KGS GROUP

Memorandum

To:	James Betke, P.Eng.	**Date:**	December 7, 2021
		Project No.:	18-0300-005
From:	Patrice Leclercq, P.Eng.	**Cc:**	Colin Siepman, P.Eng. Dave MacMillan, P.Eng.
Re:	**Preliminary Hydraulic Design of the LSMOC Outside Drain, Rev 0**		

1.0 INTRODUCTION

This document summarizes the Preliminary Hydraulic Design of the Lake St. Martin Outlet Channel outside drain. The following summarizes key components of the design criteria:

- The drain must have sufficient capacity to maintain water levels below ground surface for flows in the range of a 1:2 and 1:5 year event during construction.
- The design must minimize the potential for erosion of the clay or till soil during passage of the 1:10 year discharge event. The erosion threshold for the clay (6 Pa) or till (10 Pa) soil will be based on those assumed for the LSMOC channel. The lower threshold of 6 Pa will also be applied to peat soils however erosion of the peat would be expected over time depending on the material property and how the peat deteriorates.
- Flows outside of the excavated drain beyond the limits of the ROW is permitted but should be minimized during the 1:10 year discharge event. However, construction must remain within ROW limits.
- In areas of high topography, (Type 1 drain), long term maintenance activities will be typical of other provincial drains across Manitoba.
- In other locations (Type 2 & 3 drains) the design should assume minimal maintenance affecting the drain capacity.
- Gradient Control Structures will be required to control water velocities and reduce potential for erosion. During high flow events, they will also allow for a wider flow path in the downstream reach to promote natural filtration.

2.0 HYDRAULIC DESIGN

The drain consists of a trapezoidal excavated channel divided into 16 reaches (named A through P), and 15 Gradient Control Structures (GCS) (named 1 through 15). As indicated in the design criteria, the drain is categorized into three types, summarized in Table 1. The Manning roughness values presented in Table 1 correspond to the states of the drain during and shortly following construction (Scenario A), and many years after construction has been completed (Scenario B).

TABLE 1: DRAIN TYPE SUMMARY

			Scenario A During Construction (within 5 yrs)		Scenario B Post Construction (5+ yrs)	
Category	Invert Material	Side Slopes	$n_{channel}$	$n_{overland}$	$n_{channel}$	$n_{overland}$
Type 1	Mineral soil	4H:1V	0.03	0.10	0.03	0.12
Type 2	Peat/mineral soil	3H:1V	0.04	0.10	0.07	0.12
Type 3	Peat/mineral soil	3H:1V	0.04	0.12	0.10	0.15

Details of the drainage channel geometry are shown in Table 2.

TABLE 2: HYDRAULIC DESIGN SUMMARY OF DRAIN (1:5 YEAR DISCHARGE, SCENARIO A)

ID	Sta. Start [m]	Sta. End [m]	El. Start [m]	El. End [m]	Slope	Type	Design Event	Q [m^3/s]	B [m]	n Drain	m [h:1v]	y [m]	V [m/s]	Shear [Pa]
A	1650	4200	244.2	243.7	0.00020	Type 2	5 yr	1.33	4	0.04	3	0.84	0.24	1.6
B	4200	10000	242.7	239.2	0.00060	Type 2	5 yr	3.17	7	0.04	3	0.77	0.44	4.6
C	10000	12000	239.2	238.0	0.00060	Type 1	5 yr	3.74	6	0.03	4	0.75	0.55	4.4
D	12000	13200	237.4	236.7	0.00060	Type 2	5 yr	4.07	9	0.04	3	0.79	0.45	4.6
E	13200	14100	235.6	235.1	0.00060	Type 2	5 yr	4.32	9	0.04	3	0.81	0.46	4.8
F	14100	14700	234.0	233.6	0.00060	Type 2	5 yr	4.48	10	0.04	3	0.79	0.46	4.6
G	14700	15400	233.0	232.6	0.00060	Type 2	5 yr	4.67	10	0.04	3	0.81	0.47	4.7
H	15400	16500	232.0	231.6	0.00040	Type 2	5 yr	4.97	10	0.04	3	0.94	0.41	3.7
I	16500	17900	231.2	230.4	0.00060	Type 1	5 yr	5.34	8	0.03	4	0.80	0.59	4.7
J	17900	18500	229.4	229.0	0.00060	Type 3	5 yr	5.49	12	0.04	3	0.81	0.47	4.7
K	18500	19400	227.9	227.4	0.00060	Type 3	5 yr	5.72	13	0.04	3	0.79	0.47	4.6
L	19400	20100	226.0	225.6	0.00060	Type 3	5 yr	5.90	13	0.04	3	0.80	0.48	4.7
M	20100	20800	224.1	223.7	0.00060	Type 3	5 yr	6.07	14	0.04	3	0.79	0.47	4.6
N	20800	21100	222.2	222.0	0.00060	Type 3	5 yr	6.15	14	0.04	3	0.79	0.47	4.7
O	21100	22600	220.8	219.9	0.00060	Type 3	5 yr	6.53	14	0.04	3	0.82	0.48	4.8
P	22600	23000	218.5	218.3	0.00060	Type 3	5 yr	6.63	14	0.04	3	0.83	0.49	4.9

