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TECHNICAL MEMORANDUM No. 1

Town of Ladysmith
Stocking Lake Access Road - Culvert Repair

Town of Ladysmith
Box 220
Ladysmith, BC V9G 1A2
File 2018-TM1

Issued: June 9, 2020 Reference Drawings: Figure 1, Figure 2
Previous Issue Date: May 6, 2020

1. Objective

The objective of this technical memo is to provide culvert sizing options for replacement of the existing failed culvert that crosses the only access road to the Stocking Lake dam and water supply intake that is operated and maintained by the Town of Ladysmith and the Cowichan Valley Regional District.

2. Background

The failed culvert is a 1200 mm diameter CSP pipe located about 100 metres south of the valve house and conveys drainage from the Stocking Lake dam spillway. A second 1200 mm dia. CSP culvert (located approximately 28 metres further south) crosses the access road at a lower elevation and conveys flows from a localized catchment. The second culvert also acts as an overflow from the upper 1200 CSP. The second culvert seems to be in reasonable condition, even though it is likely the same age as the failed culvert.

3. Catchment Areas and Design Flows

Figure 1 shows the existing catchment areas and the two culverts, labeled “Culvert A” and “Culvert B”. The catchment area for Culvert A includes the 190 ha catchment for Stocking Lake and an additional 7.3 ha area located downstream of the dam. The catchment area for Culvert B is estimated to be 23 ha.

Design Flows:
In November 2018, Ecora prepared a “Dam Safety Review and Risk Assessment of the Stocking Lake Dam”. Section 11 of the document detailed a Hydrotechnical Assessment of the Stocking Lake watershed that included peak inflows and outflows. In Ecora’s report, the suggested peak outflow was computed to be 1/3rd between the 1000-year return period flood flow and the Probable Maximum Flood flow (PMF). For the dam spillway, this peak outflow was listed as 3.8 m^3/s (3,800 l/s).

A road culvert in a municipality would typically be designed using a maximum design standard of a 100-year return period. A critical highway culvert would typically be designed using a maximum design standard of a 200-year return period. As the Stocking Lake outflow that has been suggested in the Ecora report greatly exceeds flows generated using typical culvert design standards, we have used the Ecora flow as the design outflow from the dam. We feel this is justified because it could be critically important to maintain access to the Stocking Lake dam during a major outflow event. Allowing the drainage from the dam to overtop the access road and wash it out during a major event would most certainly cut off access and prevent emergency maintenance on the dam and water supply infrastructure.

In addition to the design outflow from the dam there will be a relatively small flow generated from the 7.3 ha catchment that is located below the dam. To calculate the flow from the 7.3 ha catchment we have assumed a 100-year return period and a time of concentration of 35 minutes. We feel this is a conservative assumption because by the time the 3,800 l/s outflow from the dam reaches Culvert A, the high peak flows from the 7.3 ha catchment will have already passed through Culvert A. When analysed separately, the 100-year return period flow for the 7.3 ha catchment is estimated to be 220 l/s, based on a time of concentration of 35 minutes. To establish the Culvert A design peak flow we added the 3,800 l/s outflow from the dam to the 220 l/s flow from the 7.3 ha catchment for a total design peak flow for Culvert A of 4,020 l/s.

Using the same assumptions as used on Culvert A, the 100-year flow for Culvert B is 780 l/s, based on a 23 ha catchment and a 29 minute time of concentration. Table 1 shows the design peak flows for the two culverts.

Table 1

Culvert	Catchment Area (ha)	Peak flow (l/s)	Return period
Culvert A (Ex. 1200)	190 + 7.3	4, 020	+1000/100 year
Culvert B (Ex. 1200)	23	780	100 year

Climate Change:
No additional flows have been added to account for climate change. Many jurisdictions are starting to increase peak flows or rainfall amounts by 15-20% to compensate for how climate change may increase rainfall within the next 80 years. Given that the Dam Safety Assessment peak flows greatly exceed the predicted 1000-year return period, it seems unnecessary to increase these flows further. However, the 100-year peak flow from the 7.3 and 23 ha catchments could be considered. We have made a footnote at the bottom of Table 2 indicating the status of Culvert B if 20% is added to the peak flows from the smaller catchments.

