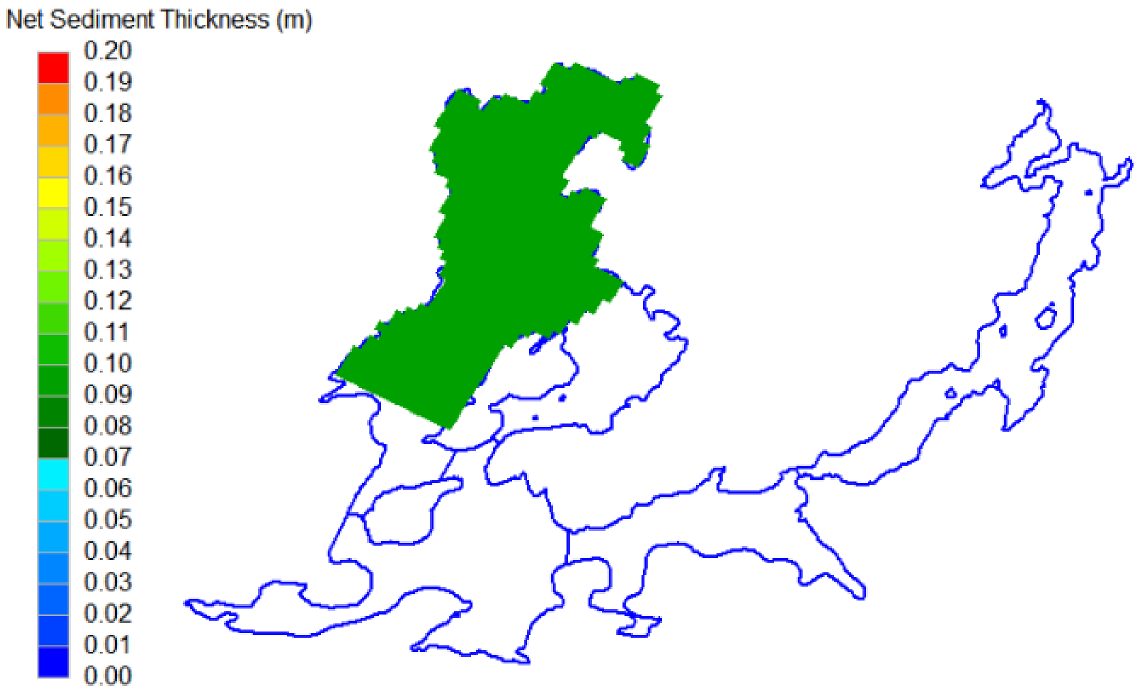
TSS concentrations were predicted to be greatest on the downwind shore of Area 2 and Areas 3 and 5 and were predicted to decrease with time as a result of dispersion and settling. These results are illustrated in Figures A-1 to A-3 and in Figures A-4 to A-6, which show the areal extent of Kennady Lake at an elevation of 417.7 m affected by sediment resuspension from a 6-h duration storm event during the open-water season with a wind speed of 6 m/s from the southwest and northeast, respectively.

As the wind speed of the storm event increased from 6 to 10 m/s and the sediment settling velocity decreased from 1 to 0.01 m/d, the volume of Area 2 and Areas 3 and 5 with TSS concentrations greater than observed background concentrations was predicted to increase. These results are illustrated in Tables B-1 to B-9, which show the percentage change in volume with time of Area 2 and Areas 3 and 5 with TSS concentrations greater than 500, 100, 25 and 5 mg/L for modelled storm events in the open-water season.

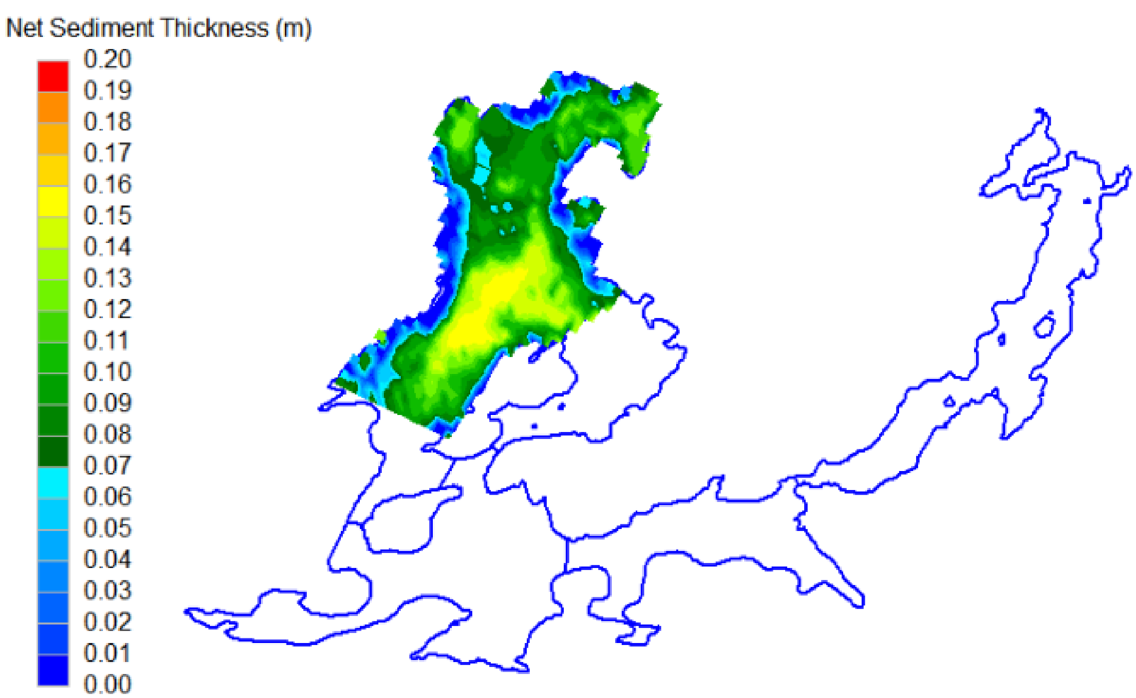
3.2.1 Open-water Season

The following sections describe the model results for the predicted maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 of Kennady Lake at an elevation of 417.7 m after a 6-h duration storm event in the open-water season.

Figure 5 Net Sediment Thickness in Area 2 and Areas 3 and 5 at a Water Surface Elevation of 420.7 m



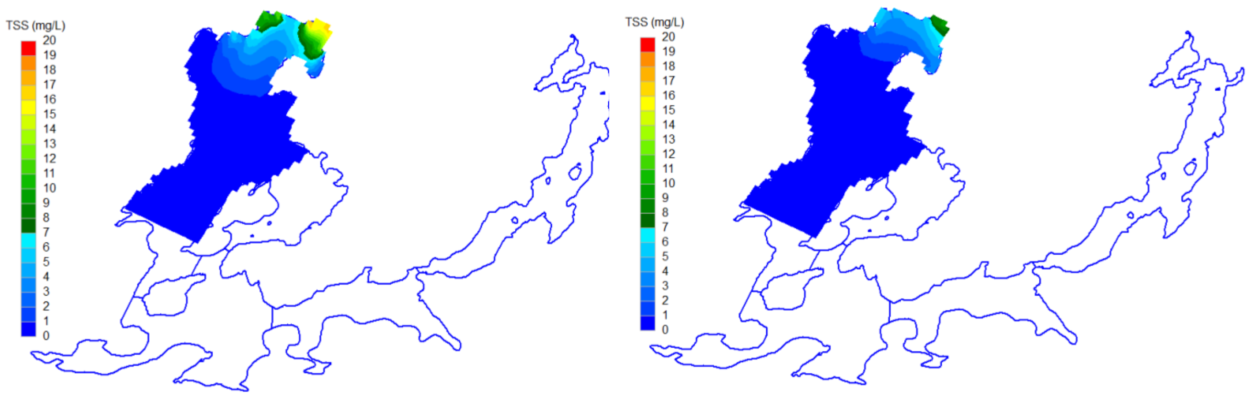
(a) Initial uniform sediment thickness of 0.10 m



(b) Movement of sediment towards deeper locations in Areas 3 and 5 after three years of modelling.

m = metre.