Notes: Q = discharge, B = base width, m = side slope, y = depth of flow, V = velocity

As shown, the drain width generally increases in the downstream direction, to maintain the normal flow depth around 0.8 m (and thus keep the velocity and shear stress approximately constant along the drain). The slope of the drain is 0.0006 everywhere, except for reaches A and H where the slope is shallower to better fit the natural ground.

The GCSs are designed to create a backwater effect that limits water velocities and shear stresses in the drain to permissible levels. Two alternatives were considered: (i) structures with a narrowed base width to create a flow constriction, and (ii) structures with a raised crest. While both options are viable to control drain hydraulics, option (ii) was selected due to the ability to utilized steeper chutes and reduce riprap quantities compared to option (i).

Properties of the GCSs are shown in Table 3. The crest heights were selected to create a backwater effect that equals the normal depth at the 1:5 year design flow (Table 1). The chute slopes were designed to pass the 1:25 year flow with no damage to the riprap, and the 1:200 year flow without ultimate failure (washout). A riprap D50 of 0.2 m was adopted for design. Refinements to the number and location of structures will be undertaken in detailed design with input from MI.

TABLE 3: SUMMARY OF GRADIENT CONTROL STRUCTURES

ID	Station [m]	Crest Height [m]	Chute Slope [h:1v]	Drop Height [m]
GCS1	4200	0.63	10:1	1.0
GCS2	12000	0.41	18:1	0.6
GCS3	13200	0.47	18:1	1.1
GCS4	14100	0.48	18:1	1.1
GCS5	14700	0.46	18:1	0.7
GCS6	15400	0.47	18:1	0.6
GCS7	16500	0.60	24:1	0.4
GCS8	17900	0.43	18:1	1.0
GCS9	18500	0.47	18:1	1.2
GCS10	19400	0.45	18:1	1.4
GCS11	20100	0.46	18:1	1.5
GCS12	20800	0.45	18:1	1.5
GCS13	21100	0.46	18:1	1.2
GCS14	22600	0.47	18:1	1.4
GCS15	23000	0.47	18:1	1.0

The total estimated volume of excavation for this drain design is approximately 520,000 m^3. The estimated volume of riprap required for the GCSs is approximately 7,500 m^3. It should be noted that the quantity estimates are preliminary and subject to change as further analyses are undertaken and the design is refined.

3.0 MODELLING RESULTS

A 1D HEC-RAS model was used to assess the drain hydraulics. Water surface profiles are shown for events ranging from the 1:2 year to the 1:10 year in Figure 1 to Figure 3. Profiles are shown for Scenario A (during and shortly after construction when the Manning's n values are low; n = 0.03 and 0.04 in the drain), and Scenario B (many years after construction when the Manning's n values in the Type 2 and 3 drains are higher where there is assumed growth of vegetation and potentially minimal maintenance affecting capacity; n = 0.07 to 0.10 in the drain).

As shown on the figures, the water surface profile for the 1:5 year event for the low Manning's n scenario (during construction) meets design criteria as it is below ground surface along the entire length of the drain. To reduce excavation quantities, there may be an opportunity to raise the drain invert or narrow the base width in discrete locations along the profile without raising the water level above the ground surface. This will be reviewed during detailed design.

