REPORT

Regional District of East Kootenay

Tie Lake Dam
Engineering Assessment

September 2016

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1 Introduction

Tie Lake Dam is an unregulated earth-filled dam used primarily to maintain lake levels for a small community of private properties and recreational purposes. Tie Lake is relatively shallow, with 5.5metres being its deepest point. The dam's outlet structure was re-constructed approximately 35 years ago, and only minor maintenance has occurred since the upgrade. The RDEK recently conducted an annual inspection of the dam, and noted concerns about the capacity of the outlet structure, the amount of freeboard and the lack of general design information available. In an effort to identify upgrades necessary to meet the minimum standards outlined in the Canadian Dam Safety Guidelines, the RDEK required the following:

1. Review the consequence classification of Tie Lake Dam;
2. Perform all tasks required to perform an engineering assessment of the Dam;
3. Liaise as required with the BC Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) Dam Safety Officer assigned to the Dam;
4. Provide conceptual designs and cost estimates for any recommendations resulting from the Dam engineering assessment; and
5. Other conditional or optional items to improve this project for the RDEK to consider.

The project team responsible for this assessment include Project Manager and Dam Safety Engineer Roderick MacLean, P.Eng., Senior Hydrologist Drew Lejbak and Structural Engineer, Dale Harrison, P.Eng.

2 Background

According to local records, the Tie Lake dam is an earth filled dam constructed in the 1920's by the Canadian Pacific Railroad. The purpose of the facility was to raise water levels sufficiently to connect three smaller natural depressions to facilitate the storage and transportation of logs and railway ties.

Tie Lake Dam is located along the south end of the lake near Tie Lake Road. The dam is 60 metres long, consisting of an earth or gravel berm forming a barrier above the normal water level of the lake. Trenched into the dam is a concrete vertical wall slab with a 500mm wide and 500 mm deep rectangular opening as a defined weir. The geodetic elevation of the weir was unknown at the time of this work. The dam is further protected by a shallow 300mm diameter corrugated steel pipe which provides some additional flow routing should water levels exceed 200mm above Full Supply Level (FSL).

The top of dam is uneven, and ranges in in height between 500mm and 600mm above FSL.

2.1 DAM OWNERSHIP RECORD

- Pre-1970 Unknown
- 1970–1984 Tie Lake Ratepayers' Association (TLRA),
- 1984–2000 Tie Lake Improvement District (TLID),
- 2000–Present Regional District of East Kootenay (RDEK)

2.2 BACKGROUND INFORMATION

Site Inspection
On July 20th, 2016, Rod MacLean of Associated Engineering conducted an inspection of the dam site. Mr. MacLean was accompanied by Kara Zandbergen and Brian Funke, A.Sc.T. from the Regional District of East Kootenay. The inspection took place primarily at the dam site, although the group drove around the lake to investigate stream entrances and potential low areas of concern. No other outlets from the lake were found.

The dam site was accessed through the Tie Lake Forest Service Campground located at the west end of the campground at a picnic and small parking area. The facility is publicly accessible, however the outlet structure on the dam is protected with a security fence.

There are no major surface streams feeding Tie Lake. The majority of inflow to Tie Lake appears to be from underground springs located primarily on the north-east side of the lake as influenced by the level of the groundwater table. For some fifty years the above culvert was the only outlet from the lake. The hydrology of Tie Lake is discussed later in this report.

2.3 OBSERVATIONS

Since the dam history and design is poorly documented, it was necessary to inspect the entire facility and note observations that may assist with determining certain design criteria. Photographs were added to help describe the observations.

1. **<u>Full Service Level (FSL):</u>** The photos below show the upstream gate invert and inlet condition. At the time of inspection, the normal water level was 100 mm below the invert of the weir. The lake water level appears static, with significant seepage noted on the downstream side. It appears the FSL is assumed to be the weir invert.
   a. The concrete structure was built with pre-fabricated materials including parking concrete barriers (others in the parking lot). The concrete has deteriorated, and it appears (as expected) that the barriers are not constructed from structural concrete, nor do they appear to contain much reinforcement.
   b. The steel weir channel and measurement appear newer. This restricts the opening to 450mm.

Photo 1.1 Outlet Structure – Upstream looking south

Photo 1.2 Outlet Structure: Looking West. Note stagnant and shallow water.

2. **Dam height and composition:** Measurements, taken roughly during the visit had the dam height ranging from 400 to 700 mm. The top width was approximately 2 metres, with side slopes estimated at 4H:1V. The lake side slope face showed minor topsoil sloughing. From discussions with RDEK staff, the south side of the dam used to have trees and shrubs on it, which helped explain some of the tree trunks, depressions and holes from rotted woody debris. The dam core, which was not excavated during this inspection, appears pervious and constructed with pit run gravel or similar gravel. Other than the depressions from the rotted trees, the top and side slopes of the dam appear stable.

Photo 2.1 Tie Lake Dam – Looking west. West side of dam. Note remnants from 2012 sandbagging.

3. **Downstream Conditions:** There is a roughly defined channel downstream, with a culvert under the Tie Lake Shore Road. There is a significant flat area which is boggy. The seepage through the dam maintains this area constantly wet. Note that if a “sunny day” breach of the dam was to occur flood capacity would be restricted by the highway culvert. The road will withstand any temporary storage from a sunny day breach.

Photo 3.1 Remnants of old channel to 600 mm road culvert – Looking South

Photo 3.2 Downstream ponding - Looking north

4. **Emergency Spillway:** This dam can be considered to have 3 spillways. The rectangular weir is the service spillway, the flat overflow on top can be considered a second (although the dam isn't high enough to provide this routing capacity), and the third is a 300mm diameter corrugated steel pipe trenched into the dam, approximately 200mm higher that the weir invert. The weir and pipeline appear to be the two official outlet works for the dam.

Photo 4.1 Spillway structure, looking North.

Photo 4.2 CSP Overflow Protection.

5. **Abutments:** There is just enough height on the abutments to allow the raising of the dam to a minimum 1 metre height.

Photo 5.1 East Abutment. The right abutment of a 1 metre dam would end within the top of the uncut grass on the left.

Photo 5.2 West Abutment. Will just be high enough. Some tree clearing will be required.

3 Hydrology

3.1 INFLOW DESIGN FLOOD (IDF)

The hydrology for the Tie Lake Dam was analyzed by Senior Hydrologist Drew Lejbak of Associated Environmental out of Vernon, BC. The analysis can be found in Appendix A. The following parameters and results are summarized below:

Inputs	
Watershed Area	12.5 km^2
Lake Surface Area (at FSL)	1.3 km^2
Lake Elevation (Approx.)	850 m
Highest Elevation in Watershed	1093 m
IDF	
Q 1:100 year	30.6 m3/s
V 1:100 year	500 ML
Storage Volumes	
Storage Volume	2,780 ML
Storage including 1 metre Freeboard	4,200 ML

Peak flows during a dam breach have been estimated using the BC Dam Safety Program's "Estimating Dam Break Downstream Inundation – Table 2", updated in January, 2016. For Tie Lake, the peak discharge estimate for a 1.2 m dam breach is approximately 11 m^3/sec for erosion resistant materials The charts do not provide breach estimates for a 700mm high dam, as 1.0 metre is considered the minimum height for any dam.

4 Hazard Classification

The Hazard Classification is defined as a professional opinion based on the consequences of failure of a dam. In British Columbia, the Dam Safety Regulations define consequence as per the Canadian Dam Safety Regulation, where three consequences are defined as:

- Loss of life,
- Environment and cultural values, and
- Infrastructure and economic loss.

The consequence classification is used to determine the level of mitigation and design protection required, along with determining the frequency of surveillance, inspection, maintenance, dam safety auditing and reviews submitted by owners.

4.1 DISCUSSIONS WITH MINISTRY REPRESENTATIVE

The Ministry of Forests, Lands and Natural Resource Operations were contacted as part of the scope of this assessment. In the last two years, the Ministry has spent considerable effort and resources improving the regulatory structure and Dam Safety responsibilities in the Province of British Columbia. Two recent dam failures: the Testalinden Dam near Oliver and the Mount Polley Mine Tailings Dam northeast of Williams Lake; have stressed the need for owners to meet regulatory requirements.

- In the Cranbrook area, the Ministry Dam Safety position was vacant as of July 31st, 2016. Mr. Michael Noseworthy, dam safety officer out of Penticton, was the temporary contact. Notes from the discussion were as follows:
  - The Dam Safety Officer determines the Hazard Classification for a dam once per year, every year. The classification should be based on the assessment consistent with Table 4-1 of the BC Dam Safety Regulations.
  - This report, along with its recommendation for Hazard Classification, should be forwarded by the Dam Owner to assist in formulating the Hazard Classification.
- Mr. Noseworthy did make himself available to review the information to date, and share his unofficial opinion concerning some of the findings of our site visit.
  - The operation of the road culvert downstream needs to be clearly explained.
  - We discussed the temporary economic loss mainly due to reduced recreation and property value from a lower lake level, and determined that this was not a factor in the determination of economic Hazard. These losses would need to be related to impacts due to the breach itself. The only hazard with possible consequences in this regard would be the road if it breached, although this appears highly unlikely given its size and height. From a recreational perspective, any lake depth changes of any size would have an impact.
- FLNRO will be filling the vacant employment position in the coming months. A final Hazard Classification will be determined by the new Dam Safety Officer.