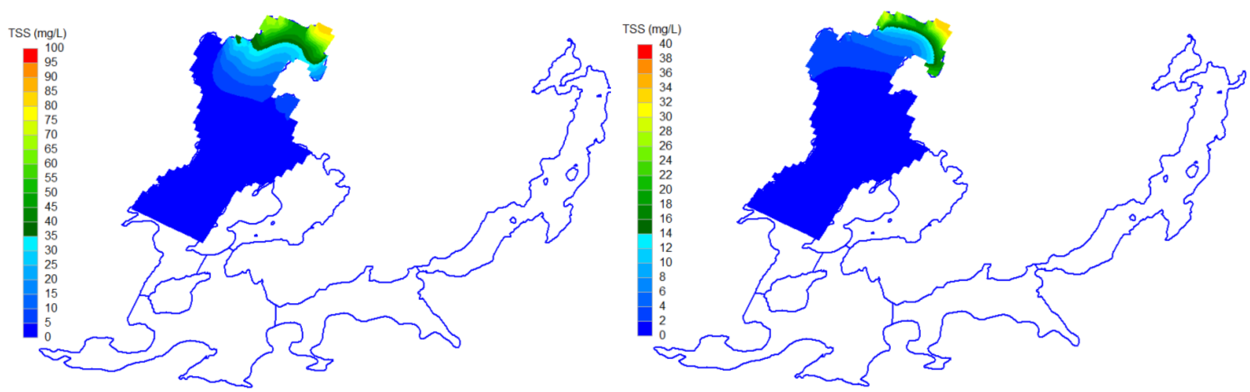
Figure 6 Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 420.7 m after a Storm Event in the Open-water Season with a Wind Speed of 8 m/s from the Southwest and a Sediment Settling Velocity of 0.01 m/d



(a) July 2 (b) July 3

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

Figure 7 Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 420.7 m after a Storm Event in the Open-water Season with a Wind Speed of 10 m/s from the Southwest and a Sediment Settling Velocity of 0.01 m/d



(a) July 2 (b) July 4

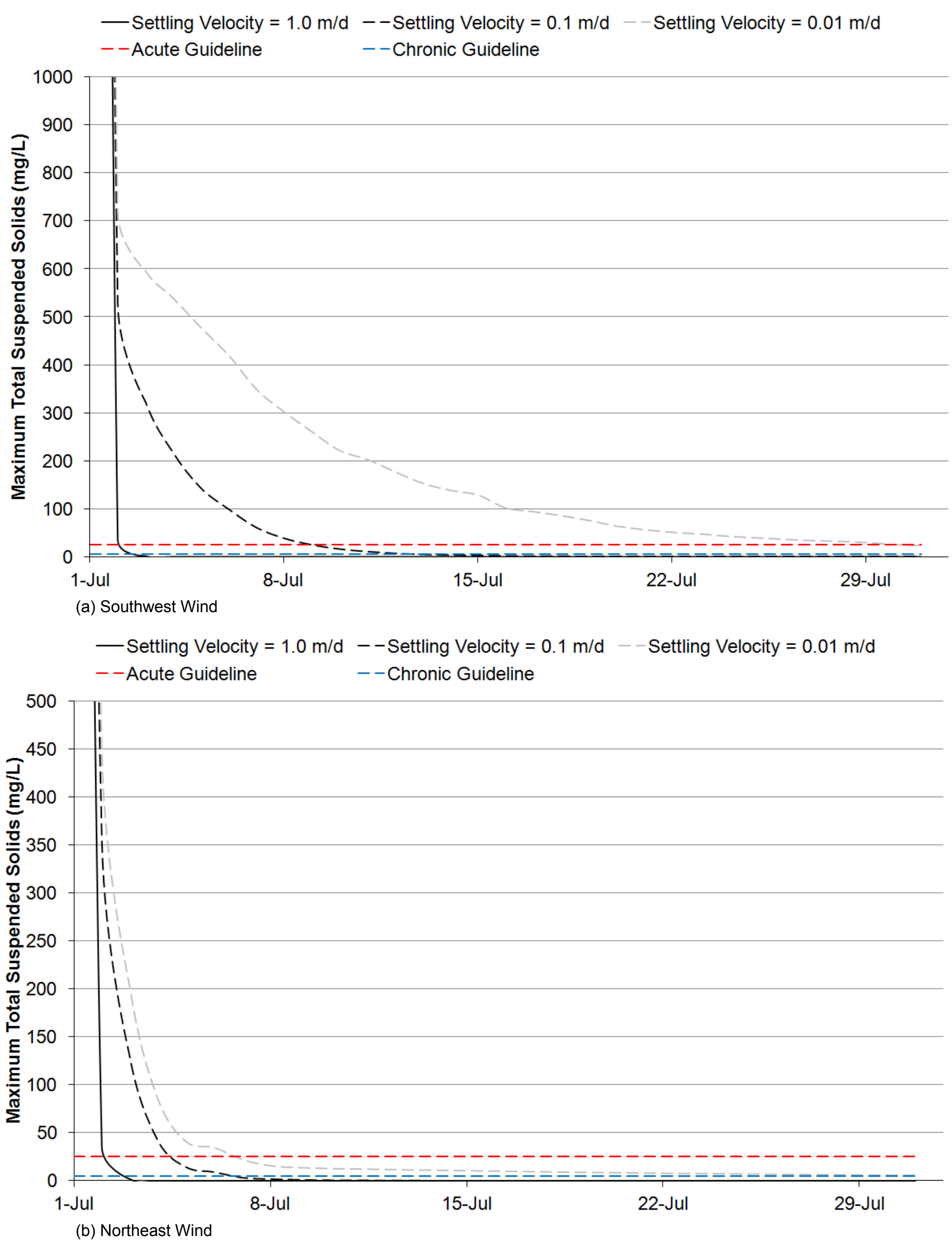
m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

3.2.1.1 Storm Event with Wind Speeds of 6 m/s

Twenty-four hours after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be higher than the acute guideline. As the sediment settling velocity decreases from 1.0 to 0.01 m/d, the maximum TSS concentrations were predicted to increase from 35 to 720 mg/L (Figure 8a), and from 35 to 450 mg/L (Figure 8b).

Thirty days after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range for all modelled scenarios with the exception of one. Maximum TSS concentrations near the surface after a storm event with winds from the southwest and with a sediment settling velocity of 0.01 m/d were predicted to be higher than the chronic guideline, with concentrations greater than 25 mg/L (Figure 8).

Figure 8 Maximum Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event in the Open-water Season with a Wind Speed of 6 m/s



m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

3.2.1.2 Storm Event with Wind Speeds of 8 m/s

Twenty-four hours after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be higher than the acute guideline. As the sediment settling velocity decreases from 1.0 to 0.01 m/d, the maximum TSS concentrations were predicted to increase from 80 to 1,700 mg/L (Figure 9a), and from 100 to 1,200 mg/L (Figure 9b).

Thirty days after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range for all modelled scenarios with the exception of one. Maximum TSS concentrations near the surface after a storm event with winds from the southwest and with a sediment settling velocity of 0.01 m/d were predicted to be higher than the chronic guideline, with concentrations greater than 55 mg/L (Figure 9).

3.2.1.3 Storm Event with Wind Speeds of 10 m/s

Twenty-four hours after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be higher than the acute guideline. As the sediment settling velocity decreases from 1.0 to 0.01 m/d, the maximum TSS concentrations were predicted to increase from 140 to 3,100 mg/L (Figure 10a), and from 190 to 1,950 mg/L (Figure 10b).

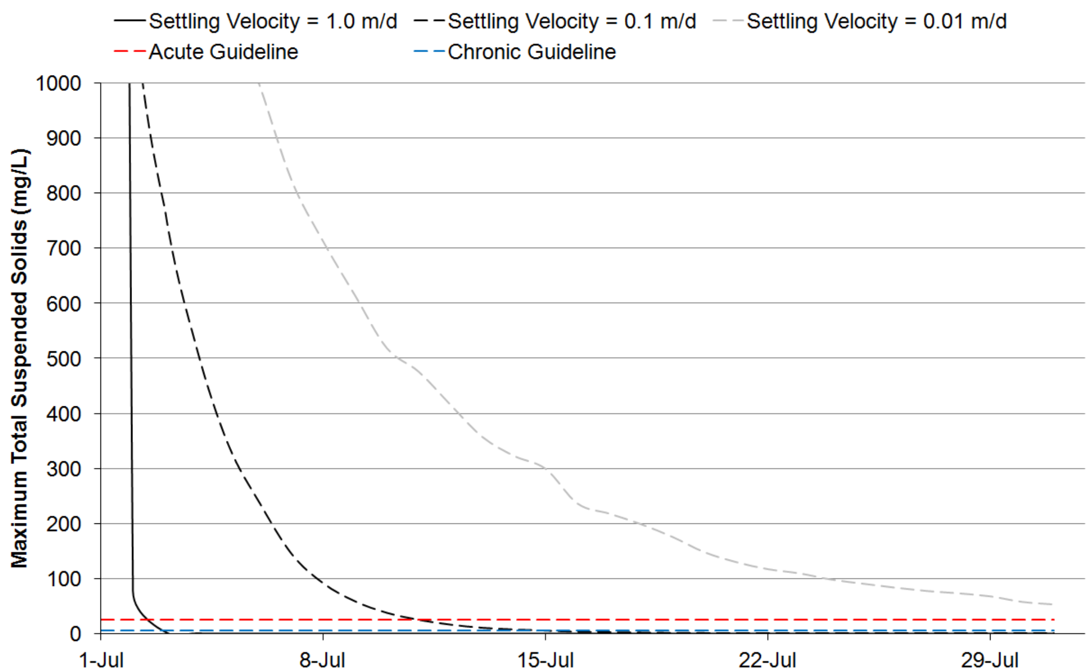
Thirty days after a storm event with winds from the southwest and northeast and with sediment settling velocities of 1.0 and 0.1 m/d, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range. Maximum TSS concentrations near the surface after a storm event with winds from the southwest and northeast and with a sediment settling velocity of 0.01 m/d were predicted to be higher than the chronic guideline, with concentrations greater than 100 mg/L (Figure 10a) and 20 mg/L, respectively (Figure 10b).