FIGURE 1: 1:2 YEAR PROFILE

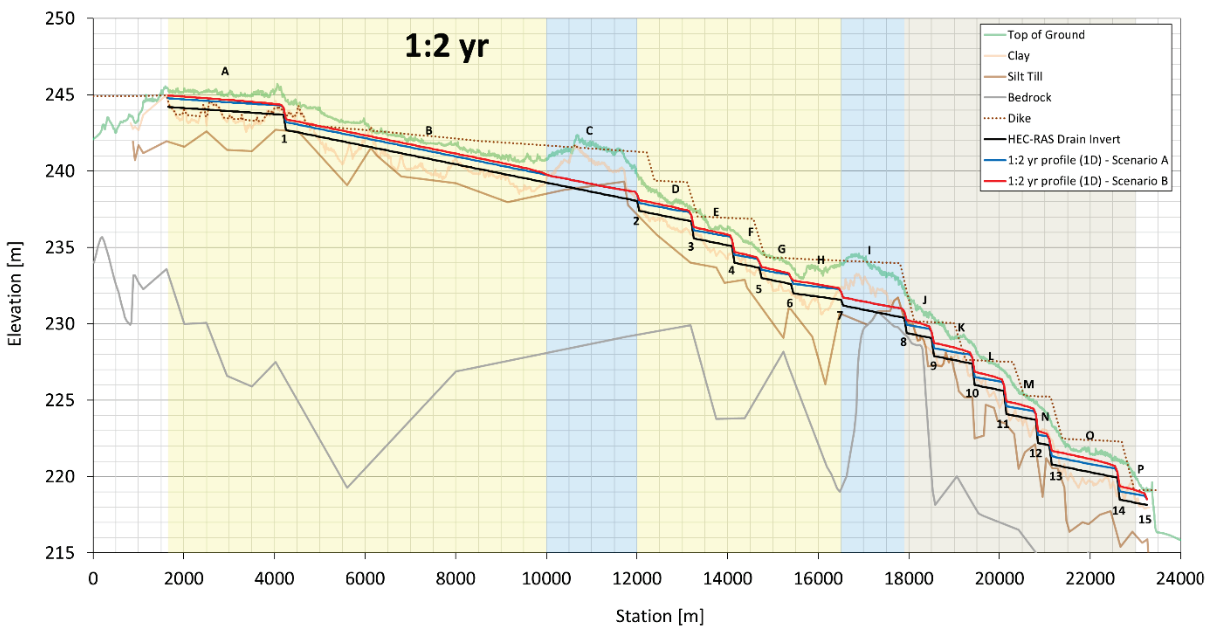


FIGURE 2: 1:5 YEAR PROFILE

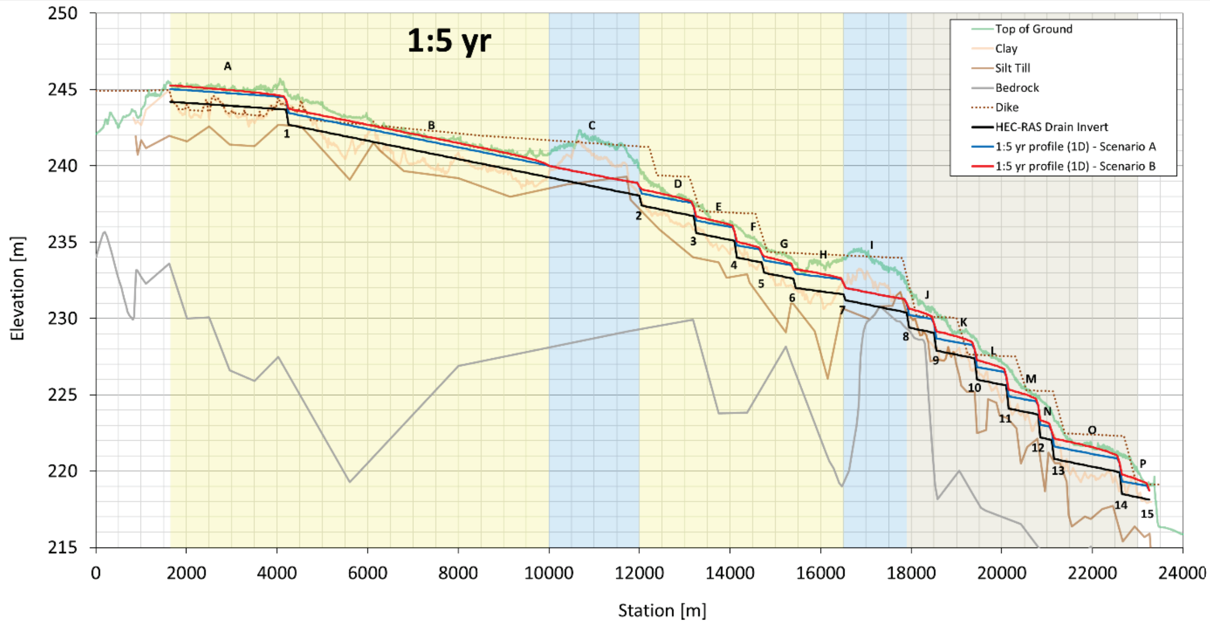
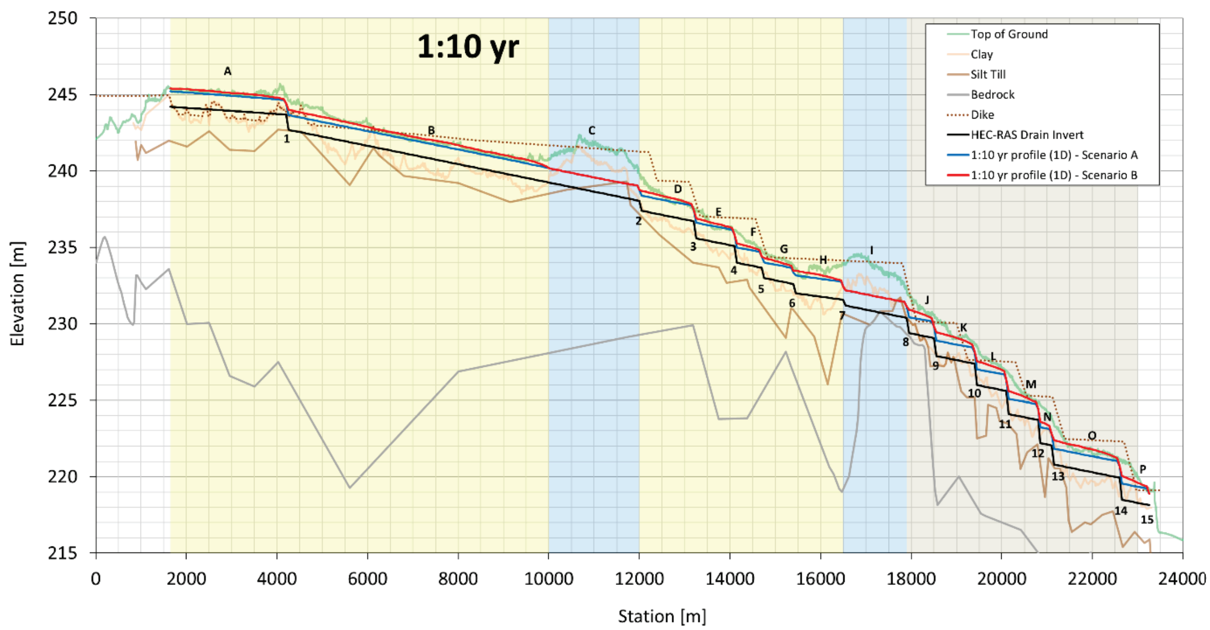


FIGURE 3: 1:10 YEAR PROFILE



The shear stress and velocity profiles for Scenario A (soon after construction) are shown in Figure 4 and Figure 5, respectively.