4.2 FAILURE MODES

The term “Failure” of a dam means the uncontrolled release of all or part of the water impounded by the dam, whether or not caused by a collapse of the dam. “Consequences of failure” are defined by the impacts on the downstream or upstream area of a dam as a result of failure of the dam or its appurtenances. These impacts are based on the damage above and beyond the damage that would have occurred in the same event or conditions had the dam not failed. Two failure modes:

- “sunny day” failures, when the dam breaches due to a sudden structural failure or
- “rainy day” failure, as failure occurs due to a performance failure during a flood event.

4.3 TIE LAKE HAZARD CLASSIFICATION

The Sunny Day Failure of the Tie Lake Dam would have negligible impacts on downstream stakeholders. For this type of structural failure, the lake water level would be at Full Service Level and operating normally. Failure of the structure would involve no more than 200mm of water (if that much) reaching the road culvert downstream. This amount would be easily captured and impounded by Tie Lake Road, and passively controlled using the culvert.

The Flood Induced failure is the only likely failure scenario on Tie Lake, and assumes an extreme precipitation and flood event coupled with lake levels reaching the top of the dam. The uncontrolled release, in this instance, would again be captured temporarily by the road and culvert which acts as a dam. The road would not overtop, as the top of dam is well below the lowest road elevation. The following determinations can then be made:

- Population at risk? No. The inspection team examined potential downstream impacts. Other than the immediate area between the road and dam, the creek further downstream expands significantly downstream at a very gradual gradient. Any flood volume would attenuate naturally in Sandy Creek.
- Loss of Life (Low): There is no possibility of loss of life other than through unforeseeable misadventure.
- Environment and cultural values (Low): There will be minimal short-term loss or deterioration and no long term loss or determination of fisheries and wildlife habitat, rare or endangered species, unique landscapes or sites of significant cultural value.
- Infrastructure and economics: Low. There is no infrastructure or items of significant value that would be impacted from a failure of the Tie Lake dam. The water intakes in the lake would not be impacted by the 200mm drop in lake water level, and the Tie Lake local road is broad enough to managed the temporary flooding upstream of the highway culvert. It is recommended that the Regional District consider additional armouring both to the inlet and outlet of the culvert to protect against any full flow conditions, as shown on attached Drawing C1003.

It would take some time for the lake levels to subside following a dam breach, and the road would need to be inspected regularly during such an event. It is our recommendation that the Tie Lake Dam be classified as a dam with a Low Hazard Classification.

Table 4-1. Downstream Consequence Classification Guide (From Schedule 1 – 2016 BC Dam Safety Regulation).

Dam failure consequences classification	Population at risk	Consequences of failure		
		Loss of life	Environment and cultural values	Infrastructure and economics
low	none[1]	no possibility of loss of life other than through unforeseeable misadventure	minimal short-term loss or deterioration and no long-term loss or deterioration of (a) fisheries habitat or wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value	minimal economic losses mostly limited to the dam owner's property, with virtually no pre-existing potential for development within the dam inundation zone
significant	temporary only[2]	low potential for multiple loss of life	no significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is highly possible	low economic losses affecting limited infrastructure and residential buildings, public transportation or services or commercial facilities, or some destruction of or damage to locations used occasionally and irregularly for temporary purposes
high	permanent[3]	10 or fewer	significant loss or deterioration of (a) important fisheries habitat or important wildlife habitat, (b) rare or endangered species, (c) unique landscapes or (d) sites having significant cultural value, and restoration or compensation in kind is highly possible	high economic losses affecting infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to scattered residential buildings
very high	permanent[3]	100 or fewer	significant loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is possible but impractical	very high economic losses affecting important infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas
extreme	permanent[3]	more than 100	major loss or deterioration of (a) critical fisheries habitat or critical wildlife habitat, (b) rare or endangered species, (c) unique landscapes, or (d) sites having significant cultural value, and restoration or compensation in kind is impossible	extremely high economic losses affecting critical infrastructure, public transportation or services or commercial facilities, or some destruction of or some severe damage to residential areas

[1] There is no identifiable population at risk.
[2] People are only occasionally and irregularly in the dam-breach inundation zone, for example stopping temporarily, passing through on transportation routes or participating in recreational activities.
[3] The population at risk is ordinarily or regularly located in the dam-breach inundation zone, whether to live, work or recreate.

[1]This table is a copy of Schedule 1 of the Dam Safety Regulation . In case of discrepancy between this table and the approved Regulation, the Regulation takes precedence.

5 Capital Works

5.1 DESIGN CRITERIA

The implications of a Low Hazard Classification to the Regional District of East Kootenay, the dam Owner, are as follows:

1. The Hazard Classification must be reviewed annually by the Ministry (requirement regardless of classification).
2. Site surveillance to be conducted monthly unless specified specifically in the OMS manual.
3. Formal inspections to be conducted annually.
4. Annual testing of any mechanical, electrical or communications components (Minimum for all classifications),
5. Collect instrumentation readings annually (none at Tie Lake),
6. Review Emergency contact information annually,
7. Review the OMS manual every 10 years.
8. A formal dam safety review is not required.

With respect to Design Criteria for a Low Hazard Consequence dam in 2016, Table 5-1 summarizes the minimum expectations for design.

Table 5-1. Minimum Design Parameters used for Dams with Low Hazard Classification (from: CDA Dam Safety Guidelines, 2007)

Classification	Minimum Factor of Safety	Inflow Design Flood	EDGM (Earthquake design ground motion)	AEP Wind
Low	1.3 U/S and D/S	1/100 year	1/100 year	1/100 yr

5.2 REQUIRED WORK

Given these minimum criteria for a low risk dam, we recommend the following parameters for consideration to bring the Tie Lake Dam to a design that meets or exceeds standard dam design in Canada or BC.:

1. Minimum Freeboard – 1 metre. This allows for:
    a. Temporary mitigation against failure or blockage of a spillway.
    b. Protection of overtopping and erosion from wave action, particularly boat waves.
    c. Depth over the emergency spillway to pass an emergency flow event.
    d. Armour the upstream slope for protection against boat waves.

2. The crest width is determined by the formula $W_m = 0.2\ H_m + 3$; where W_m is the crest width in metres and H_m is the embankment height in metres = 3.2 metres. All traffic for maintenance should be limited to the road, and not the dam side slopes.
3. Install a larger capacity emergency spillway width (4 metres).
    a. This is the minimum size of emergency spillway in addition to a low level outlet structure.
    b. The design storm for this reservoir is the 1 in 100 year event, with a 30 m^3/s peak inflow. The 500ML of storm volume can be captured within the 1 metre of freeboard proposed for the dam upgrades. A minimum 4 metre emergency spillway is reasonable for this dam.
    c. Remove the existing CSP pipe in the dam.
4. A low level outlet to empty the reservoir.
    a. As this reservoir is partially a natural depression, the effectiveness of a low level outlet is reduced at this location.
    b. To empty the lake naturally, it would be necessary to pump using other means.
    c. It is possible to combine the outlet and spillway, given the low risk of flooding downstream.
5. A log boom is highly recommended. A boom will help controlled floating debris from blocking the spillway; particularly during a major storm event. The work involves installation of two anchor points, chained, artificial logs and a warning sign for public safety. The booms should be maintained on an annual basis to prevent accumulation in front of the dam.
6. Two signs posted identifying the emergency contact, dam name and public safety information.

The figures in Appendix B outline both the existing facility and proposed upgrades required to bring the dam to code. Cost estimate for budgetary purposes are summarized starting in Table 5-2. Note that all costs in this report include assume supply, manufacturing, transportation and installation to site and do not include taxes. The estimates include a contingency (20%) to allow for the unknown make-up of the dam during this review. To obtain a more precise estimate, then further geotechnical analysis would be required to confirm the composition of the dam and the quality of the soils around the abutments.

5.2.1 Urgency of Works

Part 2 Section 4 of the 2016 Dam Safety Regulation states that as a classification is change or determined for the first time, that the owner of the dam must, as soon as practicable after awareness of the classification, comply with the Regulation’s provisions. Section 5 of the same Regulation notes that the dam owner must exercise reasonable care to avoid the risk of significant harm from a defect, insufficiency or failure of the dam or other conditions that may impact public safety, the environment or land/property.

The Tie Lake Dam, in its current configuration, does not meet minimum design criteria prescribed in the CDA (2007) Dam Safety Guidelines. As a dam owner, the Regional District of East Kootenay is responsible for operating, maintaining and upgrading the dam to meet these minimum requirements.

Given the state of the existing facility, we recommend that the required works described in this section be completed as soon as possible.

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Table 5.2. Cost Estimate for Required Works on Tie Lake

Item	Quantity	Unit	Unit Cost	Extension
Mobilization and General Contractor Expenses	1	LS	10,000	10,000
Coffer Dam	1	LS	10,000	10,000
Clearing and Grubbing	500	m^2	20	10,000
Raise Dam to 1.0m freeboard and 3m Top of Dam.				
Compacted Gravel	500	m^3	80	40,000
Topsoil and Seeding	500	m^2	10	5,000
Upstream Armouring	50	m^3	100	5,000
New Weir and Spillway	1	LS	30,000	30,000
Security Fencing	1	LS	3,000	3,000
Log Boom	1	LS	25,000	25,000
Public Signage	2	ea.	500	1,000
Sub-Total				**139,000**
Engineering & Construction Administration	25%	LS		34,000
Environmental	5%	LS		7,000
Contingencies	20%			28,000
RDEK Admin/Project Management Costs	5%			7,000
Total Cost				**$215,000**

5.3 RECOMMENDED WORK

The following work is recommended, although not required to meet regulations.