3.2.2 Ice-covered Season

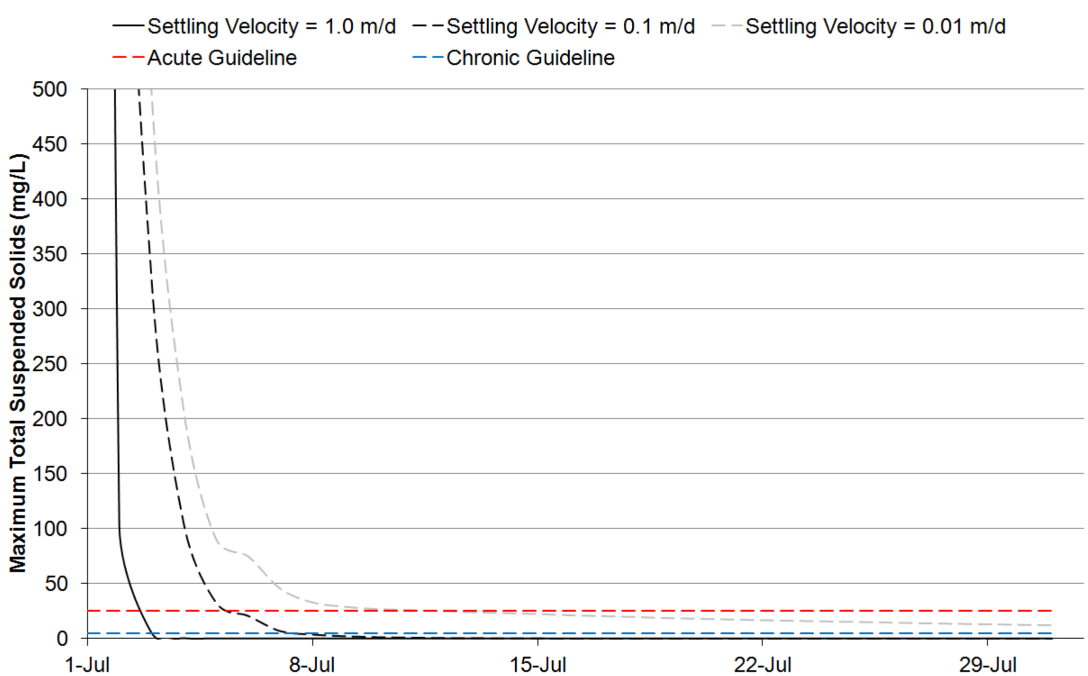
The following sections describe the model results for the predicted maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 of Kennady Lake at an elevation of 417.7 m after drawdown for three scenarios:

- seven days after a 6-h duration storm event at the beginning of the ice-covered season. This period represents an open water period one week prior to the onset of ice-covered conditions;
- three months after a 6-h duration storm event when ice formation is complete; and
- eight months after a 6-h duration storm event at the end of the ice-covered season.

Figure 9 Maximum Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event in the Open-water Season with a Wind Speed of 8 m/s



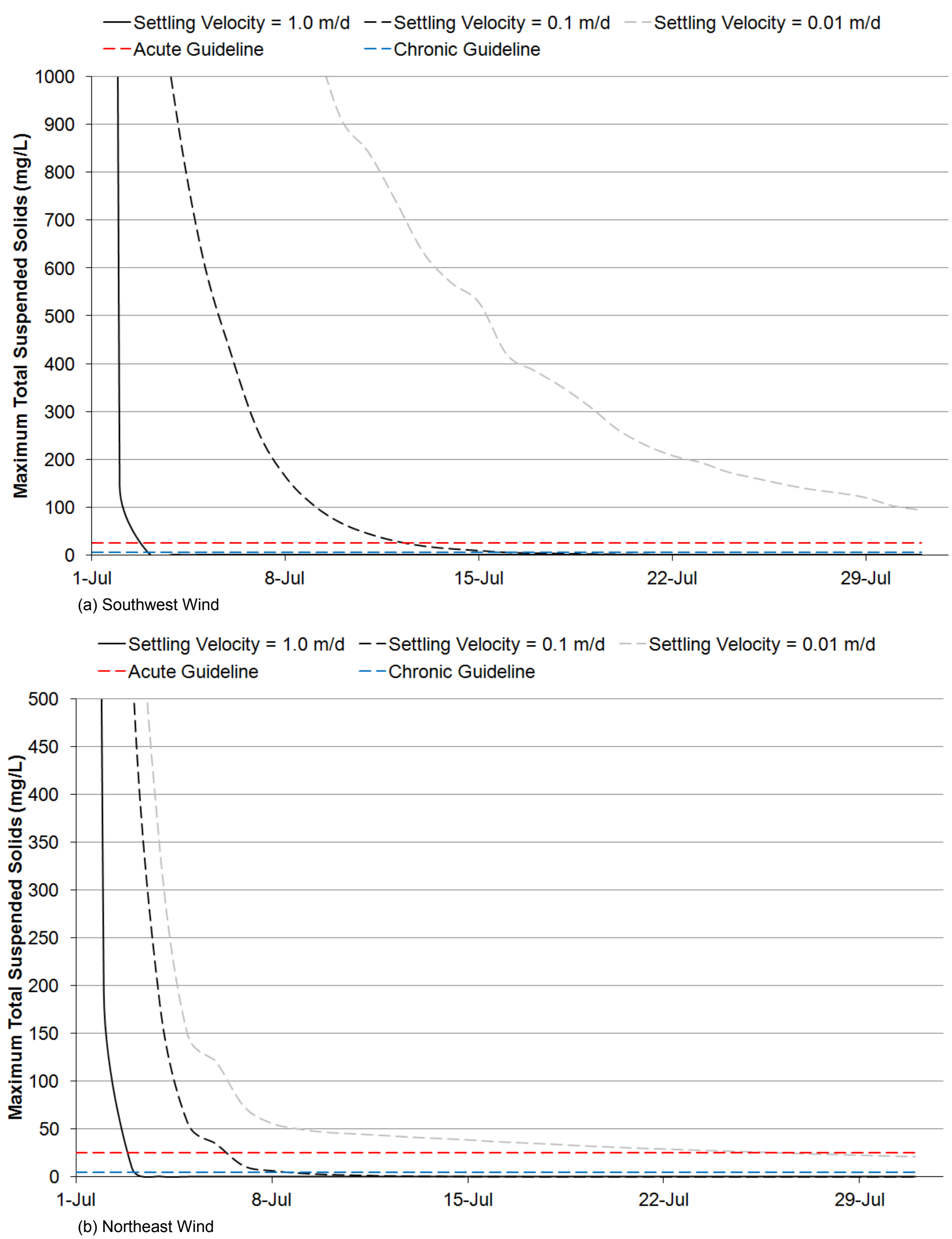
(a) Southwest Wind



(b) Northeast Wind

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

Figure 10 Maximum Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event in the Open-water Season with a Wind Speed of 10 m/s



m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

3.2.2.1 Storm Event with Wind Speeds of 6 m/s

Seven days after a storm event with winds from the southwest and with a sediment settling velocity of 1.0 m/d, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range. As the sediment settling velocity decreases from 1.0 to 0.10 m/d and from 0.10 to 0.01 m/d, maximum TSS concentrations near the surface were predicted to exceed chronic guidelines, with concentrations greater than 40 and 300 mg/L (Figure 11a). Seven days after a storm event with winds from the northeast, maximum TSS concentrations near the surface were predicted to be within the observed background TSS range for all modelled scenarios with the exception of one. Maximum TSS concentrations near the surface after a storm with winds from the northeast and with a sediment settling velocity of 0.01 m/d were predicted to be higher than the chronic guideline, with concentrations greater than 20 mg/L (Figure 11b).

Three months after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range for all modelled scenarios with the exception of one. Maximum TSS concentrations near the surface after a storm event with winds from the southwest and with a sediment settling velocity of 0.01 m/d were predicted to be higher than the chronic guideline, with concentrations greater than 18 mg/L (Figure 11a).

At the end of the ice-covered season, eight months after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range (Figure 11).