4. Culvert Sizing and Hydraulics

Koers & Associates surveyed the area around Culvert A. Figure 2 shows the invert elevations as well as the overflow and overtopping elevation. The survey confirmed that in the current configuration, Culvert A will convey 100 % of the flow from the spillway until the headwater at the culvert inlet reaches an elevation of 335.34 m, at which point the flow will split with a portion of it flowing down the overflow ditch towards Culvert B.

The following shows the existing culvert hydraulics, including the maximum capacities up to the design flows.

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Culvert A - Existing 1200 mm CSP:

Capacity (Hw/d = 1)	2200 l/s
Capacity before overflow ditch elevation (Hw/d = 0.67)	1250 l/s
Capacity to road overtopping (Hw/d= 1.04)	2250 l/s

Culvert B - Existing 1200 mm CSP:

Capacity (Hw/d = 1)	2200 l/s
Capacity at 0.6 m freeboard (Hw/d = 1.60)	3450 l/s
Capacity to road overtopping (Hw/d = 2.10)	4300 l/s

Overflow Ditch:

Capacity of overflow ditch at road overtopping elevation (0.5m depth) 600–2500* l/s

*Note: the overflow ditch may have a 2500 l/s capacity but the ditch's narrow entrance at Culvert A may act like a weir, restricting water from entering the overflow ditch and significantly reducing its ability to convey water down to Culvert B.

The capacity of any culvert can be based on either Inlet Control or Outlet Control. This mostly depends on the grade of the culvert and if there is a backwater at the culvert outlet. With Culverts A and B having steep grades of about 14% and no indication of any backwater at the outlet, their capacities will be governed by Inlet Control. The ratio of Headwater divided by inlet depth (Hw/d) is a key input for determining the culverts ability to convey flows. When Hw/d =1, the culvert is considered full. Anything above 1, would indicate a surcharged culvert inlet.

The hydraulics indicate that Culvert A (1200 mm CSP) will convey about 1250 l/s before the overflow ditch will begin to divert flow down to Culvert B. The maximum flow that Culvert A can convey before overtopping the road is 2250 l/s. However, further analysis indicates that if Culvert A had to convey the design flow of 4,020 l/s, the headwater would surcharge to the road level and about 2200 l/s would be conveyed through the culvert with about 400-1400 l/s conveyed through the overflow ditch and the remainder would overtop the access road.

The analysis of the existing culverts indicates that Culvert A is undersized for the design flow and should be upgraded to a larger size. Overflow to Culvert B may be acceptable if the total flow to Culvert B does not exceed its capacity at Hw/d=1. Any culvert where the Hw/d exceeds 1.0 is generally considered to be undersized unless it has an overflow.

<u>Sizing Options:</u>

Using the design peak flows from Table 1 and leaving the overflow elevation set at 335.39 m, we have determined several culvert sizing options and configurations. The option that is ultimately chosen will most likely depend on several factors including cost of installation, ease of installation and culvert life span. With Culvert A already having minimal cover, culverts larger than 1200mm will require additional gravel to raise the road. There is no ability to lower Culvert A without also lowering the existing shallow water supply main that was installed just below it. Widening of the flow channel to accommodate a larger culvert (or twin culverts) will likely require some rock excavation as solid rock is visible at the surface around Culvert A.

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The sizing options presented below in Table 2 assume the new culvert will have the same inverts and grade as the existing culvert and a proper inlet headwall with wingwalls will be constructed.