1. Remove trees and shrubs downstream of the dam.
   a. Given the high volume of seepage downstream of the dam, all shrubs and trees on or within a 10 metre distance from the dam should be removed to avoid root penetration and subsequence failure of the dam.
2. Shape and maintain a channel to the culvert under the road.
   a. This should be part of the overall dam design anyways, and kept maintained on a regular budget.
3. Armour the inlet and outlet of the culvert on Tie Lake Road.

The drawings in Appendix B include typical details for armouring of the culvert. The costs to complete this recommended work is summarized in Table 5-3.

Table 5.3. Cost Estimate for Recommended Works on Tie Lake

Item	Quantity	Unit	Unit Cost	Extension
Clearing and Grubbing	500	m^2	20	10,000
Shape Channel	100	m	50	5,000
Armour road culvert	30	m^3	100	3,000
Sub-Total				18,000
Engineering & Construction Administration	25%			5,000
Contingencies	20%			4,000
Regional District Administration	5%			1,000
Total Cost				$28,000

5.4 OPTIONAL DESIGN ELEMENTS

Currently, the dam is pervious to water, and as noted during the inspection, the water level appeared to be static at 200mm beneath the elevation of the weir. During discussions with Regional District staff, it was noted that local residents have inquired about increased lake levels to improve boating and other recreational activities. To achieve this, additional seepage control measures would be required to control water levels at the weir. We would suggest the installation of a strong, impermeable membrane upstream of the dam to minimize seepage through the dam itself, improving conditions for the top 200 mm of lake level without impacting the height of dam. The elements required to achieve this are (Table 5.4):

- Approximately 10% more earthworks and gravel materials.
- Coffer Dam placed approximately 15 metres into the lake to allow for dewatering.
- Excavation of silty Lake material and replace with more stable gravel base.

- Dewatering – Estimated 7 days.
- Supply and Installation of seepage barrier or membrane.

We also note that the site is 45 minutes from the RDEK office. It may be in the District's best interest to monitor lake levels. We have included some added costs to provide instrumentation and communications for Water Level Monitoring (Table 5.5).

Table 5.4. Cost Estimate for Seepage Control on Tie Lake (Additional costs to required work in Table 5.2)

Item	Quantity	Unit	Unit Cost	Extension
Additional Dam Quantities	1	LS	10,000	10,000
Removal of Lake Material	2,500	m^3	25	62,500
Additional Coffer Dam and Care of Water	100	m	100	10,000
Impervious Membrane – Supply & Installation	250	m^2	20	5,000
Compacted Gravel and Anchoring	100	m^3	50	5,000
Installation	1	LS	10,000	10,000
Sub-Total				40,000
Engineering & Construction Administration	25%			10,000
Contingencies	20%			8,000
MOE Additional Applications and Monitoring	1	LS	10,000	10,000
Regional District Administration	5%			2,000
Total Cost				$70,000

Table 5.5. Cost Estimate for Lake Monitoring Instrumentation and Communications on Tie Lake

Item	Quantity	Unit	Unit Cost	Extension
Water Level Indicator	1	ea	$2,000	$2,000
Vertical Well Supply and Installation	3	ea	$160	$500
Battery Power Supply	1	ea	$500	$500
Cellular Communications	1	ea	$2,000	$2,000
Panel Box	1	ea	$1,000	$1,000
Installation	1	LS	$10,000	10,000
Sub-Total				16,000
Engineering & Construction Administration	25%			4,000
Contingencies	20%			5,000
Regional District Administration	5%			1,000
Total Cost				$26,000

6 Conclusions

Tie Lake Dam is an unregulated earth-filled dam used primarily to maintain lake levels for recreation and fishing for private properties and public use just north of Jaffray, BC. A site visit, literature review and analysis was conducted, resulting in an engineering assessment of the dam. We concluded that:

- The Tie Lake Dam, in its current configuration, does not meet minimum design criteria prescribed in the CDA (2007) Dam Safety Guidelines. As a dam owner, the Regional District of East Kootenay is responsible for operating, maintaining and upgrading the dam to meet these minimum requirements.
- A breach of Tie Lake Dam would result in no loss of life, minimal environmental damage and minimal costs to infrastructure;
- A Dam Safety Officer from the BC Ministry of Forests, Lands, and Natural Resource Operations (FLNRO) was contacted, although this person was only temporarily assigned to the Tie Lake Dam. A separate letter to this report will be sent to the Ministry with a recommendation for a Low Hazard Classification;
- The design storm for this reservoir is the 1 in 100 year event, with a 30 m^3/s peak inflow. The 500ML of storm volume can be captured within the 1 metre of freeboard proposed for the dam upgrades. A minimum 4 metre emergency spillway is reasonable for this dam.
- Conceptual design and cost estimates were provided to bring the dam into minimum conformance with Canadian Dam Safety Guidelines,
- Other optional items were included that improve downstream conditions, an option to minimize seepage and raise the lake level by 200 mm, and a water level monitoring system to be added to the Regional District's SCADA system.

7 Recommendations

Associated Engineering recommends that:

- The Dam Safety Officer classify Tie Lake Dam as a Low Hazard Consequence Dam.
- The required works described in this report should be implemented as soon as possible to meet Canadian Dam Association Dam Safety Design Guidelines (2007).
- The Regional District of East Kootenay budget $215,000 for Tie Lake Dam capital upgrades in order to meet minimum design standards.
- The Regional District of East Kootenay budget an additional $28,000 to improve the downstream channeling of spill water and armouring of the Tie Lake Road culvert inlet and outlet.

8 References

APEGBC. 2014. Legislated dam safety Reviews in BC – Association of Professional Engineers and Geoscientists of British Columbia Professional Practice Guidelines - V2.0.

Canadian Dam Association (CDA). 2007. Dam Safety Guidelines and Associated Technical Bulletins. Revised 2013.

BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO). 2016. BC Dam Safety Guidelines Plan Submission Requirements for the Construction and Rehabilitation of Dams, Version 12, May 2016.

BC Ministry of Environment (MOE). 2016. British Columbia Dam Safety Regulation – Water Sustainability Act, British Columbia Regulation 40/2016 Effective February 29, 2016.

9 Certification

This report presents our findings regarding the Regional District of East Kootenay Tie Lake Dam Engineering Assessment.

Respectfully submitted,

Prepared by:	Reviewed by:
Rod MacLean, P. Eng. Project Manager and Dam Safety Engineer	Dale Harrison, P. Eng. Senior Structural Engineer and Reviewer
PROFESSIONAL PROVINCE OF R. T. MacLEAN # 29355 BRITISH COLUMBIA ENGINEER Sept 28, 2016	PROFESSIONAL PROVINCE OF D. B. HARRISON # 10869 BRITISH COLUMBIA ENGINEER SEP 28/16

Appendix A - Hydrology

Date:	September 28, 2016	**File:**	2016-2373.100
To:	Regional District of East Kootenay		
From:	Drew Lejbak		
Project:	Tie Lake Dam Engineering Assessment		
Subject:	Tie Lake Hydrology		

MEMO

1 INTRODUCTION

Tie Lake Dam is an old earth-filled dam that is used primarily to maintain lake levels within Tie Lake for recreational purposes and for water supply for a small community of private properties along the lakeshore. The dam's outlet structure was re-constructed approximately 35 years ago, and only minor maintenance has occurred since the upgrade. The Regional District of East Kootenay (RDEK) is the owner of the dam. A recent dam inspection noted some concerns about the capacity of the outlet structure, the amount of freeboard available, and the lack of general design information. Accordingly, the RDEK issued a Request for Proposal for completion of an engineering assessment to review the dam and to provide recommended upgrades (as required) to ensure that the dam meets minimum standards outlined through the Canadian Dam Safety Guidelines.

1.1 Objectives

The objectives of this memorandum are as follows:

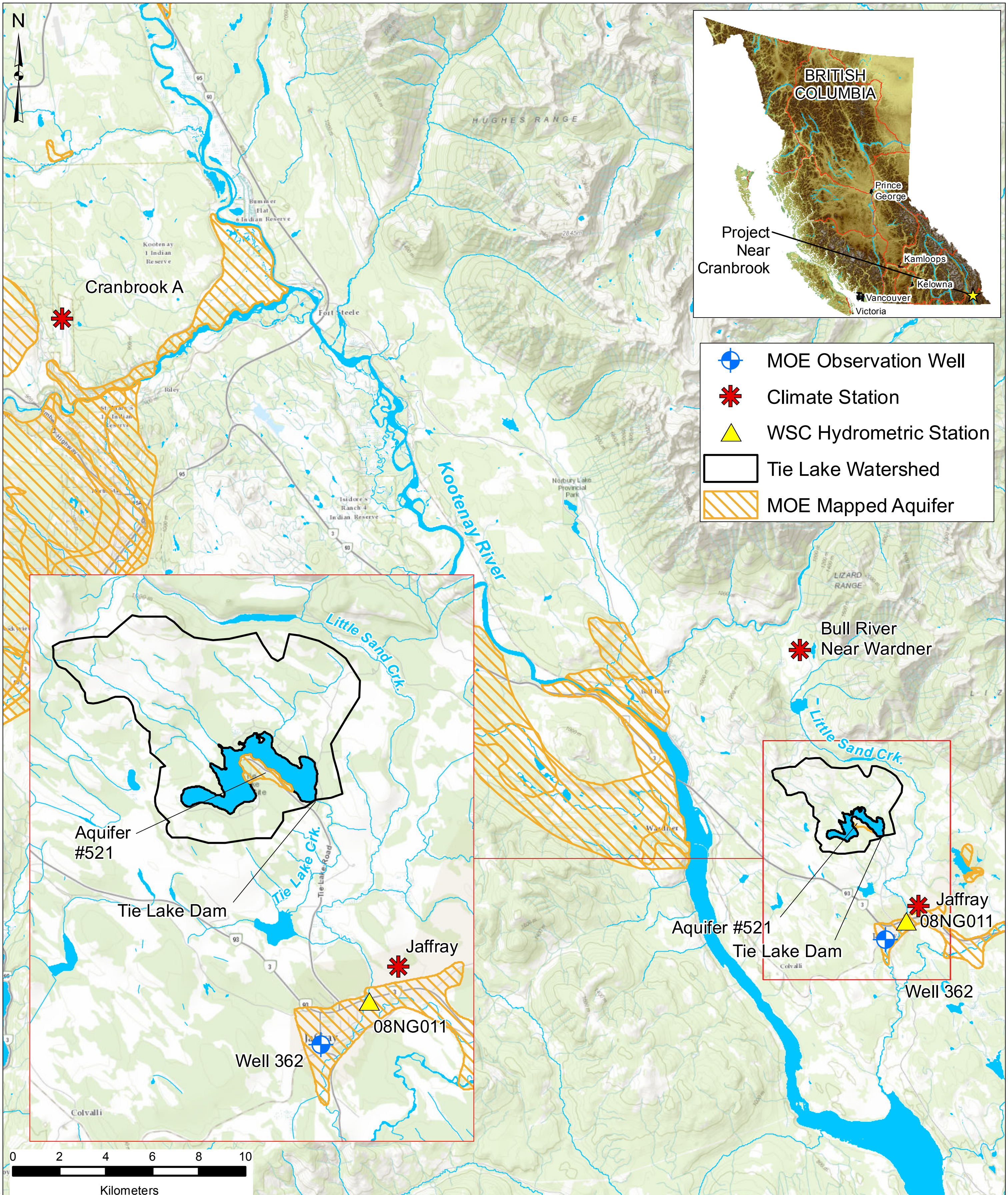
- Complete a general review of the local and regional streamflows, air temperature, precipitation, snowpack, and groundwater trends that are considered representative of the conditions for the Tie Lake area.
- Complete a general review of regional freshet trends and mechanisms that generate peak flows (e.g., snowmelt, rain, rain-on-snow) that Tie Lake and the surrounding area likely experience.
- Complete a review of local and regional hydrometeorologic information from 2012 in comparison to historic averages.
- Estimate the 100-year return period peak inflows into Tie Lake.

2 GENERAL CHARACTERISTICS – TIE LAKE AND CONTRIBUTING WATERSHED

Tie Lake is located approximately 4 km north of Jaffray, BC, within the Kootenay River Valley (Figure 2-1). The lake is within the RDEK boundary in the Central Subregion (Electoral Area B).

The surface area of Tie Lake is approximately 1.3 km^2 and the total lake volume is approximately 2,780 ML (Balkwill 1959). The maximum lake depth is 5.5 m and the mean depth is 2.2 m (Balkwill 1959; Lotic Environmental Ltd. 2012). The elevation of Tie Lake is approximately 850 m.

Tie Lake is located within the Little Sand Creek watershed (Figure 2-1). The contributing drainage area is 12.5 km^2 with elevations ranging between 850 m to 1,093 m and a median elevation of 901 m. Several small ephemeral streams/springs are reported to drain into the lake (MOE 1982; Lotic Environmental Ltd. 2012) and outflows from Tie Lake are regulated by Tie Lake Dam and weir with all outflows draining downstream into Tie Lake Creek.



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Associated Environmental

PROJECT NO.:	2016-2373.100
DATE:	August 2016
DRAWN BY:	DA

FIGURE 2-1:TIE LAKE AND SELECTED CHARACTERISTICS

Regional District of East Kootenay

Tie Lake Hydrological Assessment

3 HYDROMETEOROLOGICAL REVIEW

The following sections provide a hydrometeorological review of the Tie Lake watershed.

3.1 Climate

The climate of Tie Lake watershed is characterized by warm summers and moderate winters, with a relatively even distribution of precipitation throughout the year. Based on 1981-2010 averages (i.e. climate "normal") from ClimateBC[1], for Tie Lake the mean monthly air temperatures range from -6.2°C in December to 17.6°C in July. Air temperatures are, on average, below zero from November to February. Approximately 25% of the total annual precipitation of 483 mm falls as snow. Table 3-1 provides a summary of climate information for the Tie Lake area.

Table 3-1 Climate summary for Tie Lake, 1981-2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Air Temp (°C)	-5.3	-3.1	1.6	6.1	10.5	14.2	17.6	17.2	12	5.6	-0.8	-6.2	5.8
Rain (mm)	10	8	19	30	51	71	42	30	37	29	29	7	363
Snow (mm)	26	20	10	3	1	0	0	0	1	2	21	36	120
Total Precip. (mm)	36	28	29	33	52	71	42	30	38	31	50	43	483

Based on snow depth records collected by the BC Ministry of Transportation and Infrastructure (MOTI) at Jaffray (Station No. 36003; 1977-1994), the snowpack in the area around Tie Lake begins to develop in November and generally persists until April. Maximum snowpack occurs in late January / early February and melting occurs from late February and throughout March. The trend of snowpack development and melt is illustrated in Figure 3-1.

[1] ClimateBC (ver. 4.71) is a tool that was developed by the University of British Columbia to generate high-resolution climate data for climate changes studies and applications in British Columbia. (http://www.genetics.forestry.ubc.ca/cfcg/ClimateBC/ClimateBC.html).

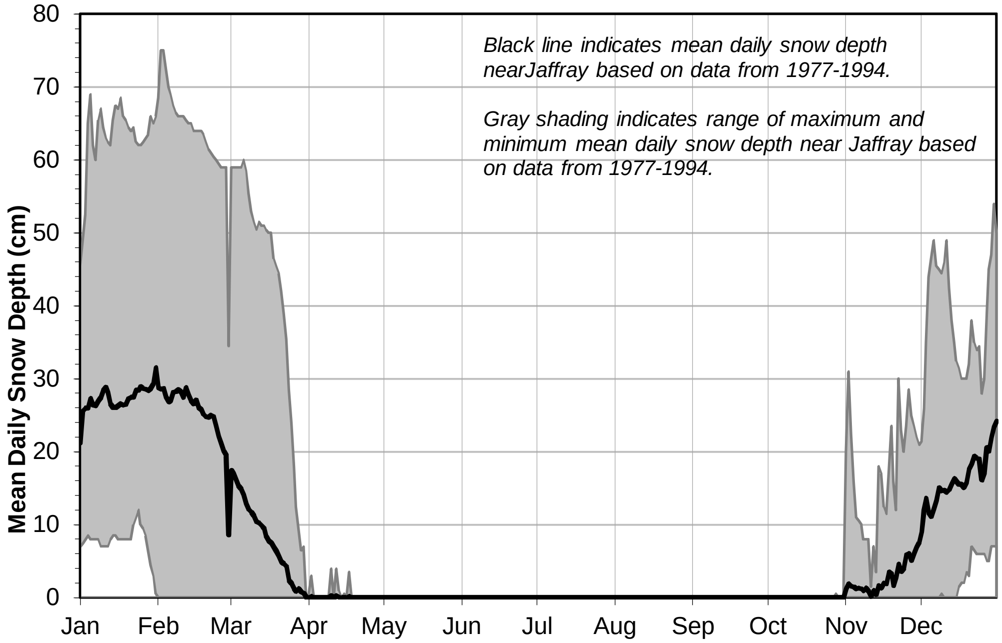

Figure 3-1 Summary of snowpack development and melt near Jaffray, BC, 1977-1994

3.2 Hydrology

Tie Lake Inflows

Tie Lake watershed is located within the Central Kootenay Basin (#20, subzone Z) hydrologic zone (Obedkoff 2002). Streams within this hydrologic zone are generally characterized by a snowmelt-dominated peak rising in April or May and peaking sometime between May or June. Rain-on-snow events occasionally occur in this region; therefore, winter flows and spring peaks can be enhanced. Late fall rainstorms are common, recharging soil moisture heading into winter and producing short duration peak flows. Low flows generally occur from the end of November to March and in the warmer summer months, with the lowest flows typically occurring in January and February.

Based on available mapping and MOE (1982), five small tributaries / springs drain into Tie Lake. The mean annual runoff into Tie Lake was estimated by MOE (1983) to be 51 mm. MOE (1982) also reported that the individual tributary inflows varied from 0.0 m^3/s to 0.014 m^3/s between March to October.

Tie Lake Water Levels

Water levels within Tie Lake are regulated by the Tie Lake Dam and weir and have been monitored since 2012 by local residents. A summary of the Tie Lake water levels in relation to the sill elevation of the outlet weir is provided in Figure 3-2. The highest lake levels were measured in June 2012 and October 2015.