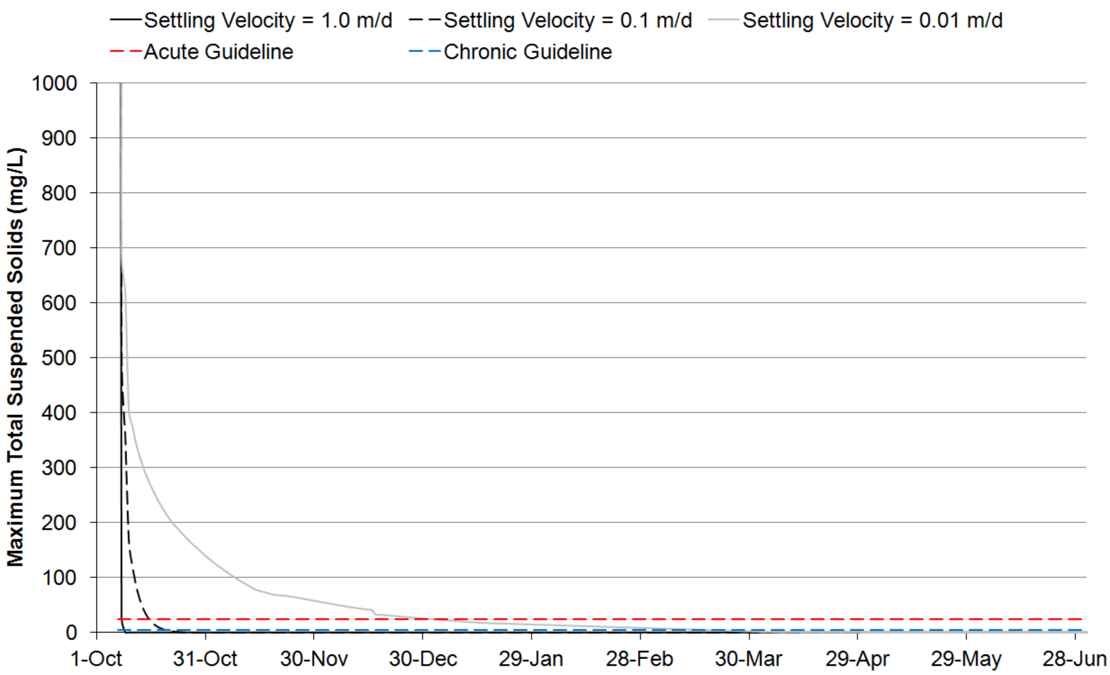
3.2.2.2 Storm Event with Wind Speeds of 8 m/s

Seven days after a storm event with winds from the southwest and with a sediment settling velocity of 1.0 m/d, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range. As the sediment settling velocity decreases from 1.0 to 0.10 m/d and from 0.10 to 0.01 m/d, maximum TSS concentrations near the surface were predicted to exceed chronic guidelines with concentrations greater than 95 and 675 mg/L (Figure 12a). Seven days after a storm event with winds from the northeast, maximum TSS concentrations near the surface were predicted to be within the observed background TSS range for all modelled scenarios with the exception of one. Maximum TSS concentrations near the surface after a storm with winds from the northeast and with a sediment settling velocity of 0.01 m/d were predicted to be higher than the chronic guideline, with concentrations greater than 40 mg/L (Figure 12b).

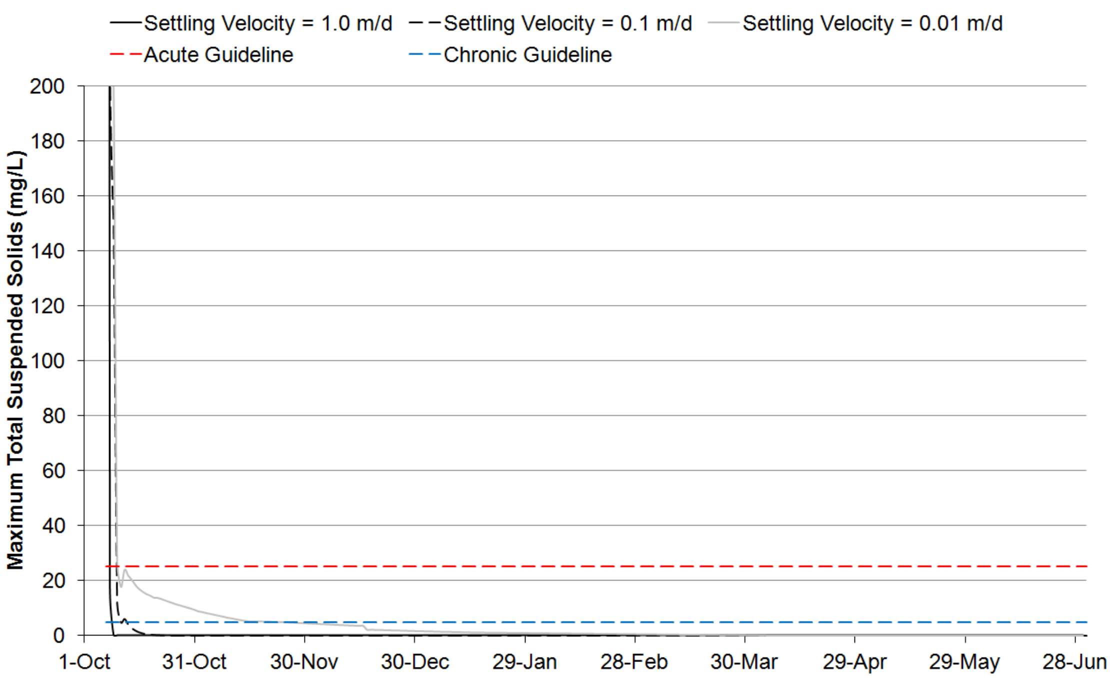
Three months after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range for all modelled scenarios with the exception of one. Maximum TSS concentrations near the surface after a storm event with winds from the southwest and with a sediment settling velocity of 0.01 m/d were predicted to be higher than the chronic guideline, with concentrations greater than 35 mg/L (Figure 12a).

At the end of the ice-covered season, eight months after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range (Figure 12).

Figure 11 Maximum Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event Before the Ice-covered Season with a Wind Speed of 6 m/s



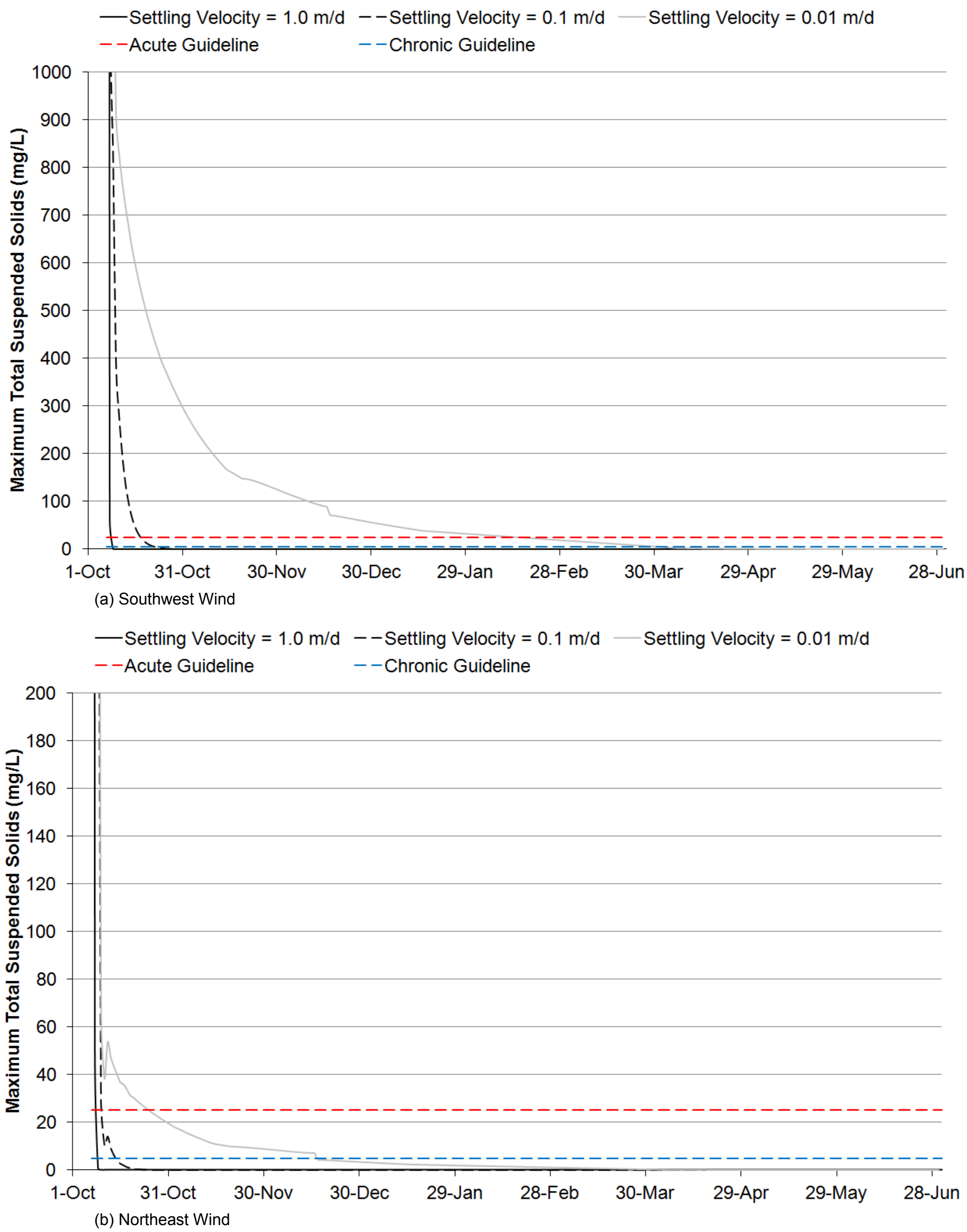
(a) Southwest Wind



(b) Northeast Wind

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

Figure 12 Maximum Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event Before the Ice-covered Season with a Wind Speed of 8 m/s