Option 1: **New 1500 mm concrete culvert**
Option 2: **New 1600 mm CSP culvert**
Option 3: **New 1.2m x 2.1m concrete box culvert**
Option 4: **New 1.2 m x 2.4m concrete box culvert**
Option 5: **New 2 x 1200 concrete culverts**
Option 6: **New 2 x 900 Boss 2000 culverts**

Table 2

Option	Culvert A	Peak Flows (l/s)			Hw/d		Headwater
		Culvert A	Overflow	Culvert B (max)	Culvert A	Culvert B	Culvert A (m)
Existing	1200mm dia CSP	2200	**370-1400**	2180	1	1.10	1.20
1	**1500mm dia Concrete**	3100	**635-920**	1700	0.87	0.83	1.30
2	**1600mm dia CSP**	3450	570	1350	0.82	0.70	1.30
3	**1.2m x 2.1m Concrete Box**	3900	120	900	0.88	0.53	1.26
4	**1.2 x 2.4m Concrete Box**	3950	70	850	0.80	0.51	0.96
5	**2 x 1200mm dia Concrete**	3900	120	900	0.93	0.53	1.10
6	**2 x 900mm dia Boss 2000**	2860	**370-1160**	1940	1.33	0.90	1.20

Notes: 1. Hw/d in Culvert B (with climate change taken into consideration) is still less than 1 for Option 6.
2. Other culvert configurations may also be feasible.

5. Discussion of Options

Option 1: Would require raising the road to accommodate the lager pipe and avoid re-locating the 250 mm dia. watermain. The inlet width at the start of the overflow ditch would also have to be widened to ensure an adequate flow is directed towards Culvert B.

Option 2: Would require raising the road for the larger pipe. The lifespan of CSP is not expected to be as long as concrete or HDPE.

Option 3: Minimal road regrading required. A pre-cast headwall structure may help simplify the installation but will need to assess conflict potential with existing watermain. Likely need to perform rock excavation to widen the flow path for the larger culvert.

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Option 4: The extra capacity compared to Option 3 is quite minimal.

Option 5: Minimal road regrading required. A pre-cast headwall structure may help simplify the installation but will need to assess conflict potential with existing watermain. Likely need to perform rock excavation to widen the flow path required for the twin culverts.

Option 6: Culvert A would not meet the preferred design standard of Hw/d = 1(max) but there is sufficient overflow capacity available. Likely need to perform rock excavation to widen the flow path required for the twin 900 mm dia. culverts. The overflow will need to be widened to ensure an adequate flow can be directed towards Culvert B. A pre-cast headwall structure may help simplify the installation otherwise a cast in place headwall should be constructed.

6. Conclusions and Recommendations

From the analysis shown in this memo, we offer the following conclusions:

- The design flows for Culverts A and B are 4,020 l/s and 780 l/s respectively. Collectively the two culverts need to handle a design peak flow of 4,800 l/s.
- The existing Culvert A (1200 CSP) is considered to be undersized.
- All the options indicate that the there will be some overflow to Culvert B. The throat of the overflow ditch should be widened to ensure an adequate amount of flow is directed into the overflow ditch and down to Culvert B.
- For all options, Culvert A has minimal cover. Some road filling and re-grading will be required for pipes 1200 mm in diameter or larger.

We recommend the following options be considered:

1. Option 3 (1.2 x 2.1m concrete box culvert). This Option requires minimal road re-grading and has less of a reliance on the overflow ditch and Culvert B. Option 3 will have higher costs and may require mobilizing a crane to install the box culvert sections.
2. If Option 6 (twin 900 mm dia. Bass 2000) is chosen, the throat of the overflow will need to be widened to accommodate a larger flow to Culvert B. With the inlet being surcharged slightly, a substantial pre-cast or cast-in-place headwall is recommended.

If additional options are considered, detailed modelling should be performed to confirm culvert capacities and freeboard.

Yours truly,

KOERS & ASSOCIATES ENGINEERING LTD.