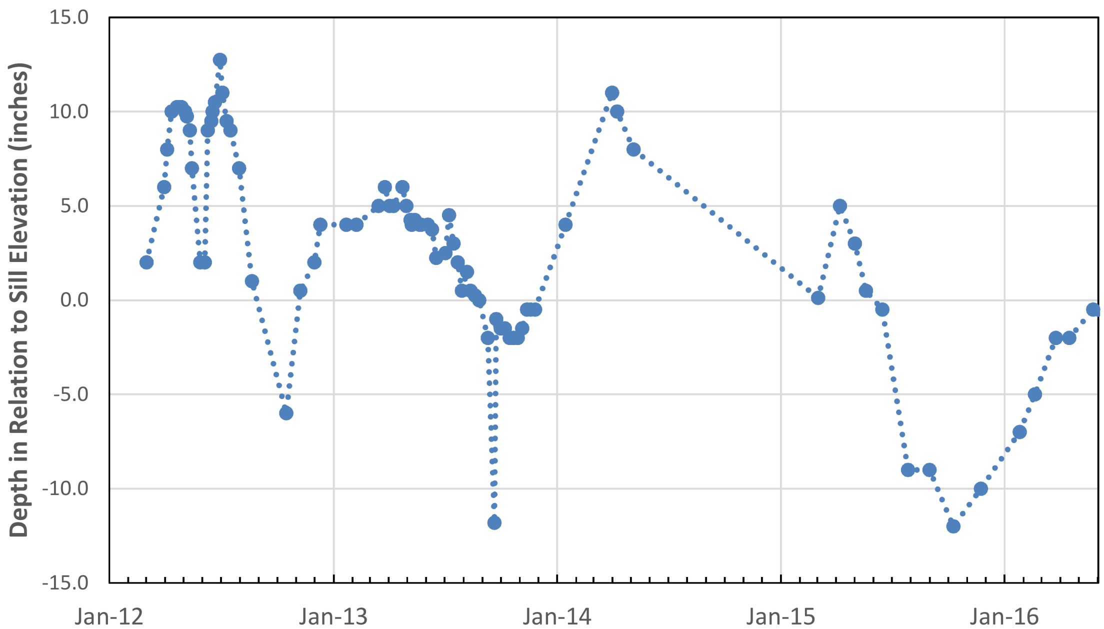

Figure 3-2 Summary of Tie Lake water levels in relation to the sill elevation of the outlet weir, 2012-2016

Upon review of Figure 3-2, it appears that Tie Lake is very responsive to precipitation events, as evidenced by the large variation in water levels that occur over relatively short periods of time. This is also supported by local resident comments noting that snow/rain can cause water levels within the lake to rise quickly.

The Tie Lake Tribune (2011) also reported that the outlet weir has been blocked by local residents a coupe times over the years, which has also influenced lake levels.

Tie Lake Outflows

The outflows from Tie Lake are regulated by a small rectangular weir that is approximately 0.50 m wide. MOE (1982) reported outflows between 0.017 m^3/s to 0.075 m^3/s, while the Tie Lake Tribune (2011) reported that between 2002-2011, outflows only occurred in four of those years.

Using the waters levels measured in Figure 3-2 and the standard rectangular weir equation, the highest outflows were estimated to be 0.117 m^3/s. These occurred in June 2012 and October 2015.

3.3 Groundwater

Tie Lake and contributing watershed is located within the Southern Rocky Mountain Trench physiographic area (Holland 1976). The Southern Rocky Mountain Trench is a gently undulating area of low relief, with soils comprised of glacial deposits (sands and gravels) and alluvium. The Kootenay River is located approximately 6 km west of Tie Lake and water levels within the river are approximately 100 m lower than the lake.

The BC Ministry of Environment (MOE) mapped a small aquifer (i.e., #531 – Tie Lake) along the middle south portion of Tie Lake (see Figure 2-1). This aquifer is categorized as a type IIB confined gravel aquifer with an areal extent of 0.2 km^2. MOE (2002a) reported that the flow direction within the aquifer is not known, but depth to groundwater can range between

2.4 m to 12.8 m below ground surface (bgs). The aquifer is reported to be recharged by Tie Lake and adjacent higher elevations (MOE 2002a).

No groundwater level monitoring is available for the Tie Lake aquifer. However, a MOE observation well (#362) is located approximately 4 km south of the lake at Jaffray (Figure 2-1). Well #362 is located within an unconfined aquifer (i.e., #521 – Jaffray) and is comprised of sands and gravels. MOE (2002b) reported that the aquifer is recharged from neighboring surface water sources (MOE 2002b). Although Well #362 is located within a different aquifer than Aquifer #531 (Tie Lake), the recorded seasonal variability of groundwater levels is likely consistent with groundwater levels around Tie Lake. Figure 3-3 provides a summary of Well #362 groundwater levels; the seasonal trend includes peak levels occurring in mid-June and lowest levels generally occurring in February. The highest groundwater levels on record occurred in 2012.

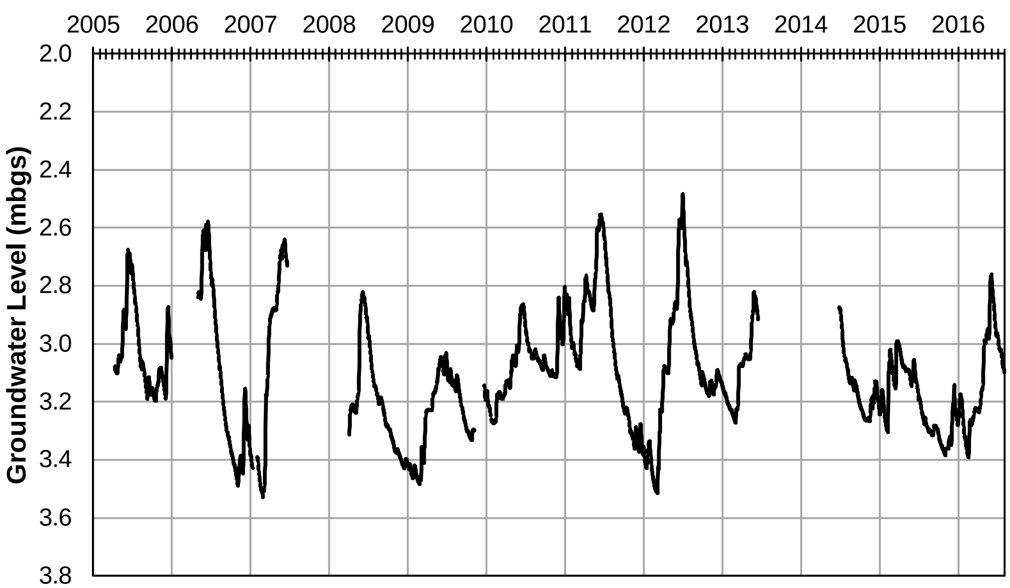

Figure 3-3 Summary of groundwater levels measured by Well #362 (Jaffray), 2005-2016

4 PEAK FLOW AND HIGH LAKE WATER LEVEL REVIEW

4.1 Hydrologic Zone Peak Flow Summary

As summarized in Section 3.2, streams within the Central Kootenay Basin hydrologic zone are generally characterized by a snowmelt dominated peak rising in April or May and peaking sometime between May or June. In addition, rain-on-snow and rainfall events can result in enhanced and/or short duration peak flows. This is evidenced by the flashiness of the hydrograph for the Little Sand River (WSC 08NG011; Drainage Area = 116 km^2; Period of Record = 1914-1922, 1928-1929, and 1953-1956) (Figure 4-1). Note that the Tie Lake watershed is a tributary to the Little Sand Creek.

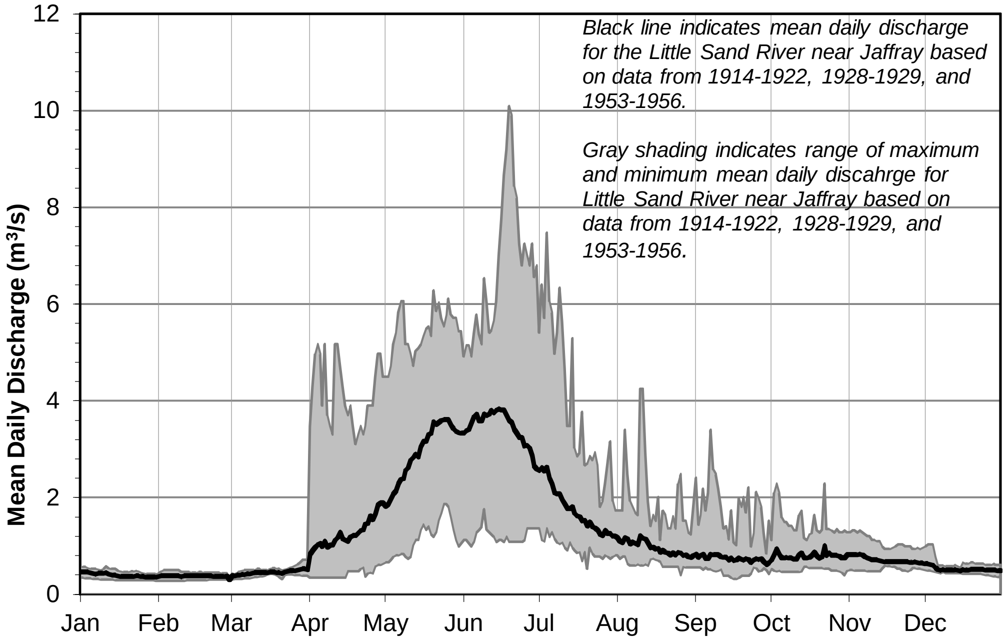

Figure 4-1 Summary of mean daily discharge for Little Sand River near Jaffray (WSC 08NG011), 1914-1956. Note that the station was operated seasonally (April 1 to September 30) for most years of record.