m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

3.2.2.3 Storm Event with Wind Speeds of 10 m/s

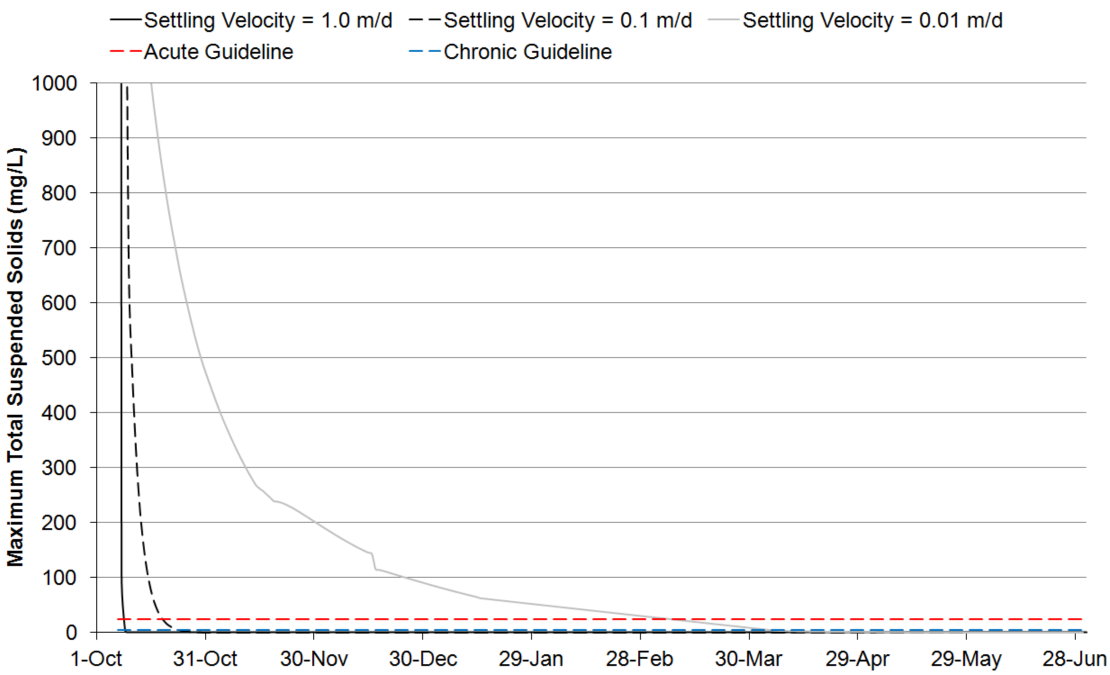
Seven days after a storm event with winds from the southwest and with a sediment settling velocity of 1.0 m/d, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range. As the sediment settling velocity decreases from 1.0 to 0.10 m/d and from 0.10 to 0.01 m/d, maximum TSS concentrations near the surface were predicted to be higher than the chronic guideline, with concentrations greater than 160 and 1,140 mg/L (Figure 13a).

Seven days after a storm event with winds from the northeast, maximum TSS concentrations near the surface were predicted to be within the observed background TSS range for all modelled scenarios with the exception of one. Maximum TSS concentrations near the surface after a storm with winds from the northeast and with a sediment settling velocity of 0.01 m/d were predicted to be higher than the chronic guideline, with concentrations greater than 70 mg/L (Figure 13b).

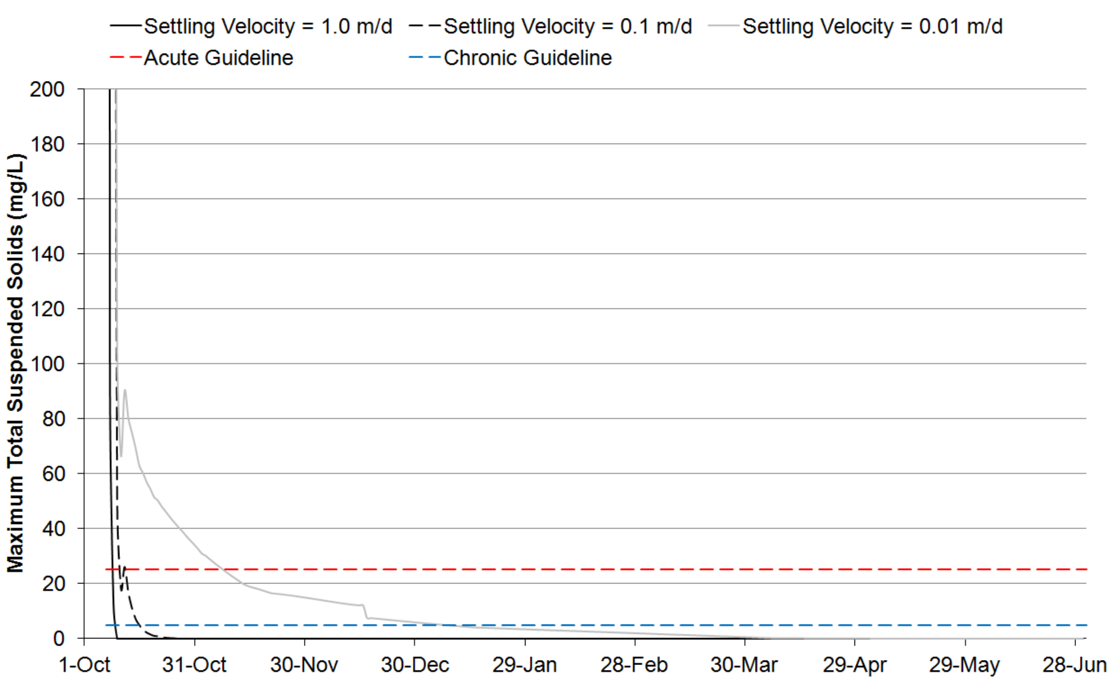
Three months after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range for all modelled scenarios with the exception of one. Maximum TSS concentrations near the surface after a storm event with winds from the southwest and with a sediment settling velocity of 0.01 m/d were predicted to be higher than the chronic guideline, with concentrations greater than 60 mg/L (Figure 13a).

At the end of the ice-covered season, eight months after a storm event with winds from the southwest and northeast, maximum TSS concentrations near the surface of Area 2 and Areas 3 and 5 were predicted to be within the observed background TSS range (Figure 13).

Figure 13 Maximum Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event Before the Ice-Covered Season with a Wind Speed of 10 m/s



(a) Southwest Wind



(b) Northeast Wind

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

4.0 DATA GAPS AND MODEL UNCERTAINTY

This section describes sources of uncertainty that arise from applying a numerical model to a real-world system.

4.1 MODEL GRID

As described in Section 2.3, the lake was segmented into grid cells for modelling. Data-related uncertainty with the model grid was considered to be moderate, because the bathymetry of the lake is well established, and care was taken to replicate the bathymetry as accurately as possible in the segmentation, particularly in shallow areas. The shallow areas of Kennady Lake are the most critical to sediment resuspension. The shallow areas of the lake will differ to a large extent from the actual bathymetry because for a low resolution bathymetry file, not all grid cells will read elevations directly from the bathymetry data. The bottom elevation for the grid cells that do not read elevations directly from the bathymetry data were derived through interpolation of the neighbouring cells.

To examine uncertainty in the model grid, two model grids were developed, and the total mass of sediment suspended in each grid and for each modelled scenario was calculated. One of the grids had a horizontal spacing of 100 m and the other grid had a horizontal spacing of 62.5 m. After drawdown to a water elevation of 417.7 m, the difference between the mass of suspended sediment for the two model grids was negligible.

4.2 SEDIMENT CHARACTERISTICS

Data-related uncertainty with substrate characteristics was considered to be high because:

- Particle size distribution analysis was completed for two screened fine clastic sediment samples from Kennady Lake. It is not known whether the samples are representative of the lake as a whole or whether sediment characteristics have a high spatial variability in the lake.
- In-situ settling velocity data for Kennady Lake sediment was not available. The settling velocity will affect the length of time that sediment from a single storm event remains in suspension.
- Samples gathered from the lake suggest that the organic carbon content ranges from 7% to 15%. The suspension behaviour of this fraction is unknown.

As discussed in Section 2.5.2.1, the screened clastic portion of the sediment samples from Kennady Lake were composed of 95% silt-sized material, and these sediment samples were assumed to be representative of the sediment throughout the resuspension zone of the lake. Therefore, equations developed by Sheng and Lick (1979) for fine-grained sediment (silt and clay) were used to calculate critical shear stress for resuspension and estimate rates of sediment resuspension.

As discussed in Section 2.5.2.3, because the in-situ settling velocity of Kennady Lake sediment was not available for the different sediment assemblages, a range of settling velocities corresponding to a range of sediment sizes was used.

4.3 METEOROLOGICAL INPUTS

Data-related uncertainty with meteorological inputs was considered to be low, because:

- A range of wind conditions was modelled and the selection of the model storm events with a 6-h duration and wind speeds of 6, 8 and 10 m/s was based on an analysis of the meteorological station's record at Snap Lake, NWT.