R Cave

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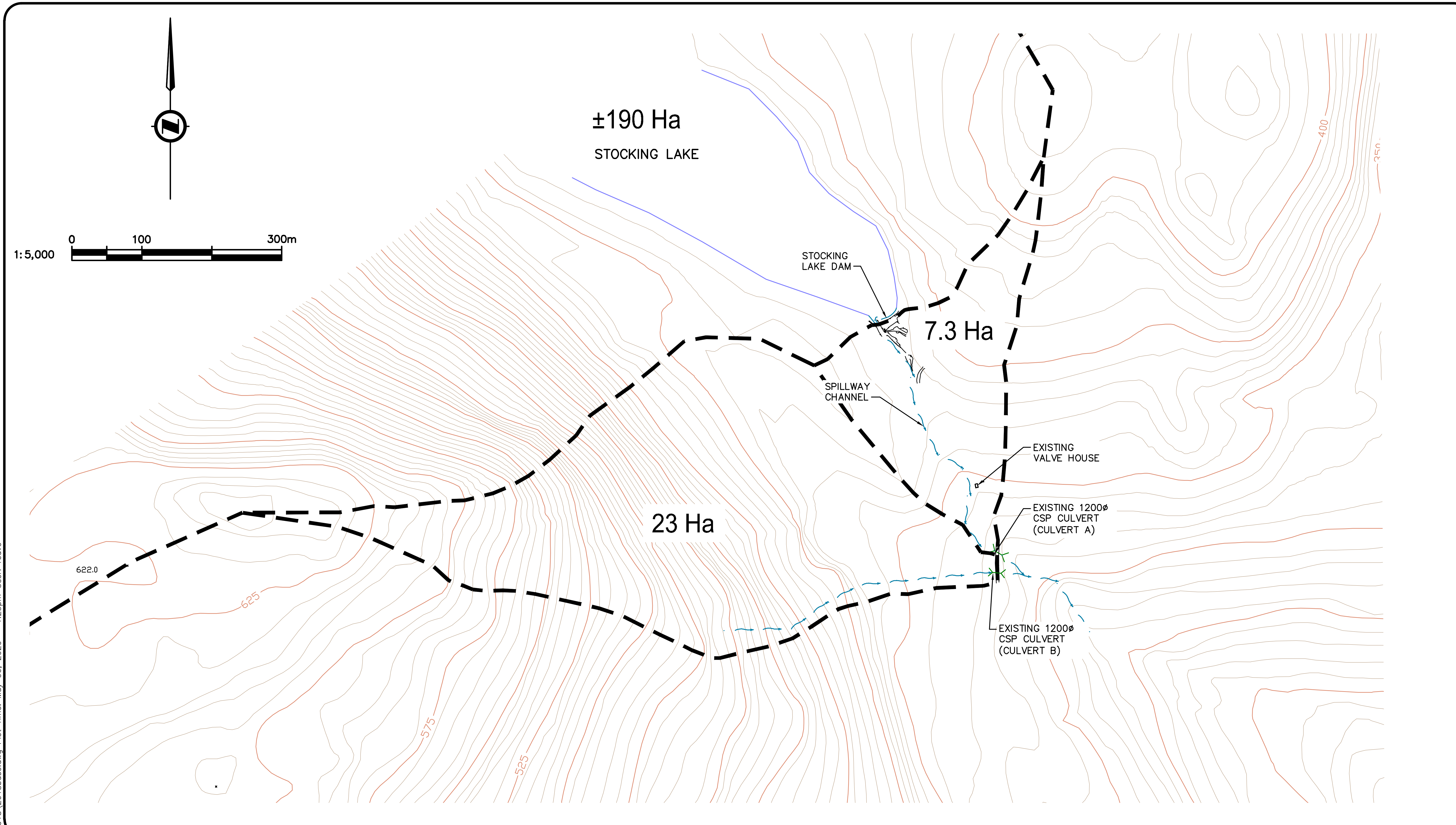
Enclosures: Figure 1, Figure 2



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CLIENT	TOWN OF LADYSMITH
PROJECT	STOCKING LAKE ACCESS CULVERT REPAIR