4.2 Tie Lake High Lake Water Levels

Due to the ephemeral nature of watercourses entering Tie Lake (i.e., five small ephemeral tributaries / springs) (Section 3.2), high flows entering Tie Lake likely occur early in the season related to snowmelt or rain-on-snow events. As the season progresses, rainfall induced high flows may occur; however, the magnitude of the high flow is tied to the intensity of the rainfall event, as well as to the antecedent soil moisture conditions. Groundwater levels in the area around Tie Lake (Figure 3-3) indicate that groundwater recharge generally begins in February/March and peaks in June; therefore, rainfall events between this period are likely to have a greater chance of producing surface runoff due to the increased potential for saturated soil conditions.

High surface runoff entering Tie Lake would directly influence water levels within the lake, in addition to precipitation that falls directly on to the lake surface. For the latter, the greater the magnitude of the precipitation event, the greater the likelihood for increases in lake water levels. It is unknown whether Tie Lake freezes during the winter period; however, if ice conditions occur, increases in lake levels would also occur as the ice melts. Based on the Tie Lake water levels recorded by local residents (Figure 3-2), the highest recorded lake levels generally occur between March and June. This is consistent with the timing of snowmelt (Figure 3-1), large spring rainfall events, and high groundwater levels (Figure 3-3) within the Tie Lake area.

For 2012, Tie Lake water levels were reported to approach the top of the dam in the spring (June). Comparing monthly precipitation information from a nearby BC Hydro climate station (Bull River at Wardner; Station No.: BUL; Period of Record: 1983-2015), it was found that the June 2012 precipitation was almost triple the average value for that month and the highest monthly June precipitation on record (Table 4-1). In addition, precipitation for March 2012 was more than double the average value for that month (Table 4-1). Following this, it is very likely that the 2012 Tie Lake water levels were influenced by the timing of the spring precipitation as follows:

- Snow within the Tie Lake watershed (if present) began melting in March 2012 and precipitation in the form of rain helped supplement snow melt or contributed directly to surface runoff into and on to the lake. This is evidenced by the increase in lake water levels in March 2012 (Figure 3-2), as well as the timing of groundwater recharge at Jaffray (Figure 3-3) with groundwater levels beginning to increase in March 2012.
- Lake water levels continued to increase into May 2012 as a result of additional surface runoff from precipitation throughout April and early May (Figure 3-2).
- Due to the low May 2012 precipitation (Table 4-1), lake water levels began to decline (Figure 3-2).
- Precipitation began again in early June 2012 and due to the significant total monthly precipitation (Table 4-1), lake water levels increased significantly to the end of the month before declining in early July 2012.

Table 4-1 Summary of total monthly precipitation recorded at Bull River near Wardner (BC Hydro Station No. BUL), 1983-2015

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1983 - 2015	43.9	26.6	42.0	36.7	59.2	82.3	46.3	32.0	37.0	39.3	51.4	44.3	541.0
2012	36.3	28.0	99.3	53.6	27.3	234	54.0	18.7	19.8	73.1	54.5	69.5	768.1

5 TIE LAKE PEAK INFLOWS

To support the engineering assessment to review the dam and to ensure that the dam meets minimum standards outlined through the Canadian Dam Safety Guidelines, the 1:100-year return period instantaneous peak inflow (Q_{100}) was calculated and adopted as the storm size event (i.e. the design flow) for dam assessment purposes. The estimation of the Q_{100} is described below.

The contributing drainage area to the lake is smaller than 25 km^2 (Section 2.0). Therefore, the Rational Formula method of estimating the design flow (Coulson [1991] and MOT [2007b]) was applied. The Rational Formula is commonly used to estimate design peak flows for small watersheds in BC. In the present application, precipitation records from the climate station at the Cranbrook airport (Meteorological Service of Canada (MSC) Station No. 1152102; Elevation: 940 m) were used since it is the closest climate station and at a similar elevation as the contributing drainage area to Tie Lake. The Rational Formula equation (Eq. 1-1) used to calculate the design flows was:

$$Q_{100} = 0.28CPA/T_c \qquad \textbf{Eq. 1-1}$$

where:

Q_{100} = the 100-year instantaneous peak design flow (m^3/s);
C = runoff coefficient (dimensionless);
A = drainage area (km^2);
T_c = time-of-concentration[2] (hrs); and
P = total precipitation occurring within the time-of-concentration (mm).

[2] This is the time required for surface runoff generated at the most distant point in a drainage basin to reach the point-of-interest.

A runoff coefficient of 0.95 was considered representative of the contributing drainage area, which is a combination of 0.8 for a steep forested slope, +0.05 for a return period >25 years, and +0.10 to account for snowmelt during the design storm event.

The time-of-concentration (T_c) value (i.e. 3.9 hrs) was taken from Figure 1 in Coulson (1991); in which curves relating T_c to drainage area (A) are presented for different physiographic classifications (i.e., flat, rolling, moderate, and steep). A physiographic classification of "steep" was selected for the Tie Lake contributing drainage area[3]. The drainage area (i.e., 12.5 km^2) was calculated using available TRIM and GIS mapping datasets; the available contour interval for the contributing drainage area was 20 m.

The precipitation (P) value (i.e., 9.2 mm/hr) was taken from the intensity-duration-frequency (IDF) curve developed for the Cranbrook airport climate station. The P value was based on the time-of-concentration using the IDF curve for a 100-year return period.

Following the above, the Q_{100} for the contributing drainage area to Tie Lake is 30.6 m^3/s. Note that this inflow value does not include direct precipitation on to the lake during a peak flow event.

[3] The average slope for the contributing drainage area to Tie Lake is 11% using available DEM information. Coulson (1991) considers a slope >10% as steep; therefore, for this assessment, the contributing drainage area to Tie Lake was considered steep.

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Appendix B - Figures

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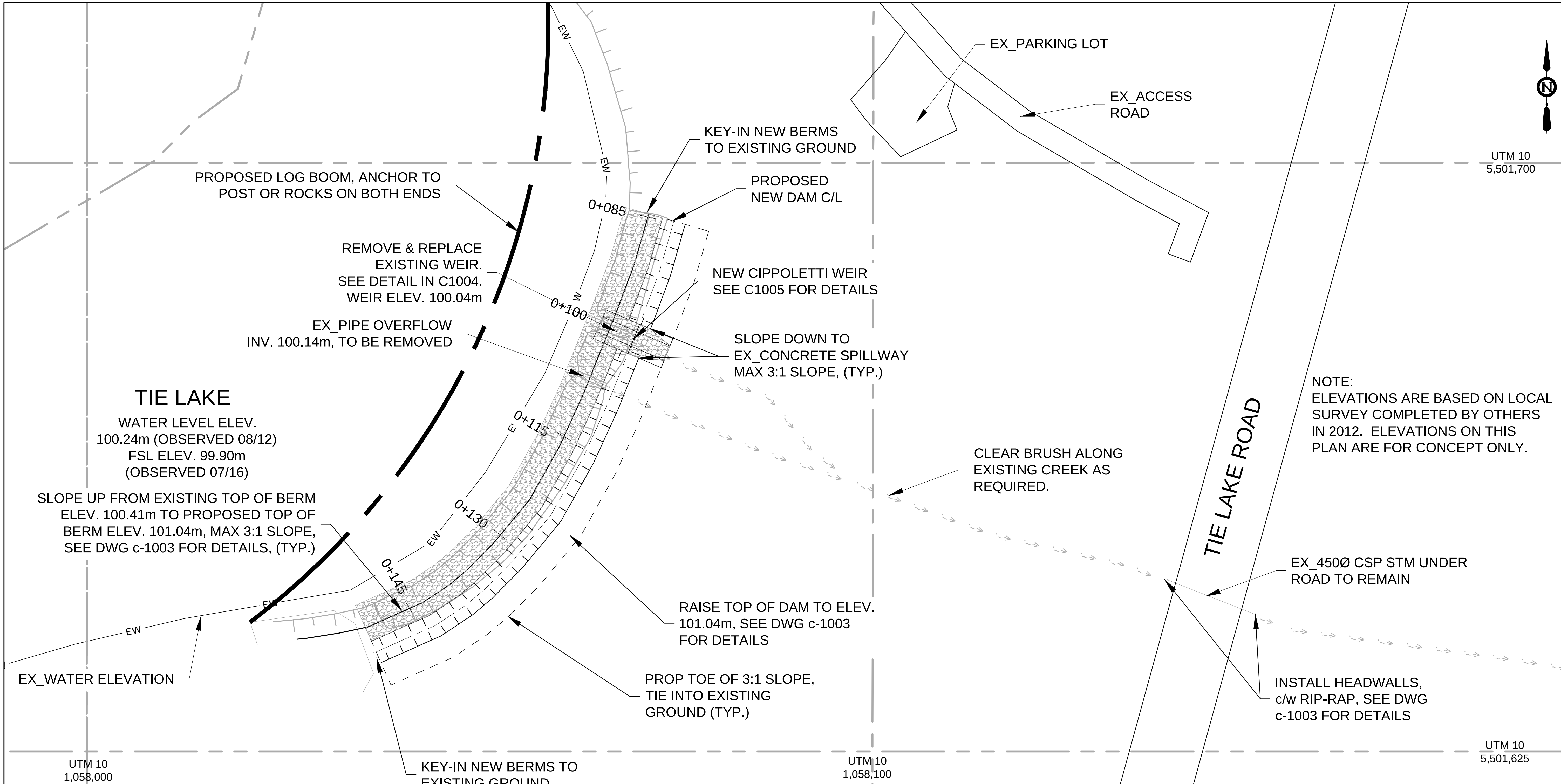