4.4 SUMMARY OF UNCERTAINTIES

The model developed to predict sediment resuspension in Kennady Lake after drawdown to a water elevation of 417.7 m should predict TSS concentrations in the lake reasonably well, because the modelling was based on a previous successful study (Laenen and Letourneau 1996). Predictions of wave geometry for single wind storms on the lake were based on the classic forecasting equations for waves in shallow water, as presented in U.S. Army Corps of Engineers (1984), predictions of wave-induced resuspension of bed sediment for shallow water were based on equations developed by Sheng and Lick (1979) and predictions of TSS concentrations in the lake after dispersion and settling were based on GEMSS®. The wave and resuspension equations were applied by Laenen and Letourneau (1996) in their successful modelling of Klamath Lake, Oregon, and a hydrodynamic and water quality model was recently developed in GEMSS® and successfully calibrated for Kennady Lake.

The greatest source of uncertainty in the model results was considered to be the choice of the suspended sediment settling velocity. However, this uncertainty was addressed through the use of a range of settling velocities.

Recommendations to improve future modelling and reduce uncertainties are provided in Section 5.

5.0 CONCLUSIONS AND RECOMMENDATIONS

After drawdown, a single storm event was predicted to increase TSS concentrations in Area 2 and Areas 3 and 5 of Kennady Lake above background concentrations. A 6-h duration storm with winds from the southwest was predicted to suspend a greater mass of sediment into the water column than a 6-h duration storm with winds from the northeast (Table 4). Therefore, for all of the modelled scenarios, TSS concentrations in Area 2 and Areas 3 and 5 as a result of a storm with winds from the southwest were predicted to be greater than TSS concentrations as a result of a storm with winds from the northeast.

The magnitudes of the wind speed and sediment settling velocity had significant effects on the mass of sediment resuspended into the water column and the TSS concentration in Kennady Lake over time, respectively. The mass of sediment resuspended into the water column was predicted to increase as the magnitude of the wind speed increased from 6 to 10 m/s, and the TSS concentration in Kennady Lake was predicted to be greater over time as the magnitude of the settling velocity decreased from 1.0 to 0.01 m/d.

The model results presented herein are for single storm events. If multiple storm events are considered, then greater concentrations of TSS would be expected in Area 2 and Areas 3 and 5 of Kennady Lake. On average, 16 storms with wind speed conditions evaluated in this study occur during the open-water season each year (Table 1).

The following recommendations are made to improve future modelling:

- Additional sampling and analysis of the lake sediments would help to further refine the TSS predictions for the drawdown scenario. Sediment samples should be collected in both shallow and deep water areas of Kennady Lake and should be analyzed for particle size distribution and density. Sediment traps should be deployed in both shallow and deep water areas of Kennady Lake so that in-situ sediment settling velocities can be determined.
- Water quality parameters, including TSS, should continue to be monitored during both open-water and ice-covered seasons. Monitoring locations should include both shallow water and deep water areas of Kennady Lake. Ideally, monitoring of TSS would be completed shortly after wind events of various intensities to validate the resuspension predictions.
- Review and application of meteorological data from the meteorological station deployed at the Project site in summer 2011. Site-specific wind speed and wind direction data from the Project site would allow for a more accurate representation of conditions at Kennady Lake.

6.0 REFERENCES

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7.0 ABBREVIATIONS

CCME	Canadian Council of Ministers of the Environment
GEMSS	Generalized Environmental Modelling System for Surfacewaters
NWT	Northwest Territories
TSS	total suspended solids
U.S.	United States
CCME	Canadian Council of Ministers of the Environment

7.1 Units of Measure

%	percent
<	less than
>	greater than
°C	degree Celsius
µm	micron
cm/s	centimetres per second
$dynes/cm^2$	dynes per square centimetre
$g/cm^2\cdot s$	grams per square centimetre second
g/cm^3	grams per cubic centimetre
h	hour
kg/m^3	kilograms per cubic meter
km	kilometres
m	metre
m/d	metres per day
m/s	metres per second
m/s^2	metres per square second
m^2/s	square metres per second
mg/L	milligrams per litre
mm	millimetres
s	seconds

8.0 GLOSSARY

Bathymetry	The measurement of water depth at various locations in a waterbody.
Clastic	Geologists use the term clastic to refer to particles in sediment transport, whether in suspension or as bed load, and in sediment deposits. Clastic sediments are composed mainly of broken pieces, or clasts, of older weathered and eroded rocks.
Clay	Sedimentary material with particles smaller than silt, typically with a diameter less than 0.004 millimetres.
Concentration	Quantifiable amount of a chemical in environmental media.
Density	The mass per unit volume of a substance.
Dewatering	The draining of surface water or groundwater from waterways or aquifers.
Dispersion	Mixing caused by a physical process.
Entrain	The pickup and movement of sediment by current flow.
Fetch	Unobstructed distance along a water surface for wave development by wind.
Gravitational acceleration	The force on an object caused by gravity.
Method detection limit	The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.
Model grid	A representation of the physical area to be modelled.
Modelling	A simplified representation of a relationship or system of relationships. Modelling involves calculation techniques used to make quantitative estimates of an output parameter based on its relationship to input parameters. The input parameters influence the value of the output parameters.
Particle size distribution	A measurement designed to determine the size range of a representative sample of a substance.
Resuspension	A renewed suspension of insoluble particles, such as sediment, in a fluid, such as water.
Sand	Small loose grains of worn or disintegrated rock with diameters between 0.06 and 2 millimetres.
Sediment	Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus.
Settling velocity	The rate at which a particle falls through water or air.
Shear stress	A force that is applied parallel to a surface.

Silt	Sedimentary material with particles intermediate in size between sand and clay
Total suspended solids	The amount of suspended substances in a water sample. Solids, found in a waterbody, which can be removed by filtration. The origin of suspended matter may be artificial or anthropogenic wastes or natural sources such as silt.
Viscosity	A measure of a fluid's (e.g. water) resistance to flow.
Wave height	The difference between the wave crest and the preceding trough.
Wave length	The distance between one peak or crest of a wave and the next corresponding peak or crest.
Wave period	The time it takes for two successive wave crests to pass a given point.

Report Signature Page

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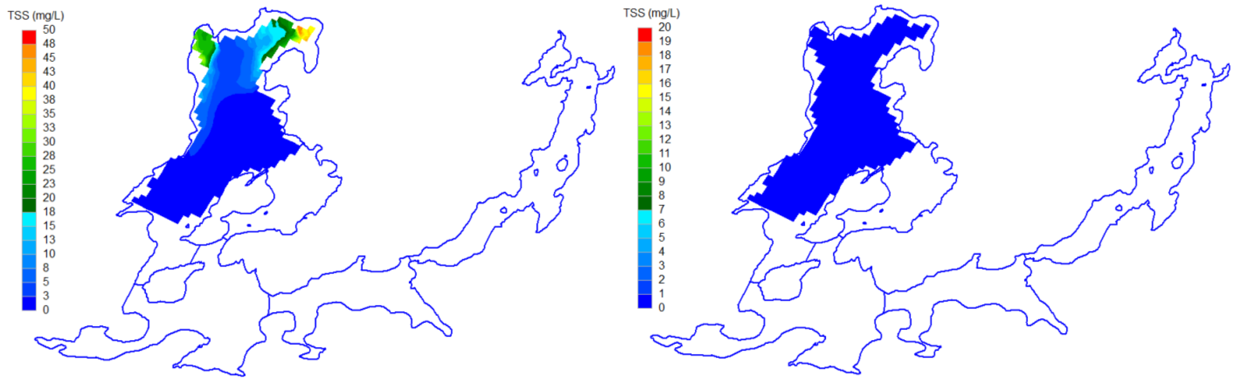
APPENDIX A

Total Suspended Solids Surface Contour Plots for the Open-water Season

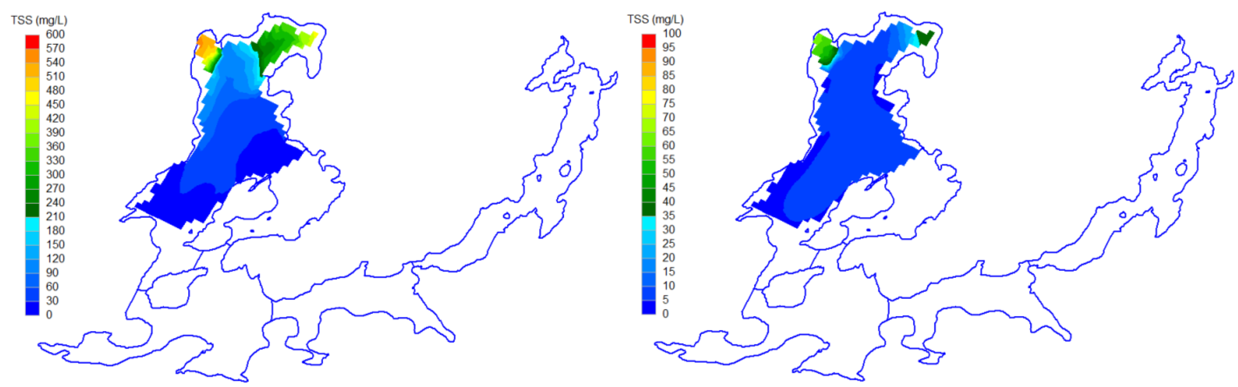
Figure A-1 Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event in the Open-water Season with a Wind Speed of 6 m/s from the Southwest and a Sediment Settling Velocity of 1 m/d