FIGURE 4: SHEAR STRESS PROFILE

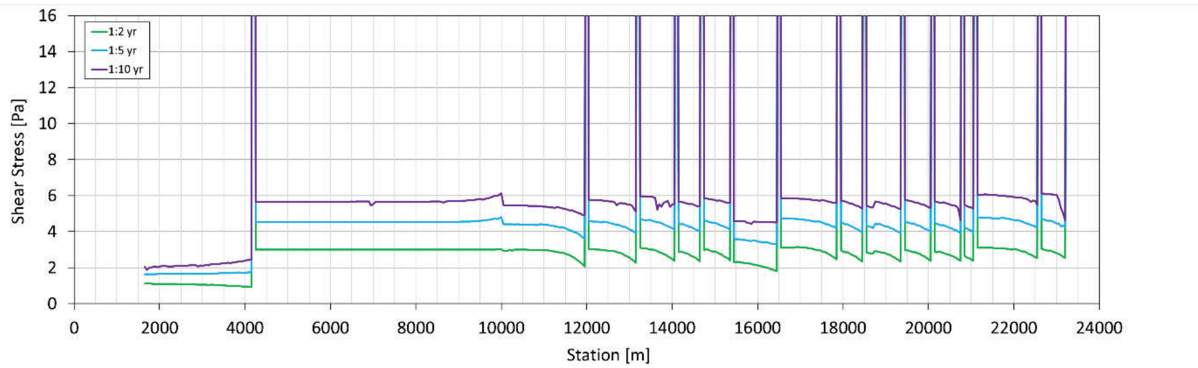
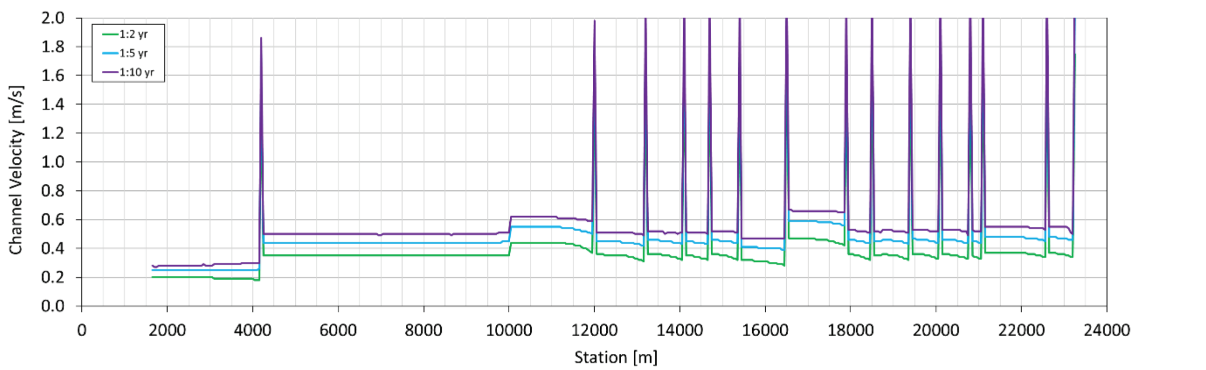


FIGURE 5: VELOCITY PROFILE



As shown, the drain design is adequate to pass the 1:10 year event while keeping shear stresses below 6 Pa. As discussed in Section 1.0, 6 Pa was adopted as the erosion criteria in clay. Where the drain invert is located in peat, erosion of the peat would be expected over time. The extent of erosion will depend on the material properties and how the peat deteriorates.

At the GCSs, there is a risk of seepage flows occurring through the peat around the structures. This may result in particle migration and erosion of the peat. The erosion could lead to settlement and movement of the riprap lined side slopes or development of alternate flow paths outside the excavated drain. The addition of flow paths around the GCSs will modify the hydraulic control provided by the structures, and could lead to increased velocities and subsequent erosion of the drain upstream. Regular monitoring of the structures will therefore be required to confirm performance and identify any required repairs. Routine maintenance activities will likely be required and would mostly consist of regrading and/or replacing of riprap that has moved or settled from its original position. Placement of additional riprap on the edges of the structures or at locations where erosion has occurred may also be required to mitigate the development of alternate flow paths.

4.0 INUNDATED AREAS

A 2D HEC-RAS model was used to assess the extent of inundated land during passage of the 1:10 year flow many years after construction (Scenario B; high Manning's roughness). Results are shown in Figure 6. During passage of the 1:5 year flood event or smaller, most of the flows are contained within the drain. During passage of flows more extreme than the 1:10 year flow, the extent of inundated areas would be greater, and could remain for a longer duration of time. Ponded water could flow overland towards Lake Winnipeg outside of the drain (i.e. bypassing the GCSs). The need to top up channel dikes or include rockfill overflow sections to prevent uncontrolled overflow from outside the LSMOC will be reviewed at detailed design.

FIGURE 6: INUNDATED AREA FOR 1:10 YEAR EVENT (SCENARIO B)

It should be noted that the results only depict the flows conveyed by the drain and did not include hydrodynamic modeling of runoff through the wetlands east of the channel before it enters the drain. During large runoff events, it would be expected that parts of the wetlands would already be flooded naturally while flows move overland towards receiving streams.

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