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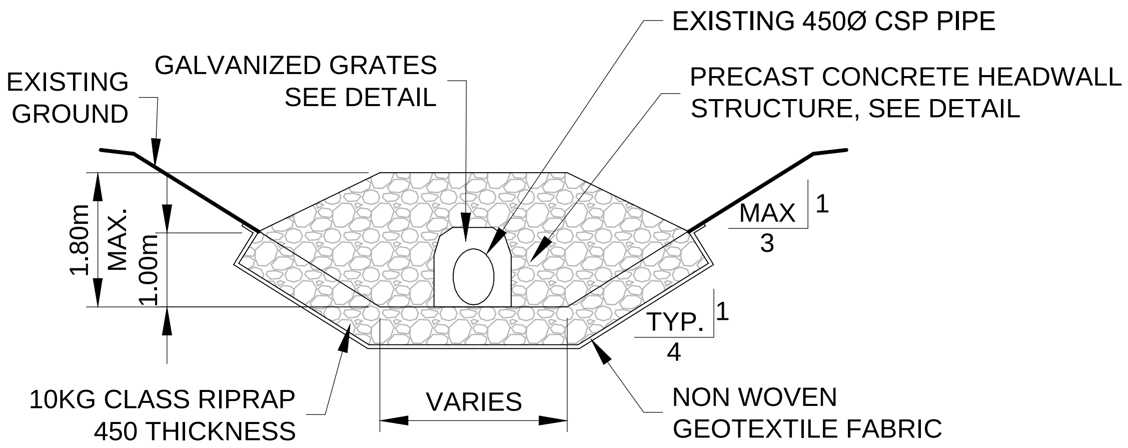

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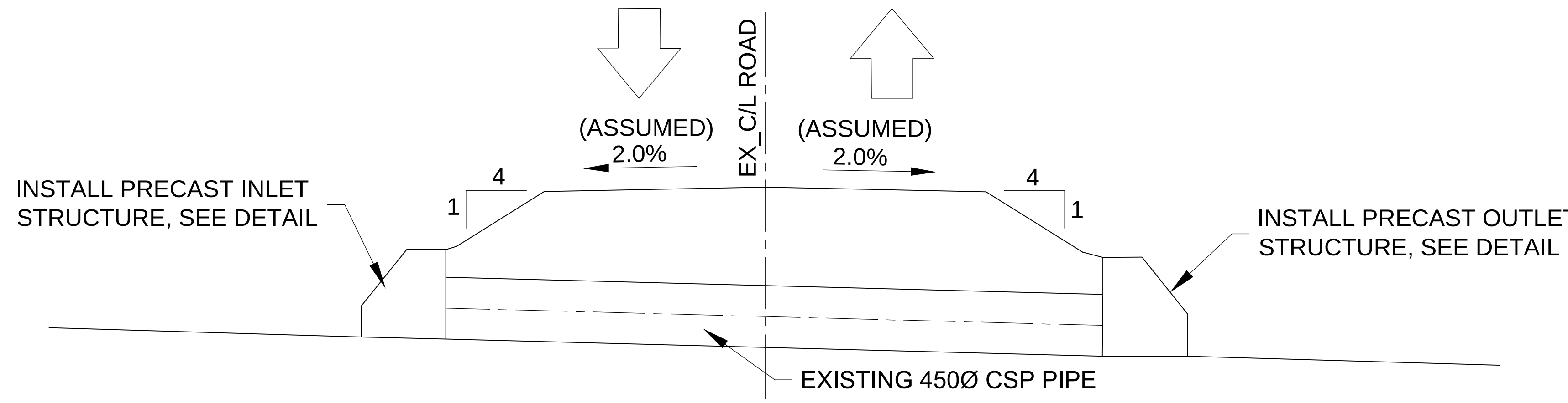

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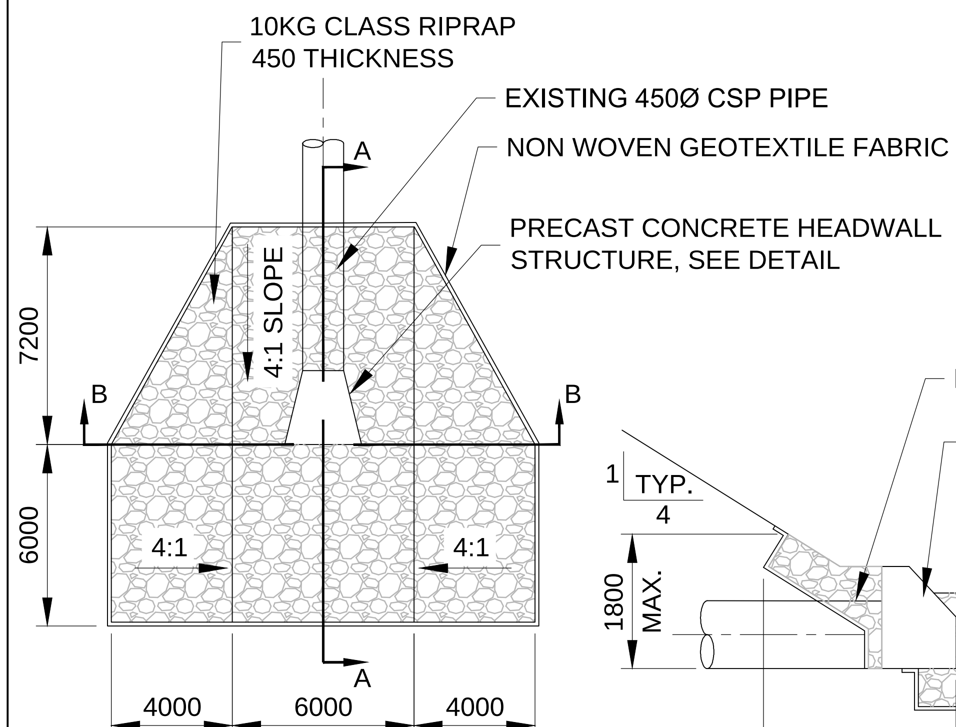

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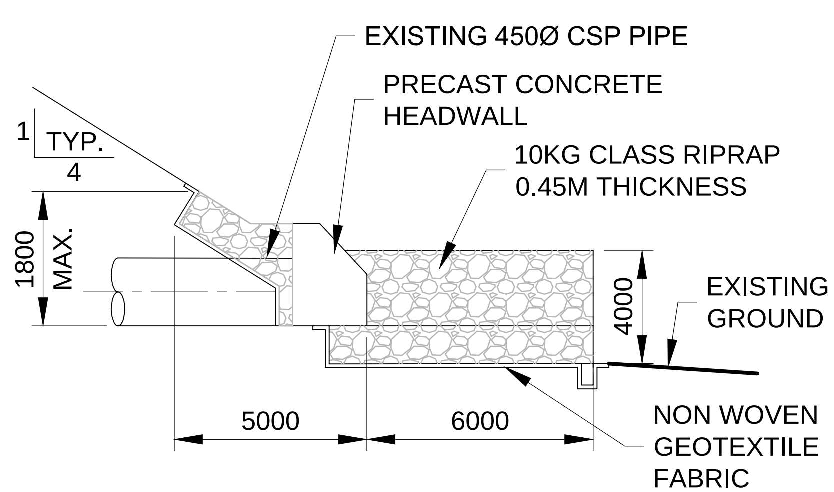

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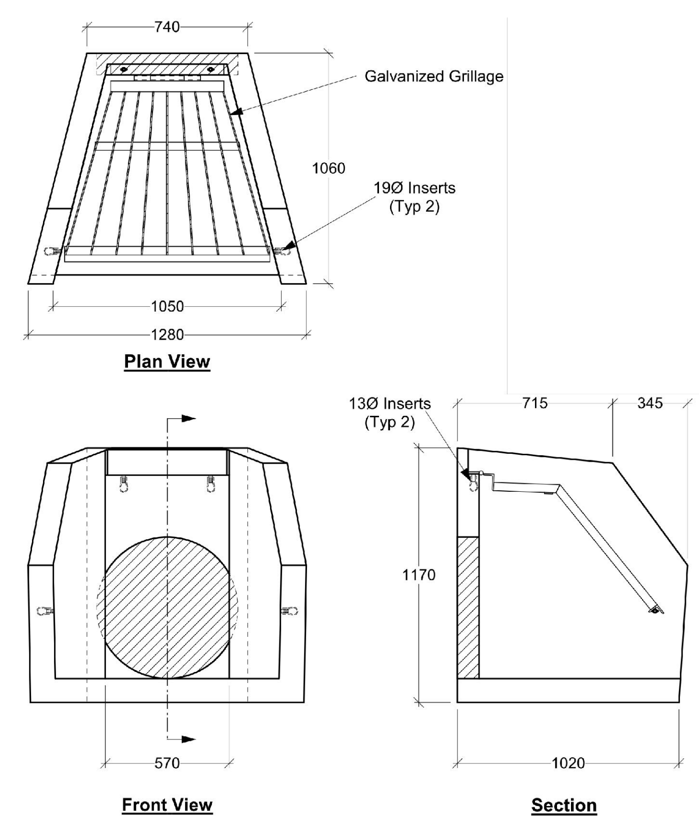