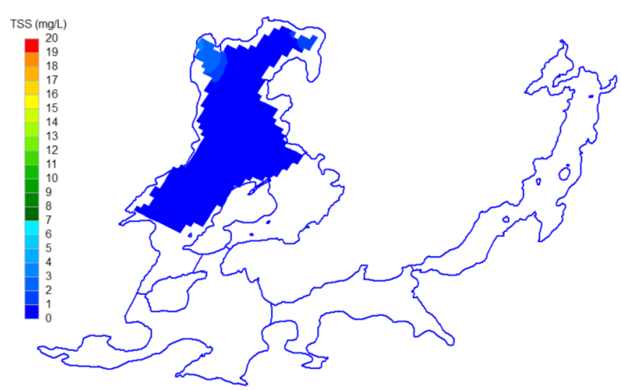
(a) July 2 (b) July 7

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

Figure A-2 Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event in the Open-water Season with a Wind Speed of 6 m/s from the Southwest and a Sediment Settling Velocity of 0.10 m/d



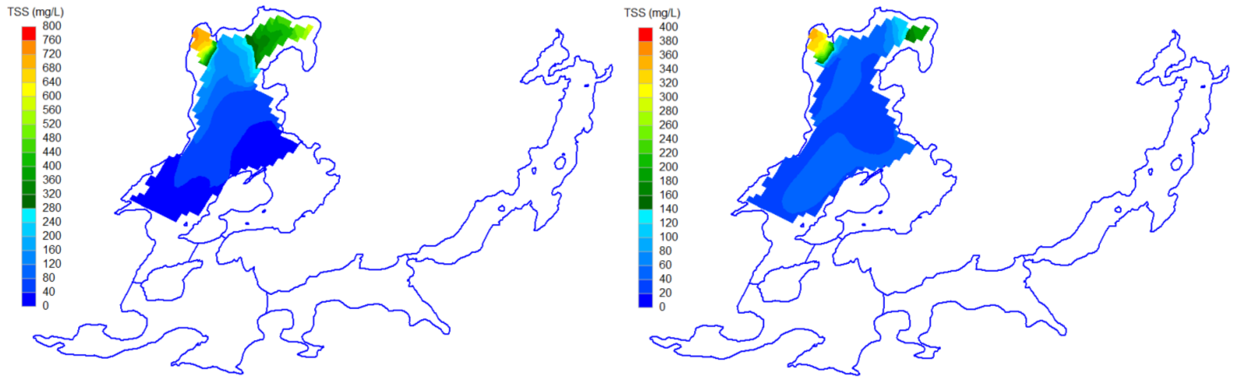
(a) July 2 (b) July 7



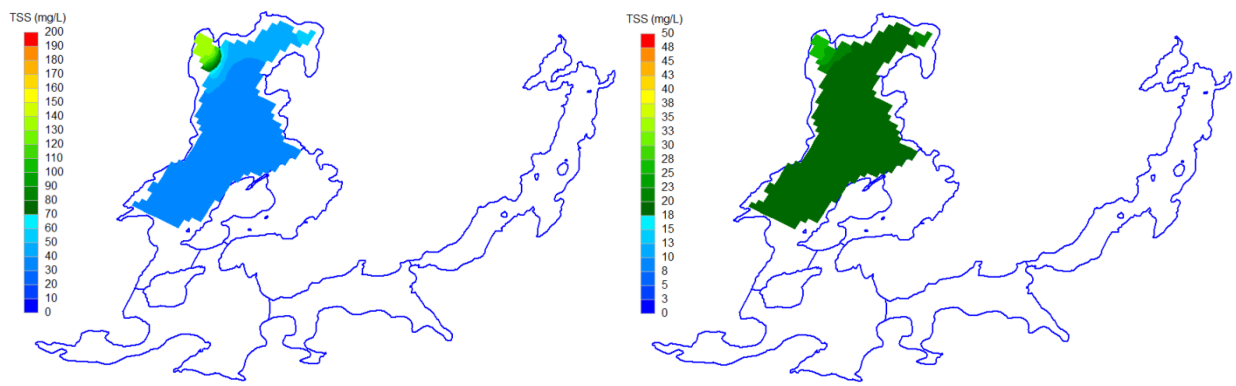
(c) July 14

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

Figure A-3 Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event in the Open-water Season with a Wind Speed of 6 m/s from the Southwest and a Sediment Settling Velocity of 0.01 m/d



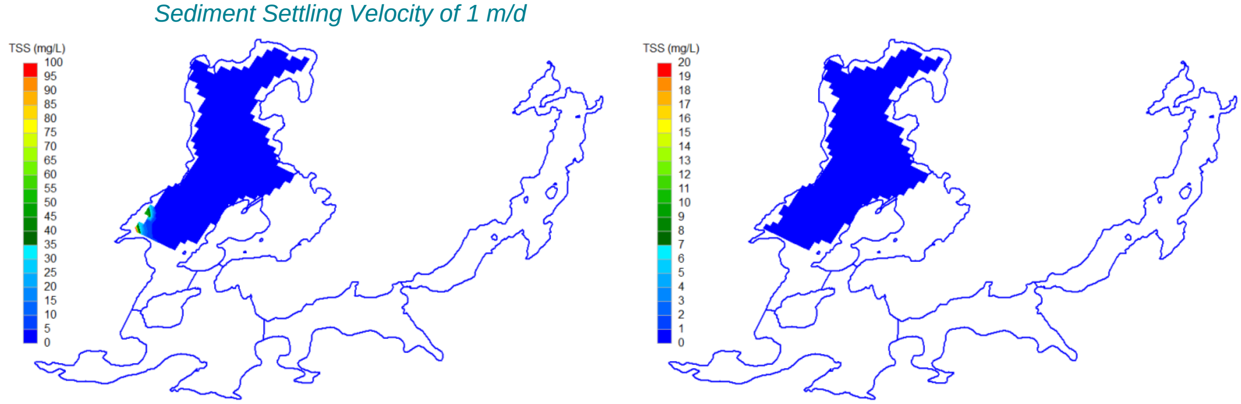
(a) July 2 (b) July 7



(c) July 14 (d) July 30

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

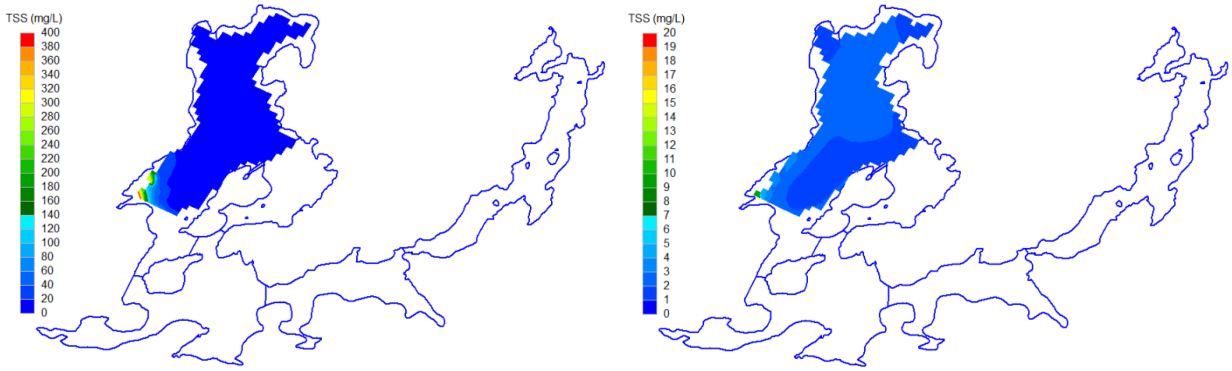
Figure A-4 Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event in the Open-water Season with a Wind Speed of 6 m/s from the Northeast and a Sediment Settling Velocity of 1 m/d



(a) July 2 (b) July 7

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

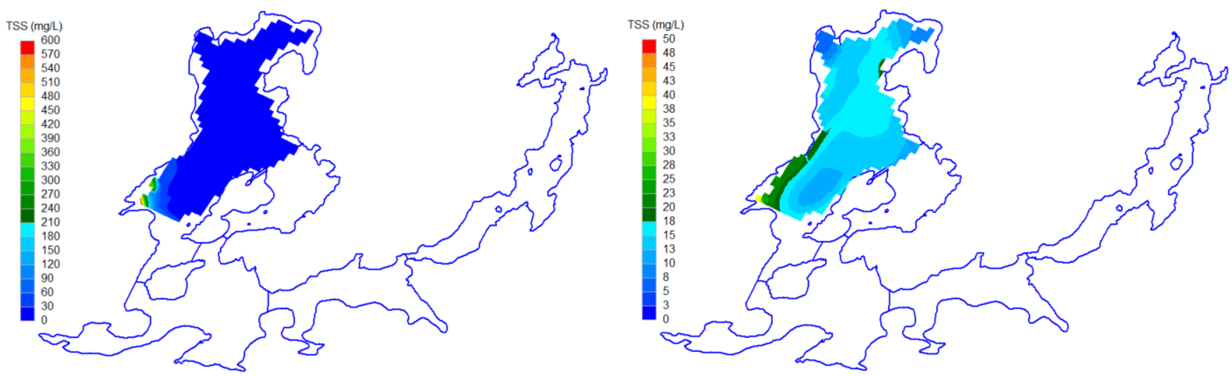
Figure A-5 Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event in the Open-water Season with a Wind Speed of 6 m/s from the Northeast and a Sediment Settling Velocity of 0.10 m/d