TITLE	CATCHMENT AREA PLAN		
APPROVED	MP	SCALE	1:2000
DATE	MAY 2020	DWG No.	FIGURE 1
PROJECT No.	2018		

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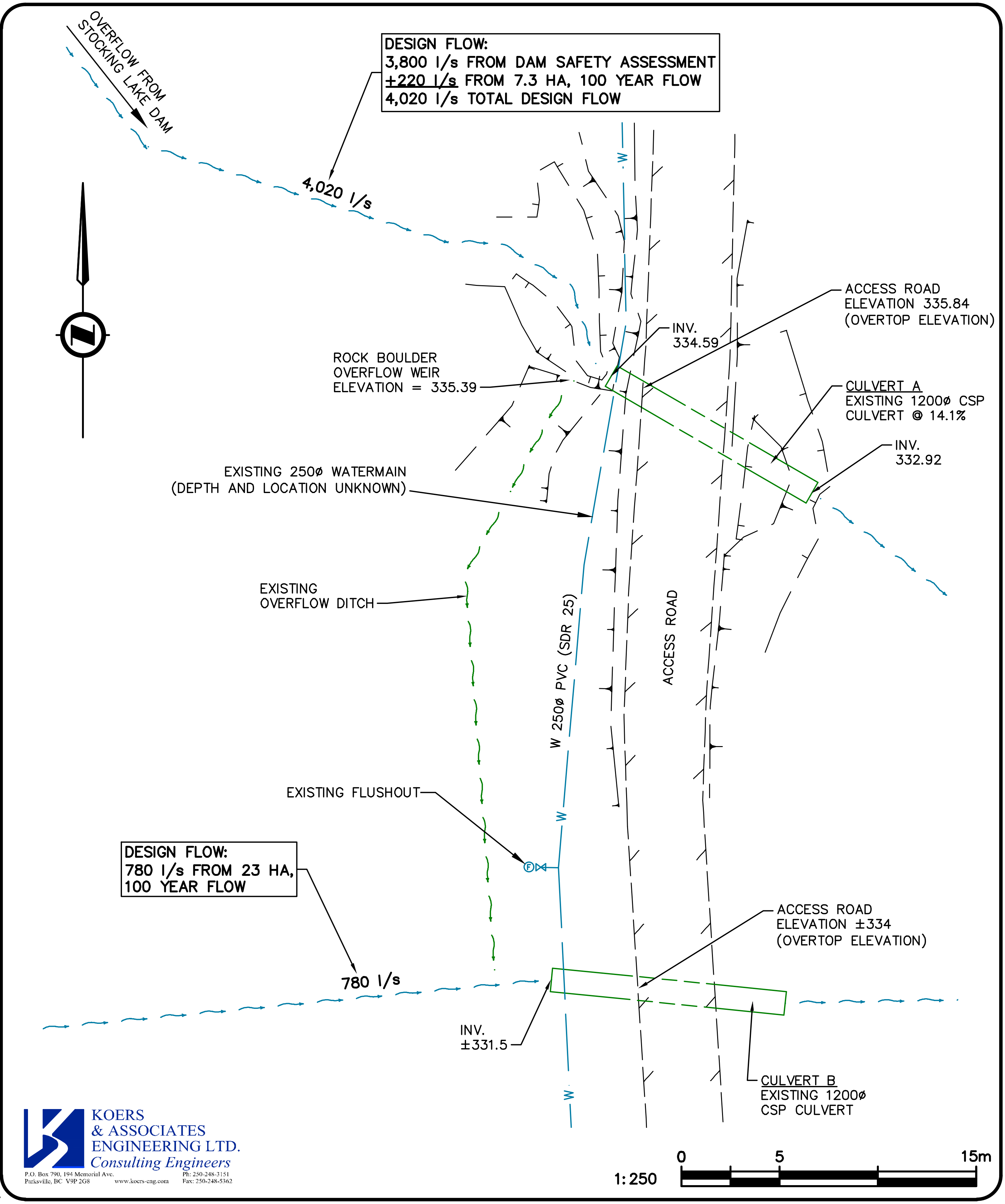

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CLIENT	TOWN OF LADYSMITH
PROJECT	STOCKING LAKE ACCESS CULVERT REPAIR

TITLE	**SITE PLAN – EXISTING CONDITIONS**		
APPROVED	MP	SCALE	1:250
DATE	MAY 2020	DWG No.	**FIGURE 2**
JOB No.	2018		