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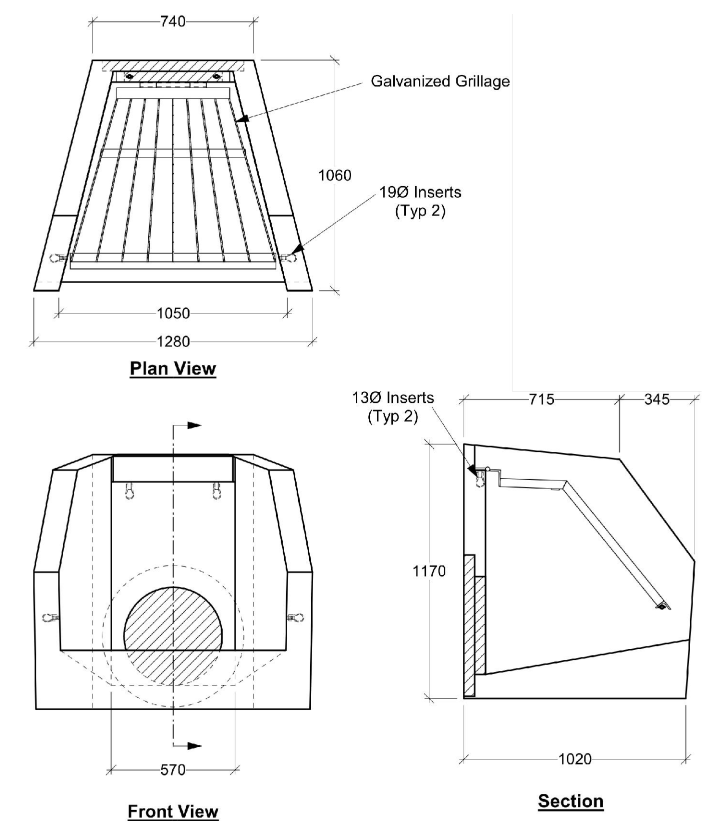

General Notes:
·Product manufactured in accordance with CSA A23.4
·Custom of Pipe Openings Available
·Lift Points Provided (See Shop Drawing for Quantity & Locations)
·Steel Products manufactured under CSA W47.1 in accordance to CSA W59
·Site Installation, Backfilling & Suitability for Use is the responsibility of others

CONCRETE INLET DETAIL
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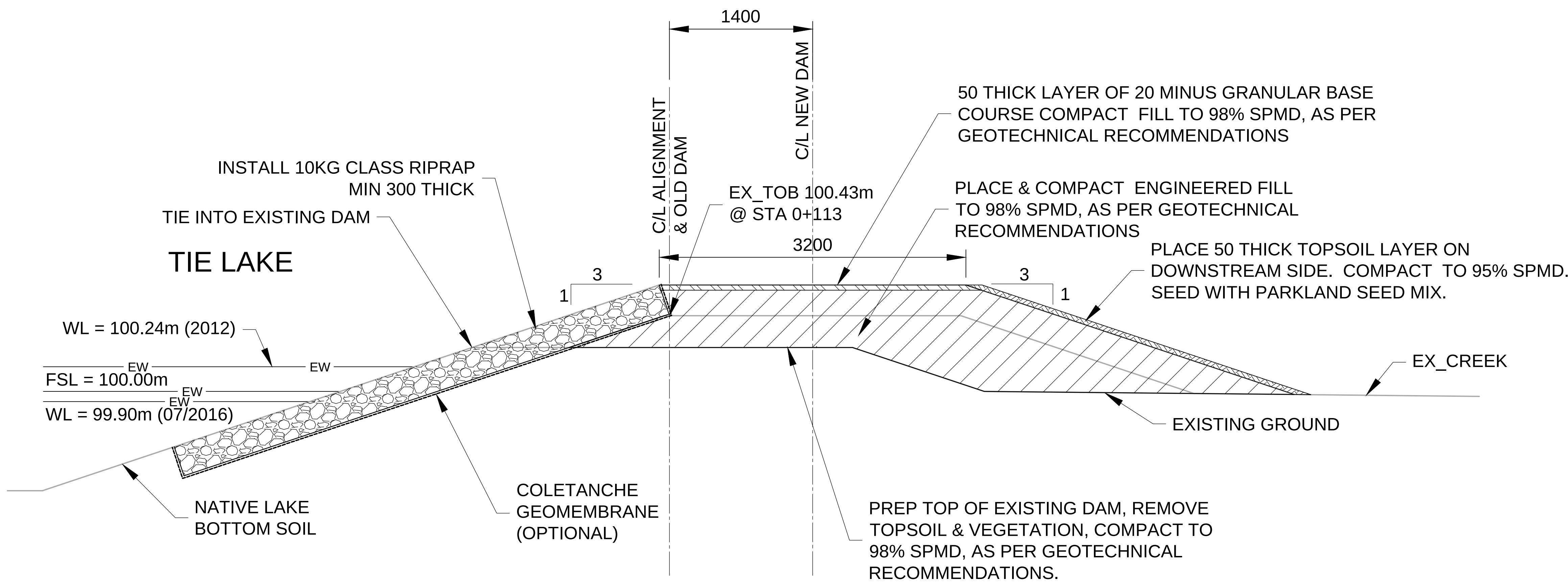

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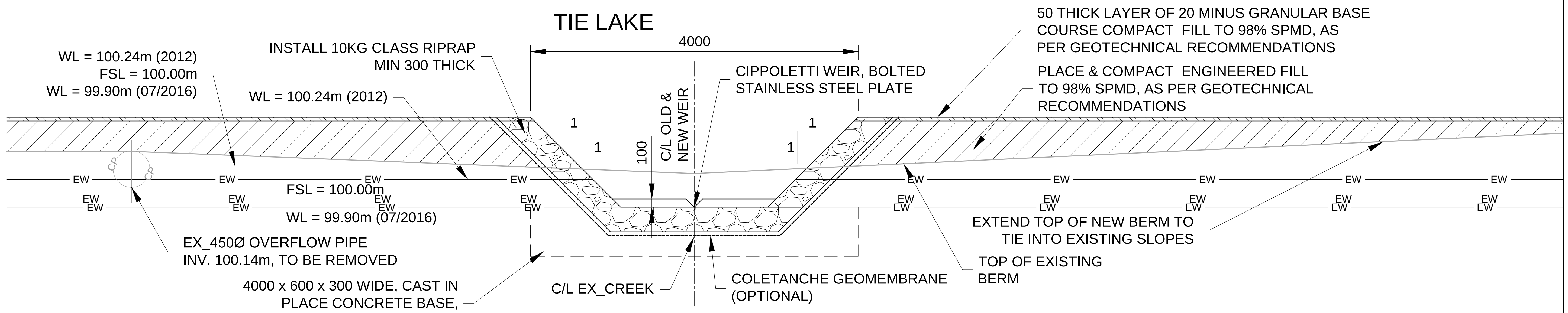

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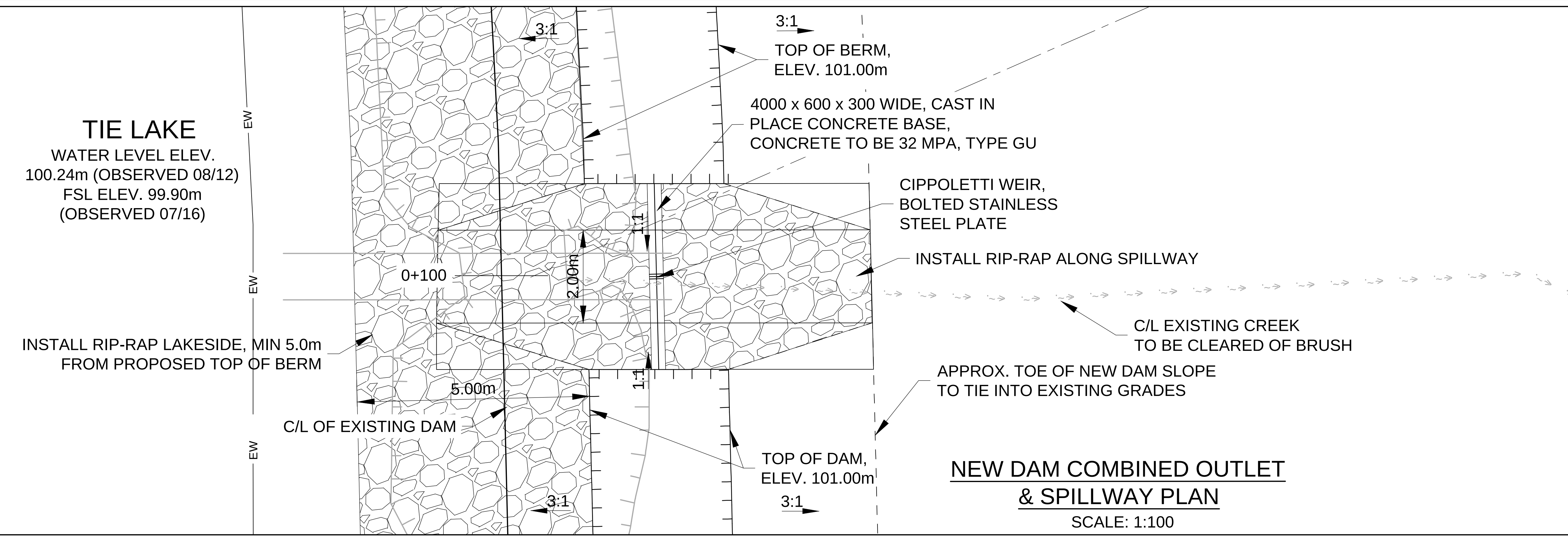

NEW DAM COMBINED OUTLET
& SPILLWAY PLAN

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