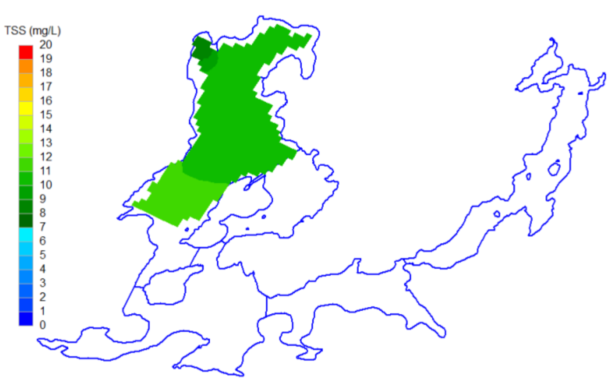
(a) July 2 (b) July 7

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

Figure A-6 Total Suspended Solids Concentration in the Surface Layer of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m after a Storm Event in the Open-water Season with a Wind Speed of 6 m/s from the Northeast and a Sediment Settling Velocity of 0.01 m/d



(a) July 2 (b) July 7



(c) July 14

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre.

APPENDIX B

Volume of Area 2 and Areas 3 and 5 Affected by Modelled Storm Events During the Open-water Season

Table B-1 Volume of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m with a Total Suspended Solids Concentration Greater Than Indicated as a Result of a Storm Event in the Open-water Season with a Wind Speed of 6 m/s and a Sediment Settling Velocity of 1.0 m/d

TSS [mg/L]	Volume of Areas 2 and Areas 3 and 5 [%]							
>500	-	-	-	-	-	-	-	-
>100	-	-	-	-	0.02	-	-	-
>25	0.8	-	-	-	0.1	-	-	-
>5	6.3	-	-	-	0.9	-	-	-
	Day 2	**Day 7**	**Day 14**	**Day 30**	**Day 2**	**Day 7**	**Day 14**	**Day 30**
	Southwest Wind				**Northeast Wind**			

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre; % = percent.

Table B-2 Volume of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m with a Total Suspended Solids Concentration Greater Than Indicated as a Result of a Storm Event in the Open-water Season with a Wind Speed of 6 m/s and a Sediment Settling Velocity of 0.10 m/d

TSS [mg/L]	Volume of Areas 2 and Areas 3 and 5 [%]							
>500	0.4	-	-	-	0.02	-	-	-
>100	7.0	-	-	-	0.5	-	-	-
>25	41.8	1.5	-	-	13.3	-	-	-
>5	86.5	76.7	-	-	55.6	0.02	-	-
	Day 2	**Day 7**	**Day 14**	**Day 30**	**Day 2**	**Day 7**	**Day 14**	**Day 30**
	Southwest Wind				**Northeast Wind**			

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre; % = percent.

Table B-3 Volume of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m with a Total Suspended Solids Concentration Greater Than Indicated as a Result of a Storm Event in the Open-water Season with a Wind Speed of 6 m/s and a Sediment Settling Velocity of 0.01 m/d

TSS [mg/L]	Volume of Areas 2 and Areas 3 and 5 [%]							
>500	1.2	-	-	-	0.02	-	-	-
>100	9.9	2.8	1.1	-	1.0	-	-	-
>25	54.4	96.6	96.8	0.8	17.1	0.02	-	-
>5	90.2	98.8	96.8	41.5	64.7	96.8	73.2	56.4
	Day 2	**Day 7**	**Day 14**	**Day 30**	**Day 2**	**Day 7**	**Day 14**	**Day 30**
	Southwest Wind				**Northeast Wind**			

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre; % = percent.

Table B-4 Volume of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m with a Total Suspended Solids Concentration Greater Than Indicated as a Result of a Storm Event in the Open-water Season with a Wind Speed of 8 m/s and a Sediment Settling Velocity of 1.0 m/d

TSS [mg/L]	Volume of Areas 2 and Areas 3 and 5 [%]							
>500	-	-	-	-	0.02	-	-	-
>100	-	-	-	-	0.1	-	-	-
>25	3.7	-	-	-	0.3	-	-	-
>5	14.3	-	-	-	4.8	-	-	-
	Day 2	**Day 7**	**Day 14**	**Day 30**	**Day 2**	**Day 7**	**Day 14**	**Day 30**
	Southwest Wind				**Northeast Wind**			

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre; % = percent.

Table B-5 Volume of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m with a Total Suspended Solids Concentration Greater Than Indicated as a Result of a Storm Event in the Open-water Season with a Wind Speed of 8 m/s and a Sediment Settling Velocity of 0.10 m/d

TSS [mg/L]	Volume of Areas 2 and Areas 3 and 5 [%]							
>500	2.8	-	-	-	0.1	-	-	-
>100	18.1	1.0	-	-	2.6	-	-	-
>25	67.0	4.2	-	-	28.1	-	-	-
>5	97.2	96.4	-	-	82.6	7.6	-	-
	Day 2	**Day 7**	**Day 14**	**Day 30**	**Day 2**	**Day 7**	**Day 14**	**Day 30**
	Southwest Wind				**Northeast Wind**			

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre; % = percent.

Table B-6 Volume of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m with a Total Suspended Solids Concentration Greater Than Indicated as a Result of a Storm Event in the Open-water Season with a Wind Speed of 8 m/s and a Sediment Settling Velocity of 0.01 m/d

TSS [mg/L]	Volume of Areas 2 and Areas 3 and 5 [%]							
>500	5.8	1.1	-	-	0.2	-	-	-
>100	25.4	32.2	3.0	-	7.2	-	-	-
>25	78.3	98.3	98.2	61.1	42.1	78.1	-	-
>5	98.9	98.3	98.2	61.1	88.7	98.2	85.0	23.9
	Day 2	**Day 7**	**Day 14**	**Day 30**	**Day 2**	**Day 7**	**Day 14**	**Day 30**
	Southwest Wind				**Northeast Wind**			

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre; % = percent.

Table B-7 Volume of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m with a Total Suspended Solids Concentration Greater Than Indicated as a Result of a Storm Event in the Open-water Season with a Wind Speed of 10 m/s and a Sediment Settling Velocity of 1.0 m/d

TSS [mg/L]	Volume of Areas 2 and Areas 3 and 5 [%]							
>500	-	-	-	-	0.02	-	-	-
>100	1.0	-	-	-	0.1	-	-	-
>25	6.7	-	-	-	0.6	-	-	-
>5	24.5	-	-	-	10.7	-	-	-
	Day 2	**Day 7**	**Day 14**	**Day 30**	**Day 2**	**Day 7**	**Day 14**	**Day 30**
	Southwest Wind				**Northeast Wind**			

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre; % = percent.

Table B-8 Volume of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m with a Total Suspended Solids Concentration Greater Than Indicated as a Result of a Storm Event in the Open-water Season with a Wind Speed of 10 m/s and a Sediment Settling Velocity of 0.10 m/d

TSS [mg/L]	Volume of Areas 2 and Areas 3 and 5 [%]							
>500	9.1	-	-	-	0.2	-	-	-
>100	30.4	1.4	-	-	12.0	-	-	-
>25	88.3	30.9	-	-	52.6	-	-	-
>5	99.4	98.3	-	-	94.6	96.1	-	-
	Day 2	**Day 7**	**Day 14**	**Day 30**	**Day 2**	**Day 7**	**Day 14**	**Day 30**
	Southwest Wind				**Northeast Wind**			

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre; % = percent.

Table B-9 Volume of Area 2 and Areas 3 and 5 at an Elevation of 417.7 m with a Total Suspended Solids Concentration Greater Than Indicated as a Result of a Storm Event in the Open-water Season with a Wind Speed of 10 m/s and a Sediment Settling Velocity of 0.01 m/d

TSS [mg/L]	Volume of Areas 2 and Areas 3 and 5 [%]							
>500	12.0	1.3	0.9	-	0.3	-	-	-
>100	41.6	96.3	91.4	0.7	17.5	0.02	-	-
>25	95.2	97.8	91.4	72.9	67.9	97.6	88.8	-
>5	99.4	97.8	91.4	72.9	97.9	98.5	88.8	33.5
	Day 2	**Day 7**	**Day 14**	**Day 30**	**Day 2**	**Day 7**	**Day 14**	**Day 30**
	Southwest Wind				**Northeast Wind**			

m = metre; m/s = metres per second; m/d = metres per day; mg/L = milligrams per litre; % = percent.

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